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Response of sweet fennel plants to irrigation requirements and different nitrogen levels under Egyptian climatic conditions

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ABSTRACT

Two field experiments were conducted to study the effect of different levels of irrigation along with various nitrogen fertigation levels in sweet fennel (*Foeniculum vulgare Mill*.) during two winter seasons of 2016/2017 and 2017/2018 under open field conditions at Dokki Protected Cultivation Experimental farm, belongs to the Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), at Giza Governorate, Egypt. The experiment comprised of three irrigation treatments (60, 80 and 100 % of irrigation requirements) applied by using drip irrigation and three levels of nitrogen doses (50, 75, 100 % of recommended dose of N) applied by fertigation. Irrigation requirements were estimated based on collected climatic data from automated weather station allocated in the farm location.

The results indicated that the higher vegetative characteristics and bulbs yield and quality were obtained from 80 % of irrigation requirement (IR) followed by 100% IR; the lowest values were obtained from the deficit irrigation treatment (60% IR). Regarding the Nitrogen rates; 75% of recommended nitrogen rate gave the highest vegetative characteristics and sweet fennel bulb yield during the both tested seasons. The chemical analysis of sweet fennel leaves took another trend, the highest NPK percentages were obtained from the 100% nitrogen rate combined by 100% irrigation level during both tested seasons.

***Keywords*:** Sweet fennel; *Foeniculum vulgare* Mill., Water use efficiency, Evapotranspiration, Nitrogen fertilization, Vegetative growth, Fresh yield and quality.

Introduction

Sweet fennel (*Foeniculum vulgare* Mill.) is a vegetable crop which is used as a traditional medicine as spice (Telci *et al.,* 2009). Sweet fennel plants belong to the family Apiaceae and is believed to be native of Southern Europe and Mediterranean region.

Water availability for agriculture sector is under challenge in the world as well as in arid lands. Today, it is more important to use water resources wisely and to irrigate intelligently by using modern irrigation system (Jeelani *et al.,* 2017).

Relationships between yield and irrigation quantity allow field quantification of water use efficiency in a concerned environment and can be assessed by developing production functions of which the simplest is the yield responses to irrigation (Ferreira and Goncalves, 2007). Karam *et al*. (2002) stated that shortage of applied irrigation quantity reduced vegetative growth (leaves number, leaf area and dry matter content characters) in spinach plants. One of the greatest challenges for agriculture in arid and semi- arid regions is to develop technology or agronomic options to improve water use efficiency (Turner, 2004). The production factors such as soil fertility, irrigation system and etc. play an essential role in achieving good conditions during growth period to achieve maximum performance and optimum water use efficiency in medicinal plants (Hassani, 2006).

Nitrogen is the element that most limits crop yields. Most of the nitrogen in plants is in organic form: nucleic acid, hormones, membrane component, coenzymes as well as pigment (Abdrabbo *et al*., 2017 and Marschner, 1995). Concerning the effects of N fertilizer on growth and yield characters of

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some leafy vegetables, investigations were also carried out by many authors such as Jun Liang *et al*. (2005) on spinach. The application of nitrogen not only increased yield but also improved oil contents of fennel (El-Wahab and Mohamed, 2007). Among the various factors which can increase yield on per unit area basis, the application of nitrogen fertilizer is considered to be the one of the most important factor (Chatzopoulou *et al*., 2006). It is well known that chemical fertilization, particularly N, is used for increasing the productivity of medicinal and aromatic plants (El- Keltawi *et al*., 2006). However, the intensive and/or excessive use of manufactured nitrogen fertilizers raises the major production cost, causes environmental pollution and reduces the acceptance of the crops for export as well as affects the soil fertility (Sherif and El-Naggar, 2005). Thus, the main objectives of this study were to investigate the effects of different irrigation water levels and nitrogen rates on some growth, yield and some chemical compositions of sweet fennel.

Materials and Methods

This study was carried out in two winter seasons of 2016/2017 and 2017/2018 under open field condition at Dokki Protected Cultivation Experimental farm, belongs to the Central Laboratory for Agricultural Climate (CLAC), Agricultural Research Center (ARC), at Giza Governorate, Egypt.

