PRODUCTIVITY AND WATER UTILIZATION EFFICIENCY OF WILLIAMS BANANA PLANTS UNDER DRIP IRRIGATION SYSTEM IN CALCAREOUS SOILS

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ABSTRACT

The present study was carried out at a private orchard farm, North Tahrir area- Behera Governorate, on Williams banana plants (Musa cavendishii Lamb.), during the 2002 and 2003 years. The experimental site represents newly reclaimed calcareous soils. The investigation aimed to estimate the effect of drip irrigation treatments on growth parameters, yield, yield parameters, amount of applied irrigation water and water utilization efficiency of Williams banana plants. The experiment implied four irrigation treatments (I_1 = irrigation every day, with amount of water equals 120% of potential evapotranspiration, ETp, determined by class A pan, I_2 = irrigation daily, with amount of water equals 100% ETp, I_3 = irrigation daily, with amount of water equals 80% ETp, and I_4 = irrigation daily with amount of water equals 60% ETp).

Results revealed that the growth parameters; yield parameters and banana yield, were significantly affected by the tested drip irrigation treatments. The I_1 irrigation treatment gave the highest values of all tested parameters. Banana yields for I_1 treatment were 70 and 90% higher than the yields of I_4 treatments in the first and second seasons, respectively. The amounts of applied irrigation water ranged from 4785 to 9477 m^3/fed/yr and from 4390 to 8840 m^3/fed/yr, in the 1st and 2nd seasons, respectively. The maximum value of applied irrigation water occurred in August. The maximum water utilization efficiency values were 4.38 and 4.13 kg banana/m^3 applied irrigation water, in the two respective years, and were obtained from I_4 irrigation treatment. While, the lowest values were 3.75 and 3.76 kg banana/m^3 applied irrigation water, in the 1st and 2nd seasons, respectively and were obtained from the I_1 irrigation treatment.

INTRODUCTION

The quantity and quality of irrigation water are the two important limiting factors for drip irrigation system. Several investigators reported that banana yield increased with increasing water quantity (Holder and Gumbs, 1983; Robinson and Nel, 1994; Bosu et al., 1995; Goenaga and Irizarry, 1998; More et al., 1999; Salvin et al., 2000 and Seidhom, 2001).

For any irrigation system, the uniformity and efficiency of using both water and fertilizer by the growing plants are of major importance. Ideally, the application of water throughout the system should be absolutely uniform. For drip irrigation system, each dripper throughout the system should deliver exactly a predetermined amount of water (Vermeiren and Jobling, 1984).

In Egypt, most of the newly reclaimed areas are planted with fruit plants, under drip irrigation. Due to the variation in the amount of irrigation water received by the growing plants in the same sub unit, growth, nutrients uptake, fruit yield and consequently, both water and fertilizers use efficiency by plants, varied also from one plant to another (Ibrahim, 1993b).

Water use efficiency was positively correlated with moisture regime. High crop coefficient values indicated high consumptive use of water (Hassan and Seif, 1999). Water utilization efficiency and yield efficiency values are affected by the amount of applied water (Ibrahim. 2003).

Main objectives of the present work are to study the effect, of drip irrigation water treatments on growth parameters, yield, water requirements and water utilization efficiency of Williams Banana plants.

MATERIALS AND METHODS

The present study was carried out during the two successive years of 2002 and 2003, in a private orchard farm at North Tahrir, Behera Governorate, on Williams banana plants. Plants were grown at 3.5 X 3.5m apart in calcareous soils. Field capacity, wilting points, available soil moisture and bulk density of the soil are given in Table 1. Some chemical and physical characters of the tested soil were determined according to Page et al. (1982). Results of the analysis are presented in Table 2. Main chemical characteristics of the irrigation water are given in Table 3.

Table 1. Field capacity (FC), wilting point (WP), available soil moisture (ASM) and bulk density (BD) values of the soil at the experimental farm.

