Bull. Fac. Agric., Cairo Univ., 59 (2008):-57-70.

EFFECT OF DEFICIT IRRIGATION AND FERTILIZATION ON CUCUMBER

(Received: 2. 10. 2007)

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ABSTRACT

Irrigation budget is essential in determining when to irrigate and how much water to apply. Hence, water can be optimized to crop use to utilize water saving in agricultural extent. Otherwise, organic fertilization has been gradually substituted in place of minerals to obtain a high quality and quantity of crop yield. For that purpose, three irrigation deficits and seven fertilization types were intentionally nominated and randomly accomplished for cucumber performance. A field experiment was carried out on cucumber grown in northern Egypt at Shibin El-Kom in 2006 and 2007 summer planting seasons to optimize water use and select fertilizer dose and type. Fertilization treatments consisted of recommended dose of nitrogen (N) only or partially added with organic manures as: T1 (160 kg/ha N), T2 (80 kg/ha N with 17 Mg/ha farmyard manure), T3 (160 kg/ha N with 17 Mg/ha farmyard manure), T4 (80 kg/ha N with 7 Mg/ha rabbit manure), T5 (160 kg/ha N with 7 Mg/ha rabbit manure), T6 (80 kg/ha N with 7 Mg/ha chicken manure), and T7 (160 kg/ha N with 7 Mg/ha chicken manure). Irrigation treatments were a ratio from crop evapotranspiration (ET) as: 1.0ET, 0.84ET and 0.64ET using trickle system. Chlorophylls a and b, leaf area index, and cucumber yield were highly achieved when adequate water and high nitrogen were used (1.0ET with rabbit or chicken treatments). The lowest values of sex ratio occurred for 1.0ET plus T7 treatment. The seasonal water use was 498 and 471 mm for 1.0ET in 2006 and 2007 plantings in almost 125 days, respectively. Crop coefficient was developed in four stages and seasonally averaged as 0.83. The yield reduction coefficient averaged as 0.7745 by irrigation deficit. An optimal scheduling was statistically developed based on crop response in deficit irrigation to achieve maximum yield for different uniformity CV values. The optimal scheduling parameter α was recorded -1.725. Then, amount of water could be determined in known interval. Cucumber performance was significantly affected by both irrigation and nutrient deficiencies. Optimal vegetative growth and management was achieved using 1.0ET with T6 treatment.

***Key words.**: chlorophyll, crop coefficient, crop response, cucumber, deficit irrigation, fertilizationleaf area index, irrigation scheduling.*

1. INTRODUCTION

Water is an essential factor in agricultural scope in Egypt. Area is located in arid regions where irrigation is required for crop production. Growers are looking for methods to save water by increasing irrigation efficiency. Irrigation water should be utilized to compensate water shortage and embrace water saving and conservation in agriculture. The optimum irrigation scheduling can be applied based on utilizing crop response to water deficit in order to improve water use efficiency. Trickle irrigation applies less amount of water than sprinkler and surface systems since plant area is partially wetted. But water uptake by the crop determines how much water to apply. Alternatively, fertilizers are essential in plant growth. Mineral fertilizers are readily available after application, and application can be timed to meet crop needs, which vary with time. Nutrient release from organic fertilizers is temperature dependent, and relatively slow. Consequently, the nutrient released may not be timed correctly to meet crop needs. If the nutrient released is mobile, like nitrate, and is not used by the crop, it can be leached from the root zone thereby posing a pollution hazard. If organic fertilizers include a mature component, it can result in unclean vegetable product, if the product makes physical contact with manure.

Cucumber is one of the most popular vegetables cultivated in the world. It needs more water than normal grain crops (Li and Wang, 2000; and Mao *et al.*, 2003). Mao *et al.* (2003) found that fresh fruit yields of cucumber were highly influenced by the total volume of irrigation water at every growth stage. Cucumber yields were decreased by increasing irrigation deficit. Well irrigation along the whole season was a clearly advisable irrigation regime. Otherwise, the least advisable regimes were those that lead to water deficiencies during fruiting set stages. As a comparison of cucumber to other vegetables, Sammis and Wu (1986) found that total tomato yield increased linearly with increasing water application up to 467 mm where maximum yield was 99 Mg/ha (ton/ha) in deficit irrigation. When water applied was reduced to 280 mm, the yield was decreased to 60.15 Mg/ha. Therefore, the yield reduction coefficient was recorded as 0.98. They found that water irrigation greater than 467 mm resulted in no increase in yield. Mao *et al.* (2003) working on cucumber and Ahmet *et al.* (2004) on summer squash found that fruit yield was significantly increased by increasing water applied in deficit irrigation. They found a linear relationship between yield and water amount applied.

The purpose of the study is to utilize irrigation scheduling based on deficit irrigation levels. A goal of the study is partially substitute organic instead of chemical fertilizers in order to obtain a high quality and quantity of crop yield. The study also includes the cucumber performance as affecting applying nitrogen (inorganic and organic) and irrigation deficiencies.

