

Response of Green Bean to Pulse Surface Drip Irrigation

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Abstract: Effects of pulse irrigation on yield and nutritional elements of green beans (*Phaseolous vulgaris* L.), irrigated with a subsurface drip irrigation system, were evaluated over two years under field conditions in the Mediterranean region of Egypt. The irrigation system consisted of four irrigation treatments based on the number of pulses which ranged from T1 where the irrigation water requirement applied at one time to T4 where the irrigation water requirement applied using four pulses. Maximum and minimum yields were obtained from T4 and T1 treatments as 4.83 and 3.78 t/fed. in the first experimental year 2008 and 4.73 and 4.06 t/fed. in the second experimental year 2009, respectively. WUE ranged from 4.59 kg/ m³ in T1 to 6.84 kg/ m³ in T4 for the first experimental year and varied from 4.44 kg/ m³ in T1 to 6.64 kg/ m³ in T4 in the second experimental year. Results showed that the vegetative growth of green bean plants (plant height, number of leaves, plant fresh weight, plant dry weight, total leaf area as well as chlorophyll content) were improved by increasing number of pulses per each irrigation. It was found that the highest concentration of all determined nutrient elements was obtained in the high pulse irrigation T4. While, the lowest concentration was obtained in the low pulse irrigation T1.

Key words: *Phaseolous vulgaris* • Drip irrigation • Yield • Growth • Nutrients

INTRODUCTION

Water supply is a major constraint to crop production worldwide. Surface irrigation is commonly used in the Mediterranean region of Egypt resulting in low irrigation efficiencies salinity and drainage problems. Efficient use of irrigation water is becoming increasingly important and alternative methods of water application such as drip and low pressure sprinkler, may contribute substantially to improving irrigation efficiency.

There is a trend towards conversion of surface to drip irrigation which is considered a more efficient delivery system. Scheduling water application is critical in improving efficiency of drip irrigation, as over irrigation reduces yield due to disease caused by *Phytophthora*, while inadequate irrigation causes water stress and reduces production. It is necessary that the soil water supply be kept at the optimal level to maximize returns. High-frequency water management by drip irrigation

minimizes soil storage and provides at least the daily water requirement 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 [1].

World green bean (*Phaseolous vulgaris* L.) production is 4,310,733 metric tones and Egypt is ranked the sixth one with the production level of 215,000 tones (FAOSTAT, 2007). Water management in green bean (*Phaseolous vulgaris* L.) production is important at all stages of plant development due to its influence on stand establishment and pod set and quality [2]. The crop must be supplied with adequate water to ensure vigorous growth.

One of the most common irrigation methods for green bean production in Egypt is furrow irrigation, where producers over irrigate, resulting in high water losses and low irrigation efficiencies. With drip irrigation, water and nutrients can be applied directly to the crop at the root level, to have positive effects on yield and water usage [3].

The dependence of crop yields on water supply is critical because of increasingly limited water resources for irrigation. Irrigation intervals and plant-pan coefficients affect green bean yield and quality [4]. Irrigation scheduling based on a 0.8 crop-pan coefficient is recommended for conventional subsurface drip irrigation (SDI), with 1.0, being more appropriate for partial root zone-drying practice by green bean producers experiencing water shortage [5].

The wetted zone size can be controlled if irrigation is pulsed [6]. Increasing vapor pressure deficit can increase plant internal water deficits. The pulsing irrigation reduced water stress [7]. Several experiments reported positive responses in crops to high pulse drip irrigation [8, 9]. The advantages of pulsing are that plant growth is generally greater than with standard irrigation and lower fertilizer rates can be used [10]. Reducing the time interval between successive irrigations in order to maintain constant, optimal water content in the root zone may reduce the variations in nutrient concentration, thereby increasing their availability to plants [11].

The objectives of this study were to determine effects of pulse irrigation on vegetative growth; yield and nutrimental elements of field grown green bean irrigated by a subsurface drip irrigation system and evaluate water use efficiency of green bean in the Mediterranean region of Egypt.

MATERIALS AND METHODS

Two field experiments were conducted during the 2008 and 2009 growing seasons from February to June, at the Agriculture Engineering Department, El-Giza, Egypt,

latitude 30.0861N and longitude 31.2122E and mean altitude 17 m above sea level. Monthly mean climatic data for the two seasons were very similar (Table 1). Maximum and minimum temperature, relative humidity and wind speed data were obtained from the Central Laboratory of Meteorology, Ministry of Agriculture. Only a small amount of precipitation which did not exceed a few minutes duration occurred during the two seasons.

