THE EFFECT OF IRRIGATION FREQUENCY AND RATE UNDER TRICKLE IRRIGATION MANAGEMENT ON YIELD GREEN BEAN GROWN IN CLAY LOAM SOIL

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ABSTRACT

This study was conducted over 2 years (2013 and 2014) to establish the optimal combinations between irrigation frequency and rate for trickle-irrigated green bean using water production functions and water use–yield relationships. A field experiment was conducted using a randomized complete block design with three irrigation frequencies (F_1, F_2 and F_3, irrigation events once every 1, 2and 3 days, respectively) and three trickle irrigation rates (I_1: 1.00, I_2: 0.80, and I_3: 0.60 of the estimated evapotranspiration, ET). Our results show that yield variables and water use efficiencies (WUEs) increased with increasing irrigation frequency and rate, with non-significant differences between F_1 and F_2 in yield variables and between I_1 and I_2 in WUEs. Moreover, the combination between various irrigation frequencies and rates had an important effect on yield variables and WUEs, with the highest values being found with F_1I_2 and F_2 I_1 and the lowest for F_2I_3 and F_3I_3. The F_1I_3 treatment had grain yield and yield components values similar to those obtained for the F_2I_3 treatments and WUEs values similar to those obtained for the F_2I_3 and F_3I_1 treatments. Production functions of yield versus seasonal crop ET were linear for all combinations of irrigation frequency and rate and for all irrigation frequency treatments with the exception of the F_1 treatment, which instead showed a second order relationship. In conclusion, we identified the optimal coupling combinations between irrigation frequency and water application rate to achieve the maximum yield and WUEs.

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INTRODUCTION

By the year 2050, it is forecast that there will be an annual global water shortage of 640 billion cubic meters (Spears, 2003).Given that water shortages currently plague almost every country in North Africa and the Middle East, insufficient water supply for irrigation in these regions, even in the short term, will almost certainly become the norm rather than the exception. Therefore, water shortage events have gained increasing importance in both the scientific and political agendas. Because the irrigation sector is the largest consumptive user of water, accounting for 71% of the fresh water use across the world, it is necessary for irrigation management practices to shift from emphasizing production per unit area towards maximizing the production per unit of irrigation water consumed (Fereres and Soriano, 2007).

Deficit evapotranspiration is also among the techniques of increasing effective use of water. Deficit evapotranspiration can be used either through agronomic practices or through changing management schemes to decrease crop evapotranspiration ET_C. Crops are exposed to water stress either throughout the entire growth season or at certain growth stages. It is therefore possible to save irrigation water without significant yield decrease which implies that irrigated area can be increased without additional water supply available (Merriam, 1965).

The main approach in deficit irrigation practice is to increase crop water use efficiency by eliminating those irrigations with the least impact on crop yield. In the areas where water supplies are limited and unit water costs are expensive, the best irrigation practice is not necessarily that which gives the highest yield. (English,1990).

Pulsing irrigation refers to the practice of irrigating for a short period then waiting for another short period, and repeating this on-off cycle until the entire irrigation water is applied (Eric et al., 2004). High-frequency water management by trickle irrigation minimizes soil as a storage reservoir for water, provides at least the daily requirements of water to a portion of the root zone of each plant, and maintains a high soil matric potential in the rhizosphere to reduce plant water stress (Phene and Sanders, 1976; Nakayama and Bucks, 1986).

WUE can be optimized by the adoption of irrigation frequency practices (Costa et al., 2007). To this regard, drip irrigation has contributed to improve WUE by significantly reducing runoff and crop evapotranspiration (ET_c) losses (Stanghellini, et al., 2003; Jones, 2004; Kirnak and Demirtas, 2006).

The goal of deficit irrigation is to increase crop water use efficiency (WUE) by reducing the amount of water applied with watering or by reducing the number of irrigation events (Kirda, 2002). Deficit irrigation involves the use of appropriate irrigation schedules, which mostly derive from field trials (Oweis and Hachum, 2001), and this because crop sensitivity to water deficit during growing season changes with the phonological stage (Istanbulluoglu, 2009). Moreover, studies have shown that water deficit during certain stages of growing season improves fruit quality, although water limitations may also determine fruit yield losses (Patanè and Cosentino, 2010).

The objectives of this study are to: (i) evaluate the impacts of trickle irrigation frequency and deficit irrigation on green bean production and water use efficiency (WUE). (ii) determine the optimum coupling combinations between irrigation frequency and water application rate, to seek maximum yield and WUE simultaneously for trickle irrigated green bean using water production functions and water use–yield relationships. (iii). studding effects of irrigation frequency and deficit irrigation on the root dynamics of green bean plants, cultivated under arid conditions.

