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Effect of Irrigation Regime and Spraying Salicylic Acid on Characteristics and Quality of (*Banzahir*) Lime Fruits (*Citrus aurantifolia* B.) at Harvest, Marketing and Some Water Relations

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IRRIGATION management is one of the most important factors for water saving, especially with limited water resources in Egypt. so, the present study was carried out during 2017 and 2018 on trees of Lime (*Citrus aurantifolia*), grown in sandy soil at Asyut Agriculture Research Station (ARC), Asyut Governorate, Egypt, to elucidate the effect of different irrigation regimes; 100%, 80% and 60% of ETc and spraying (SA); with and without spraying on yield, fruit quality and market ability; room temperature and cold temperature. The results can be summarized as follows: irrigation with 100% ETc and spraying SA recorded the highest values of Fruit length, fruit width, Fruit weight and Yield compared to the other irrigation regimes. While, irrigation with 60% ETc and spraying SA recorded the highest values of irrigation water productivity and economic water productivity in both seasons. Also, irrigation fruits with 100% ETc and treated with SA during growth season induced the highest level of Juice weight %. Moreover, the obtained results indicated that irrigating fruits with 60% ETc and treating with SA decreased weight loss % and decay % while, increased TSS %, total acidity in fruit juice, and V.C content of mature fruit compared with the other treatments under marketability.

Keywords: Drip irrigation, Egyptian lime, Fruit quality, Marketability, Water productivity, Salicylic acid

Introduction

Citrus is one of the most important crops in the world next to grapes and apples. Egyptian lime (*Citrus aurantifolia* B) is one of the most communal fruit between citrus in Egypt, due to its high yield, fresh consumption, consumesd during the year, aromatic flavor and rising fruit quality. Egyptian lime trees; about 23228.11 hactar in Egypt, represent about 10.3% of total area of citrus (225717.91 ha) and produced about, 424204.1 ton representing about 10.35% of the total citrus production (4098590 tons) according to Ministry of Agriculture and Land Reclamation statistics (2015).

In Egypt, water is the most significant factor in agricultural output. Almost vegetarian production is mainly dependent upon irrigation. The Nile River is the main source of water from the limited water resources in Egypt. Under the limited the water resources in Egypt, we should do our best towards the management of irrigation water well on the farm level. The present share of water in Egypt is less than 1000 m^3/capital/year equivalent to the international standards of water poverty limit (ELQuosy, 1998) Deficit irrigation strategies can enhance water-use efficiency and saving the agro-ecosystems. Irrigation can also have great effects on fruit quality and shelf life during harvest, packing house operations, storage, and

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distribution. These include effect on fruit color, softness, juice content, and the physiological disorders (Ritenour et al. 2002). Kallsen et al. (2011) reported irrigation influence on fruit size, quality, total yield, and time of harvest. Water stress can affect yield and fruit quality. Water deficits have increased the concentration of juice and TSS, especially sugars, through short-term fruit dehydration or longer-term osmotic adjustment (Perez-Perez et al. 2009). Salicylic acid (SA) (o-hydroxybenzoic acid), is one of a group of plant phenolics and distributed in plants. Salicylic acid is considered as a hormone-like substance, which plays a great role in the organization of plant growth and development Raskin (1992).

At the last 20 years, salicylic acid has drawn the attention of researchers because it can encourage systemic obtained resistance (SAR) in plants. Salicylic acid has the ability to motivate plant defense systems against different biotic and abiotic stresses (Tiwari et al. 2017 and Koo et al. 2020). Salicylic acid (SA) represents a plant messenger that induces the plant tolerance against biotic and abiotic stresses (Horvath et al. 2007). It has various effects on adaptation of stress and plant damage depending on the plant species, its concentration, and the applied method of SA (Metwally et al. 2003). Earlier reports showed that the exogenous application of SA can ameliorate the drought stress impact in various plant species (Arfan et al. 2007), and the plant water deficit (Bezrukova et al. 2001). Pre- and post-harvest SA treatments were found to reduce the fruits decay and the chilling injury, and improve the fruits quality, appearance, texture, and the nutritional values (Asghari and Aghdam, 2010; Glowacz and Ree, 2015). Researchers applied SA as postharvest treatments "Kinnow" mandarin (Haider et al. 2020), mango fruits (Gonchikari Lokesh et al. 2020), and murcott mandarin (Ennab et al. 2020) for increasing the quality.

Therefore, the target of the present study is to determine the effect of irrigation regime and application of SA on the yield, quality and marketability of Egyptian lime under water deficiency conditions.

Materials and Materials

Experimental site

The experiments were conducted at the Experimental Farm of Arab El-Awammer Research Station (latitude 27°, 03′ N, longitude 31°, 01′ E and 71 m above sea level), Agricultural Research Center (ARC), Asyut, Egypt. Physical and chemical characteristics of the experimental site are shown in Table 1. In addition, climatic data were obtained daily from a weather station in the experimental and it is presented in Table 2.

Plant Materials

The present study was carried out during years 2017 and 2018 on trees of Lime (*Citrus aurantifolia*), planted 4 × 4 metres, were 10 years old, irrigated with drip irrigation (one drip-line was used in each tree row with two drippers (16 L h^{-1}) per tree) to elucidate the effect of different irrigation regimes and spraying Salicylic (SA) acid on yield, fruit quality at harvest and marketing, Where the fruits were placed at room temperature and in the display refrigerator (cold temperature). Eighteen trees nearly similar in growth, healthy and subjected to the same cultural practices were selected and then divided into 6 treatments each has 3 replicates where each replicate has one tree.

The following treatments were during the growing season:

A. Main treatments (irrigation regimes)

1- Irrigation with amounts of water equal to 100% crop evapotranspiration (ETc).
2- Irrigation with amounts of water equal to 80% (ETc) and,
3- Irrigation with amounts of water equal to 60% (ETc).

B. Sub main treatments

1- Sprayed salicylic acid (400 ppm) and,
2- Sprayed water tap (0 ppm salicylic acid)

The trees were sprayed three times at the first week of June, July and August. Trees under study were sprayed in early morning using a back gun sprayer 20 liters until solution run off. The fruits were harvested in mid-August manually and carefully brought shortly after harvest, to the Agricultural Research Station laboratory. At the beginning of the harvesting, samples of 3 replicates from each treatment were taken to determine the initial characteristics, Then I took a quantity of fruits divided into two parts, the first section for fruits at room temperature and the second section for cold temperatures, and each section is divided into two groups, the first group to measure weight loss and the percentage of decay fruits while the second one was devoted juice and the chemical analysis.

