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YIELD AND FRUIT QUALITY OF BANANA (*MUSA* SPP., CV. GRANDNAIN) AS AFFECTED BY REGULATED DEFICIT IRRIGATION

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ABSTRACT

Rationalization of water use in Egypt become a national goal, therefore, this investigation was conducted to study the effect of regulated deficient irrigation as a water saving strategy on banana growth and yield. The current study was carried out during two successive seasons (2017/2018 and 2018/2019) on Grandnain banana cv. grown in a private orchard in Wadi El Natron, El-Behara governorate, Egypt. The experiment was conducted on the 2nd and the 3rd banana ratoon, grown in sandy soil spaced at 2x3 meters apart, under drip irrigation system. The tested treatments were using 100, 90, and 80 % of the actual amounts of water applied at the experimental site. Treatments were applied at three dates during banana growth. The obtained results cleared that using 90 and 80% of the actually applied amounts of water, didn't affect either vegetative growth (plant height, pseudostem circumference, leaf area and number of green leaves/plant) or yield (bunch weight and fruit quality).

Keywords: Banana, Irrigation, Regulate deficit irrigation, water use efficiency.

INTRODUCTION

Banana (*Musa* spp.) is a tropical, herbaceous evergreen plant with a rapid growth rate, large broad leaves and high leaf area index (Robinson and Saúco, 2010), hence banana had a high transpiration potential and requires high quantities of water (Van vosselen *et al*., 2005). Water is probably the most limiting factor in banana production (Bassoi *et al*., 2004). Water shortage reduces plant growth and development and ultimately leads to a considerable yield reduction (Ahmed *et al*., 2013). Several reports have shown the negative effect of drought on banana growth (Eckestein and Robinson, 1996; Firth *et al*., 2003; Kallarackal *et al*., 1990; Thomas and Turner, 1998; 2001). Drought also reduced fruit size and yield (Holder and Gumbs, 1982; Robinson and Alberts, 1986; Watson and Daniells, 1983). In Egypt, banana had the largest quantity of irrigation water requirements compared with the other fruit crops, according to Ibrahim (2003) water requirements of banana reached to 12000m^3/feddan/year, but the water amount in our study reach to 16000 m^3/feddan/year.

Water scarcity is one of the common environmental stresses that cause significant reduction of crop growth and productivity, in many regions of the world, water (not land) is the most limiting production factor (Azevedo *et al*., 2003). According to the published statistics, the percentage of drought-affected land area in the world in 2000 was double that of 1970 (Isendahl and Schmidt 2006). Moreover, it is predicted that climate change and global warming phenomena will double the drought affected area (Le Houérou, 1996). Management of water resources considered as one of the major challenges for the long-term competitiveness of the agricultural industry (Fereres and Connor, 2004; Saguy *et al*., 2013). Irrigation management under water scarcity conditions includes practices and management that result in reduction of irrigation requirements and increase crop yield per water unit (Capra *et al*., 2008). Consequently, researchers pay attention to improve regulated deficit irrigation strategies (RDI) to decrease irrigation water requirements (Lu *et al*., 2002). Regulated deficit irrigation including reduction of irrigation during drought-tolerant phonological stages of crop growth while they are full irrigated when the plants are more sensitive to water stress. The concept of regulated deficit irrigation (RDI) was first proposed by Chalmers *et al.,* (1981) and Mitchell and Chalmers (1982) to control vegetative growth in high density peach orchards. RDI have been successfully applied in many fruit tree species such as pistachio (Goldhamer and Beede, 2004), citrus (Goldhamer and Salinas, 2000), apple (Ebel *et al*., 1995), apricot (Ruiz-Sa´nchez *et al*., 2000), grapes (McCarthy *et al*., 2002), and olive (Moriana *et al*., 2003 and Gómez-Rico *et al*., 2007).

The present investigation aimed to determine the optimum quantity of water applied by drip irrigation for banana growing under the RDI system as well as determine the appropriate phonological stage of application of the RDI.