MATERIALS AND METHODS

2.1. Open-field experiment

Field experiments were conducted during the years 2012-20113 and 2013-2014, at El-Ayat El-Giza governorate, Egypt (latitude 30.1113N, longitude 31.4138E, and mean altitude 74 m above sea level). The soil of the experimental site is classified as clay loam. Some physical and chemical properties of the experimental soil are given in Table 1.

Irrigation water has been obtained from a deep well located in the experimental area, with pH 7.43, and an average electrical conductivity of 0.59dS m^{-1}.

Table1. Some physical and chemical properties of the experimental soil

Soil depth (cm)	Texture	Field capacity (%)	Wilting point (%)	Bulk density (g cm^{-3})	pH
0 – 20	Clay loam	43.4	22.3	1.30	7.92
20 – 40	Clay loam	43.6	22.5	1.30	7.88
40 – 60	Clay loam	44.0	23.7	1.29	7.89

2.2. Experimental design, treatments and agronomic practices

A randomized complete block design with three replicates was used in each season. Different treatments of irrigation frequency and water application rate were randomly assigned. A layout of the experimental plots is shown in Fig. 1.The trickle irrigation system was divided into three main sectors, with the irrigation frequency treatments (once every 1, 2 and 3days) being assigned to the three sectors. The water application rate treatments (I_1: 1.00ET_c, I_2: 0.80 and I_3: 0.60 of the estimated crop evapotranspiration) were randomly nested within each main sector as a subplot, with each subplot having three replicates of the same water application rate. Each subplot had one valve and one flow meter to control water application and measure the irrigation quantity, respectively. The amount of irrigation water applied, I, was determined from the calculated water requirement for green bean (mm) as determined from the basal crop coefficient (K_{cb}), and one for soil evaporation (K_e) and the daily reference evapotranspiration (ET_o) using the following equation:

$$I = ET_o(K_{cb} + K_e) \quad (1)$$

ET_o was calculated by the Penman–Monteith method (Allen et al., 1998) using daily data from a meteorological station located within 500 m of the research site.

