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Effect of irrigation intervals on growth and yield of Pepper (*Capsicum annuum* L.)

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Abstract

The aim of this study is to estimate the effect of irrigation intervals on the yield and the quality of Pepper under Assiut conditions. Three irrigation intervals (every 7 (IR_7), 14 (IR_{14}) and 21 (IR_{21}) days) and three Pepper genotypes (Omega F1, Pical F1 and 1515 F1) were used. Our results showed that irrigating pepper plants every week (IR_7) significantly gave the highest ascorbic acid content of pepper fruits, total fruits number per plot, average fruit weight, early fruit yield per feddan, and pepper total yield in both seasons. Also, highest value of soil field capacity was found in samples collected from the IR_7 treatment. On the other hand, plants irrigated every 21 days (IR_{21}) had the highest values of percentage of whole plant dry weight and proline content. In both seasons, Omega F1 every significantly gave the highest values of total fruit fresh yield, percentage of whole plant dry weight, and fruit vitamin C content in the second season. Bell pepper 1515 F1 significantly produced the highest values of average fruit weight in both seasons. Interestingly, under deficit irrigation Omega F1 genotype (considered as a drought tolerant genotype) which produced the highest total fruit yield, produced lower leaf proline content than 1515 F1 genotype which is more sensitive to water deficit treatments. We conclude that plant response to water deficit depends on the plant genotype, and not on the proline content.

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Introduction

Most of the Egypt's land is desert. The area of agricultural land in Egypt is restricted to the Nile Valley and delta, with a few oases and some arable land in Sinai (Ismail, 2010). The total cultivated area (arable land plus permanent crops) is about 7.2 million feddans (1 feddan = 0.42 ha), representing only 3 percent of the total land area (FAO, 2017). The entire crop area is subjected to surface irrigation, except for some rain-fed areas on the Mediterranean coast. The landholdings are fragmented, with the average size of farm units being 2.5 feddans (Elarabawy and Tosswell, 1998).

Peppers (*Capsicum spp.*) are one of the most important vegetables and spices in the world. It has been a part of the human diet since about 7500 BC(Perry *et al.*, 2007). Therefore, chili pepper plants are now planted worldwide, e.g., in Egypt (Abdalla *et al.*, 2018), Ethiopia (Samira *et al.*, 2013), India (Bharathi *et al.*, 2011), Spain (Moreno *et al.*, 2003), and Mexico (Sanogo, 2006) as well as China (Shao *et al.*, 2008, 2010; Fan *et al.*, 2014; Qiu *et al.*, 2015). Pepper (*Capsicum annuum* L.) fruits have high nutritive and culinary value (Bosland and Votava, 2000) and are commonly used as a seasoning to provide special flavor to cooked food (Premavalli *et al.*, 2010). *Capsicum* not only gives a pretty color and flavor to the foods but also provides minerals and vitamins C, A, B complex, and E. Capsaicin present in chilli pepper is used as medicine for treatment of many human diseases like lumbago, neuralgia, rheumatic disorders and non-allergic Rhinitis.

Bell and chilli peppers are considered the most susceptible horticultural crops to drought stress due to its broad range of transpiring leaf surface, high stomatal conductance (Alvino *et al.*, 1994) and shallow root system (Hulugalle and Willatt, 1987; Dimitrov and Ovtcharrova, 1995; Kulkarni and Phalke, 2009;Liu *et al.*, 2012; Nagaz *et al.*, 2012; Yildirim*et al.*, 2012; Armita *et al.*, 2017).

Various kinds of unfavorable environmental stresses (such as drought, salinity, heat, cold and oxidative stresses) retard the growth and yield of pepper plants (Kumar and Arumugam, 2013; Nouri *et al.*, 2015 and Mickelbart *et al.*, 2015; Joshi *et al.*, 2018; Wu *et al.*, 2018). Water stress during the most critical periods of pepper growth (including vegetative, flowering, or fruit setting) causes substantial yield loss (Sezen *et al.*, 2006; and Xie *et al.*, 1999).

Climate change has emerged as one of the most complex challenges of the 21st century and has become an area of interest in the past few decades (Fita, 2015). Many countries of the world have become extremely vulnerable to the impacts of climate change (Rosmaina *et al.*, 2018). The scarcity of water is a serious alarmfor food security of these countries and climate change has aggravated the risks of extreme events like drought (Smith *et al.*, 1998;Bruce *et al.*, 1980;Kang *et al.*, 2001; Dorji *et al.*, 2005; Juan, 2018).

Proper irrigation is critical for pepper production. Optimal irrigation management gives a healthy plants, maximum yields, and high-quality fruits (Askari *et al.*, 2018; Bhutia *et al.*, 2018; Singh *et al.*, 2018; Yildizli *et al.*, 2018; Joshi *et al.*, 2018; and Wu *et al.*, 2018). Thus, the aim of this study is to study the effects of using different irrigation regimes and different pepper cultivars on plants growth, yield, and water-use efficiency in the field with the purpose of selecting the cultivars that are more efficient in water utilization.

