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Effect of Different Rootstocks on Flowering, Fruiting and Yield of Kalamata and Dolce Olive Trees

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ABSTRACT

The present study was carried out through 2013 and 2014 seasons in a private orchard at Cairo/Alex. desert road on 21 years old Picholine, Frantoio, Mission, Manzanillo and Koroneiki olive rootstocks which were re-juveniled and top grafted at 2008 season by Kalamata and Dolce olive cultivars. Trees were planted at 6 × 6 meters planting distances, and grown in Sandy soil under drip irrigation system. The aim of the present study was carried out to investigate the effect of different rootstocks (Picholine, Frantoio, Mission, Manzanillo and Koroneiki) on the productivity of the main two black table cultivars in Egypt (Kalamata and Dolce). The results noticed that, vegetative growth parameters varied according to the influence of the studied rootstocks on Kalamata and Dolce cvs., whereas Kalamta scion grafted on Picholine rootstock presented the highest values of tree height, trunk perimeter, trunk cross section area and shoot length, while the first of the three previous parameters were recorded their best values with Dolce trees grafted on Frantoio rootstock. Also, Picholine rootstock with Dolce trees gave the earliest date of (beginning, full blooming and ending of flowering) and the highest numbers of inflorescences/meter, total flowers/inflorescence, fruit set/meter, while Picholine and Mission rootstocks gave the highest yield of Dolce tree Furthermore, Kalamta trees achieved the highest fruit set with Picholine rootstock and the best yield with (Picholine, Frantoio and Mission rootstocks) and gave the heaviest fruit and flesh weight with Mission rootstock. On the other hand, Koroneiki and Manzanillo rootstocks were influenced negatively on the two studied cultivars (Kalamata and Dolce) and gave the lowest values in most of studied characteristics. Under the same conditions of the present study, it could be concluded that, Picholine rootstock followed by Mission then Farantoio revealed the highest productivity of Kalamata trees. However, Dolce Cultivar has achieved the maximum productivity with Picholine and Mission rootstocks.

Keywords: Olive trees, Kalamata, Dolce, Rootstocks

INTRODUCTION

Olive (*Olea europea* L.), which is the symbol of peace has been the most important plant in Mediterranean Region since ancient times (Sesli and Tokmakoglu, 2006). It plays an important role in the economy of many countries especially where the soil is unsuitable for other crops due to its capability to grow under several conditions and contributes to soil conservation. (Denis, 1977 and Sansoucy, 1984).

Recently, olives became one of the most important fruit crops in Egypt. According to Statistics of the Ministry of Agriculture and Land Reclamation (2014), the total acreage of olive orchards increased to reach 237458 feddans, the fruiting area is 144853 feddans produced 559785 tons

Olive trees are propagated commercially by several different methods hardwood, semi-hardwood and soft cuttings, suckers and grafting on rootstocks. Furthermore in the latter case, effects on subsequent tree behavior are not usually considered in the selection of the rootstock, which influences in olives as in some other tree fruits and are likely to vary according to the scion variety under consideration (Hartmann, 1958). It was noticed also, the variation in tree size and production, which occurred from the use of olive seedlings as rootstocks (Hartmann and Whisler, 1970). Growth cultivar mechanisms differ in different stock-scion growth combinations and interrelationships that has been an important role in coordinating activities in the plant (Michael and Mary, 2002 and Laz, 2005)

Kalamata, the king of Greek black table olives and one of the best tastiest widely known outside Greece. Fruit weight varies from 3 to 7 grams and it has an excellent flesh/pit ratio. Turns a deep black colour when fully ripe. The harvesting date in Egypt from September to October. Kalamata is one of the most hard propagated cultivar by cuttings and grows more vigorously when grafted onto a strong root stock. Dolce is one of the Italian cultivars, weight varies from 3 to 6 gm. The stone is about 18% of fruit weight, used as a black table cultivar in Egypt, recognized by the heavy crop and the harvesting date in Egypt from October to December. (El-Sayed and Saad El-Din, 2011)

Seedlings of Picholine, Frantoio and Mission varieties are common commercial rootstocks in California (Hartmann, 1958), but it was not distributed as producing olive cultivars in Egypt.

The importing of olive cultivars is subjected to different ecological and agro-ecosystems resulting in positive or negative mutations under different conditions (Weiying *et al.,* 1998) and it was noticed in the last 5 years that Kalamata cultivar faces a lot of problems that lead to the impairment of the productivity in Egypt. Perhaps the change of climatic conditions is one of the main factors which has a significant impact on this phenomenon. Also, the choice of the suitable rootstock is a very important reason that has a great effect on the productivity of trees. So, it was necessary to investigate that to determine the influences of different rootstocks on the productivity of Kalamata olive trees and to accomplish the best recommendation of the best olive rootstocks which may achieve the maximum productivity and fruit quality.

Due to the previous problem of Kalamata, it turned many of farm owners by the re-juvenile pruning to exchange Dolce cultivar instead of Kalamata by grafting after the re-juvenile pruning of the old trees without paying attention to the compatibility of these rootstocks with the new scion of Dolce. Thus the needs to study the influences of these rootstocks on the productivity of Dolce trees in the future.

Therefore, the present study was carried out to investigate the effect of different rootstocks (Picholine, Frantoio, Mission, Manzanillo and Koroneiki) on the productivity of the main two black table cultivars in Egypt (Kalamata and Dolce).

MATERIALS AND METHODS

The present study was conducted during two growing seasons 2013 and 2014 in a private orchard at Cairo/Alexandria desert road on 21 years old Picholine, Frantoio, Mission, Manzanillo and Koroneiki olive rootstocks, which were re-juveniled and top grafted at 2008 season by Kalamata and Dolce olive cultivars. Trees were planted at 6 × 6 meters planting distances, and grown in Sandy soil under drip irrigation system.

Trees were free from pathogens and physiological disorders and received the common culture practices concerning pruning, irrigation, fertilization program, and pest control recommended by the Ministry of Agricultural.

Thirty uniform trees were chosen in this experiment. Three trees for each rootstock and each cultivar during the two mentioned seasons.