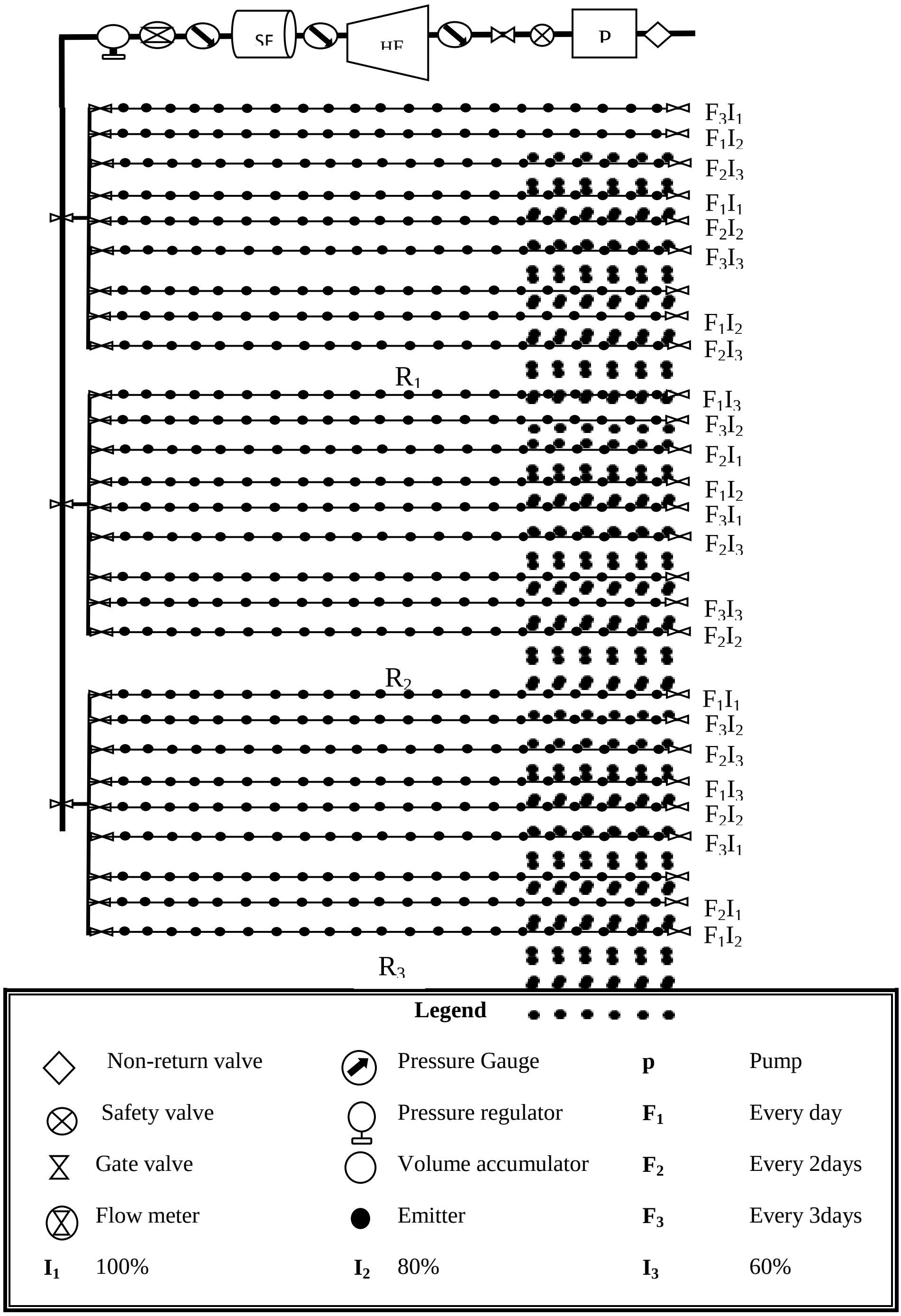

Fig. 1. Layout of an experimental design that includes three irrigation frequencies and three irrigation rates.

Each 21m^2 subplot consisted of three polyethylene lateral drip lines (16 mm in diameter, and 0.3memitter spacing, Euro drip Greece) with a length of 10m. The lateral line was laid out along each green bean row at 0.7 m. The Hydraulic characteristics experiments were carried out the National Irrigation Laboratory of Agricultural Engineering Research Institute (AERI), Dokki, Giza emitters had a operating pressure of 0.13 MPa. The water application uniformity was calculated from the statistical distribution of emitter flow rates in terms of coefficient of variation (ν) and emission uniformity (EU) using equations (2) and (3) (Keller and Karmeli, 1975), as follows:

$$v = \frac{sd}{q_a} \tag{2}$$

$$EU = 100\left(1.0 - 1.27\frac{v}{\sqrt{N'_p}}\right)\frac{q_n}{q_a} \tag{3}$$

Where: s is the standard deviation of drippers discharge (lph); q the mean dripper flow rate (lph) (Table 4), ν manufacturer coefficient of variation, N'_P the number of emitters per plant, q_n is the minimum discharge rate (l/h), q_a The average flow rate of all emitters (lph).

2.3. Crop evapotranspiration measurements and irrigation water compensation

Three seeds (Polista) were sown around each emitter on 12 October 2013 and 12 October 2014 to obtain a final plant population of about 90,000 plants ha^{-1}. Nitrogen fertilizer was applied at a rate of 50 kg ha^{-1} of N as ammonium sulphate (20.5%) by fertigation. Nitrogen fertilizer was added 2 weeks after sowing in six equal weekly doses P_2O_5 fertilizer was applied at a level of 20 kg ha-1of P as calcium super phosphate. Whole of phosphorus was applied basally before sowing in all treatments. Potassium fertilizer was applied 5 weeks after sowing at a level of 41.5 kg ha-1of K as potassium sulphate in two equal biweekly doses. Weed, pest, and disease control were done in a timely manner. Hand harvesting was performed about 60 days after sowing.

2.3. Crop evapotranspiration measurements and irrigation water compensation

Actual crop evapotranspiration under the different irrigation treatments was calculated using the soil water balance equation (Heerman, 1985):

$$ET = I + P + C_r + R - D \pm \Delta S \qquad (4)$$

where ET represents seasonal crop evapotranspiration (mm), I the amount of irrigation water applied (mm), P is precipitation (mm), C_r is the capillary rise (mm), R is the amount of runoff (mm), D is the amount of drainage water (mm).

In this study, both P and C_r were considered to be zero because there was no precipitation during either growing season and no capillary rise from the groundwater occurred. Surface runoff was assumed to be negligible because the amount of irrigation water was controlled through the trickle irrigation. Whenever available water in the root zone (0-20 cm) and the total amount of water applied by irrigation were above the field capacity, it was assumed that excess water leaked into the deeper soil zones and was called deep percolation (D = amount of available total water at 0-20 cm soil depth before irrigation (mm) + irrigation water applied (mm) - soil water hold in field capacity (mm)) (Kanber et al 1993). Whereas D_S was estimated from the respective soil water contents to a depth of 60 cm by using the soil water content value before harvesting to subtract the soil water content value before sowing.

Soil water content was monitored before irrigation every 15 days for F_1, F_2 and F_3 treatments, at soil depth intervals of 0–10 and 10-20 cm. Soil samples were taken at positions immediately under the emitters. Soil water content was determined by the gravimetric method (oven dry basis). The values were converted to a percentage volumetric basis by multiplying them by the bulk density of the soil of their layer. In addition, the contribution of the different treatments toward plant water consumption (Ertek et al., 2004) was determined according to

$$Irc = \left(\frac{I}{ET}\right) \times 100 \quad (5)$$

Where Irc is the irrigation water compensation for plant water consumption (ET) (%),I the amount of irrigation water applied.