Plant Material:

Seeds of head sweet fennel (cv. Dulce) were sown on 22th and 25th September 2016 and 2017, respectively, in polystyrene trays. After four weeks from sowing, the transplants were planted in the open field. Sweet fennel seedlings were placed in double rows on 23th and 25th October 2016 and 2017, respectively. Raised beds with one meter width was prepared one week before transplanting. Sweet fennel were cultivated two rows for every bed. The final plant spacing was 50 cm in the row, 60 cm between the rows and 70 cm in between the beds.

The Field Experiment:

Two field experiments were carried out under open field conditions in clay soil to investigate three irrigation requirement levels (60, 80 and 100% of irrigation requirements) combined with three N fertilizer levels (50, 75 and 100% of recommended dose) to present the treatments affecting growth, yield and quality of sweet fennel plants. The experiment was designed in a split plot arrangement with three replicates, the irrigation levels located as main plots and different N fertilizer treatments located as sub-plots. The plot area was 10 m (length) x 2 m (width). The physical and chemical characteristics of the experimental soil are presented in Table 1. The chemical (Chapman and Pratt, 1961) and physical properties of the clay experimental soil were determined before cultivation. The saturation point % (SP), field capacity % (FC), wilting point % (WP) and bulk density g/ cm^3 (BD) of the soil were determined according to Israelsen and Hansen (1962).

Table 1: Chemical and physical analyses of the soil at experimental site.

Soil depth	Chemical properties							
	ECe mmohs	**pH**	**Ca^{++}** mg/L	**Mg^{++}** mg/L	**Na^{+}** mg/L	**K^{+}** mg/L	**HCO_3^{-}** mg/L	**CL^{-}** mg/L
	2.59	7.55	4.85	1.56	8.46	5.06	2.80	10.60
	Physical properties							
0 – 30 cm	**Sand** (%)	**Clay** (%)	**Silt** (%)	**Texture**	**SP** (%)	**FC** (%)	**WP** (%)	**BD** g/ cm^3
	11.6	81.9	6.5	Clay	22.8	32.8	15.8	1.23

Treatments were as follows:-

A. Irrigation treatments:

Three irrigation treatments, i. e. 60, 80 and 100% of irrigation requirements applied by using drip irrigation. Each treatment supplied by one volumetric lysimeter container that used to determine the amount of water within the active root zone at the desired levels of applied irrigation water. The container dimensions is 40 cm length and 35 cm diameter was isolated from the surrounding area by a plastic sheet (1 mm thickness) used to surround this Iysimeter. The applied lysimeter contained

drainage tube in the bottom to collect the excess amount of irrigated water. The actual water consumption was applied and quantities were adjusted to ensure a drainage rate of 10-20 % from the total applied quantity, according to soil properties. In addition, evapotranspiration (ETo) mm/day was calculated by Penman Monteith equation (FAO, 1998) using the climatological data of Dokki area.

Control valves of the whole system adjust the irrigation processes and the irrigation water requirements were added by drip irrigation system. Water flow meters were fixed in each treatment to control the delivery of the amounts of water irrigation. All the experimental plots received the same amount of water after planting for one week after that different irrigation managements were applied.

B. Nitrogen treatments:

Three levels of nitrogen doses, i. e. 50, 75 and 100% of recommended dose of N (The recommended dose of nitrogen fertilizer at a rate of 90 N/ fed. was recommended according to El-Shakry, 2005) were applied by fertigation system. The nitrogen form was applied was ammonium nitrate (33% N) for all treatments during the two cultivation seasons.

Data recorded: -

I) - Vegetative growth characteristics:

Three plants of each experimental plot were taken at harvest (after 70 days from the transplanting date) to determine growth parameters. The following data were recorded, i.e. plant length (cm), leaves number per plant, bulb dimensions (Thickness, width and length (cm), fresh and dry weight of leaves, bulbs and total plant (g/ plant).

II) - Total green yield and quality:

All the plants of every plot of the experiment were harvested at 120 days from transplanting and the data were recorded:-

1. Total yield of sweet fennel plants (ton/fed.)
2. Physical bulb quality: Bulbs of such plants were excised by cutting 5 cm above the bulb using a sharp stainless steel knife. Also, roots were excised and the outer-leaf was removed for obtaining clean bulbs. Afterwards, flatten, cylinder and elongated shape ratios of bulbs were calculated according to Pascale and Barbieri (1995) as follows:

• Flatten shape ratio = W / T
• Cylinder shape ratio = L / (WT) 0.05
• Elongated shape ratio = L / W

Where: W, width (cm); T, thickness (cm); L, length (cm).

