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Morphological, Anatomical, Physiological and Productivity Responses of Two Chickpea (*Cicer arietinum* L.) Cultivars to Water Deficit Stress

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ABSTRACT

A trail was conducted in greenhouse of Crops Physiology Department, Giza Experimental Research Station, ARC, during the two successive growing seasons of 2013/2014 and 2014/2015 to study the morphological, anatomical, physiological and productivity responses of two chickpea cultivars; *i.e*., Giza 3 and Giza 4 under four water applied levels; *i.e*., 1800 m^3/fad (wet), 1600 m^3/fad (moist), 1400 m^3/ fad (medium) and1200m^3/fad (dry). Results indicated that:

- The lowest values of plant height, primary branches number/plant, leaf area/plant, number of days to 50% flowering, leaves dry weight/plant, shoot dry weight/plant,pods number/plant, seeds number/plant, 100 – seed weight, seed yield/plant, straw and seed yields/fad were obtained when plants received 1200 m^3 / fad (dry treatment). Such treatment induced inhibitive effect on anatomical structures of both stem and leaf of chickpea cv. Giza 3. Water deficit decreased stem diameter due to the prominent decrease in stem wall thickness due to prominent decrease in all included tissues (cortex, phloem and xylem tissues as well as vessel diameter). Likewise, water deficit decreased thickness of both midvein and lamina of leaflet blades of chickpea cv. Giza 3. The decrease in lamina thickness was accompanied with decrements in thickness of palisade and spongy tissues compared with the control. Also, the main vascular bundle of the midvein was decreased in size as a result of drought treatment.
- The maximum values of total carbohydrates content in seeds and water consumptive use (WCU) were scored from irrigated plants by 1800 m^3 / fad (wet treatment). While protein content in seeds recorded the lowest value with respect to such treatment. Water use efficiency (WUE) recorded the maximum value when plants irrigated by 1600 m^3 / fad (moist treatment).
- Giza 3 surpassed Giza 4 cultivar in all traits under study. Giza 3 scored the highest values of seed yield and WUE under all irrigation treatments compared with Giza 4 cultivar which proved that Giza 3 endure water deficit conditions. Giza 3 obtained the maximum value of total carbohydrates and protein content of seeds.
- The interaction between water applied treatments and chickpea cultivars had a significant effect on all traits under study. The maximum value of seed yield and WUE were recorded when Giza 3 irrigated by 1600m^3 / fad (moist treatment). The highest value of total carbohydrates content in seeds was obtained from irrigated Giza 3 by 1800 m^3 / fad (wet treatment). While, the maximum value of protein content in seeds was scored when Giza 3 received 1200m^3 / fad (dry treatment).

Key words: Chickpea, *Cicer arietinum* L., Water deficit, Water use efficiency, Anatomy, Productivity.

Introduction

In Egypt, chickpea (*Cicer arietinum* L.) is an important leguminous crop raised for seed production. Its seeds contain 20-25% protein and 51-62% carbohydrate. The seeds are used either green or dry as human diet. Increasing chickpea production could be achieved by introducing more productive varieties and the application of the best agronomic practices.

Few information on the response of chickpea to water deficit stress under Egyptian condition. Assey *et al.* (1987 a) reported that, chickpea plants received three irrigations at 45, 75 and 105 days from sowing were superior in most studied growth characters, while plants irrigated twice at 45 and 75 days from sowing had the lowest values on growth characters. Assey *et al.* (1987 b) concluded that chickpea plants received three irrigations at 45, 75and 105 days after sowing were superior in filling pods percentage and seeds number/plant.Oweis *et al.* (2004) studied the response of chickpea to supplemental irrigation (SI): Full SI, ⅔ SI, ⅓ SI and no SI;*i.e.*,rain fed. The results reveal that a ⅔ SI level gives the optimum water use efficiency for chickpea under supplemental irrigation.Nayyar *et al.* (2005) reported that the stressed plants of chickpea cultivated species lost more number of flowers (62%) and pods (65%) when compared with unstressed ones. Mafakheri *et al.* (2010) working on chickpea cultivars, found that underdrought conditions the drought tolerant

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variety Bivaniej gave the highest yield, whereas the drought sensitive variety Pirouz gave the lowest yield. Shamsi *et al.* (2010) conducted a study on chickpea to evaluate the effect of water stress using deficit irrigation strategy showed that stressing the crop early during the crop cycle stabilize yield and biomass production, while flowering and pod filling stay sensitive to water deficit. Hirich *et al.* (2011) on chickpea plants, reported that drought stress during the vegetative period showed highest yield with 6.5 t/ha which was more than the yield obtained for the control (4.9 t/ha). Ghassemi-Golezani and Ghasemi (2013) using different irrigation levels; *i.e.* 70, 100, 130 and 160 mm evaporation on three chickpea cultivars; *i.e.* (Azad, Arman and Jam from Kabuli type). Results showed that with increasing water stress, percentage and duration of ground cover and seed yield per unit area were decreased.

So, the present investigation was carried out to evaluate two chickpea cultivars; *i.e.* Giza 3 and Giza 4 to four water regimes; *i.e.* 1800, 1600, 1400 and 1200 m^3/fad under Giza region conditions.

Materials and Methods

The present work was carried out in greenhouse of Crops Physiology Department at Giza Experimental Research Station, ARC, during the two successive seasons of 2013/2014 and 2014/2015 to study the morphological, anatomical, physiological and productivity responses of two chickpea cultivars to water deficit conditions. The experiment was carried out in cementing basins 10 m length, 2 m width and 70 cm depths. The soil was clay loam in structure with pH value of 7.7 and 1.9% organic matter and containing 33.5 ppm nitrogen. The experiment was laid out in split plot design with three replicates. The main plots were occupied by water applied levels, while sub-plot contained chickpea cultivars. Each sub-plot was $3m^2$(1.5 × 2m) and included 3 ridges, 2 m long and 50 cm apart.

