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Response of Sweet Pepper to Irrigation Intervals and Humic Acid Application

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ABSTRACT

Two field experiments were carried out at the private field in El-Hawawsha Village, Dakahlia Governorate, Egypt, during the two successive summer seasons of 2016 and 2017 to study the effect of irrigation intervals, humic acid application and their interaction on growth and productivity of sweet pepper cv. "California wonder". The experiments were carried out in split-plots design with three replications. The obtained results showed that 15 days irrigation interval significantly increased number of leaves/plant, fresh and dry weight/plant, leaf area/plant, yield/plant, total yield, chlorophylls a, b and total chlorophyll of sweet pepper leaves and vitamin C, total soluble solids (TSS %) and acidity of pepper fruits as compared with irrigation at 20 days, which had the lowest significant values. Soil application of humic acid showed significant increases in all studied parameters as compared with control in both seasons. The superior application was soil application of 3 kg humic acid/fed, followed by soil application of 2 kg humic acid/fed, then foliar application of 2 g humic acid/L and foliar application of 1 g humic acid /L in both seasons. The highest values of all the studied characters were resulted from irrigation sweet pepper plants every 15 days combined with soil application with humic acid at the rate of 3 kg/fed in both seasons. Therefore, this treatment can be concluded under the same conditions.

Keywords: Sweet pepper, *Capsicum annuum* L., Irrigation intervals, Humic acid.

INTRODUCTION

Capsicum (*Capsicum annuum* L.) commonly known as sweet pepper belongs to family *Solanaceae*. In Egypt, it is one of the most popular vegetable crops and favorite in the domestic market and export. High cash crops such as sweet peppers have been raised in Egyptian agriculture (Rajput and Poruleker, 1998).

Irrigation plays an important role in sustaining the sustainable growth of each crop, particularly by reducing wilt responsible for crop loss by 60 to 80%(McNiesh and Welch, 1985). Delfine *et al.* (2002) reported that photosynthetic limitation resulted from water stress was sufficient to reduce plant growth and fruit marketability of pepper plants. According to Adeoye*et al.* (2014), the irrigation intervals (daily, 3 days, 6 days and 9 days and a no-irrigation plot to serve as control) affected vegetative growth characters (stem diameter, number of leaves, leaf area) and yield and its components (number and size of fruits and total yield) of sweet pepper.

Humic acid is one of the main components of humic substances, which are the main organic constituents of soil (humus). Humic substances have a significant impact on plant growth, either directly or indirectly. Indirect effects of humic compounds on soil fertility; increased microbial concentrations in soil (including beneficial microorganisms), soil uptake ability and improved soil structure. While the direct effect of hemicic acid compounds on plant growth is influenced by biochemical effects on either cell wall or membrane permeability or cytoplasm, which increases photosynthesis and respiratory rates in plants, increases protein synthesis and promotes mineral uptake by stimulating microbiological activity. Increase the yield (Asik*et al.* 2009).

Therefore, the present investigation designed to determine the suitableirrigation interval and humic acid treatments to obtain high productivity and fruit quality, as well as storability of pepper plants under the environmental conditions of Dakahlia Governorate, Egypt.

MATERIALS AND METHODS

Two field experiments were carried out at the private field in El-Hawawsha Village, Dakahlia Governorate, Egypt, during the two successive summer seasons of 2016 and 2017 to investigate the effect of irrigation intervals and humic acid application as well as their interaction on growth and productivity of sweet pepper (*Capsicum annuum* L.) variety "California wonder".

The experiments were carried out in split-plots design with three replications. The main-plots were assigned to three different irrigation intervals (irrigation every 10, 15 and 20 days).The sub-plots were allocated with the following five treatments of humic acid application *i.e.*humic acid soil application (2 and 3 kg/fed), humic acid foliar application (1 and 2 g/L) and control (spraying with tap water).The experimental plot area included three ridges, each (0.70 m width) and (5.0 m length), resulted an area (of 10.5 m^2). Representative samples were collected from the surface layer (30 cm depth) of the experimental field and analyzed for some physical and chemical properties as shown in Table 1.

Table 1. Physical and chemical properties of the experimental soil during both seasons of 2016 and 2017.

Soil characters		2016	2017
Mechanical analysis (%)			
Hygroscopic humidity %		4.60	4.62
Sand		32.28	32.31
Silt		43.00	42.00
Clay		24.72	24.70
Texture class		Clay	Clay
Chemical analysis:			
EC dSm^{-1}		0.72	0.72
pH		8.60	8.40
O.M. %		1.71	1.73
Soluble anion (meq L^{-1})	SO_4^{-2}	0.95	0.97
	CO_3^{-2}	-	-
	HCO_3^-	0.43	0.44
	CL^-	0.34	0.35
Soluble cation (meq L^{-1})	K^{+1}	0.02	0.03
	Na^{+1}	0.66	0.68
	Ca^{+2}	0.74	0.75
	Mg^{+2}	0.30	0.33
ESP %		1.66	1.68
Micronutrients (ppm)	Fe	12.06	12.11
	Mn	7.03	7.06
	Zn	3.04	3.01
	Cu	0.96	0.94
Available (ppm)	N	34.46	34.50
	P	11.37	11.41
	K	292.69	293.00

EC: Electrical conductivity. PH: Soil reaction.
O.M.: Organic matter

The experimental field is well prepared for each experiment through two plowing, leveling, merging, clearance and then dividing into experimental units (10.5 m^2).Twenty five days old seedlings of sweet pepper (*Capsicum annuum*L.) California wonder cv were transplanted on 9th and 13th March in 2016 and 2017 seasons. Respectively, seedlings were transplanted in hills (1 seedling/hill) by hand at 25 cm apart on one side of the ridge.