2. MATERIALS AND METHODS

Beta-alfa cucumber (*Cucumis sativus*) was planted for two seasons in a loamy clay soil located at an arid site in northern Egypt (Shibin El-Kom area, 17.9 m above sea level, 30° 32′ N, 31° 03′ E). The crop was planted on 1 March in nursery, moved to permanent field on 13 April, and ended on 15 August in both 2006 and 2007 summer seasons. Replicate size which concluded three irrigation treatments and seven fertilization treatments was 18 × 21 m with 1 m row width and a 0.3 m spacing between plants within rows as shown in Fig. (1). It was unnecessary to split treatments due to partially plant area irrigated and symmetric treatments reserved. Plants were adequately watered in first and second irrigations, then, irrigation treatments were initiated at third irrigation. Irrigation water with 0.56 dS m^{-1} was applied using trickle system when soil water was reduced in between 50-60% of available water. Water applied as equivalent to 100, 80, and 60% from crop evapotranspiration (1.0ET) was determined based on soil water content before and after irrigation. These ratios were applied using trickle irrigation. Then, irrigation treatments were rated as 1.0ET, 0.84ET and 0.64ET from seasonal water use. Fertilization treatments were : T1 (160 kg/ha N), T2 (80 kg/ha N with 17 Mg/ha farmyard manure), T3 (160 kg/ha N with 17 Mg/ha farmyard manure), T4 (80 kg/ha N with 7 Mg/ha rabbit manure), T5 (160 kg/ha N with 7 Mg/ha rabbit manure), T6 (80 kg/ha N with 7 Mg/ha chicken manure), and T7 (160 kg/ha N with 7 Mg/ha chicken manure) in 2006 and 2007 summer seasons. A 1.2ET treatment was only conducted for mineral treatment (T1) in the experiment belt to find out the yield in surplus irrigation. Each treatment was replicated three times.

The amount of fertilization added in the experimental field was the recommended dose. For mineral, 477.6 kg/ha for ammonia nitrate (33.5% N), 715 kg/ha for super phosphate (15.5% P_2O_5), 240kg/ha for potassium sulfate (50% K_2O) were applied. For organic,17 ton/ha for farmyard manure and 7 ton/ha for both chicken and rabbit manures. The organic manures were applied during soil preparation. The chemical properties of the used manures were illustrated in Table (1).The total fertilizer rates (kg/ha) in terms of N, P, and K (inorganic plus organic) care given in Table (2).

Soil was classified as loamy clay with 1.28 g cm^{-3} soil bulk density. Soil particle sizes for 0.3 m of soil profile were distributed as 2% coarse sand, 23.5% fine sand, 37.7% silt, and 36.80% clay. Chemical analyses of the soil are shown in Table (3). The volumetric water content values were measured using pressure membrane as 58, 47.5, and 21.1% at saturated, field capacity, and wilting points, respectively. The water table in farm was recorded as 2.8 m. EC and minerals were measured in diluted soil in three depths and sections of soil using dilution ratio as 1 : 5.

The schedule irrigation depth d was determined in millimeters per irrigation interval based on average of moisture content of soil root depth before and after irrigation as follows:

$$d = (\theta_F - \theta_i)\,D \cdot P \text{ ---------- } (1)$$

where d is water applied depth in mm, θ_F is volumetric water content at field capacity m^3/m^3, θ_i volumetric water content before irrigation in m^3/m^3, D is wetted soil root depth, and P wetted area percentage. Ten soil samples from control treatment (1.0ET with mineral treatment) were taken along lateral before and after irrigation for almost 60 cm depth. A 0.3 m spacing between emitters with 4 L/h which individually fitted along lateral was recommended to make 0.41 m wetted strip along planting furrow for 32 mm/h soil infiltration rate. Hence, three soil samples from control treatment (1.0ET with mineral treatment) were taken each replicate along lateral before and after irrigation for almost 60 cm. So, averages of soil water content (θ_F and θ_i) were determined. The wetted root depth (D) was taken less than 0.5 m depends on plant stage. The cucumber root zone was almost refilled by water until soil reached to its field capacity.

The adequate water applied per time each irrigation (1.0ET) by trickle system in the experiment, when water was uniformly applied in small area, was determined as follows:

$$Q = \frac{d\,A}{T} \text{ ------ } (2)$$

where Q is system discharge L/h, d is water depth in mm, A is projected area in m^2, and T is irrigation time in h.

The average depth of water distribution Z_a by the system was determined as follows:

$$Z_a = \frac{T}{A \cdot P} \sum_{i=1}^{n} q_i \text{ ---- } (3)$$

where q_i is emitter discharge in the system (L/h) and n is emitter number in projected area.

The schedule parameter (α) was determined based on irrigation system as follows:

$$\alpha = \frac{1}{CV}\left(\frac{q}{q_a} - 1\right) \text{ ----- } (4)$$

where, q is scheduling of the emitter discharge, and q_a is average of the emitter discharge.

Weather instruments were positioned 2 m above the cucumber surface and collected data every 30 s into 24 h average using Campbell Scientific's CR-23X datalogger (Campbell Scientific Inc., Logan, Utah). Weather instruments were CS500 temperature and relative humidity probes, 03001-5 anemometer, and LI200X pyranometer. Datalogger was programmed to collect daily and monthly average of weather data (temperature, relative humidity, wind speed, and solar radiation.

Potential evapotranspi- ration (ET_p) was determined by two methods (Table 4): 1.The FAO Penman-Monteith formula (Allen *et al.* 1998) and 2. Pan evaporation (E_p) class A. Both ET_p and E_p were correlated taking the average of monthly weather data and formulated as follows:

$$ET_p = k_p \,.\, E_p \qquad \text{with } r^2 = 0.91$$

where k_p is pan coefficient and equals 0.77 in the area.

Seventy five days from planting, plant samples, five plants each, were taken from each experimental unit to determine chlorophylls *a* and *b* contents using the methods of Wettstein (1957). In the same samples, leaf area/plant was measured as the leaf area index (LAI) calculated according to Watson (1958) as follows:

$$lAI = \frac{\text{Leaf area per plant}}{\text{Land area per plant}}$$

The male and female flowers were counted during the intensive flowering period from 30 June to 15 July 2006 and 2007 seasons to estimate sex ratio (male/female flowers). Crop coefficient was only calculated for mineral treatment (T1) as the ratio of potential ET to measured ET. Fruit harvesting was almost performed during the period from 4 June to15 August in both seasons as crop response to both water and fertilizers. Optimal irrigation scheduling was introduced and presented in figures using crop response model. Duncan's method reference was statistically used to analysis the data.

Crop response determination in deficit irrigation.