Materials and methods

The present experiment was carried out during the summer seasons of 2014 and 2015 at the Experimental Farm of Vegetable Crops Department, Faculty of Agriculture, Assiut University, Egypt. Three irrigation intervals (IR_7, IR_{14} and IR_{21}) and the three hybrids (Omega F1, Pical and 1515 F1) of peppers (*Capsicum annuum* L.) were used to investigate their effects on growth, yield and quality of pepper crops grown under Assiut conditions. The soil texture of the experimental site was clay with an average pH of 7.65. Local cultivation practice recommendations for the control of insects and diseases were followed and were found enough to maintain normal crop growth. The experimental site has a subtropical climate, characterized by three distinct seasons, the winter season (from November to February), the summer season (from March to June) and the fall season (from July to October).

Planting and field transplantation

In order to raise seedlings for transplantation in the field, seeds of the three pepper genotypes (Omega F1, Pical and 1515 F1) were cultivated in the greenhouse of the Experimental Farm of Vegetable Crops Department. Pepper seeds were sown in the nursery on January 1st in both seasons. Transplantation took place on February 17th and 21st in the first and second season, respectively. Six-week old pepper transplants were planted by hand in the field after they were hardened-off. Hardening-off the pepper transplants was done by withholding water for about 3-7 days before digging out. At the transplanting time, ridges were thoroughly irrigated, and transplanting took place on the southern side of the ridge in the presence of water through furrows. Transplants were arranged in the experimental plots on five ridges, 70 cm apart, with 30-40 cm spacing between plants. Levels of applied fertilizer in the permanent field were maintained according to the guidelines. Experimental plot area was 12 m^2.

Irrigation treatments

Three irrigation periods (IR_7, IR_{14} and IR_{21}) were used. Each irrigation treatment was separated by five meters of non-irrigated block to avoid horizontal soil water movement. Drought treatments began 30 days after seedling cultivation in the two seasons. Irrigation treatments started on March 17th, 2014 and on March 21st, 2015. The harvest was done at the end of August in both seasons.

Measurements

Bell (1515 F1) and hot pepper (Omega F1 and Pical F1) genotypes were harvested at the same time in both seasons. Fruits were harvested from May to Augustin both seasons. Fruits were collected by hand, twice a week, in the four months' duration when they have reached the full size with maximum wall thickness while they were still immature and green. In each plot, fruits from all plants were counted and weighed. Yield and its related characters per plot were estimated. Furthermore, at the end of growing season, pepper traits such as field capacity according to Ismail (2010), total fruits fresh yield (ton/fed), average fruit weight (g), early fruits yield (ton/feddan), total fruits number (per plot), whole plant dry weights (g), percentage of proline content (mg/g dry weight)according to Bates *et al.* (1973), and vitamin C content (mg/ 50 g-1FW) were measured according to Ruck (1963).

Statistical analysis

This was a two-factor strip plot experiment with 3 replications in a randomized complete block design (RBCD). All data collected where subjected to analysis of variance using SAS 2002 and means that were significantly different (according to the F-test) were then separated by Duncan's multiple range test at Pd"0.05 (Gomez and Gomez, 1984).

Results and discussion

Field capacity

The percentage of field capacity was recorded to find out in which irrigation treatment the growth and development of pepper plants will resume without sever shortfall (Figs 1, 2, 3). Pepper is sensitive to water stress and flowering during limited irrigation periods leads to growth delay with low quality fruit caused by the lack of water (Maughan *et al.*, 2015).

The percentage of moisture content (FC) was highest (ranging between 28.5% and 32.9% of the saturation point) in the full irrigation treatment (IR_7), depending on the weather factors, particularly temperature and sunshine hours that increase the daily evapotranspiration. The high moisture content was because irrigation was continued every week till the full moisture capacity is reached, hence more humidity was remained as available moisture in the soil at the end of this treatment (IR_7). In the medium-deficit irrigation treatment (IR_{14}), soil moisture content ranged between 20% to 26%.

Table 1. Some meteorological data for Assiut governorate for the period from January 2014 to December 2015.

Climate Data for Assiut Governorate												
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average high °C	19.3	21.7	25.1	31.4	35.2	37.1	36.5	36.0	34.2	30.5	25.1	20.3
Average low °C	4.7	6.3	9.7	14.5	18.6	21.3	22.0	21.7	19.6	16.2	10.7	6.71
Monthly mean °C	11.7	13.9	17.4	23.2	27.2	29.6	29.6	29.0	26.9	23.4	17.4	13.3
Ave. RH (%)	52	42	36	28	25	27	32	36	40	42	48	52
Mean Sunshine	9	9	10	10	11	12	12	12	11	10	9	8

Table 2. Number of applied irrigations after 30 days from seedling transplanting for each irrigation interval all over the experiment period.

Years Irrigation period	2014	2015
IR_7 days (C)	21	19
IR_{14} Days	10	9
IR_{21} Days	7	6

This value was also high considering the rate of irrigation scheduling. Moisture content in severe-deficit irrigation treatment (IR_{21}) ranged between 16% and 25%. The increase in soil moisture will increase the available water in the soil. This will continue to ensure a nearly field capacity saturation leaving more humidity in the soil for the crop roots.

This, however, does not simply increase water use in the treatments (Reichardt *et al.*, 2001).

Table 3. Pepper fruit fresh total yield as affected by the three irrigation periods and three pepper hybrids in seasons of 2014 and 2015.

