

Performance of Avocado (*Persea americana* Mill.) and Mango (*Mangifera indica* L.) Seedlings Compared with Their Grafted Trees¹

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ABSTRACT. Most fruit-tree breeding projects are based on selection of seedlings in regard to their performance. The selected seedlings are vegetatively propagated, usually by grafting. It is highly important for the breeder to know whether the performance of the grafted tree will resemble the performance of the original seedling. In this study the performance of avocado and mango seedlings was compared with that of their grafted duplicates. Significant differences were found in only 8 out of 36 avocado traits and 2 out of 10 mango traits. Significant seedling x graft interaction was detected in 10 other avocado traits. These differences were considered of no practical significance, since their magnitude was of minor importance for the breeder. The conclusion for avocado and mango breeders is that for most traits selection could be carried out on ungrafted seedlings.

In most fruit tree breeding projects, the testing phase is based on vegetative propagation of selected seedlings, usually by grafting. It is known though, that the performance of a grafted tree results from the interaction of the rootstock and the scion (Ben-Ya'acov, 1987; Rom and Carlson, 1987). Rootstocks affect the adaptability of the tree to various soil conditions such as drought, flooding, salinity, and alkalinity (Rom and Carlson, 1987). Scion vigor, manifested principally in tree size, is well known to be affected by rootstock x scion interaction. Since the fifteenth century, the use of rootstocks to dwarf trees has become a common practice, and it has been widely used

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in this century (Tukey, 1964). A dwarfing rootstock tends to reduce seasonal shoot extension of the scion. Such trees are characterized by heavy production at an early age. This is exemplified in the case of apple trees grafted on East Malling IX rootstock, which reach only about one third of the normal size and produce fruit at an early age. Rootstocks may also affect ripening time, fruit color, and fruit size (Rom and Carlson, 1987; Wutscher, 1979).

Rootstocks are of great importance in the modern intensive culture of avocado. The practice of avocado grafting started in Florida at the beginning of this century (Popenoe, 1939). Avocado rootstocks have been selected in California for their relative tolerance to phytophthora root rot (Coffey, 1987) and in Israel for their higher tolerance to salinity (Kadman and Ben Ya'acov, 1976) and calcareous soils (Ben-Ya'acov et al., 1979). Avocado rootstocks have been reported to influence tree size and productivity. Tree size has been found to be affected by rootstock in California (Bergh and Whitsell, 1962). In a large-scale research project on rootstock-scion relationship conducted in Israel, rootstocks have been found to significantly affect avocado tree size and productivity (Ben-Ya'acov 1972; Ben-Ya'acov et al., 1979). Tomer and Rotem (1989) found 'Degania 400' seedling rootstocks to produce larger trees with higher production than 'Nahlat 3'. Rootstocks may have also influenced avocado productivity; trees budded on 'Nabal' seedlings have given appreciably higher yields than those budded on four other rootstocks (Oppenheimer, 1960).

As for mango, Oppenheimer (1958) compared three polyembryonic rootstocks in Israel and found 'Sabre' to be superior in growth and production to 'Warburg' and '14.12'. In a second trial trees grafted on two other rootstocks ('14.6' and '14.7') were equal to 'Sabre' in yields, while trees grafted on '3.2' and '14.12' were less productive (Oppenheimer, 1968). Giri and Yacub (1965) reported that polyembryonic mango rootstocks delivered more vigor to the scions, compared with monoembryonic rootstocks. Swamy et al. (1972) reported that mango vigor and yield are not always controlled by the rootstock, while Sen (1939) and Janhati (1972) suggested that the scion (and not the rootstock) is responsible for the tree shape.

Most fruit-tree breeding projects utilize the selection of the best performing non-juvenile seedlings, concerning agriculturally important traits. These seedlings are then vegetatively propagated, usually by grafting, to allow a more thorough assessment. Since the first-stage selection is carried out on nongrafted seedlings, it is highly important for the breeder to be aware of any potential effect on performance caused by either the rootstock or the rootstock x scion interaction. Obviously, in cases where such an effect is expected, much caution is needed at the seedling selection stage. This study was conducted to determine the potential effect of grafting on the performance of avocado and mango seedlings.