The treatments are as follows:

I- Main plots (water applied levels):

a. Irrigation by 1800 m3/fad. (wet.). (1 faddan = 4200 m^2)
b. Irrigation by 1600 m^3/fad. (moist.).
c. Irrigation by 1400 m^3/fad. (medium).
d. Irrigation by 1200 m^3/fad. (dry).

II- Sub-plots (cultivars):

1- Giza 3
2- Giza 4

Chickpea seeds were sown on 17/11/2013 and 12/11/2014 in the first and second season; respectively, in hills spaced 10 cm. Plants were thinned to two plants per hill after 30 days from sowing. 30 kg P_2O_5 / fadas calcium super phosphate (15.5%) was added before sowing. 20 kg N/fad in form of ammonium nitrate (33.5%) was added at sowing time. Irrigation treatments were applied 30 days after sowing (DAS). Other cultural practices were followed according to the methods adopted for growing chickpea crop in the locality, except irrigation treatments.

Recording of data:

A- Morphological characters of vegetative growth:

For growth traits, five plants were randomly taken from the outer ridge for each sub-plot at 105 days after sowing (DAS) to determine the following traits:

1- Plant height (cm).
2- Primary branches number / plant.
3- Leaves dry weight (g/plant).
4- Shoot dry weight (g/plant).
5- Leaf area (cm^2)/ plant: According to Wilson and Tear (1972) by the following formula :

$^{A}Leaf = {}^{A}ellipse = \pi / 4$ (L.W).

Where: L = leaf length, W= leaf width and π = 3.14

Number of days to 50% flowering was recorded at the beginning of flowering stage.

B- Anatomical studies:

Specimens of the two investigated chickpea cultivars from control plants and those exposed to water deficit treatments were taken from the median internode of the main stem as well as from the terminal leaflet of the corresponding compound leaf. Plants used for examination were taken throughout the second growing season of 2014/2015 at the age of 105 days from sowing date. Specimens from stems and leaves were killed and fixed for at least 48 hrs. in F.A.A. (10 ml formalin, 5 ml glacial acetic acid and 85 ml ethyl alcohol 70%). The selected materials were washed in 50% ethyl alcohol, dehydrated in a normal butyl alcohol series, embedded in paraffin wax of melting point 56°C, sectioned to a thickness of 20 micrometer (μm) double stained with crystal violet-erythrosine, cleared in xylene and mounted in Canada balsam (Nassar and El-Sahhar, 1998).

Sections were read to detect histological manifestations of noticeable response resulted from water deficit treatments compared to control and photomicrographed.

C- Yield and its components:

Harvesting took place at 30/4/2014 and 23/4/2015 in the first and second season; respectively. At harvest time, ten guarded plants were randomly taken from the central ridges in each sub-plot to determine the following traits:

1- Pods number / plant.
2- Seeds number / plant.
3- 100-seed weight (g).
4- Seed yield (g)/ plant.
5- Straw yield (kg/fad).
6- Seed yield (kg/fad).

D- Chemical composition of seeds:

Samples from mature dried seeds from the two growing seasons were subjected to chemical analysis to determine the total carbohydrates content as glucose % according to Duboise *et al.* (1956) and protein percentage according to A.O.A.C. (1980).

Water relations:

1-Water consumptive use (WCU):

Soil samples were taken using a regular auger, at sowing time, just before irrigation, 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 450-600mm depths and their moisture contents were determined gravimetrically and presented in Table (1).

Table 1: Soil moisture parameter at different depths

Depth (mm)	Field capacity (%)	Wilting point (%)	Available water (%)	Bulk density (g/cm^3)
0 – 150	40.15	19.45	20.7	1.02
150- 300	31.38	15.16	16.22	1.11
300 – 450	25.10	12.17	12.93	1.16
450 - 600	17.91	8.70	9.21	1.21

The following equation was used to calculating water consumptive use (WCU) 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.

2-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.

The rainfall quantities during the first and second growing seasons were 14.0 and 2.5mm; respectively.

Statistical analysis:

Data of the two seasons were combined and statistically analyzed according to Steel and Torrie (1980), using MSTAT-C method. The discussion of the results were carried out on the basis of combined analysis for the two seasons.

Results and Discussion

I- Growth traits:

Table (2) shows some growth traits as influenced by applied water treatments. Statistical analysis of variance showed that irrigation treatments had a significant effect upon all growth characters under study.

Results showed that the highest values of plant height, primary branches number/plant, leaf area/plant, number of days to 50% flowering, leaves dry weight/plant and shoot dry weight/plant were scored from irrigation plants by 1800 m^3/fad (wet) followed by irrigation with 1600 m^3/fad (moist). While the lowest values were recorded from irrigation by 1200m^3/fad (dry), with a significant difference between this treatment and others. In this respect, Nayyar *et al.* (2006) found that flowering and filling seeds seem the most sensitive chickpea growth phases to drought stress. Ghassemi-Golezani *et al.* (2008 a) concluded that water stress during vegetative stage of dill (*Anethum graveolens* L.) has the greatest impact on plant height and biomass. Pasandi *et al.* (2014) reported that plant height, canopy spread, primary and secondary branches, days to maturity, seed yield and yield components were significantly affected by irrigation regimes.