The soil was a sandy clay loam (Table 2). Available soil moisture content was estimated to be 152.66 mm in a 60 cm soil profile. Irrigation water, pH 7.2, was obtained from a deep well having an average electrical conductivity of 0.83 dS/m. Soil organic matter was 19 g/kg determined by oxidizing with chromic acid according to Walkley and Black [12] and calcium carbonate was 29 g/kg estimated using a calcimeter according to Wright [13].

The cv. Polista was planted by hand with a 70 cm row spacing at a 5 cm soil depth on 15 February 2008 and 2009. Plants were thinned to an approximate spacing of 5-7 cm in rows when they were about 15 cm tall. A common recommended fertilization practice in the area was followed in the study. The experimental design was a split plot with three replications. Each plot was 10 m long and 6 plant rows wide (4.2 m).

A subsurface trickle irrigation system was used. Laterals were laid for each row at a 15 cm depth and inline emitters with discharge rate of 4 L/h were spaced at 30 cm intervals on the lateral line. The system was operated at 100 kPa throughout the growing season. The system consisted of a pump, gravel and disk filters, a flow meter, control valves, fertilizer tank and pressure gauges. The following four irrigation treatments were used:

Table 1: Monthly and growing seasons climatic data

Month	Mean temperatures (°C)						Relative humidity (%)	
	Minimum		Maximum		Average			
	2008	2009	2008	2009	2008	2009	2008	2009
March	14.77	15.10	26.47	26.9	20.58	21.00	49.42	49.73
April	15.83	16.00	28.53	28.65	22.18	22.32	49.37	50.00
May	15.80	16.10	28.50	29.80	22.15	22.95	49.40	49.80
June	18.50	18.70	31.20	31.30	24.85	25.00	46.50	48.60

Table 2: Some physical and chemical properties of the soil.

Soil depth (cm)	Texture	FC (cm ³ /cm ³)	WP (cm ³ /cm ³)	Bulk density (g/cm ³)	pH	Ec _e (dS/m)
0-20	SCL	42.07	14.43	1.29	7.74	2.43
20-40	SCL	41.80	14.91	1.31	7.69	1.92
40-60	SCL	38.96	17.15	1.33	7.81	1.78

- T1: The irrigation water requirement was applied at one time (control).
- T2: The irrigation water requirement was applied at two times.
- T3: The irrigation water requirement was applied at three times.
- T4: The irrigation water requirement was applied at four times.

The time between pulses was 1 hour between each pulse and it was determined according to the redistribution of water in the soil which depends mainly on the unsaturated hydraulic conductivity and the root water uptake. The irrigation water applied was calculated through CropWat software and the on/off time was managed using a solenoid valve.

Soil water content was measured at 20 cm increments down to 60 cm, using a profile probe before irrigations throughout the growing season. Access tubes were installed in rows at the center of the plots. The profile probe was calibrated against soil water content, determined by gravimetric sampling. The surface soil layer (0-20 cm) was sampled gravimetrically.

After 45 days of planting, five plants were taken randomly from each treatment to determine plant height, number of leaves, plant fresh weight and chlorophyll. At harvest stage, the mature pods of bean were harvested from the three center rows in each plot; harvest area in each plot was 12.6 m² (three rows, each 6 m long). Each experimental plot was collected along the harvesting season and the total pods yield was recorded as ton/fed. At the last harvest date, five bean plants were cut at the soil surface and stems and leaves separated. Plant samples were dried in a forced air oven at 70°C until constant weight was reached. Ground plant material was digested with sulphuric acid according to Yoshida *et al.* [14] and analyzed for N, P and K. Nitrogen determination according to Black [15]. Phosphorus was determined by

molybdenum blue colorimetric method according to Jackson [16] and K determined by flame photometer according to Jackson [16].

Water-use efficiency (WUE) and irrigation water-use efficiency (IWUE) values were calculated as fresh green bean yield divided by seasonal ET and total seasonal irrigation water applied, respectively [17, 18]. Chlorophyll was measured using a Minolta chlorophyll meter (SPAD-502, Spectrum Technologies).

Statistical Analyses: Data were treated by analysis of variance with using SPSS 11.0 for windows software and using Tukey test between treatments means determined at the 5% level.

