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in

Lamaddalena N. (ed.), Bogliotti C. (ed.), Todorovic M. (ed.), Scardigno A. (ed.).
Water saving in Mediterranean agriculture and future research needs [Vol. 1]

Bari : CIHEAM
Options Méditerranéennes : Série B. Etudes et Recherches; n. 56 Vol.I

2007
pages 235-247

Article available on line / Article disponible en ligne à l'adresse :

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El Gendy R.W., Gadalla A.M., Hamdy A., El Moniem M., Fahmy A. **Irrigation water saving via scheduling irrigation of snap bean and direction of soil water movement under drip irrigation system.** In : Lamaddalena N. (ed.), Bogliotti C. (ed.), Todorovic M. (ed.), Scardigno A. (ed.). *Water saving in Mediterranean agriculture and future research needs [Vol. 1].* Bari : CIHEAM, 2007. p. 235-247 (Options Méditerranéennes : Série B. Etudes et Recherches; n. 56 Vol.I)

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IRRIGATION WATER SAVING VIA SCHEDULING IRRIGATION OF SNAP BEAN AND DIRECTION OF SOIL WATER MOVEMENT UNDER DRIP IRRIGATION SYSTEM

R. W. El Gendy *, A. M. Gadalla *, A. Hamdy **, M. El moniem * and A. Fahmy *
* Soil & Water Res. Dept., Nuclear Res. Center, AEA, Cairo, Egypt
** CIHEAM – Mediterranean Agronomic Institute of Bari, Italy

SUMMARY - The aim of this work is to study application of water requirements for scheduling irrigation water of snap bean in order to save irrigation water. Other an objective is to study direction of soil water under the running scheduling in the drip irrigation system. This work was carried out at soil and water research department of nuclear research center in Egyptian atomic energy authority.
Fifteen neutron calibration curves of three sites (0,12.5 and 25 between drippers) were done. Three applied irrigation water rates (100, 75, and 50% ETc) were used. Horizontal and vertical movement of soil water was studied along the emitter lines (Between drippers) at the dripper, 12.5 cm and 25 cm distance from the dripper. Yield of snap bean, Water use efficiency and evaluating drip irrigation system were studied too.
The investigated data pointed that direction of soil water movement was useful for defining the depth of collection of active roots for water absorption and active rooting depth. These parameters were clear in effecting on water movement under 100 and 75% ETc treatments. Under 50% ETc treatment, active roots for water absorption were only clear. There was no significant difference between yield of 100% ETc and 75% ETc treatments, whenever significant differences between (50% ETc & 100% ETc) and (50% ETc &75% ETc) were found. 75% ETc treatment saved about 25% from applied water in the first treatment. The second treatment is the best water treatment in water saving and good yield.
Water use efficiency was the highest in 50% ETc, but economically, 75% ETc was the best one. As for emission uniformity of drip irrigation system was highly (92 %).

Key words: Snap bean plant, Water requirements, Direction of soil water movement, drip irrigation system, Water use efficiency, Neutron calibration curves.

INTRODUCTION

Water is one of the natural renewable resources essential for economic and social development. Yet, water resources have been taken for granted a free good to be used at will, with little or no regard to the long-term consequences of its mismanagement. Many voices have raised a note of alarm for some time now: Conferences have been held in Stockholm from 1992 to 2001, and UNESCO is focusing on the looming crisis by declaring 2001 the year of Fresh Water. Most of the Arab region lies in the arid to semi-arid zone" Rainfall is low". Several Arab countries are suffering from water deficiency and others are heading that way with an annual population growth of about 3% and rising levels of consumption due to socioeconomic development (Abu-zeid,M and H. Hamdy 2002). To achieve both water and food security we have to adapt other alternative strategies directed towards efficient and effective on farm water management to reduce the ample losses in irrigation, that means water saving.

Evapotranspiration data for agricultural crops has become increasingly important in irrigation management as well as in water resources management. It is dependent not only on the meteorological elements, but also on factors related to the crop and to the soil availability and soil environment.

The use of neutron moisture meter was adapted to overcome the time consumed for measuring the soil moisture content and it's distribution under conditions of drip irrigation system.

Snap bean (Phaseolus vulgaras L.) is one of the most important vegetable crops grown in Egypt for local market and exportation. So, the total cultivated area for green bean in Egypt was 46048 feddan (20000 hectare) in 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 winter season increased to 23000 ton in 2000.

To obtain high yield with maximum saving of water, drip irrigation system ought to be used with soil moisture content between 70%, 90% of total available water (Badr, 1992 and Abdel-Maksoud *et al.*, 1992).

One of the main advantages of using drip irrigation is water saving due to the partial wetting of the soil. The wetted area is affected by the emitter discharge rate and the hydraulic characteristics of the soil. (Gamal and Alngi, 2000).

The water savings that can be made using drip irrigation are the reductions in deep percolation, in surface runoff and in evaporation from the soil. These savings, it must be remembered, depend as much on the user of the equipment as on the equipment itself (FAO, 2001).

