Response of banana "WILLIAMS" yield and fruit quality to irrigation at Nubaria area

El-Shenawi[1], M.R., H.E. Khalifa[2], A.M. Osman[2], and A.M. El-Assar[1]

1- Horticulture Research Institute, ARC, Egypt.

2- Soil, Water and Environment Research Institute, ARC, Egypt.

ABSTRACT

A 2-yr study was conducted in a private farm in the newly reclaimed calcareous soils of Nubaria area during the 2002/2003 and 2003/2004 seasons, to determine yield, yield components, fruit quality, applied irrigation water, water utilization efficiency and crop response factor of banana crop (var. "Williams") subjected to four levels of irrigation. Irrigation treatments were based upon Class A pan factors ranged from 0.6 to 1.2 in increments of 0.2. Surface drip irrigation system was used in this experiment. A randomized complete blocks design (RCBD) with five replicates was used.

Results showed that irrigation treatments had a significant effect on banana yield, yield components and fruit quality parameters. Banana yields were 31.9, 28.47, 20.36, and 14.47 t/fed corresponding to pan factors of 1.2, 1.0, 0.8, and 0.6, respectively. This indicates that banana yields were highly linearly related to the applied irrigation water. Results revealed also that, increasing the pan factor from 0.6 to 1.2 resulted in a significant increase in finger's weight, length, and diameter. Results showed that banana fruit TSS (%) and starch (%) decreased with increasing amounts of applied water, while total acidity, pulp (%), and total sugar (%) increased with increasing Class A pan factor.

Average applied irrigation water varied from 7522 to 3761 m^3/fed/yr for the respective pan factors. An average water utilization efficiency value of 4.24 kg/m^3 applied water was obtained from the I_1 irrigation treatment (irrigation with amount of water equals 120% ETp). A banana yield response factor (Ky) of 1.08 was obtained indicating a lower impact of deficit irrigation practices on banana yield. It may be concluded from this investigation that, to obtain an optimum yield, banana crop grown under calcareous soils and drip irrigation conditions at Nubaria area should be irrigated with a pan factor of not less than 1.2.

INTRODUCTION

It is well known that banana requires an ample and frequent supply of water, but information regarding water requirements for banana grown under the newly reclaimed calcareous soil and drip irrigation conditions at Nubaria region is very limited. According to FAO (1979), water requirements for banana grown in dry tropics are about 2200mm per year. Norman *et al.* (1984) stated that, the high evaporative demand in semiarid environments combined with the large transpiring surface area and shallow root system of banana makes it susceptible to water deficits. Robinson and Alberts (1989) estimated an annual evapotranspiration (ET) of banana range from 1200 to 2690mm depending on the prevailing climatic

conditions. Goenaga *et al.* (1993) conducted an experiment to determine the optimum water requirement of drip-irrigated banana grown under semiarid conditions. The irrigation treatments were based on class A pan factors ranging from 0.25 to 1.25 with increment of 0.25. Results showed that, all yield components were significantly affected by the amount of water applied. Highest marketable yield (33.9 t/ha) was obtained with the application of a pan factor treatment of 1.25.

Water is considered a scarce and vital resource that is decreasing due to the increasing population. One method to maximize the use of this limited resource is the use of modern irrigation systems. Hedge and Srinivas (1991) stated that drip irrigation is one important method developed for economizing the use of irrigation water. It is well suited to widely spaced crops such as banana. Goenaga and Irizarry (1995) indicated that drip irrigation technology permits the efficient use of water and can help maximize the utilization of semiarid lands for agricultural production. Locascio and Smajstrla (1996) stated that as the need to conserve water increases, the use of drip irrigation system has increased. They indicated also that, applying water by drip system in relation to the amount of water evaporated from Class A pan is a convenient method to schedule irrigation.