Physical and chemical analyses of soil are presented in table (I) and analysis of irrigation water is presented in table (II)

Table (I). Soil physical and chemical analysis

Physical properties						
Texture	**Organic matter (%)**	**Clay (%)**	**Silt (%)**	**Fine Sand (%)**	**Coarse sand (%)**	**Depth (cm)**
Sandy loam	0.67	15.25	12.75	14.61	56.73	0-30
Sandy loam	0.81	11.75	11.15	25.69	50.60	30-60
Sandy loam	0.57	12.15	10.28	18.26	58.74	60-90

Chemical properties										
Cations (meq/L)				**Anions (meq/L)**			**$CaCo_3$**	**pH**	**EC (mmhos /cm)**	**Depth (cm)**
K^+	**Na^+**	**Mg^{++}**	**Ca^{++}**	**SO_4^{--}**	**Cl^-**	**HCO_3^-**				
2.92	15.4	6.55	7.7	2.4	33.3	2.66	22.9	7.6	1.69	0-30
2.17	15.22	5.20	8.3	3.1	30.8	2.26	21.2	7.9	2.09	30-60
2.12	12.17	5.35	7.0	2.4	31.4	2.01	20.0	7.9	2.55	60-90

Table (II). Analysis of irrigation water

pH	**EC (mmhos/cm)**	**SAR**	**Anions (meq/L)**			**Cations (meq/L)**			
			HCo_3^-	**Cl^-**	**So_4^{--}**	**Ca^{++}**	**Mg^{++}**	**Na^+**	**K^+**
8.2	0.964	6.7	3.42	4.9	1.228	1.5	0.5	7.27	0.048

EC= electrical conductivity
SAR = Soduim adsorption ratio

Measurements

(1) Vegetative growth measurements

- **Tree vigor**

➢ Tree Height (m)

➢ Trunk perimeter (cm)

The perimeter of the trunk was measured at 20 cm above soil level.

➢ Trunk Cross Section area TCS (cm^2)

The equation of TCS area was concluded from trunk perimeter as the following method

As, $P = 2\pi r$ thus, $r = \frac{P}{2\pi}$

As, TCS area = πr^2 thus, TCS area = $\pi \left(\frac{P}{2\pi}\right)^2$

So, $$\text{TCS area} = 3.1416 \left(\frac{P}{6.2832}\right)^2$$

(P= trunk perimeter, r= trunk radius and π= 3.1416)

➢ Canopy permit (m)

Four diameters of each tree were measured, calculated the average diameter and canopy perimeter was calculated by the following equation:

$P = 2\pi r$

(P= trunk perimeter, r= trunk radius and π= 3.1416)

- **Shoot length (cm) and number of leaves/meter**

Twenty-year-old shoots were randomly labeled on each tree (replicate) to record average shoot length (cm) and average number of leaves per meter was calculated

No. of leaves per meter = 100* No. of leaves / shoot length (cm)

(2) Flowering dates and measurements

- **Flowering dates**

At the flowering time, flowering periods; the dates of beginning, full and end of blooming were recorded for each cultivar on different rootstocks in 2013 and 2014 seasons as following:

➢ Flowering period : Duration from beginning to end of flowering

➢ Beginning of flowering: When 10% of the flowers on the inflorescences open.

➢ Full bloom: When the majority of flowers on the inflorescences open.

➢ (more than 70%).

➢ End of flowering: When the petals of the majority of the flowers darken in color and separate from the caylex.

- **Flowering characteristics**

All developing inflorescences (panicles) on one year old shoots were assigned before onset of flowering to record number of inflorescences per meter, inflorescence length (cm), number of total flowers per inflorescence and sex expression which was calculated as percentage of perfect flowers to total flowers according to Rallo and fernandez-Escobar(1985)

- **No. of inflorescences per meter = 100*No. of inflorescences per shoot/shoot length**
- **Sex expression = 100* No. of perfect flowers / No. of total flowers**

(3) Fruit set and yield/tree

Percentage of fruit set was calculated after 60 days from full bloom.

Percentage of fruit set = 100* No. of set fruits/No. of total flowers

The yield per tree was recorded by weight (kg) of fruits/tree for each cultivar on different rootstocks.

(4) Fruit physical characteristics

At the first week of November 2013 and 2014 seasons 50 fruits from each tree were taken at random to determine the following characters [fruit length(cm), fruit diameter (cm), stone length(cm), stone diameter (cm) fruit weight (gm), stone weight (gm), flesh weight (gm) and flesh/pit ratio].

Statistical analysis:

All data were tested for treatments effects on analyzed parameters by the analysis of variance (ANOVA). Difference between treatments were compared by Duncan's Multiple Range Test (Duncan, 1955), according to the method described by Snedecor and Cochran (1990).

RESULTS AND DISCUSSION

(1) Vegetative growth measurements

- **Tree vigor of Kalamata cultivar**

Data in table (1) indicated that, there was a significant increment in tree height which was affected by the different rootstocks, the highest significant average was observed with picholine rootstock (3.55 and 3.67 m) respictievely, in 2013 and 2014 seasons followed by Koroneiki and Manzanillo rootstocks in the first season. However, rest of rootstocks didn't give any significant effect on tree height in the second season.

Regarding to trunk perimeter and trunk cross section area which have the same trend. The highest values of those parameters were noticed with Picholine rootstock (140 & 145 cm) and (1561.03 & 1674.43 cm^2) respectively, in 2013 and 2014 seasons, Followed by Frantoio and Mission Rootstocks, while Koroneiki and Manzanillo gave the lowest values of those measurements.

Koroneiki rootstock gave the lowest Canopy perimeter (13.30 & 13.65 m) respectively, in 2013 and 2014 seasons. Whereas the rest of rootstocks gave more than the previous values with slightly significant differences between them in the two seasons of the study.