The crop response between yield and water under deficit irrigation was shown by a linear response model (Doorenbos and Kassam, 1979; Solomon, 1983; Warrick and Gardner, Martin *et al.*, 1984; Sammis and Wu, 1985; Wu and Barragan, 2000). The linear model showed a sloped straight line in the deficit water application and a horizontal line for the crop response for surplus applications indicating no yield reduction by overirrigation. The crop response of deficit irrigation was expressed when water was uniformly applied as follows**:**

$$1-\frac{Y}{Y_m}=K_y\left(1-\frac{W}{W_m}\right) \quad ----- \ (5)$$

where Y_m and W_m represent maximum yield and its corresponding maximum water application; Y and W are yield and its corresponding water application under deficit condition; and K_y is a reduction coefficient which is considered as a constant for a crop in deficit irrigation.

In a practical matter, irrigation systems apply water with a degree of non-uniformity. If schedule irrigation depth (d) is considered in between minimum and maximum depths of water distribution ($Z_{min} \le d \le Z_{max}$), the area wetted by irrigation system will be divided into surplus and deficit areas. Then, the situation will be called underirrigation condition. When $d \ge Z_{max}$, the whole area will be deficit irrigated. When $d \le Z_{min}$, the whole area will be surplus irrigated.

In underirrigation condition, the crop yield will be varied in deficit areas and maximized in adequate and surplus areas. Wu (1988) and Wu and Barragan (2000) formulated the relative crop yield under trickle irrigation systems in deficit model as follows:

$$1-\frac{Y}{Y_m}=K_y\,P_D \quad ----- \ (6)$$

where P_D is the percent of deficit in unity.

In underirrigation condition, the percent of deficit in unity defined as the ratio of water deficit to the required water into the root zone can be formulated using linear distribution for water applied by the irrigation system according to Amer (2005) as follows:

$$P_D=\frac{(1.725+\alpha)^2\,CV}{6.9\,(1+\alpha\,CV)} \quad ---- \ (7)$$

where CV is system's coefficient of variation and α is schedule parameter.

The schedule parameter (α) specifies the deviation of any schedule irrigation depth (d) to average of water distribution depth (Z_a) in terms of CV and can be formulated as follows:

$$\alpha=\frac{1}{CV}\left(\frac{d}{Z_a}-1\right) \quad ---- \ (8)$$

where d is scheduling water depth expressing the plant water requirement and Z_a is average water distribution depth applied by irrigation system. When the linear distribution is used to express the water profile of irrigation system, α. ranges from -1.725 to 1.725 in underirrigation condition, $\alpha. \ge 1.725$ in complete deficit irrigation, and $\alpha. \ge -1.725$ in complete surplus irrigation.

The total relative yield in underirrigation condition ($Z_{min} \le d \le Z_{max}$ and $-1.725 \le \alpha \le 1.725$) affected by both system's coefficient of variation (CV) and schedule parameter (α) can be calculated by substituting the left side of Eq. 7 by P_D in Eq. 6 as follows:

$$\frac{Y}{Y_m}=1-K_y\frac{(1.725+\alpha)^2\,CV}{6.9\,(1+\alpha\,CV)} \quad ---- \ (9)$$

In complete deficit condition, when $\alpha \ge 1.725$ and $d \ge Z_{max}$, no deep seepage is occurred. The percent of deficit in unity can be reduced as follows:

$$P_D=\frac{\alpha\,CV}{1+\alpha\,CV}=1-\frac{Z_a}{d} \quad ---- \ (10)$$

The relative yield by the deficit condition was determined as follows:

$$\frac{Y}{Y_m}=1-K_y\frac{\alpha\,CV}{1+\alpha\,CV} \quad ---- \ (11)$$

or

$$\frac{Y}{Y_m}=1-K_y\left(1-\frac{Z_a}{d}\right) \quad ---- \ (12)$$

Table (1): Chemical properties of the organic manures

Manure Fert	Total organic matter (%)	pH	EC (dS/m)	N (%)	P (%)	K (%)
Farmyard	39.20	6.20	3.40	0.50	0.51	0.60
Rabbit	41.40	6.18	3.30	1.70	1.18	1.05
Chicken	44.40	6.15	3.28	2.20	1.20	0.72

Table (2): Total fertilizer rates in kg/ha for N, P, and K in treatments.

Fert.	T1	T2	T3	T4	T5	T6	T7
N	160.0	165.0	245.0	199.0	279.0	234.0	314.0
P	48.4	135.1	135.1	131	131	132.4	132.4
K	99.6	201.6	201.6	173.1	173.1	150.0	150.0

Table (3): Soil chemical properties in soil solution for the experimental site

Depth cm	pH	EC dS/m	Soluble ions meq/L							
			Cations				Anions			
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	CO_3^{-2}	$H\,CO_3^{-}$	Cl^{-}	SO_4^{-2}
0–30	7.73	0.51	6.52	4.48	9.86	0.64	0.00	6.53	9.98	4.99
30–60	7.85	0.42	5.38	6.27	6.27	0.38	0.00	4.10	8.06	6.14
60–90	7.92	0.45	5.76	7.81	4.61	0.13	0.00	3.10	7.93	7.28

Table (4): Meteorological data at Shibin El-Kom, Egypt during the two growing seasons.