Regarding the behavior of two chickpea cultivars (Giza 3 and Giza 4) under study, results recorded a significant effect on all growth traits presented in Table (2). It could be observed that Giza 3 surpassed Giza 4 in all growth traits.

These results could be attributed to the superiority of genetic market for Giza 3 compared with Giza 4. In this respect, Pasandi *et al.* (2014) reported that chickpea cultivars; *i.e.,* FLI P 98 – 106 C and Aman can be selected as the best tolerant genotypes to drought condition.

The interaction between water applied and chickpea cultivars was found to be significant on all growth triats under study. The maximum values of plant height, number of days to 50% flowering and shoot dry weight were obtained when Giza 3 watered by 1800 m^3/fad (wet treatment). Whereas, the highest values of primary branches number / plant, leaf area/plant and leaves dry weight/plant were obtained when Giza 3 irrigated by 1600 m^3/fad (moist treatment).

Table 2: Effect of water deficit on plant height, primary branches number / plant, leaf area/plant, number of days to 50% flowering, leaves dry weight and shoot dry weight for two chickpea cultivars under Giza region conditions.

Irrigation	cultivars	Plant height (cm)			Primary branches number / plant			Leaf area / plant $(cm)^2$			Number of days to 50% flowering			Leaves dry weight (g/plant)			Shoot dry weight (g/plant)		
		2013/14	2014/15	Comb.	2013/14	2014/15	Comb.	2013/14	2014/15	Comb.	2013/14	2014/15	Comb.	2013/14	2014/15	Comb.	2013/14	2014/15	Comb.
I_1 (1800 m^3/fad) (wet)	Giza 3	77.87	75.00	76.43	7.13	7.07	7.10	806.3	799.1	802.7	101.00	99.67	100.33	2.12	2.10	2.11	5.25	4.98	5.11
	Giza 4	75.13	74.17	74.65	6.03	6.10	6.06	719.3	707.4	713.3	100.70	98.33	99.51	2.04	2.04	2.04	3.58	3.50	3.54
mean		76.50	74.58	75.54	6.58	6.58	6.58	762.8	753.2	758.0	100.85	99.00	99.92	2.08	2.07	2.07	4.41	4.24	4.32
I_2 (1600 m^3/fad) (moist)	Giza 3	76.97	74.20	75.58	7.30	7.20	7.25	819.3	816.8	818.0	100.30	99.33	99.81	2.18	2.13	2.15	4.60	4.97	4.78
	Giza 4	71.20	69.93	70.56	5.20	5.00	5.10	666.3	701.8	684.0	99.67	96.00	97.83	1.89	1.89	1.86	2.07	2.22	2.14
mean		74.08	72.06	73.07	6.25	6.10	6.17	742.8	759.3	751.0	99.98	97.66	98.82	2.00	2.01	2.00	3.33	3.59	3.46
I_3 (1400 m^3/fad) (medium)	Giza 3	73.03	72.90	72.96	6.40	6.70	6.55	750.9	762.9	756.9	99.67	98.00	98.83	1.90	1.91	1.90	4.60	4.24	4.42
	Giza 4	65.23	65.10	65.16	4.13	4.07	4.10	625.9	567.0	596.4	99.67	94.67	95.67	1.79	1.73	1.76	1.97	1.87	1.92
mean		69.13	69.00	69.06	5.26	5.38	5.32	688.4	664.9	676.6	98.17	96.33	97.25	1.84	1.82	1.83	3.28	3.06	3.17
I_4 (1200 m^3/fad) (dry)	Giza 3	71.67	68.03	69.85	5.93	5.53	5.73	613.0	595.4	604.2	97.33	95.33	96.33	1.79	1.77	1.78	2.00	1.79	1.89
	Giza 4	59.40	57.13	58.26	3.27	3.13	3.20	503.3	493.6	498.4	93.33	92.33	92.83	1.45	1.37	1.41	1.82	1.62	1.72
mean		65.53	62.58	64.05	4.60	4.33	4.46	558.1	544.5	551.3	95.33	93.83	94.58	1.62	1.57	1.59	1.91	1.70	1.80
General mean of cultivars	Giza 3	74.88	72.53	73.70	6.69	6.62	6.66	747.3	743.5	745.4	99.57	98.08	98.82	2.00	1.98	1.98	4.11	3.99	4.05
	Giza 4	67.74	66.58	67.16	4.66	4.57	4.61	628.7	617.4	623.0	97.59	95.33	96.46	1.78	1.76	1.77	2.36	2.30	2.33
LSD 5%	I	2.56	2.32	1.59	0.98	0.89	0.61	50.0	42.7	30.1	1.41	1.28	0.87	0.59	0.56	0.37	0.67	0.57	0.40
	Cultiv.	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
	I×Cultiv.	2.97	2.88	1.90	1.21	1.10	0.75	62.1	53.0	37.4	1.74	1.58	1.08	0.77	0.73	0.49	0.87	0.75	0.53

II- Anatomical studies:

As inferred earlier throughout the morphological investigation of vegetative growth, drought treatment had significant inhibitive effect on morphological characters of vegetative growth of both chickpea cultivars under investigation. This may justify a further study on the internal structure of vegetative organs of chickpea plants grown under water deficit and of those grown under wet condition.

A preliminary comparative study was made of the microscopical characters of specimens from both investigated cultivars. As would be expected either cultivar was similar in its internal structure. Hence, further detailed examinations were confined to chickpea cv. Giza 3.

a-Stem anatomy:

Microscopical measurements of certain histological characters in transverse sections through the median portion of the main stem of chickpea cv. Giza 3 as affected by water deficit stress and those of control (wet treatment) are given in Table (3). Likewise, microphotographs illustrating these treatments are shown in Figure (1).