III) - Chemical content:

Three plant samples of each plot were dried at 70 ^{o}C in an air forced oven for 48 h. Dried leaves were digested in H_2SO_4. N, P and K percentages were estimated in the acid digested solution by colorimetric method (Ammonium molybdate) using spectrophotometer and flame photometer (Chapman and Pratt, 1961). Total nitrogen was determined by Kjeldahl method according to the procedure described by FAO (1982). Phosphorus content was determined using spectrophotometer according to Watanabe and Olsen (1965). Potassium content was determined photo-metrically using Flame photometer as described by Chapman and Pratt (1961).

Analysis of data was done, using SAS program for statistical analysis. The differences among means for all traits were tested at 5 % level of probability according to Waller and Duncan (1969).

Results and Discussion

1. Climate data:

Data in Table (2) represent the climatic data in the open field during the cultivation period last week of October till the second week of March (harvesting date) for Dokki farm during 2016/2017 and 2017/2018 seasons. The maximum and minimum temperature gradually decreased during the first fourteen weeks and then starts to increase gradually from the week number fifteen till the end of the season.

The relative humidity took almost the same trend; average daily relative humidity was decreased gradually after the fifth week till the sixteenth week of the cultivation period and then start increase again. There were no clear trend for the wind speed at was almost the same during the both seasons with values around from 1.6 to 2.0 m/s. the evapotranspiration took the same tend of maximum temperature it was decreased gradually after the first week of cultivation till fourteenth week from transplanting and then start increase gradually.

Table 2: Average weekly climatic data for Dokki farm during the two seasons 2016/2017 and 2017/2018.

Month	Weeks	First season (2016/2017)					Second season (2017/2018)				
		Max. Temp. °C	Min. Temp. °C	RH (%)	Wind Speed (m/s)	ETo (mm/day)	Max. Temp. °C	Min. Temp. °C	RH (%)	Wind Speed (m/s)	ETo (mm/day)
Oct.	1	21.6	15.5	60.1	1.7	3.4	23.1	16.2	58.2	1.8	3.5
Nov.	2	21.0	13.4	62.9	1.8	3.3	20.4	14.2	60.9	1.7	3.2
	3	19.1	12.7	57.5	1.9	2.9	20.3	12.1	60.7	1.8	3.0
	4	16.9	10.7	61.7	2.0	2.4	18.3	11.1	65.6	1.9	2.6
	5	16.3	10.3	62.8	1.9	2.4	16.4	10.6	61.6	1.9	2.5
Dec.	6	14.9	9.4	57.8	1.9	2.2	14.8	10.1	56.0	1.8	2.2
	7	15.3	8.3	56.9	1.7	2.3	14.8	9.1	55.2	1.8	2.2
	8	16.3	8.9	56.9	1.7	2.2	17.2	9.3	60.4	1.8	2.4
	9	16.6	9.2	55.6	1.8	2.4	18.3	9.3	58.6	1.9	2.5
Jan.	10	15.8	10.0	53.5	1.8	2.4	16.8	10.6	56.7	1.9	2.4
	11	16.6	9.0	52.8	1.8	2.3	17.6	9.5	56.0	1.9	2.5
	12	17.0	8.5	53.5	1.6	2.5	18.0	9.0	56.7	1.7	2.6
	13	17.1	10.6	52.7	1.8	2.5	18.1	11.3	55.9	1.9	2.6
Feb.	14	17.5	10.5	54.5	1.7	2.7	19.3	10.2	57.8	1.8	2.8
	15	19.1	10.7	52.0	1.7	3.0	20.3	11.1	55.2	1.8	3.2
	16	19.6	11.5	61.7	1.7	3.2	19.9	12.2	62.5	1.7	3.2
	17	20.0	12.4	66.0	1.6	3.4	19.5	13.2	63.5	1.7	3.3
March	18	20.5	12.8	63.6	1.6	3.5	19.9	13.7	61.5	1.7	3.5
	19	21.0	13.1	61.3	1.5	3.7	20.4	14.2	59.4	1.6	3.6