2.4. Water use efficiencies

WUE (kg ha^{-1} mm^{-1}), defined as the ratio of yield to seasonal water consumption per hectare, and irrigation water use efficiency (IWUE, kg ha^{-1} mm^{-1}), as the ratio of grain yield to the seasonal amount of irrigation water applied per hectare, were calculated using Eqs. (6) and (7), respectively (Howell et al., 1990).

$$WUE = \left(\frac{Y}{ET_C}\right) \quad (6)$$

$$IWUE = \left(\frac{Y}{I}\right) \quad (7)$$

Where Y is the economical yield (kg ha^{-1}), ET the seasonal crop evapotranspiration (mm), and I is the amount of irrigation water applied (mm).Relationships were derived from seasonal crop evapotranspiration and grain yield data was obtained from the experiment.

2.6. Statistical analysis

All measurements in this study were analyzed using an analysis of variance (ANOVA) appropriate for a randomized complete block design in factorial arrangement two factors irrigation frequency and water application rate. They were replicated among blocks. Mean square of the product between the irrigation frequency and water application rate was used as the error term to test the interaction between both factors. Mean separation of treatment effects used Duncan's protected least significant differences (LSD) test. Probability levels lower than 0.05 were categorized as significant. All analyses used the Mstat program.

Results and discussions

3.1. Irrigation water and crop evapotranspiration (ET_C)

Table (2) presents seasonal crop ET_C and irrigation water compensation values (Irc) as estimated by Eqs. (5) and (6), respectively. In both seasons, indicating that the soil became drier at the end of the growing season.

Seasonal irrigation water requirement of green bean for the recommended treatment was 271.6 and 233.mm for the experimental years, respectively. (Silim and Saxena 1993) reported seasonal irrigation water requirement for drip-irrigated green beans in Syria as 439 mm; and (Borosic et al. 2000) determined water requirement of green beans as 400 mm in Zagreb. Since the rainfall received during the growing season was not significant, the crop water consumption practically depended only on the amount of the irrigation water supplied to the plots. In this study, the seasonal crop ET_C during the crop growing period (i.e., after establishment of the crop) was found to be lower than the amount of irrigation water applied (I) in the F_1I_1 and F_3I_1 treatments

Table 5. Green bean evapotranspiration calculated using the water balance equation. I, ET_C and Irc indicate amount of irrigation water applied (mm), change of soil water storage (mm), crop evapotranspiration (mm) and irrigation water compensation (%), respectively.

Year	Treatments		I (mm)[a]	ET_c (mm)	Irc (%)
2013	F_1 (once in 1 day)	1.00ET	242.5	271.6	89.3
		0.80ET	194	217.3	89.3
		0.60ET	145.5	163.0	89.3
	F_2 (once in 2 day)	1.00ET	242.5	286.4	84.7
		0.80ET	194	229.1	84.7
		0.60ET	145.5	171.8	84.7
	F_3 (once in3 day)	1.00ET	242.5	327	74.2
		0.80ET	194	261.6	74.2
		0.60ET	145.5	196.2	74.2
2014	F_1 (once in 1 day)	1.00ET	209.3	233.5	89.6
		0.80ET	167.4	186.8	89.6
		0.60ET	125.5	140.2	89.6
	F_2 (once in 2 day)	1.00ET	209.3	240	87.2
		0.80ET	167.4	192	87.2
		0.60ET	125.5	144	87.2
	F_3 (once in3 day)	1.00ET	209.3	302.7	69.0
		0.80ET	167.4	242.2	69.0
		0.60ET	125.5	181.6	69.0

a: Amount of irrigation water applied was calculated by using Penman–Monteith equations

3.2. Yield components

All yield components (the number of pods, the number of leaves and the area of leaves, and the yield per hectare were significantly affected by irrigation frequency and rate (Table 3). The maximum yield components and grain yield averaged across irrigation rate treatments were obtained at the two most frequent irrigation frequencies (F_1 and F_2). Averaged over the two seasons, the irrigation frequency treatment F_3 resulted in decreases in ear weight per plant by 39.2 pods number per plant by 31.2 and 22.5%, number of leaves 18.9 and 21.2% and yield per hectare of 48.1 and 22.6%, respectively, when compared with the F_1 treatment (Table 3).