The NPK fertilizers were added to the experimental field cultivated with pepper plants during the growing seasons as recommended by the Ministry of Agriculture and Land Reclamation (150 kg N/fed, 200 kg P_2O_5/fed and 50 kg K_2O/fed).

Sampling and collecting data:

A) Vegetative growth characteristics:

Five plants were randomly taken from each sub-plot after 70 days from transplanting) and the vegetative growth parameters were measured in expression of:

- Number of branches/plant.
- Fresh weight of plant (g/plant).
- Dry weight of plant (g/plant). Plant samples were oven dried at 70 °C till constant weight, and then dry weight in g/plant.
- Leaf area/plant (cm^2). Leaf area was calculated according to the formula described by Koller (1972) as follows:

Leaf area (cm^2) =

B) Flowering characteristics:

Five representative plants were randomly labeled from each sub-plot after 70 days from transplanting to calculate:

- Number of flowers/plant, which calculated every week during growing season.
- Number of fruits/plant, which calculated every week during growing season.
- Fruit set percentage (%).

C) Yield and its components:

Ten pickings with 7 days intervals were harvested starting after 70 days from transplanting. The following data were recorded:

- Fruit weight (g).
- Yield/plant (g).
- Total yield (kg/fed). Data of all pickings in the two seasons were calculated, to estimate the total yield.

D) Chemical analysis of leaves:

- Leaves samples from every treatments of pepper were taken from the fourth leaf from stem top after 70 days from transplanting, then chlorophyll a and b were calorimetrically determined (mg/g F.W.) using spectrophotometer according to the method described by Lichtenthaler and Wellburn (1983). The chlorophyll, a and b determination, was conducted using methanol solvent (pure) as a blank at wavelength of (666 and 653 nm), respectively. Then, chlorophyll a, b and total were calculated as follows:

Chl. a = (15.65 A666 - 7.34 A653) (X_1).

Chl. b = (27.05 A653 - 11.21 A666) (X_2).

The content (mg/g F.W.)=(X)×volume of alcohol/weight of sample (mg) × 1000

Total chlorophyll (mg/g F. W.) = (chl.a content) + (chl.b content).

E) Quality characteristics of pepper fruits:

Representative samples of pepper fruits were taken from all sub-plot at the fourth picking to determine the quality parameters of pepper fruits, were expressed as follows:

- Vitamin-C content (mg/100 g F.W.). It was determined according to the method described in A.O.A.C. (2000).
- Acidity (%). It was determined according to the method reported in A.O.A.C. (2000).
- Total soluble solids percentage (TSS %): (10) random samples of pepper fruits from each sub-plot were taken to determine (TSS %) by using Hand Refractometer.

F) Storability:

Before beginning storage, a sample from each treatment were taken and stored in refrigerator in polyethylene bags at 5 °C relative humidity 90-95% until 20 days. The samples were observed every week to observe weight loss in fruits during the storage period. Chemical composition of pepper fruits (Vitamin-C content, acidity and TSS percentages) were estimated before and after storage.

Percentage of weight loss and Weigh the fruits (every week) during the storage period was estimated using the following formula:

$$\text{Weight loss (\%)} = \frac{\text{Initial weight of fruit} - \text{fruit weight in 7days}}{\text{Initial weight of fruit}} \times 100$$

Each obtained data were statistica analyzed depend on the technique of analysis of variance (ANOVA) for the split-plot design as mentioned by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

1- Vegetative growth characteristics:

1- Effect of irrigation intervals:

Regarding the effect of irrigation intervals (irrigation sweet pepper plants every 10, 15 and 20 days intervals) on vegetative growth characteristics *i.e.* (number of branches/plant), (fresh and dry weights of plant) and (leaf area/plant), the obtained results in Table (2) apparently cleared that there were significant effects in both seasons comparing with control. It could be noticed that irrigated sweet pepper plants every 15 days, all vegetative growth characteristics were significantly increased and produced the highest values of number of branches/plant, fresh weight of plant, dry weight of plant and leaf area/plant in the first and second seasons. These increases in vegetative growth characteristics referred to moderately water stress by irrigated sweet pepper plants every 15 days may be because of provide moisture for sweet pepper plants constantly which allows better growth, there by enhancement vegetative growth attributes. Suitable irrigation plays an important role to maintain sustainable growth for each crop, especially by reducing wilt responsible for a 60 to 80% crop loss (McNiesh and Welch, 1985). These results are in good accordance with those reported by Delfine*et al.* (2002), Khan *et al.* (2005), Ismail and Ozawa (2009), Owusu-Sekyere*et al.* (2010), Yahaya*et al.* (2012), Adeoye*et al.* (2014) and Mardaninejad*et al.* (2017).

2- Effect of humic acid application:

As seen from Table (2), all humic acid applications *had* significantly affected vegetative growth characteristics

of sweet pepper *i.e.* (number of branches/plant), (fresh and dry weights of plant) and (leaf area/plant). This is true in both seasons. Pepper plants growing under humic acid addition at 3 kg/fed surpassed other humic acid applications and produced the highest values of number of branches/plant, fresh weight of plant, dry weight of plant and leaf area/plant in the two seasons of the study. The positive effect of humic acid on vegetative growth of sweet pepper may be because of the role of humic acid contains many elements, which improve soil fertility and increase the nutrients availability and consequently increased plant growth. In addition, humic acid application significantly increased soil organic matter which improved plant growth of onion plants (El-Desuki, 2004). These results were similar with those reported by Cimrin*et al.* (2010), Gulser*et al.* (2010) and El-Bassiony*et al.* (2012).