Zedan (2005) used a drip irrigation system for cultivating squash plant in order to study the soil water distribution under a dripper, he found that the maximum width in onion shape of water distribution was 45 cm depth below dripper. Doorenbos and Pruitt (1977) reported that water consumptive use increased with the progressive in plant growth depending on crop variety, plant growth stage and climatic condition. The reported also that crop water requirements are expressed by the rate of evapotranspiration (ET) in mm/day. The level of (ET) has been shown to be related to evaporative demand of air, which can be expressed as a reference evapotranspiration (ET_o). They also calculated the crop evapotranspiration (ET_c) by using the following formula:

$$ETc = Kc \times ETo \text{ [mm/day]} \quad (1)$$

The “ crop coefficient “ (k_c) value related to evapotranspiration of diseases-free crop grown in large fields under optimum soil water and fertility condition and achieving full production potential under given growing environment. Factors affecting the value of k_c are mainly the crop characteristics, crop planting or sowing data, rate of crop development, length of growing season and climatic conditions. Also, he added that for many crops ET_c has shown direct relationship with dry matter production. El Gendy, et al (2000) compared values of ETc for barley cultivated in Ras Sudr (Sinia, Egypt) from using climatical equations and total soil moisture depletion using neutron probe. They found good agreement between the two methods.

The soil water moisture content under drip irrigation system decreased by increasing the distance from emitters and reached its minimum value at the distance of 60 cm from the emitters. Increasing the applied water volume tended to increase the soil moisture content in both vertical and horizontal direction under drip irrigation system and vertical direction under furrow irrigation. The soil moisture content was higher under drip irrigation system than that of the furrow irrigation because the irrigation was daily under drip irrigation system. Increasing the amount of applied water tended to decrease the soil salinity because the soil moisture content increased (Helmy *et al.*, 2000).

Mauk (1982) found that yield per plant of bean plants (*Phaseolus vulgaris L*.) was increased by increasing irrigation (water applied at -0.6 bar soil water potential).

Karas (1997) studied the effect of water stress on productivity of bean (*Phaseolus vulgaris* L.) plants. She found that Bronco cultivar obtained the highest percentage of protein content when treated with 75% and 65% of field capacity compared to high water levels 100% and 125% - excessive water of field capacity.

The objective of this work is to study using of water consumption for scheduling irrigation water of snap bean for water saving. Other an objective is to study direction of soil water under the running scheduling irrigation under drip irrigation system.

MATERIALS AND METHODS

Field experiment was conducted in reclaimed sandy soil at the experimental farm of Soils and Water Research Department, Nuclear Research Center, Atomic Energy Authority, Cairo, Egypt.. Three irrigation treatments (i.e.T1 100%, T2 75% and T3 50% Etc) were applied. Response of snap bean (*phasoeolus vulgaras* L.) cv. Bronco to these treatments was detected.This soil was mixed at (0-30 cm layer) with chicken manure and clay mineral. Disturbed and undisturbed sandy soil samples were collected from five successive soil depths (0 – 15, 15 – 30, 30 – 45, 45 – 60 and 60 – 75 cm) before cultivation to determine the physical and chemical characteristics of the soil *(Tables 1 and 2),* as well as characteristics of irrigation water are shown in *Table 3*.

Table 1. Physical characteristics of the soil

Soil depth (cm)	Particle size distribution %			Texture class	Bulk density ($gm.cm^{-3}$)
	Sandy	Silt	Clay		
0-15	78.8	15	6.2	Loamy Sand	1.37
15-30	95.47	2.5	2.03	Sand	1.63
30-45	98.67	0.3	1.03	Sand	1.67
45-60	98.6	0.43	0.97	Sand	1.64
60-75	98.55	0.93	0.52	Sand	1.68

* according to Jacobs *et al* (1971). ** according to Klute (1986)

Table 2. Chemical characteristics of the soil *

C.E.C Mo/kg	PH 1:5	EC (dS/m) At 25°c	Soluble cations (meq / l)				Soluble anions (meq / l)			
			Ca^{++}	Mq^{++}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}	Cl^{-}	SO_4^{--}
9.3	8	0.22	1.8	0.8	3.1	0.4	-	2.1	2.0	2.0

*according to Page (1982)

Table 3. Some chemical characteristics of irrigation water

SAR	pH	EC (dS/m) At 25°c	Soluble cations (meq / l)				Soluble anions (meq / l)			
			Ca^{++}	Mq^{++}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{-}	Cl^{-}	SO_4^{--}
2.66	8.6	0.48	1.48	0.79	2.82	0.25	-	2.91	0.52	1.91

**according to Page (1982)

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 T1: 100% ETc (500 mm), T2: 75% Etc (375 mm) and T3: 50% ETc (250 mm).These amounts were scheduled through out 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)* . A trickle irrigation system consists of PVC for main lines with of (50 mm) diameter, 32 mm diameter as sub main lines and 16 mm low laterals laid parallel to serve crop rows with 80 cm distance between each other. GR built in emitters with nominal discharge 4 l/hr spaced with 50 cm between each other. Sandy screen filter, pressure gauges and control valves constructed in the system to adjust and control the amounts of irrigation water delivered to each treatment.

Three neutron access tubes were installed to 150 cm depth at different locations around the emitter (Fig. 1) Location 1 was at 25 cm distance from the dripper along dripper line. Location 2 was at 12.5 cm distance from dripper along dripper line, and location 3 was at 0 cm distance from. The three locations replicated under the three water treatments in order to study direction of soil water movement in horizontal and vertical directions.