Table (1) : Effect of different rootstocks on tree vigor of Kalamata cultivar during 2013 and 2014 seasons

Rootstock	Tree height (m)		Trunk Perimeter (cm)		Trunk cross section area (cm^2)		Canopy perimeter (m)	
2013 season								
Pitcholin	3.55	A	140.00	A	1561.03	A	16.55	A
Frantoio	3.05	C	121.70	B	1183.73	B	16.37	AB
Mission	3.10	C	123.00	B	1213.90	B	16.18	AB
Koroneiki	3.30	B	106.00	C	899.43	C	13.30	C
Manzanillo	3.30	B	106.30	C	900.00	C	14.90	B
2014 season								
Pitcholin	3.67	A	145.00	A	1674.43	A	17.14	A
Frantoio	3.20	B	125.00	B	1247.40	B	16.89	AB
Mission	3.25	B	128.00	B	1311.43	B	16.55	AB
Koroneiki	3.40	B	110.00	C	968.20	C	13.65	C
Manzanillo	3.35	B	107.67	C	922.80	C	15.57	B

Values followed by the same letter (s) within the same column not significantly different at 0.5% level of probability.

- **Tree vigor of Dolce cultivar**

Regarding to Dolce as shown in table (2), there were insignificant differences in tree height between the different rootstocks in the first season and slightly significant effect was observed in the second season of the study.

However, Frantoio rootstocks gave the highest values of trunk perimeter and trunk cross section area (190 & 197 cm) and (2888.2 & 3088.8 cm^2) respectively, in 2013 and 2014 seasons, while koroneiki and Manzanillo produced the lowest ones of those measurements in the two seasons of the study.

In a descending order, Mission, Picholine, Manzanillo, Koroneiki and Frantoio rootstocks, gave the best canopy perimeter with inconsiderable significant differences between them.

Table (2) : Effect of different rootstocks on tree vigor of Dolce cultivar during 2013 and 2014 seasons

Rootstock	Tree height (m)		Trunk perimeter (cm)		Trunk cross section area (cm^2)		Canopy perimeter (m)	
				2013 season				
Pitcholin	3.40	A	140.50	B	1572.0	B	15.18	A
Frantoio	3.23	A	190.50	A	2888.2	A	13.23	B
Mission	3.45	A	141.50	B	1597.1	B	15.99	A
Koroneiki	3.06	A	119.33	C	1134.6	C	13.33	B
Manzanillo	3.20	A	113.00	C	1017.4	C	14.55	AB
				2014 season				
Pitcholin	3.40	AB	145.00	B	1674.4	B	15.81	AB
Frantoio	3.45	AB	197.00	A	3088.8	A	13.58	C
Mission	3.35	AB	140.00	B	1565.0	B	16.55	A
Koroneiki	3.65	A	122.50	C	1197.2	C	13.93	C
Manzanillo	3.25	B	115.00	C	1053.7	C	14.84	BC

Values followed by the same letter (s) within the same column not significantly different at 0.5% level of probability.

These results are in general agreement with the findings of Troncoso *et al.,* (1990) they studied the influence of 20 olive rootstocks on growth (plant height and canopy diameter) of 'Gordal Sevillano', and classified the influences of these rootstocks to : inducing big growth (Acebuche, Morisca de Badajoz, Lechín de Sevilla, Real sevillana, Cornezuelo); rootstocks inducing normal growth (Cañivano, Carrasqueña, Gordal, Blanqueta, Tempranilla de la Sierra, Chariglot, Manzanilla de Jaén, Alameño and 'Picholin) and rootstocks inducing little growth (Redondilla de Logroño, Picual, Buidiego, Hojiblanca, Habichuelero). Other results have shown that some rootstocks have a strong influence on scion vigour. The lowest tree vigour was observed in ‘Arbosana’, ‘Corbella’ and ‘Limoncillo’ rootstocks, while ‘Menya’, ‘Fs-17’ and ‘Joanenca’ were the most vigorous scions. (Tous *et al.,* 2011)

Arpaia *et al.,* (1995) when they evaluated the tree size of Avocado cv. Hass on eight clonal avocado rootstocks in southern California and one of these rootstock produced a larger tree and no differences between the other rootstocks. Also, in Momsambi-sweet orange trees, growth parameters such as plant height, basal girth and canopy spread significantly varied on different rootstocks (Ghosh *et al.,* 2012). The same was obtained on eight rootstocks on lemon cv ‘Kagzi Kalan’, when Dubey and Sharma (2016) found that, tree height and canopy volume were found higher on rough lemon and RLC-4 rootstocks, while trunk cross sectional area was higher on Billikichlli and RLC-4 rootstocks than other rootstocks. Furthermore, tree vigour depended on the sour cherry cultivar and the rootstock used. (Kopytowski and Markuszewski, 2010)

On the other hand, Iqbal *et al.*(1999) reported that none of the rootstocks contributed much towards Kinnow mandarin trees height of the of scion cultivar, while, The data on canopy spread reflected the efficiency of a rootstock and its effect on the vigor of scion cultivar. Likewise, no significant differences between the rootstocks were shown for the trunk thickness or the volume of the crowns of “Kordia” sweet cherry trees. (Wocior, 2008)

- **Shoot length (cm) and number of leaves/meter of Kalamata cultivar**

Data presented in table (3) showed that, Picholine rootstocks produced the best shoot length (14.85 & 16.01 cm) respectively, in 2013 and 2014 seasons of the study, and there was no significant differences between the rest of rootstocks in the second season of the study.

On the other hand, the greatest numbers of leaves per meter were observed by Frantoio rootstock (157.1 & 168.7) and the lowest values were produced by Mission rootstocks (131.0 & 136.8) respectively in the two seasons of the study.

Table (3) : Effect of different rootstocks on shoot length (cm) and number of leaves/meter of Kalamata cultivar during 2013 and 2014 seasons

Rootstock	Shoot length (cm)		No. of leaves / meter	
		2013 season		
Pitcholin	14.85	A	145.2	C
Frantoio	10.93	BC	157.1	A
Mission	9.83	C	131.0	D
Koroneiki	10.03	C	147.8	BC
Manzanillo	12.20	B	148.6	B
		2014 season		
Pitcholin	16.01	A	152.5	C
Frantoio	13.05	B	168.7	A
Mission	12.88	B	136.8	D
Koroneiki	12.75	B	158.7	B
Manzanillo	12.67	B	155.9	B

Values followed by the same letter (s) within the same column not significantly different at 0.5% level of probability.

