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Effect of Hydrogel Soil Addition under Different Irrigation Levels on Grandnain Banana Plants

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Abstract: This investigation was carried out at private plantations, in El Bostan district, Cairo Alexandria desert road, Giza; on "Grandnain' banana plants (*Musa Cavendishii Lamb*.) during the grown seasons of 2012/2013 and 2013/2014. The experimental site represents newly reclaimed sandy soil irrigated through drip irrigation system. This investigation aimed to study the effect of hydrogel additions, as substance holding water in the soil, under different levels of irrigation quantities for saving irrigation water quantities. The water application treatments were 100, 90, 80 and 70% of plant irrigation requirement (IR) in combination with hydrogel soil addition at zero, 50, 100 and 150g /plant. The obtained results cleared that 80% of IR combined with medium or high dose of hydrogel (100 or 150g/plant) enhanced the most studied parameters. Using 150g/plant of hydrogel with irrigation by 80% of IR improved the vegetative growth (plant height, circumference, leaf area and number of green leaves/plant). Also, it increased banana bunch weight, fruit quality and saved 20% of irrigation water. While, hand number per bunch was insignificantly affected by different treatments. The lowest irrigation level (70% of IR) without hydrogel increased fruit content of total soluble solids and total sugars.

Key words: Banana · Irrigation · Hydrogel · Fruit properties · Vegetative growth · Grandnain · Soil amendment · Soil conditioners

INTRODUCTION

Banana and plantains (*Musa Cavindishii* Lamb.) are today grown in many regions and constitute the 4thhighest fruit crop production in the world, following grapes, citrus and apple. In Egypt, the total planted area of banana increased to reach 25073 hectare in 2012 season, producing1.129 million tons (20 tons/feddan) according to the FAO latest statistics [1].

Nowadays, banana are successfully grown in newly reclaimed soils because of its excellent performance, large bunches with longer fingers, excellent taste and high tolerance to transportation [2]. Banana plants require large quantities of water to maintain high production with good fruit quality [3].

Water deficit is a major problem in banana grown under arid regions climatic conditions. It affects plant growth and development and ultimately leads to a considerable bunch yield reduction or crop failure [4]. Consequently, researchers pay attention to improve deficit irrigation strategies to decrease irrigation water requirements [5].

The uses of alternative water holding amendments and irrigation methods will become more important over time, especially in regions of reduced water availability such as most Middle East and African countries [6].

Linear relations were observed between irrigation quantity and bunch weight until the maximum bunch weight was observed with 100% crop evapotranspiration [7-10]. Also, fruit physical parameters (hand and finger weight, finger number/bunch and pulp/peel ratio) and yield were improved effectively in banana plants with decreasing irrigation depths [11, 12].

Hydrogels are sometimes referred to "root watering crystals" or "water retention granules" because it swell like sponges to be as several times of their original size when it contact with freely available water, consequently increase soil water holding capacity and reduce irrigation frequency [6, 13].

Soil water and nutrients stored in hydrogel are released gradually for plant growth under water limiting conditions [14].

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This investigation aimed to study the effect of hydrogel amendments under different levels of irrigation quantities, as substance holding water in the soil to reduce irrigation water quantity in Grandnain banana plantations.

MATERIALS AND METHODS

This study was carried out during two successive seasons (2012/2013 and 2013/2014) on Grandnain banana mother plants. Mother plants were planted in a private plantation, in El-Bostan district, Cairo Alexandria desert road, Beheara Governorate. The physical and chemical properties of the soil and their moisture constants are shown in Tables (1 & 2). All selected plants were healthy, uniform and received the recommended agricultural practices, with fertilization program (400g N + 250g P + 900g K /plant/year) according to Mohamed [15]. Irrigation regimes were applied in a way to insure the equal receiving of nutrients in all plants. The plants were spaced at 2.5 * 3.5 meters apart and irrigated through drip irrigation system. The irrigation water analysis is shown in Table (3).

This investigation is aimed to study the effect of hydrogel additions under different level of irrigation quantity, as substance holding water in the soil to save irrigation water quantity in Grandnain banana orchards.

Ninety six healthy plants were chosen and arranged in 16 treatments. Each treatment was represented by 6 plants, each two plants treated as one replicate.