Materials and Methods

Assessment of avocado seedlings and their grafted trees was carried out at the Akko Experiment Station in western Galilee, Israel (Lavi et al., 1990). Seedlings were planted in breeding plots at distances of 4m between double rows of 2 x 1m. The juvenile period was shortened by the use of autumn girdling (Lahavet al., 1986). Seedlings with outstanding fruit characteristics and productivity were grafted in the nursery and also

topworked on Mexican and/or West-Indian seedling rootstocks. Each of the selected seedlings was grafted on two to four rootstock types (one to four seedlings each). Seventy original seedlings and their grafted duplicates were assessed for thirty-six traits (Table 1).

Table 1. Avocado traits analysed in comparison of seedlings and grafted plants.

Trait	Degrees of evaluation
Tree	
Tree habit	Upright (1); Branching (2); Spreading(3); Weeping (4)
Tree size	Very big (1); Big (2); Medium (3); Small (4); Dwarf (5)
Foliage density	Dense (1); Medium (2); Thin (3)
Mature leaf color	Light-green (1); Green (2); Dark-green (3)
Flush color	Green (1); Greenish-brown (2); Brown (3); Brownish-red (4); Red (5); Reddish-green (6) ² ; Yellow (7) ² ; Yellowish-green (8) ² ; Yellow-red (9) ²
Brownish-red lenticels on young shoots	Numerous (1); medium (2); Few (3); None(4); Difficult to determine (5) ²
Leaf	
Size	Very large (1); Large (2); Medium (3); Small; (4); Very small (5)
Margin	Straight (1); Other (2)
Anise odor	Strong (1); Medium (2); Weak (3); None (4)
Flowering	
Intensity	Profuse (1); High (2); Medium (3); Light (4); Very light (5); None (6)
Time	Precocious (1); Early (2) Early-mid season; (3); Late-mid season (4); Late (5); Very late (6)
Fruit and production	
Weight	
Size uniformity	High (1); Medium (2); None (3)
Shape uniformity	High (1); Medium (2); Slight (3)
Density on the tree	Dense (1); Medium (2); Light (3); Very light (4)
Fruit stalk	
Length of peduncle	<5 cm (1); 6–10 cm (2); 11–15 cm (3); 16–20 cm (4); >20 cm (5)
Length of pedicel	<5 mm (1); 6–10 mm (2); 11–15 mm (3); 16–20 mm (4); >20 mm (5)
Attachment of stalk	Central (1); Slightly asymmetrical (2); Strongly asymmetrical (3)
Thickness of stalk (in relation to fruit size)	Thick (1); Medium (2); Thin (3)
Damage by snap-picking	Minimal (1); Slight (2); Medium-severe (3)
Softened fruit	
Skin	
Gloss	High (1); Medium (2); Slight (3); Matte (4)
Surface	Smooth (1); Slightly rough (2); Rough (3); Slightly pimpled (4); Medium pimpled (5); Heavily pimpled (6)
Thickness	Mexican type (1); Like 'Fuerte' (2); Like 'Tova' (3); Like 'Hass' (4); Like 'Nabal'(5); West-Indian type (6)
Ease of peeling	Excellent (1); Good (2); Medium (3) Difficult (4); Impossible (5)
Seed	
Separation of seed from flesh	Easily (1); With some difficulty (2); Impossible (3)
Weight (% of fruit weight)	<6% (1); 6%–10% (2); 11%–15% (3); 16%–20% (4); 21%–25% (5); 26%–30% (6); >30% (7)
Surface	Smooth (1); Pebbled (2); Ridged (3)
Flesh	
Fibers	None (1); A few (colorless) (2); A few (colored) (3); Apparent (colorless) (4); Apparent (colored) (5); Numerous (6); Woody fibers (7)
Bitterness	None (1); Slight (2); Medium (3); Strong (4)
Sweetness	Strong (1); Medium (2); Slight (3); None (4)
Aroma (nut-like flavor)	Strong (1); Medium (2); Weak (3); None (4)
Taste evaluation	Excellent (1); Very good (2); Good (3); Poor (4); Bad (5)
Darkening of cut surface (6 h after cutting)	None (1); Slight (2); Severe (3)
Storage	
Harvest to softening time (room temperature)	<6 days (1); 6–10 days (2); 11–15 days (3); 16–20 days (4); 21–25 days (5); 26–30 days (6); >30 days (7)
Shelf life	In days

²Degrees of evaluation not included in analysis.

