Effect of Irrigation Systems and Water Regime on Growth, Yield Components, Water Use Efficiency and Water Productivity of Guava (PSIDIUM GUAVAJA L.) Grown in Clay Soil

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ABSTRACT

Field experiments were conducted during two successive growing seasons (2017/2018 and 2018/2019) in Guava orchard at Kafr Al Dawar district, Beheira Governorate, Egypt, to investigate the effect of water regime levels: 100% (E_1), 80% (E_2) and 60% (E_3) of crop evapotranspiration (ET_c) under two irrigation systems: furrow irrigation (I_1) and surface drip irrigation (I_2) on water use efficiency, growth parameters, yield components, and economic analysis of four years old guava trees grown in clay soil. The field experiments were implemented in a randomized complete block design with three replicates. The obtained results indicated that the highest shoot length, number of leaves/m and leaf area were obtained due to T_2E_1 treatment (drip irrigation with 100% ET_c), followed by I_2E_2 treatment (drip irrigation with 80 % ET_c). The average highest guava yield of the two growing seasons was 26.64 tons/ha which was obtained as a result of I_2E_1 treatment (drip irrigation with 100% of ET_c). The lowest guava yield (20.24 and 17.90 tons/ha) were obtained due to I_1E_3 treatment (furrow irrigation with 60% of ET_c) for the two growing seasons, respectively. Yield components such as number of fruits/m, length of fruit (cm), diameter of fruit (cm) , fruit size (cm^3) , fruit weight (gm.) and yield (kg/tree) were significantly effected ($P< 0.05$) by water regime levels and irrigation systems. Water use efficiency (WUE) of drip-irrigated treatments was higher than that obtained from furrow irrigated treatments in the two growing seasons. WUE increased from 2.37 to 3.34 $kg.m^{-3}$ for drip - irrigated treatment, and from 1.63 to 2.18 $kg.m^{-3}$ for furrow - irrigated treatments. Fruit quality such as TSS (%), acidity (%) and TSS / Acidity ratio were not significantly affected by irrigation systems and water regime. For the economical results, the maximum value of net return was due to I_2E_1(24411 LE/fed) treatment for the two growing seasons and the minimum value of total return was the result of T_1E_3 (6344 LE/fed)treatment for the two growing seasons. The maximum values of water productivity were obtained under T_2E_1 (5.56 LE/m^3) and I_2E_2 (5.25 LE/m^3) treatments in the two growing seasons.

Key Words: Guava, Clay soil, Drip irrigation, Furrow irrigation, Yield component, Water use efficiency, Water productivity.

INTRODUCTION

Guava *(PSIDIUM GUAVAJA L.)* is one of the major fruits in Egypt and is ranked the eighth most important fruit as per area and production. The fruit is a rich source of vitamin C, pectin and minerals like calcium, phosphorus and iron. The total area planted with guava is about 16,531 hectares. This area is divided into 12,838 hectares in old areas that are irrigated by surface irrigation methods, while 3,692 hectares in new lands that are irrigated by modern irrigation methods.

Egypt is seeking to increase the new reclaimed lands, but limited water resources constrain ambitious expansion plans (Abdel Mowgowd et al., 2010 and Darwish et al., 2013). Therefore, Egypt initiated a strategic program aiming to reclaim 1.4 million hectares of desert during the coming years till 2020 (Abdel - Mowgowd et al., 2010). Climate change has forced decision makers and scientists to think about the future of water resources (Bisbis et al., 2018) and their sustainability in a scarcity situation, taking into account less water coming from Ethiopia to Egypt and a high rate of population growth (Ouda, 2016) . So that, Badr et al., (2010) and Saleh et al., (2012) recommend the use of modern irrigation systems, instead of traditional surface irrigation such as furrow irrigation. Efficient water delivery systems can contribute towards increased crop yield and improving crop water use efficiency (Badr et al., 2010). Improving WUE may help to minimize water consumption, reduce losses of irrigation water, and increase cultivated area.

Currently in Egypt, the country's tendency to convert surface irrigation systems into modern irrigation systems due to a 30% decrease in the efficiency of surface irrigation on modern irrigation methods due to the loss of seepage and evaporation, as well as increasing the amount of water added during irrigation and deep percolation (Singh, 2005).

Drip irrigation has arguably become the world's most valued innovation in agriculture irrigation since the invention of the impact sprinkler, which replaced flood irrigation. It proves efficiently in providing irrigation water and nutrients to the roots of plants, while maintaining high yield production. Furrow irrigation is the conventional method widely used to irrigate most of the fruit crops grown in old areas, Egypt. However, this method uses more water

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compared to other high-tech water-saving irrigation methods such as sprinkler, drip etc…. Many researchers have reported higher application efficiency of drip irrigation systems over the conventional basin irrigation systems (Salvin et al., 2000; Bharambe et al., 2001; Agrawal and Agrawal, 2007) as compared to drip and furrow irrigation systems in fruits since they found that there was savings of 40 to 60% more irrigation water than another surface irrigation methods.

Guava is often marketed as "super-fruit" which has a considerable nutritional importance in terms of vitamins A and C with seeds that are rich in omega-3, omega-6 polyunsaturated fatty acids and especially dietary fiber, riboflavin, as well as proteins, and mineral salts. The high content of vitamin C (ascorbic acid) in guava makes it a powerhouse in combating free radicals and oxidation that are key enemies that cause many degenerative diseases. The high content of vitamin A in guava plays an important role in maintaining the quality and health of eyesight, skin, teeth, bones and the mucus membranes (Singh and Singh, 2007). Patil and Patil (1999) revealed that guava fruit yield was high at maximum when irrigated at 80% of the potential evapotranspiration. Singh and Singh (2007) observed that there was 164% greater yield in case of drip as compared to furrow irrigation in guava.

The aim of this research was to evaluate the effect of deficit irrigation treatments and irrigation systems on the vegetative growth, yield and yield components, applied irrigation water, water use efficiency and economic return analysis of guava plants grown in clay soil.

MATERIALS AND METHODS

Field experiments were carried out in a private orchard at Kafr Al Dawwar district , Beheira Governorate , Egypt (31º 13′ N, 30º 25′ E) during two growing successive seasons : 2017 / 2018 and 2018 / 2019 to study the effects of irrigation systems and water regime on the growth performance of guava (Psidium Guavaja L.) grown in clay soil . The meteorological data of the experimental site are given in Table 1.