The water regimes were 100, 90, 80 and 70% of plant irrigation requirements (IR) in combination with zero, 50, 100 and 150g hydrogel/plant (incupated in the dug holes mixed with manure).

The historical climatologically data in the district were used to compute potential evapotranspiration (ETo) rates using penman monteith equation.

The water requirements of banana (ETc) were estimated monthly according to Taha [16].

Etc = crop co-efficient (Kc) x reference evapotranspiration (ETo).

While banana irrigation requirements were calculated monthly according to following equation [17].

Irrigation requirement (IR) = ETc x Area (m2) x reduction (R) / irrigation system efficiency x leaching requirement

Irrigation system efficiency = 90%
Leaching requirement = 15%

The aforementioned fertilizers were fertigated in away ensuring similar distribution assessed.

The Following Characters Were Estimated

Vegetative Growth Parameters: After the emergence of the inflorescences, the following vegetative characteristics were determined

Table 1: Water relations in the experimental soil under study

Constant Depth(cm)	Field capacity% (by vol.)	Wilting Point% (by vol.)	available water%	Bulk Density (gm/cm^3)
00-15	12.1	4.1	8.0	1.62
15-30	11.2	4.3	6.9	1.64
30-45	10.6	3.9	6.7	1.67
45-60	10.4	3.8	6.6	1.68

Table 2: Physical and chemical characteristics of the soil

Physical characteristics %		Chemical characteristics	
Coarse sand	46.2	pH	8.32
Fine sand	38.4	EC(ds/m)	3.25
Silt	11.8	Ca(mg/100g)	0.15
Clay	3.6	Na (mg/100g)	0.29
Texture class	Sandy	K (mg/100g)	0.21
$CaCO_3$ %	12.1	Cl (mg/100g)	0.47
Organic matter %	0.31	----	----

Table 3: Irrigation water analysis

					Soluble Cations (meq/l)				Soluble Anions (meq/l)		
EC (ds/m)	pH	SAR (meq/l)	RSC (meq/l)	TDS Ppm	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Cl^{-}	SO_4^{-}	$CO_3 + HCO_3$
0.8	7.8	3.45	-1.3	512	2.1	1.3	4.5	0.1	3.6	2.3	2.1

- Pseudostem height (cm) from the ground surface to junction of the first leaf.
- Circumference of the pseudostem (cm) at 20 cm above soil surface.
- Leaf area (m^2) of the third full expanded leaf from the top according to the following equation: Leaf area = length x width x area coefficient [18].

Area coefficient of Grandnain banana = 0.86 [19]

- Number of green leaves per plant at flowering.

Bunch Weight and Fruit Physical Characteristics: Bunch weight (kg) was measured after harvesting at green maturity stage. Then, it was artificially ripened [20]. After that, samples of three hands were taken from bunches of considered replicate, with small pieces of pedicel as possible from three parts of bunch (base, middle and terminal) to estimate hand number/bunch, net hand weight (kg), net finger weight (g) and fingers number/bunch.

Fruit Chemical Characteristics: Percentage of total soluble solids (TSS) was determined in fruit pulp juice by using a hand refractometer (model, OPTIKA HR-150) [21].

Total sugars content was determined according to the method previously described by Smith [21].

Statistical Analysis and Experimental Design: This experiment was designed as split plot design, with irrigation treatments in the main plot and hydrogel doses as subplot. Each treatment contained three replicates and each replicate had three holes with two plants in each hole. The obtained data were tabulated and subjected to analysis of variance (ANOVA) according to Snedecor and Cochran [22], using MSTAT software package. Means of results were compared using least significant difference (LSD) at 5% level [23].

RESULTS AND DISCUSSION

Effect of Different Irrigation Levels and Soil Hydrogel Amendments on Grandnain Banana Vegetative Growth Parameters

Pseudostem Height: Results presented in Table (4) revealed that pseudostem heights (cm) of plants were significantly affected by different irrigation levels in both seasons. 100%of crop irrigation requirement recorded the highest pseudostem length. There was no significant difference observed between 100% and 90% of crop irrigation requirement in both seasons. On the other hand, pseudostem height was significantly affected by hydrogel treatments in both seasons. Soil addition of 150 g hydrogel per plant resulted in longest pseudostem compared with insignificant differences from 100 g/plant results.

Furthermore, the Grandnain banana plant height was significantly varied as influenced by the interaction between levels of irrigation requirements and hydrogel treatments. Using 150g hydrogel per plant, as soil application and 70% of estimated needs recorded the highest plant height.