Productivity, one of the economically most important traits, was compared in a larger population of 229 graft-seedling pairs. These included the above mentioned 70 seedlings which were grafted on young rootstocks in the nursery and also topworked grafts (one to three trees each). The other 159 seedlings were grafted in only one of the

two methods. Evaluation of productivity (in five grades) was averaged for all the grafted trees of the same seedling. The same trait in the 70 original seedlings and their grafted duplicates was evaluated in 4 degrees of evaluation only (see fruit density on the tree in Table 1).

Comparison between mango seedlings and their grafted trees was conducted at the Bsor Experiment Station in the southwest of Israel (Lavi et al., 1989). Seedlings were planted in a breeding plot at distances of 4 x 2 m. Seven interesting seedlings were selected and each was grafted on seven '13/1' polyembryonic seedling rootstocks (Gazit and Kadman, 1980). A comparison of the performance of the original seedling with its grafted duplicates for 10 traits was carried out 4 years after grafting.

Table 2. Mango traits analysed in comparison of seedlings and grafted plants.

Trait	Degree of evaluation
Flowering intensity	Profuse (1); High (2); Medium (3); Light (4) Very light (5); None (6)
Tree habit	Weeping (1); Domed (2); Upright (3)
Mature leaf color	Light-green (1); Green (2); Dark-green (3)
Harvest to softening interval	In days
Fruit weight	In grams
Fruit color	Green and/or yellow (1); Pink-red matte cheek (2); Red-pink cheek (3); Fully red (4); Shining red (5)
Skin blemishes	Many (1); Medium (2); None (3)
Flesh color	Yellow (1); Light-orange (2); Dark-orange (3)
Fibers	Many (1); Few (2); None (3)
Internal defects	Many (1); Moderate damage (2); None (3)

Seedlings and grafted trees of avocado and mango were located in the same orchard, under similar soil and climatic conditions. Similar agrotechniques were performed for the seedlings and for their grafted duplicates. However, the grafted duplicates were usually prepared only after seedlings were selected, at the age of 6 to 10 years. Thus, as a rule, evaluation of the original seedlings and their grafted duplicates was performed in different years. Only once did we have the opportunity to compare the performance of seedlings and their grafted duplicates at the same period of time. In that case, graftwood was taken from 12 seedlings in the nursery and seedlings and their grafted duplicates were planted, side by side, at the selection plot.

Evaluation of avocado and mango seedlings and grafted duplicates was based either on measurements or on visual scoring (Tables 1 and 2). Two-way analysis of variance was carried out for each trait between seedlings and their grafts by Program GLM of SAS (SAS Institute, 1989).

Results

AVOCADO. Thirty-five traits having gradual trends in evaluation were compared. For 17 traits no significant differences were found between the performance of the original seedlings and their grafted duplicates. These traits were tree size; foliage density; leaf anise odor; flowering time; length of pedicel; fruit stalk thickness; damage by snap picking; fruit skin gloss, surface, and ease of peeling; seed weight; flesh fibers, bitterness, sweetness, and darkening; time from harvest to softening and shelf life. For eight traits, significant main effect differences were detected between the performance of the seedlings and those of their grafts (Table 3). For the remaining ten traits a significant interaction was detected between the performance of the original seedlings

and that of their grafted trees (Table 4). However, in all these cases the difference was relatively small in relation to the 2 to 7 degrees of evaluation (Table 1).

Table 3. Avocado traits in which significant main effect difference between performance of seedlings and their grafted duplicates were detected.