TABLE 1. Chemical and physical characteristics for experimental site

Chemical properties										
pH (1:1)	EC dS m^{-1} (1: 1)	Soluble cations ($mmol_c$ l^{-1})				Soluble anions ($mmol_c$ l^{-1})			Available P (mg kg^{-1})	Total N (%)
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{--}	Cl^{-}		
8.37	0.33	1.43	1.16	0.19	0.75	0.0	1.68	1.47	8.31	0.009
Physical properties										
Particle size distribution (%)			Texture class	Moisture content (as volume %)			O.M (g kg-1)	$CaCO_3$ (%)	Bulk density (g cm^{-3})	
Sand	Silt	Clay		S. P.	F.C.	W.P.				
89.9	7.1	3.0	Sandy	23.3	10.9	4.5	1.9	309	1.63	

TABLE 2. Average monthly meteorological data of Assiut weather station during two years (2017 and 2018)

Year	Month	T max (°C)	T min (°C)	RH %	w.s / km/h	Sunshine	ETo (mm/day)
2017	January	19.3	5.3	55.3	14.8	8.9	3.73
	February	20.5	6.3	52.6	14.5	9.7	4.33
	March	25.3	11	42.5	17.2	9.9	6.44
	April	31.3	15.5	36.6	17.3	10.3	8.59
	May	36.3	20	31.4	16.2	11.4	10.29
	June	37.4	23.4	34.6	21	12.3	11.77
	July	39.1	25.3	32.7	16.3	12.2	11.11
	August	37.8	24.6	38.8	17.6	11.9	10.50
	September	35.3	20.9	44.6	20.7	10.8	9.50
	October	30.3	16.5	47	17.2	10.0	6.94
	November	25.1	10.9	54.6	15.2	9.4	4.75
	December	23.2	9	58.8	14.6	9.0	3.98
2018	January	19.9	6.5	57.4	15.3	8.9	3.77
	February	26.1	11.2	44.3	14.4	9.7	5.63
	March	30.5	14.2	36.2	16.9	9.9	7.90
	April	32.4	16.6	36.2	18.4	10.3	10.93
	May	37.7	21.7	29.2	17.5	11.4	11.13
	June	38.5	23.2	33.6	20	12.3	11.90
	July	38	24.7	41.5	18.7	12.2	10.84
	August	37.6	24.3	40.7	19.8	11.9	10.81
	September	35.5	22	46.2	20.5	10.8	9.43
	October	32.6	18.9	46.5	18.1	10.0	7.58
	November	26.5	13.1	53.8	14.7	9.4	4.93
	December	20.8	8	62.8	16.3	9.0	3.62

T Max = Maximum temperature (°C) **T min**= Minimum temperature (°C) **RH**= Relative humidity (%) **W.S** = Wind speed (Km/h) **ETo** = Reference evapotranspiration.

All were fruits selected without any decay and, fruits were washed with tap water. Thereafter, air dried under room temperature. Each fruit was packed using perforated bag and weighted. Fruits were stored in two different temperatures, room temperature at 28°C ± 2 and 50- 65% relative humidity) and cold temperature (7°C ± 2 and 70-85% relative humidity). Fruits kept at room temperature were examined every 2 days but under cold temperature conditions, the samples were examined every 4 days to study the change in Fruits and Fruits characteristics through marketing.

Irrigation-water measurements and crop-water relations

Crop evapotranspiration (ETc)

CROPWAT model was used to calculate reference evapotranspiration according to Penman Monteith.

Crop evapotranspiration (ETc) was calculated according to (Allen et al. 1998)

$$ET_c = ET_0 \times Kc$$

Where:
ETc = Crop evapotranspiration.
ET_0 = Reference evapotranspiration, and
Kc = Crop coefficient (from FAO paper 56)

Irrigation applied water

The amounts of actual irrigation applied water under each irrigation treatment were determined using the following equation: James (1988)

$$I.Ra = \frac{ETc + Lf}{Er}$$

Where:
I.Ra = total actual irrigation applied water mm/ interval.
ETc = Crop evapotranspiration
Lf = leaching factor 10 %, and
Er = irrigation system efficiency.

Productivity of irrigation water

The productivity of irrigation water (PIW, kg/ m^3) values were calculated according to Ali *et al* (2007) as follows :

$$PIW = \frac{Y}{I}$$

Where :
PIW = productivity of irrigation water (Kg m^{-3}),
Y = yield kg ha^{-1}, and
I = irrigation applied water, m^3 ha^{-1} (Irrigation water + effective rainfall).
Note: effective rainfall = rianfall*0.7 (Novica, 1979).

Economic productivity of irrigation water

Irrigation productivity of irrigation water can be expressed as economical productivity (EPIW) and (EWP) according to Molden (1997). It was calculated as follows:

$$EPIW = \frac{Gross\ value\ of\ product\ (L.E.\ ha^{-1}}{Total\ amount\ of\ irrigation\ applied\ water\ (m^3\ ha^{-1})}$$

Measurements

Fruit weight loss

Fruit weight loss was calculated according to the equation as follows:

Fruit weight loss % = (Initial Fruit weight- Final Fruit weight / Initial Fruit weight) x 100

Decay

Decay rate was calculated according to the equation as follows:

Fruit decay % = (Weight of decayed Fruit / Initial Fruit weight) x 100

Juice weight percentage/fruit

Juice weight was calculated according to the equation as follows:

Juice weight % = (Juice weight / fruit weight) x 100

Total soluble solids

Total soluble solids (TSS%) were determined using hand refractometer.

Titratable acidity

Acidity of the fruit juice was determined by titration of 5 ml juice against 0.3 N sodium hydroxide using phenolphthaline as an indicator. Titratable acidity was expressed as grams of citric acid per 100 ml fruit juice according to the A.O.A.C. (1985).

Total soluble solids/acidity ratio (TSS/Acid ratio)

TSS/acid ratio was calculated by dividing TSS% by total acidity % in fruit juice.

Ascorbic acid (V.C.) content

The vitamin "C" content was determined, in fruit juice during cold storage titration with, 2,6-Dichlorophenol indophenol blue dye. According to the A.O.A.C. (1985), and expressed as mg of ascorbic acid/100 g juice.

Statistical analysis

In the field experiment : irrigation regimes treatments were three whole plots while the spraying Salicylic acid (SA) were considered as splits. This experiment was conducted in split-plot with three replicate, one bag each. The field treatments were six whole plots (T), while the storage periods were considered as splits (P). All recorded data were tabulated and statistically analyzed according to Snedecor and Cochran (1990) using new L.S.D. at the level of 0.05 in comparison between various treatment means.

Results and Discussion

Irrigation water relations

Crop evapotranspiration

Data in Fig. 1, show the values of the crop evapotranspiration (ETc) calculated according to Penman Monteith equations for trees of Lime during the two years (2017 and 2018). Results showed that the total values of ETc were 2264.82 mm during year 2017 and were 2423.32 mm during year 2018. The results also indicated that the total ETc values in the second year were higher than the values of the first year. This difference may be due to low air temperature (mean air temperature in the year 2017 was 15.7°C minimum and 30.1 °C maximum) and wind speed (mean wind speed in the year 2017 was16.9 Km/h) in the first year compared to the second year (mean air temperature in the year 2018 were 17.0 °C minimum and 31.3°C maximum and mean wind speed in the year 2018 was117.6 Km/h). The maximum crop evapotranspiration was in June this is due to increase the reference evapotranspiration during this month compared to the other months in the year. These results are in the same line with those reported by Al- Naeem (2014), Zaghloul and Moursi (2017), Silva et al. (2019) and Jamshidi et al. (2020).

Irrigation applied water (m^3/ha)

The monthly irrigation applied water for lime trees were presented in Fig. 2. The data showed that, the values of irrigation applied water for lime trees were greatly affected by irrigation regimes (100, 80 and 60% ETc). The irrigation applied water was found to be 27681, 22144 and 13286 m^3/ha. in the first year (2017) for 100%, 80 and 60% ETc, respectively, and were 29618, 23694 and 14216 m^3 ha^{-1} in the second year (2018). The results also, indicated that the values of total irrigation applied water in the second year were higher than the values of the first year. This difference may be due to the increases air temperature and wind speed in the second year. These results agree with Amer (2020) on sugar beet and cotton.

The irrigation applied water varies from growth month to another through the two growth years. The irrigation applied water reached its peak in June. This may be due to the high reference evapotranspiration through this month. The seasonal level of irrigation applied water was mostly influenced by irrigation treatments. The increase in Irrigation applied water under 100% ETc treatments may be attributed to the increase in direct evaporation. Therefore, the seasonal irrigation applied water is higher under 100% followed by 80% and 60% ETc for lime trees during the two growth years. These results are in the same line with those reported by Zaghloul (2017), Silva et al. (2019) and Jamshidi et al. (2020).