3- Effect of interaction:

The interaction between the two studied factors *i.e.* irrigation intervals and humic acid application have significant effects on vegetative growth characteristics of sweet pepper. Data in (Table 2) showed that the highest values of (number of branches/plant 5.90 and 6.33), (fresh weight of plant 197.40 and 223.47g), (dry weight of plant 34.17 and 42.75 g) and (leaf area/plant 3.38 and 3.59 m^2) were resulted from irrigation sweet pepper plants every 15 days and adding 3 kg/fed humic acid in both seasons, respectively.

Table 2. Number of branches/plant, fresh and dry weights of plant and leaf area/plant as affected by irrigation intervals, humic acid application and their interaction during 2016 (S_1) and 2017 (S_2) seasons.

Treatments		Number of branches /plant		Fresh weight (g/plant)		Dry weight (g/plant)		Leaf area/plant (m^2)	
		S_1	S_2	S_1	S_2	S_1	S_2	S_1	S_2
A- Irrigation intervals:									
10 days		5.60	5.84	176.85	191.39	29.39	38.25	3.19	3.40
15 days		5.68	5.93	183.81	200.07	31.39	39.49	3.24	3.45
20 days		5.47	5.67	169.71	179.99	28.33	36.78	3.16	3.37
LSD at 5 %		0.04	0.03	0.44	0.32	1.06	1.00	0.0058	0.0058
B- Humic acid application:									
Soil humic acid (2 kg/fed)		5.61	6.01	178.44	190.98	29.92	38.53	3.25	3.46
Soil humic acid (3 kg/fed)		5.84	6.24	191.63	213.98	33.46	41.99	3.33	3.54
Foliar humic acid (1 g/L)		5.43	5.63	178.49	188.44	29.79	37.82	3.23	3.45
Foliar humic acid (2 g/L)		5.76	5.8	181.28	195.80	29.51	38.64	3.24	3.44
Control treatment		5.27	5.38	154.10	163.20	25.82	33.89	2.93	3.14
LSD at 5 %		0.04	0.05	0.67	0.75	0.61	0.51	0.0096	0.0096
C- Interaction:									
	Soil HA (2 kg/fed)	5.73	6.03	172.70	192.20	29.85	38.55	3.25	3.46
	Soil HA (3 kg/fed)	5.87	6.27	190.73	215.67	33.78	42.03	3.32	3.53
10 days	Foliar HA (1 g/L)	5.40	5.53	181.07	189.27	30.05	37.83	3.22	3.43
	Foliar HA (2 g/L)	5.73	5.90	179.33	190.93	28.72	38.83	3.24	3.45
	Control	5.27	5.47	160.43	168.87	24.49	34.01	2.93	3.14
	Soil HA (2 kg/fed)	5.83	6.07	183.37	193.13	32.37	39.81	3.29	3.50
	Soil HA (3 kg/fed)	5.90	6.33	197.40	223.47	34.17	42.75	3.38	3.59
15 days	Foliar HA (1 g/L)	5.50	5.87	182.97	195.80	31.86	38.96	3.26	3.47
	Foliar HA (2 g/L)	5.83	5.93	185.17	208.07	31.32	39.13	3.27	3.48
	Control	5.33	5.47	170.13	179.87	27.22	36.83	2.98	3.19
	Soil HA (2 kg/fed)	5.27	5.93	179.27	187.60	27.53	37.24	3.21	3.42
	Soil HA (3 kg/fed)	5.77	6.13	186.77	202.80	32.43	41.19	3.29	3.50
20 days	Foliar HA (1 g/L)	5.40	5.50	171.43	180.27	27.45	36.69	3.19	3.41
	Foliar HA (2 g/L)	5.70	5.57	179.33	188.40	28.50	37.96	3.21	3.42
	Control	5.20	5.20	131.73	140.87	25.74	30.83	2.89	3.10
LSD at 5 %		0.08	0.10	1.16	1.28	1.09	0.88	0.017	0.017

2- Flowering characteristics:

1- Effect of irrigation intervals:

A significant effect of irrigation intervals on flowering characteristics *i.e.* number of flowers and fruits/plant and fruit set percentage of sweet pepper was observed in the first and the second seasons as shown in (Table 3). The highest number of flowers and number of fruits/plant and fruit set percentage were recorded with moderate water stress (irrigation sweet pepper plants every 15 days) in both seasons. These results might be because of the adverse effects of water stress by irrigation sweet pepper plants every (20 days) on flowering characteristics as a result of usually decreases in photosynthesis and vegetative growth. Comparable effect of irrigation intervals on flowering characteristics of bell pepper. These results was obtained by Khan *et al.* (2005), Yahaya*et al.* (2012), Adeoye*et al.* (2014) and Mardaninejad*et al.* (2017).

2- Effect of humic acid application:

The statistical analysis of the obtained data on the subject of flowering characteristics *i.e.* number of flowers and fruits/plant and fruit set percentage of sweet pepper confirm that the studied humic acid applications had significantly effect on flowering characteristics of sweet pepper in both seasons (data in table 3). It is clearly seen

that, the highest number of flowers and number of fruits/plant and fruit set percentage were formed from soil application with humic acid at the rate of 3 kg/fed in the first and second seasons. The desirable effect of soil application on sweet pepper flowering with the highest rate of humic acid might have been due to its effective role in enhancing uptake of macronutrients and micronutrients as well as beneficial effects on soil microbial populations, soil structure and increasing modify mechanisms involved in plant growth stimulation, which reflected on enhancing flowering characteristics. These results are in partial compatible with those showed by Arancon *et al.* (2006) and El-Bassiony *et al.* (2012).

