Applying Deficit Irrigation and Natural Fertilization for Cucumber Yield Enhancement under Greenhouse

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Abstract

Deficit irrigation combined with appropriate type of fertilizer is commonly considered as the best management practice for irrigated agriculture. The objective of this work is to study the influence of applying deficit irrigation and natural stimulant materials fertilization under greenhouse condition on yield and quality of cucumber and soil chemical characteristics.

A field experiment was conducted in 2016- 2017 using a split plot design with four deficit irrigations (0, 10, 20 and 30% deficit ratio) and with three fertilizer types (chemical, humic and algea) as the main and split plots, respectively. The results revealed that 30% deficit irrigation with algea fertilizer to be more efficient than 0% deficit irrigation and common fertilizer (chemical). This combination resulted in the maximum yield of cucumber, optimum water use efficiency and net profit. Common fertilizer increases the heavy metals in the soil followed by humic and then algea fertilizer, while algea increases the water use efficiency and net profit. Using algea fertilizer and deficit irrigation achieved maximum yield, net profit and water saving.

***Keywords*:** Deficit irrigation, fertilizer, humic, algea, Greenhouse, net profit, cucumber, economic analysis

1. INTRODUCTION

Water is the most important constraint factor in Egypt for agricultural production expansion. Growers seek methods to save water by increasing irrigation efficiency. Approximately 40% of world food is produced using irrigation (FAO, 2002) and agriculture consumes the largest amount of the available water in Egypt, with its share exceeding 85% of the total national demand for water (Water Scarcity in Egypt 2014). Optimum irrigation scheduling based on water use patterns and crop response to water deficit can potentially improve water use efficiency. There is a need for crop producers to use both field and sheltered production systems to adopt sustainable irrigation methods and water management practices. This is especially the case in arid and semiarid areas which are subjected to frequent droughts and/or with limited water resources. One technique to improve water productivity is the deficit irrigation, an irrigation practice whereby water supply is reduced below maximum levels and mild stress is allowed with minimal effects on yield. Deficit water budgets lead to numerous physiological changes such as altered root to shoot ratio, reduced leaf area or number of leaves, and finally reduce plant growth and yield. Fresh fruit yields of cucumber and tomato are highly affected by the total amount of irrigation water at all growth stages (Mao *et al.*, 2003; Patanè *et al.*, 2011).

Greenhouse production is one of the most important sheltered production systems for supply of vegetables, fruits, and ornamental plants. Greenhouse production is an intensive farming method that involves heavy fertilizer and irrigation water use (Ling, 2004). Kirda (2002) reported that under scarce water supply conditions, deficit irrigation technique could lead to greater economic gains than maximizing yields per unit of water for a given crop. Mao *et al.* (2003) studied the effect of deficit irrigation on yield and water use of grown cucumber and reported that the Water Use Efficiency (WUE) decreased when increasing the irrigation water applied from stem fruiting to the end of the growth stages. However, the WUE increased with the increase of irrigation water from cucumber fruit setting to first fruit ripening.

Nowadays, increasing productivity of vegetative crops with high quality is considered an important aim that could be achieved through using some natural stimulant materials as fertilizer. Reduction of chemical fertilizers became very important due to their increasing prices and also to reduce groundwater pollution which affects human health (Gawish *et al.*, 2012).

Nikbakht *et al.* (2008**)** found that humic acid increased the number of harvested flowers per plant gerbera by about (52%). Hamideh *et al.* (2013) found that the beneficial effects of humic acid on plant growth and development are their effect on cell membranes which lead to the enhanced transport of minerals, improved protein synthesis, plant hormone-like activity, promoted photosynthesis, modified enzyme activities, solubility of micro-elements and macro-elements, reduction of active levels of toxic minerals and increased microbial populations. Humic acid treatment resulted in higher flower quality, longer vase life, higher number of cormels per clump, and greater cormel diameter and weight of Gladiolus (*Gladiolus grandiflorus* L.) (Ahmad *et al.* 2013).

Abeer *et al.* (2015) found that using humic acid increased plant height, number of leaves, root length, shoot and root fresh and dry weights as well as chlorophyll contents of common bean. Malaka *et al.*, (2016) indicated that spraying inflorescences date palm with algae extract and/or potassium nitrate had a significant effect on yield, fruit physical and chemical characteristics of Medjool date palm when compared to the check treatment.