It is clear from Table (3) and Figure (1) that drought treatment decreased stem diameter by 30.0% below the control (wet treatment). Such reduction in stem diameter due to water deficit could be attributed mainly to the prominent decrease in stem wall thickness by 36.0% below the control, although a negligible increase of 2.5% in hollow pith diameter was observed over the control. The decrease in stem wall thickness could be attributed mainly to the prominent decrease in all included tissues. The thickness of cortex, phloem tissue and xylem tissue as well as vessel diameter were 30.7, 24.2, 38.1 and 15.1% less than those of the control; respectively.

Table 3: Measurements in micrometers (μm) of certain histological characters in transverse sections through the median portion of the main stem of chickpea cv. Giza 3, aged 105 days, as affected by water deficit (Means of three sections from three specimens)

Histological characters (μ m)	Treatments		
	Control	Water deficit treatment	± % to control
Stem diameter	3692	2585	- 30.0
Stem wall thickness	1548	991	- 36.0
Cortex thickness	296	205	- 30.7
Phloem tissue thickness	149	113	- 24.2
Xylem tissue thickness	1104	683	- 38.1
Vessel diameter	73	62	- 15.1
Hollow pith diameter	593	608	+ 2.5

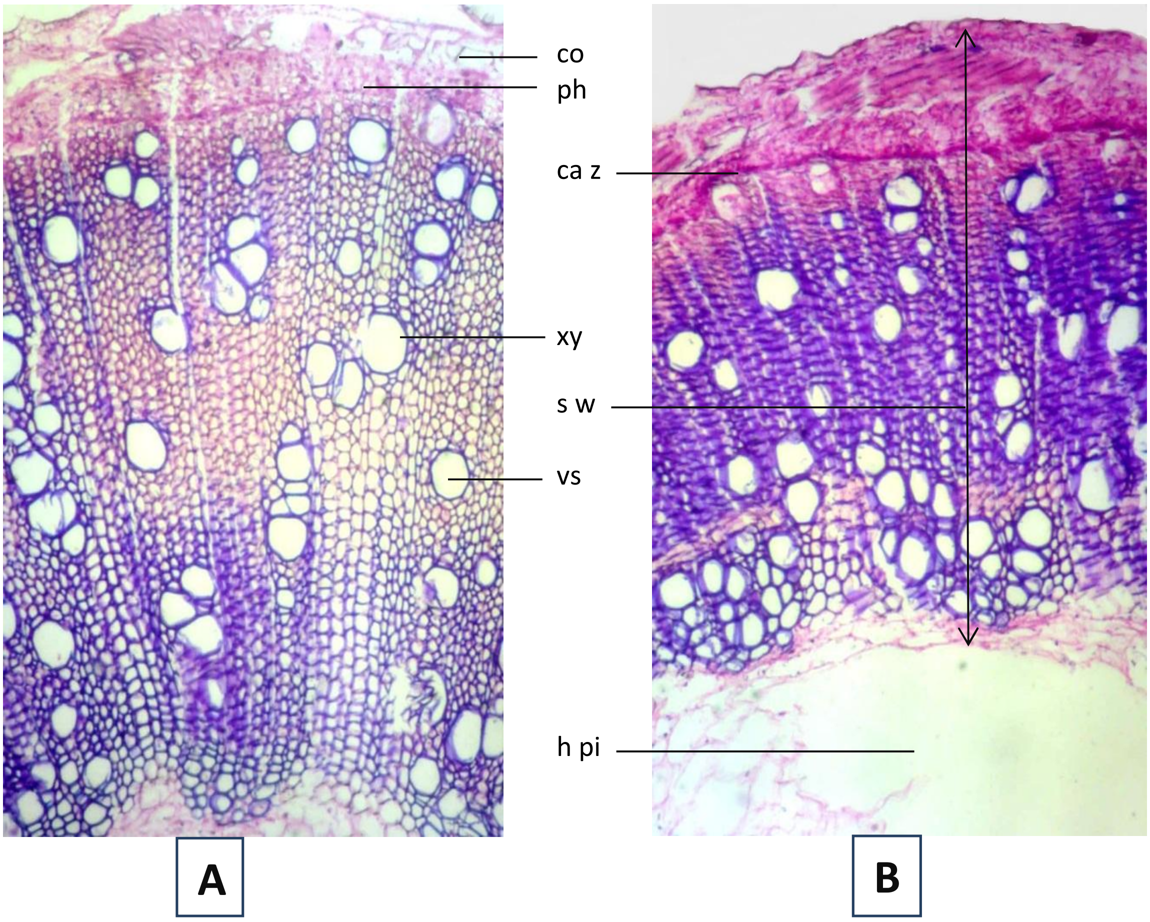

Fig. 1: Transverse sections through the median portion of the main stem of chickpea cv. Giza 3 aged 105 days as affected by water deficit stress. (X 136)
A- From control plant (wet treatment, 1800 m^3 water/fad.).
B- From plant exposed to drought treatment (1200 m^3 water/fad.).
Details: ca z, cambium zone; co, cortex; h pi, hollow pith; s w stem wall; vs, vessel and xy, xylem.