Productivity of irrigation water (PIW kg/m^3)

The data in Fig. 3 and 4, show the effects of irrigation regime and spraying salicylic acid on the productivity of irrigation water (PIW). PIW in agricultural production system is focused on producing more food with the same water resources or, producing the same amount of food with less water resources. PIW was significantly decreased when lime orchard was irrigated with 100% ETc compared to 80 and 60% ETc. The highest PIW (0.57 and 0.45 kg m^3) in this study were produced by spraying salicylic acid under irrigated with 60% ETc. These results agree with those obtained by Zaghloul and Moursi (2017) reported that irrigation water use efficiency was decreased linearly due to increasing irrigation water (Darwesh, 2018; Aiad, 2019; and Abdel-Fattah et al. 2020).

Economic productivity of irrigation water (L.E. m^{-3})

Economic productivity of irrigation water in agricultural production system is focused on gross value of product, L E m^{-3}. EPIW shows in Fig. 5 and 6 take the same liner of PIW, it was significantly decreased when lime orchard was irrigated with 100% ETc compared to 80 and 60% ETc. The highest EPIW, 7.73 and 4.29 LE m^{-3} in the first and second season respectively were produced by spraying salicylic acid under irrigated with 60% ETc.

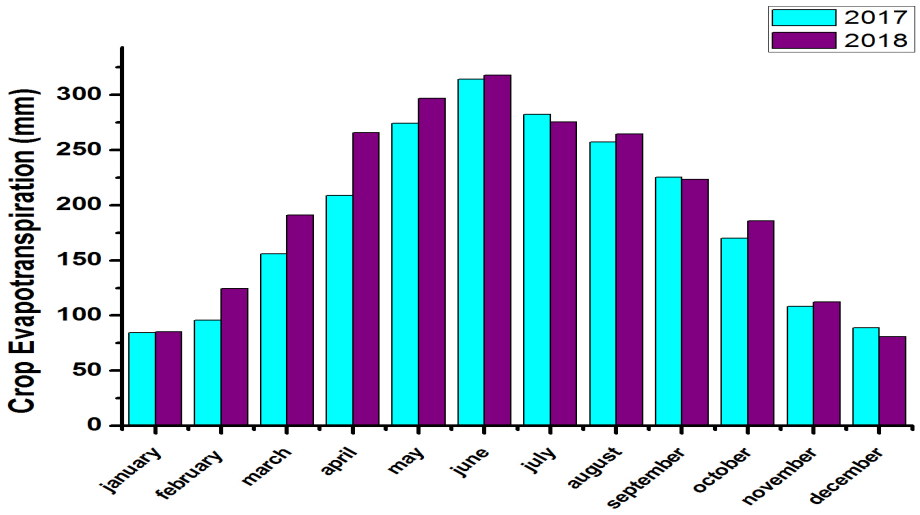

Fig. 1. Crop evapotranspiration ETc (mm) during years 2017 and 2018 of Lime trees calculated according to Penman Monteith equations

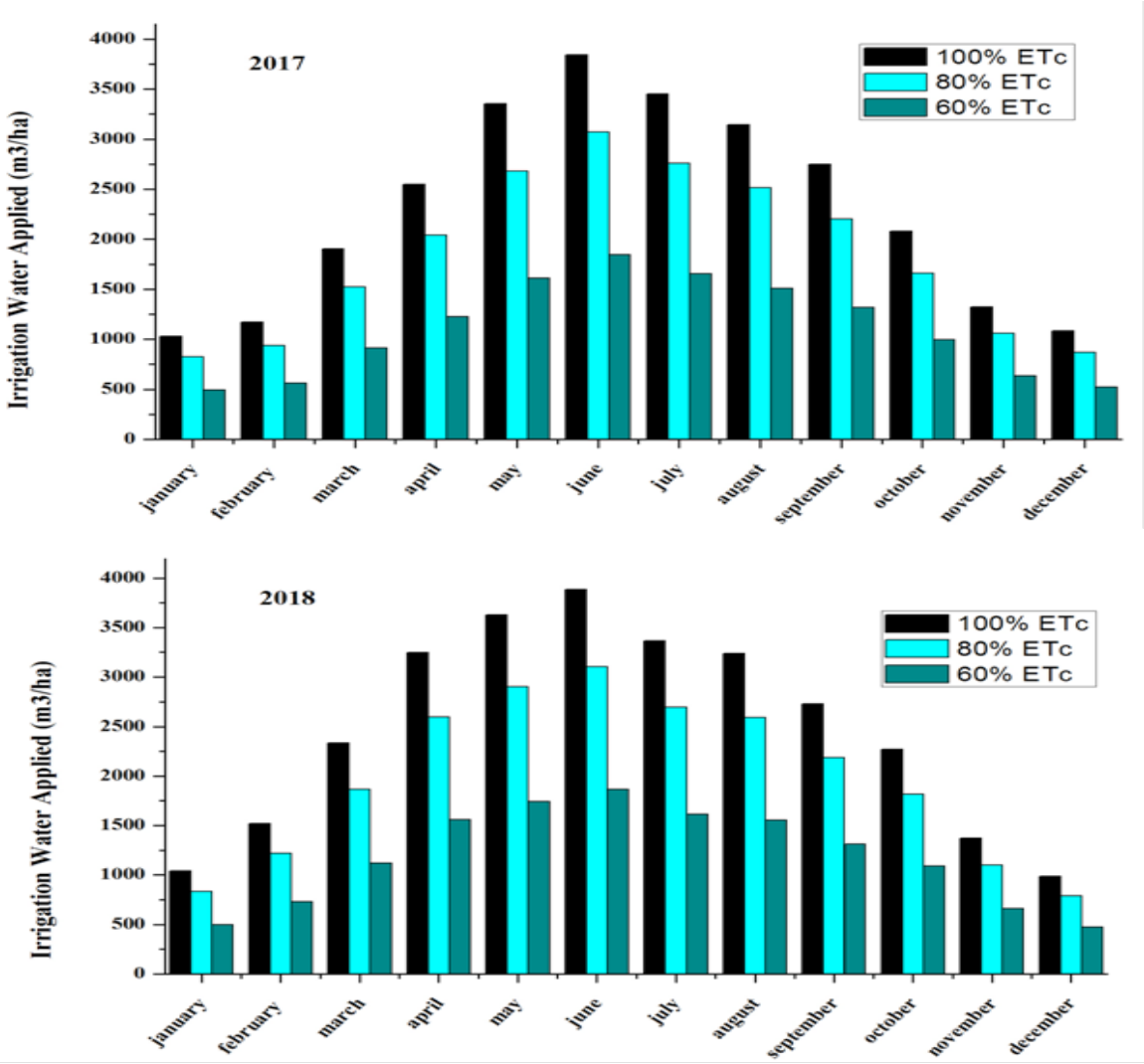

Fig. 2. Irrigation applied water (m^3/ha) as affected by irrigation regime during years 2017 and 2018