3- Effect of interaction:

The interaction between irrigation intervals and humic acid application had significant effects on flowering characteristics *i.e.* (number of flowers and fruits/plant) and (fruit set percentage) of sweet pepper in both seasons as presented in (Table 3). Irrigation sweet pepper plants every 15 days and soil application with humic acid 3 kg/fed produced the highest number of flowers and number of fruits/plant and fruit set percentage in two seasons.

Table 3. Number of flowers and fruits/plant and fruit set percentage as affected by irrigation intervals, humic acid application and their interaction during 2016 (S_1) and 2017 (S_2) seasons.

Treatments		Number of flowers/plant		Number of fruits/plant		Fruit set (%)	
		S_1	S_2	S_1	S_2	S_1	S_2
A- Irrigation intervals:							
10 days		37.78	41.76	14.03	17.31	36.91	41.47
15 days		40.18	44.81	15.37	19.13	38.45	42.99
20 days		36.27	40.15	12.95	16.77	35.52	41.21
LSD at 5 %		0.70	0.59	0.35	0.22	0.44	0.47
B- Humic acid application:							
Soil humic acid (2 kg/fed)		38.28	42.02	14.58	18.47	37.96	42.73
Soil humic acid (3 kg/fed)		41.40	45.44	16.17	18.82	39.39	44.31
Foliar humic acid (1 g/L)		38.97	43.47	14.23	17.47	36.13	41.19
Foliar humic acid (2 g/L)		38.00	42.78	13.83	18.09	37.26	41.81
Control treatment		33.74	37.49	11.76	15.82	34.05	39.42
LSD at 5 %		0.56	0.51	0.43	0.23	0.42	0.57
C- Interaction:							
	Soil HA (2 kg /fed)	38.83	42.87	14.30	17.93	37.13	42.29
	Soil HA (3 kg/fed)	41.00	44.93	16.60	17.93	40.48	43.59
10 days	Foliar HA (1 g/L)	37.20	41.60	13.43	17.10	36.22	40.76
	Foliar HA (2 g/L)	37.77	42.00	13.60	17.27	36.31	41.11
	Control	34.10	37.40	12.20	16.30	34.38	39.61
	Soil HA (2 kg/fed)	39.20	43.13	15.77	20.07	40.11	44.00
	Soil HA (3 kg/fed)	44.03	49.07	17.73	20.60	40.93	46.53
15 days	Foliar HA (1 g/L)	40.67	46.00	14.77	18.33	36.49	41.56
	Foliar HA (2 g/L)	42.97	47.67	16.23	20.07	39.38	42.68
	Control	34.03	38.20	12.33	16.57	35.37	40.19
	Soil HA (2 kg/fed)	36.80	40.07	13.67	17.40	36.65	41.90
	Soil HA (3 kg/fed)	39.17	42.33	14.17	17.93	36.78	42.79
20 days	Foliar HA (1 g/L)	36.13	41.13	13.03	16.97	35.68	41.25
	Foliar HA (2 g/L)	36.17	40.33	13.13	16.63	36.07	41.63
	Control	33.10	36.87	10.73	14.60	32.41	38.46
LSD at 5 %		0.96	0.88	0.74	0.40	0.73	0.98

3- Yield and its components:

1- Effect of irrigation intervals:

The results in Table (4) indicate that yield and its components of sweet pepper *i.e.* fruit weight, yield/plant and total yield/fed were significantly affected by irrigation intervals in both growing seasons. Temperate water stress of sweet pepper plants (irrigation every 15 days) significantly surpassed other irrigation intervals and resulted in the highest values of yield and its components in both seasons. The corresponding data were 48.45 and 47.84 g for fruit weight, 745.61 and 915.79 g for yield/plant and 17.04 and 20.93 t/fed for total yield/fed in the first and second seasons, respectively. This reduction in sweet pepper yield and its components may be because of imbalance of respiration and photosynthesis process and limitation of leaf area expansion by temporary of wilting or by early leaf senescence (Xianshi*et al.*, 1998). In addition, Water supply in the critical stages of development and high sensitivity of sweet peppers to water stress are of the importance of immunity. Whereas, water is important for maintaining the turgidity of plants (Rasheed and Rahman, 2013).These results are in harmony with those recorded by Jaimez*et al.* (2000 a and b), Dalla-Costa and Gianquinto (2002), Delfine*et al.* (2002), Khan *et al.* (2005), Owusu-Sekyere*et al.* (2010), Yahaya*et al.* (2012), Adeoye*et al.* (2014), Agele*et al.* (2015) and Mardaninejad*et al.* (2017).

2- Effect of humic acid application:

Results in Table (4) showed significant effects on the studied yield and its components of sweet pepper in two seasons. It can be reported that, the highest fruit

weight, yield/plant and total yield/fed were formed from soil application sweet pepper plants with humic acid at the rate of (3 kg/fed) in two seasons. These results may be attributed to the encouraging effects of humic acid in improvement early sweet pepper growth, more dry matter accumulation and stimulated the building of metabolic products that translocated to fruits. Moreover, its desirable effects in improvement in plant growth characters which reflected in turn increase in fruit yield of pepper. These results are in harmony with those noticed by Sun *et al.* (2004), Karakurt *et al.* (2009) and El-Bassiony*et al.* (2012).

3- Effect of interaction:

The interaction between the two studied factors *i.e.* irrigation intervals and humic acid application had a significant effect on yield and its components of sweet pepper in two seasons as presented in Table (4), also the highest fruit weight (49.54 and 49.01 g), yield/plant (878.44 and 1009.54 g) and total yield/fed (20.07 and 23.07 t/fed) were resulted from irrigation sweet pepper plants every 15 days in addition soil application with humic acid at the rate of (3 kg/fed) in the both seasons.