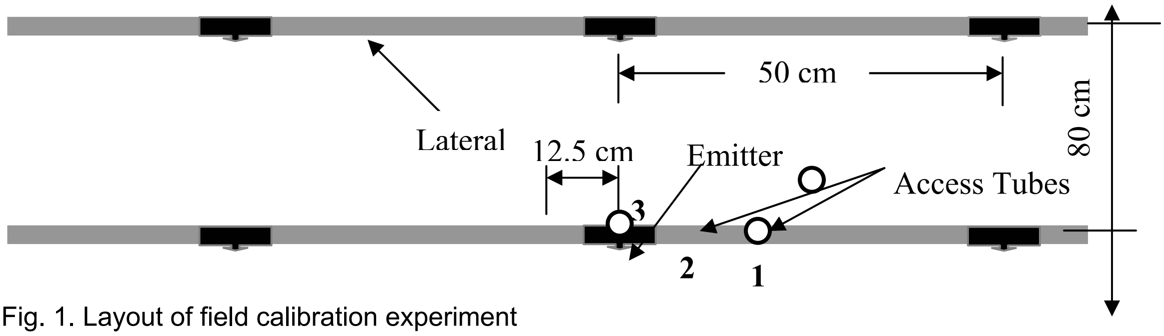

Fig. 1. Layout of field calibration experiment

Table 4. Amount of irrigation water added through out bean growth season according to Doorenbos and Kassam (1986)

Duration	No. of days	Growth stage	K_c	Irrigation treatments (A) 100% ET_c	(B) 75% ET_c	(C) 50% ET_c
20/2 - 22/2	3	Initial	0.4	8.45	6.34	4.22
23/2 - 25/2	3		0.4	8.45	6.34	4.22
26/2 - 28/2	3		0.4	8.45	6.34	4.22
1/3 - 3/3	3		0.4	8.45	6.34	4.22
4/3 - 6/3	3		0.4	8.45	6.34	4.22
7/3 - 9/3	3		0.4	8.45	6.34	4.22
10/3 - 12/3	3		0.4	8.45	6.34	4.22
13/3 - 15/3	3	Development	0.75	15.85	11.88	7.92
16/3 - 18/3	3		0.75	15.85	11.88	7.92
19/3 - 21/3	3		0.75	15.85	11.88	7.92
22/3 - 24/3	3		0.75	15.85	11.88	7.92
25/3 - 27/3	3		0.75	15.85	11.88	7.92
28/3 - 30/3	3		0.75	15.85	11.88	7.92
31/3 - 2/4	3		0.75	15.85	11.88	7.92
3/4 - 5/4	3		0.75	15.85	11.88	7.92
6/4 - 8/4	3		0.75	15.85	11.88	7.92
9/4 - 11/4	3		0.75	15.85	11.88	7.92
12/4 - 14/4	3	Mid Season	1.05	22.19	16.64	11.10
15/4 - 17/4	3		1.05	22.19	16.64	11.10
18/4 - 20/4	3		1.05	22.19	16.64	11.10
21/4 - 23/4	3		1.05	22.19	16.64	11.10
24/4 - 26/4	3		1.05	22.19	16.64	11.10
27/4 - 29/4	3		1.05	22.19	16.64	11.10
30/4 - 2/4	3		1.05	22.19	16.64	11.10
3/5 - 5/5	3		1.05	22.19	16.64	11.10
6/5 - 8/5	3		1.05	22.19	16.64	11.10
9/5 - 11/5	3		1.05	22.19	16.64	11.10
12/5 - 14/5	3	Late	0.95	20	15	10.00
15/5 - 17/5	3		0.95	20	15	10.00
18/5 - 20/5	3		0.95	20	15	10.00

Fifteen field calibration curves of neutron moisture meter CPN, 50 mCi. (503 Dr hydro probe) amercum-241 beryllium source were done. Five curves for each location at the different soil depths (30, 45, 60, and 75 cm depths). These calibration curves used to detect the soil moisture content horizontally around emitter and vertical one within the soil depths, as shown in *Table 5* according to IAEA (1976).

Soil moisture retention curve was determined for the different soil depths under study by van Genuchten model (1980):

$$\theta_h = \theta_r + (\theta_s - \theta_r) [1 + (\alpha h)^n]^{-m} \quad (2)$$

Where:

θ_h, is the volumetric soil moisture content at h,mbar.
θ_r, is the volumetric residual soil moisture content.
θ_s, is saturation point on volume fraction.
α, is the inverse of the air entry suction (h_b), and
n &m, are constants of the fitting curve.

Soil matric potential (h) could be obtained via rewrite the model in h as function to θ, which determined using neutron probe. Total hydraulic potential (H) could be obtained as summation of soil matric potential and the soil depth (gravity potential). Direction of soil moisture movement can be detected via follow H at each soil depth along the soil profile according to El Gendy (2004). Using SURFUR program could be studied in horizontal and vertical directions to define soil water movement around emitters.

Table 5. Regression equation of calibration curves of the 5 locations around emitter and for the different soil depths under studied.

