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AVOCADO ROOTSTOCK-SCION RELATIONSHIPS: A LONG-TERM, LARGE-SCALE FIELD RESEARCH PROJECT V. FINAL REPORT ON SOME ORCHARDS PLANTED DURING THE YEARS 1960-1964

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In avocado, very little is known about rootstock characteristics, their suitability to various soil conditions, and their influence on tree growth and productivity. This lack of knowledge applies also to differences in traits between various sources of graftwood. The problem has been discussed extensively in previous articles in this series (1, 2). In the first of these (1), a field experiment was described which was initiated in 1968 and today (1975) comprises over 220 different trials to test various rootstock/scion combinations under different cultivation conditions.

In the second article of the series (2) we presented data collected from mature, fruit-bearing orchards, not designed as experimental orchards. Data collection in these orchards has now been completed and the present article is intended to summarize the material and to draw the relevant conclusions.

The limitations of the orchards under discussion lie in the lack of control over the various stages of the foundation of the plots, lack of the correct design in the distribution of the plants in the experimental plots — as required by principles of experimental design, as well as lack of design—in accordance with rootstock/scion combinations, which would permit comparison.

Consequently, the analysis of data collected from these orchards requires great care. However, if such care is taken, it is possible to reach important conclusions, both with regard to the continuation of the present study and the design of new avocado commercial plantations.

DESCRIPTION OF THE ORCHARDS

The present article summarizes data collected from six avocado orchards.

1. TAIYIBA ORCHARD—planted in heavy, well-drained, alluvial soil, on the eastern fringe of the Coastal Plain. All the rootstocks are of Mexican origin; the comparisons are between different Mexican stocks, between various scion sources, and between various rootstock/scion combinations.

2. MA'ABAROT ORCHARD—planted in heavy alluvial soil. All the stocks are of Mexican origin, with comparisons between different graftwood sources.

3. USHA ORCHARD—planted in heavy, reddish soil, containing lime, and on a slope. Irrigation with water of moderate salinity. Varieties—Fuerte, Ettinger and Hass—planted alternately on various Mexican and West Indian rootstocks, and the comparisons are among them.

4. LAHAVOT HAVIVA ORCHARD—planted in heavy, well- drained soil. Varieties and rootstocks planted alternately in order similar to that of the Usha Orchard. Comparisons between different Mexican and West Indian rootstocks could be done. It was also possible to compare various sources of scion.

5. GAT ORCHARD—planted in medium-heavy, poorly aerated, lime soil, irrigated with quite saline water. Comparison is among three different rootstock/scion combinations, in two of which the stock is West Indian, and in the third—Lula (West Indian x Guatemalan hybrid).

6. MA'AGAN MIKHA'EL—planted in heavy, lime soil and irrigated with quite saline water. Water salinity increased throughout the experimental period. Comparison among Mexican, Guatemalan and West Indian stocks, the exact identities of which are unknown.

RESULTS

1. Var. Fuerte

In several experimental plots a marked effect was found of propagation material source on tree development and productivity in var. Fuerte.

EFFECT OF SCION source was evident when various sources of scion were grafted on the same stock.

At Ma'abarot, yield data were collected over a period of five years. During the whole period one scion—Zerifin 50—was conspicuous in low productivity, in comparison with four other scion sources. Average yield for the last two recorded years (1971, 1972), evaluated on a 0 to 3 scale (0 equals no yield, 3 equals high yield), was only 0.6 for the scion Fuerte Zerifin 50 (on rootstock 'Northrop'), whereas trees grafted with Zerifin 42, 51, 52 or 53 scions gave yield ratings of 1.8 to 2.0 for these years.

Differences in yield evaluation between Zerifin 50 and the other scions were highly significant. Similar results were obtained over the entire 5-year survey period, as well as for Mexicola rootstock.

Differences in productivity for different scion sources were found also in the Taiyiba orchard (Table 1).

Data from Plot 1 indicate superior productivity of scion source Naeh 1 in comparison with Naeh 5, when both are grafted on the same stock—Glickson. 8. As for the outstanding combination in this plot—Zerifin 47 grafted on Glickson 2—it was not

established whether the advantage sterns from characteristics of the stock or the scion. The data from Plot 1 also show the lack of any permanent correlation between tree size and productivity, where the tree size is measured as trunk circumference. In both combinations—the highest and the lowest in productivity—tree trunk circumference values were found to be considerably lower than in the combination giving medium yields.