Soil depth (cm)	FC (%)	WP (%)	ASM (%)	BD (g/cm^3)
0 – 15	29.8	16.2	13.6	1.10
15 – 30	28.5	15.9	12.6	1.18
30 – 45	27.7	15.2	12.7	1.23
45 – 60	25.4	13.8	11.6	1.28
Average	27.8	15.2	12.6	1.20

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Table 2. Chemical and mechanical analysis of the soil at the experimental farm.

Soil depth (cm)	Chemical analysis				Mechanical analysis				
	$CaCO_3$ (%)	O.M. (%)	pH	EC (dS/m)	Coarse Sand (%)	Fine Sand (%)	Silt (%)	Clay (%)	Texture
0–30	25.2	0.27	8.2	1.00	13.0	38.3	26.9	21.8	Sandy loam
30-60	27.8	0.35	8.1	0.79	10.2	40.1	28.5	21.2	Sandy loam

Table 3. Main chemical characteristics of irrigation water at the experimental site.

Sample	pH	EC_w dS/m	Soluble cations – meq/l				Soluble anions – meq/l				SAR
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	CO_3^{--}	HCO_3^{-}	SO_4^{--}	
1	8.42	0.62	2.27	0.76	2.91	0.26	4.03	0.00	1.43	0.74	2.35
2	8.34	0.63	2.50	0.83	2.88	0.19	3.97	0.00	1.53	0.77	2.23
Average	8.38	0.63	2.39	0.80	2.90	0.22	4.00	0.00	1.48	0.76	2.29

The suckers were planted in March 2001 (Three offshoot/mother plant). The experiment started on the first ratoon and its suckers were chosen on the 1st week of July 2001, as well as, on the second ratoon and its suckers were chosen at the same time in 2002. The stools were thinned, and three suckers were left for fruiting in the following season. In addition, three plants were left to give the crop in the current season.

The drip irrigation system, used in the orchard farm includes, an irrigation pump connected to sand and screen filters, and a hydraulic fertilizer injection pump. The main line is made of a PVC pipe of 63mm diameter. Laterals of 16mm diameter are connected to sub main line. Each lateral is 50m long with standard drippers of 4 l/h discharge rate, spaced at 0.5m apart. Two laterals served each row of banana plants. The system was setup such that 6 drippers/hole was used. Class A pan was used to determine the amount of applied irrigation water for the tested irrigation treatments.

Irrigation treatments were as follows:

I_1: Irrigation daily with amount of water equals 120% of potential evapotranspiration (ETp) values determined by class A pan.

I_2: Irrigation daily with amount of water equals 100% of potential evapotranspiration (ETp) values determined by class A pan.

I_3: Irrigation daily with amount of water equals 80% of potential evapotranspiration (ETp) values determined by class A pan.

I_4: Irrigation daily with amount of water equals 60% of potential evapotranspiration (ETp) values determined by class A pan.

Potential evapotranspiration (ETp) values were obtained from the class A pan method as follows:

$$ETp = Epan \times Kpan$$ (Doorenbos and Pruitt,1984)

where:

Epan: is pan evaporation (mm/day)

Kpan: is pan coefficient. Its value depends on the relative humidity, wind speed and the site of the pan (vegetative or bare soil). A Kpan value of 0.75 was used at the experimental site according to the weather conditions.

For both seasons, the selected plants (15 plants/treatment, 3 plants/replicate) received all agronomic practices usually used in banana plantation. The following parameters were used to evaluate the tested treatments:

1- Vegetative growth.

At the bunch shooting stage, plant height (from soil surface to the top of the curve of bunch stalk), girth of pseudostem (20cm above ground level), number of green leaves was measured, and number of suckers was determined, on each experimental plant during the period from April to the end of June in both seasons. All leaves were used to determine leaf area. The area of each leaf was determined according to the following equation:

$$Leaf\ area = length \times width \times 0.86$$

(Obiefiuna and Ndubizu, 1979)

2- Yield and yield parameters.

At harvest time, all bunch weights (in kg) and harvested yield (t/fed) were determined. Also, number of hands and number of fingers per bunch were counted.

3- Soil – water relations.