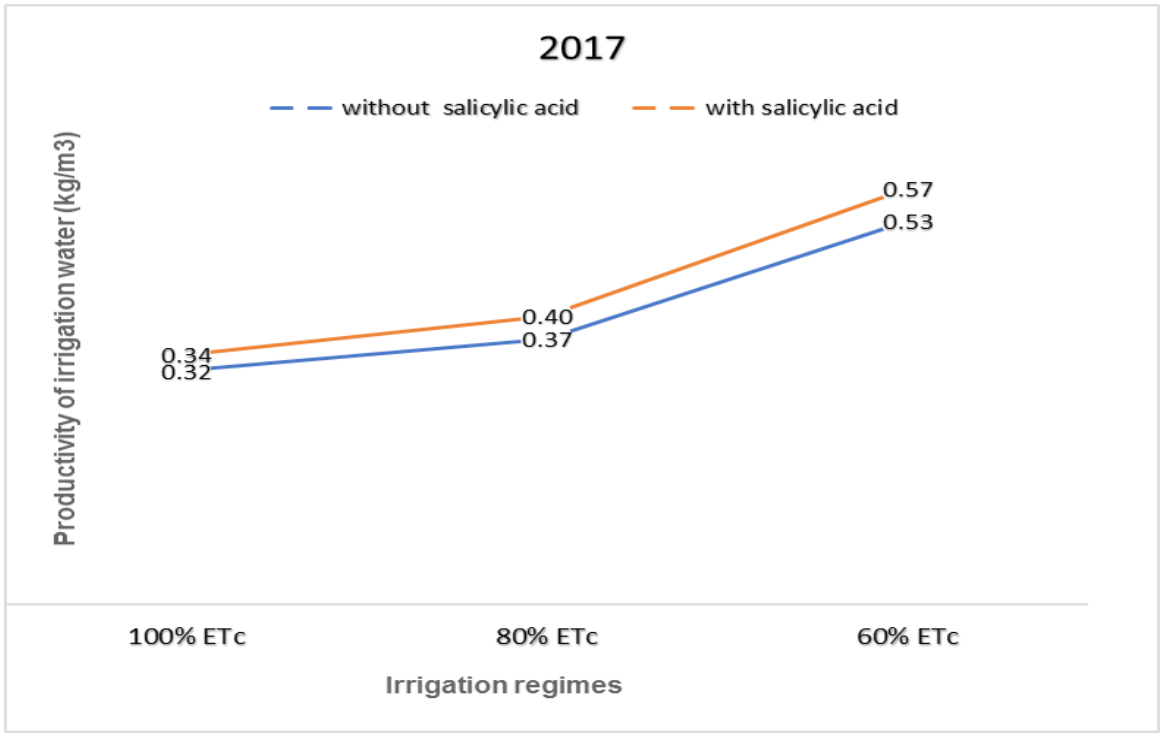

Fig. 3. Productivity of irrigation water kgm^{-3} of Lime fruit as influenced by irrigation regime and spraying Salicylic acid during 2017 year

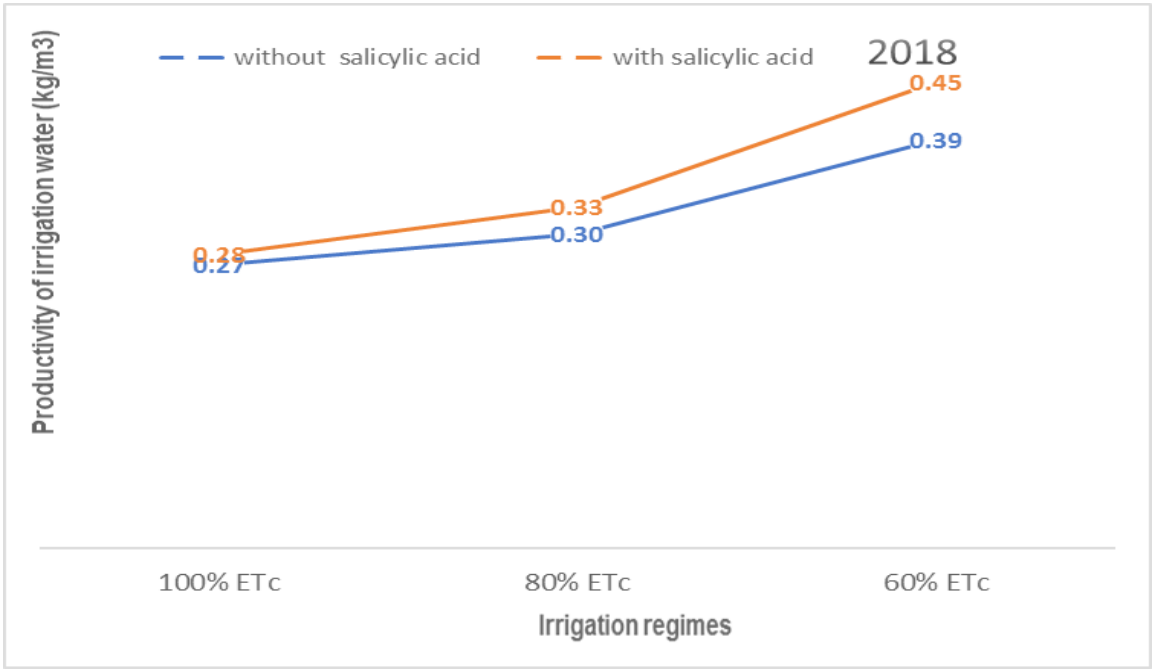

Fig. 4. Productivity of irrigation water kgm^{-3} of Lime fruit as influenced by irrigation regime and spraying Salicylic acid during 2018 year

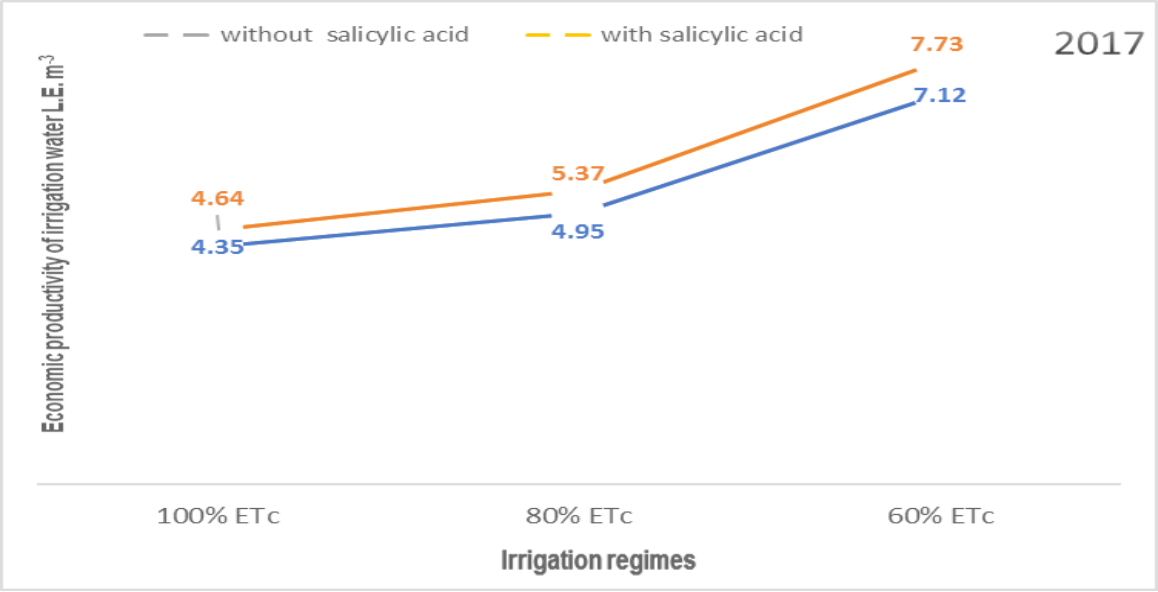

Fig. 5. Economic productivity of irrigation water kgm^{-3} of Lime fruit as influenced by irrigation regime and spraying Salicylic acid during 2017 year