In this respect, Selim and El-Nady (2011) recorded inhibitive effect of low water supply on anatomical structure of tomato stem. They stated that water deficit induced a reduction in stem diameter of tomato plant due mainly to a reduction induced in thickness of cortex and vascular tissues (phloem and xylem), being in harmony with the present finding.

b-Leaf anatomy:

Microscopical counts and measurements of certain histological characters in transverse sections through the blade of the terminal leaflet of the compound leaf developed on the median portion of the main stem of ckickpea cv. Giza 3 as affected by water deficit stress (drought treatment) and those of control (wet treatment) are presented in Table (4). Likewise, microphotographs illustrating these treatments are shown in Figure (2).

Table 4: Counts and measurements in micrometers (µm) of certain histological features in transverse sections through the blade of terminal leaflet of the compound leaf developed on the median portion of the main stem of chickpea cv. Giza 3, aged 105 days, as affected by water deficit (Means of three sections from three specimens)

Histological characters	Treatments		
	Control	Water deficit treatment	± % to control
Midvein thickness	281.0	264.0	- 6.10
Lamina thickness	219.0	152.0	- 30.6
Palisade tissue thickness	121.4	79.2	- 34.8
Spongy tissue thickness	68.2	46.9	- 31.2
Dimensions of the midvein bundle:			
Length	82.7	76.3	- 7.70
Width	75.9	71.5	- 5.80
Number of vessels / midvein bundle	13.3	11.5	- 13.5
Vessel diameter	19.5	17.6	- 9.70

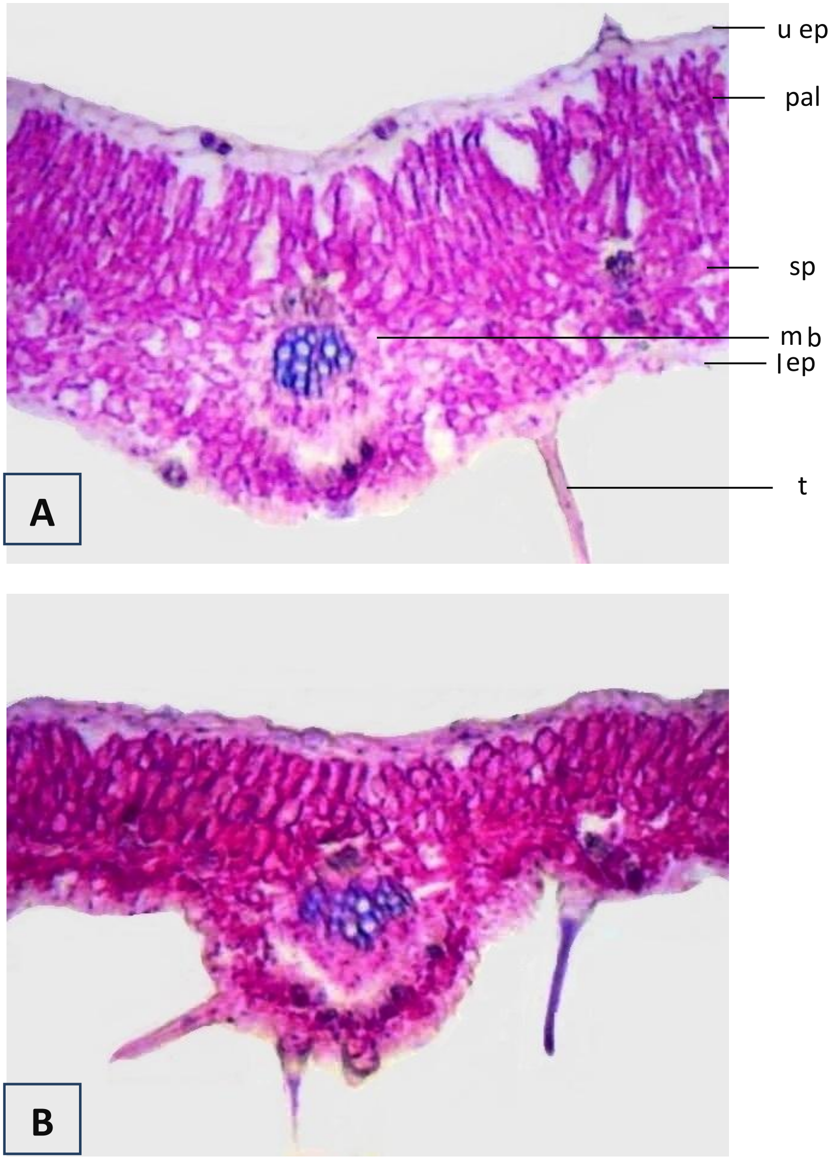

Fig. 2: Transverse sections through the blade of terminal leaflet of the compound leaf developed on the median portion of the main stem of chickpea cv. Giza 3 aged 105 days as affected by water deficit stress. (X 136)

A- From control plant (wet treatment, 1800 m^3 water/fad.).

B- From plant exposed to drought treatment (1200 m^3 water/fad.).

Details: l ep, lower epidermis; m b, midvein bundle; pal, palisade tissue; sp, spongy tissue; t, trichome and u ep, upper epidermis.

It is obvious from Table (4) and Figure (2) that drought treatment decreased thickness of both midvein and lamina of leaflet blades of chickpea cv. Giza 3 by 6.1 and 30.6% less than those of the control; respectively. It is noted that the decrease induced in lamina thickness was accompanied with 34.8 ad 31.2% decrements in thickness of palisade and spongy tissues compared with the control; respectively. Likewise, the main vascular bundle of the midvein was decreased in size as a result of drought treatment. The decrement was mainly due to the decrease induced in length by 7.7% and in width by 5.8% less than the control. Also, average number of vessels per midvein bundle was decreased by 13.5% less than the control. Moreover, xylem vessels decreased in diameter, being 9.7% less than the control.