3.a- Applied irrigation water (AIW):

The amount of irrigation water was calculated according to the following equation:

$$AIW = \frac{ETp \times Kc \times Kr}{Ea} + LR$$

(Vermeiren and Gopling, 1984)

where:

AIW = Daily applied irrigation water depth (mm/day)

ETp = potential evapotranspiration (mm/day) values obtained by class A pan evaporation method.

Kc = crop coefficient values given as 0.5, 0.8, 1.1, 0.9 and 0.75 for initial, development, mid-season, late season, and at harvest stages of banana growth, respectively (Doorenbos and Kassam, 1986).

Kr = reduction factor that depends on ground cover. It equals 0.7 for mature plants (Doorenbos and Kassam, 1986).

Ea = irrigation efficiency = $K_1 \times K_2$ = 0.85 (these two values were determined during the evaluation of drip irrigation system that was done before conducting the field experiment). Where:

K_1 = emitter uniformity coefficient = 0.9 for the experimental site.

K_2 = drip irrigation system efficiency = 0.95 for the experimental site.

LR = leaching requirements = 10% of the total amount of water applied.

3.b- Water utilization efficiency (WUtE):

Water utilization efficiency values were calculated according to Jensen (1983) as:

$$WUtE = \frac{Banana\ Yield\ (kg/fed)}{Applied\ Irrigation\ Water\ (m^3/fed)}$$

A complete randomized blocks design, with five replicates, was used in this experiment and the obtained data were statistically analyzed according to Snedecor and Cochran (1973).

RESULTS AND DISCUSSION

1- Growth parameters:

Effect of drip irrigation treatments on growth parameters (final pseudostem height, final pseudostem girth, number of green leaves, number of suckers, leaf area and number of days from shooting to harvest) during the 2002 and 2003 growing years, is presented in Table 4. For the two growing years, results showed that all growth parameters were significantly affected by drip irrigation treatments. The I_1 irrigation treatment (120% ETp) gave the highest values of all growth parameters. As such, increasing amount of irrigation water will significantly increase all growth parameters. It is clear from the results that adequate soil moisture along the growing year, enhanced the development of growth parameters. The obtained results agree with those reported by Holder and Gumbs (1993), Robinson and Nel (1994) and Salvin et al. (2000).

2- Yield and yield parameters:

Results in Table 5, present the effect of drip irrigation treatments on banana yield and yield parameters, in the two growing years. Irrigation treatments significantly influenced number of hands and number of fingers per bunch, bunch weight (kg) and yield (t/fed).

The I_1 irrigation treatment gave the highest values of all parameters in the two years. The number of hands per bunch, number of fingers per bunch and banana yield recorded significant increase of 102, 120, and 69%, in the first year and 140, 116, and 90%, in the second year, respectively, as compared with I_4 irrigation treatment (60% ETp). Therefore, banana yield tended to increase by increasing amount of irrigation water, in the two growing years. Also, water deficit adversely affected crop growth and yield. The establishment, vegetative, flowering and yield formation periods were affected by water deficits. Water deficits during the previous periods affected the rate of leaf development,
which in turn, influenced number of flowers, number of hands and bunch production. The obtained results were in line with those of Bosu et al. (1995), More et al. (1999), Seidhom (2001), and Ibrahim (2003).

Table 4. Means of growth parameters of Williams banana plants as affected by drip irrigation treatments during 2002 and 2003 growing years.

Irri. Treat.	2002						2003					
	Final pseud. Height (cm)	Final pseud. girht (cm)	No. of green leaves	No. of suckers	Leaf area (m^2)	Days to harvest (day)	Final pseud. Height (cm)	Final pseud. girht (cm)	No. of green leaves	No. of suckers	Leaf area (m^2)	Days to harvest (day)
I_1	321.4	104.0	16.0	3.0	2.28	144	321.6	101.2	16.6	3.4	2.03	137
I_2	292.0	89.4	13.8	2.2	1.80	128	298.2	91.0	14.8	2.4	1.61	129
I_3	257.0	74.0	12.2	1.6	1.18	119	263.0	78.2	11.6	1.8	1.34	118
I_4	208.0	65.8	10.4	1.2	1.28	115	204.6	62.4	9.2	0.8	1.10	108
F. test	***	***	***	**	***	***	***	***	***	***	***	***
LSD0.05	30.7	5.4	1.1	0.77	0.25	6	19.5	4.1	1.2	0.71	0.26	3.5

Table 5. Means of yield parameters of Williams banana plants as affected by drip irrigation treatments during 2002 and 2003 growing years.