Dalia *et al.*, (2014) showed that spraying pea plants with algae extract at 10 or 15 % increased significantly the vegetative growth characters and yield and its components, as well as seed content of nitrogen, phosphorus and protein content, as well as leaf chlorophyll content compared to the other algae extract concentrations.

Cucumber *(Cucumis sativus L.)*, is a popular and well-liked vegetable around the world. It is sensitive to drought and requires maximal amount of water during its growth (Wang *et al., 2010*). Amer *et al.* (2009), evaluated nutrient source and rates (commercial fertilizer or with chicken manure) and deficit irrigation (1.0, 0.84, and 0.64 of ET) on growth and yield of cucumber grown and found that Chlorophyll a and b, leaf area index, and yield were greatest when adequate water and high N were used (1.0 ET with chicken manure at 7 Mg/ha). Al-Omran *et al.* (2013) found that the full irrigation at the early and late stages and then irrigation with 80% of ET was the most appropriate treatment in terms of crop water productivity and the final yield. The increase of irrigation quantity over 80% ETc led to decrease in water use efficiency for all irrigation treatments, while the highest WUE was obtained with 80% ET.

Therefore, water scarcity and unavailability of alternative water resources, raised the need to look for alternative ways to save water, including the deficit irrigation. The same can be said about chemical fertilizer as it is one of the causes of pollution in the soil and due to the increasing prices there was a need to provide alternative sources. We find that there is other natural source more economical and friendly to the environment and gives the same performance of chemical fertilizers. There is a need for this research because there are limited available works on the impact of use different fertilization types under deficit water circumstances, especially under greenhouse condition for improving the crop yield and the environment.

The objective of this research is to evaluate the possibility of using deficit irrigation with natural stimulant material fertilization (algae and humic acid compared to the common chemical fertilizer) under greenhouse and drip irrigation system and to: 1) Evaluate water use efficiency and cucumber yield and quality and 2) Provide economic analysis.

2. MATERIALS AND METHODS

2.1. Experimental Location

The experiment was carried out in the greenhouse at Wadi El-Natroon station which is operated by Water Management Research Institute- National Water Research Center. The Station is 80 km away from Cairo that is located at (latitude: 30° 25’ 0 N, longitude: 30° 13’ 0 E, altitude: 25.5m). Water and soil samples were collected for laboratory analyses at Central Laboratory for Environmental Quality Monitoring (CLEQM). Soil samples were collected at depths (0-20 cm), (20- 40 cm) and (40- 60 cm) to identify physical characteristics of soil texture, soil-water field capacity (F.C**)**, and permanent wilting point (W.P), Table (1). The chemical analysis of irrigation water is presented in Table (2). Soil moisture content was measured in each treatment by dielectric sensor Delta Devices model Profile Prob-PR2 (England) at 30 cm deep.

Table 1: Soil Physical Properties of Wadi EL Natroon Site

Soil layer (cm)	Particle size distribution %			Texture class	Moisture content by volume (%)		
	Sand	Silt	Clay		F.C	W.P	A.W
0 –20	94.5	3.5	2.0	Sandy	13.25	5.49	7.76
20-40	95.0	3.3	1.7		14.24	4.9	9.34
40-60	95.7	3.0	1.3		14.5	4.31	10.2

Table 2: Chemical Analysis of Irrigation Water

PH	EC (dS/m)	Soluble anions (meq / l)				Soluble cations (meq / l)			
		CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
7.14	1.18	0.1	4.7	10.6	8.15	1.8	2.8	18.4	0.55

2.2. Description of Experimental Greenhouse And Cucumber Treatments

The experimental Greenhouse was 50 m long, 8 m wide, 3 m height (with total area of about 400 m^2) and covered by 100µm transparent polyethylene film treated against ultraviolet ra diation. Drip irrigation system has been used in the greenhouse, irrigation water was obtained from the groundwater (well) on the irrigation network near the greenhouse and distributed to the plots by laterals. The drip system of each plot consists of two irrigation lines of 4.8 m long, and each plot contains 16 plants. The distance between the two irrigation lines was 1m. The discharge of each dripper was about 4 l/h.