The combination of irrigation frequency and irrigation rate had a significant effect on both yield components and grain yield in both seasons (Table 3). The Duncan's protected LSD test of the various combinations for the effect on yield components and grain yield placed F_1I_2 and F_2I_1 in the first position; F_1I_1, F_3I_1 and F_2I_2 in the second position; F_3I_2 and F_1I_3 in the third position; F_2I_3 in the fourth position; F_3I_3 in the fifth position with similar results for all parameters in both seasons. (Boutraa and Sanders 2001) stated that water stress during the vegetative growth period and prior to fruit set had the greatest effects on limiting green bean yields.

3.3. Water use efficiencies

The highest WUE 22.3kg mm^{-1} was obtained in F_1I_2 treatment in the first year and the minimum WUE was observed in F_3I_3 treatment in the second year. In general, WUE values decreased with decreasing number of frequency. IWUE values varied from a minimum of 13.2 kg mm^{-1} in F_3I_3 treatment to a maximum of 24.2 kg mm^{-1} in F_1I_2 treatment in the first year. Treatment was only 24.9 and 30.7% less than those at F_1 treatment, whereas the respective values for the F_2 and F_3 treatments showed significant decreases: IWUE, 37.5 and 45.9%; WUE, 40.9 and 55.1% (for F2 andF3, respectively, in both cases). Averaged over all irrigation frequencies and seasons, 0.80 ET_C had comparable water use efficiencies as did 1.00 ET_C, but 0.60 ET_C had IWUE and WUE values that were 41.1 and 34.7% lower than those of 1.00 ET_C, respectively.

The interaction effect between irrigation frequency and rate on IWUE and WUE was also significant in both seasons (Table 3).

Table 3. Effects of irrigation frequency, irrigation rate and their combination on grain yield, irrigation water use efficiency, ET_C, Irrigation water used and water use efficiency in 2013 and 2014.

Irrigation Frequency	2013				2014			
	1.00 ET_C (I_1)	0.80 ET_C (I_2)	0.60 ET_C (I_3)	Mean	1.00 ET_C (I_1)	0.80 ET_C (I_2)	0.60 ET_C (I_3)	Mean
Grain yield (kg ha^{-1})								
F_1 (once in 1 day)	10320ab	11430a	6613de	9453a	10290b	11930a	6516e	9578a
F_2 (once in 2 days)	10450ab	8946bc	5446e	8280ab	10460	8706c	5510f	8224ab
F_3 (once in 3 days)	10240ab	7820cd	4757e	7606b	10280b	7417d	4561g	7418b
Mean	10340a	9398b	5605c		10340a	9352b	5529c	
LSD (0.05)	F 1364	ET 283.4	F×ET 1817		F 1477	ET 433.7	F× ET 595.3	
IWUE (kg mm^{-1})								
F_1 (once in 1 day)	42.35c	59.20a	45.75b	49.10a	49.90b	72.05a	51.45b	75.80a
F_2 (once in 2 days)	42.60c	45.60b	37.25e	41.82ab	50.45b	51.20b	43.50c	48.38b
F_3 (once in 3 days)	41.5cd	39.85d	32.5f	37.97b	50.10b	43.60c	36.00d	43.23b
Mean	42.17b	48.22a	38.5c		50.15b	55.62a	43.65c	
LSD (0.05)	F 7.715	ET 1.173	F×ET 2.033		F 8.256	ET 0.958	F×ET 1.66	
WUE (kg mm^{-1})								
F_1 (once in 1 day)	38.40b	52.65a	40.35b	43.80a	44.90b	64.20a	45.80b	51.63a
F_2 (once in 2 days)	36.65bc	38.70b	36.05bc	37.13b	44.25b	44.65b	38.25c	42.38b
F_3 (once in 3 days)	31.0cd	29.95d	24.05e	28.33c	34.45d	30.55e	25.15f	30.05c
Mean	35.35b	40.43a	33.48b		41.20b	46.47a	36.40c	
LSD (0.05)	F 1.151	ET 3.343	F×ET 5.790		F 6.586	ET 0.932	F×ET 1.62	

Means followed by the same letter are not significantly different from one another based on Duncan's protected LSD test at $P \leq 0.05$.

An important finding of this study was the strong response of both grain yield and yield components to the combination of irrigation frequency and amount. It is interesting to note that the values of both grain yield and yield components obtained for F_1I_2 were comparable with those of F_2I_1, and that both were higher than those obtained for F_1I_1. Crucially, the F_1I_3 treatment produced grain yield and yield components values similar to those obtained for the $F_2I_3$and F_3I_2 treatments (Table 3). The was non-significant difference between the F_3I_1 and F_1I_3 treatments for IWUE and ET_c (Table 3),despite the amount of water applied in the former case being 31.0% higher in 2013 and 30.4% in 2014 (Table 3), this may be explained by the application of water at high volume and low frequency in the F_3I_1 treatment exceeding the soil–water storage capacity, leading to excessive water percolation under the effective root zone. Therefore, frequent low rates of irrigation (e.g., F_1I_3) were more effective for increasing irrigation efficiencies than were infrequent high irrigation rates (e.g., F_3I_1) (Table 3).

