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Yield, fruit quality and leaf mineral content of mango trees as affected by subsurface drip irrigation system

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FagriKalan mango trees which grown under sandy soil conditions were irrigated with 12, 9 or 6 drippers per tree, either as a subsurface or surface irrigation system. The effect of the irrigation system and the number of drippers on yield, fruit quality, chlorophyll and leaf mineral content were studied. The obtained results indicate that the subsurface irrigation system was more effective than the surface one. In addition, the drippers' number shows different effects concerning yield per tree or the fruit's quality and the leaf mineral content. From one hand, it could be concluded that the trees which were irrigated with 9 subsurface drippers save the irrigation water without significant decrease in the yield compared to the control. On the other hand, as a subsurface dripper irrigation system, the highest significant yield as Kg/ tree was obtained due to 12 drippers/ tree compared with the 9 or 6 drippers/ tree.

Keywords: FagriKalan, mango, subsurface, irrigation, drippers, yield, fruit quality.

INTRODUCTION

Mango (Mangiferaindica L) is one of the most economically important fruit crops in the tropics and subtropics regions. In Egypt, mango is considered as a popular fruit and ranked third in acreage after citrus and grapes. In 2015, the mango cultivated area in Egypt reached about 265350 feddan that produced about 927352 ton with an average of 4.4 ton/feddan (according to the statistics of Ministry of Agriculture and Land Reclamation, 2015). With the World's population set to increase by 65% (3.7 billion) by 2050, the additional food required to feed future generations will put further enormous pressure on freshwater resources, so it is important to save the water and provide the maximum amount of water used, whether drinking or irrigation and other activities that depend on water as their primary source. The Arab Republic of Egypt basically relies on the River Nile as a source of water which indicates that Egypt's share will not meet the future regularity of life as a result of population increase and both of agriculture and industrial projects or lack of quota in Egypt from the head of the Nile Basin Countries. These reasons focus on the development of irrigation methods that reduce water use or to achieve maximum efficiency in the water usage. Since the middle of the 20^{th} century, drip irrigation has been used in horticultural operations (Hillel, 2008) and it is the most effective method to apply nutrients and water directly to the plants and beside saving the irrigation water, also increases yields (Tiwari et al., 2003 and Alaoui et al., 2014). Traditional methods of subsurface irrigation can conserve scarce water resources in many less developed parts of the world. Subsurface irrigation systems are capable of applying small amounts of water directly to the plant root zone where the water is needed and these small amounts can be applied frequently to maintain suitable moisture conditions in the root zone. The potential benefits of subsurface irrigation include the improvements in both yield and quality, therefore reducing the costs of the production (Toljander et al., 2008 and Alguacil et al., 2009). Sprinkler irrigation can be replaced by subsurface drip irrigation that saves approximately 50% of the investment costs; with the subsurface irrigation, fertilizers can be applied near the center of the crop root zone (Lamm, 2002).

So, the idea underlying this study aims to improve the water usage efficiently of the mango trees grown under sandy soil conditions using subsurface drip irrigation system at different irrigation rates compared with the surface one.

MATERIALS AND METHODS

This experiment was carried out during two successive seasons (2016 and 2017) to study the effect of subsurface drip irrigation compared with the surface one under different irrigation rates on yield and fruit quality of FagriKalan mango trees that grown on sandy soil, at the National Research Centre farm, Nubaria district, Behaira Governorate, Egypt. The trees were budded on seeded rootstocks and planted at 3X5 meters apart under drip irrigation system. Soil analysis according to the method of Wilde et al., (1985) in Table (1) shows that the soil texture is sandy.Each treatment was replicated four times on one tree plot and the randomized complete block design was arranged. The selected trees were seven years old and nearly uniformed in vigor as possible. The fertilization program and other horticultural practices were the same for all trees under investigation.