In Egypt, Hassan and Seif (1999) reported positive correlation between water use efficiency of banana and moisture regime. El-Sayed et al. (2002) stated that yield efficiency tended to increase as quantity of applied irrigation water increased. Ibrahim (2003) evaluated the productivity of Grand Nain banana under two irrigation systems (drip and micro-sprinkler) and three amounts of applied irrigation water (6000, 9000, and 12000 m^3/fed/yr). Results showed significant effect of the tested variables on banana yield. The highest yields of 26.4, 39.2, and 36.2 t/fed for the mother plant, 1st ratoon, and 2nd ratoon, respectively were obtained from the combined effect of micro-sprinkler irrigation system and the 12000 m^3/fed/yr amount of applied irrigation water treatment.

The main objectives of this study were to test the effect of four irrigation treatments on banana's (var. "Williams") yield, physical and chemical fruit parameters, amount of applied irrigation water, water utilization efficiency, and yield response factor under drip irrigation in the newly reclaimed calcareous soils conditions at Nubaria region.

MATERIALS AND METHODS

The present study was conducted in a private farm at Nubaria region during the 2002/2003 and 2003/2004 growing seasons. The soil texture at the farm is sandy clay loam with the following features, soil pH of 8.4, soil

saturation extract conductivity (EC_e) of 2.5 dS/m, organic matter (OM) content of 0.4%, and calcium carbonate contents of 29%. Average values of field capacity, wilting point and bulk density are 24%, 13%, and 1.3 g/cm^3, respectively.

The surface drip irrigation system used in the farm includes an irrigation pump (50 hp) connected to sand and screen filters and a fertilizer injector tank. The conveying pipeline system consists of a main line that is made of PVC pipe of 76.2mm diameter connected to sub-main line of 50.8mm and manifold of 38.1mm. The drip lateral lines of 16mm diameter are connected to the manifold line. Each plant line is served by two lateral lines about 0.60m apart (i.e., 0.30m from each side of the pseudostems). Lateral lines equipped with build-in emitters of 3.4 l/h discharge were spaced 0.3m apart on the lateral line. There were 6 emitters per hole (i.e., 2 banana plants).

Suckers of banana (var. "Williams") were planted at a 3.0 x 3.0m spacing (equivalent to 467 plants per feddan) in March 2001. In both growing seasons, the mother plants were removed and two offshoots were selected and left in each hole to carry out the present experiment. All agricultural practices for banana production at Nubaria region, except for irrigation, were followed.

A randomized complete blocks design (RCBD) with five replicates was adopted. Each experimental unit consisted of five plant-lines. Each plant-line consisted of nine holes, where two plants per hole were kept for fruiting in the current season and two suckers were kept for fruiting the following season. On the 1st of December of 2003 and 2004, bunches were picked and weight was recorded. Before artificial ripening, yield (t/fed) was computed. After ripening, the following measurements were carried out:

A: Physical fruit parameters:

1- Average finger weight (g), length (cm), and diameter (cm).

B- Chemical fruit parameters:

1- Starch percentage, according to A.O.A.C. (1995).

2- Total acidity percentage (g malic acid/100g pulp), according to A.O.A.C. (1995).

3- Pulp percentage.

4- Total soluble solid (TSS, %).

5- Total sugar (%).

Four amounts of applied irrigation water based on Class A pan factors (proportion of pan evaporation) were tested in this experiment. The irrigation treatments were as follow:

I_1: Irrigation with amount of water equals 120% of potential evapotranspiration (ETp) determined by Class A pan (i.e., pan factor of 1.2).

I_2: Irrigation with amount of water equals 100% of ETp (i.e., pan factor of 1.0).
I_3: Irrigation with amount of waequals 80% of ETp (i.e., pan factor of 0.8).
I_4: Irrigation with amount of water equals 60% of ETp (i.e., pan factor of 0.6).