Circumference of the Pseudostem: Pseudostem circumference (cm) of Grandnain banana plants were significantly affected by different irrigation levels in both seasons (Table 5). Irrigation by 90% of banana water requirement increased plant circumference as compared with other irrigation levels in both seasons.

Table 4: Effect of different irrigation levels and hydrogel soil additions on pseudostem height (cm) of Grandnain banana plants during 2012/2013 and 2013/2014 seasons.

	First Season (2012/2013)					Second Season (2013/2014)				
	Hydrogel treatments (g/plant)					Hydrogel treatments (g/plant)				
Water Treatments (% of IR)	Zero	50	100	150	Mean	Zero	50	100	150	Mean
100% of IR*	254.3	255.3	255.7	252	254.3	255.0	256.7	257.0	252.7	255.4
90% of IR	250.7	252.3	256.0	256.3	253.8	251.3	253.0	257.0	256.7	254.5
80% of IR	246.7	250.0	252.7	256.3	251.4	247.0	250.7	254.0	257.0	252.2
70% of IR	242.0	246.7	250.0	254.3	248.3	242.7	246.3	250.0	257.0	249.0
Mean	248.4	251.1	253.6	254.7	----	249.0	251.7	254.5	255.9	----
LSD value at 0.05 for			First Season					Second Season		
Water treatments (A)			2.5					2.6		
Hydrogel treatments (B)			2.2					2.1		
(A) X (B)			3.7					4.1		

*IR: irrigation requirement of banana plant.

Table 5: Effect of different irrigation levels and hydrogel soil additions on pseudostem circumference (cm) of Grandnain banana plants during 2012/2013 and 2013/2014 seasons

	First Season (2012/2013)					Second Season (2013/2014)				
	Hydrogel treatments (g/plant)					Hydrogel treatments (g/plant)				
Water Treatments (% of IR)	Zero	50	100	150	Mean	Zero	50	100	150	Mean
100% of IR*	78.87	78.67	79.23	78.13	78.72	79.37	78.53	79.67	78.47	79.01
90% of IR	77.70	78.30	79.23	79.28	78.67	77.93	78.70	79.63	79.63	78.97
80% of IR	76.50	77.50	78.57	79.43	78.00	76.47	77.73	78.83	79.70	78.18
70% of IR	75.30	76.40	77.97	79.33	77.25	75.03	76.83	77.97	79.63	77.44
Mean	77.09	77.72	78.75	79.08	----	77.20	78.03	79.03	79.36	----
LSD value at 0.05 for			First Season					Second Season		
Water treatments (A)			0.68					0.76		
Hydrogel treatments (B)			0.71					0.73		
(A) X (B)			1.19					1.40		

*IR: irrigation requirement of banana plant.

Table 6: Effect of different irrigation levels and hydrogel soil additions on Leaf area (m2) of Grandnain banana plants during 2012/2013 and 2013/2014 seasons

	First Season(2012/2013)					Second Season(2013/2014)				
	Hydrogel treatments (g/plant)					Hydrogel treatments (g/plant)				
Water Treatments (% of IR)	Zero	50	100	150	Mean	Zero	50	100	150	Mean
100% of IR*	1.42	1.42	1.43	1.41	1.42	1.43	1.43	1.43	1.41	1.42
90% of IR	1.40	1.41	1.43	1.43	1.41	1.40	1.41	1.43	1.43	1.41
80% of IR	1.37	1.39	1.41	1.43	1.40	1.38	1.40	1.42	1.43	1.40
70% of IR	1.35	1.38	1.39	1.42	1.38	1.35	1.38	1.40	1.43	1.39
Mean	1.38	1.40	1.41	1.42	---	1.39	1.40	1.42	1.42	---
LSD value at 0.05 for			First Season					Second Season		
Water treatments (A)			0.02					0.02		
Hydrogel treatments (B)			0.01					0.02		
(A) X (B)			0.03					0.04		

*IR: irrigation requirement of banana plant.

Moreover, hydrogel treatments as soil addition significantly affected plant girth in both seasons. It was clearly noticed that plant circumference recorded the greatest value with 150g hydrogel/plant compared with other hydrogel treatments used in both seasons.