As far as the authors are aware, previous information about the effect of water deficit on anatomical structure of leaflet blades of chickpea plant or other related species are not available in the literature. However, Selim and El-Nady (2011) recorded inhibitive effect of low water supply on anatomical structure of tomato leaves. They found that low water supply decreased lamina thickness and size of main vascular bundle. They stated that the decrease in lamina thickness induced by drought stress was mainly due to the decrement induced in both palisad and spongy tissues, being in agreement with the present findings.

III- Yield and yield components:

a- Yield components:

Data in Table (5) Showed that applied water levels resulted in a significant effect on pods number/plant, seeds number/plant, 100-seed weight and seed yield/plant. The highest values of pods number/plant and seeds number/plant were scored from irrigation plants by moist treatment (irrigated by 1600 m^3/fad) with insignificant difference between such treatment and irrigation by 1800 m^3/fad (wet treatment). The maximum values of 100-seed weight and seed yield/plant were obtained when chickpea plants received 1800 m^3/fad (wet treatment). While the lowest values of yield components traits were recorded from irrigation by 1200 m^3/fad (dry treatment).Similar results were obtained by Anjamshoaa *et al.* (2011) using different irrigation treatments; *i.e.,* 100, 90, 80 and 50% ETC on four chickpea cultivars (Jam, Karaj 12-60-31, Kaka and ILC 482). The obtained results showed that different levels of irrigation had significant effect on number of pods/m^2, number of seeds/m^2 and 100-seed weight.

Results in Table (5) showed significant differences between Giza 3 and Giza 4 cultivars in pods number/plant, seeds number/plant and seed yield/plant. Giza 3 had the maximum values of such characters compared to Giza 4. In this connection, Pasandi *et al.* (2014) on chickpea found that Azad cultivar surpassed Arman and Jam cultivars in all yield components trait under all irrigation treatments.

The interaction between water applied and chickpea cultivars was found to be significant on all yield components traits under study. The maximum values of 100-seed weight was obtained when Giza 3 irrigated by 1800 m^3/fad (wet treatment). While, the highest values of pods number/plant, seeds number/plant and seed yield/plant were recorded when Giza 3 irrigated by 1600m^3/fad (moist treatment).

Table 5: Effect of water deficit on pods number / plant, seeds number / plant, 100 seed weight, seed yield/plant, straw yield / fad and seed yield/fad for two chickpea cultivars under Giza region conditions.

Irrigation	Cultivars	Pods number / plant			Seeds number / plant			100 seed weight (g)			Seed yield / plant (g)			Straw yield (kg/fad)			Seed yield (kg/fad)		
		2013/14	2014/15	Comb.	2013/14	2014/15	Comb.	2013/14	2014/15	Comb.	2013/14	2014/15	Comb.	2013/14	2014/15	Comb.	2013/14	2014/15	Comb.
I_1 (1800 m^3/fad) (wet)	Giza 3	27.30	27.87	27.58	33.23	32.17	32.70	17.21	17.40	17.30	5.07	5.06	5.06	2087.4	2018.9	2053.1	861.4	825.7	843.5
	Giza 4	25.60	25.50	25.55	30.70	31.23	30.96	17.15	17.10	17.12	4.04	4.04	4.04	1795.1	1817.3	1806.2	683.8	664.4	674.1
Mean		26.45	26.68	26.56	31.96	31.70	31.83	17.18	17.25	17.21	4.55	4.55	4.55	1941.2	1918.1	1929.6	772.6	745.0	758.8
I_2(1600 m^3/fad) (moist)	Giza 3	29.77	27.67	28.72	35.13	34.63	34.88	17.13	17.09	17.11	5.23	5.33	5.28	1972.7	1978.6	1975.6	878.2	845.9	862.0
	Giza 4	24.57	25.27	24.92	29.60	29.40	29.50	16.92	16.83	16.87	3.83	3.77	3.80	1491.0	1455.7	1473.3	649.3	635.5	642.4
Mean		27.17	26.47	26.82	32.36	32.01	32.19	17.02	16.96	16.99	4.53	4.55	4.54	1731.8	1717.1	1724.4	763.8	740.7	752.2
I_3(1400 m^3/fad) (medium)	Giza 3	25.10	24.70	24.90	31.03	31.70	31.36	16.28	15.99	16.13	4.32	4.34	4.33	1927.8	1934.5	1931.1	728.3	745.9	737.1
	Giza 4	20.17	19.10	19.63	24.83	24.33	24.58	16.60	16.67	16.63	3.23	3.05	3.14	1472.5	1389.8	1431.1	548.5	557.8	553.1
Mean		22.63	21.90	22.26	27.93	28.01	27.97	16.44	16.33	16.38	3.77	3.69	3.73	1700.1	1662.1	1681.1	638.4	651.9	645.1
I_4(1200 m^3/fad) (dry)	Giza 3	21.90	22.30	22.10	25.60	24.67	25.13	15.66	15.33	15.49	2.18	1.72	1.95	1475.5	1445.6	1460.5	368.9	384.3	376.6
	Giza 4	15.73	15.47	15.60	17.93	17.13	17.53	14.33	14.00	14.16	1.45	1.33	1.39	1370.9	1283.5	1327.2	259.6	252.0	255.8
Mean		18.81	18.88	18.85	21.76	20.90	21.33	14.99	14.66	14.82	1.81	1.52	1.67	1423.2	1364.6	1393.8	314.3	318.2	316.2
General mean of cultivars	Giza 3	26.02	25.63	25.82	31.25	30.79	31.02	16.57	16.45	16.51	4.20	4.11	4.15	1865.8	1844.4	1855.1	709.2	700.4	704.8
	Giza 4	21. 52	21.33	21.42	25.76	25.52	25.64	16.25	16.15	16.19	3.14	3.05	3.09	1532.4	1486.6	1509.4	535.3	527.4	531.3
LSD 5%	I	1.66	1.51	1.03	4.18	3.80	2.59	1.78	1.62	1.11	0.48	0.44	0.30	128.9	134.0	85.4	77.3	72.2	48.6
	Cultiv.	*	*	*	*	*	*	N.S	N.S	N.S.	*	*	*	*	*	*	*	*	*
	I×Cultiv.	2.04	1.86	1.27	5.15	4.68	3.19	2.19	2.00	1.36	0.60	0.54	0.37	158.8	165.1	105.3	95.2	89.0	59.9