To determine the leaf mineral content, about twenty leaves were taken in late August in each studied season. Leaf samples were washed with tap water and with distilled water then dried at 70^{o}C and finally grinded and digested. The digested solution was used to determine N, P, K, Ca and Mg content as percentage on dry weight due to the methods described by Cottenie et al., (1982). Total chlorophyll in the fresh leaves was determined as spad units (spad = 100 mg chlorophyll/gm fresh weight) using Minolta chlorophyll meter (spad, 502).

At the harvest time (on the last week of July in each season), tree yield was estimated as a number and weight as kg/tree of the harvested fruits per tree.

Fruit quality:

Five mature fruits were randomly sampled from those harvested ones per each tree to determine the following fruit physical and chemical properties:

Fruit physical properties such as fruit weight (gm), fruit length (cm), fruit width (cm) and fruit circumference (cm) were determined.

Fruit chemical characteristics: samples of the fruit juice were used to determine the total soluble solids percentage (TSS %) using hand refractometer and total sugars (as g/100 g fresh weight) as the method described by Dubois *et al*. (1956). In addition, the total acidity was measured as percentage of the citric and the malic acids according to A.O.A.C (1985). Fruit ascorbic acid (V.C) content in milligrams was determined in 100 ml of the juice, according to A.O.A.C (1985).

Statistical analysis

The obtained data was subjected to analysis of variances (ANOVA) according to Snedecor and Cochran (1989). Mstat-C program was used to calculate the least significant difference. LSD letters were used for comparing means of different treatments according to Wallar and Duncan (1969) at probability of 0.05 level.

Table (1): Mechanical and chemical analysis of experimental soil.

Sand (%)	Silt (%)	Clay (%)	pH	Organic matter (%)	$CaCO_3$ (%)	E.C. (dS/m)	Soluble N (ppm)	Available P (ppm)	Exchangeable K (ppm)
91.2	3.7	5.1	7.3	0.3	1.4	0.3	8.1	3.2	20

The experiment included six irrigation treatments as follows:

1. Surface irrigation with 12 drippers per tree (control as the orchard program).
2. Surface irrigation with 9 drippers per tree.
3. Surface irrigation with 6 drippers per tree.
4. Subsurface irrigation with 12 drippers per tree.
5. Subsurface irrigation with 9 drippers per tree.
6. Subsurface irrigation with 6 drippers per tree.

Note: Dripper discharge = 4 liters per hour.

RESULTS

Table (2) shows the effect of subsurface drip irrigation on yield and fruit physical properties of FagriKalan mango trees.

Concerning the fruit number, it is clear that subsurface drip irrigation has a positive effect on the fruits' number compared to the surface one. However, the irrigated trees by both irrigation systems, with 12 drippers recorded the highest fruits number followed by 9 then 6 drippers. The interaction shows that the trees irrigated with 12 subsurface drippers produced the highest value of fruits number followed without significance by subsurface 9 drippers. The obtained results were true in the two studied seasons.

Regarding fruit weight, the obtained results indicate that either surface or subsurface drip irrigation gave more or less the same value of fruit weight. While, the number of drippers was more effective on the fruit weight, since 12 drippers recorded the heaviest fruit weight compared with 9 or 6 drippers. The interaction between irrigation system and number of drippers showed that 12 drippers as subsurface irrigation recorded the heaviest fruit followed without significance by 12 drippers as surface irrigation. These results were observed in the two studied seasons.

As for the fruit length, in general subsurface irrigation gave taller fruits than the surface irrigation. The number of drippers improved the fruit length especially when the trees were irrigated with 12 drippers followed by 9 then 6 drippers. The interaction between the treatments reveals that subsurface irrigation with 12 drippers, recorded the highest value of fruit length followed without significance with 12 drippers as surface irrigation. The lowest value was obtained due to 6 drippers as surface irrigation. These results were obtained in both seasons.

The recorded results of fruit width show that the surface irrigation gave the widest fruit compared with the subsurface one, while the number of drippers did not show a clear trend. However, the interaction between the irrigation systems and the number of drippers shows different trends between the first and the second seasons; since in the first season, no significant effect was observed among the treatments, while in the second season, trees which irrigated with 12 surface drippers gave the highest value followed without significance by 9 drippers either as surface or subsurface irrigation.