Table 4. Fruit weight, yield/plant and total yield/fed as affected by irrigation intervals, humic acid application and their interaction during 2016 (S_1) and 2017 (S_2) seasons.

Treatments		fruit weight (g)		Yield/plant (g)		Total yield (t/fed)	
		S_1	S_2	S_1	S_2	S_1	S_2
A- Irrigation intervals:							
10 days		48.24	47.34	677.57	819.99	15.49	18.74
15 days		48.45	47.84	745.61	915.79	17.04	20.93
20 days		48.00	47.21	622.21	791.76	14.22	18.09
LSD at 5 %		0.366	0.58	14.66	12.54	0.393	0.287
B- Humic acid application:							
Soil humic acid (2 kg/fed)		48.59	47.75	708.37	881.74	16.19	20.15
Soil humic acid (3 kg/fed)		49.28	48.14	797.01	906.79	18.22	20.73
Foliar humic acid (1 g/L)		47.85	47.69	681.29	832.85	15.57	19.03
Foliar humic acid (2 g/L)		48.18	47.69	666.51	862.98	15.24	19.72
Control treatment		47.27	46.05	555.81	728.22	12.70	16.65
LSD at 5 %		0.205	0.41	20.46	11.78	0.484	0.269
C- Interaction:							
	Soil HA (2 kg/fed)	48.60	48.18	694.98	864.07	15.88	19.75
	Soil HA (3 kg/fed)	49.27	47.95	817.89	859.86	18.69	19.65
10 days	Foliar HA (1 g/L)	47.88	48.13	643.17	822.96	14.70	18.81
	Foliar HA (2 g/L)	48.10	47.89	654.13	826.94	14.95	18.90
	Control	47.35	44.56	577.71	726.16	13.20	16.59
	Soil HA (2 kg/fed)	48.69	47.71	767.61	957.40	17.54	21.88
	Soil HA (3 kg/fed)	49.54	49.01	878.44	1009.54	20.07	23.07
15 days	Foliar HA (1 g/L)	48.12	47.59	781.17	872.49	17.85	19.94
	Foliar HA (2 g/L)	48.42	47.96	715.06	962.34	16.35	21.99
	Control	47.49	46.91	585.76	777.19	13.38	17.77
	Soil HA (2 kg/fed)	48.48	47.35	662.51	823.74	15.14	18.83
	Soil HA (3 kg/fed)	49.04	47.54	694.69	851.01	15.88	19.45
20 days	Foliar HA (1 g/L)	47.54	47.33	619.52	803.09	14.16	18.36
	Foliar HA (2 g/L)	48.00	47.22	630.36	799.68	14.41	18.27
	Control	46.95	46.67	503.97	681.31	11.52	15.57
LSD at 5 %		0.35	0.70	35.44	20.40	0.84	0.47

4- Leaf chemical constituents:

1- Effect of irrigation intervals:

As seen in Table (5) irrigation intervals significantly affected chemical analysis of leaf *i.e.* chlorophyll a, b and total chlorophylls in pepper leaves in both seasons. The obtained findings showed that the highest (chlorophyll a), (chlorophyll b) and (total chlorophylls) in pepper leaves were produced when sweet pepper plants exposed to moderate water stress irrigation every 15 days in two growing seasons, respectively. This improving in chemical analysis of plants owing to reduce water stress by irrigation each 15 days might be refer to the availability of water during the growing seasons, thereby maximizing sweet pepper growth, development and chemical constituents. Similar trend was recorded by Jamiez*et al.* (2000 b).

2- Effect of humic acid application:

With consider to the effect of humic acid application on chemical analysis of leaves *i.e.* chlorophyll a, b and total chlorophylls in pepper leaves, it was significant in two seasons Table (5). It should be noted that the differences between the applications of hemic acid in chemical analysis of leaves were important compared to treatment in two seasons of this study.The highest chlorophyll a, chlorophyll b and total chlorophylls in pepper leaves were resulted from soil application sweet pepper plants with humic acid at the rate of 3 kg/fed in the two seasons. These increase in chemical analysis of plants as a result of humic acid application may be because of that it is believed that humic acid maintains the stability of soil interaction, fixation, adsorption, chelate of cation, thereby

increasing the availability of water and nutrients. Also, application of humic acid significantly decreased soil pH and EC and increased exchangeable Na, Ca, Mg and K (Mindari*et al.*, 2014), therefore improving chemical analysis of sweet pepper plants. Similar results were stated by Cimrin*et al.* (2010) and Unlu*et al.* (2010).

3- Effect of interaction:

It is obviously from Table (5) that leaves content of chlorophyll a, b and total chlorophyll significantly affected by the interaction between irrigation intervals and humic acid application.

The highest chlorophyll a, chlorophyll b and total chlorophylls in pepper leaves were resulted from irrigation sweet pepper plants every 15 days in addition soil application with humic acid at the rate of 3 kg/fed in two seasons.

The positive effect of humic acid at (3 kg / fed.) on chemical composition of leaves refer to the availability of minerals in the soil solution which enhanced their uptake by roots. These results are in agreement with those showed byFawzy*et al.,* (2007) on eggplant and Çimrin*et al.,* (2010) on pepper plant.

Table 5. Chlorophyll a, b and total chlorophylls in pepper leaves as affected by irrigation intervals, humic acid application and their interaction during 2016 (S_1) and 2017 (S_2) seasons.