Table 1. The meteorological* data of the experimental site during the two growing seasons 2017 /2018 and 2018 / 2019

Months	Temperature (c^0)			Relative humidity(%)	Precipitatin (mm)	Wind speed(m/hr)	Sun shine (hr.)
	Maximum	Minimum	Mean				
				2017 / 2018			
Jan.	18.2	12.6	15.4	69.1	33.9	5.4	9.3
Feb.	20.1	12.8	16.5	69.1	12.1	4.3	10.5
Mar.	23.7	14.2	19.0	59.6	1.5	5.2	11.3
Apr.	25.6	16.2	20.9	59.7	2.8	4.5	12.1
May	28.9	20.0	24.5	60.9	0.0	4.4	12.8
June	31.0	22.5	26.3	58.2	0.0	4.3	13.2
July	32.2	24.2	28.2	63.5	1.7	4.7	13.3
Aug.	32.1	25.0	28.6	64.5	0.0	4.5	12.8
Sep.	31.2	24.0	27.6	63.6	0.0	4.8	12.1
Oct.	28.1	21.7	24.9	63.6	11.1	4.6	10.9
Nov.	24.2	18.3	21.3	64.4	23.4	4.1	9.7
Dec.	19.5	14.8	17.2	68.5	51.0	5.3	9.2
				2018 / 2019			
Jan.	17.3	10.4	13.9	64.1	25.2	5.9	9.6
Feb.	18.3	11.1	14.7	67.2	14.3	4.9	10.4
Mar.	19.8	12.5	16.2	66.5	25.3	5.1	11.1
Apr.	22.8	14.2	18.5	62.0	3.5	4.8	12.2
May	29.1	18.4	23.8	53.9	0.0	4.6	12.6
June	30.9	22.8	26.9	63.1	0.0	4.6	13.4
July	32.4	24.5	28.5	61.1	0.0	4.7	13.5
Aug.	32.7	24.6	28.7	63.3	0.0	4.4	13.0
Sep.	30.4	23.4	26.9	63.7	0.0	4.6	12.2
Oct.	28.8	21.9	25.4	65.8	17.9	4.4	10.7
Nov.	26.3	18.9	22.6	63.1	0.2	4.3	9.5
Dec.	20.4	14.9	17.8	67.7	40.2	5.6	9.3

*From the following website: https://power.larc.nasa.gov/ data-access-viewer.

Four years old guava trees were grown at 4.0 x 4.0 m. apart in clay soil. The fertilizers dose of 100 % which included, 138 g N, 244 g P and 360 g K was applied to each tree of the recommended dose as suggested by Ministry of Agriculture and Land Reclamation (MALR) was followed.

Experimental Layout:

Two irrigation methods and irrigation water regime was applied during two successive growing seasons; 2017/2018 and 2018/2019. Two irrigation methods were furrow irrigation (FI) and surface drip irrigation (SDI) and three irrigation water regime (100, 80 and 60 % of crop evapotranspiration (ET_c) from class A pan evaporation (FAO, 1998).

The overall treatments were:

i.	I_1E_1	Furrow irrigation + 100 % of ET_c (Control)
ii.	I_1E_2	Furrow irrigation + 80 % of ET_c
iii.	I_1E_3	Furrow irrigation + 60 % of ET_c
iv.	I_2E_1	Surface drip irrigation + 100 % of ET_c
v.	I_2E_2	Surface drip irrigation + 80 % of ET_c
vi.	I_2E_3	Surface drip irrigation + 60 % of ET_c

The drip irrigation system, used in the orchard farm, included, 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 16 mm diameter are connected to sub main line. Each later is 50 m long with standard drippers of 4 l/h discharge rate, spaced at 0.5m apart. Two laterals served each row of guava trees.

Class A pan was used to determine the amount of applied irrigation water for the proposed irrigation treatments. Potential evapotranspiration (ETp) values were obtained from the class A pan method as follows:

$ET_p = E_{pan} \times K_{pan}$ (Doorenbos and Pruitt, 1984)

Where:

E_{pan}: is pan evaporation rate (mm/day)

K_{pan}: is pan coefficient. Its value depends on the relative humidity, wind speed and the site of the pan

K_{pan} value of 0.75 was used at the experimental site according to the weather condition.

Soil water relations :

Soil moisture content was gravimetrically determined in soil samples taken from consecutive depth of 20 cm each till 100 cm depth. These samples were taken just before each irrigation, 24 hours after irrigation and at harvesting to determine water consumptive use. Field capacity, wilting points and available soil moisture were determined in the field (Michael, 1978). The bulk density was determined by using the core method (Vomocil, 1957) to a depth of 100 cm .The average values are presented in Table 2. Some chemical and physical properties of the used soil were determined according to Black (1965) and Page et al. (1982) and the results obtained are presented in Table 3.

Table 2. The mean values of field capacity (FC) , wilting points(WP) , available soil moisture (ASM) and bulk density (D_b) of the soil of the experimental farm

Soil depth (cm)	FC (%)	WP (%)	ASM (%)	D_b (g / cm^3)
0-20	38.7	17.3	21.4	1.11
20-40	37.5	16.7	20.8	1.13
20-60	32.3	16.3	16.0	1.22
60-80	29.9	15.1	14.8	1.27
80-100	28.3	14.5	13.8	1.32
Average	33.3	16.0	17.4	1.21

Table 3. The mean values of chemical and physical proprties of the soil of the experimental farm

Soil depth (cm)	Chemical analysis EC (dS/m)	pH	O.M. (%)	$CaCO_3$ (%)	Particle size distribution Coarse Sand(%)	Fine Sand(%)	Silt (%)	Clay (%)	Texture
0-20	1.08	8.01	1.12	2.03	4.9	8.5	31.2	55.4	Clay
20-40	1.01	7.93	1.01	1.76	7.9	10.5	29.4	52.2	Clay
20-60	0.89	8.03	0.74	1.70	10.6	14.1	29.0	46.3	Clay
60-80	0.79	7.82	0.64	1.55	12.9	15.5	27.1	44.5	Clay
80-100	0.67	7.84	0.34	1.04	11.3	22.7	26.5	39.5	Clay loam
Average	0.89	7.93	0.77	1.62	9.5	14.3	28.6	47.6	Clay

Water consumptive use (WCU):

Water consumptive use was calculated using the following equation (Israelsen and Hansen, 1962).

$$Cu = \sum_{i=1}^{n} \frac{(\theta 2 - \theta 1)}{100} \ X \ Db \ X \ Di$$

Where:

Cu = Water consumptive use (cm), in effective root zone (100 cm).

D_i = Soil layer depth (20 cm).

D_b = Soil bulk density (g/cm^3), of the specified soil layer.

$\theta 1$ = Soil moisture % before irrigation.

$\theta 2$ = Soil moisture %, 24 hours after irrigation.

Applied irrigation water (AIW) :

The amount of water applied per each irrigation was measured by flow meter in furrow irrigation and calculated according to the following equation in drip irrigation:

$$AIW = \frac{\mathrm{ET0 \ x \ Kc \ x \ Kr}}{\mathrm{Ea}} + LR$$

Where:

AIW = Applied irrigation water depth (mm).

ET_0 = Reference crop evapotranspiration (mm/day) values obtained by class A pan evaporation method.

K_c = Crop coefficient.

K_r = Reduction factor that depends on ground cover. It equals 0.7 for mature plants.

E_a = Irrigation efficiency (%) = 0.85.

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

Water use efficiency (WUE) :

It was calculated according to the following equation (Vites, 1962 and Stanhill, 1986).

$$\mathrm{WUE} = \frac{Ya}{AIW}$$

Where:

WUE : water use efficiency (kg/m^3).