- **Shoot length (cm) and number of leaves/meter of Dolce cultivar**

Frantoio rootstock gave the longest shoot length (17.88 & 18.59 cm) respectively. However, the best numbers of leaves per meter were obtained with Picholine rootstock (137.7 & 143.8) respectively, in 2013 and 2014 seasons of the study. Whereas, Manzanillo rootstock presented the shortest shoot length (10.03 & 10.68 cm) and the lowest number of leaves per meter (114.4 & 128.3) respectively, in the two seasons of the study. (Table 4)

Table (4) : Effect of different rootstocks on shoot length (cm) and number of leaves/meter of Dolce cultivar during 2013 and 2014 seasons

Rootstock	2013 season			
	Shoot length (cm)		No. of leaves per meter	
Pitcholin	12.85	B	137.7	A
Frantoio	17.88	A	117.1	CD
Mission	11.63	B	131.6	B
Koroneiki	12.98	B	117.9	C
Manzanillo	10.03	C	114.4	D
	2014 season			
Pitcholin	13.34	B	143.8	A
Mission	18.59	A	122.7	E
Frantoio	11.76	C	137.6	B
Koroneiki	13.06	B	135.8	C
Manzanillo	10.68	D	128.3	D

Values followed by the same letter (s) within the same column not significantly different at 0.5% level of probability.

In this respect, Satisha *et al.*, (2010) observed that, significant differences were observed in shoot length and other vegetative parameters among different rootstocks of Thompson seedless grapes during all years of the study. However, there was no effect of rootstock on shoot growth rate of Hass avocado trees (Mickelbart *et al.*, 2012).

(2) Flowering dates and characteristics

- **Flowering dates of Kalamata cultivar**

Data noticed in table (5) and Fig. (1) illustrated that, Kalamta grafted on Picholine rootstock was the earliest trees in the beginning of flowering dates (April 7th & April 9th) respectively in the two seasons of the study, however the latest date was observed with trees of Kalamata grafted on Koroneiki rootstock (April 13th). Picholine rootstock was the earliest in fullblooming and the end of flowering dates (April 15th & April 20th) respectively in the second season of the study. However Koroneiki rootstocks maintained its ranking in the last position of full blooming and end of flowering dates (April 18th & April 21st) and (April 23rd & April 25th) respectively in 2013 and 2014 seasons. Also, Mazanillo rootstock participated with Koroneiki in last place of the end of flowering date in the second season and other rootstocks were intermediate of these results in both seasons.

In view of flowering periods, it was observed that flowering periods extended for 11 to 14 days from the beginning to the end of flowering in all Kalamata trees grafted on the studied rootstocks during the two seasons of the study.

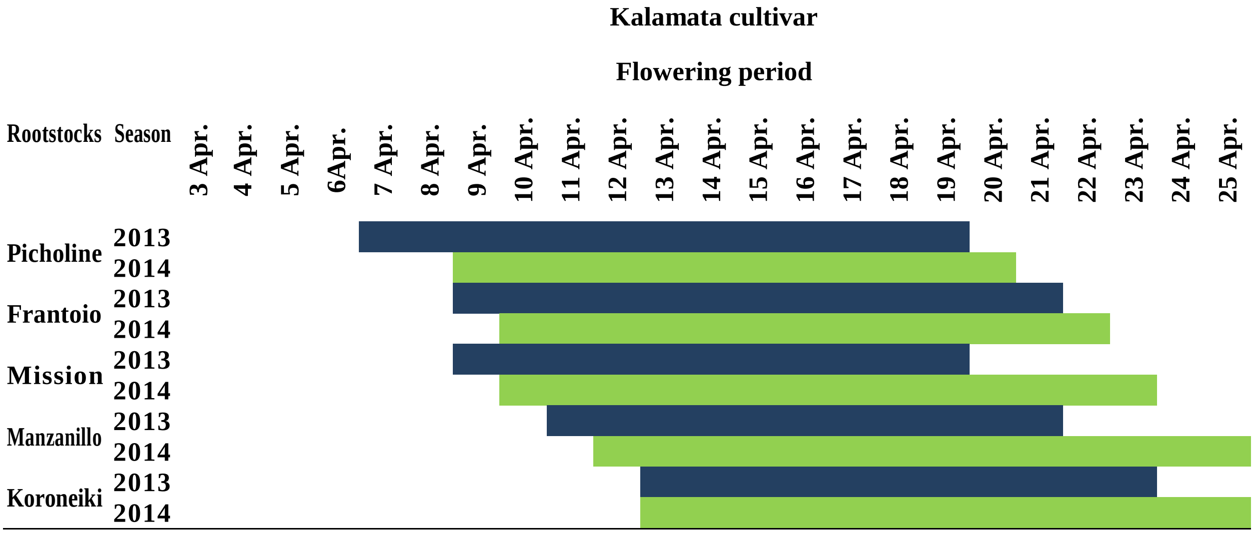

Fig. (1). Effect of different rootstocks on flowering periods of Kalamata and Dolce cultivars during 2013 and 2014 seasons

Table (5) : Effect of different rootstocks on beginning, fullbloom and end of flowering of Kalamata cultivar during 2013 and 2014 seasons

Rootstocks	Beginning		Full bloom		End of flowering	
	2013	2014	2013	2014	2013	2014
Picholine	07-Apr.	09-Apr.	13-Apr.	15-Apr.	19-Apr.	20-Apr.
Frantoio	09-Apr.	10-Apr.	15-Apr.	18-Apr.	21-Apr.	22-Apr.
Mission	09-Apr.	10-Apr.	13-Apr.	18-Apr.	19-Apr.	23-Apr.
Manzanillo	11-Apr.	12-Apr.	16-Apr.	20-Apr.	21-Apr.	25-Apr.
Koroneiki	13-Apr.	13-Apr.	18-Apr.	21-Apr.	23-Apr.	25-Apr.

- **Flowering dates of Dolce cultivar**

Data presented in table (6) and illustrated in Fig. (2) showed that, Dolce grafted on Picholine rootstock was the earliest trees in the beginning of flowering dates (April 3rd & April 5th) respectively in the two seasons of the study and was the earliest also in fullblooming during the second season (April 13th) and in the end of flowering during the first season (April 16th). Whereas, the latest of these dates were observed with trees of Dolce grafted on Koroneiki rootstock in the beginning of flowering in the second season (April 9th), full blooming and end of flowering April 15th & April 17th) and (April 21st & April 22nd) respectively, in both seasons of the study. Dolce grafted on other rootstocks were intermediate of the pervious dates in both seasons.