b- Yield:

The effect of water applied levels and cultivars on the productivity of chickpea expressed as straw and seed yields (kg/fad) is presented in Table (5). Both straw and seed yields recorded a significant effect. The highest values of such traits were scored from irrigation plants by 1800 m^3/fad (wet treatment) followed by irrigation with 1600 m^3/fad (moist treatment). While the lowest values were recorded from irrigation by 1200 m^3/fad (dry treatment) with a significant difference between this treatment and others. It can be noticed that chickpea productivity decreased with increasing water deficit gradually up to irrigation by 1200 m^3/fad (dry treatment). This trend could be attributed to the effect of water deficit on chickpea growth and yield components which in turn reflected on straw and seed yields. It is worthy to mention that insignificant differences was observed between irrigation by 1800m^3/fad (wet) and 1600 m^3/fad (moist) with respect to seed yield. So, from view of water conservation, it is more efficient to irrigate chickpea plants by 1600 m^3/fad (moist treatment). These results are in line with those reported by Chaves and Oliveira (2004). It was found that, drought causes huge decrease in crop yield by inhibiting plant growth and photosynthesis. Nasrullahzadeh *et al*. (2007) concluded that, water stress reduce growth index which can reduce photosynthesis, plant biomass, yield components and consequently seed yield of faba bean. Anjamshoaa *et al.* (2011) found that different irrigation treatments had significant effects on seed yield, biological yield and harvest index of chickpea plants.

Concerning the behavior of two chickpea cultivars under study, results recorded a significant effect on straw and seed yields. It could be observed that Giza 3 surpassed Giza 4 in straw and seed yields under all irrigation treatments. This result may indicate that Giza 3 was tolerant to water deficit conditions. Also, Giza 3 out yielded Giza 4 in straw and seed yields by about 22.9 and 32.66%; respectively. These results are in line with those reported by Anjamshoaa *et al*. (2011), Ghassemi-Golezani and Ghassemi (2013) and Pasandi *et al*. (2014).

The interaction between water deficit and ckickpea cultivars was found to be significant in straw and seed yields. The maximum value of straw yield was scored when Giza 3, received 1800 m^3/fad (wet treatment). Whereas, seed yield obtained the maximum value when Giza 3 irrigated by 1600 m^3/fad (moist treatment).

c- Chemical composition of seeds (seed quality):

1. Total carbohydrates content:

Table (6) show that total carbohydrates in seeds increased significantly when plants received 1800 m^3/fad (wet treatment), compared to other irrigation treatments. Such trait decreased gradually by increasing water deficit up to irrigation by 1200 m^3/fad (dry treatment). Boyer (1970) explained such carbohydrates reduction, to that plants grown under drought condition have a lower stomatal conductance in order to conserve water. Consequently, CO_2 fixation is reduced and photosynthetic rate decreased, resulting in less assimilate production. Ommen *et al.* (1999) reported that leaf chlorophyll content decreases as a result of drought stress, resulting in less assimilate production.

Regarding the difference between the two cultivars under study. It could be noticed that Giza 3 gave the highest value of total carbohydrates content in seeds compared to Giza 4.

The maximum value of total carbohydrates content in seeds were obtained when Giza 3 received 1800m^3/fad (wet treatment).

Table 6: Effect of water deficit on total carbohydrates and protein contents in seeds as well as seasonal water consumptive use (WCU) and water use efficiency (WUE) for two chickpea cultivars under Giza region conditions.

Irrigation	Cultivars	Total carbohydrates in seeds (%)			Protein in seed (%)			WCU (m^3/fad)			WUE (g/ m^3)		
		2013/14	2014/15	Comb.	2013/14	2014/15	Comb.	2013/14	2014/15	Comb.	2013/14	2014/15	Comb.
I_1 (1800 m^3/fad) (wet)	Giza 3	56.12	54.24	55.18	21.75	20.42	21.08	1278	1246	1262	674	663	668
	Giza 4	54.70	52.46	53.58	19.70	18.66	19.18	1203	1245	1224	568	534	551
Mean		55.41	53.35	54.38	20.72	19.54	20.13	1240	1245	1243	621	598	609
I_2(1600 m^3/fad) (moist)	Giza 3	53.52	52.36	52.94	23.18	22.50	22.84	1168	1136	1152	752	745	748
	Giza 4	52.61	51.20	51.90	21.73	20.77	21.25	1132	1108	1120	574	574	574
Mean		53.06	51.78	52.42	22.45	21.63	22.04	1150	1122	1136	663	659	661
I_3(1400 m^3/fad) (medium)	Giza 3	51.23	48.54	49.88	24.56	23.91	24.23	1065	1035	1050	684	721	702
	Giza 4	49.51	46.78	48.14	22.75	21.94	22.34	1034	1010	1022	530	552	541
Mean		50.37	47.66	49.01	23.65	22.92	23.28	1049	1022	1036	607	636	621
I_4 (1200 m^3/fad) (dry)	Giza 3	48.61	45.97	47.29	26.58	25.84	26.21	944	928	936	391	414	402
	Giza 4	45.10	44.08	44.59	23.77	22.96	23.36	928	900	914	280	280	280
Mean		46.85	45.02	45.94	25.17	24.40	24.78	936	914	925	335	347	341
General mean of cultivars	Giza 3	52.37	50.28	51.32	24.02	23.17	23.60	1114	1086	1100	625	636	630
	Giza 4	50.48	48.63	49.55	21.99	21.08	21.53	1073	1066	1070	488	485	486
LSD 5%	I	5.69	5.58	3.66	3.44	3.31	2.19	-	-	-	69	70	45
	Cultiv.	*	*	*	*	*	*	-	-	-	*	*	*
	I×Cultiv.	7.41	7.27	4.77	4.48	4.31	2.86	-	-	-	85	87	56