2. Effect of irrigation requirement:

The total amounts of the irrigation water requirements (liter/ plant/ day) of each treatment were determined during the two growth seasons as shown in Table (3). The irrigation requirement during the first four weeks were higher than the next weeks because of higher temperature and higher evapotranspiration during the first four weeks see above Table. From the fifth week till sixteen week irrigation water requirement was decreased because of low temperature during December and January and then irrigation requirement increased during last four weeks of experimental duration during both seasons. The irrigation water requirement (liter/plant/ season) was higher during the second season because higher air temperature and higher evapotranspiration values during the most weeks.

a)- Vegetative growth characteristics:

Regarding to irrigation treatments 80% from irrigation requirement (IR) produced the significant highest vegetative characteristics (plant length, number of leaves per plant, fresh and dry weight of leaves and bulbs as well as bulb dimension (length, width and thickness) during the both tested seasons (Table 4). The 100% IR came in the second order, while 60% IR were produced the lowest sweet fennel vegetative characteristics during the both seasons.

b)- Total green yield and physical bulb quality:

The presented data in Table (5) show that there were significant difference between irrigation treatments during the both seasons. The highest sweet fennel bulb yield and physical bulb quality were obtained by 80% irrigation level followed by 100% IR compared with other treatments during the both studied seasons. The lowest yield of sweet fennel bulbs were obtained by 60 % IR.

These increases in total green yield were statistically significant and amounted to 3.183 and 4.339 ton/ feddan which equal 17.04 and 23.01 % by 80% irrigation level compared with 60% IR treatment in the two seasons, respectively. These increases might be due to the resulting increases in the vegetative growth and N, P and K content of leaves and bulbs as well as dry matter content by using 80% of irrigation level. These findings were similar and true in both seasons of this study.

Table 3: The average weekly irrigation requirements (liter/ plant/day) under different irrigation levels for sweet fennel in the Dokki farm.

Weeks	First season (2016/2017)			Second season (2017/2018)		
	60%	80%	100%	100%	80%	60%
1	0.32	0.53	0.66	0.29	0.48	0.60
2	0.34	0.57	0.71	0.32	0.53	0.66
3	0.36	0.60	0.75	0.34	0.56	0.70
4	0.36	0.60	0.75	0.34	0.57	0.71
5	0.34	0.57	0.72	0.33	0.56	0.70
6	0.33	0.55	0.69	0.33	0.55	0.68
7	0.32	0.53	0.66	0.32	0.53	0.66
8	0.29	0.49	0.61	0.30	0.51	0.63
9	0.28	0.46	0.58	0.30	0.49	0.62
10	0.27	0.46	0.57	0.30	0.49	0.62
11	0.28	0.46	0.57	0.30	0.51	0.63
12	0.27	0.46	0.57	0.31	0.52	0.65
13	0.27	0.46	0.57	0.31	0.52	0.65
14	0.27	0.45	0.57	0.32	0.53	0.66
15	0.30	0.50	0.62	0.35	0.58	0.72
16	0.33	0.55	0.69	0.38	0.64	0.80
17	0.37	0.61	0.76	0.42	0.70	0.88
18	0.39	0.65	0.81	0.45	0.75	0.93
19	0.41	0.69	0.86	0.48	0.81	1.01
Total	60.2	99.0	123.7	65.5	107.8	134.8

Table 4: Effect of irrigation water levels on vegetative growth of sweet fennel during two seasons (2016/2017 and 2017/2018).

Irrigation levels	Plant length (cm)	Leaves No./ plant	Bulb dimensions			Fresh weight (g / plant)			Dry weight (g /100 g F*W*)	
			Thickness (cm)	Width (cm)	Length (cm)	Leaves	Bulbs	Total	Leaves	Bulbs
First season (2016/2017)										
60%	78.00	8.44	6.28	12.16	10.13	440.0	335.0	775.1	10.89	7.30
80%	82.72	9.89	8.71	12.73	10.81	555.0	379.1	934.2	10.59	6.69
100%	80.67	9.44	7.80	12.19	10.29	495.9	365.3	861.2	9.59	7.11
L.S.D at 0.05	1.10	0.39	0.17	N.S.	0.32	26.60	18.07	38.62	0.36	0.34
Second season (2017/2018)										
60%	80.56	9.11	6.60	12.11	10.04	436.9	288.9	725.9	10.88	7.29
80%	82.06	10.22	8.36	12.92	11.22	484.5	458.3	942.8	10.29	6.78
100%	79.89	9.11	7.99	12.61	10.53	443.2	409.7	852.9	10.08	6.56
L.S.D at 0.05	1.05	0.31	0.24	0.25	0.51	24.45	18.82	27.60	0.40	0.16

Data shown in Table (5) indicated that using of 80% irrigation level treatment significantly improved the physical bulb quality whereas, sweet fennel bulbs were more rounditive, less flatten and less cylindrical shape ratio. The similar trends were obtained in both seasons, except for cylinder shape ratio of sweet fennel bulbs in the second season only and elongated shape ratio in the first and second seasons, where there no significant differences were realized among treatments. The lowest values of physical bulb quality were recorded by using 60% irrigation level treatment.