Table (6) : Effect of different rootstocks on Beginning, fullbloom and End of flowering of Kalamata cultivar during 2013 and 2014 seasons

Rootstocks	Beginning		Full bloom		End of flowering	
	2013	2014	2013	2014	2013	2014
Picholine	03-Apr.	05-Apr.	11-Apr.	13-Apr.	16-Apr.	18-Apr.
Frantoio	05-Apr.	07-Apr.	13-Apr.	15-Apr.	18-Apr.	20-Apr.
Mission	05-Apr.	07-Apr.	11-Apr.	15-Apr.	18-Apr.	18-Apr.
Manzanillo	07-Apr.	07-Apr.	13-Apr.	15-Apr.	19-Apr.	18-Apr.
Koroneiki	07-Apr.	09-Apr.	15-Apr.	17-Apr.	21-Apr.	22-Apr.

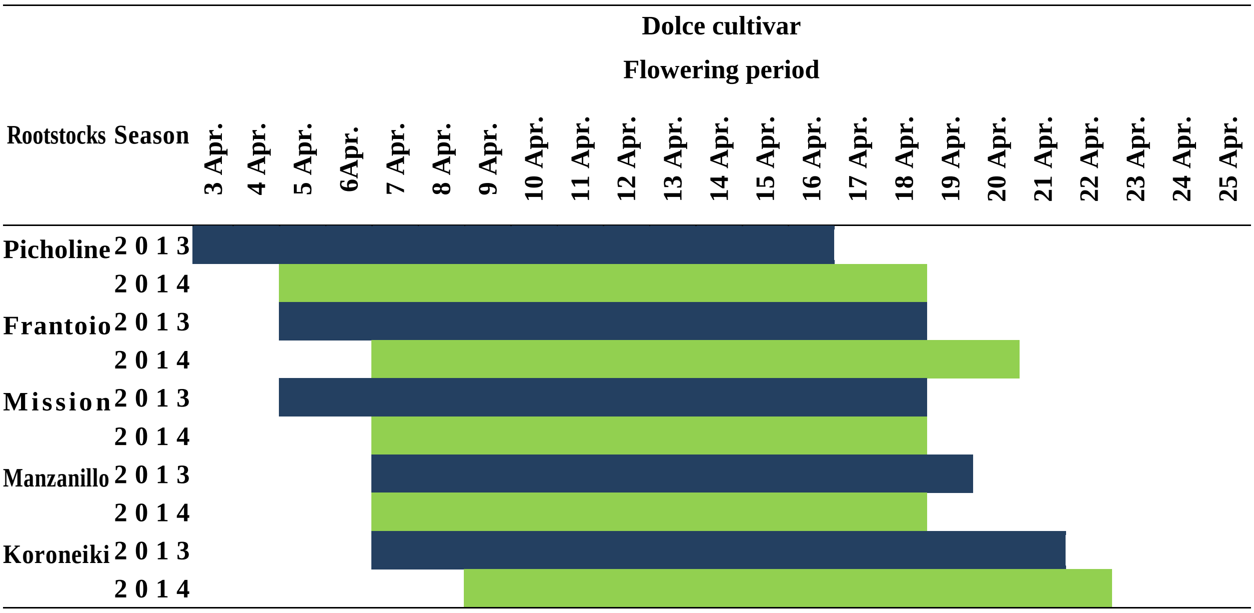

Fig. (2). Effect of different rootstocks on flowering periods of Kalamata and Dolce cultivars during 2013 and 2014 seasons

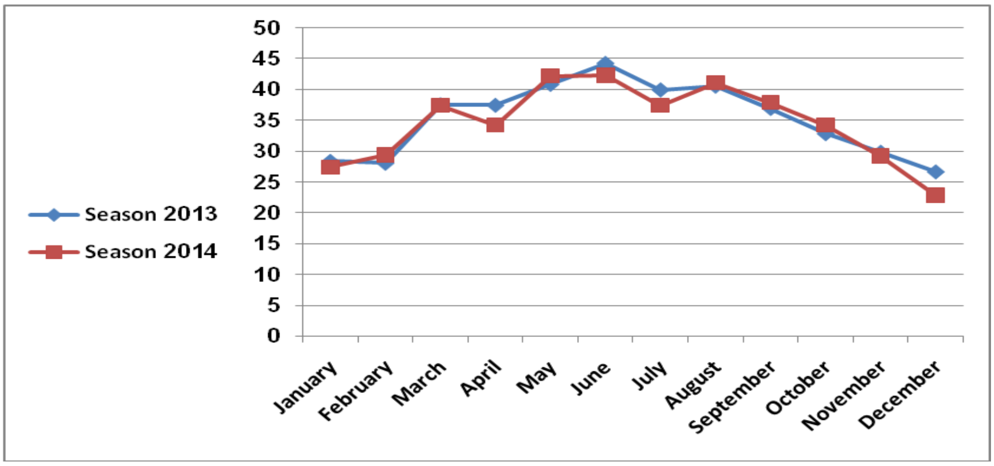

Fig. (3). Maximum temperature during the period from Jan. 2013 to Dec. 2014.

Regarding to the flowering periods, it was observed that flowering periods extended for 12 to 16 days from the beginning to the end of flowering in all Dolce trees grafted on the investigated rootstocks during the two seasons of the study

From all the pervious results of the flowering dates and periods, these durations might be differed strongly according to cultivars but were differed weakly according to the rootstocks of the same cultivar. Also, the climatic conditions especially the temperature during the flowering periods plays a great role and have an impact on those variations of flowering dates from season to another. But, it had a slight effect in this investigation which was noticed from fig (3) that the differences between the temperatures of 2013 and 2014 seasons were not great. These observations are in harmony with those of Cesaraccio *et al.*, (2006), who mentioned that the phenological behavior of olive tree is largely influenced by environmental factors such as temperature.