Y_a : actual yield (kg/ fed.)

AIW : applied irrigation water (m^3/fed)

Yield and chemical quality analysis:

At the proper time, data were determined and registered as follows:

Vegetative and flowering growth:

The shoot lengths (cm), number of leaves/ m and leaf area (cm^2) using planimeter were measured.

Fruit characteristics and yield:

Number of fruits/m, mean length and diameter of fruit (cm), mean fruit size (cm^3), mean fruit weight (g) and yield (kg/tree) were measured..

Fruit chemical properties:

These properties included:

1. Total soluble solids (TSS %) were determined by a`bbe refractometer using the method of A.O.A.C. (1995).
2. Total acidity (%) was determined by titration method as described by A.O.A.C. (1975).
3. TSS/acidity was calculated as a ratio.
4. Vitamin C (ascorbic acid) was determined by the method described by Horwitz (1970) as mg/100 g fruit flesh.

Economic Analysis

The prices in-puts and out-puts were calculated for the different treatments for guava. Concerning costs of irrigation in the two seasons for different treatments was calculated on the basis of rent of water. According to the marketing and employment conditions of the private orchard at Kafr El Dawar district, Beheira Governorate.

Total production costs (LE/fed.) was calculated according to the following equation:

Total production costs (LE/fed.) = Irrigation system costs (fixed and running cost) + cost of cultivation (Preparation of soil, different agriculture practices, price of seed, labours and harvesting)

Total return (LE/fed): was calculated according to the following equation:

Total return = Price (LE/ton) × Fruit yield (ton/fed)

Net return: was calculated according to the following equation:

Net return = Total return - Total costs

Water productivity, (WP, LE/m^3): was calculated by using the following formula:

$$\text{Water productivity} = \frac{\text{Net return (LE/fed.)}}{\text{Amount of water applied } (\mathrm{m^3/fed})} \ \mathrm{LE/m^3}$$

Statistical Analysis.

The obtained data were subjected to statistical analysis of the least significance difference (LSD) at 5% level of probability to compare treatment means when F-test was significant (SAS Institue, 1996).

RESULTS AND DISCUSSION

Vegetative growth parameters :

Table 4 indicated that irrigation systems and water regime significantly affected all vegetative growth parameters of guava plants during the two growing seasons. The highest significant values were obtained as a result of drip irrigation and 100% ET_c treatment (I_2E_1), followed by drip irrigation and 80 % ET_c treatment (T_2E_2) with non-significant differences between them. However, the lowest values were obtained as result of furrow irrigation and 60% ET_c (I_1E_3) treatment.

The mean values of *shoot length* were 21.9 , 21.2 , 16.3 , 23.6 , 23.3 and 17.3cm as result of the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for the first growing season (2017/ 2018) and were 20.8 , 20.4, 16.8 , 23.3 , 22.8 and 17.2 cm as result of the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for the second growing season (2018/ 2019) .

The mean *number of leaves /m* were 84.3 , 78.3, 65.2 , 100.5 , 93.4 and 72.3 due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for the growing season 2017/ 2018 and were 91.8 , 86.2 , 62.3 , 103.4 , 97.6 and 76.8 due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for the growing season 2018/ 2019 .

The mean values of leaf area *(cm^2)* were 49.10 , 46.30 , 36.20 , 52.40 , 50.30 and 41.60 *cm^2* due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for growing season 2017/ 2018 and were 46.3 , 44.2, 34.4 , 51.6 , 49.3 and 37.2 *cm^2* due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for growing season 2018/ 2019 .

These results are in harmony with those obtained by El-Dakroury (2008), who showed that increasing irrigation level from 60% up to 100% ET_c significantly increased the vegetative growth parameters of beans. This may be due to the role of water in increasing the uptake of nutrients from soil and translocation for photosynthetic assimilates. Thus, increasing in the leaf number and leaf area as well as foliage weight per plant (Leilah, 2009). Farooq et al. (2009) and Zhang and Huang (2013) reported that drought stress causes various physiologic and biochemical effects in plants. Mutava et al. (2015) found that the reduction in shoot fresh and dry biomass, shoot length, leaf area per soybean plant, transpiration rates, stomata conductance, photosynthetic rate, relative water content and leaf water potential were accompanied to drought water stress.

Yield and Yield components

***Yield of Guava*:**

Table 5 showed that yield and yield components of guava were significantly affected ($P< 0.05$) by irrigation systems and water regime. The yield of guava were 10.58 , 9.96, 8.50 , 11.33 , 10.90 and 9.32 ($ton.fed^{-1}$) due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for the growing season 2017/ 2018 and were 10.32 , 9.53, 7.52 , 11.05 , 10.33 and 8.75 ($ton.fed^{-1}$) due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3,respectively for the growing season 2018/ 2019 . The lowest guava yield was obtained as a result of T_1E_3 treatment (furrow irrigation and 60% of ET_c), which recorded 8.50 and 7.52 $ton.fed^{-1}$, respectively for the growing seasons 2017/ 2018 and 2018/ 2019. The highest guava yield was obtained as a result of T_2E_1 treatment (drip irrigation and 100% of ET_c), which recorded11.33 and 11.05 $ton.fed^{-1}$, respectively for the growing season 2017/ 2018 and 2018/ 2019. These results are in harmony with those obtained by Biswas et al. (1999) and Patil and Patil (1999) who observed that at drip irrigation, the guava fruit yield was the highest when irrigated with 100 % of ET_c.

Yield components:

The yield components were measured during each growth season for each treatment (Table 5). It is clear that yield components had significantly affected ($P< 0.05$) by irrigation systems and water regime.

The number of fruits/ m were 30.9 , 27.6 , 18.5 , 34.6 , 31.2 and 22.3 due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for the growing season 2017/ 2018 and were 27.40 , 23.80, 15.10 , 32.60 , 29.50 and 19.6 due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for the second growing season 2018/ 2019 (Table 5) .

Table 4. Effect of irrigation systems and water regime on some vegetative growth parameters during the two growing seasons 2017/2018 and 2018/2019

Treatments	Shoot length (cm)		No. of leaves / m		Leaf area (cm^2)	
	2017/2018	2018/2019	2017/2018	2018/2019	2017/2018	2018/2019
I_1E_1	21.9 b	20.8 b	84.3 b	91.8 b	49.1 b	46.3 b
I_1E_2	21.2 b	20.4 b	78.3 b	86.2 b	46.3 b	44.2 b
I_1E_3	16.3 d	16.8 c	65.2 c	62.3 d	36.2 d	34.4 c
I_2E_1	23.6 a	23.3 a	100.5 a	103.4 a	52.4 a	51.6 a
I_2E_2	23.3 a	22.8 a	93.4 a	97.6 a	50.3 a	49.4 a
I_2E_3	17.3 c	17.2 c	72.3 c	76.8 c	41.6 c	37.2 c
$LSD_{0.05}$	0.8	0.7	8.5	7.9	3.3	3.0

Table 5. Effect of irrigation systems and water regime on yield and yield component of guava (Psidium Guavaja L.) during the two growing seasons 2017/2018 and 2018/2019