2- Protein content:

Table (6) show that protein content of seeds recorded a significant effect. The maximum value of protein content obtained from irrigated plants by 1200 m^3/fad (dry treatment). Such finding was the reverse trend to that observed with carbohydrates percentage. Anton and El-Raies (2000) explained such finding on sesame that the increase in protein content by water deficit may accrue on the account of the decrease in carbohydrate accumulation in sesame seeds suffer from drought.

Concerning the difference between the two cultivars under study. It could be observed that Giza 3 significantly surpassed Giza 4 cultivar in such trait.

As for the interaction between water applied and chickpea cultivars, results recorded a significant effect. The maximum value of protein content in seeds was recorded when Giza 3 irrigated by 1200 m^3/fad (dry treatment).

IV- Water relations:

a-Seasonal water consumption (WCU):

Water consumptive use by chickpea plants under various treatments are presented in Table (6). Results indicated that WCU ranged from 914 to 1262 for the mean of both seasons under study. The highest value of WCU was achieved when plants irrigated by 1800 m^3/fad (wet treatment), however the lowest value was obtained under irrigation by 1200 m^3/fad (dry treatment). The value of irrigation by 1600 m^3/fad (moist) and 1400 m^3/fad (medium) falls in between. Such results could be explained on the basis that increasing water applied provides chance for more luxuriant use of water. These finding could be ascribed to the availability of soil water to chickpea plants in addition to high evaporation rate from wet soil surface than the dry one. Ehrler *et al*. (1978) and Siddiau *et al*. (2000) explained the reduction in WCU under water deficient condition (dry treatment), that increasing leaf temperature due to water stress is possibly related to decreasing stomatal conductance and consequently transpiration reduce.

Regarding the difference between the two cultivars under study for WCU, data revealed that the maximum value of WCU was obtained by Giza 3 compared to Giza 4. Such results could be attributed to, that Giza 3 own the larger leaf area / plant and shoot dry weight (Table, 2), which induced a more transpiration. Shaw and Laing (1966) reported that, under stress conditions, transpiration was reduced when water deficit reached a critical characteristic value for the species, turgor induced changes in stomatal aperture which causes an increase in the resistance to transpiration in gaseous phase, which caused a reduction in transpiration to prevent or limit desiccation rather than to maintain flow at the level of evaporation demand.

For the interaction between the two factors under study, the highest value of WCU was obtained when Giza 3 irrigated by 1800 m^3/fad.

b-Water use efficiency (WUE):

Data on water efficiency expressed as grams of seeds produced per $m^3$of water consumed in complete evapotranspiration are presented in Table (6). Results show that irrigation treatments and cultivars as well as interaction effect recorded significant effects on WUE trait. The maximum value of WUE was recorded when chickpea plants were irrigated by 1600 m^3/fad (moist treatment), with significant difference between such treatment and other irrigation treatments. Such finding attributed to high seed yield/fad which obtained in proportion to the water consumed. It could be concluded that irrigation chickpea plants by 1600 m^3/fad (moist treatment) seemed to be more efficient in consuming water compared with other irrigation treatments. In other words, from the stand point of water conservation, irrigated plants by 1600m^3/fad seemed to be more economic for saving water and gained a suitable seed yield. Similar results on barley were obtained by El-Rais *et al.* (1999) and El-Bawab *et al.* (2014).

Concerning the difference between the two cultivars under study with respect to WUE, results in Table (6) show that the maximum value of such character was obtained by Giza 3 compared to Giza 4. Such result indicated that Giza 3 gave high seed yield more than the increase in water consumed by plants. In other words, Giza 3 yielded high seed yield in proportion to water consumed.

The interaction between irrigation and cultivars recorded a significant effect. Results revealed that the maximum value of WUE obtained when Giza 3 received 1600 m^3/fad. It can be noticed that, Giza 3 gave the maximum value of WUE under all irrigation treatments, these results mat reveal that such cultivar produced the maximum seed yield under water deficit condition.

Conclusion:

In the light of the present results, it is clear that the maximum seed yield of chickpea was obtained from irrigation plants by 1800m^3/fad (wet) followed by 1600 m^3/fad (moist) with insignificant differences between such two treatments. It's suitable to irrigate chickpea plants by moist treatment (1600 m^3/fad) to obtained suitable seed yield and save water.

However, from economic point of view and water conservation, it is more efficient to irrigate Giza 3 by 1600 m^3/fad due to the maximum value of WUE, under Giza region conditions. These results prove that Giza 3 endure water deficit conditions.

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