Cucumber was planted on Dec. 25th, 2016 at 1 × 0.6 m spacing. Cucumber was hand-harvested several times taking edge effects in the study plots into consideration and weighed in March, April and May 2017.

For soil preparation before cucumber planting cultivation, 8 m^3 Organic compost and 60 kg phosphate fertilizer were added, and all cultural practices (pest and disease control, etc.) were carried out whenever necessary (from beginning of Jan. to end of May 2017) (Ministry of Agriculture and Reclamation Lands).

The experimental design was split plot design with three replicates. The main plot was deficit irrigation while the sub main was fertilization. Four deficit Irrigation treatments (0, 10, 20 and 30%) of applied depth of irrigation water, while there was three fertilizer treatments (common F1 "Chemical fertilizer", Humic acid F2 and Algae ("***Amphora co feaeformis***") F3, respectively. Some chemical composition of humic acid and algea are shown in table (3).

Table 3: Some chemical composition of humic acid and algea

Humic acid	PH	EC (dS/m)	Macronutrients (%)			Micronutrients (mg/kg)			Humic acid (%)
			N	P	K	Zn	Fe	Mn	
	7.0	0.85	5.04	0.48	4.1	265	397	241	87
Algea			N	P	K	Zn	Fe	Mn	Moisture (%)
			8.01	2.45	1.1	766	2021	737	4.12

2.3. The Studied Parameters

2.3.1. Soil characteristics.

Soil samples at depths (0-20 cm) and (20- 40 cm) were collected and analyzed to identify heavy metal contents (copper, iron, manganese, nickel and zinc) before and after the experiment.

2.3.2. Cucumber characteristics

- **Yield:**

The fresh cucumber fruits were harvested successively at three day intervals over 10 week's period. The sum all pickings was expressed as total fruit yield (kg/m^2).

- **Quality:**

A random sample of 5 fruits was taken from each treatment to measure moisture content, total nitrogen, total phosphors and heavy metals.

2.3.3.Water relations

- **Depth of applied water**

Applied depth of irrigation water was calculated by using the following equation as cited from (***Hamza and Almasraf, 2016***):

$$dg = \frac{Q \times T}{A}$$ ……………………………………………………………………*Equation 1*

Where:

dg: depth of applied water (cm).
Q: applied discharge from the drip system (cm^3/min.),
T: time of irrigation (min.),
A: wetted area (cm^2), wetted area under the emitter was assumed to be circle in a shape.

- **Estimation of Crop Evapotranspiration for the Cucumber in the Greenhouse**

Actual evapotranspiration (ET_c) values for the cucumber in the greenhouse were calculated according to the following equation (**Israelsan and Hansen, 1979**).

$$ET_c = \left(\theta_p - \theta_n\right) \times RD$$ ………………………………………………………..*Equation 2*

Where:

θ_p: soil moisture in the previous reading (% by volume),
θ_n : soil moisture in the next reading (% by volume), and
RD: rooting depth (mm).

- **Water use efficiency**

The following equation was used for calculating the WUE (kg/m^3) as cited from (***Hamza and Almasraf, 2016***):

$$WUE = \frac{Yield\ (Kg/m^2)}{Total\ depth\ of\ applied\ water\ (m^3/m^2)}$$ **……………………………………….***Equation 3*

2.3.4. Statistical analysis

Data recorded were analyzed using statistical software "SPSS 18". The purpose of analysis of variance was to determine the significant effect of treatments.

2.3.5. Economic analysis

The prices of inputs and outputs were calculated for different treatments for cucumber during the experiment in the greenhouse. Costs of irrigation and fertilization during the entire season for different treatments were also calculated.

3. RESULTS AND DISCUSSION

1- Soil characteristics

Data in Table 4 depict the results of heavy metals of soil samples taken from soil before and after use of common, humic and algea fertilizer. The effect of different types of fertilizer on heavy metals, chemical fertilizer increased the heavy metals of soil compared with humic and algea fertilizer. Algea fertilizer increased the copper from 0.058 and 0.108 to 0.317 and 0.211, while humic increased to 0.558 and 0.251 meg/l under 0-20 and 20-40 soil depth. Algea fertilizer decreased the heavy metals on soil, with no effect on plant absorption.