Trait	Seedling average	Graft average	F value	P
Tree habit	1.61	1.92	11.25	0.0012
Flowering intensity	3.53	3.03	14.70	0.0003
Fruit density	2.93	2.65	4.28	0.0417
Fruit weight (g)	279	296	5.50	0.0217
Length of peduncle	1.71	1.93	4.19	0.0435
Skin thickness	2.35	2.14	11.78	0.0010
Aroma	3.22	3.55	20.00	0.0001
Taste evaluation	3.26	3.42	6.15	0.0156

(4.18 grades vs. 5.5, respectively). Contradictory results between the data of this plot and the previous analysis were found only in leaf size. The productivity distribution of the grafted trees is presented in Fig. 1 and the correlation ($R= 0.55^{***}$) between the productivity of the seedlings and that of their grafted duplicates in Fig. 2. It seems that the productivity variation of the grafted trees is less extreme than that of the seedlings. High-yielding selections yielded less as grafted trees while low-yielding selections produced more fruit after being grafted. A change of one grade in the seedling productivity was paralleled by an average change of 0.5 grade in that of its grafted duplicate.

MANGO. Out of the ten traits evaluated, eight traits showed no significant differences between the performance of the original seedlings and that of their grafted duplicates. These were tree habit; harvest to softening interval; fruit weight; fruit color; skin blemishes; and flesh color, fibers, and internal defects. For only two traits, flower intensity and mature leaf color, a significant seedling x graft interaction was detected (Table 3).

Discussion

Avocado and mango breeding projects are based on selection of ungrafted seedlings, which are later grafted for the final assessment. Therefore, it is very important to study the possible effects of rootstocks on the performance of seedling scions. We are not aware of any other comparison carried out between fruit-tree seedlings and their own grafted trees. Our findings and analyses for avocado and mango (Tables 3 and 4) indicate that there was no difference of practical importance

The comparison carried out concurrently on the second population of seedlings and their grafted trees grown side by side confirmed these findings. Also in this case, no significant differences between seedlings and their grafted plants were found in any trait but one. A significant difference ($P < 0.22$; $F = 0.55$) was found in flowering intensity; the grafted trees flowered more intensively than the seedlings

Table 4. Avocado and mango traits in which significant seedling x graft interactions were detected.

Trait	Seedling average	Graft average	F value	P
<i>Avocado</i>				
Mature leaf color	2.44	2.29	2.13	0.0007
Leaf size	2.87	3.12	1.94	0.0026
Flush color	2.84	2.69	1.98	0.0021
Lenticels on young shoots	3.01	3.06	2.00	0.0019
Leaf margin	1.39	1.63	1.66	0.0163
Fruit size uniformity	1.39	1.21	1.72	0.0141
Fruit shape uniformity	1.40	1.14	2.01	0.0024
Fruit stalk attachment	1.68	1.51	1.69	0.0173
Separation of seed from flesh	1.10	1.04	5.49	0.0001
Seed surface	1.57	2.43	3.13	0.0021
<i>Mango</i>				
Flowering intensity	2.00	1.48	2.55	0.0397
Mature leaf color	2.00	2.09	2.96	0.0212

between the original seedlings and their grafted duplicates, even though some minor differences were found.

Some of the traits significantly affected by grafting in avocado may be interrelated. Reduced flowering intensity found in grafted avocado trees may have resulted in lower production (expressed as fruit density) and therefore resulted in larger fruit as compared with the seedlings. Similarly, less aroma (nut-like flavor) resulted in lower general taste evaluation in the grafted avocados as compared with the seedlings. Reduced vegetative growth by grafting probably resulted in smaller trees and leaf sizes as compared with the ungrafted seedlings.

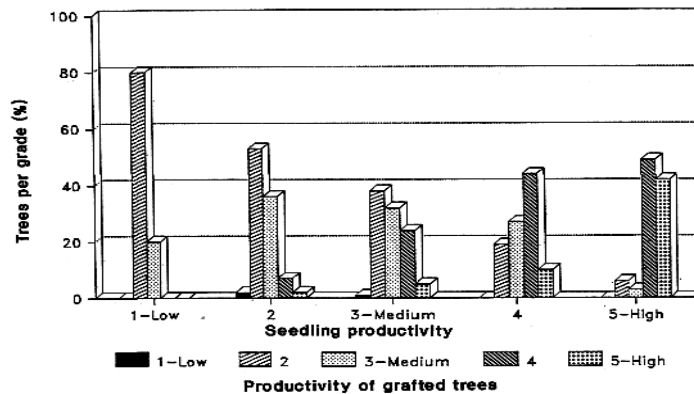


Fig. 1. Productivity distribution of grafted avocado trees relative to their original seedlings.