Soil depth (cm)	Location no.	Regression equations of calibration curves	Coeff. of Determination
30	1	θ v % = 24.104 CR – 4.8219	0.9537
	2	θ v % = 25.734 CR – 3.6778	0.9233
	3	θ v % = 20.580 CR – 3.3504	0.9810
45	1	θ v % = 17.229 CR – 5.1839	0.9963
	2	θ v % = 6.3253 CR + 0.1599	0.9234
	3	θ v % = 15.829 CR – 3.4588	0.9336
60	1	θ v % = 15.234 CR – 4.1672	0.9567
	2	θ v % = 17.827 CR – 5.3960	0.9763
	3	θ v % = 16.713 CR – 4.4908	0.9517
75	1	θ v % = 14.914 CR – 3.1257	0.9695
	2	θ v % = 17.548 CR – 4.2185	0.9662
	3	θ v % = 17.010 CR – 4.4064	0.9756

After plowing, the rabbits manure was added at rate of 5 m^3/fed. Chemical fertilizer was applied following:

A. Ammonium sulphate (20.6 % N) was added at rate of 100 kg / fed.
B. Super phosphate (15.5 % P_2O_5) was added at rate of 300 kg / fed.
C. Potassium sulphate (48 % K_2O) was added at rate of 50 kg / fed.

The experimental area of 144 m^2 was divided into three sections represent the three irrigation treatments. Each section includes three experimental plots, with 20 m^2 /plot (Fig. 4) shows the layout of the experiment. The experiment was conducted using a complete randomized block design (Little and Hills, 1975), consisting of three treatments replicated three times. The obtained values were tested statistically using Duncan new multiple rang test . Emission uniformity (EU) of the system was determined in the field by using EU test and calculated using the equation:

$$EU = \frac{Q_n}{Q_a} \quad (3)$$

Where:
Q_n = Mean of the lowest quarter of discharge of the selected emitters (l/h).
Q_a = Mean of the total discharge rate (l/h).
Water use efficiency values for the tested treatments were calculated according to Jensen (1983), as follows:

$$WUE = \frac{Total \quad fresh \quad yield \quad (kg / fed)}{Total \quad water \quad applied \quad (m^3 / fed)} \quad kg / m^3 \quad (4)$$

RESULTS AND DISCUSSIONS

Emission uniformity

.
Emission uniformity is a scale for known the validation of drip irrigation system for its application in the experimental work. This scale estimates the homogeneity of irrigation water distribution. Data in *Table 6* include volume of received water through 25 cups, which were put below 25 drippers.

Table 6. Data for calculating emission uniformity for the drip irrigation system under study

No. Cup	Water volume, mliter
1	360
2	370
3	370
4	370
5	370
6	370
7	380
8	380
9	380
10	390
11	390
12	390
13	400
14	400
15	400
16	400
17	410
18	410
19	420
20	430
21	430
22	430
23	440
24	450
25	480

Average of the lowest quarter, average of received water and emission uniformity were shown on Fig. 2. Emission uniformity of the drip irrigation system under study was high (92 %) this indicates the water distribution within the soil profile was homogeneity.

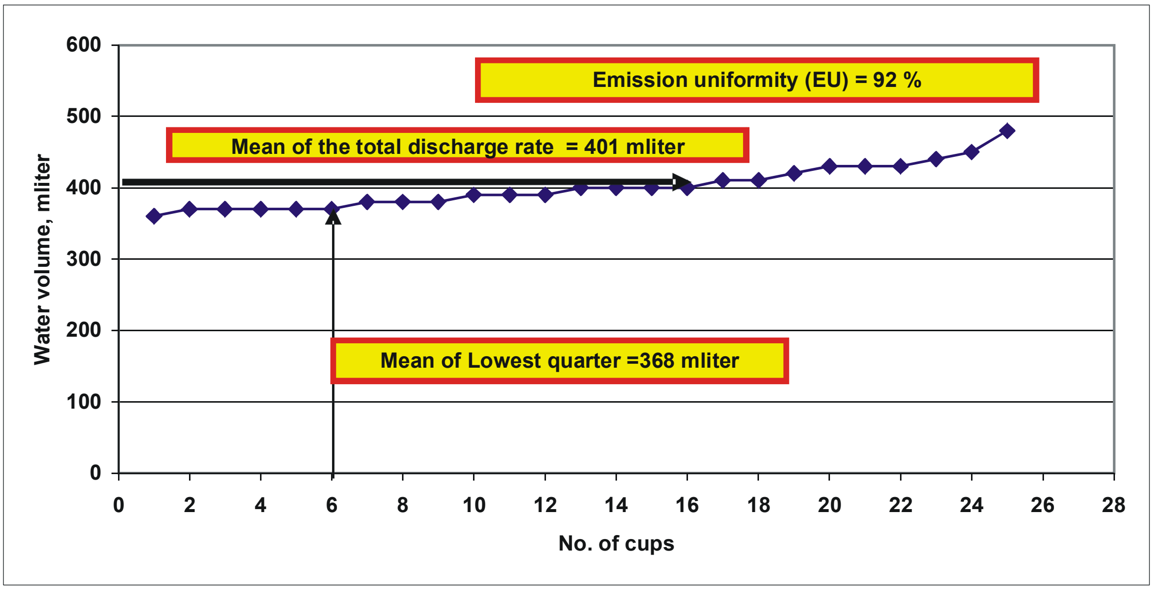

Fig. 2. Emission uniformity of the drip irrigation system under study

Effect of water application rate on snap bean yield

Figs 3 and 4 illustrate the effect of different irrigation water quantities (T(1) 100 % ETc, T(2) 75% ETc and T(3) 50 % ETc) on snap bean yield under using drip irrigation system .These figures illustrate that the maximum yield was obtained with the first treatment T(1) whenever the lower yield resulted from the third treatment T(3). Yield of snap bean was calculated for a drip line (as average), per plot (32 m^2), per feddan (4200 m^2), and per hectare (10,000 m^2). The concomitant tables of these figures show the yield of snap bean for the previous dimensions. Generally, high yield was achieved may due to high soil fertility (reclaimed sandy soil) by addition the organic and inorganic fertilizers. The variation between the three 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.

