EFFECT OF WATER DEFICIT ON SNAP BEAN YIELD AND WATER USE EFFICIENCY UNDER DRIP IRRIGATION SYSTEM

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ABSTRACT

Field experiment was carried out at the Research Farm of Faculty of Agriculture, Suez Canal University, Ismailia, Egypt, during the summer 2016 growing season in a sandy soil with snap bean (*Phaseolus vulgaris L.*) *under drip irrigation system. The main goal of the present work was to study effect of different emitters and water deficit (*T_1*: 100 %,* T_2*: 75 % and* T_3*: 50 % of* evapotranspiration *(ETc)) on snap bean* yield and water use efficiency (*WUE*). *Two different emitters manufactured (in-line '*Em_1*' and on-line '*Em_2*') were evaluated with lateral length 50 m at different operating pressures of 50, 100, 150 and 200 kPa.* The obtained results *indicated that, the coefficient of uniformity (CU) increased with increasing operating pressure from 50 to 100 kPa and decreased with increasing operating pressure from 100 to 200 kPa. The first treatment produced high yield without significant differences of the second treatment, so, concerning the different irrigation regimes the 75 % ETc treatment gave a remarkable yield and pronounced water saving equal 25 % from applied water of* T_1 *therefore it is technically and economically recommended and the best one for saving water. Water use efficiency was the highest in 50 % ETc, but 75 % ETc was the best one economically. Yield was the greatest when fresh and adequate irrigation was applied. Snap bean yield was significantly affected in a linear relationship (*$r^2 \geq 0.90$*) by deficit irrigation conditions.*

Keywords: *Drip irrigation, Yield, Water use efficiency, Snap Bean.*

1. INTRODUCTION

Water is fast become an economically scarce resource in many areas of the world and consider as a limiting factor in any agricultural expansion depending on its quantity, quality and methods of application. In Egypt, land has been classified as arid region. Most of the Egyptian soils, out of the Nile Delta and valley, represents about 96 % of the whole area, (sandy soil).

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There are three major groups of irrigation systems: surface, sprinkler and drip (micro-irrigation). Under sandy soil condition, drip irrigation is the artificial application of water to agriculture lands in order to insure adequate for crop growth. Also, it is considered as highly efficient system because it allows small but frequent application of water with minimum losses (**Locascio, 2005**).

Irrigation management is a tool whereby timely application of water can improve irrigation efficiencies and ultimately yields (**Baille, 1997**). To improve water use efficiency (*WUE*), integrative measures should aim to optimize cultivar selection and agronomic practices. The relationships between crop yield and water use has been a major focus of agricultural research in arid and semi-arid regions and have been reviewed previously (**Howell *et al.*, 1998**). Also water-yield relationship has been investigated using different methods of limited water applications and programs (**Pandey *et al.*, 2000**).

Uniformity is an important parameter in the design and evaluating of microirrigation systems (**Li *et al.*, 2012**). In Egypt, the new reclaimed areas must be use modern irrigation systems; since the traditional surface irrigation has low water use efficiency (**Ragab and Prudhomme, 2002**). Most of the Egyptian farmers who are living in the new reclaimed areas are small holder and facing poverty.

Snap beans (*Phaseolus vulgaris L*.) is one of the most important vegetable crops grown in Egypt for local market and exportation, which is rich in protein, carbohydrates, calcium (Ca), vitamins and amino acids. The major constituents are carbohydrates (39.7 %), protein (28.9 %), fiber (22 %), fat (0.88 %), Ca (1.8 %) and phosphorus (P) (0.13 %). It is also among the most important fresh vegetables exported from developing countries and several African countries have focused on exporting snap beans to high value European markets (**Ghonimy *et al.*, 2009**). So, the total cultivated area for green bean in Egypt was 46048 feddan (19347.8 hectare) in year 2000, with average of 4.3 ton/feddan, total production of 200,021 ton and the exporting crop of green bean to European markets during the summer season increased to 23000 ton in year 2000.

Considering all other factors of production at their optimum level, crop response is defined as a crop yield decreased constantly by decreasing quantity of water applied into the root zone in deficit irrigation (**Richard *et al*., 2002 and Amer, 2010**); nevertheless, crop yield is decreased constantly by increasing quantity of water applied in surplus irrigation. The relationship between crop yield and irrigation quantity can be found from irrigation experiments in which a large range of irrigation application is conducted.

Ahmet *et al.* (2004) using furrow irrigation on squash found that fruit yield significantly increased in linear relationship from 22.4 to 44.7 Mg ha^{-1} as irrigation water applied increased from 279 to 475 mm in deficit irrigation where no deep percolation occurred.

Al-Omran *et al.* (2005) studied squash using both surface (*DI*) and subsurface drip irrigation (*SDI*) methods in sandy soils with three clay deposits found that fruit yield has a linear relationship to increased irrigation water level for each season within the same treatment. They found that fruit yields significantly increased with clay deposits compared with control. The differences between *SDI* and *DI* on fruit yields were also significant. Water use efficiency linearly increased as irrigation water applied increased for deficit irrigation level and decreased for excessive irrigation level.

