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Performance of Manzanillo Olive Trees Grafted on Two Different Rootstocks

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Abstract: The current study was conducted on Manzanillo olive cultivar grafted on Frantoio and Chemlali olive rootstocks, during the 2019 and 2020 growing seasons at a private orchard in Cairo/Alexandria desert road. Trees were grown under sandy soil conditions with drip irrigation and planted at 6×6 meters as planting distances. The current study was set out to determine the impact of, Frantoio and Chemlali rootstocks, on productivity of Manzanillo olive cultivar. In this study, we assessed the effect of the examined rootstocks on Manzanillo olive's flowering, production, fruit quality and mineral content of the leaves. The obtained results indicated that different rootstocks had significant effects on the evaluated variables of the grafted Manzanillo olive trees, as compared to the same parameters measured for own-rooted Manzanillo trees. Furthermore, Manzanillo olive cultivar grafted on Frantoio rootstock had the highest flowering characteristics; N, P and K leaf mineral content and the highest yield and oil content. Meanwhile, Chemlali rootstock ranked the second place in improving the productivity and quality characteristics of the fruits. So, to maintain high productivity from Manzanillo olive trees, it is recommended to graft Manzanillo scions on Frantoio rootstocks followed by Chemlali.

Key words: Olive · Manzanillo · Frantoio · Chemlali · Rootstocks · Grafting · Yield · Fruit quality

INTRODUCTION

Olive (*Olea europea* L.), a widely cultivated tree that is native to the Mediterranean region, grown healthily in many dry regions of the world. Recently, olives became one of the most important fruit crops in Egypt. The total area of olive orchards expanded to be around (241,982) feddans, producing about (3.85 ton/feddan) [1]. Manzanillo olive is an early-ripening variety that bears heavily and is used to produce both table and oil olives, it is also considered as the world's most extensively grown and esteemed table olive cultivar in the world [2].

The productivity, survival and reproductive biology of plants and crops are greatly influenced by environmental stresses [3]. Additionally, biotic and abiotic challenges, such as drought, extremely high temperatures, water shortages, poor irrigation water quality and salinity in soil and water, are issues that are getting worse [4]. Moreover, these stresses may have a negative impact on the scions' and rootstocks' growth and development, resulting in a decrease in fruit yield and fruit quality. There are only a few scientific methods for overcoming these challenges, one of which involves using certain resistant varieties/ rootstocks. Therefore, in this case, the rootstock, which has been utilized for fruit tree propagation for more than 2000 years ago, is one of the practical choices that are generally available to us [5].

On the other hand, there is a need to use effective rootstocks for boosting fruit yield and productivity due to an expanding population, reducing per capita land availability and efficient use of poor soils. Many of the utilized rootstocks have an impact on scions development, flowering, fruit bearing, productivity and reacting to various biotic and abiotic challenges. Plants are concurrently exposed to biotic and abiotic stresses in nature, which reduce yields [6]. A higher tolerance for abiotic stress conditions such as salinity, heavy metals, nutritional stress, water stress and alkalinity is also included in the usage of rootstocks in fruit production, in addition to increased resistance to pathogens. Finding the best rootstock for fruit crops continues to be quite difficult.

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Accordingly, grafting is one of the oldest horticultural practices, having its origin in China around 7000 BC [7]. Even now, grafting using rootstocks is still a significant part of the majority of commercial perennial fruit production. Grafting is a popular and effective method of propagating several woody plants of the same species. Through the use of their roots, plants may help one another grow and adapt to their environment more readily [8]. Grafting is a beneficial technique for propagating plants that are difficult to root and it can also speed up the production of fruits for commercial use [9].

In this concern, olive trees are commercially propagated through different techniques, including suckers, grafting on rootstocks, hardwood, semi-hardwood and soft cuttings. Variations in cultivars and rootstocks are increasingly in demand due to modern fruit cultivation. More and more people are realizing the value of rootstocks, which are just as significant as grafted scions in terms of their impact on crop production. Numerous studies have demonstrated that vegetative development and growth habits are influenced by the genetic structure of the plant and rootstock as well as by environmental factors or growing techniques [10, 11].

Furthermore, grafting different cultivars of olive trees onto wild olive rootstocks may lead to the trees' having increased resistance to pests, diseases and environmental changes. Additionally, grafting is a known technique in fruit trees that joins a scion and a rootstock to create a new plant with a fusion of characteristics [12]. The relationships between the kind of rootstock and scion in a grafted tree are based on several physiological characteristics [13].