The statistical tests for the yield of snap bean under the tested treatments pointed to there is significant difference between the three treatments (calculated F value was 7.475 and the tabulated F was 6.94 at P= 0.05). Value of the least square difference (LSD) between the means was 2.761, so there is no difference between yield of T(1) and T(2), whenever, while there are significant differences between T(3) and T(1) and T(2).

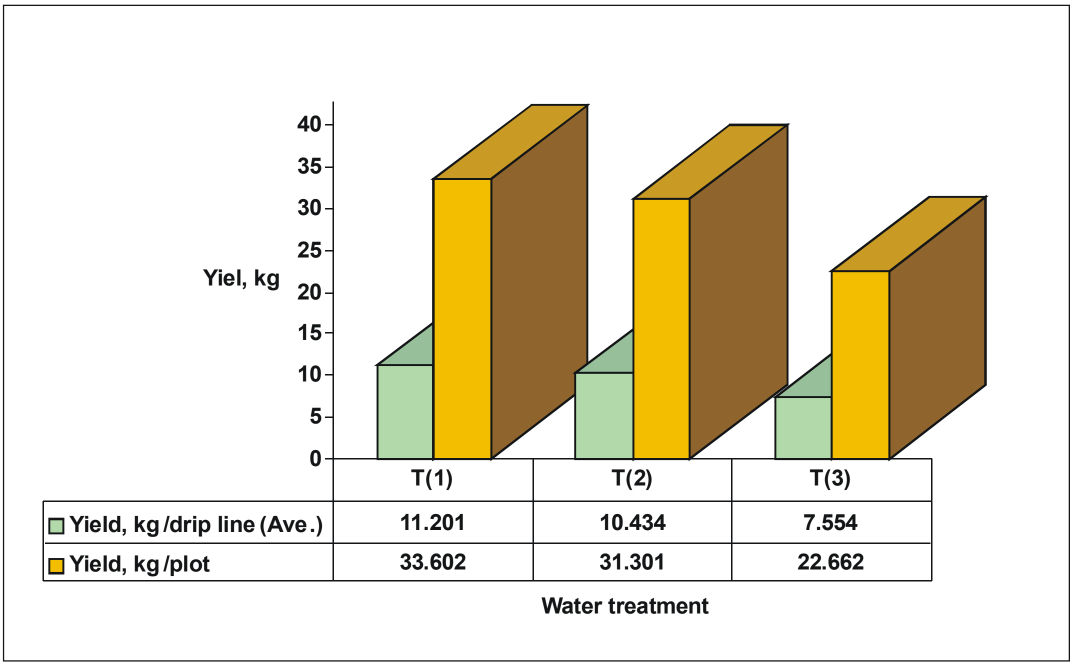

Fig. 3. Effect of irrigation water treatments and snap bean yield per drip line (mean) and per plot

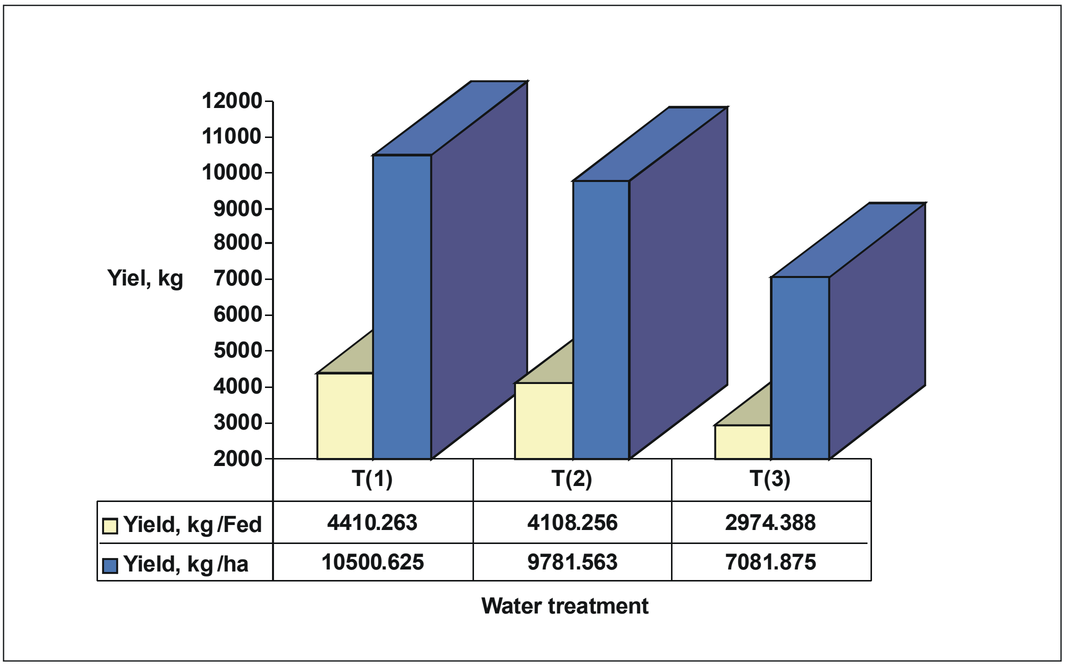

Fig. 4. Effect of irrigation water treatments and snap bean yield per feddan and per hectare

Water quantities were used for the three water treatments T(1), T(2), and T(3) were 50, 37.5 and 25 cm as water head, which equal 2098.110, 1575.236 and 1048.908 m^3/fed; 4995.5, 3745.8 and 2497.4 m^3/ha, respectively.