Table 5: Effect of irrigation water levels on total yield, physical bulb quality and chemical content in leaves of sweet fennel during two seasons (2016/2017 and 2017/2018).

Irrigation Levels	Total yield (ton/fed.)	Physical bulb quality			Chemical content in leaves		
		Flatten shape ratio	Cylinder shape ratio	Elongated shape ratio	N (%)	P (%)	K (%)
				First season (2016/2017)			
60%	15.502	1.96	1.16	0.84	1.90	0.32	2.60
80%	18.685	1.46	1.03	0.85	1.92	0.34	2.69
100%	17.225	1.56	1.06	0.85	2.08	0.37	2.91
L.S.D at $_{0.05}$	0.772	0.05	0.05	N.S.	0.04	0.02	0.03
				Second season (2017/2018)			
60%	14.518	1.84	1.13	0.83	1.95	0.35	2.67
80%	18.857	1.55	1.08	0.87	2.03	0.37	2.76
100%	17.059	1.59	1.05	0.83	2.20	0.40	2.98
L.S.D at $_{0.05}$	0.552	0.06	N.S.	N.S.	0.06	0.02	0.03

c)- Chemical content:

Data in Table (5) show the highest NPK percentages were obtained by 100% irrigation level followed by 80% IR during the both seasons. The lowest NPK percentages were obtained by 60 % IR. Data in Table 8 show the NPK percentages during the two tested season. There were significant differences between the tested treatments during the both seasons. The 100% of recommended N rate gave the highest NPK percentages of sweet fennel leaves followed by 100% N treatment while the lowest NPK percentages were obtained by 50% N.

3. Effect of nitrogen levels

a) - Vegetative characteristics:

The obtained results in Table (6) revealed that the application of N fertilizer significantly affected different vegetative characteristics (plant length, number of leaves per plant, fresh weight and dry weight of leaves and bulbs as well as sweet fennel bulb dimension (length, width and thickness) in the two growing seasons. Data indicated that 75 % N from the recommended level gave the highest plant length number of leaves per plant, fresh and dry weight followed by 100 % N during the two tested season. The lowest sweet fennel vegetative characteristics were obtained by 50% N.

b) - Total green yield and bulb quality:

Regarding the nitrogen level data in Table (7) show the sweet fennel yield during the two tested season. There were significant differences between the tested treatments. The 75% of recommended N rate gave the highest yield and quality of sweet fennel bulbs followed by 100% N treatment while the lowest yield of sweet fennel bulbs were obtained by 50% N. These increases in total green yield were statistically significant and amounted to 2.595 and 5.787 ton/ feddan which equal 14.19 and 29.51 % by applying 75 % of recommended N dose compared with 50% N treatment in the two seasons, respectively. These increases might be due to the resulting increases in the vegetative growth and N, P and K content of leaves and bulbs as well as dry matter content by 75% of recommended N rate. These findings were similar and true in both seasons of study.

Table 6: Effect of nitrogen-fertilization rates on vegetative growth of sweet fennel during two seasons (2016/2017 and 2017/2018).

N-fertilization recommended doses (kg/ fed.)	Plant length (cm)	Leaves No./ plant	Bulb dimensions			Fresh weight (g / plant)			Dry weight (g /100 g F*W*)	
			Thickness (cm)	Width (cm)	Length (cm)	Leaves	Bulbs	Total	Leaves	Bulbs
First season (2016/2017)										
50	75.83	8.78	7.20	12.14	9.97	464.50	319.97	784.47	10.12	6.77
75	85.22	10.00	8.00	12.47	11.07	530.83	383.39	914.22	10.78	7.62
100	80.33	9.00	7.59	12.47	10.20	495.67	376.24	871.92	10.17	6.71
L.S.D at 0.05	1.50	0.40	0.22	N.S.	0.23	25.06	10.07	30.41	0.28	0.39
Second season (2017/2018)										
50	79.50	9.22	6.98	12.22	10.71	379.31	311.91	691.23	10.10	6.39
75	84.44	10.22	8.18	13.21	11.56	517.99	462.62	980.61	11.01	7.22
100	78.56	9.00	7.79	12.21	9.53	467.45	382.40	849.85	10.13	7.02
L.S.D at 0.05	1.57	0.44	0.14	0.28	0.25	22.76	9.94	22.05	0.32	0.23