Amer (2005) found that maximum potato yield (Y_m) of 23.6 and 24.45 Mg ha^{-1} was achieved for 325 and 402 mm of optimum water use (W_m) in winter and spring seasons, respectively. A yield reduction ($1-Y/Y_m$) was linearly decreased in a rate of 0.741 by increasing water deficit fraction ($1-W/W_m$) in complete deficit irrigation in range of 0.6 *ET* to 1.0 *ET*. It was constantly decreased in a rate of 0.29 by increasing deep seepage fraction in complete surplus irrigation in range of 1.0 *ET* to 1.4 *ET*. **Amer (2010)** working with furrow irrigated corn (Zea Mays) found that maximum yield (Y_m) of 9.12 Mg ha^{-1} was achieved by 325 mm adequate irrigation quantity (d). A yield reduction ($1-Y/Y_m$) was linearly decreased in a rate of 1.15 by increasing water deficit fraction ($1-\mu /d$) in complete deficit irrigation in range of 0.6 - 1.0 ET_c, where *Y* is the corresponding yield achieved by irrigation quantity. He found that the crop yield was linearly decreased in surplus areas by increasing irrigation water quantity ranged from 1.0 to 1.4 *ETc* in a rate of 0.32. Furthermore, an optimal irrigation scheduling is statistically developed based on crop response to extrapolate data from the small experiment (uniform condition) to large field (non-uniform condition) under the experiment constraints.

Enciso *et al*. (2007) working on onion (*Allium cepa*) during 2006 - 2007 fall-spring growing season with subsurface drip irrigation found that onion yield was 36.4, 39.2, 42.5 Mgha^{-1} for 313, 353, and 393 mm water use (water applied plus 133 mm rainfall) using ET-based irrigation scheduling approach, respectively. They were 43.6, 42.2, and 34.4 Mgha^{-1} for 413, 363, and 323 mm water use using direct soil moisture monitoring based approach.

The objective of this research work was the studying the effect of different emitters and quantities of irrigation water in sandy soil on snap bean yield and water use efficiency under drip irrigation system.

2. MATERIALS AND METHODS

Experimental setup

Field experiment was carried out in sandy soil, at the Research Farm of Faculty of Agriculture, Suez Canal University, Ismailia, Egypt (latitude angle of 30° 58′ N, Longitude angle of 32° 23′ E, and elevation above sea level of 13 m), Egypt, during the summer season of 2016. The setup of field experiment consists of water source from Ismailia canal (branched from Nile River), pump unit of the farm, main line with inside diameter (*ID*) of ٧٠.6 mm, submain line having 59.2 mm inside diameter, manifold lines with 44.6 mm branched from the submain, control valves, flow meter, pressure gauge (0 - 250 kPa) with scale accuracy of 10 kPa distributed through the submain unit to control the flow and pressure. Lateral lines made from polyethylene (*PE*) with internal diameter (*ID*) of 13.6 mm were connected with manifold line. Three irrigation treatments (irrigation with 100%, 75% and 50% of required water were considered as the main plots and Two different emitters were considered as sub-plots. Each sub-plot consisted of three rows each 50 meters long; rows separated from each other by 1٠0 cm and plants spaced 50 cm apart in the rows. Small earth bunds and a two-meter distance between main-plots were provided to prevent water running from one main-plot to another.

Two emitters from the local market were tested at different operating pressures of 50, 100, 150 and 200 kPa with lateral length of 50 m. The tested emitters were divided into in-line manufactured (Em_1) and on-line manufactured (Em_2), emitter type with discharge 4.0 ℓ/h. The internal distance between lateral line was 100 cm and 50 cm between emitters. Irrigation water was applied at three rates based on (T_1: 100 %, T_2: 75 % and T_3: 50 %) from the crop evapotranspiration (ET_c) which calculated using CROPWAT software version 8.0 based on Penman-Monteith equation which recommended by FAO **(Allen *et al.*, 2011)**.

Snap bean variety (*Phaseolus vulgaris L.*) was planted on 20th february to 20th may 2016, the growing season lasted 90 days and chemical fertilizers were applied as following: super phosphate at rate of 150 kg/fed, ammonium sulphate at rate of 300 kg/fed and potassium sulphate at rate of 100 kg/fed. The experiment was conducted using randomized block design (**Little and Hills, 1975**).

Soil and water analysis are shown in Tables (1, 2 and 3), soil properties were determined according to **Black (1969**). Soil mechanical analysis was carried out using the international pipette method according to **Jacobs *et al.* (1971)**. The dry bulk density of soil was determined using undisturbed soil cores according to **Klute (1986)**. The analysis showed that at this depth the soil is considered to be homogeneous layer. The water content at field capacity (*FC*), was measured by the method described by **Tan (2005).** Permanent wilting point was estimated by ROSETTA software (**Shaap *et al.*, 2001**). Available water (*AW*) was calculated based on **Allen *et al.* (1998).**

Table (1). Physical characteristics of the experimental soil.

Soil depth (cm)	Particle size distribution %			Texture Class	*DBD* (g/cm^3)	*FC* (%)	*PWP* (%)	*AW* (%)
	Sand	Silt	Clay					
0-15	95.47	2.5	2.03	Sand	1.63	8.6	1.8	6.8
15-30	98.67	0.3	1.03	Sand	1.67	8.6	1.8	6.8
30-45	98.60	0.43	0.97	Sand	1.64	8.6	2.0	6.6
45-60	98.55	0.93	0.52	Sand	1.68	8.6	1.8	6.8

FC: Field capacity (- 0.1 atm), *PWP*: Permanent wilting point (- 15 atm),
AW: Available water, *DBD*: Dry bulk density.

Electrical conductivity (*EC*), soil reaction (*PH*) and soluble cations and anions (extract 1: 5) were determined according to **Page (1982).**

Total calcium carbonate was determined volumetrically according to **Page (1982)**. Sodium and potassium were determined photometrically by using flame photometer (*JENWAYPEP7*) according to (**Richard, 1954**).

Table (2): Chemical characteristics of the experimental soil.