Regarding nutrient absorption, water potential, plant vigour, fruit quality and production effectiveness, choosing the right graft combination might be critical [13]. Numerous studies have shown that rootstock has a major effect on grafted varieties' fruit quality [14]. The interacting impacts of scion/rootstock combinations as well as the direct effects of rootstock on scion physiology and fruit composition are not, however, known. Since rootstocks compensate a tree's root system, they largely affect how water and nutrients are absorbed by and moved among the plant's organs. Each rootstock-scion combination has a unique rate of nutrient absorption and transport, which has a crucial influence on physiological and biochemical processes, fertility, yield and fruit quality [15-17]. Depending on the soil and climatic variables, rootstock behavior might vary and have an impact on the scion. Therefore, choosing rootstocks unique to an area is just as crucial as choosing cultivars [18]. On the other hand, rootstocks with improved nutrient absorption and consumption capabilities and the ability for these benefits to be transmitted to the budded cultivar will assist in developing a fertilization program that is more environmentally friendly and cost-effective.

So, the present study aim was to investigate the influences of different rootstocks, namely Frantoio and Chemlali, on the productivity of Manzanillo olive trees and to achieve the best recommendation of the most appropriate olive rootstocks which may achieve maximum productivity and fruit quality.

MATERIALS AND METHODS

This study was carried out during two successive seasons (2019 and 2020) in a private orchard at Cairo/Alexandria desert road on 21 years-old Frantoio and Chemlali olive rootstocks, which were re-juvenile and top-grafted at 2009 season by Manzanillo olive cultivar. Trees were planted at 6×6 meters as planting distances and grown in sandy soil under a drip irrigation system. Trees were free from pathogens and physiological disorders and received the common cultural practices concerning pruning, irrigation, fertilization program and pest control that were recommended by the Ministry of Agriculture and Land Reclamation. Twelve uniform trees were chosen for this experiment, since each rootstock was presented by four trees during the two mentioned seasons. The response to the investigated treatments was evaluated by determining the following parameters:

Flowering Characteristics: Two branches were marked on each side of the tree, with a total number of 8 branches for each tree; and then, all developed inflorescences (panicles) on one-year-old shoots were assigned before the onset of flowering (at full bloom) to record the total number of flowers, perfect and male flowers/ inflorescences. In addition, sex ratio was calculated as the percentage of perfect flowers to total flowers [19].

Yield and Fruit Characteristics: t the maturity stage (September), fruits of each replicate tree were separately harvested, then weighed and the yield as kg/ tree was estimated. Samples of 20 fruits from each replicate tree *i.e.,* 80 fruits from each of the applied treatments were picked randomly at harvest to determine: Average fruit weight (g), fruit length (cm), fruit diameter (cm), fruit shape index, flesh fresh weight (g) and seed weight (g). In addition, fruit oil content as a dry weight was determined [20].

Leaf Mineral Content: Twenty leaves from the middle part of the shoots were selected randomly from each replicate (in the second week of August) to determine their content of N, P, K, Ca and Mg on a dry weight basis [21].

Statistical Analysis: Our experiment was arranged in a completely randomized block design and all obtained data during both the 2019 and 2020 experimental seasons were subjected to analysis of variances using COSTAT software [22]. The least significant difference (LSD) was used to compare the means of treatments according to Snedecor and Cochran [23] at a probability of 5%.

RESULTS

Flowering Characteristics: Concerning flowers classification per inflorescence, Table (1) shows that the maximum significant total flower number per inflorescence was counted when Manzanillo scions were grafted on Frantoio rootstock (M/F) (28.50 and 30.20) in the two seasons, respectively, while the minimum significant total flower number per inflorescence (12.67 and 13.40) was counted with own-rooted Manzanillo (M) in both seasons, successively.

As for perfect flowers, the maximum significant number/inflorescence (26.50 and 28.10) was counted with M/F in both seasons successively, whereas the minimum significant number/inflorescence (6.33 and 7.30) was recorded with M in the two seasons, respectively.

Regarding male flower number/inflorescence, the highest significant values (6.33 and 6.10) were recorded with M in the 2019 and 2020 seasons, respectively, while the lowest significant number (2.00 and 2.10) was obtained due to M/F in both successive seasons.