Total fruit fresh yield (ton/fed), 2014				
Genotypes Drought period	Omega	Pical	15-15	Average
IR 7 days (C)	13.96 a	12.83 a	8.13 bc	11.64 A
IR 14 Days	10.03 b	5.80 cde	5.33 cde	7.06 B
IR 21 Days	6.38 cd	4.11 de	3.04 e	4.51 C
Average	10.12 A	7.58 B	5.50 B	
Total fruit fresh yield (ton/fed), 2015				
IR 7 days (C)	11.15 a	9.77 b	9.39 b	10.10 A
IR 14 Days	7.88 c	6.31 d	6.65 d	6.94 B
IR 21 Days	5.09 e	3.76	2.86 f	3.90 C
Average	8.04 A	6.61 B	6.30 B	

The genotypes 1515 F1 recorded the highest percentage of field capacity (water availability) followed by Pical F1, while Omega F1 gave the lowest percentage of field capacity. The data recoded for the first season inconsistent with the results recorded for the total yield, number of fresh fruits, and average fruit weight. In both seasons, the combination between 1515 F1 hybrid and the shortest irrigation treatment (IR_7, that received the highest amount of irrigation) gave the highest field capacity, while the combination of any pepper hybrid with the severest irrigation treatment (IR_{21}) gave the lowest fieldcapacity.

Total fresh fruit yield (ton/fed)

Table 3 show that pepper total fresh fruit yield per feddan was significantly affected by the three drought intervals studied in the two seasons of 2014 and 2015. Results of the two seasons, as an average of all tested pepper hybrids, indicate that regular watering (every one week to keep soil moisture continuously near field capacity) gave significantly the highest pepper total yield in the first (11.64 ton/fed) and the second (10.10 ton/fed) seasons.

Table 4. Effect of drought periods and pepper genotypes on the early fruit yield in 2014 and 2015 seasons.

Early fruit yield (ton/fed.), 2014				
GenotypesDrought period	Omega	Pical	15-15	Average
IR 7 days (C)	1.05 bc	3.05 a	1.35 b	1.82 A
IR 14 Days	0.68 bcd	1.39 b	0.85 bcd	0.97 B
IR 21 Days	0.23 d	0.48 cd	0.24 d	0.32 C
Average	0.65 B	1.64 A	0.81 B	
Early fruit yield (ton/fed.), 2015				
IR 7 days (C)	0.75 bc	1.48 a	1.30 a	1.18 A
IR 14 Days	0.57 c	1.16 ab	1.56 a	1.10 A
IR 21 Days	0.50 c	0.79 bc	0.76 bcd	0.68 B
Average	0.61 B	1.14 A	1.20 A	

Means with different letter(s) are significantly different at 0.05 level of probability.

Table 5. Effect of drought periods and pepper genotypes on the proline content in 2015 seasons.

Proline content (mg/g^{-1} DW), 2015				
GenotypesDrought period	Omega	Pical	15-15	Average
IR 7 days (C)	0.35 c	0.46 b	0.36 c	0.39 C
IR 14 Days	0.48 b	0.52 b	0.45 b	0.48 B
IR 21 Days	0.54 b	0.51 b	0.97 a	0.67 A
Average	0.45 A	0.49 A	0.59 A	

Means with different letter(s) are significantly different at 0.05 level of probability.

The higher yield obtained in the non-stressed treatment (IR_7) might be because of the lower proline content recorded.

Similar findings were recorded by Hare and Cress (1997);Terao *et al.* (2003); Mattioli *et al.* (2009);Hahm *et al.* (2017); Sahitya *et al.* (2018); Yildizli *et al.* (2018) found that the higher yield may be also caused by the good irrigation that made the plants don't need to accumulate proline. Likewise, Yao *et al.* (2009) and Yang *et al.* (2018) found that the tolerance of tomato plants to salt stress was not related to either increase in proline or phenolic compounds accumulation.

However, accumulation of proline has been advocated as a parameter of selection for stress tolerance (Yancy *et al.* 1982. Jaleel *et al.* 2007). Opposite results were recorded by Abebe, (2009); and Nagaz *et al.* (2012) whofound that high irrigation regimes increased fresh and dry fruit yield, fruit number, harvest index, and top dry matter production but decreased total fruit yield.

In the present study, the long repetitive severe stress treatment (IR_{21}) significantly gave the lowest pepper total fruit yield in the first (4.51ton/fed) and second (3.90 ton/fed) seasons.