C.E.C Mo/kg	PH 1:5	EC (dS/m) At $25^{o}c$	Soluble cations (meq / l)				Soluble anions (meq / l)			
			Ca^{++}	Mq^{++}	Na^{+}	K^{+}	CO^{-}	HCO^{-}	Cl^{-}	SO^{--}
9.3	8.0	0.22	1.8	0.8	3.10	0.4	-	2.1	2.0	2.0

Electrical conductivity (*EC*), Water reaction (*pH*), soluble cations and anions were determined according to **Page (1982)** as shown in Table (3).

Table (3): Chemical characteristics of irrigation water.

SAR	PH 1:5	EC (dS/m) At $25^{o}c$	Soluble cations (meq / l)				Soluble anions (meq / l)			
			Ca^{++}	Mq^{++}	Na^{+}	K^{+}	CO^{-}	HCO^{-}	Cl^{-}	SO^{--}
2.66	8.1	0.48	1.48	0.79	2.82	0.25	-	2.91	0.52	1.91

The coefficient of uniformity (*CU*) is a better way of expressing the variation in discharge along lateral lines, it was classified as below 60 %, from 60 to 70 %, 70 to from 80 %, from 80 to 90 %; above 90 % is referred to as low, poor, fair, good; excellent uniformity, respectively, and calculated using the following equation **(Christiansen, 1942 and ASAE EP 458.0, 1999)**:

$$CU = 100\left(1 - \frac{\sum_{i=1}^{i=n}\left|q_i - \bar{q}\right|}{n\,\bar{q}}\right)$$

where, $\sum_{i=1}^{i=n}\left|q_i - \bar{q}\right|$ is the summation of absolute values of deviation from the means of emitter discharge, q_i is the individual discharge of each emitter (ℓ/h), $\bar{q}$ is the mean of emitter discharge (ℓ/h) and n is the number of collectors measured.

Irrigation water requirements of snap bean through the growing season were calculated based on the determination of crop evapotranspiration (*ETc*) by the following equations:

$$ET_c = ET_o . k_c$$

$$IWR = ET_c .\ A .\ F$$

where, ET_o is the reference evapotranspiration (mm/day), ET_C is the crop evapotranspiration (mm/day), k_c is the crop coefficients were obtained from FAO No. 56 blication's tables (**Allen *et al.*, 1998**) for stages of snap bean, *IWR* is amounts of applied irrigation water (ℓ/Irri.), *A* is the plant area (m^2) and *F* is the irrigation frequency.

The water application time was calculated as in the following equation **(Merriam and Keller, 1978)**:

$$I_t = \frac{IWR}{q}$$

Where, I_t is water application time (h) and *q* is the emitter discharge (ℓ/h). Three regimes (treatments) of irrigation water were applied based on the recommended crop water requirement (500 mm for snap bean) according to FAO, **Doorenbos and Kassam (1986)** as percentages T_1: 100 % ET_c (500 mm), T_2: 75 % ET_c (375 mm) and T_3: 50 % ET_c (250 mm).

These amounts were scheduled throughout the growth season and the amounts of water that were added every irrigation and calculated according to the values of the recommended crop coefficient (k_c) as well as the period of each stage, **Doorenbos and Kassam (1986)**. The amounts of irrigation water were added every three days. (Table 4)

Table (4): Water applied rates throughout the growing season of snap bean in the three irrigation treatments.

Duration	Growth stage	Length of growth stages (day)	K_C	Irrigation treatments (mm/day)		
				(T_1) 100 % Et_C	(T_2) 75 % ET_C	(T_3) 50 % ET_C
20/2-12/3	Initial	20	0.50	2.82	2.11	1.41
13/3-11/4	*Develop.	30	0.75	5.28	3.96	2.64
12/4-11/5	Mid	30	1.05	7.39	5.54	3.69
12/5-20/5	Late	10	0.90	6.66	4.99	3.33

*Development stage of snap bean

Determination of Water Use Efficiency

The total fresh pod weight (marketable and unmarketable yield) of the crop in each treatment was used to determine the water use efficiency

(*WUE*), the *WUE* was calculated according to **James (1988**) and **Bilalis *et al.* (2009)**.

$$WUE = \frac{Total\ weight\ of\ \ fresh\ pod}{Total\ water\ applied}$$

where, *WUE* is the water use efficience (kg/m^3), total weight of fresh pod yield (kg/fed) and the total water applied (m^3/fed).

Crop response to water application

Crop response between yield and water use under deficit irrigation was determined by a linear model (**Doorenbos and Kassam, 19٨٦; Wu and Barragan, 2000).** The linear response 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 over irrigation. The crop response to deficit irrigation was expressed when water was uniformly applied as follows:

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

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 yield reduction coefficient which is considered as a constant for a crop in deficit irrigation.

3. RESULTS AND DISCUSSION

Discharge Uniformity

The coefficient of uniformity *(CU)* and the manufacturer's coefficient of variation (C_v) as show in Table (5). The results indicated that the C_v value classification of Em_1 emitter was excellent, due to emitter the higher quality of these emitter than Em_2 emitter. Meanwhile, Em_2 was classified as marginal, maybe due to the lowest initial price. The coefficient of uniformity (*CU*) increased with increasing operating pressure from 50 to 100 kPa and decreased with increasing operating pressure from 100 to 200 kPa as shown in Figure (1).

Table (5): The coefficient of uniformity and manufacturing coefficient of variation (C_v) for emitters.

Emitter	Coefficient of uniformity (CU, %) operating pressure (kPa)				"C_v"	
	50	100	150	200	Value	Classi.*
Em_1	94.35	96.78	93.62	90.82	0.02	Excellent
Em_2	75.31	84.01	79.81	75.25	0.10	Marginal

*Classification of the emitter manufacturing coefficient of variation.