*	Month	T_{avg} °C	T_{max} °C	T_{min} °C	RH_{avg} %	U_2 m/s	R_s $MJ/m^2/d$	R_n $MJ/m^2/d$	ET_p mm/d	E_p mm/d
2006 season	April	20.9	28.7	14.2	53.4	0.92	23.0	12.5	4.1	5.0
	May	24.1	32.5	16.3	49.3	0.87	24.7	14.1	4.9	6.1
	June	27.2	35.1	19.9	51.6	1.12	25.9	15.5	5.7	7.1
	July	27.8	35.1	21.8	61.9	0.86	23.2	14.4	5.0	6.8
	Aug.	28.9	35.6	23.1	63.6	1.20	21.3	13.2	4.9	6.4
2007 season	April	21.5	30.3	14.2	55.1	0.85	19.4	10.7	3.6	4.5
	May	23.8	32.4	16.1	51.9	1.09	21.1	12.2	4.4	5.5
	June	27.4	35.9	19.6	53.8	0.89	24.1	14.6	5.2	7.0
	July	28.3	36.3	21.1	61.1	0.96	22.7	14.1	5.0	6.8
	Aug.	28.2	36.0	21.5	63.5	1.02	20.6	12.7	4.6	6.2

*** T_{avg}, T_{max}, and T_{min} are monthly average, maximum, and minimum temperatures, respectively, RH_{avg} is monthly average relative humidity, U_2 is monthly average wind speed, R_s is monthly average solar radiation, R_n is monthly average net radiation determined according to Allen *et al.* (1998) , ET_P is monthly average potential evapotranspiration (Allen *et al*. 1998), and E_P is monthly average of measured pan evaporation class A.**

When a relationship is drawn between relative yield Y/Y_m and schedule parameter (α) using eqs. 9 and 11, it will significantly be affected by system's coefficient of variation. for a relationship between relative yield and relative scheduling irrigation depth (Z_a/d) as in eq.12, the coefficient of variation which represents the uniformity will be insignificant when α is larger than 1.725. in case of cv = 0, the relative irrigation depth will be unity for optimal scheduling and d will equal z_a.

The storage efficiency (E_s) was determined as follows:

$$E_s = 100(1 - P_D) \quad ----- \quad (13)$$

In complete surplus irrigation condition ($\alpha \leq -1.725$ and $d \leq z_{min}$), the whole area should be surplus irrigated. In complete surplus irrigation condition, storage efficiency will be 100% because the root zone is fully irrigated ($p_d = 0$). but application efficiency, E_a, will be taken a value less than 100% depends on uniformity cv values. application efficiency was determined using the following equation:

$$E_a = 100(1 - P_s) \quad ------ \quad (14)$$

where p_s is the percent of deep seepage in unity.

The percent of deep seepage in unity was determined under linear distribution as derivative in this work using the basic analyses done by amer (2005) as follows:

In undeirrigation

$$P_s = \frac{(1.725 - \alpha)^2 \, CV}{6.9} \quad ---- \quad (15)$$

in surplus irrigation

$$P_s = -\alpha \, CV = 1 - \frac{d}{Z_a} \quad ---- \quad (16)$$

3. RESULTS AND DISCUSSION

3.1.Chlorophyll

Chlorophylls a and b in 2006 season were obtained in cucumber leaves as shown in Table (5). both chlorophylls a and b decreased significantly by increasing water deficit. the highest values were achieved when adequate water was applied (1.0et) within fertilization treatment. chlorophylls a and b were significantly increased when nitrogen was highly used. the high values were obtained when chicken manure was used in combination with the recommended n and half-n doses (t7 and t6). these treatments were followed by rabbit manure in combination with both mineral n doses. results could be explained as the chicken and rabbit manures contain much more organic nitrogen. nitrogen was also reported by mardanov (1985) on squash and mitchell *et al*. (1991) on lettuce to increase chlorophyll content in plant leaves. for using half dose of n, significant difference was found in chlorophyll a between using chicken or rabbit manures. a significant difference was found in chlorophyll a among rabbit manure, farmyard manure, and mineral treatments. chlorophyll b insignificantly varied among all treatments except t5 against t6 and t6 against t7. Treatments shared in the same letter had no significant differences and vice versa in Table (5).

3.2.Leaf Area Index

Leaf area index (LAI) was insignificantly larger for 2007 growing season that had less radiation compared to 2006 planting (Table 6). LAI which was measured in full growth stage showed significant differences among irrigation treatments at 2.5% level for the same fertilization treatment. It was insignificant between 1.0ET and 0.84ET treatments and significant between was significant between 1.0ET and 0.84ET treatments and significant between 0.64ET and 0.64ET at 5% level within fertilization treatment. The highest leaf area indices were achieved when water was adequately applied (1.0ET treatment). Obtained results are in harmony eith those of Saleh and Ibrahim (2007) on cantaloupe plants .LAI showed also significant differences at 5% level for mineral and farm yard manure treatments (T1, T2, and T3) that achieved the lesser vegetative than the chicken manure with both nitrogen doses treatments (T6 and T7) within irrigation treatment. The half dose of nitrogen with farm yard manure (T2) achieved minimum value. Recommended dose of nitrogen with chicken manure achieved the maximum leaf area indices within irrigation treatment. LAI insignificantly varied among rabbit and chicken treatments. The highest LAI was achieved in mid-season in both growing season under interaction between T7 and 1.0ET treatment. Results could be explained that organic fertilizations especially chicken and rabbit manures achieved the high values

Table 5: Chlorophylls a and b of cucumber plants in 2006.

Fertilization treatment	Chlorophyll a (mg/100g F. Wt)				Chlorophyll b (mg/100g F. Wt)			
	1.0ET	0.84ET	0.64ET	Mean	1.0ET	0.84ET	0.64ET	Mean
T1	0.99	0.69	0.24	0.64 a	0.14	0.1	0.04	0.09 a
T2	0.98	0.68	0.23	0.63 a	0.13	0.09	0.03	0.08 b
T3	1.00	0.70	0.25	0.65 a	0.16	0.12	0.05	0.11 c
T4	1.07	0.79	0.33	0.69 b	0.22	0.16	0.11	0.16 d
T5	1.15	0.85	0.40	0.8 bc	0.24	0.18	0.14	0.19 e
T6	1.19	0.89	0.44	0.84 c	0.25	0.2	0.15	0.2 ef
T7	1.30	1.00	0.55	0.95 d	0.26	0.21	0.16	0.21 f
Mean	1.10 a	0.80 b	0.35 c		0.20 a	0.15 b	0.10 c	

Table (6): Cucumber leaf area index (LAI) in full coverage stage.