3.4. Yield–seasonal crop evapotranspiration relationship

The best fit for the relationship between grain yield and seasonal crop ET was power and positive for each year: 2013, $Y = 49.528\ ET^{0.9431}$ (R^2 = 0.4899); 2014, $Y = 121.83ET^{0.7965}$ (R^2 = 0.3618) (Fig. 2). The power regression coefficients, which represent the increase in grain yield for each unit increase in seasonal crop ET, were 36.71 $kg.mm^{-1}$ in 2013 and 41.48 $kgmm^{-1}$ in 2014. The intercepts of the two regression lines were also highly similar. From the equations reported in Fig.2, the basal seasonal crop ET necessary to start grain yield production was determined to be 271.6 and 233.5mm in 2013 and 2014, respectively (252.5mm on average).

First, the shorter irrigation durations for higher irrigation frequencies in combination with high irrigation rates (i.e., F_1I_1) may mean that the amount of water extracted by the roots was not commensurate with the amount of water applied, resulting in more water moving below the root zone. Second, in the case of low irrigation frequencies in combination with high irrigation rates (i.e., F_3I_1), the amount of water applied at each irrigation event was (excessively) higher than the water storage capacity of the sandy soil, thereby like increasing the amount of water that could move below the root zone. In both cases, the amount of water that percolated under the root zone was not depleted by the roots.

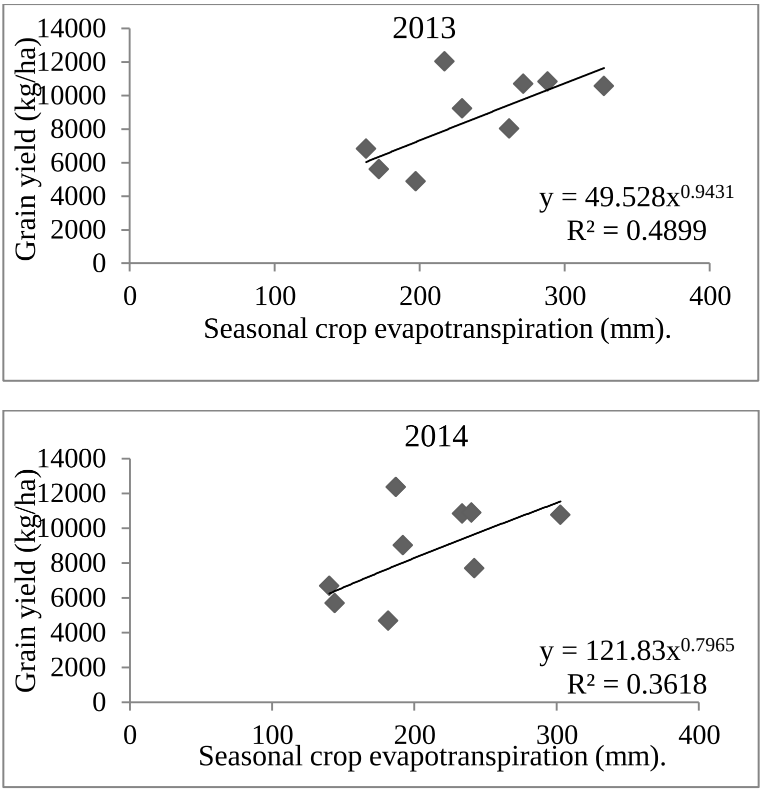

Fig. 2. Relationship between seasonal crop evapotranspiration (ET_C) and grain yield under the two growing seasons.

CONCLUSIONS

- In this study, our results demonstrated that the deficit irrigation had significant effect on yields of field grown green bean under the Mediterranean climatic conditions in Egypt.
- The maximum yield of 11430 kg ha^{-1} was obtained from F_1I_2 treatment in 2013 and 11930 kg ha^{-1} in 2014. Moreover, F_1I_2 treatment resulted in better quality than as compared to other treatments.
- The results indicated that WUE and IWUE values decreased with the decreasing frequency irrigation, it is recommended to frequency irrigate F_1 (once in 1 day) with irrigation rate of 0.80ET (I_2).

- In conclusion, F_1I_2 treatment is recommended for trickle-irrigated green bean grown under field conditions in order to save water by giving the media time to moisten from the first pulse of water thereby allowing it to absorb subsequent irrigation.
- We would be able to reduce the quantities of water apply needed to achieve optimal production. Considering the IWUE and WUE, F_1 I_2 irrigation regime can be recommended in case of water shortage.

REFERENCES

Allen, R.G., Pereira, L.S., Raes, D., Smith, M. 1998. Crop evapotranspiration: guide lines for computing crop water requirements. FAO Irrigation and Drain. Pp. 56. UNFAO, Rome.