Table 7: Effect of nitrogen-fertilization rates on total yield, physical bulb quality and chemical content in leaves of sweet fennel during two seasons (2016/2017 and 2017/2018).

N-fertilization recommended doses (kg/ fed.)	Total yield (ton. /fed.)	Physical bulb quality			Chemical content in leaves		
		Flatten shape ratio	Cylinder shape ratio	Elongated shape ratio	N (%)	P (%)	K (%)
First season (2016/2017)							
50	15.689	1.76	1.08	0.82	1.71	0.24	1.94
75	18.284	1.57	1.12	0.89	1.95	0.37	2.88
100	17.438	1.66	1.05	0.82	2.24	0.43	3.38
L.S.D at 0.05	0.608	0.09	0.03	0.04	0.04	0.01	0.02
Second season (2017/2018)							
50	13.825	1.77	1.16	0.88	1.82	0.27	2.01
75	19.612	1.63	1.11	0.87	2.07	0.40	2.95
100	16.997	1.58	0.98	0.78	2.29	0.46	3.45
L.S.D at 0.05	0.441	0.05	0.03	0.02	0.02	0.01	0.02

Results were shown in Table (7) indicated that applying of 75% of recommended N rate significantly improved the physical bulb quality. Sweet fennel bulbs were more rounditive and less flatten and less cylindrical shape ratio.

The similar trends were obtained in the two seasons, except for cylinder shape ratio of sweet fennel bulbs in the second season only and elongated shape ratio in the first and second seasons, where there no significant differences were realized among treatments. The lowest values of physical bulb quality were recorded by using 50% of recommended N rate treatment.

c) - Chemical content:

Data presented in Table (7) show the highest values of NPK percentages were obtained by 100% of recommended dose of N followed 75% of recommended dose of N during the both seasons. The lowest values of NPK percentages were obtained by 50% of recommended dose of N. There were significant differences between the tested treatments during the both seasons. The 100% of recommended N rate gave the highest NPK percentages of sweet fennel leaves followed by 75% N treatment while the lowest NPK percentages were obtained by 50% N.

4. Effect of the interaction

a)- Vegetative growth characteristics:

The interaction among irrigation level and N fertilizer treatments was significant for vegetative characteristics during the two studied seasons (Table, 8). The highest vegetative growth was preceded by 80 % irrigation level combined with 75% N fertilizers followed by 100 % IR combined with 100% N fertilizer. The lowest vegetative characteristics were obtained by 60% irrigation combined with 50% N.

Table 8: Effect of the interaction (Irrigation water levels x N-fertilization rates) on vegetative growth of sweet fennel during two seasons (2016/2017 and 2017/2018).