The data obtained from the interaction between hydrogel treatments with different irrigation levels, show that adding 150g of hydrogel to the soil root zone of plants and irrigating with 80% of the estimated requirements recorded increases in plant girth comparing with the other interactions in the study.

Leaf Area (m^2) and Number of Green Leaves per Plant at Flowering: Tabulated results in Tables (6 &7) revealed that number and area of Grandnain banana leaves were significantly affected by irrigation levels in both seasons, since 100% of banana irrigation requirement recorded the highest leaf area and number of green leaves. Also, hydrogel treatments showed significant effects on fore mentioned parameters in both seasons of the study. Leaf area recorded the highest value with 150g hydrogel compared with the other treatments used in both seasons.

Regarding leaves number, different irrigation levels significantly affected it in the two seasons of the study. Irrigation by 70% of IR produced the lowest number of leaves comparing with the other levels in the study. However, irrigation with 80, 90 or 100% of IR was the same statistical leaves number in the two seasons of study.

Concerning to hydrogel soil addition, using hydrogel at 50, 100 or 150g/plant significantly increased Grandnain banana leaves number comparing with the control treatment.

The obtained results from the interaction between different hydrogel dose and irrigation levels showed that irrigation banana plants with 80% of IR and treating by 150 g hydrogel/plant into root zone gave the highest leaf area and leaves number comparing with the other interactions in the first and second seasons.

Table 7: Effect of different irrigation levels and soil additions of hydrogel on leaves number of Grandnain banana plants during 2012/2013 and 2013/2014 seasons

	First Season(2012/2013)					Second Season(2013/2014)				
	Hydrogel treatments (g/plant)					Hydrogel treatments (g/plant)				
Water Treatments (% of IR)	Zero	50	100	150	Mean	Zero	50	100	150	Mean
100% of IR*	11.74	11.79	11.79	11.63	11.74	11.82	11.84	11.86	11.68	11.80
90% of IR	11.57	11.64	11.81	11.82	11.71	11.61	11.68	11.86	11.85	11.75
80% of IR	11.38	11.54	11.64	11.82	11.60	11.39	11.58	11.72	11.87	11.64
70% of IR	11.16	11.38	11.54	11.73	11.45	11.20	11.38	11.55	11.86	11.50
Mean	11.46	11.59	11.70	11.75	---	11.50	11.62	11.75	11.82	---
LSD value at 0.05 for			First Season					Second Season		
Water treatments (A)			0.13					0.11		
Hydrogel treatments (B)			0.12					0.13		
(A) X (B)			0.21					0.22		

*IR: irrigation requirement of banana plant.

Table 8: Effect of different irrigation levels and soil additions of hydrogel on Grandnain banana bunch weight during 2012/2013 and 2013/2014 seasons

	First Season (2012/2013)					Second Season (2013/2014)				
	Hydrogel treatments (g/plant)					Hydrogel treatments (g/plant)				
Water Treatments (% of IR)	Zero	50	100	150	Mean	Zero	50	100	150	Mean
100% of IR*	27.97	27.98	27.89	27.33	27.79	27.73	27.88	27.62	27.12	27.59
90% of IR	26.15	26.94	27.74	28.06	27.22	25.88	26.93	27.50	27.92	27.06
80% of IR	24.26	26.11	27.26	27.88	26.38	24.14	26.27	27.01	27.75	26.29
70% of IR	23.22	25.29	26.60	27.66	25.69	22.57	25.28	26.61	27.58	25.51
Mean	25.40	26.58	27.37	27.73	---	25.08	26.59	27.19	27.59	---
LSD value at 0.05 for			First Season					Second Season		
Water treatments (A)			1.19					1.51		
Hydrogel treatments (B)			1.38					1.31		
(A) X (B)			2.56					2.64		

*IR: irrigation requirement of banana plant.

The obtained results were in agreement with those reported that vegetative growth of banana plants positively correlated with irrigation water quantities. Moreover, reducing water quantities during irrigation for banana plantations significantly reduced the most of banana vegetative growth parameters such as, pseudostem height, circumference, leaf area and number of green leaves [24-33]. These findings may be due to the ability of banana plants to more efficiently photosynthesize under non water stress conditions, which in return is reflected on vigorous plant growth [24]. Also, Turner and Thomas [31] reported that soil water deficit was sufficient to close stomata which inhibit other physiological processes such as net photosynthesis and leaf elongation.