Also, Lichev and Berova (2004) observed that, physiological state affected flower bud development, trees grafted on Weiroot 72, Weiroot 158 and Weiroot 13 had significantly more flowers per flower bud than trees grafted on GiSelA 5

- **Flowering characteristics of Kalamta cultivar**

Table (7) shows that, the best numbers of inflorescences and number of total flowers/ inflorescences were produced by Kalamata trees grafted on Frantoio and Mission rootstocks [(78.6 & 85.2);(78.3 &84.9)] and [(24.77 & 23.98); (24.60&24.11)] respectively in 2013 and 2014 seasons. However, the lowest values of those parameters were obtained by Koroneiki rootstock (60.9 &64.7) and (20.73 & 19.88) respectively in the two studied seasons. On the other hand, there were insignificant differences between all studied rootstocks in inflorescence length in the two seasons of the study. Regarding to the sex expression, Mission rootstock gave the best percentage of perfect flowers to total flowers (75.15% & 77.98%) in the two seasons, participated with Koroneiki rootstock (75.69%) in the first season, while Frantoio rootstock gave the lowest ones (66.97% & 67.56) respectively, in 2013 and 2014 seasons.

Table (7) : Effect of different rootstocks on some flowering characteristics of Kalamata cultivar during 2013 and 2014 seasons

Rootstock	No. of inflor. /meter		Inflorescence length (cm)		No. of total flowers/inflor.		Sex expression (%)	
			2013 season					
Pitcholin	76.7	B	3.36	A	22.68	B	70.20	B
Frantoio	78.6	A	3.65	A	24.77	A	66.97	C
Mission	78.3	A	3.26	A	24.60	A	75.15	A
Koroneiki	60.9	C	3.58	A	20.73	C	75.69	A
Manzanillo	79.2	A	3.49	A	22.03	BC	70.58	B
			2014 season					
Pitcholin	81.7	B	3.44	A	22.69	AB	72.64	C
Frantoio	85.2	A	3.67	A	23.98	A	67.56	D
Mission	84.9	A	3.35	A	24.11	A	77.98	A
Koroneiki	64.7	C	3.52	A	19.88	C	75.25	B
Manzanillo	81.9	B	3.52	A	22.38	B	71.69	C

Values followed by the same letter (s) within the same column not significantly different at 0.5% level of probability.

- **Flowering characteristics of Dolce cultivar**

Table (8) shows that, Dolce trees grafted on Picholine gave the best numbers of inflorescences and number of total flowers/ inflorescences (88.8 & 88.7);(15.60 &15.68)respectively in the two studied seasons, participated with Koroneiki rootstock (15.7 &

15.60) in the measurement of number of total flowers/inflorescence. Inefficient significant differences with no clear trend were observed in inflorescence length during the studied seasons. Furthermore, Dolce cv. grafted on Koroneiki rootstock produced the lowest percentage of sex expression (96.66% & 95.89%) in 2013 & 2014 seasons compared with other studied rootstocks which gave more than that percentage.

Table (8) : Effect of different rootstocks on some flowering characteristics of Dolce cultivar during 2013 and 2014 seasons

Rootstock	No. of inflor. /meter		Inflorescence length (cm)		No. of total flowers/inflor.		Sex expression (%)	
	2013 season							
Pitcholin	88.8	A	2.92	AB	15.60	A	99.03	A
Frantoio	72.4	D	2.96	AB	12.93	CD	98.91	A
Mission	71.1	D	2.91	AB	15.07	AB	99.47	A
Koroneiki	75.5	C	2.61	B	12.17	D	96.66	B
Manzanillo	82.5	B	3.33	A	13.80	BC	99.80	A
	2014 season							
Pitcholin	88.7	A	3.01	AB	15.68	A	99.25	A
Frantoio	73.8	D	3.18	AB	13.66	B	99.43	A
Mission	73.5	D	3.33	A	15.60	A	99.68	A
Koroneiki	77.6	C	2.78	B	12.68	B	95.89	C
Manzanillo	83.6	B	3.26	AB	13.45	B	98.07	B

Values followed by the same letter (s) within the same column not significantly different at 0.5% level of probability.

(3) Fruit set/meter and yield/tree

- **Fruit set /meter and yield/tree of Kalamata cultivar**

The average fruit set/meter, as shown in table (9) was significantly higher in Kalamata trees which grafted on Picholine rootstock (46.44 & 51.23) respectively in the first and second season of the study. Whereas, it was significantly lower in Koreiniki and Mnazanillo rootstocks in the first season and Manzanillo rootstock only (29.89) in the second season as compared with those values of the other studied rootstocks.

The highest significant average of yield/tree was noticed on Kalamata trees grafted on Picholine, Frantoio or Mission rootstocks in both seasons. However, the most rootstocks which affected negatively on Kalamata yield/tree were Manzanillo and Koreiniki rootstocks (15.50 in 15.17 Kg) respectively in 2013 season and Manzanillo followed by Koroneiki rootstocks (20.67 & 31.17 Kg) respectively, in 2014 season.

Table (9) : Effect of different rootstocks on fruit set and yield of Kalamata cultivar during 2013 and 2014 seasons

Rootstock	Final fruit set / meter		Yield/tree (kg)	
	2013 season			
Pitcholin	46.44	A	31.67	A
Frantoio	35.88	B	25.00	A
Mission	34.09	B	25.00	A
Koroneiki	30.77	C	15.17	B
Manzanillo	27.97	C	15.50	B
	2014 season			
Pitcholin	51.23	A	51.90	A
Frantoio	39.87	B	47.33	A
Mission	39.56	B	47.00	A
Koroneiki	34.47	C	31.17	B
Manzanillo	29.89	D	20.67	C

Values followed by the same letter (s) within the same column not significantly different at 0.5% level of probability.

- **Fruit set and yield/tree of Dolce cultivar**

Results in table (10) showed that, the average fruit set/meter of Dolce trees grafted on the studied rootstocks were be arranged in descending order as follow; Picholine (68.84&71.56), Mission, Frantoio, Koreniki and Manzanillo which produced the lowest values (48.03&49.98) respectively, in 2013&2014 seasons. Regarding to the yield of Dolce trees, Picholine and Mission rootstocks had the best significant positive effect (95&102.33Kg) and (95 & 98.33Kg) respectively in the first and second season. While, the lowest yield/tree values were obtained by Manzanillo rootstock (42.67&55.83Kg) respictievly, during the two studied seasons. Frantoio and Koroneiki rootstocks were in-between of these previous values.