Table 4: The heavy metals meg/l before and after the experiment under different treatments

	Fertilizer types	Depth	Copper	Iron	Manganese	Nickel	Zinc
Before	Control	0-20	0.058	7.12	0.13	0.005	0.035
		20-40	0.108	7.54	0.157	0.008	0.039
After	Chemical	0-20	1.03	9.976	0.363	0.007	0.021
		20-40	0.427	8.843	0.169	0.006	0.004
	Humic	0-20	0.558	9.517	0.176	0.009	0.020
		20-40	0.251	8.26	0.127	0.008	0.017
	Algae	0-20	0.317	9.227	0.158	0.009	0.014
		20-40	0.211	8.019	0.122	0.008	0.035
Recommended (WHO, 1989)			2.795	5.99	3.549	16.972	3.993

2- Cucumber characteristics

- **Yield**

The evolution of yield for cucumber under the studied variables and the impact of deficit irrigation treatments and use of different types of fertilizer are presented in Table (5). Yield increased significantly with increasing the amount of irrigation water applied. The investigated treatments showed yield values always below that obtained under full irrigation practices. However, under the deficit irrigation treatments the yield was subjected to various losses that varied according to the variation in the volumes of applied water within the individual deficit irrigation treatments.

Irrigating with a volume of water 30% lower than that of full irrigation resulted in nearly 32.5, 28.4 and 11.9% losses compared with 0, 10 and 20% deficit irrigation, respectively. With respect to the effect of fertilizer types, it is obvious that fertilizer affected significantly the yield.

Under fertilizer treatment, where using chemical there was a drastic drop in the yield showing losses nearly 4 and 20.4% of that under humic and algea fertilizer, respectively. Comparing the yield increase under the algea treatment, with that found under the chemical and humic treatment the data indicated that there was further increase in the yield nearly 20.4 and 15.7%, respectively. The maximum value of the yield was (14.7 kg/m^2) found under full irrigation and algea fertilizer.

Table 5: Yield results (kg/m^2) for cucumber under different treatments

Fertilizer	30	20	10	0	Mean
Chemical	8.29	9.90	11.16	12.48	10.46
Humic	8.79	9.71	11.11	13.95	10.89
Algea	10.70	11.51	13.41	14.77	12.60
Mean	9.26	10.37	11.89	13.73	11.32
	F test	LSD* at 5%			
Fertilizer (F)	*	5.223			
Deficit (D)	*	10.521			
F x D	*	8.559			

*LSD: Least significant difference

- **Quality**

The data in Table (6) indicated that there were significant effects of the type of fertilizer. As for copper and iron, the algae had lowest value compared to the chemical and humic fertilizer. On contrast the highest value of copper and iron was observed at the humic acid which recorded (1.94 and 5.15), respectively. Regarding to manganese, nickel and zinc, chemical had the highest value compared with humic and algea fertilizer, on contrast the lowest value was observed at the algea acid which recorded (0.69, 0.06 and 0.53), respectively. Concerning the total N and P, the highest value (17918 and 14.3 respectively) consecutively, was detected by the algea. Whereas, the lowest value was observed at the humic that reached (1891.5 and 3.5). These results are in harmony with those reported by **Awad et al. (2006) on potato; Abou El-Khair *et al.* (2010)** on garlic and **Hegazi *et al.* (2010)** on bean, they found that added blue green algae extract with irrigation water showed increases in N and P percentages.

Table 6: Heavy metals, total nitrogen and total phosphor concentration (mg/l) of cucumber fruits under different treatments

