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Evaluation of Drought Stress on Yield and Physiological Attributes in Cantaloupe Crop (*Cucumis melo L.*)

KEYWORDS Cucumis melo; deficit irrigation ; crop yield; water use efficiency ; semi-arid, arid region.

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ABSTRACT *This research was conducted in order to study the effect of different irrigation regimes on yield and it's compenents and on water use efficiency of melon. It was realized in the experimental station of the High Agronomic Institute of Chott Mariem, University of Sousse (Tunisia) during 2013 season. Full irrigation (I 100) and two deficit irrigation (I 70 and I 40) strategies were examined based randomized completely block design (RCBD) with three replications. Chlorophyll a Chlorophyll b, Total Chlorophyll, Total Crop Yield, main stem length, total leaf area, chlorophyll stability index, mean number fruit per plant, mean fruit weight, Brix and Water Use Efficiency were determined. Leaf Relative Water Content, Water Saturation Deficit, Leaf Water Content and leaf water content per unit leaf area were also determined. Results showed that yield was maximum with full irrigation (5.2 t. ha -1). This irrigation regime gave maximul main number of fruits per plant (5.2), main fruit weight (1603 g), and maximum total leaf area (94361 cm). Otherwise, maximum total chlorophyll content (0.0028 mg. g FW-1) and chlorophyll stability index (137.5) were recodered at moderate water stress (I 70). So it's prefaerable to use full irrigation regime to obtain maximum yield.*

1. Introduction

Climatic changes due to global warming can cause serious reductions in yield and crop quality. Among the agricultural crops such as field crops and fruit trees, the vegetables are more vulnerable for climatic changes. Drought is the major environmental constraints to crop productivity. Consequently, it is necessary to study the physiological response of crop plants to drought stresses in order to develop appropriate strategies to carry on food production under adverse environmental conditions (Zheng *et al.*, 2009). Drought causes detrimental effects on plant's life. The reduction in growth is consequence of several physiological responses including modifications of ion balance, water status, mineral nutrition, stomatal behavior, photosynthetic efficiency, carbon allocation, and utilization. The rate of photosynthetic CO_2 assimilation is generally reduced by drought. This reduction is partly due to a reduced stomatal conductance and consequent restriction of the availability of CO_2 for carboxylation (Brugnoli and Lauteri, 1991). Physiological changes (stomatal conductance, water potential, osmotic potential) in plants growing under water-deficit conditions have been developed as effective indices for resistant screening in plant breeding programs (Ashraf and Foolad, 2007; Cha-um and Kirdmanee, 2009). Loss of water from turgid leaf tissue in response to transpiration results is not only a significant decline in water potential but also a decline in osmotic potential. Greater plant fresh and dry weights under drought are desirable characters. A common adverse effect of water stress on crop plants is the reduction in fresh and dry biomass production (Dasgan and Koc, 2009; Kusvuran, 2010). The response of plants to drought stress have been assessed using different physiological measurement techniques, such as water potential, leaf osmotic potential and stomatal conductance and these parameters have been used in assessment of abiotic stress-related studies such as drought screening (Ashraf and Oleary, 1996).

Cucumis melo belongs to cucurbitaceae family. It is a branched prostrate annual and/or perennial herb mostly infesting pearl millet, sorghum, maize, cotton and range lands. Its seed emergence is one of the most critical phases in plant development at which the weed can compete for an ecological niche (Forcella *et al.*, 2000) and is mediated by various environmental factors such as temperature, light, soil pH, osmotic stress (Chauhan and Johnson, 2009; Kegode *et al.*, 2010). It's an important horticultural crop, often cultivated in arid and semi-arid regions of the world, where drought begins to threat, or has already been a problem. In general, melon is known to be moderately resistant to drought. It has been shown that this stresse cause several types of damage such as growth inhibition (Dasgan and Koc, 2009; Kusvuran, 2010), metabolic disturbances (Mavrogianopoulos *et al.*, 1999), and yield and quality losses (del Amor *et al.*, 1999). The aim of this work was to compare the changes in yield, yield components, growth parameters water use efficiency to severe or mederate drought stress.