RESULTS AND DISCUSSION

Effect of Irrigation Treatments on Water Use, Seasonal Irrigation, Yield, Water Use Efficiency and Irrigation Water Use Efficiency:

The effect of irrigation treatments on green bean yields, irrigation amounts, water use and water use efficiency (WUE) data is presented in Table 3. Seasonal water used by green bean varied from 382 mm in 2008 to 390 mm in 2009. In both years, water use values decreased with increasing number of pulses per day. Pulse irrigation had significantly affected green bean yields (Table 3). The highest yield (4.83 t/fed.) was obtained in T4 treatment, followed by T3 and T2 with 4.32 and 3.95 t/fed. in 2008, respectively. The minimum yield was obtained from the T1 treatment as 3.78 t/fed. for the first experimental year. In 2009, similar to the previous year, the maximum yield was obtained from the T4 treatment and followed by T3, T2 and T1. These results are in line with those obtained by Sezen *et al.* [4]. They reported that pulse irrigation had significant effect on yields of field grown green bean under the Mediterranean climatic conditions. The maximum yield was obtained from the treatment which had the highest

Table 3: Water use, seasonal irrigation, yield, water use efficiency (WUE) and irrigation water use efficiency (IWUE) of green bean under four irrigation treatments and two growing seasons

Seasons	Treatments	Water use (mm)	Seasonal irrigation (mm)	Yield (t/fed.)	WUE Kg/m ³	IWUE Kg/m ³
2008	T1	382	458.40	3.78 c	0.046	0.038
	T2	370	444.00	3.95 c	0.051	0.043
	T3	356	427.20	4.32 b	0.060	0.050
	T4	344	412.80	4.83 a	0.071	0.059
2009	T1	390	468.00	4.06 c	0.044	0.037
	T2	378	453.60	4.00 c	0.049	0.041
	T3	363	435.60	4.33 b	0.058	0.048
	T4	351	421.20	4.73 a	0.069	0.057

Values followed by the same letter are not significantly different at 0.05 level of probability.

Table 4: Effect of pulse irrigation on vegetative growth of cv. Polista green bean during 2008 and 2009 seasons

Seasons	Treatments	Plant height (cm)	No. of leaves	Fresh weight (g)	Dry weight (g)	Leaf area (cm ²)	Chlorophyll (SPAD)
2008	T1	28.34 c	5.33 c	15.34 c	2.60 c	101.77 c	37.66 b
	T2	34.75 b	5.25 c	18.00 c	3.35 bc	144.70 b	38.35 b
	T3	39.67 ab	7.66 b	28.33 b	4.06 b	141.53 b	38.46 b
	T4	44.00 a	10.33 a	43.00 a	6.66 a	169.00 a	42.96 a
2009	T1	31.00 c	5.33 c	16.00 c	2.56 c	113.97 d	39.66 b
	T2	36.00 b	5.66 c	20.67 c	3.40 bc	125.67 c	37.40 b
	T3	43.34 a	7.33 b	30.67 b	4.30 b	132.20 b	39.30 b
	T4	44.00 a	9.66 a	44.67 a	6.86 a	177.73 a	45.53 a

Values followed by the same letter (s) in each column are not significantly different at 0.05 level of probability.

water use. Previous studies demonstrated that increasing fertigation frequency significantly increased plant yield, especially at low nutrient concentrations [19] and that the yield improvement was primarily related to increased P uptake [20].

The highest WUE 6.84 kg/ m³ was obtained in T4 treatment in the first year and the minimum WUE was observed in T1 treatment in the second year. In general, WUE values decreased with decreasing number of pulses. IWUE values varied from a minimum of 4.38 kg/ m³ in T1 treatment to a maximum of 6.53 kg/ m³ in T4 treatment in the first year; and green bean response to pulse irrigation applied with subsurface trickle system indicated that the higher the number of pulses, the higher the yield of green bean in each irrigation.