Treatments	Number of fruits / lm	Length of fruit (cm)	Diameter of fruit (cm)	Fruit size (cm^3)	Fruit weight (gm)	Yield (ton/fed)	Yield (kg/tree)
			2017 / 2018				
I_1E_1	30.9 b	6.0 a	4.5 b	48.0 b	48.2 b	10.6 b	44.1 b
I_1E_2	27.6 bc	5.8 a	4.3 c	42.2 b	42.3 c	10.0 b	41.5 c
I_1E_3	18.5 e	4.9 b	4.1 c	35.0 c	35.6 c	8.5 d	35.4 e
I_2E_1	34.6 a	6.5 a	5.0 a	65.0 a	64.7 a	11.3 a	47.2 a
I_2E_2	31.2 b	6.1 a	4.7 b	53.3 a	52.8 b	10.9 a	45.4 a
I_2E_3	22.3 d	5.3 b	4.2 c	38.0 c	38.2 c	9.2c	38.5 d
$LSD_{0.05}$	3.2	0.8	0.3	6.9	8.2	0.7	2.5
			2018 / 2019				
I_1E_1	27.4 b	5.8 a	4.3 b	42.2 b	43.1 b	10.3 b	43.0 b
I_1E_2	23.8 c	5.6 b	4.1 c	36.9 c	36.9 c	9.5 c	39.7 c
I_1E_3	15.1 e	4.5 c	4.0 c	33.2 c	33.4 c	7.5 e	31.3 e
I_2E_1	32.6 a	6.4 a	4.9 a	60.8 a	61.1 a	11.1 a	46.0 a
I_2E_2	29.5 b	6.0 a	4.5 b	48.3 b	49.1 b	10.5 a	43.9 a
I_2E_3	19.6 d	5.2 b	3.9 c	31.5 c	31.6 c	8.8 d	36.5 d
$LSD_{0.05}$	2.9	0.8	0.3	6.2	7.8	0.7	2.3

The length of fruit were 6.0 , 5.8 , 4.9 , 6.5 , 6.1 and 5.3 cm due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for the growing season 2017/ 2018 and were 5.8 , 5.6, 4.5 , 6.4 , 6.0 and 5.2 cm due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for the growing season 2018/ 2019 (Table 5) .

The diameter of fruit were 4.5 , 4.3 , 4.1 , 5.0 , 4.7 and 4.2 cm due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for the growing season 2017/ 2018 and were 4.3 , 4.1, 4.0 , 4.9 , 4.5 and 3.9 cm due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for the growing season 2018/ 2019 (Table 5) .

The mean values of Fruit size were 48.0 , 42.2 , 35.0 , 65.0 , 53.3 and 38.0 cm^3 due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for growing season 2017/ 2018 and were 42.2 , 36.9, 33.2 , 60.8 , 48.3 and 31.5 cm^3 due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for growing season 2018/ 2019 (Table 5) .

The mean values of fruit weight (gm.) were 48.2 , 42.3, 35.6 , 64.7 , 52.8 and 38.2 gm. due to he : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3,respectively for growing season 2017/ 2018 and were 43.1 , 36.9, 33.4 , 61.1 , 49.1 and 31.6 gm. due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for growing season 2018/ 2019 (Table 5) .

The mean values of yield of tree (kg/tree) were 44.1 , 41.5 , 35.4 , 47.2 , 45.4 and 38.5 kg./tree due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for the growing season 2017/ 2018 and were 43.0 , 39.7, 31.3 , 46.0 , 43.9 and 36.5 kg./tree due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for the growing season 2018/ 2019 (Table 5) . The obtained results are in agreement with those obtained by Kumar et al. (2009), Boora et al. (2002) and Singh et al. (2005).

Reference Evapotranspiration (ET_0), Actual or Crop Evapotranspiration (ET_c) and Irrigation Requirements (IR.)

Table 6 showed that the values of reference or potential evapotranspiration (ET0 or ET_p) are affected by the climatic factors, and has ET_0 increased in summer and decreased in winter. Maximum values of ET_0 or ET_p were found in July (5.69 and 5.73 mm/day) in 2017 / 2018 and 2018 / 2019 seasons, respectively. Minimum value of ET_0 or ET_p was found in December 2017/2018 (1.50 mm/day) while minimum value of ET_0 (1.48 mm/day) was found in January 2018/2019.

It is clear from the obtained data, that daily and monthly crop or actual evapotranspiration (ET_c) had the same behavior as reference evapotranspiration (ET_0), where the values of daily and monthly ET_c had increased in summer and decreased in winter. Maximum values of daily ET_a or ET_c were found in July (4.78 and 4.81 mm/day) in 2017 / 2018 and 2018 / 2019 seasons, respectively. Minimum values of daily ET_a or ET_c were found in December (0.83 and 0.87 mm/day in 2017 / 2018 and 2018 / 2019 seasons, respectively). Cumulative crop evapotranspiration in the first growing season (2017/2018) was 1060.29 mm, while in second growing season (2018/2019) was 1043 mm. These findings agreed with the data obtained by Gad El-Rab et al. (1993), Attia et al. (1994) and Abbas and Anton (1999).

Table 6 showed that irrigation requirements of guava had ascending values during January - July and descending values during August - December. Cumulative irrigation requirements (IR.) of the first growing season (2017/2018) recorded 963.59 mm, while in the second growing season (2018/2019) it recorded 922 mm. The obtained results are in agreement with those obtained by Pouget (1981), Kliewer (1977), Kliewer (1971) and Kliewer and Schultz (1973).

Table 6. Monthly reference evapotranspiration (ET_0), crop evapotranspiration, effective rainfall and irrigation requirements during the two growing seasons: 2017 / 2018 and 2018 / 2019

Months	ET_0 (mm/ day)	K_c	ETc (mm/ day)	ETc (mm/ month)	Effective Rainfall (mm/ month)	Irr. Req. (mm/ month)
			2017 / 2018			
Jan.	1.52	0.85	1.29	39.99	13.60	26.39
Feb.	2.19	0.85	1.86	52.08	11.80	40.28
Mar.	3.14	0.85	2.67	82.77	1.50	81.27
Apr.	4.09	0.86	3.52	105.60	2.80	102.80
May	4.97	0.86	4.27	132.37	0.00	132.37
June	5.43	0.86	4.67	140.09	0.00	140.09
July	5.69	0.84	4.78	148.17	1.70	146.47
Aug.	5.38	0.81	4.36	135.16	0.00	135.16
Sep.	4.52	0.70	3.16	94.80	0.00	94.80
Oct.	3.23	0.66	2.13	66.03	10.90	55.13
Nov.	2.09	0.60	1.25	37.50	22.50	15.00
Dec.	1.50	0.55	0.83	25.73	46.80	(-21.07)
∑				1060.29	111.70	963.59
			2018 / 2019			
Jan.	1.48	0.85	1.26	35.28	24.00	11.08
Feb.	2.08	0.85	1.77	49.50	14.00	35.00
Mar.	2.96	0.85	2.52	78.00	24.30	53.7
Apr.	3.88	0.86	3.35	100.50	3.50	97.00
May	4.71	0.86	4.05	125.55	0.00	125.55
June	5.57	0.86	4.79	143.71	0.00	143.71
July	5.73	0.84	4.48	149.21	0.00	149.21
Aug.	5.44	0.81	4.41	136.71	0.00	136.71
Sep.	4.46	0.70	3.12	93.66	0.00	93.66
Oct.	3.22	0.66	2.13	66.03	17.40	48.63
Nov.	2.15	0.60	1.29	38.70	0.20	38.50
Dec.	1.58	0.55	0.87	26.97	37.60	- 10.63)(
∑				1043	121	922