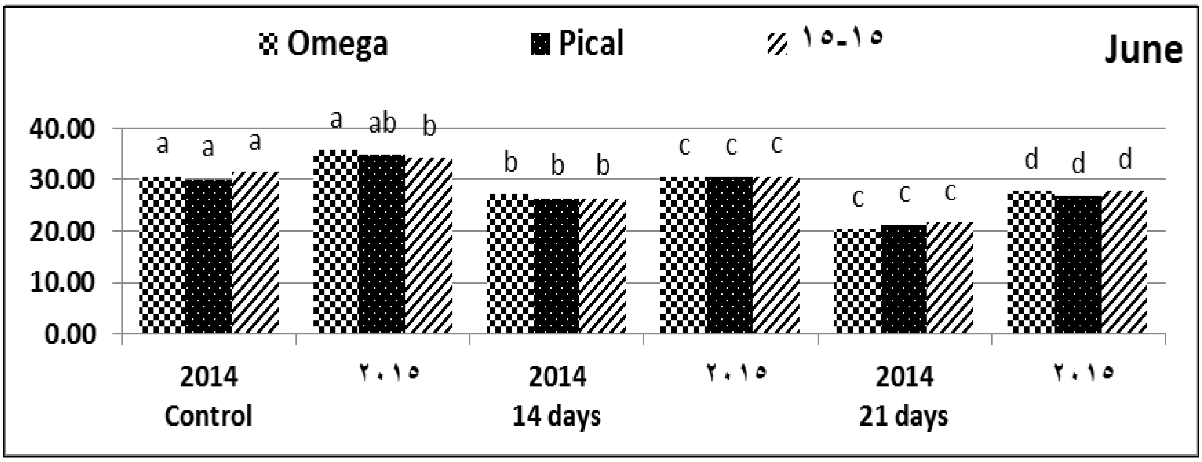
Percentage of yield decrease in IR_{21} treatment was 60% compared to the control (every 7 days) treatment as an average of the two seasons. Opposite findings were reported by Foday *et al.*, (2012) whoshowed that treatment with moderate irrigation schedule (50% of evapotranspiration at vigorous fruit bearing) recorded high yield as compared to the control treatment (100% irrigation schedule of evapotranspiration) throughout the four stages of plant growth).

Table 6. Effect of drought periods and pepper genotypes on ascorbic acid content in 2015 seasons.

Ascorbic acid content (mg/ 50 g-1FW), 2015				
Genotypes Drought period	Omega	Pical	15-15	Average
IR 7 days (C)	6.46 cde	4.37 e	9.88 ab	6.90 AB
IR 14 Days	8.55 ab	7.41 bcd	7.79 bc	7.92 A
IR 21 Days	6.65 cde	6.27 de	5.32 ef	6.08 B
Average	7.22 A	6.02 B	7.66 A	

Means with different letter(s) are significantly different at 0.05 level of probability.

Bell pepper 1515 F1 significantly produced the lowest total fruit fresh yield in both seasons. The fruit yield of the high pungent hybrids (Omega and Pical) did not severely decrease under drought stress. Omega F1 significantly gave the highest average total fruit fresh yield in both seasons followed by Pical F1 without significant differences between these two hybrids. Regarding the effect of capsaicin content on pepper tolerance to drought stress, Phimchan *et al.* (2012) noted that high pungent cultivars have good water retention that resulted in a minimal effect of drought stress on the yield and capsaicinoid contents.



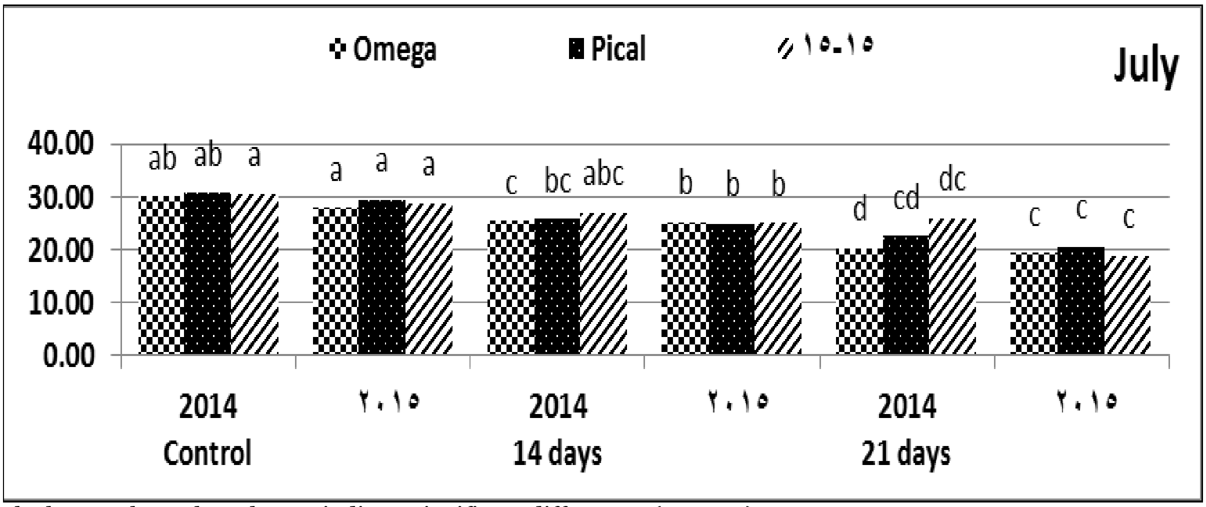
The letters above the columns indicate significant differences (P< 0.05).

Fig. 1. Effect of field capacity on the drought periods and pepper genotypes in June, 2014 and 2015 seasons.

The higher proline content (0.59 mg/g FW) recorded in 1515 F1 hybrid compared to the other two hybrids did not help this genotype to overcome drought stress to produce enough yield in both seasons.

Similar findings were recorded by Verbruggen and Hermans, (2008) who stated that variety differences in proline content or interactions between variety and drought treatment were absent. Gharsallah *et al.* (2016); Askari *et al.* (2018) andRosmaina*et al.* (2018) found thattolerant chilli varieties will increase the proline content and maintain the total sugar and chlorophyll content. Tanamo, Lado, Kastilo, and BCA are varieties that can survive under drought stress and still provide the higher yield.