Also, the plants that grown in hydrogel, produced plants with large volume comparing with those grown in media free of hydrogel [26, 27].

The Effect of Different Irrigation Levels and Hydrogel Soil Addition on Bunch Weight and Fruit Physical Characteristics

Bunch Weight (kg): Decreasing irrigation amounts showed significant differences in bunch weight (Kg) in both seasons (Table 8). However, irrigation with 70% of IR decreased the bunch weight, while there were no significant differences between the other irrigation levels (80% and 90% of IR) in the first season and 80%, 90 and 100% of IR in the second season. On the other hand, soil addition of hydrogel in different amounts significantly affected bunch weight in both seasons. Addition of hydrogel (50, 100 and 150 g/ plant) to banana plants increased the bunch weight compared to control (without hydrogel addition) in the two seasons of the study.

Furthermore, the interaction between different irrigation levels and different amounts of soil amended (hydrogel) had a significant effect on bunch weight.

Table 9: Effect of different irrigation levels and soil additions of hydrogel on Grandnain banana Hand number/bunch during 2012/2013 and 2013/2014 seasons

	First Season (2012/2013)					Second Season (2013/2014)				
	Hydrogel treatments (g/plant)					Hydrogel treatments (g/plant)				
Water Treatments (% of IR)	Zero	50	100	150	Mean	Zero	50	100	150	Mean
100% of IR*	11.06	11.26	11.28	11.38	11.25	11.09	11.19	11.24	11.10	11.16
90% of IR	11.00	11.27	11.12	11.17	11.14	11.07	11.10	11.15	11.17	11.12
80% of IR	10.98	11.39	11.85	11.01	11.31	10.97	11.09	11.22	11.21	11.12
70% of IR	10.94	11.33	11.10	11.34	11.18	10.85	11.16	10.94	11.07	11.01
Mean	11.00	11.32	11.34	11.23		11.00	11.14	11.14	11.14	
LSD value at 0.05 for			First Season					Second Season		
Water treatments (A)			NS					NS		
Hydrogel treatments (B)			NS					NS		
(A) X (B)			NS					NS		

*IR: irrigation requirement of banana plant.

Table 10: Effect of different irrigation levels and soil additions of hydrogel on Grandnain banana Net Hand weight (kg) during 2012/2013 and 2013/2014 seasons

	First Season (2012/2013)					Second Season (2013/2014)				
	Hydrogel treatments (g/plant)					Hydrogel treatments (g/plant)				
Water Treatments (% of IR)	Zero	50	100	150	Mean	Zero	50	100	150	Mean
100% of IR*	2.32	2.30	2.31	2.22	2.29	2.33	2.32	2.29	2.28	2.31
90% of IR	2.21	2.25	2.32	2.35	2.28	2.19	2.27	2.30	2.31	2.27
80% of IR	2.09	2.15	2.14	2.36	2.19	2.08	2.21	2.25	2.31	2.21
70% of IR	1.96	2.11	2.23	2.26	2.14	1.93	2.13	2.25	2.33	2.16
Mean	2.15	2.20	2.25	2.30		2.13	2.23	2.27	2.31	
LSD value at 0.05 for			First Season					Second Season		
Water treatments (A)			0.06					0.08		
Hydrogel treatments (B)			0.07					0.09		
(A) X (B)			0.15					0.18		

*IR: irrigation requirement of banana plant.

Irrigation with 90% of IR with addition of 150g hydrogel in root zone recorded the highest bunch weight in both seasons.

Hand Number/Bunch: Data presented in Table (9) clear that no significant differences obtained in hand number per bunch as affected by all treatments in the study during both seasons. However, irrigation with 80% of IR produced the highest hand number per bunch in the first season. Whereas, irrigation at 100% of IR in the second seasons was the superior in this respect. On the other hand, using soil amendments of hydrogel increased hand number per bunch compared with the control in both seasons. Regarding the interaction between irrigation levels and hydrogel soil amendments, its effects were statistically equal.

Net Hand Weight: Application of different irrigation levels induced significant differences in net hand weight (Kg) in both seasons (Table 10). Both 70% and 80% of IR decreased the net hand weight in both seasons. There was no significant differences observed between 90% and 100% IR in both seasons.