Treatments		Chlorophyll a (mg/g FW)		Chlorophyll b (mg/g FW)		Total chlorophylls (mg/g FW)	
		S_1	S_2	S_1	S_2	S_1	S_2
A- Irrigation intervals:							
10 days		0.920	0.960	0.550	0.476	1.470	1.436
15 days		0.980	0.980	0.597	0.495	1.577	1.475
20 days		0.890	0.940	0.512	0.463	1.402	1.403
LSD at 5 %		0.013	0.005	0.009	0.002	0.013	0.002
B- Humic acid application:							
Soil humic acid (2 kg/fed)		0.990	0.970	0.567	0.484	1.557	1.454
Soil humic acid (3 kg/fed)		1.090	0.980	0.619	0.489	1.709	1.469
Foliar humic acid (1 g/L)		0.870	0.960	0.531	0.476	1.401	1.436
Foliar humic acid (2 g/L)		0.900	0.970	0.565	0.479	1.465	1.449
Control treatment		0.790	0.930	0.484	0.461	1.274	1.391
LSD at 5 %		0.011	0.003	0.015	0.002	0.011	0.002
C- Interaction:							
	Soil HA (2 kg /fed)	0.990	0.964	0.548	0.487	1.538	1.451
	Soil HA (3 kg/fed)	1.080	0.972	0.602	0.482	1.682	1.454
10 days	Foliar HA (1 g/L)	0.850	0.960	0.518	0.475	1.368	1.435
	Foliar HA (2 g/L)	0.860	0.963	0.578	0.478	1.438	1.441
	Control	0.810	0.931	0.503	0.461	1.313	1.392
	Soil HA (2 kg/fed)	1.040	0.996	0.612	0.502	1.652	1.498
	Soil HA (3 kg/fed)	1.170	1.015	0.689	0.508	1.859	1.523
15 days	Foliar HA (1 g/L)	0.920	0.981	0.559	0.495	1.479	1.476
	Foliar HA (2 g/L)	0.990	0.992	0.615	0.497	1.605	1.489
	Control	0.820	0.933	0.512	0.471	1.332	1.404
	Soil HA (2 kg/fed)	0.950	0.947	0.541	0.463	1.491	1.410
	Soil HA (3 kg/fed)	1.040	0.941	0.568	0.478	1.608	1.419
20 days	Foliar HA (1 g/L)	0.830	0.936	0.516	0.459	1.346	1.395
	Foliar HA (2 g/L)	0.860	0.957	0.501	0.462	1.361	1.419
	Control	0.770	0.919	0.435	0.453	1.205	1.372
LSD at 5 %		0.019	0.010	0.001	0.003	0.009	0.003

5- Quality characteristics of pepper fruits:

1- Effect of irrigation intervals:

Regarding the effect of irrigation intervals on quality characteristics of pepper fruits *i.e.* (vitamin-C content), (acidity) and total soluble solids (TSS) percentages in pepper fruits at harvest and after storage (20 days), the results in Tables (6 and 7) clearly showed a significant effects in the two seasons of the study. Also, it can be reported that irrigated sweet pepper plants every 15 days produced pepper fruits with highest content of vitamin C, acidity and TSS at harvest and after storage in two study seasons. These increases in quality characteristics of pepper fruits at harvest and after storage due to moderately water stress by irrigated sweet pepper plants every 15 days may be because of to the vegetative growth improvement in when sweet pepper plants did not subjected to water stress, which resulting in increases in all metabolism processes in plant and dry matter accumulation and consequently increasing quality characteristics of pepper fruits at harvest and after storage. These results are compatible with those obtained by Jamiez *et al.* (2000 b) and Delfine *et al.* (2002).

Table 6. Vitamin-C content, acidity and total soluble solids (TSS) percentages in pepper fruits at harvest as affected by irrigation intervals, humic acid application and their interaction during 2016 (S_1) and 2017 (S_2) seasons.

Treatments		Vitamin-C content (mg/100 g F.W.)		Acidity (%)		TSS (%)	
		S_1	S_2	S_1	S_2	S_1	S_2
A- Irrigation intervals:							
10 days		70.33	68.53	0.426	0.436	6.47	8.33
15 days		74.21	80.13	0.479	0.493	6.80	8.87
20 days		55.00	64.00	0.380	0.396	5.90	7.97
LSD at 5 %		1.61	0.58	0.01	0.01	0.18	0.39
B- Humic acid application:							
Soil humic acid (2 kg/fed)		72.71	80.00	0.440	0.462	6.64	8.81
Soil humic acid (3 kg/fed)		91.77	97.78	0.499	0.514	7.92	9.92
Foliar humic acid (1 g/L)		58.70	58.89	0.420	0.429	5.89	7.78
Foliar humic acid (2 g/L)		66.87	72.22	0.429	0.442	6.28	8.33
Control treatment		42.52	45.56	0.353	0.360	5.22	7.11
LSD at 5 %		0.88	0.73	0.01	0.01	0.60	0.48
C- Interaction:							
	Soil HA (2 kg /fed)	76.43	80.00	0.436	0.458	6.50	8.50
	Soil HA (3 kg/fed)	92.47	99.33	0.495	0.514	8.00	10.00
10 days	Foliar HA (1 g/L)	65.93	43.33	0.412	0.407	6.17	7.83
	Foliar HA (2 g/L)	74.50	73.33	0.418	0.427	6.33	8.17
	Control	42.30	46.67	0.372	0.371	5.33	7.32
	Soil HA (2 kg/fed)	84.37	90.00	0.488	0.512	7.42	9.58
	Soil HA (3 kg/fed)	94.10	100.67	0.589	0.597	8.75	10.75
15 days	Foliar HA (1 g/L)	69.10	80.00	0.474	0.490	6.00	8.00
	Foliar HA (2 g/L)	76.57	80.00	0.477	0.497	6.50	8.67
	Control	46.93	50.00	0.367	0.369	5.33	7.33
	Soil HA (2 kg/fed)	57.33	70.00	0.398	0.415	6.00	8.33
	Soil HA (3 kg/fed)	88.73	93.33	0.416	0.431	7.00	9.00
20 days	Foliar HA (1 g/L)	41.07	53.33	0.374	0.391	5.50	7.50
	Foliar HA (2 g/L)	49.53	63.33	0.394	0.404	6.00	8.17
	Control	38.33	40.00	0.319	0.341	5.00	6.83
LSD at 5 %		1.52	1.26	0.01	0.01	1.04	0.82