Treatments	Copper	Iron	Manganese	Nickel	Zinc	Total N.	Total P.
Fertilizer types							
Chemical (C)	1.33	4.42	0.72	0.15	0.4	3082.9	6.87
Humic (H)	1.94	5.15	0.7	0.12	0.78	1891.5	3.5
Algea (A)	0.84	4.01	0.69	0.06	0.53	17918	14.3
F test	*	*	*	*	*	*	*
LSD	1.21	1.32	0.7	0.1	0.61	35.2	1.98
Deficit irrigation							
0	2.78	15.12	2.1	0.27	1.4	32513.6	41.4
10	3.39	14.83	2.73	0.34	1.66	24104	25.3
20	5.67	12.61	1.7	0.25	1.4	20377	21.6
30	4.59	11.7	1.91	0.47	2.38	14575	16.8
F test	*	*	*	*	*	*	*
LSD	4.840	12.667	2.108	0.282	0.580	65.712	2.738
Interaction effects							
C 0	0.59	3.75	0.54	0.14	0.3	6166	14.6
C 10	0.57	3.6	1.08	0.14	0.34	1681	7
C 20	1.91	3.57	0.84	0.15	0.46	1681	7.6
C 30	2.24	6.75	0.41	0.15	0.49	2803	4.6
H 0	1.2	3.44	0.8	0.05	0.35	1681	4.4
H 10	2.17	8.86	1.29	0.13	0.78	1681	3.9
H 20	2.94	5.2	0.48	0.05	0.52	1401	3
H 30	1.44	3.07	0.24	0.26	1.49	2803	2.8
A 0	0.99	7.93	0.76	0.08	0.75	24666	22.4
A 10	0.65	2.37	0.36	0.07	0.54	20742	14.4
A 20	0.82	3.84	0.38	0.05	0.42	17295	11
A 30	0.91	1.88	1.26	0.06	0.4	8969	9.4
F test	*	*	*	*	*	*	*
LSD	1.295	4.443	0.701	0.104	0.324	75.701	3.778
Recommended Max. con.	**0.05**	**5**	**0.2**	**0.2**	**2**	**-**	**-**

3- Depth of applied water and crop evapotranspiration.

The depth of applied water and crop evapotranspiration for cucumber throughout the growing season under different deficit irrigations for the investigated treatments is given in Figure (1). The obtained data showed that the deficit irrigation plays an important role to save water in the field. By irrigating with 10, 20 and 30% deficit irrigation the depth of applied water reduced from 0.89 to 0.8, 0.71 and 0.63 m^3/m^2 and crop evapotranspiration reduced from 0.65 to 0.6, 0.54 and 0.48 m^3/m^2 compared to 0% deficit.

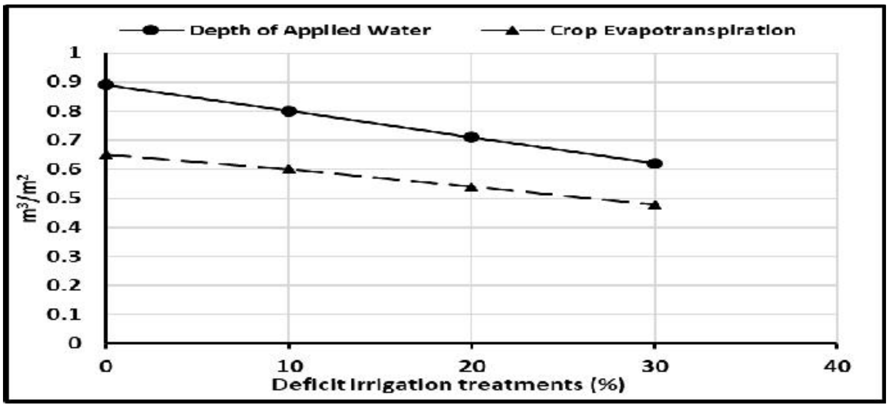

Figure 1: Depth of applied water and crop evapotranspiration for cucumber under different deficit irrigation

- **Water use efficiency**

Water use efficiency, is a key in the evaluation of deficit irrigation strategies as well as the sustainable use of non-conventional water resources as an additional water source for irrigation. Under the deficit irrigation treatments and the different fertilizers yields are given in Figure (2). The data indicated that Water use efficiencies were not of equal values for the investigated deficit irrigation treatments. Under the investigated irrigation treatments, the 30% deficit irrigation and algea fertilizers treatment resulted highest yield among the others showing the highest value of an average 17.26 kg/m^3.

Irrigation with volumes of water 10% lower than the full irrigation, showed water use efficiency with an average value nearly 29% lower than that of 30% deficit irrigation under algea fertilizer. Regarding water use efficiency under different fertilizers, chemical showed the lowest water use efficiency as compared with the other investigated treatments corresponding to 5.6 and 17.6% of humic and algea under 30% deficit irrigation, respectively.