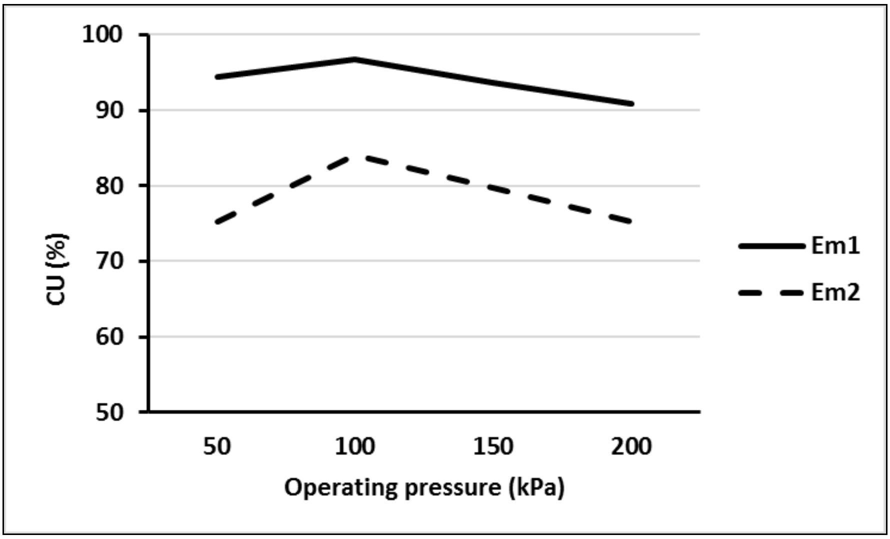

Figure (1): The relationship between operating pressure and coefficient of uniformity.

Yield and water application rate:

The effect of water application rate on snap bean yield under the drip irrigation system during the growing season was shown in Figures (2 and 3). It is evident that the maximum yield of snap bean is obtained in the treatment of T_1 for Em_1 emitter, while the lower yield is recorded in T_3 for Em_2 emitter due to the Em_1 high coefficient of uniformity (CU). Generally, high yield was achieved may be due to high soil fertility (reclaimed sandy soil) caused by addition of the organic and inorganic fertilizers. The variation between the three water treatments is due to the distinctness of applied water quantities. Yield of the first and second treatments did not expose to soil water stress because of the irrigation water quantity, which was applied for irrigating the snap bean which covered its water requirements.

Figures (2 and 3) shows that the depths of water application in T_1 is (2088.10 m^3/Fed), (1565.23 m^3/Fed) for T_2 and (1038.9 m^3/Fed) for T_3, while the average yields are (4400.26 & 4000.81 kg/Fed), (4098.26 & 3710.30 kg/Fed) and (2964.39 &2610.12 kg/Fed) of Em_1 and Em_2 emitter for T_1, T_2 and T_3, respectively. The yield increments may be attributed to the increase of leaves number per plant in (T_1 and T_2) which developed photosynthesis process. This leads to improve fruit number per plant in these treatments. On contrary, lower yield under T_3 may be due to the small fruits of plant did not complete their life cycle. Also, snap bean plant is classified drought sensitive crops, and so plants suffer from water stress. This finding is in agreement with **Raj Kumar and Kamia (1985).** There is no difference between yield of T_1 and T_2, while there are significant differences between T3 and T_1 and T_2. Results indicated, in general, that, T_2 saved about 522.874 m^3/fed which equal 25 % from applied water of T_1. So, T_2 is the best water treatment in water saving and good yield since there is no any significant difference with T_1 especially when yield was considered.

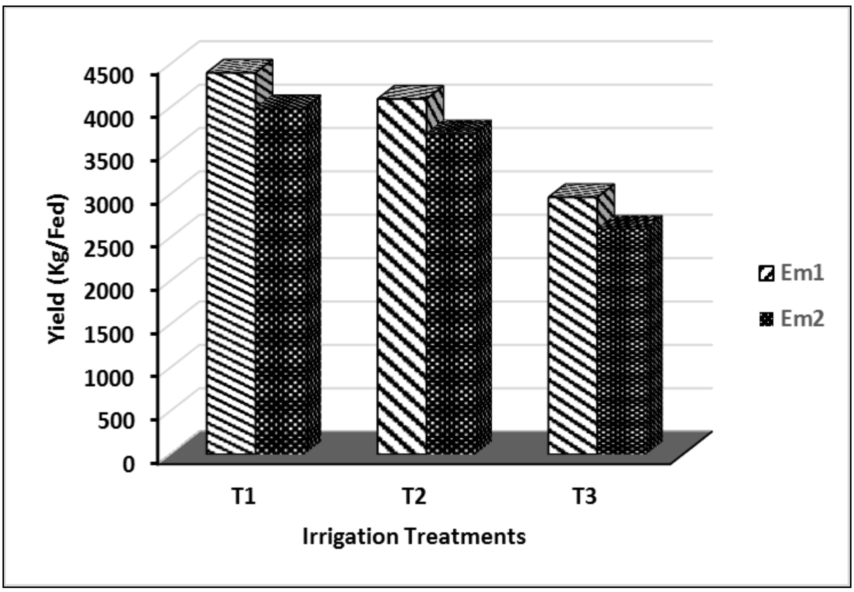

Figure (2): Effect of water application rate on snap bean yield.