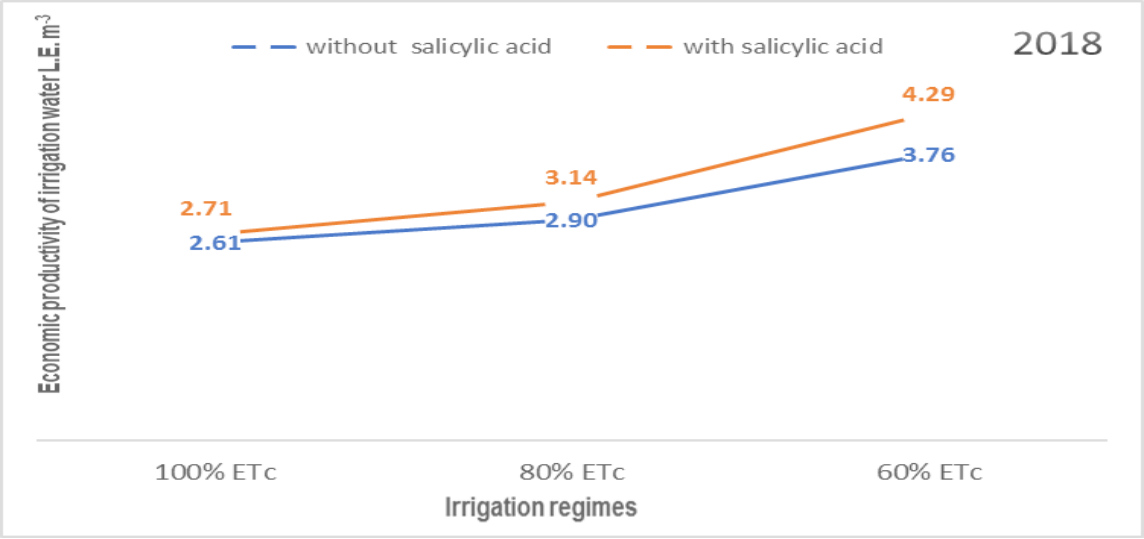

Fig. 6. Economic productivity of irrigation water kgm^{-3} of Lime fruit as influenced by irrigation regime and spraying Salicylic acid during 2018 year

Yield, yield components and quality of lime fruits at harvest

Data in in Table 3, cleared that the results of the two seasons took the similar data trend as following; the yield (Ton ha^{-1}) was significantly affected by different irrigation water regime, fruit weight was gradually decreased by decreasing the irrigation in both seasons. Salicylic acid increasing the fruit weight compared to untreated. Fruit dimensions results indicated that length and diameter were significantly decreased by reducing irrigation regime and the smallest fruit were produced under deficit irrigation regime 60%. Salicylic acid spraying has also significant increase effects on both the length and diameter of the fruit. Decreasing the irrigation regime from100% to 80% and 60% induced increase in Reg weight % from (51.93 to 53.20 and 58.45%) in the first season and (51.80 to 55.20 and 57.40%) in the second season, respectively. Salicylic acid spray caused an improvement in Reg weight % (53.79and 54.33) compared to untreated fruits

(55.27 and 55.27) in both seasons, respectively. The reduction in fruit weight and size under deficit soil moisture content could be due to reduce the fruit cell enlargement through reduce fruit trugor early in the season and to decrease cell water content (Li et al., 1989). Behbudian et al. (1994) pointed out that, reduce the fruit size under water stress might be due to less assimilate availability through decrease net photosynthesis rate (Pn). These results are in the same line of Mikhael and Maddy (2007) on apple and Ibrahim and Abd El-Samad (2009) on pomegranate, *and* Magda - Khattab et al. (2011) on pomegranate which found a progressive reduction in fruit yield was observed in deficit irrigation treatment as compared to higher irrigation treatment. The increase in yield parameters due to salicylic acid observed in the present investigation can be attributed to increased photosynthetic activity in leaves and translocation of more photo-assimilates to fruits. Salicylic acid is responsible for increasing yield by increasing fruit set percentage, increase in fruit weight and number of fruits per tree. It also stimulates cell division and the tolerance of plants to all stresses namely diseases, water and salt stresses and protects plant cells from oxidation by free radicals (Raskin, 1992; Lee et al. 1995; Shah, 2003). These findings agree with the findings of Ngullie et al. (2014) and Ahmed et al. (2015a) in mango, Ashraf et al. (2013) in kinnow, Rahmani (2017) on Mango and Amer et al. (2019).

TABLE 3. Effect of irrigation regime, spraying salicylic acid on Yield (Ton ha^{-1}), Yield (kg tree^{-1}), Fruit weight (g), Fruit length (cm^2), fruit width (cm^2) and Reg weight of lime fruits at harvest

Irrigation (ETc)	**100%**	**80%**	**60%**	**100%**	**80%**	**60%**
Spraying	**2017**			**2018**		
			Yield (Ton/ha)			
non spraying SA	8.9	8.1	7.0	8.1	7.2	5.6
spraying SA	9.5	8.8	7.6	8.4	7.8	6.4
L.S.D. 0.05	**I; 0.43**	**SA;0.42**	**I*SA; 0.72**	**I;0.28**	**SA; 0.41**	**I*SA; 0.71**
Yield (kg/tree)						
non spraying SA	14.2	13.0	11.3	12.9	7.2	8.9
spraying SA	15.2	14.1	12.2	13.4	7.8	10.2
L.S.D. 0.05	**I; 0.56**	**SA; 0.29**	**I*SA; 0.49**	**I; 0.53**	**SA; 0.14**	**I*SA; 0.26**
			Fruit weight (g)			
non spraying SA	30.17	27.87	27.87	27.87	26.66	23.72
spraying SA	31.27	29.63	29.63	29.63	28.95	25.00
L.S.D. 0.05	**I; 0.83**	**SA; 1.05**	**I*SA; 1.82**	**I; 1.53**	**SA; 0.42**	**I*SA; 0.74**
			Fruit length (cm^2)			
non spraying SA	38.20	36.27	32.64	37.61	35.67	32.63
spraying SA	39.57	37.03	35.22	38.25	36.88	34.57
L.S.D. 0.05	**I; 1.25**	**SA; 0.78**	**I*SA; 1.36**	**I; 0.85**	**SA;1.01**	**I*SA; 1.74**
fruit width (cm2)						
non spraying SA	36.66	34.96	32.75	35.66	33.70	33.43
spraying SA	37.83	35.63	34.82	35.42	35.91	33.70
L.S.D. 0.05	**I; 0.49**	**SA;0.67**	**I*SA; 1.17**	**I; 0.53**	**SA; 0.53**	**I*SA;0.93**
			Reg weight %			
non spraying SA	52.02	54.42	59.41	51.16	56.32	58.34
spraying SA	51.85	52.00	57.51	52.37	54.12	56.48
L.S.D. 0.05	**I; 1.09**	**SA; 0.24**	**I*SA; 1.02**	**I; 1.17**	**SA;0.81**	**I*SA; 1.41**

Physico-chemic Juice al fruit attributes of lime fruits at harvest

Data in Table 4, cleared the effect of irrigation regime or spraying salicylic acid on juice weight %. Decreasing the irrigation regime from 100 % to 80% and 60% induced a reduction in juice weight % from (48.07 to 46.79 and 41.5%) in the first season and (48.23to 44.78 and 42.59%) in the second season, respectively. Salicylic acid caused an improvement in the weight of the juice (46.21and 45.68) compared to untreated fruits (44.72and 44.73) in both seasons, respectively. There was a gradual increase in Total soluble solids % (TSS %) with the decrease in irrigation regime from 100% to 80 % 60% in both seasons. While, spraying salicylic acid was superior for raising TSS value. These results could be attributed to advance fruit maturity under drought condition. Titratable acidity % (TA %) was not significantly affected by all irrigation and spraying salicylic acid treatments, in 1st and 2nd seasons. Moreover, the irrigation regime and spraying salicylic acid failed to show any measurable effect on (TSS/ TA ratio). With regard to the effect of irrigation regime and spraying salicylic acid on vitamin C content (as mg of Ascorbic acid/100 ml juice) of lime fruit, it was found that, the percent of vitamin C content in lime fruit were increased by reducing irrigation regime and spraying salicylic acid. These finding was supported by Pérez-Pérez *et al*. (2009) on Sweet orange Lan late and Abo El-Enien (2012) on Navel orange, Zaghlou and Moursi (2017) on Navel Orange they found that, moderate water stress produced the highest TSS, acid ratio and as vitamin C. The promoting effect of SA on plant pigments and the biosynthesis of carbohydrates surely reflected on advancing maturity and improving fruit quality (Shah, 2003). These results are in agreement with these obtained by Eshmawy (2010); Saied (2011) and Ahmed (2013) on Mango.