Amount of applied irrigation water and crop water use efficiency :

Amount of applied irrigation water (AIW)

Table 7 showed that the amount of AIW, for the treatments I_1E_1, I_1E_2 and I_1E_3 have recorded 1550.39, 1240.31 and 930.23 mm. respectively in the 1st growing season, and 1474.90, 1179.94 and 884.95 mm. respectively in the 2nd growing season. The results of AIW for the treatments I_2E_1, I_2E_2 and I_2E_3 were 1138.88, 911.10 and 683.33 mm. respectively in the 1st growing season, and were 1040.15, 832.13 and 624.09 mm. respectively in the 2nd growing season.

At the beginning of the growing season, the amount of applied water was low then and increased due to increasing vegetative growth of guava plant. However, the amounts of applied water declined at maturity.

Maximum value of AIW (249.18 mm / month) for guava trees was recorded in July at 2018/ 2019 by applying 100% of ET_c and furrow irrigation (I_1E_1), while minimum value of AIW (24.78 mm / month) occurred in February at the growing season 2018/ 2019 by applying 60 % of ET_c and drip irrigation (I_2E_3) .These results are in agreement with those reported by Ekren et al. (2012) and Ibrahim (2003).

Water use efficiency(WUE):

The furrow irrigation method used higher amounts of water than drip irrigation method (Table 8). Water use efficiency of drip-irrigated treatment was higher and differed from furrow irrigated treatment in the two growth seasons ($P<0.05$). Maximum water use efficiency (3.34 $kg.m^{-3}$) was recorded in guava trees as a result of I_2E_3 treatment (60% ET_c + drip irrigation) in the 2nd season 2018/2019 (Fig.1).

Table7. Applied irrigation water (AIW, mm / month) for guava trees, as affected by irrigation systems and water regime during the two growing seasons ,2017 /2018 and 2018 /2019

Month	Furrow Irrigation (I_1)			Drip Irrigation (I_2)		
	100% ET_c (E_1)	80 % ET_c (E_2)	60% ET_c (E_3)	100% ET_c (E_1)	80% ET_c (E_2)	60% ET_c (E_3)
			2017 / 2018			
Jan.			Without Irrigation			
Feb.	67.27	53.82	40.12	47.35	37.88	28.41
Mar.	135.72	108.58	81.43	95.90	76.72	57.54
Apr.	171.68	137.34	103.01	121.3	97.04	58.22
May	221.06	176.85	132.64	156.20	124.96	93.72
June	233.95	187.16	140.37	165.31	132.25	99.19
July	244.60	195.68	146.76	172.83	138.26	103.70
Aug.	225.72	180.58	135.43	159.49	127.59	95.69
Sep.	158.32	126.66	94.99	111.86	89.49	67.12
Oct.	92.07	73.66	55.24	108.64	86.91	65.18
Nov.			Without Irrigation			
Dec.			Without Irrigation			
∑	1550.39	1240.31	930.23	1138.88	911.10	683.33
			2018 / 2019			
Jan.			Without Irrigation			
Feb.	58.45	46.76	35.07	41.30	33.04	24.78
Mar.	89.68	71.74	53.81	63.37	50.70	38.02
Apr.	161.99	129.59	97.19	114.46	91.57	68.68
May	209.67	167.74	125.80	146.15	116.92	87.69
June	240.00	192.00	144.00	169.58	135.66	101.75
July	249.18	199.34	149.51	176.07	140.86	105.64
Aug.	228.31	182.65	136.99	161.32	129.06	96.79
Sep.	156.41	125.13	93.85	110.52	88.42	66.31
Oct.	81.21	64.99	48.73	57.38	45.90	34.43
Nov.			Without Irrigation			
Dec.			Without Irrigation			
∑	1474.90	1179.94	884.95	1040.15	832.13	624.09

Table 8. The mean values of water use efficiency (WUE) mean values, as affected by irrigation systems and water regime during the two growing seasons

Treatments	Water use efficiency (kg /m^3)	
	1ST season	2nd season
I_1E_1	1.63	1.67
I_1E_2	1.91	1.92
I_1E_3	2.18	2.03
I_2E_1	2.37	2.53
I_2E_2	2.58	3.02
I_2E_3	3.23	3.34
$LSD_{0.05}$	0.21	0.18

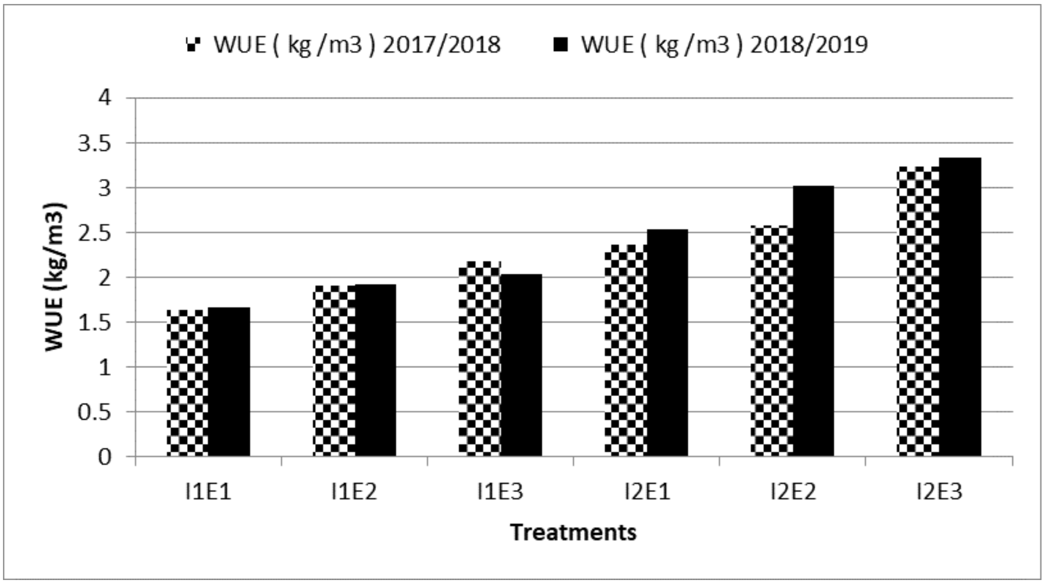

Fig 1. Effect of irrigation systems and water regime on crop water use efficiency (kg/m^3) of guava (Psidium Guavaja L.) during the two growing seasons (2017 / 2018 and 2018 / 2019)

Water use efficiency ranged from 1.63 to 3.34 kg.m^{-3} and increased with the decreasing applied water in the two growing seasons. Alaa et al. (2012) concluded that WUE increased from 5.129 to 7.379 kg.m^{-3} for furrow- irrigated treatment, and from 6.907 to 10.257 kg.m^{-3} for drip-irrigated treatments.