On the other hand, soil addition of hydrogel with different amounts significantly affected net hand weight in both seasons. Addition of hydrogel (50, 100 and 150 g/ plant) to banana plants increased the net hand weight compared with the control (without hydrogel addition). Whoever, using 150g/plant progressively increased net hand weight comparing with the other doses used in the two seasons.

Furthermore, the interaction between different irrigation levels and hydrogel doses significantly affected banana net hand weight during both seasons of study. Irrigation with 90% IR with addition of 100g hydrogel recorded the highest net hand weight in the first season, while irrigation with 70% of IR with addition of 150g hydrogel recorded the highest net hand weight in the second season.

Table 11: Effect of different irrigation levels and soil additions of hydrogel on finger number/bunch of Grandnain banana during 2012/2013 and 2013/2014 seasons

	First Season (2012/2013)					Second Season (2013/2014)				
	Hydrogel treatments (g/plant)					Hydrogel treatments (g/plant)				
Water Treatments (% of IR)	Zero	50	100	150	Mean	Zero	50	100	150	Mean
100% of IR*	195.2	194.6	194.3	195.8	194.9	189.2	189.2	189.9	190.5	189.7
90% of IR	196.6	193.9	194.7	195.5	195.2	188.7	188.7	189.6	189.5	189.1
80% of IR	194.6	195.7	193.6	194.0	194.5	189.1	187.8	189.8	189.7	189.1
70% of IR	195.8	194.3	193.0	195.4	194.6	187.1	188.2	189.7	189.4	188.6
Mean	195.5	194.6	193.9	195.1		188.5	188.5	189.7	189.8	
LSD value at 0.05 for			First Season					Second Season		
Water treatments (A)			NS					NS		
Hydrogel treatments (B)			NS					NS		
(A) X (B)			1.8					2.2		

*IR: irrigation requirement of banana plant.

Table 12: Effect of different irrigation levels and soil additions of hydrogel on Grandnain banana net finger weight (g) during 2012/2013 and 2013/2014 seasons

	First Season (2012/2013)					Second Season (2013/2014)				
	Hydrogel treatments (g/plant)					Hydrogel treatments (g/plant)				
Water Treatments (% of IR)	Zero	50	100	150	Mean	Zero	50	100	150	Mean
100% of IR*	130.97	131.42	131.20	127.58	130.29	133.96	134.68	132.94	130.12	132.93
90% of IR	121.57	126.99	130.22	131.19	127.49	125.35	130.44	132.57	134.66	130.76
80% of IR	113.94	121.94	128.70	131.35	123.98	116.68	127.85	130.07	133.70	127.08
70% of IR	108.39	118.97	125.97	129.38	120.68	110.26	122.77	128.21	133.09	123.58
Mean	118.72	124.83	129.02	129.88	---	121.56	128.94	130.95	132.89	---
LSD value at 0.05 for			First Season					Second Season		
Water treatments (A)			4.19					3.2		
Hydrogel treatments (B)			3.6					3.7		
(A) x (B)			8.65					8.22		

*IR: irrigation requirement of banana plant.

Finger Number/Bunch: Results presented in Table (11) clear that values of finger number/bunch had the same statistical stand point due to different irrigation levels or doses of soil addition of hydrogel during first and second seasons. However, in the first season, finger number/bunch was the highest in banana plants treated with 90% of IR. While, in the second season 80% IR recorded the highest fruit number/bunch.

Grandnain banana plants that planted in soil free of hydrogel recorded the highest finger number compared with the hydrogel treatments in the first season. Whereas in the second season, 150g of hydrogel/plant produced the highest finger number/bunch.

The interaction between hydrogel treatments and levels of irrigation needs did not show a clear trend concerning the results of fingers/bunch number in the two seasons. Irrigation with 90% of IR without hydrogel recorded the highest number of fruits/bunch in the first season. While, 80% of IR with 150g hydrogel was the superior treatment in the second season.

Finger Weight (g): Net weight of finger was significantly affected by different levels of irrigation treatments during the first and second seasons (Table, 12). Banana plants that received 90% of IR recorded the highest finger weight in both seasons. Also, soil amendment had a significant effect on this parameter in both seasons. Soil addition of 100g hydrogel had the highest ability for increasing fingers net weight comparing with the other hydrogel treatments used. No significant differences were noticed between 100 and 150g hydrogel dosage on net finger weight during the studied seasons.