TABLE 4. Effect of irrigation regime, spraying salicylic acid on physico-chemic Juice al fruit attributes of lime fruits at harvest

Irrigation / Spraying	100% ETc	80% ETc	60% ETc	100%% ETc	80% ETc	60% ETc
	2017			2018		
Juice weight %						
non spraying SA	47.98	45.58	40.59	48.84	43.68	41.66
spraying SA	48.15	48.00	42.49	47.63	45.88	43.52
L.S.D. 0.05	**I;3.01**	**SA; 0.59**	**I*SA; 1.03**	**I; 1.17**	**SA;0.81**	**I*SA;1.41**
TSS %						
non spraying SA	7.40	7.73	8.13	7.00	7.20	8.00
spraying SA	7.50	7.77	8.43	7.30	7.40	8.20
L.S.D. 0.05	**I; 0.82**	**SA; NS**	**I*SA; 0.26**	**I; 0.43**	**SA; NS**	**I*SA; 0.46**
TA						
non spraying SA	6.68	6.89	7.04	6.58	6.46	6.74
spraying SA	6.78	6.91	7.17	6.69	6.68	7.04
L.S.D. 0.05	**I; NS**	**SA; NS**	**I*SA;NS**	**I; NS**	**SA; NS**	**I*SA;NS**
TSS/TA ratio						
non spraying SA	1.11	1.12	1.15	1.06	1.11	1.19
spraying SA	1.11	1.12	1.18	1.09	1.11	1.16
L.S.D. 0.05	**I; NS**	**SA; NS**	**I*SA; NS**	**I; NS**	**SA; NS**	**I*SA ;NS**
V.C content						
non spraying SA	49.87	57.79	59.40	50.16	53.68	59.40
spraying SA	52.51	53.39	60.28	51.92	58.08	60.72
L.S.D. 0.05	**I; 2.71**	**SA; NS**	**I*SA; 4.21**	**I; 0.61**	**SA;1.70**	**I*SA; 2.94**

Physico-chemical fruit attributes of lime fruits during marketing

Decay percentage

The results in Table 5, clearly showed that Decay Percentage were markedly increased with advanced of marketability period and reached its maximum values at the end of the marketing period. Also, decayed fruits could not be detected for 2 days being under room temperature and four days cold temperature in both seasons. Data indicated that the reduction irrigation water from 100% to 60% ETc decreased the decayed fruit percentage under both room temperature and cold temperature. Data proved that the spraying with SA, gave the best effect to prevent the fruits from decay compare to untreated with SA. The According to recorded data, it could be noticed that irrigated fruits with 60% with SA resulted in the least decay (%) while irrigated with 100% gave the highest value of decay (%). These results are in agreement with those reported by Abdel-Razik (2012) on mango, who reported that irrigation trees with 70% decreased decay % when compared with those irrigated with 100% ETc under cold storage, Hamdy (2017) on Valencia Orange who reported that irrigation trees with 60% decreased decay % when compared with those irrigated with 80 or 100% ETc under cold storage. Exogenous application of SA provided efficient control of decay caused by post harvest pathogens. Khademi and Ershadi (2013) and inducing systemic resistances against post harvest pathogen which extend storability of fruits with higher antioxidant activity that activates natural defense mechanism (Muzammil et al. 2014).

TABLE 5. Effect of irrigation regime, spraying salicylic acid on decay of lime fruits during marketing

Treatments	At room temperature				At a cold temperature				
	Marketing period								
	0 days	2 days	4 days	6 days	0 days	4 days	8 days	12 days	16 days
	Season 2017								
100% ETc	0.00	0.00	11.96	37.70	0.00	0.00	8.33	16.33	29.15
100% ETc + SA	0.00	0.00	6.22	30.42	0.00	0.00	5.56	16.07	27.35
80% ETc	0.00	0.00	6.93	28.21	0.00	0.00	0.00	14.70	26.45
80% ETc + SA	0.00	0.00	3.11	25.55	0.00	0.00	0.00	11.28	23.13
60% ETc	0.00	0.00	2.77	24.14	0.00	0.00	0.00	10.63	19.81
60% ETc + SA	0.00	0.00	0.00	19.97	0.00	0.00	0.00	10.39	17.50
L.S.D. 0.05:	**(T): 0.45**	**(P): 0.40**	**(TxP): 0.91**		**(T): 0.36**	**(P): 0.56**	**(TxP): 0.80**		
	Season 2018								
100% ETc	0.00	0.00	14.06	31.40	0.00	0.00	5.33	17.00	25.76
100% ETc + SA	0.00	0.00	13.33	29.96	0.00	0.00	2.77	16.33	22.56
80% ETc	0.00	0.00	9.10	25.63	0.00	0.00	3.09	14.71	19.70
80% ETc + SA	0.00	0.00	3.03	25.07	0.00	0.00	0.00	13.70	16.33
60% ETc	0.00	0.00	3.33	20.11	0.00	0.00	0.00	10.34	16.39
60% ETc + SA	0.00	0.00	0.00	21.17	0.00	0.00	0.00	8.08	15.70
L.S.D. 0.05:	**(T): 0.44**	**(P): 0.53**	**(TxP): 0.87**		**(T): 0.43**	**(P): 0.05**	**(TxP): 0.96**		

Fruit weight loss

Data in Table 6, clear that fruit weight loss were markedly increased with advanced of marketability period, which may be due to respiration and transpiration of water through peel tissue and perishable fruit is a serious concern in its marketability because loss of moisture decreases visual quality; salable weight and may result in physiological dysfunctions. Furthermore, all treatments were significant in reducing weight loss compare with control. A decrease in fruit weight loss percentages was noticed when the trees received 60 % of water compared with 100%, while the loss in weight percentages were increased in general by increasing number of days being under room temperature and cold temperature. The present results are in agreement with those obtained by of Abdel-Razik (2012) who studied that fruits of mango trees treated with 70% of ETc gained lower weight loss as compared with that of other treatments, And Hamdy et al. (2017) on Washington navel orange who indicated that trees treated with 60% of ETc gained lower weight loss as compared with that of other treatments. On the other hand, spraying SA reduced weight loss. As for data concerning SA are in line with those of Sartaj et al. (2013) who reported that higher concentrations of salicylic acid that role as an electron donor produces free radical which decrease normal respiration and transpiration.