Soil water relations:

1- Amount of applied irrigation water (AIW):

The amount of applied water was measured by a flow meter and was calculated according to the following equation (FAO, 1984):

$$AIW = \frac{S_p \, X \, S_l \, X \, ET_o \, X \, K_c \, X \, K_r \, X \, I \, interval}{Ea} + LR$$

where:

AIW = applied irrigation water depth (liters/day).
Sp = distance between plants in the same line (m).
S_l = distance between lines (m).
ET_o = potential evapotranspiration (mm/day) values obtained by Class A pan evaporation method (FAO, 1979) and calculated as follows:

$$ET_o = E_{pan} \, X \, K_{pan}$$

where :

E_{pan} = measured pan evaporation daily values (mm/day).
K_{pan} = pan coefficient. K_{pan} values depend on the relative humidity, wind speed and the site conditions (bare or cultivated). A K_{pan} value of 0.75 was used for the experimental site (FAO, 1979).
K_c = crop coefficient, the values used in this study were 1.0, 1.1, 1.2, and 1.1 for initial, crop development, mid-season, and late-season growth stages, respectively (FAO, 1977).
K_r = reduction factor that depends on ground cover. It equals 0.7 for mature trees (FAO, 1979).
E_a = irrigation efficiency = K_1 x K_2 = 0.80

where:

K_1 = emitter uniformity coefficient = 0.90 for the experimental site.
K_2 = drip irrigation system efficiency = 0.89 for the experimental site.
$I_{interval}$ = irrigation intervals (days) = 1 day for the experimental site.

LR = leaching requirements (FAO, 1977) = $\frac{EC_w}{2 \, Ma \, X \, EC_e}$

where:

EC_w = electrical conductivity of the irrigation water (1.2 dS/m).
Max EC_e = maximum tolerable electrical conductivity of the soil saturation extract for banana crop (5 dS/m).

2- Water utilization efficiency (W.U.E):

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

$$W.U.E. = \frac{\text{Fruit Yield (Kg/Fed)}}{\text{Applied Irrigation Water (m}^3\text{/Fed)}}$$

3- Yield response factor (K_y):

The yield response factor, which links relative yield decrease to relative evapotranspiration deficit, is expressed by the standard formulation given by Vaux and Pruitt (1983) as follows:

$$Ky = \frac{\left(1 - \frac{Ya}{Ym}\right)}{\left(1 - \frac{AIWa}{AIWm}\right)}$$

where:

K_y: yield response factor,
Y_a: actual yield (t/fed) under experimental conditions,
Y_m: maximum yield (t/fed) under experimental conditions,
AIW_a: actual amounts of applied irrigation water (m^3/fed/yr).
AIW_m: maximum amount of applied irrigation water (m^3/fed/yr).

Statistical analysis:

The data were analyzed using the CoHort Software (1986) statistical package. Average values from the five replicates of each treatment were interpreted using the analysis of variance (ANOVA). The Duncan's Multiple Range Test was used for comparisons between different sources of variance as advised by Steel and Torrie (1980).

RESULTS AND DISCUSSION

1- Banana yield and yield components (physical fruit parameters):

The effect of irrigation treatments on banana yield (t/fed) and finger's weight (gm), length (cm) and diameter (cm) is presented in Table 1. Results indicated that differences in the obtained yield from the irrigation treatments were significant. Average yield were 31.87, 26.79, 20.36, and 14.47 t/fed for the I_1, I_2, I_3, and I_4 irrigation treatments, respectively. The highest yields represent an increase of 122% and 119% over those obtained from the I_4 (60% ETp) irrigation treatment in the 2002/2003 and 2003/2004 growing seasons, respectively. Similar results were reported by Ibrahim (2003). He reported 13.2, 29.34, and 36.12 t/fed for the 6000, 9000, and 12000 m3/fed/yr amounts of applied irrigation water.

Results showed also that, increments in Class A pan factor treatments resulted in significant increases in finger's weight, length, and diameter. Finger weights received amounts of irrigation water according to a Class A pan factor of 1.2 were 13.5, 32.8, and 97% heavier than those for the 1.0, 0.8, and 0.6 pan factors, respectively. The same trend was noticed for finger's length and diameter. Average finger length for the I_1 (120% ETp) irrigation treatment was 16.4, 30.7, and 51.3% longer than those of I_2, I_3, and I_4 irrigation treatments, respectively. Average finger diameter for the Class A pan factor of 1.2 was 13.7, 30.6, and 73.4% thicker than those of the respective pan factors.