Irrigation Levels	N-fertilization recommended doses (kg/ fed.)	Plant length (cm)	Leaves No./ plant	Bulb dimensions			Fresh weight (g / plant)			Dry weight (g /100 g F*W*)	
				Thickness (cm)	Width (cm)	Length (cm)	Leaves	Bulbs	Total	Leaves	Bulbs
First season (2016/2017)											
60%	**50**	72.00	7.00	5.43	12.50	9.77	409.20	283.23	692.43	10.32	6.38
	75	82.67	9.67	6.97	12.03	10.60	433.38	368.80	802.18	11.86	8.09
	100	79.33	8.67	6.43	11.93	10.03	477.58	353.10	830.68	10.48	7.42
80%	**50**	78.50	9.33	8.43	12.23	10.60	520.10	321.80	841.91	10.66	6.88
	75	87.33	10.33	9.17	13.17	10.93	672.17	409.67	1081.84	10.71	7.17
	100	82.33	10.00	8.53	12.80	10.90	472.88	406.10	878.99	10.41	6.02
100%	**50**	77.00	10.00	7.73	11.70	9.53	464.18	354.88	819.07	9.38	7.04
	75	85.67	10.00	7.87	12.20	11.67	486.94	371.70	858.64	9.78	7.60
	100	79.33	8.33	7.80	12.67	9.67	536.56	369.52	906.08	9.60	6.68
L.S.D at $_{0.05}$		1.60	0.56	0.25	0.62	0.47	38.50	26.16	55.91	0.52	0.49
Second season (2017/2018)											
60%	**50**	81.67	8.67	6.27	12.40	10.73	411.23	229.87	641.10	10.43	6.85
	75	81.67	9.67	6.93	12.60	9.90	462.55	332.67	795.21	11.80	7.62
	100	78.33	9.00	6.60	11.33	9.50	437.18	304.22	741.40	10.40	7.40
80%	**50**	80.17	10.33	7.73	12.00	11.20	379.29	389.11	768.40	10.40	5.82
	75	86.33	11.33	8.83	13.87	12.53	586.25	538.78	1125.03	11.44	7.94
	100	79.67	9.00	8.50	12.90	9.93	488.08	447.01	935.08	9.01	6.58
100%	**50**	76.67	8.67	6.93	12.27	10.20	347.42	316.77	664.19	9.46	6.51
	75	85.33	9.67	8.77	13.17	12.23	505.17	516.43	1021.59	9.79	6.09
	100	77.67	9.00	8.27	12.40	9.17	477.11	395.97	873.07	10.99	7.07
L.S.D at $_{0.05}$		1.51	0.44	0.34	0.37	0.73	35.40	27.24	39.96	0.58	0.24

b)- Total green yield and bulb quality:

Regarding the interaction effect between irrigation and N fertilizer rates, the highest green yield and physical bulb quality of sweet fennel were obtained by 80% irrigation level treatment combined with 75% N rate during the two seasons; 100% irrigation level combined with 100 N fertilizer came in the second order. The lowest values of green yield and physical bulb quality were obtained by 60% irrigation level combined with 50% N fertilizer rate (Table 9).

These increases in total green yield were statistically significant and amounted to 7.788 and 9.679 ton/ feddan which equal 35.99 and 43.01 % by using 80% irrigation level treatment combined with 75% N treatment compared with the least values of the interaction between 60% irrigation level combined with 50% N fertilizer rate in the two seasons, respectively. These increases might be due to the resulting increases in the vegetative growth and N, P and K content of leaves and bulbs as well as dry matter content by 80% irrigation level treatment combined with75% of recommended N rate. These findings were similar and true in both seasons of this study.

Also, the interaction effect between irrigation and N fertilizer rates recorded significant differences effect on physical bulb quality of sweet fennel bulbs in both seasons. Generally, it could

be stated that the highest values of bulb quality of sweet fennel bulbs were recorded by 80% irrigation level treatment combined with 75% N rate.

c)- Chemical content:

Regarding the interaction effect between irrigation and N fertilizer rates, the highest NPK percentages was obtained by 100% irrigation level combined with 100% N rate during the two tested seasons; followed by 80% irrigation level combined with 75% N fertilizer rate (Table, 9). The lowest value of NPK percentage was obtained by 60% irrigation level combined with50% N fertilizer rate. The statistical analysis show there were no significant different of P percentage in sweet fennel yield during the two season as well as there were no significant among interaction for K during the second season.

Table 9: Effect of the interaction (Irrigation water levels x N-fertilization rates) on total yield, physical bulb quality and chemical content in leaves of sweet fennel during two seasons (2016/2017 and 2017/2018).