TABLE 6. Effect of irrigation regime, spraying salicylic acid on weight loss % of lime fruits during marketing

Treatments	At room temperature				At a cold temperature				
	Marketing period								
	0 days	2 days	4 days	6 days	0 days	4 days	8 days	12 days	16 days
	Season 2017								
100% ETc	0.00	6.54	11.42	16.39	0.00	6.11	8.66	11.57	15.75
100% ETc + SA	0.00	5.62	10.71	15.53	0.00	5.53	8.08	11.52	15.05
80% ETc	0.00	5.16	10.39	14.95	0.00	4.09	7.18	10.36	15.02
80% ETc + SA	0.00	4.79	10.26	14.65	0.00	3.78	6.98	10.32	14.36
60% ETc	0.00	4.74	9.43	13.73	0.00	3.83	6.56	9.99	13.93
60% ETc + SA	0.00	4.76	8.96	13.46	0.00	3.14	5.16	9.09	13.49
L.S.D. 0.05	**(T): 0.87**	**(P): 0.76**	**(TxP): 1.75**		**(T): 0.63**	**(P): 0.59**		**(TxP): 1.41**	
	Season 2018								
100% ETc	0.00	5.68	9.9	16.38	0.00	7.34	9.08	12.02	16.07
100% ETc + SA	0.00	5.16	9.55	15.53	0.00	6.63	8.99	11.98	15.15
80% ETc	0.00	4.99	9.22	14.95	0.00	5.11	7.98	10.71	15.41
80% ETc + SA	0.00	4.79	9.07	14.65	0.00	4.97	7.43	9.14	13.25
60% ETc	0.00	4.78	8.86	13.94	0.00	4.73	6.89	8.51	12.83
60% ETc + SA	0.00	4.18	7.96	13.73	0.00	4.18	6.16	7.29	12.92
L.S.D. 0.05	**(T): 0.65**	**(P): 1.12**	**(TxP): 1.30**		**(T): 0.51**	**(P): 0.95**		**(TxP): 1.13**	

Juice weight

Presented data in Table 7, receded that, fruit Juice content % was gradually and proportionally decreased with decreasing either the irrigation water % of ETc from 100% to 60% or with increasing marketability period under Room temperature and cold temperature in lime in both seasons. At the end of marketing period the lowest value of juice content % were found in the ETc 60% fruits (36.59 and 36.60%) in room temperature and (36.66 and 36.60%) in cold marketing during 2017 and 2018 seasons, respectively. On the other hand, it was clear that SA has reduced the decrease in juice weight % It could be noticed that fruit treated with SA during growth season resulted in the highest level of juice weight %, compared with untreated.

Total soluble solids percentage

Data in Table 8, cleared that, Total soluble solids percentage significantly increased and gradually from the beginning of marketability either in room temperature or cold temperature till the six days or Sixteen days, respectively. Thus, the maximum values of TSS% were recorded at the end of marketing period in both seasons. Total soluble solids percentage is a function of total dissolved solids and moisture content of fruit and the increase in TSS% may be due to loss of fruit moisture content during marketing period. Moreover, results indicated that TSS% was increased by decreasing of irrigation water given to the trees whereas maximum increase was recorded at 60% of ETc. These results are in harmony with those found by Abdel-Razik (2012) on mango trees and Hamdy (2017) on Valencia Orange. In addition, there was no significant difference between fruits treated with salicylic acid and untreated fruits under the same level of irrigation. These results agree with those obtained by Ranjbaran et al. (2011) on grapes reported that SA treatment had no effect on TSS. Contrarily, (Khademi and Ershadi, 2013).

TABLE 7. Effect of irrigation regime, spraying salicylic acid on juice weight % of lime fruits during marketing

Treatments	At room temperature				At a cold temperature				
	Marketing period								
	0 days	2 days	4 days	6 days	0 days	4 days	8 days	12 days	16 days
	Season 2017								
100% ETc	47.98	43.37	40.65	37.29	47.98	46.08	44.16	42.53	39.58
100% ETc + SA	48.15	44.86	40.63	37.31	48.15	47.31	45.07	44.62	40.35
80% ETc	45.58	41.89	39.46	37.21	45.58	43.56	41.94	40.74	39.44
80% ETc + SA	48.00	44.30	41.11	37.51	48.00	44.12	43.91	40.91	40.91
60% ETc	40.59	38.86	37.68	36.59	40.59	40.59	43.26	41.79	36.66
60% ETc + SA	42.49	39.84	37.04	37.04	42.49	40.48	42.66	39.44	38.00
L.S.D. 0.05	**(T): 0.92 (P): 0.59 (TxP): .85**				**(T) 0.74: (P): 0.43 (TxP): 1.65**				
	Season 2018								
100% ETc	48.84	44.81	43.86	40.18	48.84	44.81	44.18	40.18	38.38
100% ETc + SA	47.63	44.92	43.25	44.45	47.63	45.92	44.63	43.45	42.38
80% ETc	43.68	43.68	42.15	40.77	43.68	43.68	41.88	40.44	40.40
80% ETc + SA	45.88	43.24	42.38	40.83	45.88	43.24	42.71	40.83	41.94
60% ETc	41.66	40.73	37.52	36.60	41.66	43.73	41.46	40.68	36.60
60% ETc + SA	43.52	42.12	38.69	37.55	43.52	42.12	41.68	41.51	39.55
L.S.D. 0.05	**(T): 3.41 (P): 3.37 (TxP): .83**				**(T): 0.81 (P): 0.96 (TxP): 1.82**				

TABLE 8. Effect of irrigation regime, spraying salicylic acid on total soluble solids percentage (TSS %) of lime fruits during marketing

Treatments	At room temperature				At a cold temperature				
	Marketing period								
	0 days	2 days	4 days	6 days	0 days	4 days	8 days	12 days	16 days
	Season 2017								
100% ETc	7.40	7.77	7.80	8.00	7.40	7.50	7.37	8.00	8.07
100% ETc + SA	7.50	7.80	7.90	8.17	7.50	7.53	7.83	7.93	8.13
80% ETc	7.73	7.57	7.73	8.07	7.73	7.23	8.00	8.07	8.13
80% ETc + SA	7.77	7.67	7.73	8.33	7.77	7.73	7.80	7.87	8.13
60% ETc	8.13	8.27	8.43	9.33	8.13	8.00	8.07	8.47	9.00
60% ETc + SA	8.43	8.60	8.73	9.00	8.43	8.60	8.73	8.93	9.03
L.S.D. 0.05	**(T): 0.17 (P): 0.21 (TxP): 0.34**				**(T): 0.18 (P): 0.35 (TxP): 0.41**				
	Season 2018								
100% ETc	7.00	7.50	8.00	8.40	7.00	7.20	7.80	8.00	8.40
100% ETc + SA	7.30	7.50	8.00	8.20	7.30	7.40	7.60	8.20	8.40
80% ETc	7.20	7.50	8.00	8.50	7.20	7.80	8.00	8.20	8.60
80% ETc + SA	7.40	7.50	7.80	8.33	7.40	7.80	8.00	8.20	8.40
60% ETc	8.00	8.60	9.00	9.13	8.00	8.13	8.30	8.80	9.33
60% ETc + SA	8.20	8.40	8.60	9.00	8.20	8.30	8.40	8.60	9.00
L.S.D. 0.05	**(T): 0.39 (P): 0.31 (TxP): 0.79**				**(T): 0.29 (P): 0.28 (TxP): 0.66**				

Titratable acidity

Data presented in Table 9, indicated that gradual decrease for titratable acidity was found in all treatments. Hence the minimum TA% was recorded at the end of marketability period in room temperature or cold during the two studied seasons. The highest value of acidity was found at 60% of ETc, while the lowest at 100% of ETc. while, fruits treated with SA retained higher content of TA during the entire storage period compare to untreated fruits. These results are in line with those reported by Chanikan et al. (2015) who illustrated that the slight decline in TA was probably due to the slow rate of respiration and metabolic processes converting citric acid into sugars as a function of applied SA.