In respect to the fruit circumference, it is clear that surface irrigation gave slightly higher significant value than the subsurface one. Also, the dripper number shows slight increment for 12 drippers than 9 or 6 ones. The interaction between irrigation systems and the number of drippers showed that 12 drippers as the surface irrigation (control) recorded the highest significant value followed by the 12 drippers as the subsurface irrigation in the first season; while in the second season the highest recorded value was obtained due to 12 drippers followed without significance by 9 surface drippers.

Regarding the yield weight per tree, the obtained results show that the subsurface irrigation increased the yield significantly than the surface one especially in the second season. In addition, the results show that the number of drippers was more effective on the increment of the tree yield than the irrigation system especially when the trees irrigated with 12 drippers.

The interaction shows that the trees that irrigated with 12 drippers as subsurface irrigation recorded the highest yield value followed without significance by the 12 surface drippers. The lowest yield value was recorded with 6 drippers as surface irrigation system.

Table (3) shows the effect of subsurface drip irrigation and number of drippers on the fruit chemical properties.

As for the total soluble solids percentage (TSS %), no differences were detected between the surface and the subsurface irrigation systems. Also there were no differences between 12, 9 or 6 drippers, although the TSS tended to increase with 6 drippers than the rates. The interaction shows that the effect differs from one season to another; since in the first season, using 12 surface drippers recorded the highest TSS value followed without significance by the 6 drippers as subsurface irrigation which gave the highest value in the second season followed without significance by the 12 surface drippers.

Concerning the total sugars of the fruit flesh, the obtained results show that the surface irrigation significantly increased the total sugars more than that of the subsurface one. In addition, the number of drippers showed different trends in the two seasons. The interaction among the treatments shows that the trees which were irrigated with 6 drippers as a surface application recorded the highest value of the total sugars followed by 9 drippers as surface irrigation in both studied seasons.

Regarding the acidity of the fruit flesh, no differences were detected between the surface and the subsurface irrigation systems.

Table 2. Yield and some physical fruit properties as affected by subsurface irrigation and number of drippers in the two studied seasons.