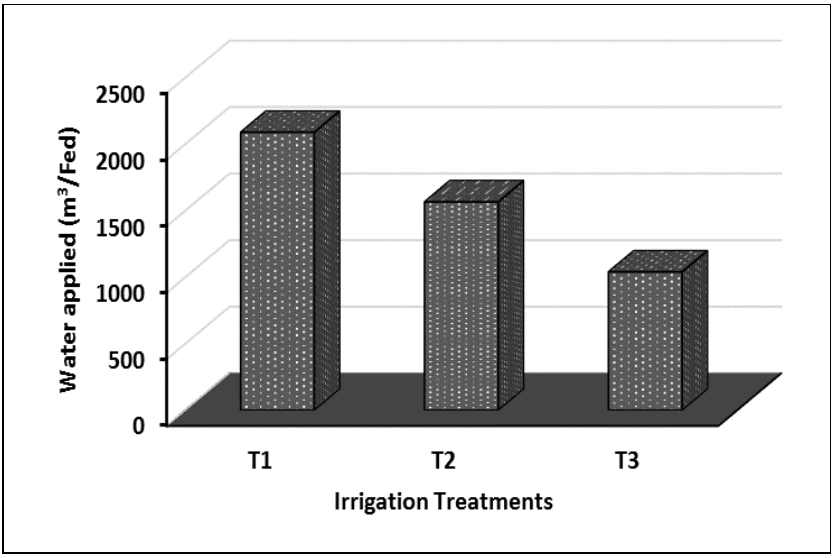

Figure (3): Water application rate by the three irrigation treatments.

Water use efficiency (*WUE*)

The uniformity plays an important role in water use efficiency (*WUE*). Water use efficiency is the ratio between crop yield and total amount of water, and expresses as kg of yield per m^3 of used water. Data illustrated by (Figure 4) clarified the effect of water application rate on water use efficiency. The efficient use of applied water was graphically illustrated by Figure (4). The output of water use efficiency for irrigating Snap Bean plant under drip irrigation system three water treatments was calculated using *WUE* formula. This formula often uses to know the importance of plant yield relative to irrigation water in a certain area. *WUE* was 2.107, 2.618 and 2.853 kg/m^3 of Em_1 and 1.916, 2.37 and 2.512 kg/m^3 of Em_2 for T_1, T_2 and T_3 treatments, respectively. In general, it could be noticed that the yield decreases with decreasing the water application rate. It is clear from the obtained results that the highest value of *WUE* was achieved at Em_1 emitter, which could be recommended for drip irrigated Snap Bean in sandy soil. The high yield is induced at T_1 for Em_1 emitter. The values of water use efficiency (*WUE*) are decreased with increasing the amount of irrigation water added, except under the treatment of T_3 due to the lowest obtained yield in this treatment. These results are in agreement with **Lin *et al.* (1983)** who reported that, the values of *WUE* were increased with decreasing the amount of irrigation water added.

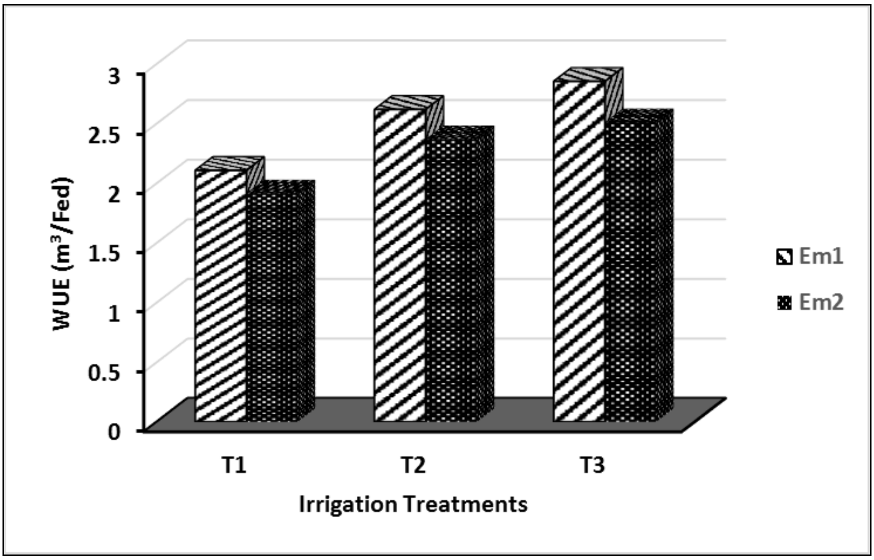

Figure (4): Effect of water application rate on water use efficiency.

The highest *WUE* value was recorded with T_3 followed by T_2 and then T_1 treatment. Snap bean yield for T_3 represents 67 % from yield of T_1, whenever yield of T_2 was 93 % from yield of T_1. This increment in yield (93 - 67 = 26 %) between T_2 and T_3 was due to increasing irrigation water with 25 % from used water in T_1, so yield of T_2 represents the economic yield because of increasing water 25 % gives also the same ratio from yield approximately (26 %). So, T_2 is considered the best treatment between the three treatments under study. T_3 is considered the best treatment under rainy areas because of rarely water (irrigation water shortage). Generally, *WUE* for snap bean yield decreases with increasing irrigation water applied.

<u>Snap bean response</u>

Snap bean was affected by irrigation regime with used both two emitters Em_1 and Em_2 (Figure 5). Maximum yields (Y_m) for 100 % ET_c were 4.4 and 4.0 Mg/fed for Em_1 and Em_2 respectively. Yield for T_2 (75 % ET_c) was 4.09 and 3.71 Mg/fed and minimum yield obtained by T_3 (50 % ET_c) was 2.96 and 2.61 Mg/fed for Em_1 and Em_2, respectively. A no significant difference was found between snap bean yield obtained by both T_1 and T_2 treatments with Em_1 and Em_2. Snap bean yield significantly decreased in linear relationship with increasing water deficit. However, it was not significantly changed by water applied above 75% ETc. the highest yields were achieved with the 100%ETc treatment, similar results were obtained by **Mao *et al.* (2003)** on cucumber and **Saleh and Ibrahim (2007)** on cantaloupe.