TSS / TA ratio

Presented data in Table 10, indicated that A gradual increase for TSS / TA was found in all treatments. Hence the minimum TSS / TA were recorded at the end of marketability period in room temperature or cold during the two studied seasons. All treatments were not significant TSS / TA during marketing at room temperature. While it was significant in its impact during cold marketing in both seasons of study The results are in agreement with those obtained by Abdel-Razik (2012) on mango trees and Hamdy (2017) on Valencia Orange. On the other hand, our results agree with those of Sartaj et al., (2013) who found that 2mM of salicylic acid was effective in retaining keeping quality of apricot up to 12 days at ambient storage.

Ascorbic acid

Data in Table 11, indicated that, during marketability period the ascorbic acid content of fruits gradually decreased with prolonging the marketability period at room temperature or cold. Moreover, fruit V.C content was affected by irrigation treatments. Significant differences were noticed between fruits in relation to water regime as fruits of trees received 60% of ETc possessed the highest vitamin C values under room temperature or cold followed descendingly by those receiving 80% and 100% treated fruit with SA reduced the loss of ascorbic acid in fruits compared with un treated. The conserving of ascorbic acid % in fruits which were treated with SA due to the reducing of respiration process and water loss thus decreasing of oxidation of ascorbic acid content compared with the reducing rate of ascorbic acid in control where increase respiration process and there for increasing of oxidation. The results of this study were in line with Ali et al. *(*2009), Ali et al. (2013). Abdel-Razik et al. (2012) and Hamdy et al. (2017).

TABLE 9. Effect of irrigation regime, spraying salicylic acid on titratable acidity % (TA) of lime fruits during marketing

Treatments	At room temperature				At a cold temperature				
	Marketing period								
	0 days	2 days	4 days	6 days	0 days	4 days	8 days	12 days	16 days
	Season 2017								
100% ETc	6.68	6.10	5.89	5.78	6.68	6.61	6.46	6.11	5.85
100% ETc + SA	6.78	6.14	5.89	5.63	6.78	6.58	6.41	5.98	5.89
80% ETc	6.89	5.89	5.76	5.63	6.89	6.31	6.23	6.21	5.96
80% ETc + SA	6.91	6.14	5.89	5.75	6.91	6.10	5.96	5.59	5.75
60% ETc	7.04	6.66	6.55	6.12	7.04	6.60	6.39	5.88	5.71
60% ETc + SA	7.17	6.66	6.58	6.14	7.17	6.74	6.22	6.12	6.13
L.S.D. 0.05	(T): 0.45 (P): 0.39 (TxP): 0.90				(T): 0.22 (P): 0.13 (TxP): 0.51				
	Season 2018								
100% ETc	6.58	6.45	6.16	5.68	6.58	6.53	6.09	6.42	5.68
100% ETc + SA	6.69	6.62	6.49	5.89	6.69	6.17	6.09	6.06	5.89
80% ETc	6.46	6.14	5.85	5.89	6.46	6.14	6.09	6.02	5.69
80% ETc + SA	6.68	6.63	6.11	6.02	6.68	6.40	6.04	5.89	5.55
60% ETc	6.74	6.64	6.55	5.76	6.74	6.96	6.68	6.36	5.76
60% ETc + SA	7.04	6.62	6.31	6.14	7.04	6.91	6.87	6.31	6.14
L.S.D. 0.05	(T): 0.18 (P): 0.16 (TxP): 0.35				(T): 0.23 (P): 0.09 (TxP): 0.52				

TABLE 10. Effect of irrigation regime, spraying salicylic acid on TSS/TA ratio of lime fruits during marketing

Treatments	At room temperature				At a cold temperature				
	Marketing period								
	0 days	2 days	4 days	6 days	0 days	4 days	8 days	12 days	16 days
	Season 2017								
100% ETc	1.11	1.27	1.32	1.38	1.11	1.13	1.14	1.31	1.38
100% ETc + SA	1.11	1.27	1.34	1.45	1.11	1.14	1.22	1.33	1.38
80% ETc	1.12	1.29	1.34	1.43	1.12	1.15	1.28	1.30	1.36
80% ETc + SA	1.12	1.25	1.31	1.45	1.12	1.27	1.31	1.41	1.41
60% ETc	1.15	1.24	1.29	1.52	1.15	1.21	1.31	1.44	1.58
60% ETc + SA	1.18	1.29	1.33	1.47	1.18	1.28	1.40	1.46	1.47
L.S.D. 0.05	(T):NS (P): NS (TxP): NS				(T): 0.23 (P): 0.13 (TxP): 0.51				
	Season 2018								
100% ETc	1.06	1.16	1.30	1.48	1.06	1.10	1.28	1.25	1.48
100% ETc + SA	1.09	1.13	1.23	1.39	1.09	1.20	1.25	1.35	1.43
80% ETc	1.11	1.22	1.37	1.44	1.11	1.27	1.31	1.35	١.٥١
80% ETc + SA	1.11	1.13	1.28	1.38	1.11	1.22	1.32	1.39	1.51
60% ETc	1.19	1.30	1.37	1.59	1.19	1.17	1.24	1.38	1.62
60% ETc + SA	1.16	1.27	1.36	1.47	1.16	1.20	1.22	1.36	1.47
L.S.D. 0.05	(T): NS (P): NS (TxP): NS				(T): 0.05 (P): 0.02 (TxP): 0.12				

TABLE 11. Effect of irrigation regime, spraying salicylic acid on vitamin C content of lime fruits during marketing

Treatments	At room temperature				At a cold temperature				
	Marketing period								
	0 days	2 days	4 days	6 days	0 days	4 days	8 days	12 days	16 days
	Season 2017								
100% ETc	49.87	48.75	46.67	40.15	49.87	44.88	36.08	36.44	34.93
100% ETc + SA	52.51	48.67	46.00	41.55	52.51	47.52	35.47	38.36	35.88
80% ETc	57.79	47.33	42.59	38.63	57.79	47.81	43.27	40.53	31.69
80% ETc + SA	53.39	47.83	38.48	38.76	53.39	50.45	42.53	40.53	33.65
60% ETc	59.40	52.68	44.20	38.89	59.40	54.55	43.12	38.00	33.62
60% ETc + SA	60.28	58.63	46.00	39.90	60.28	48.40	43.07	41.36	34.34
L.S.D. 0.05	**(T): 3.50 (P): 2.81 (TxP): 7.01**				**(T): 1.15 (P): 0.91 (TxP): 2.58**				
	Season 2018								
100% ETc	50.16	48.00	39.90	34.90	50.16	44.00	41.36	35.64	31.92
100% ETc + SA	51.92	48.52	41.80	38.00	51.92	46.64	36.96	35.66	31.92
80% ETc	53.68	48.00	44.88	38.76	53.68	49.28	44.00	34.20	27.60
80% ETc + SA	58.08	48.55	40.48	38.53	58.08	51.40	42.24	36.12	33.45
60% ETc	59.40	52.00	45.76	39.14	59.40	48.40	41.36	34.68	29.04
60% ETc + SA	60.72	48.40	48.20	39.90	60.72	52.80	43.00	35.15	30.42
L.S.D. 0.05	**(T): 1.55 (P): 1.11 (TxP): 2.34**				**(T): 1.47 (P): 1.05 (TxP): 2.21**				

Conclusion

This current investigation recommended that, under Asyut region, Irrigation lime trees with 100% ETc to have the highest yield and its component, in addition spraying salicylic acid to obtain the best irrigation water productivity, economic water productivity and reduced weight loss of marketability yield. Hence, could be used successfully for other crops as well as become important for Egyptian agriculture, especially when economic and environmental points of view are considered.

Ethics approval and consent to participate

This article does not contain any studies with human participants or animals performed by any of the authors.

Consent for publication

All authors declare their consent for publication.

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