	First season				Second season			
Fruits number								
	12 Drippers	**9 Drippers**	**6 Drippers**	**Means (A)**	**12 Drippers**	**9 Drippers**	**6 Drippers**	**Means (A)**
Surface	40.67	34.33	30.67	35.22	39.67	36.67	33.33	36.56
Subsurface	47.33	40.67	34.00	40.67	49.33	42.00	36.33	42.56
Means (B)	44.00	37.50	32.33		44.50	39.33	34.83	
LSD $_{at\ 5\%}$ (A)	6.90				LSD $_{at\ 5\%}$ (A)	4.59		
LSD $_{at\ 5\%}$ (B)	8.45				LSD $_{at\ 5\%}$ (B)	5.62		
LSD $_{at\ 5\%}$ (A*b)	11.96				LSD $_{at\ 5\%}$ (A*b)	7.95		
Fruit weight (gm)								
Surface	471.7	435.0	408.3	438.3	483.3	450.0	428.3	453.9
Subsurface	478.3	403.3	396.7	426.1	493.3	446.7	430.0	456.7
Means (B)	475.0	419.2	402.5		488.3	448.3	429.2	
LSD $_{at\ 5\%}$ (A)	27.5				LSD $_{at\ 5\%}$ (A)	18.9		
LSD $_{at\ 5\%}$ (B)	33.7				LSD $_{at\ 5\%}$ (B)	23.1		
LSD $_{at\ 5\%}$ (A*b)	47.7				LSD $_{at\ 5\%}$ (A*b)	32.7		
Fruit length (cm)								
Surface	13.63	12.37	11.63	12.54	13.77	12.67	11.77	12.73
Subsurface	14.23	13.40	12.77	13.47	14.63	13.80	13.67	14.03
Means (B)	13.93	12.88	12.20		14.20	13.23	12.72	
LSD $_{at\ 5\%}$ (A)	0.54				LSD $_{at\ 5\%}$ (A)	0.52		
LSD $_{at\ 5\%}$ (B)	0.66				LSD $_{at\ 5\%}$ (B)	0.63		
LSD $_{at\ 5\%}$ (A*b)	0.93				LSD $_{at\ 5\%}$ (A*b)	0.89		
Fruit width (cm)								
Surface	8.70	8.73	8.73	8.72	9.00	8.80	8.77	8.86
Subsurface	8.47	8.43	8.50	8.47	8.50	8.73	8.33	8.52
Means (B)	8.58	8.58	8.62		8.75	8.77	8.55	
LSD $_{at\ 5\%}$ (A)	0.34				LSD $_{at\ 5\%}$ (A)	0.23		
LSD $_{at\ 5\%}$ (B)	0.41				LSD $_{at\ 5\%}$ (B)	0.28		
LSD $_{at\ 5\%}$ (A*b)	0.58				LSD $_{at\ 5\%}$ (A*b)	0.39		
Fruit circumference (cm)								
Surface	26.07	25.90	25.60	25.86	26.83	26.40	25.73	26.32
Subsurface	25.93	24.17	24.60	24.90	25.57	25.77	25.10	25.48
Means (B)	26.00	25.03	25.10		26.20	26.08	25.42	
LSD $_{at\ 5\%}$ (A)	0.47				LSD $_{at\ 5\%}$ (A)	0.71		
LSD $_{at\ 5\%}$ (B)	0.58				LSD $_{at\ 5\%}$ (B)	0.87		
LSD $_{at\ 5\%}$ (A*b)	0.82				LSD $_{at\ 5\%}$ (A*b)	1.23		
Yield / tree (Kg)								
Surface	18.96	14.86	12.45	15.42	19.08	15.15	14.12	16.12
Subsurface	22.50	15.59	13.41	17.16	24.05	18.52	15.55	19.37
Means (B)	20.73	15.22	12.93		21.56	16.84	14.84	

LSD at 5 % (A)	2.88				LSD at 5 % (A)	2.02		
LSD at 5 % (B)	3.52				LSD at 5 % (B)	2.47		
LSD at 5 % (A*b)	4.98				LSD at 5 % (A*b)	3.49		

Table 3. Some chemical fruit properties as affected by subsurface irrigation and number of drippers in the two studied seasons.

	First season				Second season			
TSS %								
	12 Drippers	**9 Drippers**	**6 Drippers**	**Means (A)**	**12 Drippers**	**9 Drippers**	**6 Drippers**	**Means (A)**
Surface	26.33	23.87	24.60	24.93	25.67	23.93	25.20	24.93
Subsurface	22.80	24.20	25.60	24.20	23.33	24.13	26.63	24.70
Means (B)	24.57	24.03	25.10		24.50	24.03	25.92	
LSD at 5 % (A)	1.30				LSD at 5 % (A)	1.30		
LSD at 5 % (B)	1.60				LSD at 5 % (B)	1.59		
LSD at 5 % (A*b)	2.26				LSD at 5 % (A*b)	2.25		
Total sugars %								
Surface	24.73	26.37	28.53	26.54	27.27	25.93	27.90	27.03
Subsurface	21.70	23.47	24.20	23.12	24.90	23.23	23.03	23.72
Means (B)	23.22	24.92	26.37		26.08	24.58	25.47	
LSD at 5 % (A)	1.55				LSD at 5 % (A)	1.12		
LSD at 5 % (B)	1.89				LSD at 5 % (B)	1.38		
LSD at 5 % (A*b)	2.68				LSD at 5 % (A*b)	1.95		
Acidity %								
Surface	0.38	0.35	0.36	0.36	0.36	0.34	0.36	0.35
Subsurface	0.34	0.36	0.34	0.35	0.36	0.37	0.39	0.37
Means (B)	0.36	0.36	0.35		0.36	0.35	0.38	
LSD at 5 % (A)	0.01				LSD at 5 % (A)	0.03		
LSD at 5 % (B)	0.01				LSD at 5 % (B)	0.03		
LSD at 5 % (A*b)	0.02				LSD at 5 % (A*b)	0.04		
Ascorbic acid (mg/100g)								
Surface	34.17	31.23	31.23	32.21	33.53	30.40	33.40	32.44
Subsurface	42.30	50.17	43.07	45.18	39.50	43.50	41.30	41.43
Means (B)	38.23	40.70	37.15		36.52	36.95	37.35	
LSD at 5 % (A)	4.36				LSD at 5 % (A)	3.39		
LSD at 5 % (B)	5.34				LSD at 5 % (B)	4.15		
LSD at 5 % (A*b)	7.55				LSD at 5 % (A*b)	5.86		