2. Materials and Methods

Location, plant material, and growth conditions

The experiment was conducted from July to October, 2013 in an experimental field at High Agronomic Institute of Chott Mariem, University of Sousse, Tunisia. Transplant took place at a density of 3 plants/m2, using the hybrid F1 'Calypso', considered as one of the most representative muskmelon varieties cultivated in Tunisia; seeing its high crop performance and fruit quality.

It was carried out in a 255 m^2 mono tunnel (8.5 x 30 m) covered with a 220 µm polyethylene film, It's located in an semi-arid climate with mean of maximum and minimum temperature of 23.9 and 9.8°C, respectively. To define e the properties of the soil, a composite sample from 5 points was collected from 0-25 cm depth and analyzed in the laboratory for pH, EC and particle size distribution. Description of soil chemical and it's physical properties of the site are shown in Table 1.

Table 1 : Chemical and physical properties of the site.

Soil texture	pH	EC (ds m^{-1})	N (%)	P (ppm)	K (ppm)	Mn (ppm)
Loam	6.9	2.3	1	12	611.2	25.68

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Nutrient solution management

The nutritive solution was pumped using a pump with 1 atm power, through an open drip irrigation system with one emitter per plant and a flow rate of 4 L/h. This solution was formulated according to the chemical composition of water of irrigation and norms of fertilization of muskmelon (Table 3). The nutritional needs of plants were determined referring to Huguet *et al*. (1985) (Table 4).

Plants were fertilized by fertigation. The plants were irrigated daily 4 to 5 times, depending on the size of the plant and the growing climatic conditions. The experiment plan was of a completely randomized design with three replications and each one was represented by 24 plants per row (three rows in the greenhouse). The irrigation treatments were applied, from 17 July to 20 October, though the regimes were scheduled weekly.

Table 2. Characteristics of local compost.

C/N (%)	Organic Matter	Total porosity (%)	pH	EC (ms/cm)	Rate of retention water
29.2	71	59.9	7.19	5.4	29

Table 3. Chemical composition of nutritive solution (%).

	N	K	Ca	Mg	H_2PO^{4-}	$SO4^{2-}$
Water of irrrigation	0	1.17	15	6.9	0	12
Norms of fertilization	16.1	7.14	9.7	2.7	1.1	3.1
Nutritive solution	15.3	5.13	0	0	1.9	0

Table 4. Composition of nutritive solution regards to stage of development of plants

Stage of growth chemical	Plantation-first fruit Set	First fruit set - last fruit set	Last fruit set- start of Harvest	Start of harvest-end of harvest
NH_4NO_3	20	100	71.5	94
KNO_3	19	100	73.8	45
H_2PO_4 -	17	88.5	80	100
HNO_3	20	100	71.5	94

Data collection and analysis

Experimental Design and Performance: The experiment is comprised of three irrigation treatments including 40, 70 and 100% crop evapotranspiration (ETc), to induce a range of water stress from transplanting and harvest stages. The ET0 was calculated with the method of Allen *et al.* (1998) to evaluate the weekly ETc according to equation : ETc=ET0 x Crop Coefficient (Kc) (Doorenbos and Pruitt, 1974) that was obtained in the same area during last year. In this semi-arid region, the efficiency of the system was calculated as 0.79. (Rhimi *et al.*, 2007). To measure the amount of water appled for each treatment, we used water meters at the valve.

Measured parametres

At the end of vegetative growth (80 days after transplanting) we measured Plant heights and total leaf area (LAI-2000 plant canopy analyzer). Chlorophyll content (a, b and total chlorophyll content was measured. It is extracted by homogenizing and boiling 1 g of fresh weight leaves in 35 ml ethanol 96%. After centrifugation (10 min at 4.000 g), the chlorophyll content is determined spectro-photometrically from the ethanolic supernatant at 654 nm, as described by Wintermans *et al.* (1965). The chlorophyll stability index (CSI) was estimated according to the method of Water Sairam *et al.* (1997). To measure the leaf Relative Water Content (RWC), Water Saturation Deficit (WSD), Leaf Water Content (LWC) and leaf water content per unit leaf area (LWCA), three leaves was sampled from one plant per plot. Then, the leaves were wrapped immediately in aluminum foil, put in a plastic bag and kept in a cool place. Fresh weight was determined one h after cutting. Turgid weight was determined as follows: the leaves were held in distilled water at room temperature (approximately 4°C) for 24 h; then, they were quickly and carefully dried by tissue; and their turgid weight was determined; next, the samples were then dried in an oven at 70°C for 24 h and weighed (Ritchie and Nguyen, 1990). Finally, RWC, WSD, LWCA and LWC were calculated using the following equations:

RWC (%) = (FW –DW/TW-DW) x 100
WSD (%)= 100 –RWC
LWC (%) = (FW-DW) x 100/DW
LWCA = (FW –DW)/L

Where, FW, DW, TW and L are fresh weight (g), dry weight (g), turgid weight (g) and leaf area (Cm^2) respectively. At the end of the culture (22 October) we have completed the harvest at maturity to estimate the data on yield and it's components (mean number of fruits/ plant, MNFPP, mean fruit weight , MFW, total crop yield, TCY, total soluble solid content TSS and water use efficiency WUE.

TSS was determined from three samples taken randomly from harvested fruits of each plot with handheld refractometer (Master-T 2312). For each treatment, WUE was estimated as the ratio of total crop yield to total of applied water 14 (WUE = CY = total crop yield, t ha^{-1} / WA = total of water applied, cm^{-1}).

Statistical analyses were performed using a level of 0.05 (5%) for the ANOVA and Tukey's post hoc tests. Differences between the means were compared, using the least significant difference (LSD). Levels of significance are represented by *($P < 0.05$), ** ($P <001$ and *** ($P < 0.001$) and NS (not significant).

3. Results

Results illustrated showed that main stem length, total leaf area chlorophyll content, Brix, CSI, MNFPP, MFW, TCY and WUE are affected by deficit irrigation. We can notice that DI decrease concentration of chlorophyll as it's mentioned on table 5. Chlorophyll a content (0.0028 mg. g FW $^{-1}$) and total chlorophyll content (0.0033 mg. g FW $^{-1}$) are increased with I 70. While I 40 decreased chlorophyll a content (0.0024 mg. g FW $^{-1}$), total chlorophyll content (0.0028 mg. g FW $^{-1}$) as well as Yield (1.9 t. ha $^{-1}$). It's clear that more the DI is high more the TCY is less stimulated. The lowest TCY value is 1.9 (t. ha $^{-1}$) obtained with I 40. Consequently, I 40 reduced TCY by 64% comparing with I 100.

Table 5 : Effect of irrigation levels on chlorophyll a, b, total chlorophyll and yield

Irrigation	Chlorophyll a (mg. g FW $^{-1}$)	Chlorophyll b (mg. g FW $^{-1}$)	Total Chlorophyll (mg. g FW $^{-1}$)	Total Crop Yield (t. ha $^{-1}$)
I 40	0.0024^b	0.0004^b	0.0028^b	1.9^c
I 70	0.0028^a	0.0005^a	0.0033^a	3.8^b
I 100	0.0025^b	0.0002^c	0.0027^b	5.2^a

Within each column, values followed by the same letter are not significantly different at $p < 0.05$.

In addition, deficit irrigation inhibit plant main stem lenght, the lowest (99.7 cm) and the highest values (201.4 cm) were recorded with I 40 and I 100 respectively (Table 6). Otherwise, plant leaf area decreased significantly (27125 cm^2) at I 70 comparing with I 100 and I 40 (94361 and 17139 cm^2 respectively). In the same vision, we noted that lowest value of MNFPP (1.9) and MFW (1102 g) were recorded with I 40, while maximum values of MNFPP (5.2) and MFW (1603 g) were recorded by I 100 as it's mentioned in Table 6.

Table 6 : Effects of deficit irrigation (DI) on main stem length, total leaf area, chlorophyll stability index (CSI), mean number fruit per plant (MNFPP) and mean fruit weight (MFW).