T(2) saved about 524.874 m3/fed or 1249.7 m3/ha, which equal 25% from applied water of T(1). So, T(2) is the best water treatment in water saving and good yield because of there is no any significant difference with T(1) especially with yield.

SOIL MOISTURE RETENTION CURVES

Soil moisture retention curve (SMRC) is the important soil characteristic, which predicts the matric potential via volumetric soil water content (θ) after making h = f (θ), in order to use neutron probe to predicate soil matric potential via measuring volumetric water content. Total hydraulic potential (H) is the summation of matric potential and gravitational potential (Z) in unsaturated soil. H can be obtained (El Gendy, 2004)

$$h = -\left(\frac{1}{\alpha}\right)\left[\left(\frac{\theta - \theta r}{\theta s - \theta r}\right)^{\left(\frac{-1}{m}\right)} - 1\right]^{\left(\frac{1}{n}\right)} \quad (5)$$

$$H = h + Z \quad (6)$$

$$H = -\left(\frac{1}{\alpha}\right)\left[\left(\frac{\theta - \theta r}{\theta s - \theta r}\right)^{\left(\frac{-1}{m}\right)} - 1\right]^{\left(\frac{1}{n}\right)} - Z \quad (7)$$

Where:

h, Soil metric potential, mbar,
H, Total hydraulic potential, mbar,
Z, Gravitational potential, which equals soil depth for measuring soil moisture content (taken negative sign, where Soil surface was the reference level,
θ, is the measuring soil moisture content via neutron moisture content,
θr, is the residual moisture content,
θs, is the saturation point ,
α, is the inverse of bubbling pressure (or air entry suction), $mbar^{-1}$ and
n, m ,are the constants for fitting data on the van Genuchten model of soil moisture retention curve.

This technique is considered one from applications of neutron moisture meter via determination of soil moisture content in situ.

Direction of soil water movement

Direction of soil water movement had been studied at mid stage because the activity of roots in initial and developing stages will be in changing and at late stage some roots will be die. So, mid stage the best stage because of the roots activity will be constant and so to study the role of roots on direction of soil water. Total hydraulic potential also calculated before the next irrigation where in order to appear the result of roots for water absorption.

100% Etc treatment

Fig. 5 illustrates there are active roots for water absorption at 15 cm below the dripper (Site 0) because water movement directed from up and down to this depth, where low water potential. Also there are active roots for water absorption at 50 cm depth approximately below the 12.5 site because water movement directed from up and down to this depth, where low water potential., as well as active rooting depth was found at 60 cm depth (separates between upward movement resulted from active roots for water absorption at 50 cm depth and downward movement from 60 cm depth to deeper depth 75 cm depth.