Table 1: Effect of irrigation treatments on banana's yield (t/fed) and yield components (physical fruit parameters) in the 2002/2003 and 2003/2004 seasons.

Irri. Treat.	Yield (t/fed)		Finger weight (gm)		Finger length (cm)		Finger diameter (cm)	
	2002/2003	2003/2004	2002/2003	2003/2004	2002/2003	2003/2004	2002/2003	2003/2004
I_1	33.00	30.74	114.96	118.04	21.18	21.18	4.04	3.90
I2	27.06	26.88	102.22	97.70	18.44	17.96	3.56	3.42
I_3	20.92	19.80	87.64	83.26	16.44	15.96	3.14	2.94
I_4	14.86	14.07	59.10	56.20	14.06	13.94	2.32	2.26
$LSD_{0.05}$	2.188	1.512	7.892	7.575	0.827	1.521	0.222	0.270

2- Chemical fruit parameters:

Results indicated significant effect of irrigation treatments on the tested chemical fruit quality parameters (Table 2). Results showed that banana fruit TSS (%) and starch (%) decreased with increasing amounts of applied water. Average TSS (%) values were 14.9, 17.9, 20.1, and 22.3% for the I_1, I_2, I_3, and I_4 irrigation treatments, respectively. The obtained results agreed well with those of Patel *et al.* (1993). They stated that banana fruit TSS were lowest in treatments irrigated with high amounts of irrigation water. Results of this investigation revealed that average value of starch (%) for I_4 irrigation treatment was 46.4, 29.9, and 12% more than those of I_1, I_2, and I_3 irrigation treatments, respectively.

Table 2: Effect of irrigation treatments on chemical fruit parameters in the 2002/2003 and 2003/2004 seasons.

Irri. Treat.	TSS (%)		Total acidity (%)		Pulp (%)		Total sugar (%)		Starch (%)	
	2002/2003	2003/2004	2002/2003	2003/2004	2002/2003	2003/2004	2002/2003	2003/2004	2002/2003	2003/2004
I_1	15.20	14.60	0.392	0.374	76.4	73.8	18.18	19.80	7.48	7.47
I_2	18.60	17.20	0.328	0.319	70.0	68.6	17.38	18.52	8.39	8.36
I_3	20.12	20.00	0.272	0.246	61.4	63.0	14.80	16.41	9.53	9.89
I_4	22.88	21.76	0.221	0.174	59.2	58.0	12.64	14.45	10.92	10.96
$LSD_{0.05}$	1.728	1.984	0.044	0.048	2.901	4.051	1.105	1.490	0.636	0.512

The obtained values of total acidity, pulp (%), and total sugar (%) increased with increasing Class A pan factor. Average total acidity values were 0.383, 0.324, 0.259, and 0.198 for the I_1, I_2, I_3, and I_4 irrigation treatments, respectively. Average values for pulp (%) were 75.1, 69.3, 62.2, 58.6% for the same respective irrigation treatments. Average total sugar (%) for the I_4 irrigation treatment was 40.2, 32.5, and 15.2% less than those of I_1, I_2, and I_3 irrigation treatments, respectively.

3- Banana's water relations:

3.1. Applied irrigation water (AIW):

The effect of tested irrigation treatments on applied irrigation water expressed as liters/hole/day, m^3/fed/month, and m^3/fed/year for the 2002/2003 and 2003/2004 growing seasons is presented in Table 3. Results show that the lowest amounts of water requirements occur during January of both seasons and the highest amounts occur during August. Average amounts of applied irrigation water were 7522, 6268, 5014, and 3761 m^3/fed/yr for the I_1, I_2, I_3, and I_4 irrigation treatments, respectively. The obtained amounts equal 1791, 1493, 1194, and 896 mm/fed/yr for the same respective treatments. From the results of this study, it could be concluded that the amount of applied irrigation water for a good yield of banana crop should be ? 7522 m^3/fed/yr (1791 mm/fed/yr). The obtained result was within the irrigation requirements for banana crop reported by FAO (1979). They stated that the water requirements per year vary between 1200mm in the humid tropics to 2200mm in the dry tropics.