Concerning the sex ratio (perfect flowers/total flowers), the maximum significant ratio (92.39 and 93.05%) was calculated with M/F in both successive seasons; however the minimum significant ratio (51.43 and 54.48 %) was calculated with M in the two seasons, by order.

Yield and Fruit Characteristics: Results of Table (2) show that, the own rooted Manzanillo (M) trees produced significantly the highest fruit weight (5.39 and 5.20 g), while the significant lightest fruits (5.02 and 5.12 g) were recorded with M/F in both seasons and with M/C (5.12 g) in the first season.

Considering fruit length, it did not differ significantly among different grafting combinations since the tallest fruits (2.54 cm) were obtained with M in the first season and with M/C in the second one. However, the shortest fruits (2.42 and 2.45 cm) were measured with M/F in the two seasons, by order.

In the same line, fruit diameter wasn't significantly affected by rootstocks; the highest value (1.99 cm) was measured with M and M/C in the first season, followed by 1.98 cm with M in the second season. The smallest fruits (1.88 and 1.92 cm) were measured with M/F in both seasons, respectively.

According to the fruit shape index, the highest values (1.28 and 1.27) were scored with M/F in both seasons, successively and (1.27) with M in the first season. The lowest value (1.25) was recorded with M/C in the first season and with M in the second one. No significant differences in the fruit shape index were noticed among all grafts.

As for flesh weight, the heaviest significant weights (4.46 and 4.51 g) were recorded with M in both seasons, respectively. However, the lightest significant weights (4.16 and 4.21 g) were recorded with M/F in the two seasons, sequentially.

Regarding seed weight, the significant heaviest seeds (0.77 and 0.79 g) were recorded with M in both seasons, by order. Whereas the finest seed weight (0.67 and 0.68 g) has been recorded with M/F in the two seasons, successively, with a significant difference among the results.

Regarding the effect of rootstocks on the tree yield, M/F graft yielded the maximum significant values (60.05 and 62.51 kg/tree) in both seasons, respectively. However, the own-rooted Manzanillo (M) yielded the minimum significant values (24.68 and 26.50 kg/tree) in the two seasons, successively. These results are a reflection of the great difference in the number of flowers produced, especially the number of perfect flowers, which was mentioned previously.

Moreover, olive oil content differed significantly among grafts since the highest percentages (16.21 and 16.00 %) were extracted from own-rooted Manzanillo (M) in the two seasons, by order. The lowest oil percentage in the first season (15.62 %) was gained from M/C, while it was noticed with M/F olives in the second season (15.40 %).

Leaf Mineral Content: According to Table (3), the highest significant nitrogen (N) content (1.88 and 1.85 %) was measured with M/F in both seasons of the study in that order, whereas the lowest significant content (1.62 and 1.64%) was detected with M in both seasons, respectively.

Table 1: Effect of different rootstocks on flowering characteristics of Manzanillo scions in 2019 and 2020 seasons

	Total flowers		Perfect flowers		Male flowers		Sex ratio (%)	
Rootstock	2019	2020	2019	2020	2019	2020	2019	2020
M	12.67	13.40	6.33	7.30	6.33	6.10	51.43	54.48
M/ F	28.50	30.20	26.50	28.10	2.00	2.10	92.39	93.05
M/ C	16.83	17.50	13.00	13.30	3.83	4.20	77.60	76.00
LSD $_{(0.05)}$	3.11	2.82	2.41	2.81	0.52	0.56	9.21	10.40

M (Manzanillo), M/F (Manzanillo grafted on Frantoio), M/C (Manzanillo grafted on Chemlali)

Table 2: Effect of different rootstocks on fruit characteristics and oil content of Manzanillo olive trees in 2019 and 2020 seasons

	Fruit weight (g)		Fruit length (cm)		Fruit diameter (cm)		Fruit shape index		Flesh weight (g)		Seed weight (g)		Yield (kg/ tree)		Oil Content (%)	
Rootstock	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
M	5.39	5.20	2.54	2.51	1.99	1.98	1.27	1.25	4.46	4.51	0.77	0.79	24.68	26.50	16.21	16.00
M/ F	5.02	5.12	2.42	2.45	1.88	1.92	1.28	1.27	4.16	4.21	0.67	0.68	60.05	62.51	15.81	15.40
M/ C	5.12	5.16	2.50	2.54	1.99	1.95	1.25	1.26	4.31	4.28	0.75	0.76	44.23	46.22	15.62	15.42
LSD $_{(0.05)}$	0.10	0.09	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	0.15	0.14	0.05	0.05	10.5	11.8	0.24	0.21