Table 7. Vitamin-C content, acidity, total soluble solids (TSS) percentages in pepper fruits after storage of sweet pepper fruits yield as affected by irrigation intervals, humic acid application and their interaction during 2016 (S_1) and 2017 (S_2) seasons.

Treatments		Vitamin-C content (mg/100 g F.W.) after storage		Acidity (%) after storage		TSS (%) after storage	
		S_1	S_2	S_1	S_2	S_1	S_2
A- Irrigation intervals:							
10 days		66.01	67.33	0.401	0.390	4.80	6.60
15 days		69.93	74.93	0.459	0.451	5.17	7.02
20 days		50.70	54.80	0.357	0.353	4.27	6.13
LSD at 5 %		1.55	0.86	0.01	0.01	0.18	0.52
B- Humic acid application:							
Soil humic acid (2 kg/fed)		68.41	74.80	0.419	0.419	5.21	7.03
Soil humic acid (3 kg/fed)		87.47	92.58	0.479	0.472	6.32	8.12
Foliar humic acid (1 g/L)		54.40	56.80	0.399	0.385	4.18	6.03
Foliar humic acid (2 g/L)		62.57	63.91	0.404	0.400	4.57	6.48
Control treatment		38.22	40.36	0.327	0.313	3.46	5.26
LSD at 5 %		0.82	0.60	0.01	0.01	0.49	0.46
C- Interaction:							
	Soil HA (2 kg /fed)	72.13	74.80	0.415	0.416	5.23	6.87
	Soil HA (3 kg /fed)	88.07	94.13	0.474	0.472	6.40	8.20
10 days	Foliar HA (1 g/L)	61.63	58.13	0.391	0.365	4.40	6.20
	Foliar HA (2 g/L)	70.20	68.13	0.397	0.385	4.57	6.37
	Control	38.00	41.47	0.331	0.313	3.40	5.37
	Soil HA (2 kg/fed)	80.07	84.80	0.467	0.468	5.82	7.70
	Soil HA (3 kg/fed)	89.90	95.47	0.568	0.555	7.15	8.95
15 days	Foliar HA (1 g/L)	64.80	74.13	0.453	0.448	4.40	6.20
	Foliar HA (2 g/L)	72.27	75.47	0.456	0.455	4.90	6.87
	Control	42.63	44.80	0.350	0.327	3.57	5.37
	Soil HA (2 kg/fed)	53.03	64.80	0.377	0.373	4.57	6.53
	Soil HA (3 kg/fed)	84.43	88.13	0.395	0.389	5.40	7.20
20 days	Foliar HA (1 g/L)	36.77	38.13	0.353	0.343	3.73	5.70
	Foliar HA (2 g/L)	45.23	48.13	0.359	0.362	4.23	6.20
	Control	34.03	34.80	0.298	0.299	3.40	5.03
LSD at 5 %		1.42	1.04	0.02	0.01	0.86	0.80

2- Effect of humic acid application:

Quality characteristics of pepper fruits *i.e.* vitamin C content and acidity and total soluble solids (TSS) percentages in pepper fruits at harvest and after storage (20 days) during the two growing seasons of 2016 and 2017 were significantly affected. Soil application sweet pepper plants with humic acid at the rate of 3 kg/fed exceeded other humic acid application and produced the rich fruits with vitamin C, acidity and TSS in pepper fruits at harvest and vitamin-C content, acidity and TSS in pepper fruits after storage in both seasons. These increases in quality characteristics of pepper fruits at harvest and after storage by soil application with humic acid at the rate of 3 kg/fed may be due to various biochemical effects of humic acid either on cell wall, membrane level or in the cytoplasm, including increased photosynthesis and respiration rates in plants, which reflected on increases in quality characteristics of pepper fruits at harvest and after storage.

Similar results were parallel with those reported by Karakurt *et al.* (2009), Unlu *et al.* (2010) and Aminifard*et al.* (2012).

3- Effect of interaction:

The interaction between irrigation intervals and humic acid soil application have significant effects on quality characteristics of pepper fruits *i.e.* vitamin C , acidity and total soluble solids (TSS) contents in pepper fruits at harvest and after storage (20 days) in two seasons as presented in (Tables 6 and 7).

The highest contents of vitamin-C, acidity and TSS in pepper fruits at harvest and after storage were resulted from irrigation sweet pepper plants every 15 days and soil application with humic acid at the rate of 3 kg/fed in both seasons.

6- Storability:

1- Effect of irrigation intervals:

As seen in (Table 8), it is clearly that increasing water stress by irrigation sweet pepper plants every 20 days led to increase in percentage of weight loss of sweet pepper fruits and produced the highest values of weight loss percentage after 7 days (18.96 and 18.76 %), weight loss percentage after 14 days (20.61 and 20.20) and weight loss percentage after 20 days (21.93 and 21.63) in both seasons, respectively. Water stress adversely affect growth of pepper by decreasing photosynthesis, chemical constituents and quality characters and increasing percentage of weight loss of sweet pepper fruits. Comparable effect of irrigation intervals on flowering characteristics was obtained by Bayogan*et al.* (2017). On the other hand, the moderate water stress (15days intervals) gave the lowest weight loss percentages in both seasons.