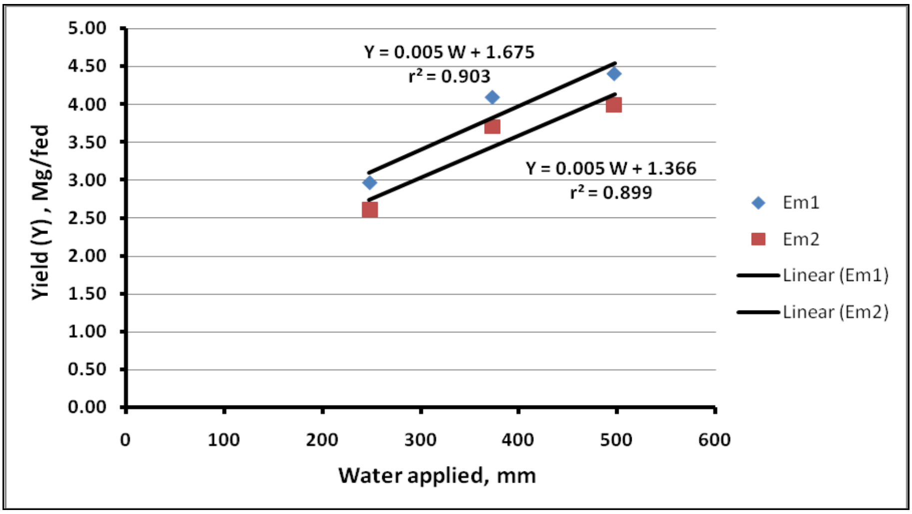

Figure (5): Snap bean yield versus water applied under different irrigation levels.

The results showed that snap bean yield increased linearly with increasing irrigation water application up to 497.2 mm where maximum yield was 4.4 Mg/fed. When water applied was reduced to 372.7 mm, the yield decreased to 4.09 Mg/fed. Therefore, the yield reduction coefficient was recorded as 0.28, and found that water irrigation greater than 497.2 mm resulted in no significant increase in yield.

The result founded that a linear relationship for whole growth period as

$Y = 0.005\ W + 1.675$ with $r^2 = 0.903$ for Em_1;

$Y = 0.005\ W + 1.366$ with $r^2 = 0.899$ for Em_2, where, Y is in Mg/fed and W is in mm. the snap bean maximum yield was 4.4 and 4.0 Mg/fed for 497.2 mm optimum water use with Em_1 and Em_2 respectively. The yield reduction coefficient (K_y) was determined as 0.28 and 0.32 for Em_1 and

Em_2, respectively by applying deficit irrigation T_2 (75 % treatments), on the other hand when applying T_3 (50 %) the yield reduction coefficient (K_y) was determined as 0.66 and 0.70 for Em_1 and Em_2, respectively, so T_2 recommended for saving water with minimum yield reduction coefficient.

Expressing yield and application of water or *ET* in relative terms by dividing yield (Y_a) by maximum yield (Y_m) and Eta by ET_m and subtracting from results in a relative deficit water production function:

The yield reduction coefficients Ky_1 and Ky_2 were, respectively, considered as k_1 and k_2 in deficit irrigation conditions as:

$$\left(1-\frac{Y_a}{Y_m}\right)=0.28\left(1-\frac{ET_a}{ET_m}\right)$$ For T_2 with Em_1

$$\left(1-\frac{Y_a}{Y_m}\right)=0.32\left(1-\frac{ET_a}{ET_m}\right)$$ For T_2 with Em_2

$$\left(1-\frac{Y_a}{Y_m}\right)=0.66\left(1-\frac{ET_a}{ET_m}\right)$$ For T_3 with Em_1

$$\left(1-\frac{Y_a}{Y_m}\right)=0.70\left(1-\frac{ET_a}{ET_m}\right)$$ For T_3 with Em_2

The coefficient of 0.28, 0.32, 0.66 and 0.70 are a crop deficit coefficient and relates the relative reduction in yield to the relative in *ET*.

Snap bean yield was decreased by decreasing water applied due to water deficit into root zone. It was decreased by increasing irrigation water amount in surplus irrigation due to over wetting stress on plant roots and causing more weed and insect problems, even those were controlled; also, Snap bean plants are also very sensitive to excessive water and tended to produce more vegetative growth and lessening grain yield. Other problem which is leaching some fertilizers from root zone by deep seepage could be the reason if additional fertilizers were not added. A relative yield (Y_a/Y_m) was found as a linear relationship with uniform water applied ratio (ET_a/ET_m) in deficit irrigation conditions as shown in Figure 6.

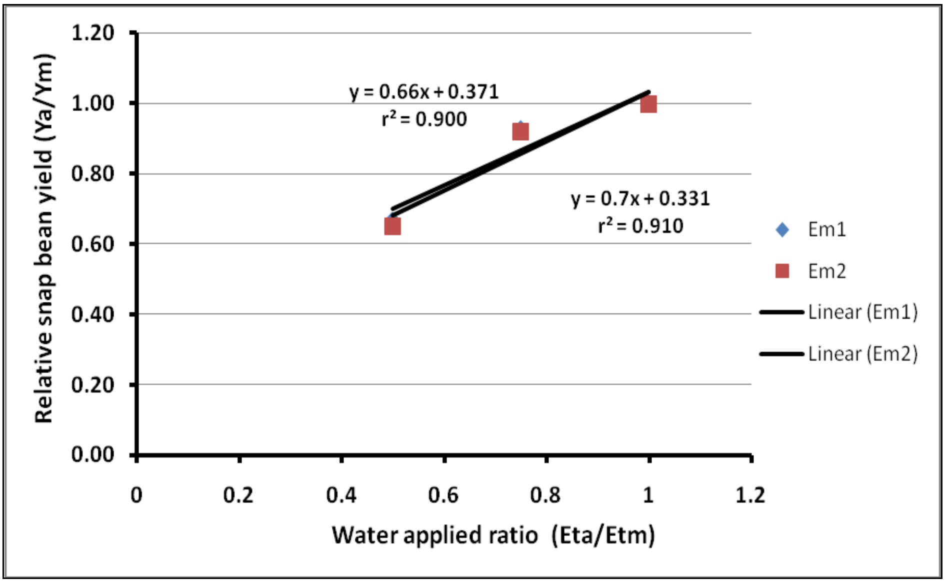

Figure (6): Relative snap bean yield versus water applied ratio under different irrigation levels.