Table 4. Leaf mineral and chlorophyll content as affected by subsurface irrigation and number of drippers in the two studied seasons.

	First season				Second season			
	Total chlorophyll (spad)							
	12 Drippers	**9 Drippers**	**6 Drippers**	**Means (A)**	**12 Drippers**	**9 Drippers**	**6 Drippers**	**Means (A)**
Surface	46.37	47.57	49.17	47.70	47.50	48.77	51.07	49.11
Subsurface	56.17	52.50	49.93	52.87	56.33	53.00	51.10	53.48
Means (B)	51.27	50.03	49.55		51.92	50.88	51.08	
LSD at 5 % (A)	2.63				LSD at 5 % (A)	2.79		
LSD at 5 % (B)	3.22				LSD at 5 % (B)	3.41		
LSD at 5 % (A*b)	4.55				LSD at 5 % (A*b)	4.83		
	N %							
Surface	0.92	1.03	0.96	0.97	0.91	1.03	0.94	0.96
Subsurface	1.17	1.17	0.97	1.10	1.15	1.12	0.94	1.07
Means (B)	1.04	1.10	0.96		1.03	1.07	0.94	
LSD at 5 % (A)	0.04				LSD at 5 % (A)	0.05		
LSD at 5 % (B)	0.05				LSD at 5 % (B)	0.06		
LSD at 5 % (A*b)	0.06				LSD at 5 % (A*b)	0.08		
	P %							
Surface	0.10	0.11	0.08	0.10	0.10	0.11	0.09	0.10
Subsurface	0.22	0.26	0.18	0.22	0.21	0.26	0.17	0.22
Means (B)	0.16	0.18	0.13		0.16	0.19	0.13	
LSD at 5 % (A)	0.01				LSD at 5 % (A)	0.01		
LSD at 5 % (B)	0.02				LSD at 5 % (B)	0.02		
LSD at 5 % (A*b)	0.02				LSD at 5 % (A*b)	0.02		
	K %							
Surface	0.67	0.73	0.60	0.67	0.67	0.74	0.58	0.66
Subsurface	0.83	1.08	0.74	0.88	0.80	1.06	0.75	0.87
Means (B)	0.75	0.91	0.67		0.74	0.90	0.67	
LSD at 5 % (A)	0.04				LSD at 5 % (A)	0.04		
LSD at 5 % (B)	0.04				LSD at 5 % (B)	0.05		
LSD at 5 % (A*b)	0.06				LSD at 5 % (A*b)	0.07		
	Ca %							
Surface	1.75	1.95	1.70	1.80	1.75	1.97	1.72	1.81
Subsurface	2.31	2.38	2.04	2.24	2.32	2.33	2.00	2.22
Means (B)	2.03	2.17	1.87		2.04	2.15	1.86	
LSD at 5 % (A)	0.12				LSD at 5 % (A)	0.11		
LSD at 5 % (B)	0.15				LSD at 5 % (B)	0.14		
LSD at 5 % (A*b)	0.21				LSD at 5 % (A*b)	0.20		
	Mg %							
Surface	0.15	0.20	0.13	0.16	0.15	0.19	0.13	0.15
Subsurface	0.21	0.23	0.21	0.22	0.22	0.22	0.20	0.22
Means (B)	0.18	0.21	0.17		0.18	0.21	0.17	
LSD at 5 % (A)	0.01				LSD at 5 % (A)	0.01		
LSD at 5 % (B)	0.01				LSD at 5 % (B)	0.01		
LSD at 5 % (A*b)	0.01				LSD at 5 % (A*b)	0.02		