M (Manzanillo), M/F (Manzanillo grafted on Frantoio), M/C (Manzanillo grafted on Chemlali)

Table 3: Effect of different rootstocks on leaf mineral content of Manzanillo scions in 2019 and 2020 seasons

	N (%)		P (%)		K (%)		Ca (%)		Mg (%)	
Rootstock	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
M	1.62	1.64	0.182	0.181	1.54	1.64	1.52	1.62	1.74	1.75
M/ F	1.88	1.85	0.205	0.214	1.92	1.87	1.63	1.78	1.84	1.79
M/ C	1.75	1.81	0.194	0.192	1.77	1.74	1.74	1.77	1.88	1.85
LSD $_{(0.05)}$	0.19	0.20	0.021	0.020	0.15	0.17	N.S	N.S	N.S	N.S

M (Manzanillo), M/F (Manzanillo grafted on Frantoio), M/C (Manzanillo grafted on Chemlali)

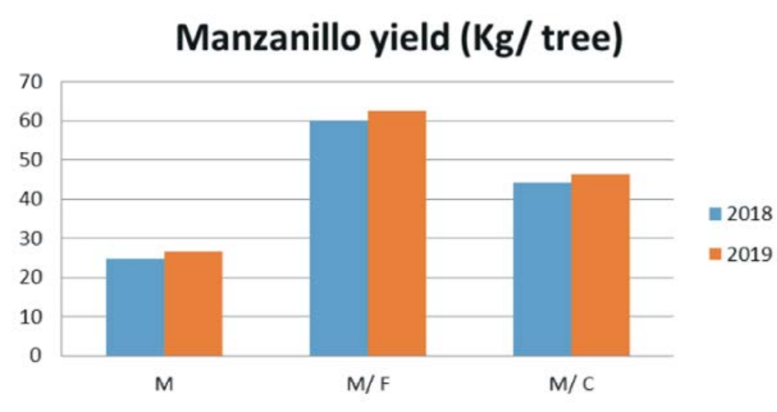

Fig. 1: Different rootstocks impact on Manzanillo yield (Kg/ tree)

Concerning phosphorus content (P), the maximum significant content (0.205 and 0.214 %) was recorded with M/F in the two seasons, successively, while the minimum significant content (0.182 and 0.181 %) was found with M in the two seasons, by order.

Similarly, the highest potassium (K) significant content (1.92 and 1.87 %) was scored by M/F in the two seasons, successively and the lowest significant contents (1.54 and 1.64 %) were detected with M in both experimental seasons, sequentially.

Meanwhile, calcium content (Ca) in olive leaves did not differ significantly among grafts, since the highest values were measured in the second season (1.78 and 1.77 %) with M/F followed by M/C, respectively. However, the lowest values (1.52 and 1.62 %) were measured with (M) in the two seasons, successively.

Moreover, magnesium content (Mg) did not differ significantly among grafts in olive leaves, since the highest percentages (1.88 and 1.85 %) were recorded with M/C in both seasons by order, whereas the lowest percentages (1.74 and 1.75 %) were detected with M in both seasons, respectively.

DISCUSSION

The findings of Pulgar *et al.* [24] and Hu *et al.* [25], who showed that grafting effects the absorption and translocation of phosphorus, nitrogen, magnesium and calcium, are consistent with the present findings on the influence of various rootstocks on leaf mineral content. Additionally, rootstock on citrus trees had a significant influence on nutrient absorption and the efficiency of nutrient uptake varied with rootstock [26]. Also, Taylor and Dimsey [27] found that the mineral element concentrations of scion leaves were influenced differently by rootstock type and scion cultivar. Additionally, the rootstock affects the transport and absorption of macro-and micronutrients in fruit crops. In peach, the different rootstock had an impact on the nutritional content of the 'UFSun' peach leaves. Some authors have previously proven that significant rootstock impacts on plants' mineral absorption [28]. Additionally, Mestre *et al.* [29] and Mayer *et al.* [30] reported on the impact of several Prunus rootstocks on the scion's nutritional status. Rootstocks frequently differ in terms of root architecture, root cation exchange capabilities and root exudates, all of which can affect nutrients levels in the leaves [31]. In our situation, the amounts of several leaf macronutrients varied amongst rootstocks. According to some scientists, leaf micronutrients had a smaller impact on rootstock macronutrient content than they did [32]. Therefore, it may be concluded that different rootstocks have varying capacities for absorbing macronutrients, as demonstrated by Rosati *et al.* [33]. On the other hand, the right rootstock supports optimum nutrient uptake and translocation and allows a decrease in fertilizer applications, which lowers the danger of nutrient leaching and potential toxicity without lowering fruit quality and output [34-35].