Snap bean yield related to its corresponding uniform irrigation water applied depth was found under trickle irrigation method as shown in Figure 5. It decreased as water applied decreased in deficit irrigation due to plant stress causing by drier soil. The same results were also obtained by **Diaz-Perez *et al.* (2004)** working on pepper and **Wan *et al.* (2010)** working on cucumber, both of them found that yield was negatively affected by excessive irrigation. For an adequate irrigation quantity (100% ET_c), maximum yield values were 4.4 and 4.0 $Mg.fed^{-1}$ for T_1 and 4.09, 3.71 $Mg.fed^{-1}$ for T_2 under trickle irrigation method with Em_1 and Em_2, respectively. However, yield reduction $(1-Y_a/Y_m)$ was found in a linear relationship with uniform water applied fraction in small experiment plots in either deficit irrigation conditions $(1-Et_a/Et_m)$ as shown in Figure 7. Snap bean yield reduction coefficients using regression as shown in Figure 7 were, respectively, found as 0.28 (Ky_1 with $r^2 = 0.91$) and 0.32 (Ky_2 with $r^2 = 0.90$) in deficit irrigation conditions for emitters Em_1 and Em_2, respectively.

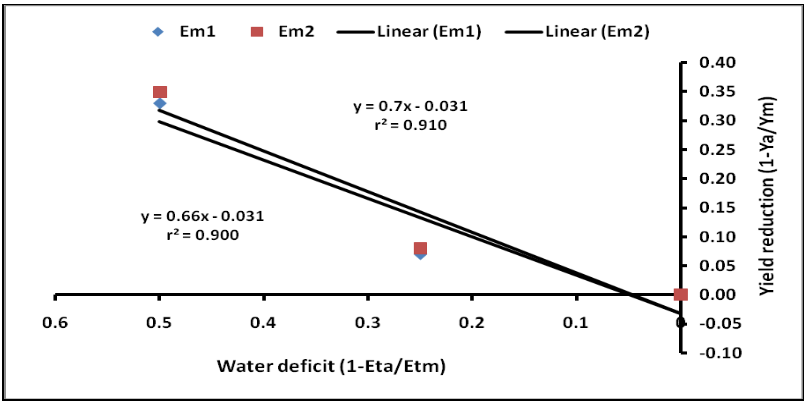

Figure (7): Relationship between snap bean yield reduction and water deficit

Distribution pattern of emitters

The soil moisture pattern content before and after irrigation for emitters *Em_1 and Em_2* at water deficit (T_1: 100 %, T_2: 75 % and T_3: 50 % *ETc*) as shown in (Figure 8). The results of emitters showed that before irrigation the soil moisture content decreased by increasing the depth for all treatments, except at depth of 30 cm at 0-12.5 cm horizontally from emitter. The soil available water (*AW*) of the snap beans was 6.80 % where the radial available water (*RAW*) equal 4.50 %, so that, the crop was not exhausted. It is well known that after irrigation directly the soil moisture content increases in all layers of the soil depth and filled completely. The results showed that the soil moisture content after irrigation with increased at the depth of 0-30 cm reaching value of 8.2 % and decreased up till 3.44 % at a depth of 45-60 cm when the distance from emitters was 0-12.5 cm at water deficit (T_1: 100 % *ETc*) of emitter *Em_1*. However, water deficit (T_3: 50 % *ETc*) decreased the soil moisture content from 8.2 % to 5.2 % at the same depth, respectively. Generally, for all emitters the soil moisture distribution pattern value was inversely proportional with the depth and the horizontal distance from emitter. The best soil moisture distribution pattern was noticed at *Em_1* emitter at water deficit (T_1: 100 % *ETc*) due to an increase in the time of irrigation and low flow rate. These results showed that the soil moisture distribution pattern were between field capacity (*FC*) and permanent wilting point (*PWP*) or may be at radial available water (*RAW*) for all different emitters at different treatments.