Fertilization treatment	Summer 2006				Summer 2007			
	1.0ET	0.84ET	0.64ET	Mean	1.0ET	0.84ET	0.64ET	Mean
T1	8.85	8.10	7.23	8.06 ab	9.12	8.52	7.50	8.38 ab
T2	8.43	7.95	7.05	7.81 a	8.76	8.40	7.35	8.17 a
T3	8.73	8.25	7.35	8.11 ab	9.06	8.55	7.65	8.42 ab
T4	9.21	8.70	7.80	8.6 abc	9.54	9.00	8.10	8.88 abc
T5	9.60	9.00	8.10	8.9 bc	9.90	9.30	8.40	9.20 bc
T6	9.75	9.15	8.25	9.05 c	10.05	9.45	8.55	9.35 c
T7	10.17	9.57	8.67	9.47 c	10.47	9.87	8.97	9.77 c
Mean	9.25 a	8.67ab	7.78 c	8.57	9.56 a	9.01ab	8.07 c	8.88

Table (7): Sex ratio (male/female flowers) of cucumber in 2006 and 2007 summer seasons.

Fertilization treatment	Summer 2006				Summer 2007			
	1.0ET	0.84ET	0.64ET	Mean	1.0ET	0.84ET	0.64ET	Mean
T1	3.50	3.90	4.50	4.20 a	4.52	5.10	6.07	5.59 a
T2	3.20	3.65	4.20	3.93 ab	4.10	4.75	5.70	5.23 ab
T3	3.20	3.60	4.25	3.93 ab	4.05	4.78	5.61	5.20 ab
T4	3.00	3.45	4.00	3.73 bc	3.90	4.50	5.50	5.00 bc
T5	2.90	3.25	3.82	3.54 cd	3.60	4.15	5.20	4.68 cd
T6	2.60	2.95	3.60	3.28 d	3.40	4.00	4.95	4.48 d
T7	2.55	2.90	3.55	3.23 d	3.40	3.85	4.80	4.33 d
Mean	3.07 a	3.47 b	4.06 c		3.95 a	4.57 b	5.54 c	

Table (8): Cucumber yield reduction coefficient, K_y, in two growing seasons.

Seasons	Fertilization treatments							
	T1	T2	T3	T4	T5	T6	T7	Average
2006	0.72	0.7	0.8	0.85	0.844	0.726	0.78	0.774
2007	0.75	0.71	0.86	0.83	0.82	0.727	0.73	0.775

of LAI due to increasing the capacity of soil to reserve water and containing a high amount of nitrogen which was essential element to cucumber vegetative growth. LAI was insignificantly higher in 2007 season than that obtained in 2006 planting at 5% level. But it at 1% level.

3.3.Sex Ratio

Sex ratio (male/female) was calculated in summer 2006 and 2007 seasons as shown in Table (7). Significant differences in sex ratios were found by increasing irrigation water deficit. The highest values of sex ratio were achieved when 64% from adequate water was applied (0.64ET) within fertilization treatment. Water deficit decreased sex ratio as it increased carbohydrates accumulation. The relation between carbohydrates and sex ratio was previously mentioned by Mardanov (1985). Sex ratio was significantly decreased when nitrogen was highly used within irrigation treatment. The lowest values were obtained by applying recommended dose of nitrogen mixed with chicken manure treatment (T7) followed by applying half nitrogen dose plus chicken manure (T6), then came rabbit manure in combination with studied mineral nitrogen doses within irrigation treatment. The less value of sex ratio meant an increase in female flowers and this appeared logic as nitrogen was frequently reported to positively affect female flowers in cucumbers. These results are in harmony with those of Abd El-Fattah and Sorial (2000) on squash and El-Dakish (2004) on cucumber. It is obvious that sex ratio was decreased with increasing the use of nitrogen. A significant difference occurred between mineral treatment (T1) against chicken and rabbit manure treatments (T4, T5, T6, and T7). There were insignificant differences among T5, T6, and T7. It is obvious from Table (7) that the treatments shared in the same letter had no significant differences and *vice versa*.

3.4.Crop coefficient

Cucumber crop coefficient (K_C) under trickle irrigation was determined as the ratio of actual (ET_c) to potential (ET_p) evapotranspiration for 1.0ET treatment with mineral fertilization (T1) as illustrated in Fig. (2) in both seasons. The average length of both growing seasons was almost 125 days. The seasonal amount of actual water use which applied in 26 irrigations was 498 and 471 mm in 2006 and 2007 plantings, respectively. K_C was almost initialed as 0.32 to 0.37 for 22 days when cucumber ground cover ranged from 1.5 to 8%, respectively, due to evaporation from soil partially wetted area by trickle irrigation and transpiration from a few leaves surfaces. By increase plant age, K_C showed rapid increases in early growth stages from almost 0.37 to 0.98 when ground cover reached 100% in 30 days. In full vegetative stage, K_C was fluctuated in between 0.98 to 1.15 for 50 days. K_C was insignificant higher in 2007 season because vegetative growth was larger compared to the 2006 planting. K_C decreased in maturity stage in 23 days from 0.98 to almost 0.65 and 0.6 at the end of both 2006 and 2007 seasons, respectively, because of senescing leaves in the beginning part of the canopy. It was lower during 2007 planting that had more senescing leaves than 2006 planting.