A linear regression analysis was run to develop a relationship between banana yield (t/fed) and the amounts of applied irrigation water (m^3/fed/). The obtained linear Yield – AIW relationship is illustrated in Figure 1 and expressed as:

Yield (T/Fed) = .0047 AIW (m^3/Fed/Yr) – 3.047 r^2 = 0.9944

The high coefficient of determination value (r^2 = 0.9944) indicates that banana yield is linearly related to the amount of applied irrigation water under the experimental conditions and the tested irrigation treatments (i.e., 3500 ? AIW ? 8000 m^3/fed/yr). The obtained result indicates that, a Class A pan factor of ? 1.2 should be used to obtain a good yield of banana crop at Nubaria region.

Table 3: Effect of irrigation treatments on the amounts of applied irrigation water for the 2002/2003 and 2003/2004 growing seasons.

Month	AIW	2002/2003				2003/2004			
		I_1	I_2	I_3	I_4	I_1	I_2	I_3	I_4
Jan.	L/hole/day	16	13	11	8	10	8	7	5
	m³/fed/month	230	192	153	115	146	122	98	73
Feb.	L/hole/day	20	16	13	10	17	14	12	9
	m³/fed/month	259	216	173	130	227	189	151	113
Mar.	L/hole/day	33	27	22	16	28	24	19	14
	m³/fed/month	475	396	317	238	411	343	274	206
Apr.	L/hole/day	44	37	29	22	42	35	28	21
	m³/fed/month	620	516	413	310	587	490	392	294
May	L/hole/day	45	38	30	23	48	40	32	24
	m³/fed/month	654	545	436	327	691	576	460	345
Jun.	L/hole/day	68	56	45	34	68	57	45	34
	m³/fed/month	949	791	633	474	953	794	635	476
Jul.	L/hole/day	71	59	48	36	70	58	46	35
	m³/fed/month	1032	860	688	516	1006	839	671	503
Aug.	L/hole/day	77	64	51	38	76	63	51	38
	m³/fed/month	1111	926	741	556	1102	919	735	551
Sep.	L/hole/day	56	46	37	28	52	43	35	26
	m³/fed/month	781	651	520	390	729	608	486	365
Oct.	L/hole/day	45	37	30	22	42	35	28	21
	m³/fed/month	650	542	433	325	612	510	408	306
Nov.	L/hole/day	40	33	27	20	39	33	26	20
	m³/fed/month	559	466	373	280	550	459	367	275
Dec.	L/hole/day	25	21	17	13	24	20	16	12
	m³/fed/month	366	305	244	183	341	284	228	171
Total	m^3/fed/year	7686	6405	5124	3843	7357	6131	4904	3678

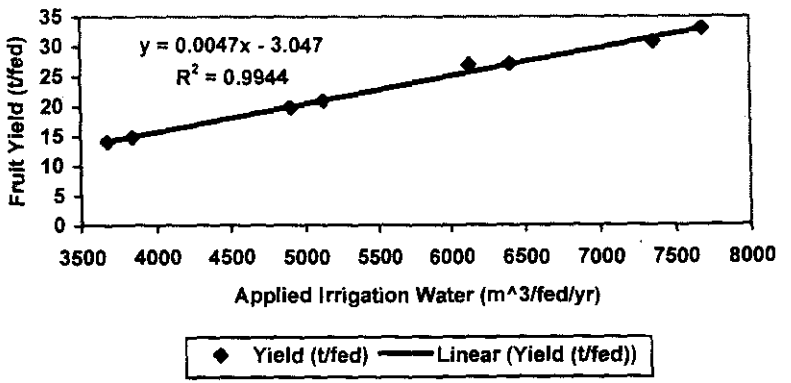

Figure 1: Linear relationship between applied irrigation water banana yield.