MATERIAL AND METHODS

The current study was carried out during two successive seasons (2017/2018 and 2018/2019) on Grandnain banana cv. grown in private orchard in Wadi El Natron, El-Behara governorate. The experiment was carried out on the 2nd and the 3rd banana ratoon, plants grown in sandy soil

spaced at 2x3 meters apart, under drip irrigation system, soil and irrigation water analysis are shown in Tables (1 and 2). The total amount of irrigation water under the study condition was about 16000 m^3/ feddan/year. The standard horticultural management practices were carried out as usual and the recommended fertilizer dose was added by fertigation.

Table (1) Physical and chemical analysis of the soil under investigation

Physical characteristics		**Chemical characteristics**	
Coarse sand	45.7	pH	7.94
Fine sand	44	EC(ds/m)	7.64
Silt	7.6	Ca(mg/100g)	19.8
Clay	2.7	Na(mg/100g)	38.2
Texture class	Sandy	K(mg/100g)	0.9
Field capacity	13.3	Mg (mg/100g)	14.1
Wilting point	7.9	Organic matter%	0.17
Available water	5.4	SO_4	10.5
		Cl	59.2
		HCO_3	3.3
		CO_3	-

Table (2) Analysis of irrigation water

Ec (ds/m)	**pH**	**SAR** (meq/L)	**Soluble cations** (meq/L)				**Soluble anions** (meq/L)		
0.75	7.1	2.5	Ca	Mg	Na	K	CO_3	Cl	SO_4
			2	1.3	3.6	0.1	0.14	6.54	0.32

Optimization of irrigation requirements

The daily metrological data of Central Lab. for Agricultural Climate were used to compute reference evapo-transpiration (ETo). Crop water requirement was calculated according to (Allen *et al*., 1998) by the following equation: ETc = ETo * Kc, where ETc is crop evapo-transpiration [mm d^{-1}], Kc is crop coefficient and ETo is reference crop evapo-transpiration [mm d^{-1}]. Irrigation requirements in liter/plant was calculated by the following equation

IR = ETc * A * irrigation system efficiency * leaching requirements, where IR is volume of water in liter per plant, ETc is evapo-transpiration, A is plant area (Raw spacing (m) *plant spacing (m) (Choudhary and Kadam, 2006)

The irrigation water application treatments

Fifty-four healthy plants of similar size (90 to 100cm with 7 to 9 green leaves) were selected. RDI was applied at three different phonological stages with low water demand as the following

1. 1st of December to 15th of January

2. 15th of January to 1st of March

3. 1st of March to 15th of April

Irrigation was scheduled at two levels (90 and 80% of the IR) under drip irrigation. The treatments were replicated 3 times in randomized complete block design (RCBD) and each replicate comprised 4 plants.

Measurements

Vegetative growth parameters

after inflorescences emergence (15th of July to 1st of August), the following vegetative characteristics were determined

• Pseudostem height (cm) from the ground surface to junction of the first leaf.

• Number of leaves per plant

• Leaf area (m^2) of the third full expanded leaf from top was calculated according to Murry (1960) using the following equation: Leaf area = length x area coefficient. Area coefficient of Grandnain banana = 0.86 according to (Obiefuna and Ndubizu, 1979)

• Leaves number per plant at flowering.

Yield and fruit physical characteristics

yield was estimated after bunches harvesting at green maturity stage by kg, then the 3rd hand was taken from bunches of each treatment to estimate the following fruit properties (hand weight (kg), finger weight (g) and number of hands per bunch)

Statistical analysis

This experiment was designed as split plot design, with irrigation date treatments in the main plots and irrigation doses in the subplots, each treatment contained three replicates and each replicate had four plants. The obtained data were tabulated and subjected to analysis of variance (ANOVA) according to Snedecor and Cochran (1990) using MSTAT software packaged. Means of results were compared using least significant difference (LSD) at 5% level (Steel and Torrie, 1982).