Effect of Irrigation Treatments on Vegetative Growth:

The effect of the irrigation treatments on plant height, number of leaves, fresh weight, dry weight, leaf area and chlorophyll content is presented in Table 4. Treatment four (T4) produced the highest plant height followed by treatment three (T3) then treatment two (T2). The lowest value was recorded in treatment one (T1). Moreover, the difference between T3 and T4 was not significant. This trend was similar in both seasons under study. This result was in accordance with Son and Oh [21]. They indicated that continuous and high pulse irrigation (four times per irrigation) enhanced a more stable water content and increased growth and plant height compared with the case where plants were irrigated once a day. The number of leaves was significantly affected by treatments. The highest value was observed in T4 followed by T3; the lowest values were recorded in T2 and T1. No significant difference was found between T2 and T1. The same trend was observed in both seasons.

Significant differences in plant fresh weight were found among treatments (Table 4). The best value was observed in T4 followed by T3; although T2 was higher than T1, but the difference between them was not significant. Same results were observed in both seasons.

Assouline *et al.* [22] reported that high pulse irrigation with freshwater had led to an increase in plant weight, as compared with the once daily irrigation. There is a proportional relation between increasing pulse irrigation and dry weight. The highest dry weight was reported in T4. There were no significant differences either between T3 and T2 or between T2 and T1 in both seasons. The significant effect of the frequent irrigation treatments on the dry weight may be attributed to improved phosphorus mobilization and uptake [20]. Plants leaf areas was significantly greater in treatment that received high number of pulses per irrigation (T4 and T3) than in those that received less number of pulses per irrigation (T2 and T1). Similar results were obtained in both seasons. This result is in accordance with Assouline *et al.* [22] who found that frequent irrigation had little positive effect on leaf area in the first stage of growth. Chlorophyll content had the highest significant value in T4. Chlorophyll content did not differ statistically between the rest treatments.

Effect of Irrigation Treatments on NPK Contents in Pods and Shoots:

The effect of the irrigation treatments on NPK in pods and shoots is presented in Table 5. In general, the amounts of NPK were usually greater in the pods and shoots from the plots which received high pulses irrigation per treatment (T4 and T3) than in those that received less number of pulses per irrigation (T2 and T1) in both seasons. T1 reflected the lowest concentration of all determined macro-elements in shoots and pods during both seasons of the experiment. High pulse irrigation improved concentration of N and P in leaves [22]. More frequent irrigation may increase the amount of water in the root zone reducing the water solution viscosity and increasing movement and absorption of such macro-elements from the soil by plants on bean [23]. The lower pulses per irrigation was connected with the effect of this method on decreasing the vegetative growth of plant and the chemical composition of shoots which consequently affect the chemical composition of

Table 5: NPK concentrations in shoots and pods of cv. Polista green bean during 2008 and 2009 seasons

Seasons	Treatments	N (g/kg) DW		P (g/kg) DW		K (g/kg) DW	
		Shoots	Pods	Shoots	Pods	Shoots	Pods
2008	T1	18.61 c	22.21 d	4.43 d	4.86 d	19.80 d	27.31 c
	T2	18.91 b	22.59 c	4.75 c	5.22 c	20.86 c	28.85 bc
	T3	19.11 ab	22.76 b	5.02 b	5.52 b	21.70 b	29.81 bc
	T4	18.96 b	22.95 a	5.25 a	5.79 a	22.59 a	30.88 ab
2009	T1	18.63 c	22.24 d	4.44 d	4.88 d	19.81 d	27.33 c
	T2	18.95 b	22.610 c	4.76 c	5.25 c	20.88 c	28.89 bc
	T3	19.14 ab	22.79 b	5.01 b	5.54 b	21.74 b	29.84 bc
	T4	19.23 a	22.99 a	5.00 b	5.80 a	21.87 b	33.15 a

Values followed by the same letter (s) in each column are not significantly different at 0.05 level of probability.

produced pods. Obtained results are in agreement with those reported by Gawish [24]. Increased fertigation frequency increased plant yield, especially at low nutrient concentrations and yield improvement was primarily related to increased P uptake [19, 20]. Less irrigation caused decreased vegetative growth and lower chemical composition of shoots which affected chemical composition of pods. Our results agree with Gawish [24] in this respect.

CONCLUSION

In this study, our results demonstrated that the pulse irrigation had significant effect on yields of green bean under the Mediterranean climatic conditions in Egypt. The higher number of pulses per each irrigation (three or four times) had significant effect on yield and nutrients concentration. Thus, it is recommended to apply irrigation water at three or four times per each irrigation. We hypothesized that by applying pulse irrigation and nutrients at the rates that the plant requires, we would be able to reduce the quantities of fertilizer needed to achieve optimal production.

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