3.2. Water utilization efficiency (WUtE):

The calculated water utilization efficiency (kg yield/m^3 applied water) values for the tested irrigation treatments are presented in Table 4. Results indicate that, increasing the amounts of applied irrigation water led to an increase in water utilization efficiency values. Average water utilization efficiency values were 4.23, 4.30, 4.06, and 3.85 kg fruit/m^3 applied irrigation water for the I_1, I_2, I_3, and I_4 irrigation treatments, respectively. The highest WUtE value of 4.38 kg/m^3 was obtained from the I_2 (100% ETp) irrigation treatment during the 2003/2004 growing season. The obtained results were in close agreement with those reported by FAO (1979). They showed that the water utilization efficiency for harvested yield of banana fruits is 2.5 to 4.0 kg/m^3 for plant crops and 3.5 to 6.0 kg/m^3 for ratoon crops. The results were also close to those of Ibrahim (2003). He reported WUtE values of 2.2, 3.26, and 3.01 kg fruit/m^3 of applied water for the 6000, 9000, and 12000m^3 of the amounts of applied irrigation water treatments, respectively.

Table 4: The calculated water utilization efficiency values for the 2002/2003 and 2003/2004 growing seasons.

Irrigation Treatments	WUtE (kg yield/ m^3 applied irrigation water)	
	2002/2003	2003/2004
I_1 (120% ETp)	4.29	4.18
I_2 (100% ETp)	4.22	4.38
I_3 (80% ETp)	4.08	4.04
I_4 (60% ETp)	3.87	3.83

3.3. Yield response factor (Ky):

Banana yield response data from the tested irrigation treatments were fitted to the linear equation relating the relative yield decrease to the relative decrease in applied irrigation water (Figure 2). The equation representing this relation can be expressed as:

$$Y = 1.0812\ X,\ r^2 = 0.9878$$

where:

Y: represents relative yield reduction ($1 - Y_a/Y_m$).

X: represents relative reduction in applied irrigation water ($1 - AIW_a/AIW_m$).

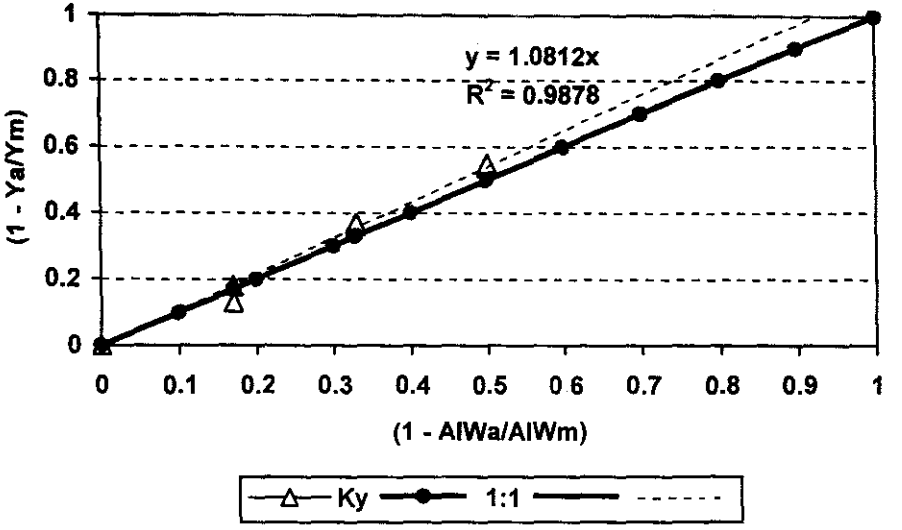

Figure 2: Crop response factor for banana (var. "Williams").

The constant 1.0812 represents the crop response factor (K_y) that relates relative yield reduction of the banana crop grown under the experimental conditions to the relative decrease in applied irrigation water. The coefficient of determination (r^2) value of 0.9878 indicates a good relation between relative yield reduction and elative reduction in applied irrigation water.