Omega F1 irrigated every one week (IR_7) significantly produced the highest fruit fresh yield in the both seasons. However, bell pepper hybrid 1515 irrigated every three weeks (the severest water deficit treatment, IR_{21}) significantly gave the lowest total fresh fruit yield in the two seasons (Table 3).



The letters above the columns indicate significant differences (P< 0.05).

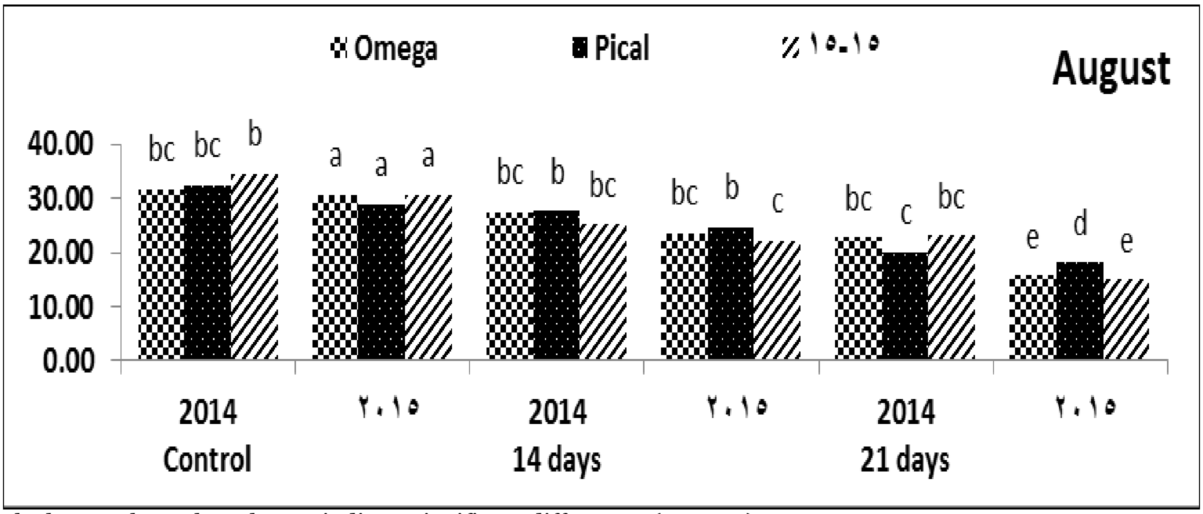
Fig. 2. Effect of field capacity on the drought periods and pepper genotypes in July, 2014 and 2015 seasons.

Average fruit weight (g)

The effect of the three irrigation intervals as an overall average of the three tested genotypes had a significant effect on the average fruit weight in the second season only (Fig. 4).

The control treatment irrigated every 7 days gave a significant increase of the average fruit weight (11.91g), however, the severest irrigation treatment (IR_{21}) gave the lowest average fruit weight (10.20g).

These results agreed with those documented by Nagaz *et al.* (2012); Kipchirchir (2016), and Rosmaina *et al.* (2018) who showed that water stress significantly decreased fruit yield (16.6%), fruit weight (13.8%), stem girth (31.9%), and chlorophyll content (12.6%).The sweet pepper 1515 F1 gave the highest values of average fruit weight in the first (18.81g) and the second (19.08g) seasons followed by Pical hybrid (8.89g and 9.26g, respectively), with significant differences between the two hybrids (Fig. 4).



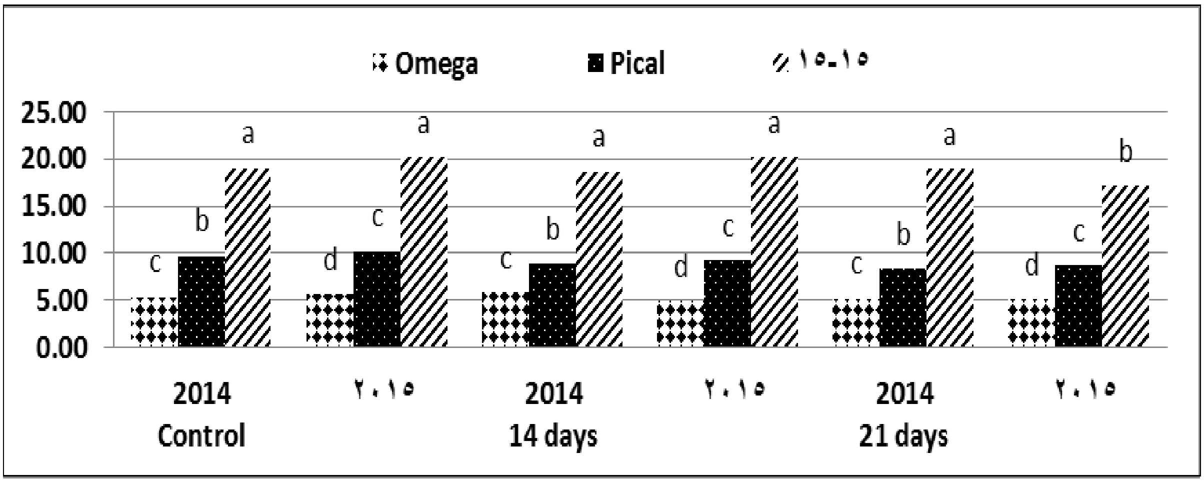
The letters above the columns indicate significant differences (P< 0.05).