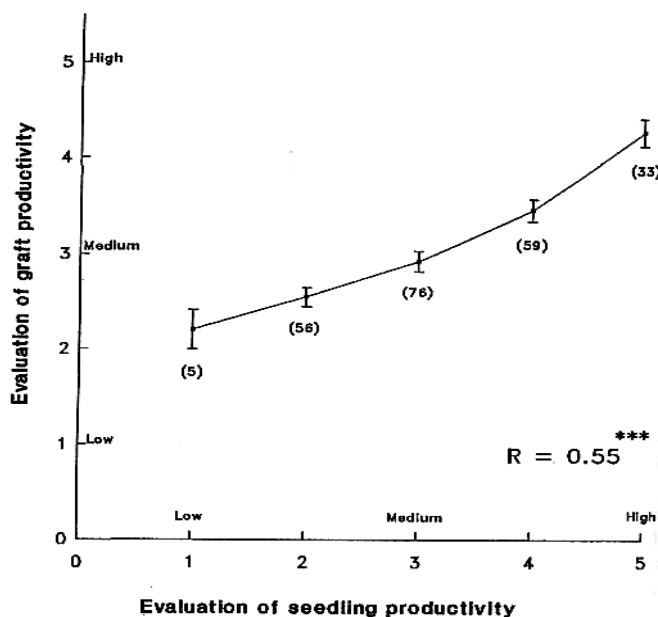


Fig. 2. Avocado seedling productivity (\pm SE) as related to their grafted duplicates. Number in parentheses are numbers of selections per grade.

It is interesting to note that grafting had the same effect on flowering intensity in both avocado and mango. In both species, seedlings flowered less heavily than their grafted duplicates. This might indicate some residual juvenility of the seedlings.

Mature leaf color was affected by grafting in avocado and mango. Leaves were darker in grafted mangos but lighter in grafted avocados as compared with their ungrafted seedlings. We have no explanation for this phenomenon.

The narrower range of production of grafted trees as compared with their parallel seedlings (Fig. 2) may result from the fact that only one original seedling was compared in each case with several grafted trees. Thus, each seedling had its own unique environmental conditions, whereas the conditions for grafted trees were averaged for several individuals. However, the very high and significant relationship between the yields of the seedlings and their grafted duplicates indicates that both are similar regarding the breeding objectives and hence may be used for avocado seedling selection. This conclusion is emphasized by the fact that similar

results were obtained in the comparison of the group of seedlings which were assessed in the same plot and the same year with their grafted duplicates.

A fixed-effects statistical model was used in this study and therefore the conclusions are restricted to the seedling populations analysed. Although we found some statistically significant interactions or main effects, they are of no practical importance, since the differences were relatively small in relation to the two to seven grades of evaluation and were, therefore, of minor importance for the breeder. A significant interaction suggests that the difference in performance between the original seedling and its grafted duplicates is not a general effect of the rootstock but is rather limited to some seedlings and their grafts. We had expected environmental effects to cause some differences between the performances of seedlings and that of their grafts in traits having low heritability (Lavi et al., 1993) and also to find differences due to assessment errors by the experimenters, but such differences were not detected. Rootstocks might have affected scion performance positively or negatively, especially in regard to productivity (Ben-Ya'acov, 1987). In this study no significant rootstock effect on productivity was found. This discrepancy may be the result of the fact that we used only recommended rootstocks.

The conclusion for avocado and mango breeders is that breeding programs for the above mentioned traits could be carried out on ungrafted seedlings. No significant practical differences are to be expected between the performances of the seedlings and that of their grafted duplicates.

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