Irrigation	Main stem length (cm)	Total Leaf area (cm)	CSI (%)	MNFPP	MFW (g)
I 40	99.7^c	17139^c	93.4^b	1.9^c	1102^c
I 70	169.8^b	27125^b	137.5^a	3.8^b	1417^b
I 100	201.4^a	94361^a	98.1^b	5.2^a	1603^a

Within each column, values followed by the same letter are not significantly different at $p < 0.05$.

Brix as well as WUE increased with DI levels. Maximum levels of Brix (9.1 %) and WUE (0.87 $t.ha^{-1}.cm^{-1}$) were recodered with I 40.

Table 7 : Effect of irrigation levels on Brix and on Water Use Efficiency (WUE)

Irrigation	Brix (%)	WUE ($t.ha^{-1}.cm^{-1}$)
I 40	9.1^a	0.87^a
I 70	7.8^b	0.79^b
I 100	6.3^c	0.65^c

Within each column, values followed by the same letter are not significantly different at $p < 0.05$.

Although WSD increased with DI levels (47.12, I 40), we notice that RWC, LWCA and LWD are reduced with DI (61.48 ; 0.017 and 612 % respectively for I 40) (Table 8).

Table 8 : Comparisons of the means for of chlorophyll and growth parameters of cantaloupe under water deficit treatments

Irrigation	LWCA	RWC (%)	WSD	LWD (%)
I 40	0.017^c	61.48^b	47.12^a	612^c
I 70	0.024^b	62.17^b	42.36^b	623^b
I 100	0.030^a	63.22^a	36.14^c	635^a

Within each column, values followed by the same letter are not significantly different at $p < 0.05$.

4. Discussion

Under DI treatments, leaf area and stem height decreases (Table 5). The obtained results are generally similar to results found by Cabello (2009) and Keshavarzpour (2011) on cantaloupe. Stem height and leaf area was decreased by decreasing leaching fraction, due to a reduction of the avilable water on active root zone, which caused a disturbance in the physiological processes needed for plant growth (Badr, 2007; Cabello *et al.* 2009; Keshavarzpour and Rashidi, 2011). Also, the results (Table 6) could be explained as a result of enhancing cell division and enlargement that need more water supplies (Seyfi and Rashidi, 2007; Abou El-Yazied *et al.* 2012).

From the overall results, it could be concluded that yield and quality of fruit were inhanced, when the water level at I 100 was applied. However, decreasing irrigation quantaty up to 40% (Etc), decreased total yield, and has negative impact on fruit quality. Differences in yield among the three irrigation, and thus in the competition for assimilates between leaves (sources) and fruits (sinks). Fagan *et al.* (2006) stated that high fruit load affects leaf biomass negatively and Valantin *et al.* (1998) reported that the fruit number is the factor determining the allocation of resources between vegetative and reproductive organs; fruits constitute large sinks, which grow at the expense of leaf formation.We can explain the difference between yield by the fact that an increasing N uptake produces an increase in the fruit yield up to a maximum value (Kirnak *et al.*, 2005). On the other hand, in severe DI treatment, yield decreased while moderate DI (I 70) yield is stimulated. It seems that these DI are favorable for plant growth where physiological and biochemical process are stimulated leading to more accumulation of chlorophyll, dry matter and maximum yield (Gaafer and Refaie ,2006 ; Simsek and Comlekcioglu, 2011).

Data in Table (5) indicated that, water level at I 70, increased significantly chlorophyll a and b content and the stem diameter, than the other two irrigation levels. This increase of chlorophyll a and b can be a result of a slowdown in leaf growth, as the fruit required photoassimilates. In similar species, such sas cucumber, the translocation of photoassimilates to the fruit can exceed 50% of the total (Cabello *et al.*, 2009).This is also supported by Rashidi and Seyfi (2007) . They showed that when the highest yield was obtained, the vegetative growth was slower, especially when the fruit biomass was greater.