Irrigation Levels	N-fertilization recommended doses (kg/ fed.)	Total yield (ton/fed.)	Physical bulb quality			Chemical content in leaves		
			Flatten shape ratio	Cylinder shape ratio	Elongated shape ratio	N (%)	P (%)	K (%)
				First season (2016/2017)				
	50	13.849	2.30	1.19	0.78	1.60	0.22	1.82
60%	**75**	16.044	1.73	1.16	0.88	1.86	0.33	2.71
	100	16.614	1.86	1.15	0.84	2.25	0.42	3.26
	50	16.838	1.45	1.04	0.87	1.72	0.24	1.88
80%	**75**	21.637	1.44	1.00	0.83	1.89	0.37	2.87
	100	17.580	1.50	1.04	0.85	2.15	0.41	3.32
	50	16.381	1.51	1.00	0.82	1.81	0.27	2.11
100%	**75**	17.173	1.55	1.19	0.96	2.10	0.40	3.05
	100	18.122	1.63	0.97	0.76	2.33	0.45	3.55
L.S.D at $_{0.05}$		1.118	0.08	0.07	0.05	0.05	N.S.	0.04
				Second season (2017/2018)				
	50	12.822	1.98	1.22	0.87	1.71	0.25	1.89
60%	**75**	15.904	1.82	1.06	0.79	1.97	0.36	2.78
	100	14.828	1.72	1.10	0.84	2.16	0.45	3.33
	50	15.368	1.56	1.16	0.93	1.83	0.27	1.95
80%	**75**	22.501	1.57	1.13	0.90	2.00	0.40	2.94
	100	18.702	1.52	0.95	0.77	2.26	0.44	3.39
	50	13.284	1.77	1.11	0.83	1.92	0.30	2.18
100%	**75**	20.432	1.50	1.14	0.93	2.23	0.43	3.12
	100	17.461	1.50	0.91	0.74	2.44	0.48	3.62
L.S.D at $_{0.05}$		0.799	0.09	0.10	0.07	N.S.	N.S.	0.04

Discussion

The presented data reveal that the 80 % of irrigation requirements gave the best sweet fennel vegetative growth, total fresh yield and physical bulb quality during the two studied seasons. Similarly, Bozkurt *et al*. (2009) reported that the best yield in plant grown obtained from proper irrigation level. Moreover, Sefer and Mansuroglu (2011) reported that the decreased water quantity had a greater effect on the plants fresh weight than on the dry weight. The higher yield production under 80% IR may be due to proper balance of soil moisture in plants, which led to make favorable conditions for metabolites translocation according to Farrag *et al.* (2016). Other possibility maybe proper soil available water led to enhance the rate of vegetative growth and obtained yield (Farag *et*

al., 2014). Furthermore, water stress during the early growth stage reduces leaf area and root expansion, plant height and delays canopy development; reduced leaf growth limits the photosynthetic capacity (Farrag *et al*., 2016). The same results also obtained by Anita and Mauromicale (2006) who mentioned that the reduced root development limits the plant's ability for water and nutrients uptake.

Regarding the N treatments, 75% of recommended N gave the highest sweet fennel yield and bulb quality followed by 100%; while the lowest growth and productivity of sweet fennel was produced by 50% N treatment.

These results might be due to adequate nitrogen availability in the soil solution which might have led to increase various physiological processes, better uptake of nitrogen and other nutrients and then higher rates of photosynthesis (Abdrabbo *et al*., 2005). A large portion of reduced N in plant associated with the machinery of plant's energy metabolism, whereas smaller portion was incorporated in structural cell components, thus, sufficient supply of N led to increase plant growth (Marschner, 1995). Increase in N dose led to increase in N concentration in plant tissues achieve higher machinery and plant growth rate. Therefore, plant uptake more P and K, from soil solution to build cell structure and activate metabolic enzymes (Farag *et al.*, 2014 and Abdrabbo *et al.* 2005). These results were in accordance with those reported by El-Shakry, (2005) on sweet fennel cultivars.

Rahemi *et al.,* (2005) indicated that the yield is dependent on many factors like the amount of available nutrients in the soil, plant spacing, cultivars etc. Response to N of the first increment of fertilizer usually brings about the greatest response in yield, followed by a more gradual increase with succeeding N increments. As the N rate increases, however, the potential for losses also increases. In addition to environmental concerns due to excessive N applications, high rates of N can detrimentally affect production by promoting excessive vine growth, delaying maturity, reducing yields (Abdrabbo *et al.*, 2015). Selecting a realistic N rate is therefore important for both production and environmental standpoint. Unfortunately, the effect of excess N on fruit quality is dependent on soil moisture and temperature as well as the cultivar grown. Otherwise, limitation of nitrogen can considerably reduce the plant growth (Zelalem *et al.,* 2009).

Conclusion

The present investigation revealed that, using proper irrigation quantity and nitrogen rate increased the productivity of sweet fennel. The superior treatment was 80% of irrigation requirement combined with 75% of nitrogen rate during the both tested season. Increasing irrigation level and / or nitrogen rate led to decrease the obtained yield and bulb quality of sweet fennel.

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