Table 13: Effect of different irrigation levels and soil additions of hydrogel on total soluble solids (%) in Grandnain banana fruit during 2012/2013 and 2013/2014 seasons

	First Season (2012/2013)					Second Season (2013/2014)				
	Hydrogel treatments (g/plant)					Hydrogel treatments (g/plant)				
Water Treatments (% of IR)	Zero	50	100	150	Mean	Zero	50	100	150	Mean
100% of IR*	21.90	21.86	21.86	22.03	21.91	21.94	21.94	22.03	22.12	22.01
90% of IR	23.51	22.29	21.86	21.86	22.38	23.92	22.46	21.94	21.94	22.57
80% of IR	25.21	23.15	22.20	21.86	23.11	25.30	23.24	22.29	21.94	23.19
70% of IR	25.47	24.18	23.24	21.94	23.71	25.56	24.27	23.32	21.94	23.77
Mean	24.02	22.87	22.29	21.92	---	24.18	22.98	22.40	21.99	---
LSD value at 0.05 for			First Season					Second Season		
Water treatments (A)			0.45					0.52		
Hydrogel treatments (B)			1.14					1.16		
(A) X (B)			1.42					1.96		

*IR: irrigation requirement of banana plant.

Table 14: Effect of different irrigation levels and soil additions of hydrogel on total sugar in Grandnain banana fruit during 2013/2014 seasons

	First Season (2012/2013)					Second Season (2013/2014)				
	Hydrogel treatments (g/plant)					Hydrogel treatments (g/plant)				
Water Treatments (% of IR)	Zero	50	100	150	Mean	Zero	50	100	150	Mean
100% of IR*	13.42	13.42	13.42	13.56	13.46	13.47	13.47	13.49	13.52	13.49
90% of IR	14.56	13.68	13.44	13.42	13.78	14.70	13.79	13.47	13.47	13.86
80% of IR	15.49	14.22	13.65	13.42	14.20	15.56	14.27	13.69	13.47	14.25
70% of IR	15.66	14.87	14.22	13.47	14.56	15.70	14.90	14.32	13.47	14.60
Mean	14.78	14.05	13.68	13.47	---	14.86	14.11	13.74	13.48	---
LSD value at 0.05 for			First Season					Second Season		
Water treatments (A)			0.31					0.36		
Hydrogel treatments (B)			0.58					0.64		
(A) X (B)			1.12					1.44		

*IR: irrigation requirement of banana plant.

Furthermore, the interaction between different levels of banana water requirement and hydrogel soil conditioner treatments showed that 80% of IR with 150g hydrogel, as soil addition, was the best interaction comparing with other interactions used in both seasons since it increased net weight of fingers.

The Effect of Different Irrigation Levels on Tss and Total Sugars Content of Grandnain Banana Fruits: The presented results in Tables (13&14) reveal that by decreasing the level of irrigation, fruit content of total soluble solids and total sugar increased in both seasons. Plants irrigated with 70% IR recorded the highest values of TSS and total sugars in the fruits in both studied seasons.

Also, the TSS% and the total sugar% in fruit pulp were significantly affected by hydrogel treatments in the two studied seasons. Adding150g hydrogel as soil addition, showed the lowest values of TSS and total sugars in fruit pulp.

Concerning the effect of the interaction between hydrogel treatments and irrigation levels on fruit content of TSS and total sugars, it was found that plants planted in soil free of hydrogel and irrigated with 70% IR recorded the highest concentration of total sugars and total soluble solids in fruits.

Generally, these results are in agreement with those mentioned that yield and yield component (number of hands per bunch, hand weight, finger weight and number per bunch) were linearly related to the amount of water applied in the plant crop and first ratoon up to 100% of IR [4, 29, 33-36]. While, Costa *et al*.[12] stated that the lowest total soluble solids values in fruits pulp were obtained with the highest irrigation depth.

CONCLUSION

From the obtained results it could be concluded that using 100 or 150g of hydrogel/plant as soil amendment are usable to save 20% of irrigation water in Grandnain

banana orchard without any reduction of yield or fruit quality. This is evident when soil addition of 100 or 150g hydrogel/plant with irrigation by 80% IR increased pseudostem circumference, height, number of green leaves, leaf area, bunch weight, finger number and finger weight and their content of TSS and total sugars with no significant difference with the control treatment (100% IR).

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