Alvino, A., Tedeschi, P., Zerbi, G., 1988. Growth, flowering, setting and yield of kidney bean (Phaseolus vulgaris L.) as influenced by water regime, P fertilization and bnoa treatment. Acta Hort. 228, 219–226.

ASAE. 1996a. Field Evaluation of Micro Irrigation Systems. EP405.1. ASAE Standards. Amer. Soc. Agric. Engr., St. Joseph, MI, pp. 756–759.

ASAE. 1996b. Design and Installation of Micro Irrigation Systems. EP409. ASAE Standards. Amer. Soc. Agric. Engr., St. Joseph, MI, pp. 792–797.

Assouline, S., 2002. The effects of micro drip and conventional drip irrigation on

Barros, L.C.G., Hanks, R.J., 1993. Evapotranspiration and yield of beans as affected by mulch and irrigation. Agron. J. 85, 692–697.

Bergez, J.E., Deumier, J.M., Lacroix, B., Leroy, P., Wallach, D. 2002. Improving irrigation schedules by using a biophysical and a decisional model. Eur. J. Agron. 16, 123–135.

Borosic, J., Romic, D., Dolanjski, D., 2000. Growth and yield components of dwarf French bean grown under irrigation conditions. Acta Hort. 533, 451–459.

Boutraa, T., Sanders, F.E., 2001. Influence of water stress on grain yield and vegetative growth of two cultivars of bean (Phaseolus vulgaris L.). J. Agron. Crop Sci. 187, 251–257.

C¸agˇlar, G., 1998.In: Kahramanmaras kos¸ ullarında ikinci u¨ ru¨n olarak yes¸ il fasulye yetis¸ tiriciligˇine uygun yer ve sırık c¸es¸ itlerin belirlenmesi u¨ zerine bir aras¸ tırma. II. Sebze Tarımı Sempozyumu. Gaziosmanpas¸ a U¨ niv. Zir. Fak, Tokat, 28–30 Eylu¨ l, (in Turkish), pp. s: 199–s:204.

Chen, C., Payne, W.A., Smiley, R.W., Stoltz, M.A., 2003. Yield and water-use efficiency of eight wheat cultivars planted on seven dates in northeastern Oregon. Agron J. 95, 836–843.

Costa, J. M., Ortu˜no, M. F., Chaves, M. M. 2007. Deficit irrigation as a strategy to save water: physiology and potential application to horticulture. J. Integr. Plant Biol. 49, 1421–1434.

Doorenbos, J., Kassam, A.H., 1979. Yield response to water. FAO Irrigation and Drainage Paper 33. UN-FAO, Rome, Italy.

El-Hendawy, S.E., Abd El-Lattief, E.A., Ahmed, A.S., Schmidhalter, U. 2008. Irrigation rate and plant density effects on yield and water use efficiency of drip-irrigated corn. Agric. Water Manage. 95, 836–844.

El-Hendawy, S.E., Hokam, E.M., Schmidhalter, U., 2008. Drip irrigation frequency: the effects and their interaction with nitrogen fertilization on sandy soil water distribution, maize yield and water use efficiency under Egyptian conditions. J. Agron. Crop Sci. 194, 180–192.

English, M. J. 1990. Deficit irrigation: an analytical framework. J. ASCE (IR). 116: 399-412.

English, M., Raja, S. N. 1996.Perspective on deficit irrigation. Agric. Water Management 32, 1–14.

Eric, S., David, S., Robert, H. 2004. To pulse or not to pulse trickle irrigation that is the question UF/IFAS - Horticultural Sciences Department. Florida, USA NFREC-SV-Vegetarian (04-05).

Ertek, A., S¸ensoy, S., Ku¨ c¸u¨ kyumuk, C., Gedik, I., 2004. Irrigation frequency and

Fereres, E., Soriano, M.A. 2007. Deficit irrigation for reducing agricultural water use J. Exp. Bot. 58, 147–159.

Heerman, D.F. 1985. ET in irrigation management. In: Proceedings of the National Conference on Advances in Evapotranspiration. Trans. ASAE. Pp. 323–334.

Hillel, D. 1972. The relationship between field water balance and water use efficiency. In: Hillel D(Ed) Optimizing the Soil Physical Environment Toward Greater Crop Yields (pp. 79-100) Academic Press, New York.

Howell, T.A., Cuenca, R.H., Solomon, K.H., 1990. Crop yield response. In: Hoffman, G.J., Howell, T.A., Solomon, K.H. (Eds.), Management of Farm Irrigation Systems. ASAE Monograph No. 9, 2950 Niles Road, St. Joseph, MI, pp. 93–122.