Table (10) : Effect of different rootstocks on fruit set and yield of Dolce cultivar during 2013 and 2014 seasons

Rootstock	2013 season			
	Final fruit set / meter		Yield/tree (kg)	
Pitcholin	68.84	A	95.00	A
Frantoio	62.41	C	70.00	B
Mission	67.34	B	95.00	A
Koroneiki	56.23	D	68.00	B
Manzanillo	48.03	E	42.67	C
	2014 season			
Pitcholin	71.56	A	102.33	A
Frantoio	65.89	C	82.33	B
Mission	68.29	B	98.33	A
Koroneiki	59.68	D	71.67	C
Manzanillo	49.98	E	55.83	D

Values followed by the same letter (s) within the same column not significantly different at 0.5% level of probability.

These results are supported by the results of Hartamann and Whisler, (1970) who mentioned that, production of olive fruits was strongly influenced by the rootstock , and Troncoso *et al.*, (1990), who determined 7 rootstocks of olive influenced in high production (Morisca de Badajoz, Cañivano, Acebuche, Manzanilla de Jaén, Carrasqueña, Gordal and Tempranilla de la Sierra).

As well, two rootstocks produced the highest yield of (Hass) avocado trees and three rootstocks caused the lowest productivity and no differences effect between the others (Arpaia *et al.*, 1995). Likewise, degree of yield expression of a scion variety (mosambi – sweet orange) , grafted on specific rootstock is considered as one of the important indicators for rootstock- scion suitability under a certain condition (Ghosh *et al.*, 2012). Also, Dubey and Sharma (2016) recommended by RLC-4 and Attani-2 rootstocks which had higher fruiting density of lemon cv 'Kagzi Kalan'. Furthermore, yield of Thompson seedless grapes varied significantly among the different rootstocks, influenced by root distribution pattern and total root number. (Satisha *et al.*, 2010), and the greatest benefits of using rootstocks were seen by Kocsis *et al.*, (2012*)* and yields of two Vitis vinifera L. cultivars were increased 11-30% depending on different rootstocks. Sitarek and Bartosiewicz, (2012) confirmed these results after 8 studied years showed the strong effect of rootstock on yield of sweet cherry trees. In contrast slightly with the previous findings, Iqbal *et al.* (1999) found on Kinnow mandarin that, fruit setting depicted insignificant differences for rootstock effect but yield revealed significant differences for various rootstock means.

Fruit physical characteristics

- **Fruit physical characteristics of Kalamata cultivar**

In table (11) and table (12), Impotent significant differences were noticed in most of physical characteristics of Kalamata fruits as affected by the studied rootstocks, whatever Mission rootstock produced the highest significant effect in the measurements of fruit diameter (2.133&1.953 cm), fruit weight (7.453&5.997 gm) and flesh weight (6.537&5.207 gm) respectively, in the two studied seasons and the best ratio of flesh/pit (6.570) on the second season of the study. Whereas Koroneiki rootstock gave the lowest values of fruit weight (4.120&4.481 gm) and flesh weight (3.540&3.767) respectively, in the 2013 &2014 seasons, and of flesh/pit ratio (5.263) in the second season. There is no significant differences between the effects of the studied rootstocks on the measurements of fruit length and flesh/pit ratio in the first season of the study.

Table (11) : Effect of different rootstocks on fruit and stone length, width of Kalamata cultivar during 2013 and 2014 seasons

Rootstock	2013 season							
	Fruit length (cm)		Fruit diameter (cm)		Stone length (cm)		Stone diameter (cm)	
Pitcholin	2.973	A	2.033	B	1.970	A	0.8300	AB
Frantoio	3.003	A	1.960	BC	2.000	A	0.7867	B
Mission	3.100	A	2.133	A	2.027	A	0.8633	A
Koroneiki	2.867	A	1.647	D	1.780	B	0.7300	C
Manzanillo	2.863	A	1.897	C	2.047	A	0.8467	A
	2014 season							
Pitcholin	2.887	B	1.843	B	2.003	B	0.8100	B
Frantoio	2.947	AB	1.857	B	2.077	A	0.8700	A
Mission	3.000	A	1.953	A	2.087	A	0.8100	B
Koroneiki	2.753	C	1.777	C	1.967	B	0.8033	B
Manzanillo	2.933	AB	1.810	BC	2.110	A	0.8833	A

Values followed by the same letter (s) within the same column not significantly different at 0.5% level of probability.

Table (12) : Effect of different rootstocks on fruit, stone , flesh weight and Flesh/pit ratio of Kalamata cultivar during 2013 and 2014 seasons

Rootstock	Fruit weight (gm)		Stone weight (gm)		Flesh weight (gm)		Flesh/pit Ratio	
	2013 season							
Pitcholin	6.610	B	0.8033	B	5.807	B	7.243	A
Frantoio	6.340	B	0.7167	B	5.623	B	7.847	A
Mission	7.453	A	0.9167	A	6.537	A	7.133	A
Koroneiki	4.120	C	0.5800	C	3.540	C	6.663	A
Manzanillo	6.270	B	0.8000	B	5.470	B	6.857	A
	2014 season							
Pitcholin	5.016	B	0.7487	CD	4.267	B	5.713	B
Frantoio	5.240	B	0.8337	AB	4.407	B	5.283	C
Mission	5.997	A	0.7930	BC	5.207	A	6.570	A
Koroneiki	4.481	C	0.7153	D	3.767	C	5.263	C
Manzanillo	5.001	B	0.8683	A	4.133	B	4.767	D

Values followed by the same letter (s) within the same column not significantly different at 0.5% level of probability.