Results indicate that, since Ky value is more than 1.0, banana yield is more sensitive to deficit irrigation and the relative reduction in yield is more than the relative reduction in applied water. Results reveal also that the obtained yield response factor of 1.08 is 10 to 20% less than those reported by FAO (1979). The short irrigation interval practiced in this experiment (daily irrigation) proved to have a pronounced effect on decreasing the effect of water stress on the obtained yield. The smaller Ky value obtained under the experimental conditions could be due to practicing daily irrigation while conducting the experiment.

CONCLUSIONS

From the obtained results it could be concluded that:

1- There is a significant effect of irrigation treatments on banana yield and physical and chemical fruit quality parameters.
2- There is a strong linear relationship (r^2 = 0.9944) between banana yield and the tested amounts of applied irrigation water.

3- The value of crop response factor (Ky) of 1.08 indicates a less impact of the tested irrigation treatments on banana yield than that was previously published.
4- Under similar field conditions, irrigation with amounts of water equals 1.2 of Class A pan factor is recommended to obtain a optimum banana yield.

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الملخص العربي

استجابة انتاجية محصول الموز (صنف "وليامز") وصفات الجودة للري بمنطقة النوبارية

محمد رجب الشناوى[1] أشرف محمد العصار[1] حمدي الحسيني خليفة[2] عبد السلام مرغني عثمان[2]

1- معهد بحوث البساتين ، مركز البحوث الزراعية ، جمهورية مصر العربية.

2- معهد بحوث الأراضى والمياه والبيئة ، مركز البحوث الزراعية ، جمهورية مصر العربية.

نفذت تجربة حقلية في مزرعة خاصة خلال موسمي 2003/2002 و 2004/2003 بالأراضي الجيرية لمنطقة النوبارية لدراسة تأثر انتاجية محصول الموز (صنف "وليامز") و مكونات المحصول وصفات الجودة وكمية مياه الري المضافة وكفاءة استخدام الوحدة من مياه الري المضافة ومعامل استجابة المحصول لأربعة مستويات من مياه الري. تم تقدير مياه الري علي أساس نسب (0.6 ، 0.8 ، 1.0 ، 1.20) من وعاء البخر القياسي. أضيفت كميات مياه الري باستخدام نظام الري بالتنقيط السطحي. تم تنفيذ التجربة باستخدام طريقة القطاعات الكاملة العشوائية وخمسة مكررات.

ويمكن تلخيص أهم النتائج المتحصل عليها في النقاط التالية:

1- هناك تأثير معنوي لمعاملات الري المستخدمة علي انتاجية وجودة ومكونات محصول الموز.

2- بلغت انتاجية الموز 31.9 ، 28.47 ، 20.36 ، 14.47 طن/فدان للمعاملات $أ_1$ ، $أ_2$ ، $أ_3$ ، $أ_4$ علي الترتيب.

3- أثبتت الدراسة وجود علاقة خطية قوية بين محصول الموز الناتج وكميات مياه الري المضافة.

4- زيادة معامل الوعاء من 0.6 الي 1.2 أدى الى زيادة معنوية فى كل من أوزان الأصابع وأطوالها وأقطارها. زيادة كمية مياه الرى أدت الى نقص محتوى الموز من الأملاح الكلية الذائبة والنشا وزيادة الحموضة والسكر.

5- متوسط أعماق الري المضافة بلغت 1791 ، 1493 ، 1194 ، 896 مم للمعاملات $أ_1$(120% جهد بخر-نتح) ، $أ_2$(100% جهد بخر-نتح) ، $أ_3$(80% جهد بخر-نتح) ، $أ_4$(60% جهد بخر-نتح) علي الترتيب.

6- بلغت كفاءة استخدام الوحدة من مياه الري المضافة 4.24 كجم/$م^3$ماء وذلك لمعاملة الري $أ_1$.

7- معامل استجابة المحصول كان 1.08موضحا تأثيرا أقل لمعاملات نقص المياه المستخدمة تحت ظروف التجربة علي انتاجية محصول الموز مما سبق الإشارة إليه في (FAO, 1979).

8- للحصول علي محصول مرتفع من الموز فإن كمية مياه الري المضافة لايجب أن تقل عن 120% من جهد البخر-نتح المقاس بواسطة وعاء البخر القياسي.