Table 8. Weight loss percentage of sweet pepper fruits yield as affected by irrigation intervals, humic acid application and their interaction during 2016 (S_1) and 2017 (S_2) seasons.

Treatments		Weight loss (%) after (7days)		Weight loss (%) after (14days)		Weight loss (%) after (20days)	
		S_1	S_2	S_1	S_2	S_1	S_2
A- Irrigation intervals:							
10 days		18.60	18.46	20.25	19.90	21.57	21.33
15 days		16.98	15.82	18.63	17.26	19.95	18.69
20 days		18.96	18.76	20.61	20.20	21.93	21.63
LSD at 5 %		0.10	0.11	0.10	0.11	0.10	0.11
B- Humic acid application:							
Soil humic acid (2 kg/fed)		16.03	15.53	17.68	16.97	19.00	18.40
Soil humic acid (3 kg/fed)		14.83	14.33	16.48	15.77	17.80	17.20
Foliar humic acid (1 g/L)		16.33	15.83	17.98	17.27	19.30	18.70
Foliar humic acid (2 g/L)		14.40	13.90	16.05	15.34	17.37	16.77
Control treatment		29.30	28.80	30.95	30.24	32.27	31.67
LSD at 5 %		0.10	0.10	0.09	0.09	0.09	0.09
C- Interaction:							
	Soil HA (2 kg/fed)	21.50	21.00	23.15	22.44	24.47	23.87
	Soil HA (3 kg/fed)	8.80	8.30	10.45	9.74	11.77	11.17
10 days	Foliar HA (1 g/L)	20.30	19.80	21.95	21.24	23.27	22.67
	Foliar HA (2 g/L)	16.80	16.30	18.45	17.74	19.77	19.17
	Control	27.40	26.90	29.05	28.34	30.37	29.77
	Soil HA (2 kg/fed)	12.70	12.20	14.35	13.64	15.67	15.07
	Soil HA (3 kg/fed)	10.20	9.70	11.85	11.14	13.17	12.57
15 days	Foliar HA (1 g/L)	21.40	20.90	23.05	22.34	24.37	23.77
	Foliar HA (2 g/L)	7.30	6.80	8.95	8.24	10.27	9.67
	Control	28.60	28.10	30.25	29.54	31.57	30.97
	Soil HA (2 kg/fed)	13.90	13.40	15.55	14.84	16.87	16.27
	Soil HA (3 kg/fed)	25.50	25.00	27.15	26.44	28.47	27.87
20 days	Foliar HA (1 g/L)	8.70	8.20	10.35	9.64	11.67	11.07
	Foliar HA (2 g/L)	17.70	17.20	19.35	18.64	20.67	20.07
	Control	31.90	31.40	33.55	32.84	34.87	34.27
LSD at 5 %		0.17	0.16	0.17	0.17	0.17	0.17

2- Effect of humic acid application:

The obtained results on the subject of storability *i.e.* percentage of weight loss of sweet pepper fruits assert that the studied humic acid application treatments significantly affected storability of sweet pepper fruits in two seasons (Table 8). It is clearly seen that, the highest percentages of weight loss of sweet pepper fruits with weight loss percentage after 7 days, and weight loss percentage after 20 days were noticed in control fruits (without humic acid application) in two seasons of this study. The differences

between humic acid and control treatment (without humic acid application) were significant in both studied seasons.

The desirable effect of sweet humic acid on storability of sweet pepper fruits might have been due to enhancing effects of humic acid on providing plant and soil with a concentrated dose of essential nutrients, vitamins and trace elements to improve plant growth, development, chemical constituents and quality characters, which reflected on enhancing storability of sweet pepper fruits. These results are in partial compatible with those showed by Saif El-Deen*et al.* (2011).

3- Effect of interaction:

The interaction between irrigation intervals and humic acid application had significant effects on storability *i.e.* percentage of weight loss of sweet pepper fruits in both seasons as presented in Table (8). Irrigation sweet pepper plants every 15 days with humic acid at the rate of 3kg/fed resulted in the lowest percentages of weight loss of sweet pepper fruits with weight loss percentage after 7 days, weight loss percentage after 14 days and weight loss percentage after 20 days in both seasons.

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استجابة نباتات الفلفل الحلو لفترات الرى والمعاملة بحمض الهيوميك

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تم إجراء هذه التجربة فى حقل خاص فى قرية الحواوشة بمحافظة الدقهلية بمصر خلال موسمى الصيف لعامى ٢٠١٦ و ٢٠١٧ لدراسة تأثير فترات الرى وإضافة حمض الهيوميك أسيد والتفاعل بينهما على نمو وانتاجية الفلفل الحلو صنف كاليفورنيا وندر. وقد أجريت التجربة فى تصميم قطاعات منشقة بثلاث مكررات. كان العامل الرئيسى (فترات الرى المختلفة) والعامل الفرعى (تطبيق حمض الهيوميك أسيد). أوضحت النتائج أن فترة الرى كل ١٥ يوم أدت بشكل ملحوظ الى زيادة عدد الأوراق على النبات والوزن الطازج والجاف للنبات ، بالإضافة الى المساحة الورقية للنبات ومحصول النبات الواحد والمحصول الكلى، كلوروفيل أ و ب ، والكلوروفيل الكلى للأوراق ، ونسبة فيتامين ج ، ومجموع المواد الصلبة الذائبة والحموضة فى الثمار مقارنة بالرى كل ٢٠ يوم والتى كانت ذات قيمة اقل اهمية .