Brix is an important indicator in determining the eating quality of melon (Sensoy *et al.*, 2007; Ferrante *et al.*, 2008; Camoglu *et al.*,2010). In our study, under water stress conditions percentage of Brix was affected. In this context Buljovcic and Engels (2001); Ferreira and Goncalves (2007) and Lovelli *et al.* (2007) gave some explications : nutrient uptake by roots was affected by a reduction in the transportation of nutrients from the soil surface to absorbing root and transportation from the roots to the shoots was also adversely affected. Otherwise, DI increased significantly water use efficiency (WUE). Similar results were reported by Fabeiro *et al.* (2002) ; Ertek *et al.* (2003) ; Ribas *et al.* (2003) ; Simsek *et al.* (2005) and Al-Mefleh *et al.* (2012). Also, we found that DI decrease RWC, LWCA and LWC. Theses findings are in line with those of Terzi and Kadioglu (2006) and Bayoumi *et al.* (2008). When WUE was examined (Table 7), the highest values were determined in DI-low (I 40 and I 70) regimes. It was calculated that WUE values were increased with the decrease in amount of water. Zeng *et al.* (2009) reported that maximum WUE for potato was obtained with low irrigation. Kirnak *et al.* (2005) also reported similar results. Although, the lowest WUE were determined in I-excessive, the maximum fruit yield was obtained from this treatment. This result showed that melon was sensitive to water stress during this period. As

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the melon has a shallowroot, it is highly sensitive to the drought stress and needs frequent irrigation to prevent the possible water deficiency in the plant root zone. Water is restricted during the vegetative stage and from full fruit expanded to physiological maturity stages of plant tolerant to water stress. Thus, i twas reported that WUE is the main factor that limits plant productivity; crop yield losses are inevitable when the plant is exposed to water stress. The correct application of the DI needs detailed assessment of economic yield losses caused by water stress (Geerts and Raes, 2009). Also, the rate of water values decreased with the increase in soil water stress. A greater volume of water applied produced higher water content within the root zone, which lead to higher water consumptive use, as also indicated by (Soto-Ortiz and Abraham, 2006; Badr and Abou Hussein, 2008).

The results presented in Table 8 demonstrate that groth parameters were highly influenced by the total amount of irrigation water. The treatments with maximum irrigation water applied had the highest growth parameters, while treatments with reduced irrigation water had the lowest growth parameters. As shown in Table (6), using, water level at I 100 significantly increased the main number of fruit per plant and main fruit wieght, than the other included irrigation water treatments. However, low water level of 70% (Etc), recorded the highest values chlorophyll stability index compared to the other tested irrigation water treatments.

The favorable results which was obtained from using both the forementioned levels of irrigation water might be due to adequate available soil moisture within the root zone, this led to increase the various physiological processes as better uptake of nutrients, good plant growth, higher rates of photosynthesis, excess of dry matter accumulation which reflect and led to the best yields and fruit quality. Also, increase the levels of both auxins and gibberellins, within the biological concentrations, promote cell division and cell size enlargement. Hence, increase vegetative growth in order to yield and fruit quality (Refaie, 2003).

According to the results, applications of Reduced DI caused greater water stress than the high DI application. Reduced DI resulted in a greater fruit yield loss as compared to other regimes.

In the same contex, Kirnak *et al*. (2005) and Cabello *et al*. (2009) reported that DI practices reduced fruit weight of melon as compared to full-irrigation. Yildirim *et al*. (2009) found similar findings, but relatively larger fruit size and heavier weight in the treatments of irrigation during ripening and harvesting were found. Our results show that the combination of full irrigation and basic fertilization gave the largest size fruit.

5. Conclusion

Our results showed that under drought stress, stem lenght, total leaf area, Brix, chlorophyll a and b, number of fruits per plant, fruit weight as well as total crop yield and water use efficiency were reduced. Thus, total chlorophyll content and chlorophyll stability index were increased under moderate irrigation (I 70). So we can conclude that moderate (I 70) and severe (I 40) drought stress decreased melon yield and it's components. Based on these results, it is important to apply optimum irrigation and fertilization programs for stabilization and maximization yield and quality. Optimization of the water and nutrient requirements of plant is also important due to both economic and environmental reasons. To obtain high fruit yield, irrigation water availability could be ajusted.

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