The same observation was noticed concerning the effect of the drippers' number. The interaction between the irrigation systems and the number of drippers shows that no stable trend was observed during the two studied seasons, since in the first season the highest value was recorded when 12 surface drippers were used, while in the second season, the highest value was recorded when the 6 subsurface drippers were used. The lowest value of acidity was differed between the first and second seasons, where it was recorded due to 6 or 12 subsurface drippers in the first season, it was detected with 9 drippers either as surface or subsurface systems in the second season.

Ascorbic acid (vitamin C) results show that the subsurface treatments had a positive effect on vitamin C than the surface irrigation system. The effect of the drippers' number was differed in the second season than the first one. The interaction effect shows that the irrigated trees with 9 drippers as subsurface system recorded the highest vitamin C value in both seasons.

Results in Table (4) show the effect of subsurface drip irrigation on total chlorophyll and leaf mineral content of FagriKalan mango trees.

As for chlorophyll content, generally it is clear that the subsurface irrigation was more effective and recorded high significant values compared with the surface irrigation. While as the number of drippers had no significant effect on chlorophyll level in the leaves. While as the interaction, results show that trees which were irrigated with 12 subsurface drippers recorded the highest value followed without significance by 9 subsurface drippers. These results were observed in both studied seasons.

Regarding the nitrogen percentage (N %) in mango leaves, the obtained results show that the subsurface drip irrigation increased N in the leaves significantly when compared with the surface one. Results of the drippers' number show that 9 drippers recorded the highest percentage followed by 12 drippers but the differences lacked significance. The interaction between the drippers' number and irrigation system shows that 12 subsurface drippers recorded the highest significant value of nitrogen than the other treatments except that of 9 subsurface drippers since there were no differences between the two treatments in both seasons.

Concerning the phosphorus percentage (P %) in the leaves, the obtained results show superiority for the subsurface irrigation compared with the surface one. Regarding the number of drippers, the trees which irrigated with 9 drippers recorded the highest value followed by those of 12 drippers. The interaction results show that the highest significant percentage of P was obtained with 9 subsurface irrigation drippers followed by 12 drippers. However, the lowest value was recorded due to the surface irrigation with 6 drippers. The above results were detected in the first and the second seasons.

The results of the potassium percentage (K %) in the mango leaves indicate that the subsurface irrigation system enhanced the potassium level in the leaves comparing with the surface one. Also the results of the drippers' number show that 9 drippers were more effective and recorded the highest K level followed by 12 drippers then 6 drippers. However, the interaction results clearly show that the trees that irrigated with 9 drippers as subsurface system recorded the highest significant value of potassium followed in a decreasing order with 12 then 6 drippers in both seasons.

Regarding the calcium percentage (Ca %) in the leaves, it was observed that the subsurface irrigation had the superiority effect on this parameter than the surface irrigation. The drippers' number also affected the calcium percentage in the leaves, since 9 drippers gave the highest value followed without significance by 12 drippers. The interaction among the treatments shows that the trees which were irrigated with 9 drippers as subsurface irrigation recorded the highest calcium value followed without significance by the subsurface 12 drippers, while the lowest calcium value was observed with the 6 surface drippers in both seasons.