Fig. 3. Effect of field capacity on the drought periods and pepper genotypes in August, 2014 and 2015 seasons.

Findings recorded by Khan *et al.* (2008); Colak *et al.* (2017) Kipchirchir (2016); and Ilahi *et al.* (2017) showed that response of pepper to drought stress with respect to growth, yield, physiological and nutritional quality was dependent on accessions.

The lowest average fruit weight values were significantly produced in the combination between

Omega F1and any of the three irrigation intervals (C, IR_{14} and IR_{21}) in both seasons (Fig. 4). These results illustrate that the effect of the genotype on average fruit weight is more pronounced than the three tested drought intervals. Or drought stress did not affect the average weight of pepper fruit in either season. The same findings were recorded by Kipchirchir (2016) who showed that the response to drought stress regarding plant growth, yield, physiological and nutritional quality was dependent on the accessions.



The letters above the columns indicate significant differences (P< 0.05).

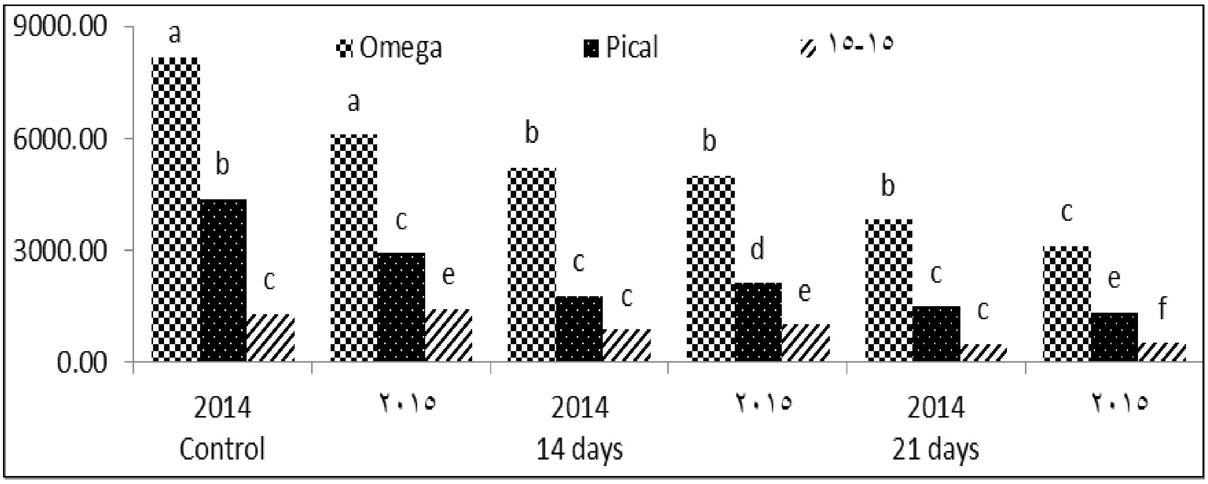
Fig. 4. Effect of drought periods and pepper genotypes on the average fruit weight in 2014 and 2015 seasons.

Early fruit yield (ton/fed)

Results of the two seasons showed a significant effect of the three irrigation treatments (IR_7, IR_{14} and IR_{21}) on the early fruit yield (Table 4). As an average of the two seasons, our results showed that the maximum and the minimum early fruit yield per feddan were recorded in the irrigation treatments IR_7 (1.5 ton/fed) and IR_{21} (0.5 ton/fed.). It is worth to mention that the difference of early fresh yield between the two irrigation treatments (every 7 and 14 days) were quite small and did not reach the statistical significance level in the second season compared to the first season. According to these results, it can be concluded that about 30% deficit irrigation (DI) in peppers did not result in significant yield reduction, while higher levels of DI may adversely affect peppers growth and yield.The same findings were reported by Khederi *et al.* (2016); Kipchirchir (2016); Kuşçu *et al.* (2016), Sara *et al.* (2017); Ichwan*et al.* (2017); and Rosmaina *et al.* (2018) who reported that the maximum decrease of growth and yield was recorded under the high level of water stress (50% field capacity) compared to optimum water supply (100% FC).Omega F1 and Pical F1 significantly produced the lowest and highest early fruit yield in both seasons, respectively (Table 4). In the second season, Pical F1 and 1515 F1 produced the highest early yield. Penella *et al.* (2014) and Singh *et al.* (2018) found that peppers response to drought stress with respect to growth, yield, and physiological and nutritional quality was dependent on the accessions. The combination of the longest irrigation period (IR_{21}) with Omega F1 or 1515 F1 hybrids significantly gave the lowest early yield in the first season (Table 4). In the second season, Omega F1 gave the lowest early yield. The combination between Pical F1 and the commercial irrigation treatment (every week) significantly produced the highest early yield in both seasons.

Total fruits number (per plot)

The preferred irrigation method for farmers (every one week) significantly produced the highest total fruits number per plot in the first (4602.0) and the second (3480.2) seasons. However, irrigating pepper plants every three weeks (IR_{21}) significantly reduced the total fruits number in the first (1934.2) and the second (1654.6) seasons (Fig. 5). Total fruits number per plot was reduced by more than 40% in (IR_{14}) and 60% in (IR_{21}), as an average of the two seasons, compared to the full irrigation treatment (IR_7). The total number of fruits per plot was positively (and significantly) correlated with branch numbers, total fruit fresh yield, fruit diameter, fruit length, and average fruit weight (Tables 11 and 12). Similar findings were reported by Phimchan *et al.* (2012) who illustrated that drought stress decreased fruit numbers and yield. Abebe (2009) found that high irrigation regimes increased fresh and dry fruit yield, fruit number, harvest index, and top dry matter production. Opposite results were recorded by Fernandez *et al.* (2005) who showed that water deficit had little effect on the total fruit number but substantially increased the proportion of unmarketable small fruits.