RESULT AND DISCUSSION

Pseudostem height and circumference

Data presented in Table (3 and 4) revealed that there was a slight effect of irrigation treatments in pseudostem

height and circumference of Grandnain banana plants in both seasons. Regarding the effect f irrigation dose; in the first season irrigation with 90 or 80% of irrigation requirements results in better plant growth compared with 100% treatment, while in the second season, there were a non-significant differences between the different irrigation levels. There was a slight difference between the different application times; application of RDI during March and April recorded higher value in the first season while there was a non-significant difference in the second season.

Table (3) Effect of irrigation regimes on pseudostem height (cm) of Grandnain banana plants during 2017/2018 and 2018/2019 seasons.

Treatment	1st seasons (2017/2018)			Mean
	100	**90**	**80**	
1st	255 c	286.7 ab	286.7 ab	276.1A
2nd	270bc	293.3 ab	290.0 ab	284.4A
3rd	280 abc	283.3 ab	300.0 a	287.8A
Mean	268.3A	287.8A	292.2 A	
2nd seasons (2018/2019)				
1st	270.0 a	263.3 ab	260.0 ab	264.4A
2nd	260.0ab	250.0 b	273.3 a	260.0A
3rd	260.0ab	260.0 ab	260.0 ab	261.1A
Mean	263.3A	257.8A	264.4A	

Means followed by the same letter within each column are not significantly different at 1% level.

Table (4) Effect of irrigation regimes on pseudostem circumference (cm) of Grandnain banana plants during 2017/2018 and 2018/2019 seasons.

Treatment	1st seasons (2017/2018)			Mean
	100	**90**	**80**	
1st	75.0b	85.0a	86.7a	82.2B
2nd	85.0a	90.0a	88.7a	87.9A
3rd	90.0a	83.3ab	91.7a	88.3A
Mean	83.3A	86.6A	89.0A	
2nd seasons (2018/2019)				
1st	85.0ab	86.7a	85.0ab	85.6A
2nd	85.0ab	83.3ab	85.0ab	84.4A
3rd	85.0ab	81.7b	83.3ab	83.3A
Mean	85.0A	82.78A	84.4A	

Means followed by the same letter within each column are not significantly different at 1% level.

Generally, the pervious studied showed that irrigation regimes at 100% and 85% ET resulted in significant increase in plant height without any significant differences (Shongwe *et al.,* 2008). Moreover, Ndayitegeye *et al.,* (2019) stated that, water application of banana could be reduced to 90% of optimal water requirement and deficit irrigation on banana could save water without affecting vegetative growth.

Leaf area (m^2) and leaves number per plant

Data in Tables (5 and 6) revealed that there was a nonsignificant effect of different irrigation doses and application date of RDI treatment on banana leaf number; the reduction of irrigation water to 80 or 90% at the different stages had a non-significant effect on plant leaf number. However, there was a slight effect of irrigation treatment on leaf area of banana; irrigation of banana at 80 or 90% recorded higher leaf area compared with 100% during the 1st season, while was a slight difference between irrigation treatments in plant leaf area in the second season.

Table (5) Effect of different irrigation regimes on number of leaves of Grandnain banana plants during 2017/2018 and 2018/2019 seasons

Treatment	1st seasons (2017/2018)			Mean
	100	**90**	**80**	
1st	23.00 b	23.33 b	24.33 ab	23.56A
2nd	24.00 ab	23.33 b	23.00 b	23.44A
3rd	25.00 a	23.33 b	24.00 ab	24.11A
Mean	24.0A	23.4A	23.78A	
	2nd seasons (2018/2019)			
1st	25.00 a	24.33 ab	24.00 bc	24.44A
2nd	25.00 a	24.00 bc	23.67 bcd	24.22A
3rd	23.00 d	23.33 cd	24.00 bc	23.44B
Mean	24.3A	23.9A	23.9A	

Means followed by the same letter within each column are not significantly different at 1% level.