Istanbulluoglu, A. 2009. Effects of irrigation regimes on yield and water productivity of safflower (Carthamustinctorius L.) under Mediterranean climatic conditions. Agric. Water Manage. 96, 1792–1798.

Jackson, M. L. 1973. Soil chemical analysis. Prentice hall, Inc. N.Y.

Jones, H., 2004. Irrigation scheduling advantages and pitfalls of plant based methods.

Kanber, R., Yazar, A., O¨ nder, S., Ko¨ ksal, H. 1993. Irrigation response of Pistachio. Irrig. Sci. 14, 1–14.

Kirda, C. 2002. Deficit irrigation scheduling based on plant growth stages showing water stress tolerance. Deficit irrigation practices. In: FAO Corp. Doc. Rep. 22, Rome, pp. 3–10.

Kirnak, H., Demirtas, M.N., 2006. Effects of different irrigation regimes and mulches on yield and macro nutrition levels of drip-irrigated cucumber under open field conditions. J. Plant Nutr. 29, 1675–1690.

Kirnak, H., Gencoglan, C., Degirmenci, V., 2003. Effect of deficit irrigation on yield and growth of second crop corn in Harran plain conditions. Atatu¨ rk Univ. J. Fac. Agric. 34 (2), 117–123.

Kriedemann, P.E., Goodwin, I. 2003. Regulated Deficit Irrigation and Partial Root-zone Drying. An Overview of Principles and Applications. Irrigation Insights no. 3.Land and Water, Australia.

Merriam, J. L. 1965. A management control concept for detonating the economical frequency of irrigation. ASAE Annual Meeting, Paper No. 65-206, St Joseph, Michigan.

Moon, D., Gulik, W.V., 1996. Irrigation scheduling using GIS. In: Proceedings of the International Conference on Evapotranspiration and Irrigation Scheduling, Am. Soc. Agric. Eng., San Antonio, TX, USA, November 3–6, pp. 644–649.

Muirhead, W.A., 1978. Snap beans. Farmers Newsletter. 144, 24–25.

Musick, J.T., Jones, O.R., Stewart, B.A., Dusek, D.A., 1994. Water–yield relationships for irrigated and dryland wheat in the U.S. Southern Plains. Agron. J. 86, 980– 986.

Oweis, T., Hachum, A. 2001. Reducing peak supplemental irrigation demand by tending sowing dates. Agric. Water Manage. 50, 109–124.

Patanè, C., Cosentino, S.L. 2010. Effects of soil water deficit on yield and quality of processing tomato under a Mediterranean climate. Agric. Water Manage. 97, 131–138.

Payero, J.O., Melvin, S.R., Irmak, S., Tarkalson, D., 2006. Yield response of corn to deficit irrigation in a semiarid climate. Agric. Water Manage. 84, 101–112.

Phene, C.J., Sanders, D.C. 1976. High-frequency trickle irrigation and row spacing effects on yield and quality of potatoes. Agron. J. 68, 602–607.

Stanghellini, C., Kempkes, F.L.K., Knies, P. 2003. Enhancing environmental quality in agricultural systems. Acta Hortic. 609, 277–283.

الملخص العربى

تأثير ادارة الرى بالتنقيط على محصول الفاصوليا الخضراء فى الاراضى الطميية الطينية

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أجريت التجارب الميدانية خلال عامي ٢٠١٣-٢٠١٤ فى مدينة العياط بمحافظة الجيزة، مصر (خط عرض ٣٠.١١١٣ شمالا وخط طول ٣١.٤١٣٨، ومنسوب ٧٤ متر فوق مستوى سطح البحر). وكانت معاملات الرى الشحيح ($1.00ET_c$ (I_1), $0.80ET_c$ (I_2), $0.60ET_c$ (I_3)) والرى المتكرر مرة كل يوم (F_1) ومرة كل يومبين (F_2) ومرة كل ثلاث أيام (F_3). في هذه الدراسة، أظهرت النتائج أن الري الشحيح مع الري اليومي F_1I_2 له اثر كبيرعلى زيادة محصول الفاصوليا الخضراء حيث تم الحصول على اعلى إنتاجية وقدرت ١١٤٣٠ كجم \هكتار من المعاملة F_1I_2 فى الموسم الاول١١٩٣٠ كجم \هكتار في الموسم الثانى. وحققت المعاملة F_1I_2 أعلى كفاءة أستخدام للمياه WUE كفاءة أستخدام لمياه الري IWUE مقارنةً بالمعاملات الأخرى، ومن النتائج السابقة يمكن التوصية باستخدام أستخدام المعاملةF_1I_2 لتوفير حوالى ٢٠% من الاحتياجات المائية للفاصوليا الخضراء في الزراعة المكشوفة من أجل توفير المياه من خلالها سوف نكون قادرين على تقليل كميات المياه اللازمة لتحقيق اقصى انتاجية.

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