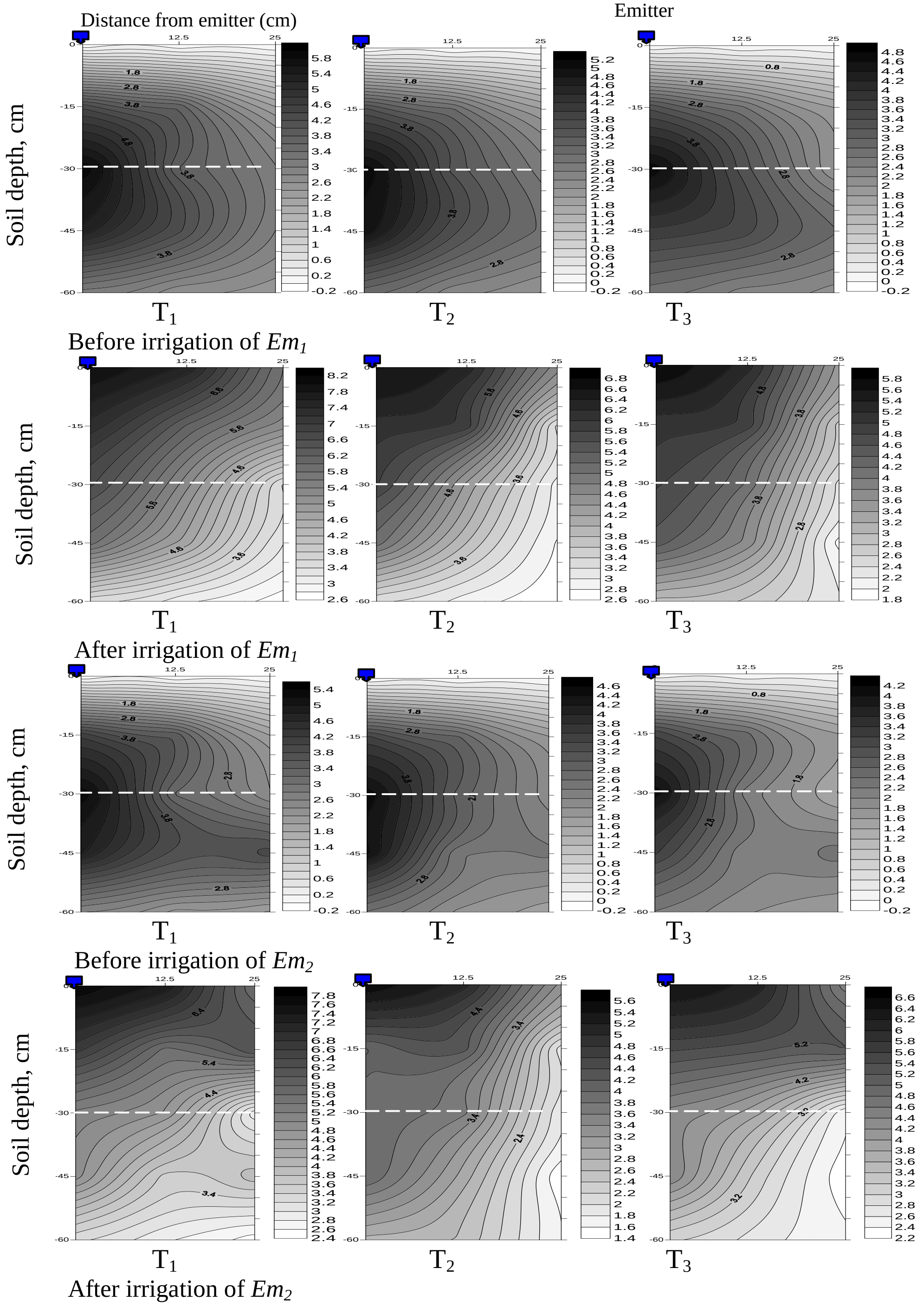

Figure (8): Average season stage of snap beans soil moisture distribution pattern of emitters (*Em_1* and *Em_2*) before and after irrigation at different treatments (*T_1*, *T_2* and *T_3*)

4. CONCLUSION

In this present research work, several conclusions can be obtained and drawn as follows:

1- Generally, the highest value of *CU*, yield and *WUE* was achieved at Em_1 emitter.
2- High yield was recorded in T_1 treatment, on the other hand, there was no significant differences between T_1 and T_2, therefore 75 % ET_c treatment saved about 25 % from applied water of the first treatment, so, it is the best water treatment for water saving and considerable yield.
3- Water use efficiency was the highest in 50 % ET_c, but 75 % ET_c was the best one economically.
4- Snap bean yield was significantly affected in a linear relationship ($r^2 \geq 0.90$) by deficit irrigation conditions.
5- The best treatment for saving water was 75 % ET_c and giving optimum yield of snap bean under sandy soil.

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الملخص العربي

تأثير العجز المائى على إنتاجية الفاصوليا وكفاءة استخدام المياه تحت نظام الرى بالتنقيط

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أجري تجربة حقلية بمزرعة كلية الزراعة - جامعة قناة السويس، بالإسماعيلية، مصر خلال فصل الصيف ٢٠١٦م فى تربة رملية على محصول الفاصوليا تحت نظام الرى بالتنقيط، وكان الهدف الرئيسي من هذه الدراسة هو دراسة تأثير العجز المائى نسبة من الأستهلاك المائى *(T_1: 100 %, T_2: 75 % and T_3: 50 % ETc)* وتأثير أنواع مختلفة من المنقطات المركبة داخل الخط (*Em_1*)، والمركبة على الخط (*Em_2*) على إنتاجية وكفاءة إستخدام المياه (*WUE*) مع طول الخط ٥٠ م وضغوط تشغيل مختلفة (٥٠، ١٠٠، ١٥٠، ٢٠٠ كيلوبسكال) وأشارت النتائج أن معامل انتظامية المياه (*CU*) يزداد بزيادة ضغط التشغيل من ٥٠ الى ١٠٠ كيلوبسكال وينخفض مع زيادة ضغط التشغيل من ١٠٠ إلى ٢٠٠ كيلوبسكال. أعطت المعاملة الأولى أعلى إنتاجية بدون أى فروق معنوية مع المعاملة الثانية لذلك فإن المعاملة الثانية ٧٥% تعتبر أحسن معاملة فى الإنتاجية وتعمل على حفظ المياه بنسبة ٢٥ % من كمية مياه الرى وتعتبر أحسن معاملة اقتصاديا. وكفاءة استخدام المياة كانت عالية فى المعاملة الثالثة ولكن المعاملة الثانية كانت احسن اقتصاديا وتاثر محصول الفاصوليا معنوياً بعلاقة خطية مع ظروف نقص الرى.

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