Table (6) Effect of different irrigation regimes on leaf area (m^2) of Grandnain banana plants during 2017/2018 and 2018/2019 seasons

Treatment	1st seasons (2017/2018)			Mean
	100	**90**	**80**	
1st	1.440 cd	1.98 a	1.58 bc	1.66AB
2nd	1.150 d	1.59 bc	1.78 ab	1.51B
3rd	1.690 bc	1.73 abc	1.70 abc	1.70A
Mean	1.43B	1.77A	1.69A	
	2nd seasons (2018/2019)			**Mean**
1st	1.54 b	1.613 ab	1.617 ab	1.59A
2nd	1.81 a	1.567 b	1.630 ab	1.67A
3rd	1.60 ab	1.623 ab	1.620 ab	1.61A
Mean	1.65A	1.60A	1.62A	

Means followed by the same letter within each column are not significantly different at 1% level.

Banana plants sensitivity to soil moisture stress is reflected in growth reduction (Kallarackal *et al.,* 1990) and increased leaf senescence (Turner, 1998). The most sensitive indicator of soil water deficit in banana is the rate of emergence of the new leaves (Kallarackal *et al.,* 1990; Hoffmann, and Turner, 1993; Turner and Thomas, 1998). and reduction of leaf size which leads to reduction in photosynthetic (Thomas and turner 1998a). Levy *et al.,* (1978) demonstrated that high leaf area enable the plant to photosynthesis more efficiently and accelerates plant growth which in return is reflected on plant yield.

Yield

Data in Table (7) showed the effect of irrigation amount on banana yield; the bunch weight ranged from 29 to 34 kg in both seasons, irrigation at 80% results in slight yield reduction (6.93 and 5.56% in the 1st and 2nd season respectively) while there was a non significant differences between the different RDI treatment level (80% and 90% of IR) at the different phonological stages. The obtained results are in agreement with Shangwe *et al.,* (2008) they reported that, the economic yield of banana was obtained with irrigation regimes ranging between 100% and 85% of ET. In addition, Bauri *et al.,* (2011) reported that the maximum yield was obtained from plants irrigated with 80% of IR.

Table (7) Effect of different irrigation regimes on Grandnain banana bunch weight (kg) during 2017/2018 and 2018/2019 seasons

Treatment	1st seasons (2017/2018)			Mean
	100	**90**	**80**	
1st	29.00a	34.00a	30.33a	31.11A
2nd	34.00a	29.33a	29.00a	30.78A
3rd	33.00a	33.00a	30.00a	32.00A
Mean	32.00A	32.11A	29.78A	
2nd seasons (2018/2019)				
1st	30.00c	33.33ab	30.67bc	31.33A
2nd	32.00abc	29.67c	29.00c	30.22A
3rd	34.00a	31.33abc	31.00bc	32.11A
Mean	32.00A	31.44A	30.22A	

Means followed by the same letter within each column are not significantly different at 1% level.

In the present study, comparing bunch weight of irrigation treatments reveals that RDI system had no negative effect on banana yield (Raina *et al.,* 2011). Since the cost of water and chemical fertilizers is the major components of banana production cost, the reduction of irrigation water will reflected in increase the water use efficiency and improves the production economics (Pramanik, and Patra, 2016).

Concerning the effect of application time of RDI, the highest bunch weight was obtained from the 3rd date (March and April), according to Bredell, (1970) moisture deficit is particularly harmful to banana when it occurs at the time of floral differentiation or at the start of flowering. Water stress prior to bunch emergence reduced the number of hands and fingers, and finally, bunch mass (Watson and Daniells, 1983).

Hand number, hand weight and weight finger

Data illustrated in Table (8) showed a significant differences in hand number/bunch among different irrigation treatments in both seasons. The highest hand number/bunch was recorded for application of RDI at 90% in the 3rd stage in both seasons (12.33 and 12 hand/bunch) while the lowest value recorded for control treatments (10 and 11 hand/bunch).