Fruit chemical composition

The chemical analysis of guava fruits included; total soluble solids (TSS %), acidity (%) , TSS / Acidity ratio and vitamin C (mg / 100 g pulp) and were shown in Table 9 and Figs 2 and 3.

Total soluble solids (TSS %):

The mean values of TSS were 11.75 , 11.32 , 10.99 , 12.23 , 11.99 and 11.02% due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for the growing season 2017/ 2018 and were 11.72 , 11.16, 10.65 , 12.62 , 12.03 and 10.42% due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for the growing season 2018/ 2019 . Maximum TSS (12.62 %) was recorded in guava trees due to the I_2E_1 treatment (100 %ET_c + drip irrigation) in the 2nd season 2018/2019.

Acidity (%):

The mean values of acidity were 0.48 , 0.45 , 0.36 , 0.53 , 0.48 and 0.43% due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3,respectively for the 1st growing season (2017/ 2018) and were 0.44 , 0.41, 0.35 , 0.49 , 0.46 and 0.37% due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for the 2nd growing season (2018/ 2019) . The maximum acidity (0.53 %) was recorded in guava trees due to the I_2E_1 treatment (100 %ET_c + drip irrigation) in the 2nd season 2018/2019.

TSS / Acidity ratio:

The mean values of this ratio were 24.48 , 25.16 , 29.92 , 23.08 , 24.98 and 25.65 due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for the 1st growing season (2017/ 2018) and were 26.64 , 27.21, 30.43 , 25.76 , 26.15 and 28.16 due to the treatments : I_1E_1 , I_1E_2 , I_1E_3 , I_2E_1 , I_2E_2 and I_2E_3 ,respectively for the 2nd growing season 2018/ 2019 . Maximum TSS / Acidity ratio (30.43) was recorded in guava trees under I_1E_3 the treatment (60 %ET_c + furrow irrigation) in the 1st season (2017/2018) and the minimum TSS / Acidity ratio (23.08) was recorded in guava trees under I_2E_1 the treatment (100 %ET_c + drip irrigation) in the 2nd season 2018/2019.

Table 9. Effect of irrigation systems and water regime on chemical composition of guava (Psidium Guavaja L.) during the two growing seasons: 2017 / 2018 and 2018 / 2019

Treatments	TSS (%)	Acidity (%)	TSS / acidity Ratio	Vitamin C (mg /100 g pulp)
		2017 / 2018		
I_1E_1	11.75	0.48	24.48	47.44
I_1E_2	11.32	0.45	25.16	47.21
I_1E_3	10.77	0.36	29.92	46.09
I_2E_1	12.23	0.53	23.08	49.46
I_2E_2	11.99	0.48	24.98	48.21
I_2E_3	11.02	0.43	25.14	46.54
$LSD_{0.05}$	NS	NS	NS	1.96
		2018 / 2019		
I_1E_1	11.72	0.44	26.64	49.52
I_1E_2	11.16	0.41	27.21	48.42
I_1E_3	10.65	0.35	30.43	46.51
I_2E_1	12.62	0.49	25.76	50.34
I_2E_2	12.03	0.46	26.15	49.63
I_2E_3	10.42	0.37	28.16	46.79
$LSD_{0.05}$	NS	NS	NS	2.03

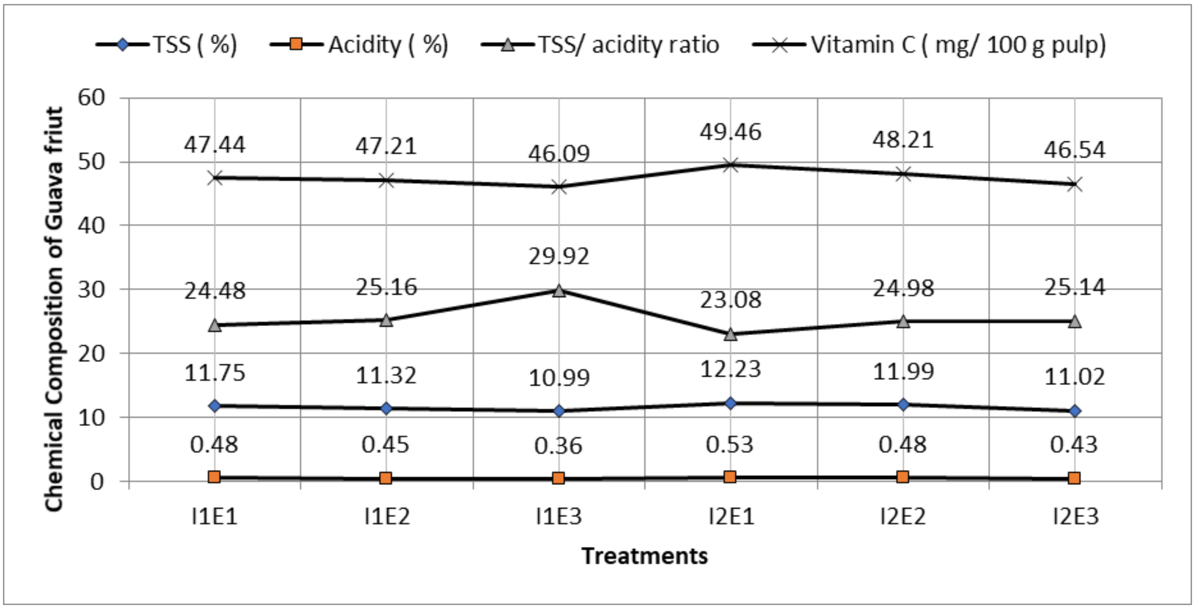

Fig 2. Effect of irrigation systems and water regime on chemical composition of guava (Psidium Guavaja L.) during the first growing season 2017 / 2018