The data from plots 2-3 again demonstrated differences in productivity between different scion sources—Naeh 9 andNaeh 21—grafted on the same rootstock (Glickson 8); however, in this case it appears that low productivity is a result of the particular combination characteristics and the scion is not solely responsible, since the same non-productive scion—Naeh 21, when grafted on a different stock (Glickson 5), was highly productive. The number of trees compared in these plots was relatively small, since we wished to base the data analysis on trees planted in the same part of the orchard. However, data obtained from a large number of trees with identical scion/stock combinations, gave results similar to the above (2).

Values of tree trunk circumference for plots 2-3 also indicate differences; they are apparently due to type of stock but are not influenced by scion, or in any way related to productivity.

In the Lahavot Haviva orchard there was another clear instance of low productivity related to scion source; in this case the scion Barkai 1 was compared with Barkai 2, with both scion sources grafted on the same rootstock (Arzi 7). Since then, low productivity with scion Barkai 1 has been observed in additional orchards.

TABLE 1: DATA ON STOCK AND SCION SOURCE, TREE DEVELOPMENT, AND YIELD OF VAR. FUERTE (TAIYIBA ORCHARD, PLANTED IN 1963).

Experimental plot No.	Combination Scion	Stock	Number of trees	Trunk circumference (cm)[1]	Multiannual yield (kg/tree) 4-yr. (67-70)	5-yr. (67-71)
1	Naeh 1	Glickson 8	52	53a[x]		201b
	Naeh 5	Glickson 8	26	49b		110c
	Zerifin 47	Glickson 2	21	48b		253a
F value				**		**
2-3	Naeh 21	Glickson 9	15[2]	70a	38b	
	Naeh 9	Glickson 8	11	74a	155a	
	Naeh 21	Glickson 5	11	62b	134a	
F value				**	**	

[x]—values followed by the same letter do not differ significantly at the 5% level.

F value: **—significant at the 1% level.

[1]—trunk circumference measurements were taken in 1968.

[2]—see text for explanation of small number of trees in comparison.

ROOTSTOCK INFLUENCE on productivity of Fuerte trees was found in several orchards, but was not so decisive as the effect of scion source. In the data presented in Table 1, the superiority of rootstock Glickson 5 over Glickson 8 is conspicuous, when the same scion source is used (Plots 2-3). In Plot 1 as well as in other parts of the Taiyiba orchard, the combination with Glickson 2 as rootstock gave outstanding yields. Unfortunately, there are no cases for comparison of this stock with other stocks, grafted with the same scion source—Zerifin 47. In the Usha orchard trees grafted on Northrop rootstock yielded 90-110 kg/tree (for different combinations), compared with 77 kg yielded by trees grafted on Mexicola stock during the same period. However, also in this case, they did not have a common scion source.

In the Lahavot Haviva, Usha and Ma'agan Mikha'el orchards it was possible to compare Mexican rootstocks with West Indian. In the first two orchards different scion sources were grafted on Mexican and West Indian rootstocks (no such information is available for Ma'agan Mikha'el) and all comparisons are therefore necessarily incomplete. It should be noted that in each of these orchards a particular or several combinations with West Indian stock were especially outstanding (Table 2). However, in Usha, one of the low-yielding combinations was grafted also on West Indian stock and in Lahavot Haviva a combination was found, grafted on West Indian stock, which was classed with the medium yielders. It appears that in general, it is not possible to discern productivity characteristics as a component of the horticultural race but only as a particular characteristic of each single rootstock. This conclusion is in agreement with the findings of Halma (3) for trials in which he compared Mexican rootstocks with Guatemalan.

ROOTSTOCK/SCION COMBINATION. In several cases it is possible to observe the effect of a specific rootstock/scion combination on productivity in Fuerte trees. This is conspicuous in the Taiyiba orchard, plots 2-3, described above. In the Usha orchard, similarly, the low-yielding combination consists of a scion source (Barkai 6) which is highly productive when combined with a different stock in another orhard. It therefore appears that a specific rootstock/scion combination is responsible also in this case for the low productivity.

THE VEGETATIVE DEVELOPMENT of trees with various root-stock/scion combinations was generally investigated in accordance with trunk circumference measurements, with some of the data presented above. The correlation tests, no relationship was found between trunk circumference and productivity and, as mentioned above, trees of combinations with outstanding yields might have a larger or smaller circumference than less productive trees. Indeed, trunk circumference measurements do not provide information on the general dimensions of the tree and they should be treated solely as indicators. It should be noted that in several orchards in which the matter was investigated, trees grafted on West Indian rootstock had a larger trunk circumference than those on Mexican stock.

TABLE 2: YIELD DATA FOR FUERTE AVOCADO TREES, GRAFTED ON VARIOUS ROOTSTOCKS IN THE ORCHARDS OF USHA (1963), LAHAVOT HAVIVA (1963), AND MA'AGAN MIKHA'EL (1961).