3.5.Crop response

Cucumber yield as affected by different types of fertilization in deficit irrigation is shown in Figs. (3) and (4) in 2006 and 2007 seasons, respectively. Cucumber maximum yields (Y_m) were averaged in both seasons for 1.0ET treatment as 30.26, 29.25, 32.30, 36.57, 37.16, 41.47, and 41.90 Mg/ha (ton/ha) for T1, T2, T3, T4, T5, T6, and T7, respectively. The yield was achieved 30.8 and 31.04 Mg/ha for 1.2ET with T1 treatment in 2006 and 2007, respectively. Cucumber yield was significantly decreased in linear relationship by increasing water deficit within fertilization treatment. But, it was insignificantly changed by excessive water applied more than 1.0ET. The bars in Figs. (3) and (4) clarify the error range using 5% percentage level. The high values of yield were achieved when water was adequately applied as in 1.0ET treatment. Similar results were obtained by Mao *et al.* (2003) on cucumber and Saleh and Ibrahim (2007) working on cantaloupe. On the other hand, cucumber yield was significantly increased using rabbit or chicken manures (T4, T5, T6, and T7) compared to mineral treatment (T1) within irrigation treatment. Yield was insignificantly achieved among T1, T2, and T3 (mineral and farmyard manure fertilizations). The highest values of yield were achieved using chicken manure and significantly increased compared to the

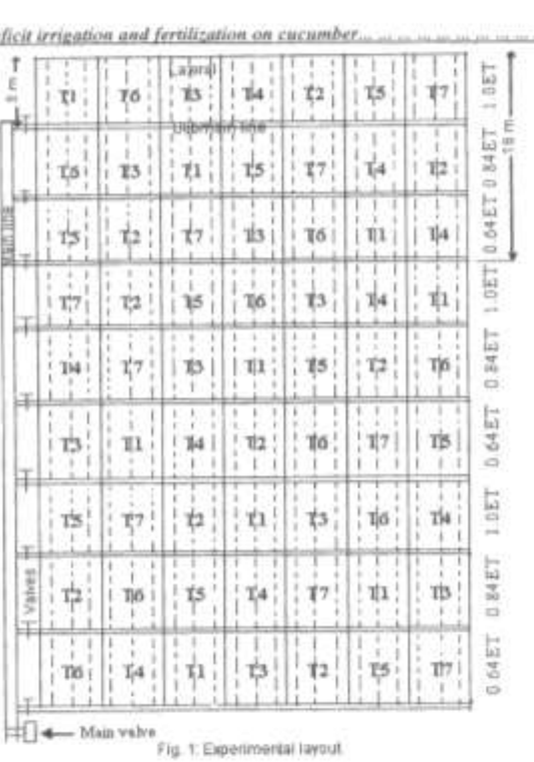

Fig. 1: Experimental layout

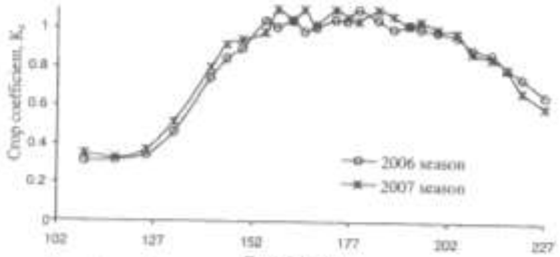

Fig. 2: Cucumber crop coefficient during 2006 and 2007 seasons.

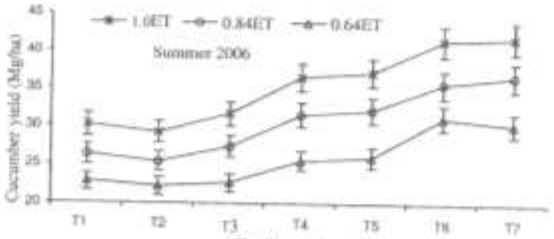

Fig. 3: Cucumber yield versus fertilization treatments at 5% level.

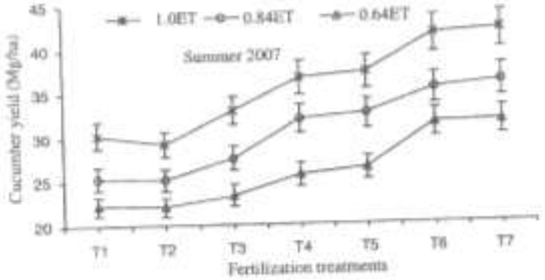

Fig. (4): Cucumber yield versus fertilization treatments at 5% level.

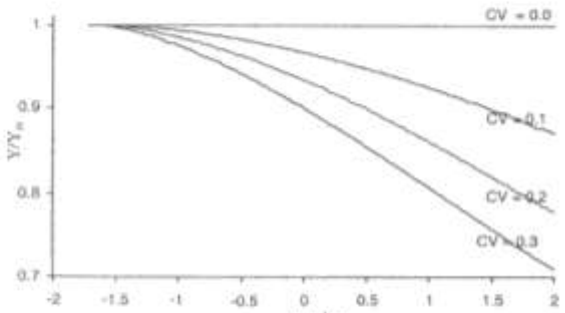

Fig. 5: Cucumber relative yield (Y/Ym) versus schedule parameter (α).

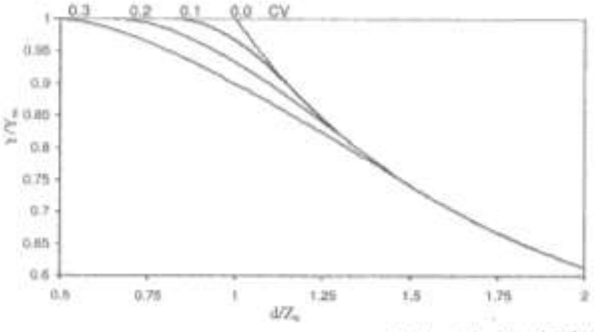

Fig.(6): Cucumber relative yield Y/Y_m versus relative irrigation depth (d/Z_n)

other fertilization treatments. The minimum value of cucumber yield was achieved using half dose of mineral with farmyard manure (T2) which had less nitrogen and slower N release from organic manure than other treatments. Results could be explained as a result of high organic nitrogen added from chicken and rabbit manures caused to achieve the high values of cucumber yield because nitrogen was an essential element to cucumber flowering and fruiting. Chicken manure was also applied by Ahmed (2004) to increase bulbs yield of onion. The organic particles that added into soil from chicken and rabbit manures increased the capacity of soil to reserve water whereof plants could obtain the adequate water so high yields were achieved. The organic rabbit and chicken manures were found by El-Dakish (2004) to positively affect female flowers and consequently fruit yield of cucumber.