The letters above the columns indicate significant differences ($P< 0.05$).

Fig. 5. Effect of drought periods and pepper hybrids on the total fruit number per plot in 2014 and 2015 seasons.

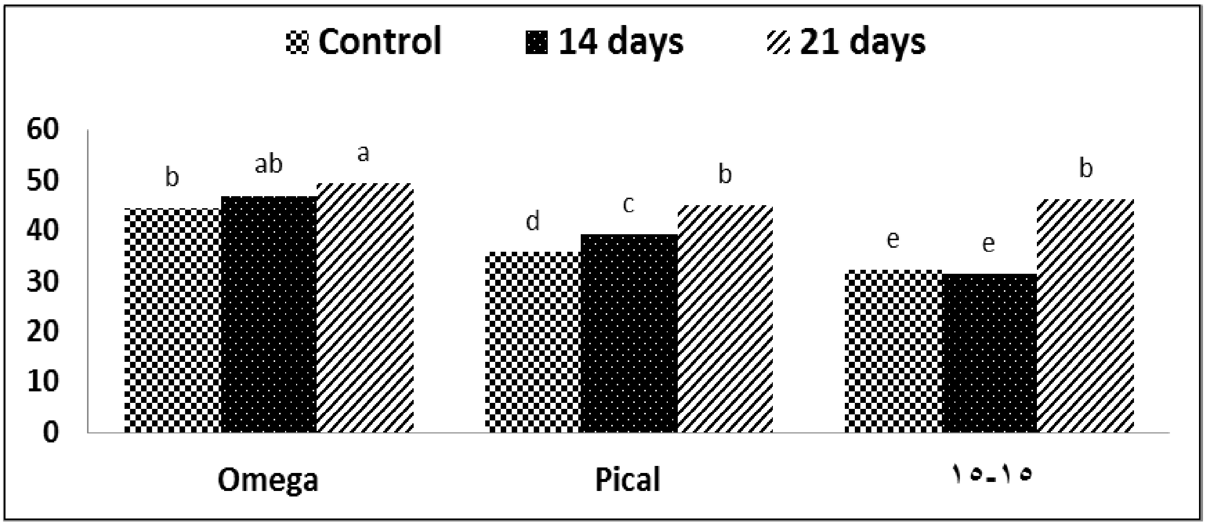
Omega F1 produced significantly the highest total fruit number and in the first (5726.2) and the second (4738.8) seasons, followed by the hybrid Pical, whereas 1515 F1 significantly produced the lowest numbers in the first (887.1) and the second (976.3) seasons (Fig. 5).

In both seasons, Omega F1 irrigated everyone one week significantly gave the highest total fruit number while the combination of the bell-shaped pepper hybrid 1515 and the irrigation treatment every three weeks (IR_{21}) gave significantly the lowest numbers in both seasons. It is noteworthy to declare that in the first season (2014), the combination between the sweet pepper hybrid 1515 with any irrigation interval gave the lowest total pepper fruit number in both seasons. The difference in the total fruit number between pepper genotypes as affected by deficit irrigation is well documented by several investigators. Abdulmalik *et al.*, (2012) and Klunklin and Savage (2017) revealed that drought stress of some genotypes of sweet and red chilli affects the number of flower buds, the percentage of flowers fall, the percentage of fruit set and fruit production.

Percentage of whole plant dry weight (g)

The studied three irrigation intervals significantly affected the percentage of whole plant dry weight (Fig. 6). Plants irrigated every 21 days (IR_{21}) possessed the highest whole plant dry weight (46.96 g) compared to the non-stressed plants (37.59 g). Similar findings were recorded by Marín *et al.* (2009) who revealed that low irrigation frequency and salinity improved peppers quality attributes (dry matter, soluble solids content and titratable acidity). Opposite findings were reported by other researchers where increasing the amount of water increased the whole plant dry matter (DM). Khan *et al.* (2008); Evangelista *et al.* (2016) and Rakha (2018) reported that short irrigation intervals significantly increased all growth measurements of eggplants while longer irrigation intervals decreased all vegetative growth parameters. Also revealed that leaf dry matter was reduced when plants were subjected to a higher water deficit. Omega F1 genotype produced the highest percentage of whole plant dry weight (46.98 g), followed by Pical F1 (40.11 g), with significant difference between the two genotypes (Fig. 6). Sweet pepper, however, (1515 F1) gave significantly the lowest percentage of whole plant dry weight (36.68 g**).** Based on the results of the present study, it can be confirmed that Omega F1 and Pical F1 have better adaptability to water shortage compared to 1515 F1. Nancy Ruiz-Lau (2011) and Klunklin and Savage (2017) found significant differences between different pepper cultivars in quality characteristics such as dry matter, total soluble solids, and pH parameters.