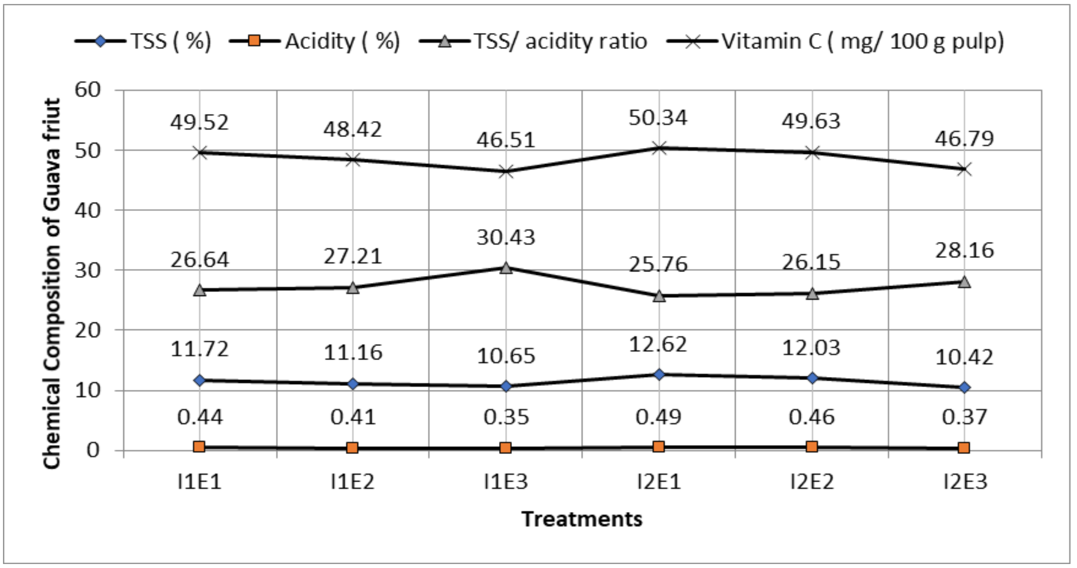

Fig 3. Effect of irrigation systems and water regime on chemical composition of guava (Psidium Guavaja L.) during the second growing season 2018 / 2019

Vitamin C (mg / 100 g pulp) :

The obtained data for *vitamin C* showed, that significant effect of irrigation systems and water regime during growing seasons 2017 / 2018 and 2018 / 2019 (Table 9) . The highest vitamin C content was found under I_2E_1 and I_2E_3 treatments and recorded 49.46 and 48.21 mg / 100 g pulp in the 1st growing season , respectively and recorded 51.34 and 49.63 (mg / 100 g pulp) in the 2nd growing season , respectively . The lowest vitamin C content was found under I_1E_3 and recorded 45.09 mg / 100 g pulp in the 1st growing season, while in the 2nd growing season was the lowest value under I_2E_3 and recorded 46.79 mg / 100 g pulp. Our results can be confirmed by those found by Khattab et al. (2011) and Lawand and Patil (1996) who found non-significant effect of different water regimes on TSS (%) , acidity (%) , while significant effect on Ascorbic acid .

Economic Analysis

Table 10 and Figs 4 and 5 showed that total cost of guava production has been affected by the various treatments which can be arranged as follows: $I_1E_1 > I_2E_1 > I_1E_2 > I_2E_2 > I_2E_3 > I_1E_3$ in the 1st season, and was $I_1E_1 > I_2E_1 > I_2E_1 > I_1E_3 > I_2E_2 > I_2E_3$ in 2nd season .

Table 10. Economic analysis of guava grown under irrigation systems and water regime treatments during the two growing seasons (2017 / 2018 and 2018 / 2019)

Treatments	Total cost (LE/fed.)	Total return (LE/fed.)	Net return (LE/fed.)	W.P. (LE/m^3)
		2017 / 2018		
I_1E_1	10510	31740	21230	3.26
I_1E_2	9208	24900	15690	3.01
I_1E_3	8279	17000	8721	2.23
I_2E_1	9279	33990	24711	5.16
I_2E_2	8326	27250	18924	4.95
I_2E_3	8357	18460	10103	3.52
		2018 / 2019		
I_1E_1	10174	30960	20786	3.37
I_1E_2	8952	23825	14873	3.00
I_1E_3	8696	15040	6344	1.71
I_2E_1	8868	33150	24282	5.56
I_2E_2	7994	26325	18331	5.25
I_2E_3	7520	17500	9980	3.81

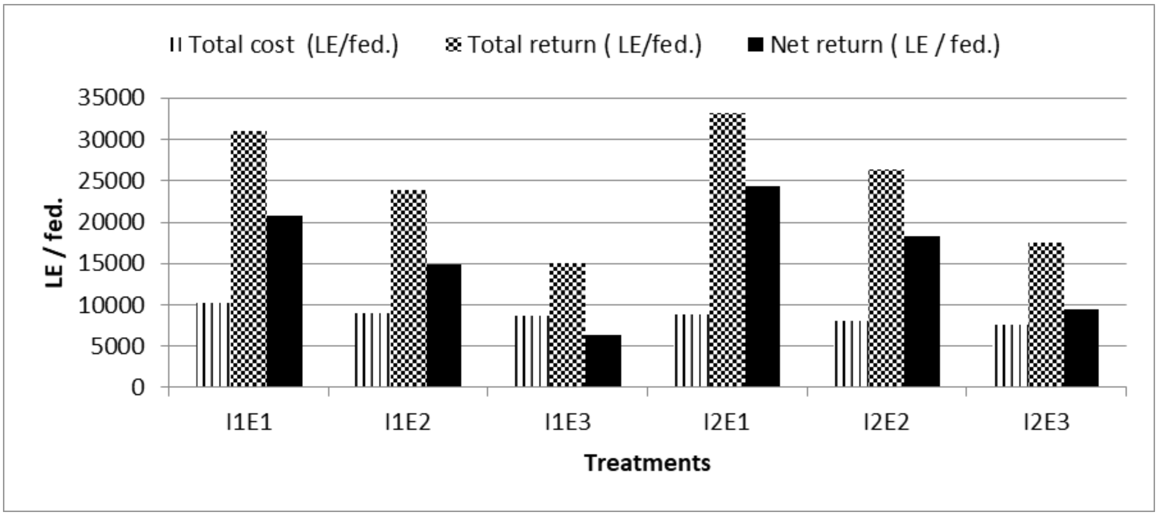

Fig 4. Economic analysis of guava as influenced by irrigation systems and water regime during the growing season 2017 / 2018