Cucumber yield was slightly increased in 2007 season because vegetative growth is insignificantly higher compared to the 2006 planting. A fertilizer treatment (T6) resulted in a different pattern of yield increase with increasing amount of water to well-watered condition than other fertilizer treatments.

Yield reduction coefficient (K_y) in deficit irrigation within the fertilization treatment is given Table (8). Crop response to water was smoothly changed according to amount of water applied, but Crop yield response to nitrogen showed inconsistencies relationship due to varying nitrogen sources. Reduction coefficient was determined using Eq. 1. The yield for 1.0ET treatment was used within each fertilization treatment to express the maximum value (Y_m). The mean reduction coefficient was 0.7745 in deficit. It had no reduction in surplus irrigation.

3.6.Optimal Irrigation Scheduling

The cucumber relative yield was related to schedule parameter α for different uniformity CV values as shown in Fig. (5). Relative yield Y/Y_m in underirrigation situation (using Eq. 9) was determined when α-values were in between ±1.725. In complete deficit ($\alpha \geq 1.725$), Eq. 9 was reduced to Eq. 11 showing the relationship between relative yield and the schedule parameter α beyond underirrigation conditions. Based on study by Amer (2001) in Egypt when irrigation system's CV was less than 30%, complete overirrigation was desired because water cost was insignificantly important compared with return yield. Consequently, the optimal scheduling was derived from the maximization of yield. Figure (4) shows the optimal scheduling parameter α was reported as -1.275 for any system's CV. The results showed that overirrigation ($\alpha \geq -1.725$) did not reduce the yield. Maximum yield was achieved for all CV values as the water applied was excessively adequate. Therefore, the relative optimum scheduling depth which achieved maximum yield could be expressed as: (1-1.725CV). On the contrary, relative yield was reduced when water applied was shortly insufficient. It was evident that the yield was significantly affected by both α and CV in underirrigation and complete deficit situations.

Figure (6) shows the relationship between cucumber relative yield (Y/Y_m) and relative depth ($d/Z_a = 1+\alpha$ CV) for different uniformity CV values. The curves started at the end of overirrigation stage when storage efficiency achieved 100% when α was -1.725. Optimum relative irrigation depths (d/Z_a) that achieved maximum yield were 1.0, 0.828, 0.655, and 0.483 for the CV values as 0.0, 0.1, 0.2, and 0.3, respectively. Then, application efficiency was recorded as 100, 82.8, 65.5, and 48.3%, respectively. The curves were diverged in underirrigation situations and concluded that the yield was significantly affected by both d/Z_a and CV. Hence, application efficiency was increased and storage efficiency decreased by increasing water deficit and *vice versa*. Relative irrigation depth values at the start of complete deficit (when application efficiency achieved 100%) were recorded as 1.0, 1.173, 1.345, and 1.518 for the CV values as 0.0, 0.1, 0.2, and 0.3, respectively. Consequently, storage efficiency was calculated as 100, 85.3, 74.3, and 65.9%, respectively. The curves were coincided in complete deficit irrigation meaning that the uniformity was insignificant when too little amount of water was applied. In case of CV = 0.3, the significant of uniformity was only in a range of d/Z_a between 0.483 and 1.518 and beyond that range it was insignificant at all for the relative yield. Results concluded that the optimum irrigation scheduling depth under different irrigation system uniformities could be taken as a ratio from adequate water treatment (1.0ET). In condition of water cost was insignificant important compared with return yield and the yield was affected only by deficit irrigation, the ratios (Z_a/d) could be determined by either dividing 1.0ET by (1-1.725CV) or 100%ET by application efficiency and resulted in 1.0, 1.21, 1.53, 2.07 ET at system's uniformity CV as 0.0, 0.1, 0.2, and 0.3, respectively. Consequently, the whole area is completely overirrigated when schedule depth (d) equal minimum applied depth (Z_{min}). Obtained conclusion was easier by the presented statistical model and was in agreement with those of Wu and Gitlin (1983) and Wu and Barragan (2000) using mathematical model and many others working on the same field.

Conclusions

Cucumber as grown in optimal weather and soil conditions needs both water and mineral deposits. Irrigation system is an essential parameter to apply water. Water should be optimized to crop use. Organic fertilizations have been used to save most minerals. On the other hand, chemicals are simply used to be the dominant these days without keeping the environment clean and obtaining the high quality of crop yield. Therefore, growers turned partially to substitute organic fertilizations rather than chemicals. This study was focused on cucumber performance as affected by both water and nitrogen deficiencies. The following results were obtained:

1- Maximum chlorophylls a and b and leaf area indices were achieved when water was adequately applied (1.0ET) and nitrogen fertilization was highly used (T7).

2- The seasonal cucumber water use was 498 and 471 mm using 1.0ET with T1 treatment in 125 days for 2006 and 2007 plantings, respectively.

3- The lowest value of sex ratio occurred for 1.0ET with T7 treatment.

4- Crop coefficient was seasonally averaged as 0.83 and developed in four stages initialed in 22 days, stated for early growth in 30 days, staged in full growth in 50 days, and matured in 23 days.

5- Maximum yield was achieved by adequate water applied within fertilization treatment and high nitrogen used within irrigation treatment.

6- The yield reduction coefficient averaged as 0.7745 in deficit irrigation.

7- Optimal irrigation scheduling was found as ratios from crop ET in case of yield was only changed by deficit irrigation. As a result, complete irrigation could be applied in known interval.