Regarding flowering characteristics, the data collected follow a similar pattern to those discovered by Mofeed [36] on Kalamata and Dolce olive trees, which revealed that the number of total flowers and sex expression varied significantly depending on the use of different rootstocks. On the other hand, grafted and non-grafted plants from the cucumber crop revealed that the grafted plants onto 6001 (*C. shantosa*) had significantly the highest number of flowers per node, number of flowers per plant and fruit setting percentage, followed by the grafted plants onto Strong (*C. maxima*), while the control (non-grafted) plants had the lowest values in both seasons. The findings suggest that the rootstock may have stopped growing the cucumber in terms of root system size. The rootstock may then move a sizable amount of xylem sap, which is known to contain a high concentration of minerals, organic compounds and plant hormones like cytokines and gibberellins that regulate the number of flowers per node [37-38]. Similar findings were observed by Abde-Alla [39], who examined the impact of grafting plants onto gourds. Fig leaf gourds had considerably the largest number of female flowers, followed by bottle gourds, while control (non-grafted) plants had the lowest values over both growing seasons.

Findings on citrus trees demonstrate that various rootstocks have an impact on fruit yield and quality. Differences in rootstock morphology and physiology, which are reflected in tree growth vigour, size and depth of roots, water and nutrient uptake capability, carbohydrate synthesis, as well as their adaptation to climatic and soil conditions, good compatibility between rootstock and cultivar and the interactions between different citrus cultivars, may be the cause of the variations in yield and fruit quality. The results are in line with those discovered by Continella *et al.* [40], Zekri and Parsons [41], since they discovered that for a suitable yield, rootstock and scion compatibility are crucial. These varied rootstock characteristics may have an impact on the scion cultivar's development, fruiting and fruit quality. Additionally, in mandarin, scion/rootstock combinations with a high capacity to assimilate critical nutritional components are expected to produce fruit with a greater yield and fruit quality. The results of Kaplankiran *et al.* [42], which reported higher N, K, Fe and Mn uptake ability of rootstocks with enhanced fruit quality parameters, were in agreement with the findings that relatively higher amounts of the essential nutrient elements are an indication of the higher yield and yield quality. On the other hand, the obtained results are in the same direction as the findings of Karlidag *et al.* [43] and Gundogdu [44] about the impacts of pear crop rootstock grafting on the cultivar characteristics such as blooming, earliness, productivity, fruit size, biochemical properties of fruits and fruit quality. The fruit characteristics of Mosambi sweet orange grown on rootstock, however, showed significant changes. Similar results were observed by Ollat *et al.* [45], who discovered that the rootstocks' root dispersion patterns and total root counts vary and that this affects the overall yield and the yield components of Thompson Seedless grafted onto various rootstocks. Many reports show that scion rootstock may be effective in the growth, yield and fruit quality of the plants, where Kurlus on sweet cherry [46] and Son and Kuden [47] on apricot demonstrated that the rootstock significantly affected growth, yield and fruit quality.

CONCLUSION

In this study, we evaluated the effects of different rootstocks on flowering characteristics, yield, fruit quality and leaf mineral composition. The results indicated that different rootstocks had significant effects on the evaluated variables of the Manzanillo olive tree, as compared to the same parameters measured for Manzanillo grown under own-rooted. Furthermore, Frantoio rootstocks had the highest flowering characteristics; leave minerals with the highest N, P and K content also had the highest yield and oil content. Meanwhile, Chemlali rootstock recorded the second place in improving yield and quality characteristics of olive fruits. A significant increase in the yield was estimated at about 67% by using Chemlali cultivar, while in the Frantoio cultivar the increment was more than double, estimated at about 130% increase in the yield compared to the ungrafted Manzanillo cultivar. So, to get high productivity from Manzanillo olive trees, it is recommended to graft Manzanillo scions on Frantoio rootstocks followed by Chemlali.

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