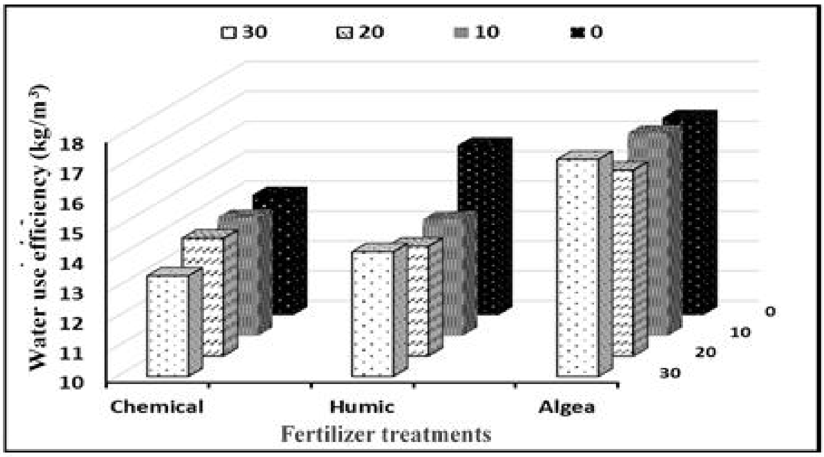

Figure 2: Water use efficiency for cucumber under different deficit irrigation

4- Economic analysis

The data listed in Table 7 indicates that treatment using algea gave the best values of the total income and net profit. Table 6 also shows that treatment using algea gave the least value of irrigation cost through the entire season compared to the other treatments. Meanwhile, the highest value of irrigation cost paid for the treatments is chemical followed by treatment humic fertilizer.

The highest total income and net profit value were 44.3 and 39.4 LE/m^2 under zero deficit irrigation and using algea, while lowest values were 16.6 and 11.6 LE/m^2 under 30% deficit irrigation and using chemical fertilizer, respectively.

Table 7: The economic analysis of the experiment LE/m^2

Fertilizer types	Deficit irrigation (%)	* Total irrigation cost and price of greenhouse	Fertilization cost	Total cost	Total income	Net profit
Chemical	**0**	4.7	1.0	5.7	25.0	19.3
	10	4.5	1.0	5.5	22.3	16.8
	20	4.3	1.0	5.3	19.8	14.5
	30	4.0	1.0	5	16.6	11.6
Humic	**0**	4.7	0.5	5.2	41.8	36.6
	10	4.5	0.5	5	33.3	28.3
	20	4.3	0.5	4.8	29.1	24.3
	30	4.0	0.5	4.5	26.4	21.9
Algae	**0**	4.7	0.2	4.9	44.3	39.4
	10	4.5	0.2	4.7	40.2	35.5
	20	4.3	0.2	4.5	34.5	30
	30	4.0	0.2	4.2	32.1	27.9

* Total irrigation included the price of the network, irrigation cost, labor and price of green house.

4. CONCLUSIONS

It is concluded that optimal use of water and algea fertilizer to meet crop requirements is essential to achieve maximum yield productivity in protected agriculture. The results led to the following concluding points:-

- Chemical fertilizer increases the heavy metals in the soil compared to humic and algea fertilizer.
- The maximum value of the yield was (14.7 kg/m^2) found under full irrigation and algea fertilizer.
- Added blue green algae extract with irrigation water showed increases in N and P percentages.
- Irrigating with 10, 20 and 30% deficit irrigation the depth of applied water reduces from 0.89 to 0.8, 0.71 and 0.63 m3/m2 and crop evapotranspiration reduces from 0.65 to 0.6, 0.54 and 0.48 m3/m2 compared with 0% deficit.
- 30% deficit irrigation and algea fertilizers treatment was the one among the others showing the highest value of an average 17.26 kg/m3 water use efficiency.
- Algea gave the least value of irrigation cost through the entire season compared to the other treatments. Meanwhile, the highest value of irrigation cost paid for the treatments chemical followed by treatment humic fertilizer

Based on the obtained results Algea fertilizer is the best management system in sustainable agriculture for increasing cucumber yield and decreasing the cost of common fertilizers. On the other hand, the excess use of common fertilizers in agriculture can lead to soil deterioration, nitrate accumulation in the plants and groundwater pollution.

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