In case of optimum management, the treatment with 238.8 kg/ha ammonia nitrate, 715 kg/ha super phosphate and 240kg/ha potassium sulfate added with 7 ton/ha chicken manure under adequate water applied was recommended to achieve optimum vegetative growth and yield.

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تأثير الرى التناقصى والتسميد على الخيار

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ملخص

يتأثر النمو الخضرى والمحصولى وبعض الصفات الأخرى للخيار بتغير كمية مياه الرى والنتروجين سواء كان من مصدر كيمائى أو عضوى تحت نظام رى المحاصيل الزراعية ، فيجب ضبط كميات المياه لكل نظام رى متبع وتوفير العناصر الأساسية الكافية للنمو والإنتاج ، فمنذ زمن طويل كان التسميد العضوى هو المستخدم لتوفير معظم العناصر للنبات ولكن فى السنوات الحديثة كانت الأسمدة الكيميائية هى الأكثر استخداماً لسهولة إضافتها دون الحفاظ على البيئة نظيفة والحصول على منتج عالى الجودة ، لهذا السبب لجأ كثير من المزارعين إلى استخدام التسميد العضوى حتى ولو جزئياً.

فى هذا البحث تم دراسة ثلاث معاملات لنقص مياه الرى مع سبع معاملات لأنواع مختلفة من التسميد بمزرعة كلية الزراعة جامعة المنوفية بمنطقة شبين الكوم خلال الموسم الصيفي لعامي 2006 ، 2007 بتربة طينية طميية كثافتها 1.28جم/سم^3 وهى الرى بالنسب 100 ، 84 ، 64٪ من بخر نتح النبات الكلى باستخدام الرى بالتنقيط ،

وكانت معاملات التسميد هى:- T1 المعدل الموصى به من نترات الأمونيوم (477.6كجم/هكتار) ، T2 سماد الإسطبل (17طن/هكتار) مع نصف المعدل الموصى به من نترات الأمونيوم ، T3 سماد الإسطبل مع المعدل الموصى به من نترات الأمونيوم ، T4 سماد مخلفات الأرانب (7طن/هكتار) مع نصف المعدل الموصى به من نترات الأمونيوم ، T5 سماد مخلفات الأرانب مع المعدل الموصى به من نترات الأمونيوم ، T6 سماد مخلفات الدواجن (7طن/هكتار) مع نصف المعدل الموصى به من نترات الأمونيوم ، T7 سماد مخلفات الدواجن مع المعدل الموصى به من نترات الأمونيوم ، أظهرت الدراسة التالى:

1- كمية الاستهلاك المائى الفعلى للخيار هو 498 ، 471 مم لطول موسم زراعة 125 يوماً خلال صيفى 2006 و 2007 على التوالى.

2- القيم العظمى للكلوروفيل a والكلوروفيل b ودليل المساحة الورقى LAI للخيار تم الحصول عليها بإضافة المياه الكافية (100٪ بخرنتح) ومعاملة التسميد التى بها مخلفات الدواجن بسبب ارتفاع نسبة النتروجين بها وهى T7 ، T6 تلتها معاملة التسميد التى بها مخلفات الأرانب.

3- القيم الدنيا للنسب الجنسية للخيار (أزهار مذكرة /أزهار مؤنثة) التى تم الحصول علبها كانت بإضافة المياه الكافية (100٪ بخرنتح) ومعاملة التسميد التى بها مخلفات الدواجن بسبب ارتفاع نسبة النتروجين بها وهى T7 ، T6 تلتها معاملة التسميد التى بها مخلفات الأرانب.

4- حقق معامل المحصول خلال الموسمين غالباً قيمة متوسطة هى 0.83 حيث بدى شبه ثابت لمدة 22 يوماً حول الرقم 0.35 فى مرحلة بداية النمو ، ازداد من 0.37 إلى 0.98 لمدة 30 يوماً فى مرحلة النمو الخضرى المبكر ، تراوح من 0.98 إلى 1.15 لمدة 50 يوماً فى مرحلة النمو الخضرى الكامل ، ثم تناقص إلى 0.62 لمدة 23 يوماً فى مرحلة النضج.

5- حققت معاملة الرى 100٪ من بخرنتح النبات مع معاملة التسميد التى بها مخلفات الدواجن قيماً عظمى فى إنتاجية الخيار بمقدار 41.867 طن/هكتار للمعاملة T7 ، 41.429 طن/هكتار للمعاملة T6 فى موسم 2006 وكانت بمقدار 41.948 ، 41.505 طن/هكتار لعام 2007 على التوالى ، حيث أظهرت النتائج عدم وجود فروق معنوية بين المعاملة T6 ، T7 .

6- كان متوسط معامل نقص المحصول نتيجة نقص مياه الرى هو 0.775 داخل معاملة التسميد الواحدة.

7- تم تقديم نموذج إحصائى لتوضيح كيفية جدولة الرى المثلى تحت نظام الرى مع اختلاف انتظامية توزيعه لمياه الرى ، حيث أثبت هذا النموذج أن أفضل جدولة هى قسمة معدل بخر النبات الفعلى 1.0ET على كفاءة الرى Application efficiency لتكون كفاءة تخزين المياه 100٪ بشرط ان تتم الجدولة على أساس أن المحصول يتأثر فقط بنقص المياه ولا يتأثر بزيادتها إلى حد ما وأن تكلفة المياه تقل عن العائد من المحصول.

عموماً يمكن التوصية بأن الرى الأمثل مع التسميد بإضافة مخلفات الدواجن (7 طن/هكتار) ونصف الجرعة الموصى بها من نترات الأمونيا (238.8 كجم/هكتار) بالإضافة إلى إضافة 715 كجم/هكتار من السوبر فوسفات ، 240كجم/هكتار من سلفات البوتاسيوم ستحقق إنتاجية عالية ونمو خضرى كامل لمحصول الخيار.

المجلة العلمية لكلية الزراعة – جامعة القاهرة – المجلد (59) العدد الأول (يناير 2008):57-70.