Table (8) Effect of different irrigation regimes on Grandnain banana hand number/bunch during 2017/2018 and 2018/2019 seasons

Treatment	1st seasons (2017/2018)			Mean
	100	**90**	**80**	
1st	10.00c	11.67ab	11.33abc	11.00A
2nd	12.00ab	11.33abc	10.67bc	11.33A
3rd	11.00abc	12.33a	11.00abc	11.44A
Mean	11.00A	11.78A	11.00A	
2nd seasons (2018/2019)				
1st	11.00b	12.00a	11.67ab	11.56AB
2nd	11.00b	11.67ab	11.00b	11.22B
3rd	12.00a	11.67ab	11.67ab	11.78A
Mean	11.33A	11.78A	11.44A	

Means followed by the same letter within each column are not significantly different at 1% level.

Measurement of middle hand showed significant differences in had weight of banana plants growing under different irrigation treatments. Data presented in Tables (9) showed that banana hand weight decreased under the RDI treatments. Banana plants treated by RDI at the 3rd stage recorded higher hand weight compared with the 1st and the 2nd phonological stage.

Table (9) Effect of different irrigation regimes on Grandnain banana hand weight (kg) during 2017/2018 and 2018/2019 seasons

Treatment	1st seasons (2017/2018)			Mean
	100	**90**	**80**	
1st	2.90ab	2.89ab	2.73ab	2.84A
2nd	3.10ab	2.75ab	2.56b	2.80A
3rd	3.00ab	3.07a	2.90 ab	3.04A
Mean	3.00A	2.95A	2.73 A	

2nd seasons (2018/2019)				
1st	2.80ab	3.00a	2.60b	2.80A
2nd	2.90ab	2.77ab	2.60b	2.76A
3rd	3.00a	3.13a	2.77ab	2.97A
Mean	2.90A	2.97A	2.66B	

Means followed by the same letter within each column are not significantly different at 1% level.

Concerning the interaction between irrigation dose and application time; the lowest hand weight recorded for 80% of IR (2.66 and 2.60 kg for the first and the second season respectively) while the highest hand weight recorded for 100% of IR at the 3rd stage (3.10kg in the first season) and 90% IR at the 3rd stage (3.13kg in the second season).

Table (10) Effect of different irrigation regimes on Grandnain banana finger weight (g) during 2017/2018 and 2018/2019 seasons

Treatment	1st seasons (2017/2018)			**Mean**
	100	**90**	**80**	
1st	118.00a	124.00a	121.67a	121.22A
2nd	121.00a	124.00a	124.00a	123.00A
3rd	125.00a	117.00a	132.00a	124.67A
Mean	121.33A	121.67A	125.89A	

2nd seasons (2018/2019)				
1st	123.00a	122.67a	122.33a	122.76A
2nd	119.00a	122.67a	128.33a	123.33A
3rd	122.00a	118.00a	127.33a	122.44A
Mean	121.33A	121.11A	126.00A	

Means followed by the same letter within each column are not significantly different at 1% level.

Regarding the average value of finger weight the obtained results (Table 10) showed that finger weight of banana fingers ranged from 117 to 132g in the first season and from 118 to 128.33g in the second season. Finger weight was not affected by different irrigation levels during the first anal second seasons.

Kunaran and Mutluvel (2009) reported that the maximum number of hands per bunch was recorded with higher irrigation level (100%). In addition, Ahmed *et al.,* (2013) found that number of hands per bunch was linearly related to the amount of water applied. These results are in harmony with the previous reports; soil water deficit reduced banana fingers growth rate fruit size yield, and delayed fruit maturation but this appeared to be dependent on the time of application and duration of the stress (Holder and Gumbs, 1982; Watson and Daniells, 1983; Robinson and Alberts, 1986; Mahouachi, 2007 Castricini, *et al*., 2011).

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