Irrigation Treatment	2002				2003			
	No. of hands/bunch	No. of fingers/bunch	Bunch weight (kg)	Yield (t/fed)	No. of hands/bunch	No. of fingers/bunch	Bunch weight (kg)	Yield (t/fed)
I_1	14.6	283.2	34.6	35.56	14.4	273.2	32.4	33.26
I_2	14.0	255.0	29.0	29.80	13.4	245.0	28.8	29.58
I_3	9.6	222.2	25.4	26.10	6.8	218.6	21.2	21.78
I_4	7.2	128.6	20.4	20.96	6.0	126.0	17.0	17.52
F. test	***	***	***	***	***	***	***	***
LSD0.05	0.83	19.12	2.61	2.69	1.25	12.57	1.51	1.59

3-Plant-water relations:

3.1. Amount of applied irrigation water (AIW):

The amount of applied irrigation water, for Williams banana plants, during 2002 and 2003 growing years, are presented in Table 6. Amounts of applied water were also expressed as, liter/plant/day and m^3/fed/month. Application of 120, 100, 80, and 60% of ETp gave 9477, 7894, 6280, and 4785 m^3/fed/year in the 1st year, and 8840, 7336, 5794, and 4390 m3/fed/year in the 2nd year, respectively. At the beginning of the season, the amount of applied water was low and increased after that due to increasing vegetative growth of banana plant. Then, the amounts of applied water declined at maturity. Maximum values of applied irrigation water to banana plants occurred in August, in the first year, and in July and August in the second year. Results of this study were in close agreement with those reported by Doorenbos and Kassam (1986) and Ibrahim (2003).

3.2. Water utilization efficiency (WUtE):

Values of water utilization efficiency for the tested variables, during the two growing years are presented in Table 7. Results showed, that the water utilization efficiency values were significantly affected by drip irrigation treatments. The maximum values of WUtE were 4.38 and 4.13 kg banan/m^3 applied irrigation water, in the first and second years, respectively, and were obtained by the I_4 irrigation treatment (60% ETp). The lowest values of WUtE were 3.75 and 3.76 kg banana/m^3 applied irrigation water in the first and second years, respectively, and were obtained by the I_1 irrigation treatment (120% ETp). Also, there was no significant difference between WUtE values for the I_3 and I_4 in the first year, and between I_2 and I_4 in the second year. The obtained water utilization efficiency values were in line with the values reported by Hegde and Srinivas (1991), Bosu et al. (1995), Hassan and Seif (1999), Salvin et al. (2000), and Ibrahim (2003).

CONCLUSIONS

From the results of the study, it could be concluded that:

1-The highest values of banana yield, were obtained by irrigation with amount of water equals 120% of potential evapotranspiration (ETp).

2-Banana yields recorded significant increase of 69 and 90% in the 1st and 2nd years, respectively for the I_1 and I_4 irrigation treatments.

3-The optimum value of irrigation water requirements, for Williams banana crop, grown in the newly reclaimed calcareous soils under drip irrigation system, was 9158 m^3/fed/year.

4-The mean values of water utilization efficiency, for Williams banana crop, ranged between 3.75 and 4.25 kg banana/m^3 applied irrigation water.

Table 6. Applied irrigation water (AIW) for Williams banana plants, as affected by drip irrigation treatments during 2002 and 2003 growing years.