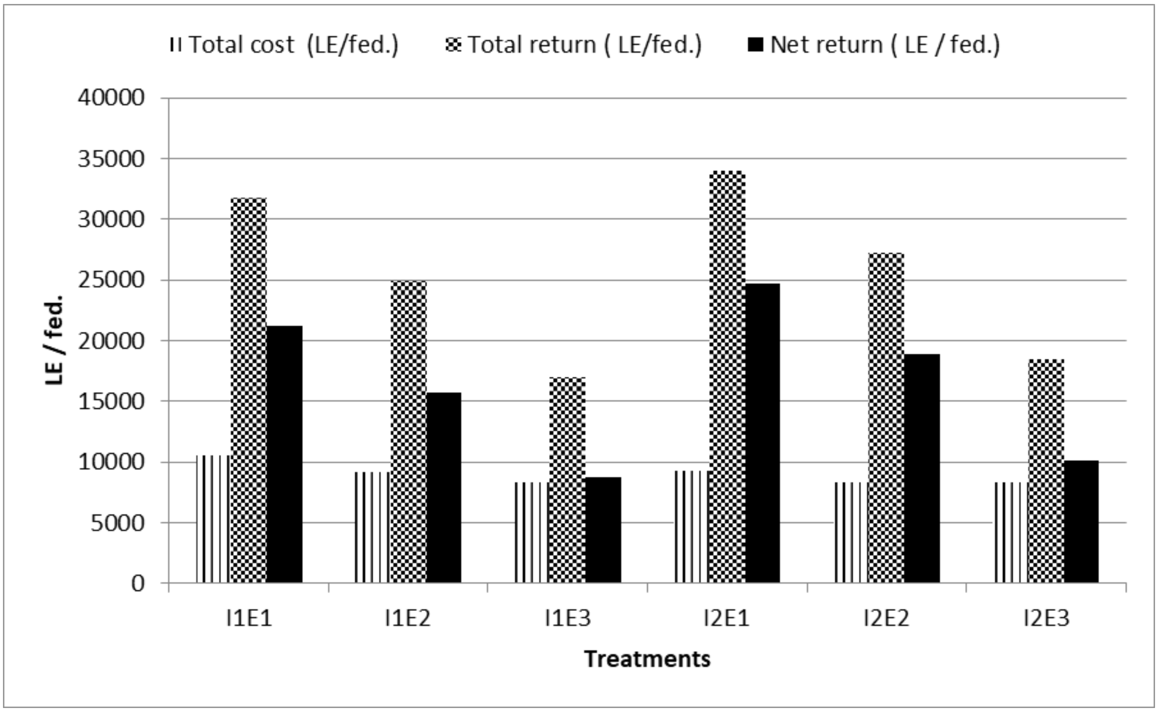

Fig 5. Economic analysis of guava as influenced by irrigation systems and water regime during the growing season 2018 / 2019.

The maximum value of total return was recorded due to T_2E_1 treatment for the two growing seasons and the minimum value of total return was recorded as a result of I_1E_3 treatment for the two growing seasons. Net return has the same trend of total return in the two growing seasons. Table 10 showed that water productivity (W.P.) has been affected by both irrigation systems and water regime.

The maximum values of water productivity (W.P.) were 5.16 and 4.95 LE/ m^3 under I_2E_1 and I_2E_2, respectively in the 1st growing season (2017/2018) and recorded 5.56 and 5.25 LE/ m^3 under I_2E_1 and I_2E_2, respectively in the 2nd growing season (2018/2019). The lowest water productivity was obtained under T_1E_3 treatment, which recorded 2.23 and 1.71 LE/ m^3, respectively for the two growing season : 2017/2018 and 2018/2019.

CONCLUSION

The results obtained in this study indicated that surface drip irrigation with 100% ET_c and 80% of ET_c produced higher yield and yield components of guava trees. The highest values of shoot length, number of leaves/m and leaf area were obtained as a result of I_2E_1 treatment (SDI (I_2) + 100% ET_c) while the lowest values were due to I_1E_3 treatment (furrow irrigation and 60% ET_c). The highest values of WUE and water productivity (W.P.) were obtained by I_2E_1 and I_2E_2 treatments in the two growing seasons, while the lowest values of WUE and water productivity (W.P.) were obtained by I_1E_1 treatment (furrow irrigation and 100 % ET_c). It is clear, therefore, that I_2E_1(drip irrigation with 100% ET_c) and I_2E_2(drip irrigation with 80% ET_c) treatments can be considered the most effective irrigation method with water regime application in improving WUE and increasing yield, yield components and water productivity of guava trees.

It is recommended through the results of this research to replace surface irrigation with drip irrigation with water regime 100% or 80%. Also, future study should be carried out to evaluate the effect of drip irrigation on clay soil, other plants and its impact on the environments.

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الملخص العربي

تاثير نظم الرى والرجيم المائى على كلا من النمو ومكونات المحصول وكفاءة إستخدام الماء والانتاجية المائية للجوافة المنزرعة فى التربة الطينية

أشرف السيد النماس

أجريت تجارب حقلية خلال موسمين زراعيين متتاليين (2017 /2018) و (2018 /2019) فى بستان للجوافة بمدينة كفر الدوار , محافظة البحيرة , جمهورية مصر العربية , للتحقق من تاثير كلا من الرجيم المائى (100% , 80% , 60 % من البخرنتح المحصولى) و نظامى رى (الرى بالخطوط , الرى بالتنقيط) على كفاءة استخدام المياه ، ومعايير النمو ، ومكونات المحصول ، والتحليل الاقتصادي لأشجار الجوافة البالغة من العمر أربع سنوات المنزرعة في التربة الطينية .تم تنفيذ التجربة في تصميم القطاعات العشوائية الكاملة بثلاثة مكررات.وقد بينت النتائج المتحصل عليها أن الرى بالتنقيط السطحى مع رجيم مائى 100 , 80 % من البخر نتح المحصولى أعطيا أقصى طول غصن(فسيلة) , عدد الأوراق لكل غصن وكذلك مساحة الاوراق (سم ^{2}) . كان أقصى محصول جوافة عند تطبيق معاملة الرى بالتنقيط و 100 % بخر نتح- محصولى حيث سجلت هذة المعاملة 11.33 و 11.05 طن / فدان خلال موسمى النمو (2017 /2018) و(2018 /2019) على الترتيب بينما أقل محصول عند تطبيق معاملة الرى السطحى بالخطوط و 60 % بخر نتح – محصولى حيث سجلت هذة المعاملة 8.50 و 7.52 طن / فدان خلال موسمى النمو (2017 /2018) و (2018 /2019) على الترتيب . كما وجد إختلافات معنوية بين مكونات المحصول والتى تشتمل على عدد الثمار لكل غصن , طول الثمرة (سم) , قطر الثمرة (سم) , حجم الثمرة (سم ^{3}) والمحصول (كجم/شجرة). كانت كفاءة إستخدام المياة لمعاملات الرى بالتنقيط أعلى عند مقارنتها لمعاملات الرى السطحى بالخطوط خلال موسمى النمو . حيث ذادت قيم كفاءة استخدام المياه من 2.37 و 3.34 كجم/م ^{3} تحت معاملة الرى بالتنقيط بينما تراوحت بين 1.63 و 2.18 كجم/م3 فى معاملة الرى بالخطوط خلال موسمى النمو (2017 /2018) و (2018 /2019) على الترتيب. كما أوضحت النتائج عدم وجود فروق معنوية للخواص الكيميائية لثمار محصول الجوافة والتى تشتمل على المكونات الصلبة الكلية والحموضة وانسبة بين الصلبة الكلية والحموضة. وكان أقصى صافى عائد (24411 جنية/ فدان) خلال موسمى النمو (2017 /2018) و (2018 /2019) تم تسجيله عند تطبيق معاملة الرى بالتنقيط و100 % بخر نتح المحصولى بينما أقل صافى عائد (6344 جنية / فدان) تم تسجيلة عند تطبيق معاملة الرى السطحى بالخطوط و 60 % بخر نتح – محصولى .تم التحصل على أقصى إنتاجية للماء (5.56 جنية / م ^{3} , 5.25 جنية / م ^{3}) عند تطبيق نظام الرى بالتنقيط ورجيم مائى 100 و 80 % من البخر نتح – المحصولى خلال موسمى النمو (2017 /2018) و (2018 /2019) على الترتيب.