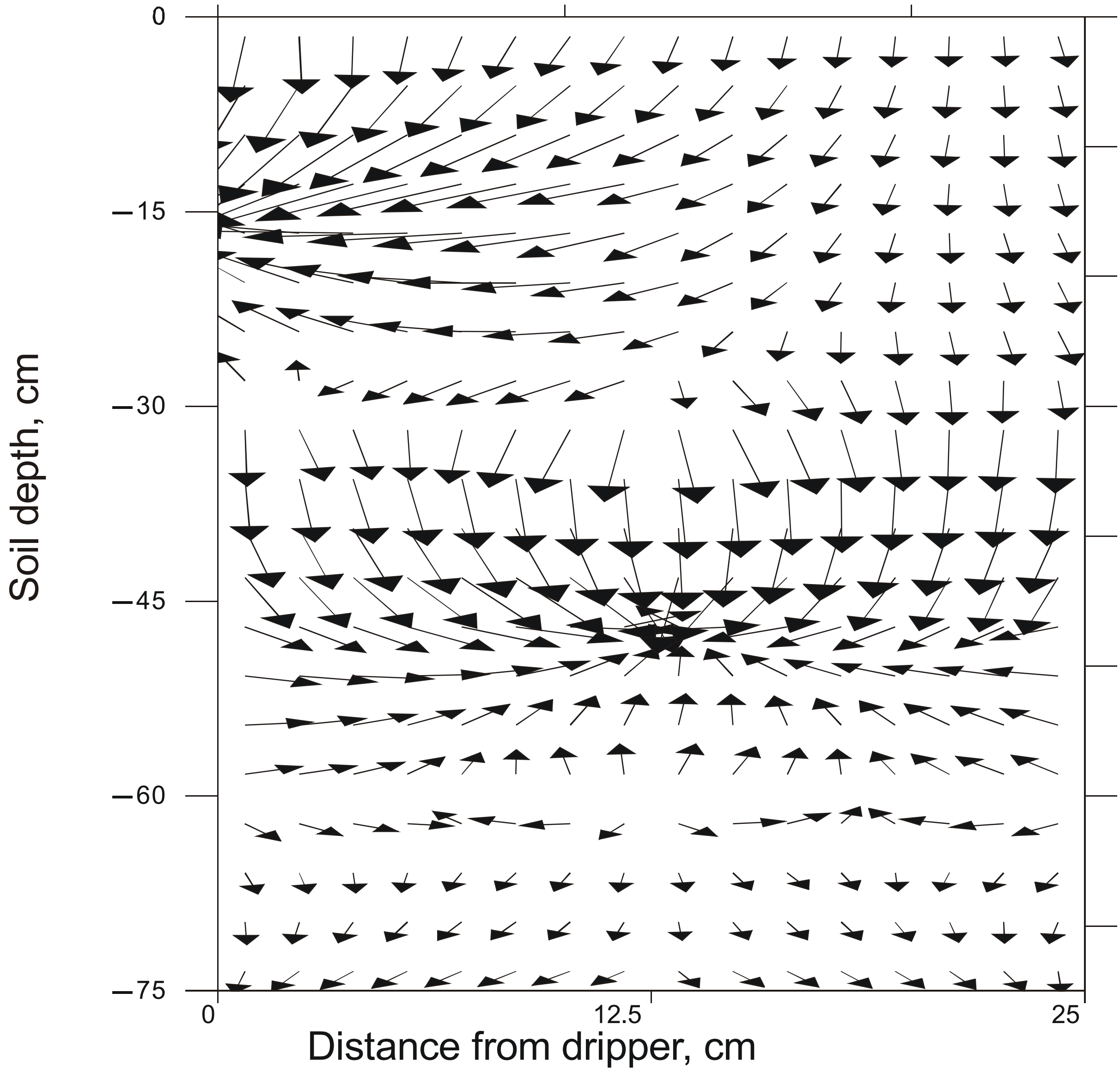

Fig. 5. Direction of soil water movement in horizontal and vertical directions between dripper before irrigation at 3/5/2006 for 100% Etc treatment

75% Etc treatment

Fig. 6 illustrates finding active roots at 15 and 45 cm depths below 25 and 12.5 sites, respectively (soil water directed from surface layer (0-15 cm) and from (15 -30 cm layer) to 15 cm depth (low water potential at 15 cm depth resulted from water absorption by roots. As for active rooting was at 60 cm depth (fig. 5) for 100% ETc treatment.

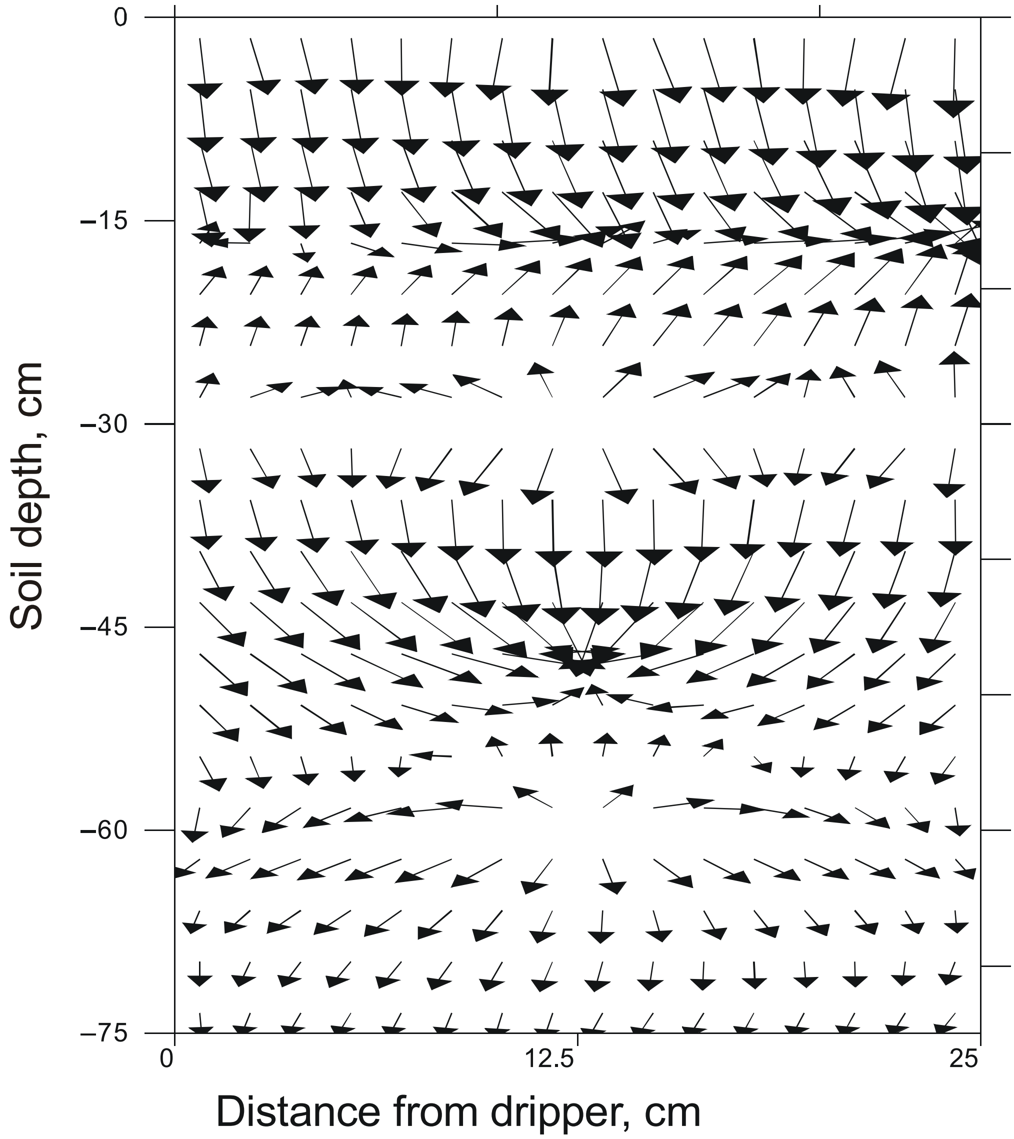

Fig. 6. Direction of soil water movement in horizontal and vertical directions between dripper before irrigation at 3/5/2006 for 75% Etc treatment