In respect to magnesium percentage (Mg %) in mango leaves, generally the subsurface irrigation system significantly increased Mg % compared with the surface irrigation. Also, the drippers' number shows that 9 drippers recorded the highest value followed by 12 drippers. The results of the interaction among the treatments indicate that the trees which were irrigated with 9 drippers as a subsurface system recorded the highest value of magnesium followed by 12 and 6 drippers as subsurface irrigation. However, irrigation with 6 drippers as surface gave the lowest magnesium percentage in the leaves. These results were detected in both studied seasons.

DISCUSSION

As the obtained results, in general, there was a distinction for the subsurface irrigation system than the surface one in the most studied parameters. This distinction could be as a result of the great uniformity distribution of the soil moisture due to the usage of the subsurface irrigation system comparing with the surface one (Douglas and Tom, 2009).

In other words, the number of drippers showed a positive effect on the obtained results, since the 12 drippers especially as subsurface irrigation were more effective than the 9 or 6 drippers concerning the yield and the fruit quality parameters, because of the mango trees' big canopy and the heavy weight of the fruit which is fleshy and containing more than 80% water; this results could be due to that the 12 drippers supplied the mango tree with the sufficient needs of water compared with the 9 or 6 drippers treatments. These results were in agreement with those of Genaidyet al., (2016) who reported a similar trend when used the high irrigation amount on Valencia orange trees as a subsurface irrigation which increased the fruit number, fruit weight and yield/ tree, also both physical and chemical fruit properties was improved.

However, the 9 drippers as a subsurface irrigation was more effective than the 12 or 6 drippers on leaf mineral contents (N, P, K, Ca and Mg %), this may be due to explanation of Payeroet al., (2005) who reported that the small and the frequent applications can be adjusted to match the water and the nutrient needs of the crop. Additionally, the spoon feeding water and nutrients could be theoretically resulted in increasing yields and decreased nutrient losses. Also Pheneet al.,(1987) noticed that, water and nutrients are used more efficiently when using subsurface drippers compared to the surface installation. In the same line, Lamm (2002) reported that there is less nutrient and chemical leaching due to deep percolation.

CONCLUSION

As the obtained results, in general, there was a distinction for the subsurface irrigation system than the surface one in the most studied parameters. This distinction could be as a result of the great uniformity distribution of the soil moisture due to the usage of the subsurface irrigation system comparing with the surface one (Douglas and Tom, 2009).

In other words, the number of drippers showed a positive effect on the obtained results, since the 12 drippers especially as subsurface irrigation were more effective than the 9 or 6 drippers concerning the yield and the fruit quality parameters, because of the mango trees' big canopy and the heavy weight of the fruit which is fleshy and containing more than 80% water; this results could be due to that the 12 drippers supplied the mango tree with the sufficient needs of water compared with the 9 or 6 drippers treatments. These results were in agreement with those of Genaidyet al., (2016) who reported a similar trend when used the high irrigation amount on Valencia orange trees as a subsurface irrigation which increased the fruit number, fruit weight and yield/ tree, also both physical and chemical fruit properties was improved.

However, the 9 drippers as a subsurface irrigation was more effective than the 12 or 6 drippers on leaf mineral contents (N, P, K, Ca and Mg %), this may be due to explanation of Payeroet al., (2005) who reported that the small and the frequent applications can be adjusted to match the water and the nutrient needs of the crop. Additionally, the spoon feeding water and nutrients could be theoretically resulted in increasing yields and decreased nutrient losses. Also Phene*et al.* (1987) noticed that, water and nutrients are used more efficiently when using subsurface drippers compared to the surface installation. In the same line, Lamm (2002) reported that there is less nutrient and chemical leaching due to deep percolation**.**

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

Both of M.M.S., Saleh and E.A.M. Mostafa worked on setting up this study and carried out it. Also, all needed measurements and analysis had been done under supervision of El-Attar, H.A; M.A. Merwad. The data reviewing, statistical analysis and writing the articles had been done by E.A.M. Mostafa. General reviewing and the final version of this article had been done by M.M.S., Saleh.

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