- **Fruit physical characteristics of Dolce cultivar**

There were a slightly significant differences between Dolce fruits as affected by the different rootstocks which didn't produced any clear trend could be considered during the two studied seasons except these values that produced by Koroneiki rootstocks which gave the lowest fruit length(2.650 cm), fruit diameter (1.407 cm), fruit weight (2.545 gm) and flesh weight (2.119 gm) in the first season of the study. (Table 13 and 14)

Table (13) : Effect of different rootstocks on fruit and stone length, width of Dolce cultivar during 2013 and 2014 seasons

Rootstock	Fruit length (cm)		Fruit diameter (cm)		Stone length (cm)		Stone diameter (cm)	
	2013 season							
Pitcholin	2.953	A	1.530	A	2.280	A	0.6933	A
Frantoio	2.970	A	1.567	A	2.223	AB	0.6667	AB
Mission	3.010	A	1.563	A	2.277	A	0.6400	BC
Koroneiki	2.650	B	1.407	B	2.100	AB	0.6100	C
Manzanillo	2.883	A	1.620	A	2.063	B	0.6333	BC
	2014 season							
Pitcholin	2.690	B	1.363	D	2.057	AB	0.6300	A
Frantoio	2.777	AB	1.417	BC	2.103	A	0.6567	A
Mission	2.717	B	1.377	CD	2.093	A	0.6267	A
Koroneiki	2.693	B	1.440	B	2.013	B	0.6500	A
Manzanillo	2.847	A	1.560	A	2.087	A	0.6200	A

Values followed by the same letter (s) within the same column not significantly different at 0.5% level of probability.

Table (14) : Effect of different rootstocks on fruit, stone , flesh weight and Flesh/pit ratio of Dolce cultivar during 2013 and 2014 seasons

Rootstock	Fruit weight (gm)		Stone weight (gm)		Flesh weight (gm)		Flesh/pit Ratio	
	2013 season							
Pitcholin	3.659	A	0.6070	A	3.052	A	5.030	C
Frantoio	3.888	A	0.5720	A	3.316	A	5.790	B
Mission	3.889	A	0.5477	AB	3.341	A	6.103	AB
Koroneiki	2.545	B	0.4260	C	2.119	B	4.963	C
Manzanillo	3.628	A	0.4750	BC	3.153	A	6.673	A
	2014 season							
Pitcholin	2.673	B	0.4657	B	2.207	B	4.735	C
Frantoio	2.999	B	0.5440	A	2.455	B	4.513	C
Mission	2.843	B	0.4883	B	2.355	B	4.822	BC
Koroneiki	2.963	B	0.4860	B	2.487	B	5.097	B
Manzanillo	3.794	A	0.4867	B	3.312	A	6.782	A

Values followed by the same letter (s) within the same column not significantly different at 0.5% level of probability.

These results are partially in harmony with those reported by Hartamann and Whisler (1970) who observed that, there was no influence on olive fruit size, and no pronounced influence of rootstock on fruit characteristics was apparent (Hartmann, 1958). However, Tous *et al.,* (2011) adduced that, rootstocks had little influence on fruit characteristics of arbequina olive cultivar. On the other hand, significant differences in fruit characters of mosambi sweet orange grown on different root stock (Ghosh *et al.,* 2012). Heaviest fruits of lemon cv 'Kagzi Kalan' were produced by RLC-4 rootstock compared with other seven rootstocks. (Dubey and Sharma, 2016). significant effect of different rootstocks on fruit characteristics of both scion cultivars of *Vitis vinifera* L. especially under drought stress (Kocsis *et al.*, 2012). Fruit quality of sour cherry expressed by the weight of the fruit and fruit parameters depended on the cultivar and the rootstock. (Kopytowski and Markuszewski, 2010). Differential effect of some rootstocks on the average fruit weight of cultivars tested of Sylvia and Karina sweet cherry trees (Sitarek and Bartosiewicz, 2012).

CONCLUSION

Under the same conditions of the present study, it could be concluded that, Picholine rootstock followed by Mission then Farantoio revealed the highest productivity of Kalamata trees. However, Dolce Cultivar has achieved the maximum productivity with Picholine and Mission rootstocks.

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تأثير الأصول المختلفة على التزهير والاثمار والمحصول لأشجار الزيتون الكلاماتا والدولسى

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أجريت هذه الدراسة خلال موسمى ٢٠١٣ ـ ٢٠١٤ بمزرعة خاصة فى طريق القاهرة / الاسكندرية الصحراوى على اصول الزيتون البيتشولين ، الفرانتويو ، الميشين ، المنزانيللو ، الكروناكى . وكان عمر الأشجار ٢١ عاما وتم تجديدها عام ٢٠٠٨ بالتطعيم القمى عليها بصنفى الكلاماتا والدولسى. الأشجار مزروعة على مسافة ٦ × ٦ متر نامية بأرض رملية تحت نظام الرى بالتنقيط . ويهدف البحث الى دراسة تأثير الاصول المختلفة (البيتشولين ، الفرانتويو ، الميشين ، المنزانيللو ، الكروناكى) على انتاجية صنفى التخليل الأسود الرئيسيين فى مصر (الكلاماتا و الدولسى) وقد لاحظت النتائج الاختلاف فى النمو الخضرى تبعا لتأثير الاصول المدروسة على صنفى الكلاماتا والدولسى ، حيث أظهر صنف الكلاماتا المطعوم على أصل البيتشولين أعلى قيم لطول الشجرة ومحيط الجذع ومساحة المقطع للجذع وكذلك طول الفرع ، بينما سجلت الصفات الاولى السابقة افضل قيمها مع أشجار الدولسى المطعومة على أصل الفرانتويو . أيضاً ، حقق أصل البيتشولين مع الدولسى أبكر المواعيد (لبداية وقمة ونهاية التزهير) وأعلى عدد للنورات الزهرية/للمتر ، واعلى عدد للأزهار الكلية على النورة ، بينما أعطى اصلى البيتشولين والميشين أعلى محصول لشجرة الدولسى . وكذلك فإن أشجار الكلاماتا حققت أعلى عقد ثمار/متر مع أصل البيتشولين وأفضل محصول للشجرة مع أصول (البيتشولين ، الفرانتيويو ، الميشين) كما اعطى أكبر وزن للثمار واللحم مع أصل الميشين . وعلى صعيد آخر ، فإن أصلى الكروناكى والمنزانيللو أثرا سلبياً على صنفى الكلاماتا والدولسى وأعطيا أقل القيم لمعظم الصفات المدروسة . ويمكن التوصية تحت نفس ظروف الدراسة بأن أصل البيتشولين أعطى اعلى انتاجية لأشجار الكلاماتا متبوعا بأصل الميشين ثم الفرانتويو ، بينما حقق صنف الدولسى أعلى انتاجية له مع أصلى البيتشولين والميشين .