50% Etc treatment

Fig. 7 shows that there are two soil depths have low total hydraulic potential. The first at 15 below 0 site where finding a collection of active roots for water absorption and the second one at 50 cm depth it may be resulted from the irrigation water did not enough to wet the whole soil profile. So, the active rooting depth was not clear.

From the discussed before, Behavior of direction of soil water movement was the same for 100 and 75% ETc treatments. This makes sure why is yield of snap bean for the two treatments was insignificant? As For 50% ETc treatment was significant relative with 100 and 75% ETc treatments**.**

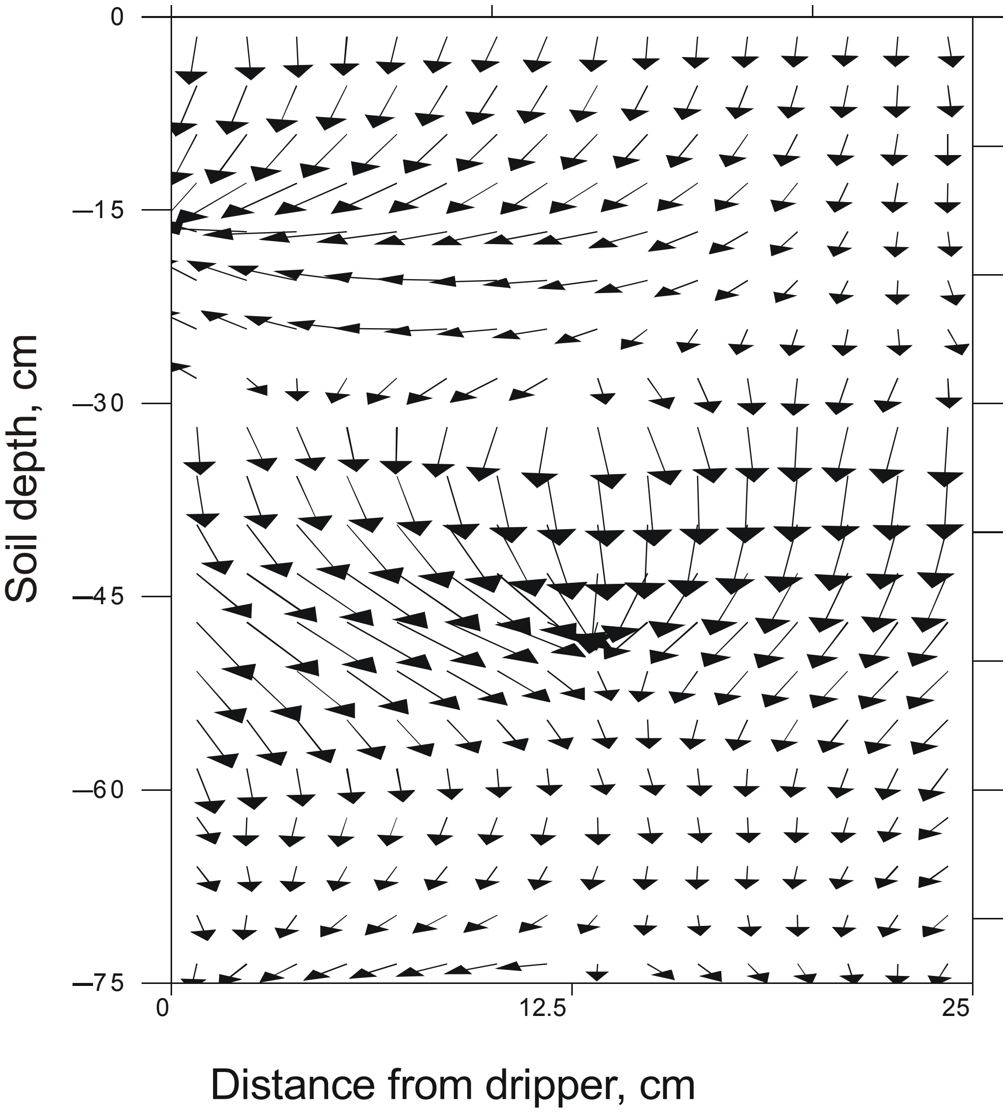

Fig. 7. Direction of soil water movement in horizontal and vertical directions between dripper before irrigation at 3/5/2006 for 50% ETc treatment

CONCLUSION

Scheduling irrigation according to water consumptive use calculations under running drip irrigation system saved 25 % from the used water in 100% ETc for irrigating snap bean plant. Studying of direction of soil water movement under drip irrigation system makes sure the same roots behavior of snap bean under the two treatments (100 and 75% ETc). Also, it illustrates finding insignificant difference for snap bean yield.

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