The combination between Omega F1 and the severest irrigation treatment (IR_{21}) significantly produced the highest percentage of whole plant dry weight (DW). The lowest percentage of whole plant DW was recorded in the combination between 1515 F1 and non-stress (IR_7) or medium-stress (IR_{14}) treatment with no significant difference between the two irrigation intervals.



The letters above the columns indicate significant differences ($P< 0.05$).

Fig. 6. Effect of drought periods and pepper hybrids on the percentage of whole plant dry weight (g) in summer season of 2015.

Proline content (mg/g^{-1} *DW)*

The three irrigation intervals significantly affected proline content in pepper plants as an overall average of pepper hybrids (Table 5). The highest proline content (0.67mg/g^{-1}DW)was recorded in the severest irrigation treatment (every 21 days, IR_{21}). On the other hand, the full irrigation treatment (every 7 days, IR_7) significantly gave the lowest proline content (0.39 mg/g^{-1} DW) for all three tested hybrids. The same trend was recorded by Ichwan *et al.* (2017); Hahm *et al.* (2017) and Yildizli *et al.* (2018) who found that drought stress generally increases levels of proline content by 4.79% (75% FC) and 62.28% (50% FC). Proline, an amino acid, plays a highly beneficial role in plants exposed to various stress conditions (Qureshi *et al.*, 2013; Bojórquez-Quintal *et al.*, (2014); Pottosin *et al.*, 2014; and Gharsallah *et al.*, 2016). No significant differences were found among the three pepper hybrids regarding the proline content. Despite the insignificant F values, the sweet pepper hybrid 1515 produced higher proline concentration (0.59 mg/g^{-1} DW) than Omega F1 (0.45 mg/g^{-1} DW). Similar results were recorded by Phimchan *et al.* (2012) who revealed that high pungent cultivars had good water retention with minimum effect of drought stress on the yield and capsaicinoid contents. Drought stress effects were higher in the low and medium pungent cultivars. The present results show that sweet pepper hybrid 1515 F1 (low in capsaicin content) although produced the highest proline content, it gave the lowest total fruit yield, demonstrating that this genotype is very sensitive to deficit irrigation (Table 9). In contrast, Omega F1 (that may be considered as a tolerant genotype) produced lower proline content (compared to bell pepper hybrid 1515 F1) but have the highest total fruit yield. The plant response to water deficit depends on the genotype of the plant not on proline content (Ashraf and Harris 2005). Conflicting results were found concerning proline content in the combination between the three irrigation intervals and the three pepper genotypes (Table 5). For example, the combination between bell pepper 1515 F1 and the full irrigation treatment (IR_7) significantly gave the lowest proline content (0.36mg/g$_-{}^{1}$DW) but when irrigated every 21 days (IR_{21}) it significantly gave the highest proline content (0.97 mg/g$_-{}^{1}$ DW).In the same line, Ahmadizadeh, 2013, reported stated that plant response to drought stress can differ significantly, depending on the stage of plant development and genotype.

Ascorbic acid content (mg/ 50 g^{-1}FW)

Short irrigation treatment (IR_7) and medium irrigation interval (IR_{14}) significantly increased the ascorbic acid content of pepper fruits compared to severe-stress (IR_{21}) treatments (Table 6). In our study, the lowest ascorbic acid content was recorded in the longest irrigation interval (IR_{21}). Similar trend was recorded by Marín *et al.* (2009) revealed that low irrigation frequency increased vitamin C content by 23% in green peppers but did not affect its levels in the red fruits. Moreover, vitamin C content was decreased as deficit irrigation was increased (Horemans *et al.*, 2000; Zechmann, 2011; Shapiguzov *et al.*, 2012).

Significant differences were recorded among the three pepper hybrids regarding ascorbic acid content (Table 6). The highest vitamin C content was obtained in Omega F1 (7.22 mg/ 50 g^{-1}FW) and 1515 F1 (7.66 mg 50/ g^{-1}FW), while Pical F1 had significantly the lowest vitamin C content (6.02 mg 50/ g^{-1}FW). The results of our study show significant differences in the vitamin C content among the three genotypes investigated and the response of each hybrid is very variable with different watering regimes. Similar trend was recorded by Kipchirchir (2016) and Klunklin and Savage (2017) whofound significant differences between different cultivars in quality characteristics as water stress significantly decreased growth and fruit yield parameters, Ca, Mg, Fe and Zn contents but increased β-carotene, vitamin C and total soluble solids.

The combination between full irrigation (IR_7) treatment and 1515 F1 with gave significantly the highest vitamin C content (9.88 mg 50 g^{-1}FW), whereas, the same irrigation treatment (IR_7) combined with Pical F1 significantly gave the lowest ascorbic acid content (4.73 mg 50 g^{-1}FW). Findings recorded by Klunklin and Savage (2017) also documented the significant differences between cultivars in quality characteristics. In the present study, the differences in the quality characteristics between well-watered and drought stress treatments were not significant.

Conclusion

Generally, Every plant has a different response to drought conditions. The present results show that sweet pepper hybrid 1515 F1 (low in capsaicin content) although produced the highest proline content, it gave the lowest total fruit yield, demonstrating that this genotype is very sensitive to drought stress.

In contrast, Omega F1 (that may be considered as a tolerant genotype) produced lower proline content (compared to bell pepper hybrid 1515 F1) but have the highest total fruit yield. The plant response to water deficit depends on the genotype of the plant not on proline content.

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