Month	AIW	2002				2003			
		I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4
Jan.	L/plant/day	10	8	6	5	9	7	6	4
	M^3/fed/month	310	248	186	155	279	217	186	124
Feb.	L/plant/day	16	13	10	8	15	12	9	7
	m^3/fed/month	448	364	280	224	420	336	252	196
Mar.	L/plant/day	19	16	13	10	18	15	12	9
	m^3/fed/month	589	496	403	310	558	465	372	279
Apr.	L/plant/day	25	21	17	13	24	20	16	12
	m^3/fed/month	750	630	510	390	720	620	480	360
May	L/plant/day	27	23	18	14	23	19	15	11
	m^3/fed/month	837	713	558	434	713	589	465	341
Jun.	L/plant/day	35	29	23	17	32	27	21	16
	m^3/fed/month	1050	870	690	510	960	810	630	480
Jul.	L/plant/day	37	31	25	19	40	33	26	20
	m^3/fed/month	1147	961	775	589	1240	1023	806	620
Aug.	L/plant/day	38	32	26	19	40	33	26	20
	m^3/fed/month	1178	992	806	589	1240	1023	806	620
Sep.	L/plant/day	34	28	22	17	29	24	19	15
	m^3/fed/month	1020	840	660	510	870	720	570	450
Oct.	L/plant/day	29	24	19	14	25	21	17	13
	m^3/fed/month	899	744	589	434	775	651	527	403
Nov.	L/plant/day	22	18	14	11	20	17	13	10
	m^3/fed/month	660	540	420	330	600	510	390	300
Dec.	L/plant/day	19	16	13	10	15	12	10	7
	m^3/fed/month	589	496	403	310	465	372	310	217
Total	**m^3/fed/year**	**9477**	**7894**	**6280**	**4785**	**8840**	**7336**	**5794**	**4390**

Table 7. Water utilization efficiency mean values, as affected by drip irrigation treatments for the 2002 and 2003 growing years.

Irrigation treatments	Water utilization efficiency (kg banana/m^3 applied water)	
	2002	2003
I_1	3.75	3.76
I_2	3.78	4.03
I_3	4.16	3.76
I_4	4.38	4.13
F. test	*	*
LSD0.05	0.44	0.25

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الملخص العربي

الإنتاجية وكفاءة استعمال المياه لمحصول الموز (صنف وليامز) تحت نظام الرى بالتنقيط فى الأراضى الجيرية

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تم دراسة الإنتاجية وكفاءة استعمال الوحدة من المياه المضافة لمحصول الموز (صنف وليامز) تحت نظام الرى بالتنقيط فى الأراضى الجيرية. وقد نفذت الدراسة بمزرعة خاصة بمنطقة شمال التحرير – محافظة البحيرة خلال سنتى ٢٠٠٢ و ٢٠٠٣.

استهدفت الدراسة بحث تأثير أربعة معاملات للرى بالتنقيط (أ١: الرى يوميا بكمية مياه تعادل ١٢٠% من جهد البخر-نتح المقدر باستخدام وعاء البخر القياسى ، أ٢: الرى يوميا بكمية مياه تعادل ١٠٠% من جهد البخر– نتح ، أ٣: الرى يوميا بكمية مياه تعادل ٨٠% من جهد البخر– نتح ، أ٤: الرى يوميا بكمية مياه تعادل ٦٠% من جهد البخر– نتح) على الإنتاجية ومكونات المحصول والإحتياجات المائية وكفاءة استعمال الوحدة من المياه.

وأوضحت النتائج مايلى:

١- يوجد اختلاف معنوى فى الناتجية المحصول والصفات المرتبطة بالمحصول باختلاف معاملات الرى.

٢- أعلى قيمة لمحصول الموز تحصل عليها من معاملة الرى أ١ وهى الرى يوميا بكمية مياه تعادل ١٢٠% من جهد البخر – نتح.

٣- زاد محصول الموز زيادة معنوية بكمية تعادل ٧٠% ، ٩٠% فى السنتين الأولى والثانية على الترتيب وذلك بمقارنة معاملتى الرى أ١ و أ٢.

٤- أنسب قيمة للإحتياجات المائية لمحصول الموز (صنف وليامز) كانت ٩١٥٨ م٣/فدان/سنة تحت نظام الرى بالتنقيط والتى تعطى أعلى محصول.

٥- متوسط كفاءة استعمال وحدة مياه الرى المضافة تراوحت بين ٣,٧٥ و ٤,٢٥ كجم موز/م٣ ماء مضاف.