Orchard	Scion	Stock	Stock Race	Number of trees in comparison	Number of yield seasons compared*	Multiannual yield (kg/tree)
Usha	Nordia 21	Ashdot (?)	West Indian	81	5	163.4
	Jacobson 6	Northrop Zerifin 20	Mexican	101	5	188.3
	Jacobson 13	Mexicola Zerifin 9	Mexican	48	5	76.8
	Barkai 6	Ma'ayan Zvi 14	West Indian	109	5	56.0
Lahavot Haviva	Levinson 9	Ashdot 9	West Indian	36	5	209.1
	Barkai 6	Degania 1 (Ashdot 16)	West Indian	89	5	197.5
	Levinson 6	Schmidt	Mexican	77	5	138.3
	Barkai 7	Ashdot 8	West Indian	25	5	132.1
Ma'agan Mikha'el	Unknown	Unknown	West Indian	21	7	291.0
	Unknown	Unknown	Mexican	20	7	172.0

* Yield seasons are not identical. In Lahavot Haviva the yields of the first three years were low and the remaining two years gave high yields; in Usha there were two low-yielding and three high-yielding seasons; in Ma'agan Mikha'el, there were three intermediate seasons followed by four satisfactory years.

Measurements were taken of the projection area of the tree on the ground surface, with the aid of aerial photographs. These measurements reflect the expansion of the tree and, in consequence, the rate of thinning to be planned for the orchard. In addition, such an assessment makes it possible to estimate the yield rate per unit area instead of per tree. The former estimate is the one most relevant for the grower.

In projection area measurements in the Lahavot Haviva orchard, significant differences were found between various rootstock/scion com binations. In the extreme cases, the area occupied by trees of combination Barkai 7 x Ashdot 8 (27.54 m^2) was approximately 50% greater than that occupied by trees of combination Levinson 6 x Duke Zerifin 32 (18.25 m^2). The yield per tree was 132 and 123 kg, respectively, but the yield per 1 m^2 was 4.8 and 6.57 kg. In another case, two combinations with an average yield per tree of 123 and 170 kg, respectively, had identical yields per unit area. Generally, it was found that trees — grafted on Mexican rootstock had a smaller projection area than those on West Indian stock, but there were also cases in which the two stock types behaved similarly, from this aspect.

The outstanding combinations at Lahavot Haviva, grafted on several West Indian rootstocks, were also the best with regard to yield per unit area, but their advantage over other combinations was greatly reduced when viewed from this aspect.

2. Other Varieties

The effect of propagation material source on tree development and productivity was investigated on several other varieties. In the local variety Ettinger, cases were found with marked differences between the yield of various scion sources (Table 3) grafted on

the same rootstock, and it appears that also with this variety the scion source is of considerable importance. In the Usha and Lahavot Haviva orchards, high- and low-yielding rootstock/scion combinations were found with both Mexican and West Indian stock combinations. Consequently, it appears that with var. Ettinger, as with Fuerte, the characteristics of each rootstock or rootstock/scion combination must be considered individually, and a specific productivity rate should not be considered a general trait of a horticultural race.

In var. Hass no differences were found between various scion sources, nor were there differences between trees grafted on Mexican stock and those on West Indian stock. In those cases in which there were variations in yield between trees grafted on different Mexican rootstocks, it appears that this can be attributed to the effect of rootstock on tree size. In var. Hass, there may be a positive relationship between tree size and tree yield and, in so far as the rootstock affects tree size, it can also affect its yield.

TABLE 3: YIELD OF ETTINGER AVOCADO TREES GRAFTED ON DIFFERENT ROOTSTOCKS IN THE ORCHARDS OF USHA (1963), LAHAVOT HAVIVA (1963), AND MA'AGAN MIKHA'EL (1961).

Orchard	Combination		Stock race	Number of trees in comparison	Number of years of yield in comparison	Multiannual yield (kg/tree)
	Scion	Rootstock				
Usha	Nordia 10	Nordia 1	Mexican	50	5	73.9
	Nordia 9	Nordia 1	Mexican	19	5	111.5
	Nordia 11	Ashdot 19	West Indian	26	5	107.7
	Nordia 11	Ashdot (?)	West Indian	52	5	122.3
Lahavot Haviva	Ramat Hakovesh 11	Ramat Hakovesh 81	Mexican	27	3	87.9
	Ramat Hakovesh 12	Ramat Hakovesh 81	Mexican	26	3	123.3
	Barkai 9	Ma'ayan Zvi 5	West Indian	63	3	84.0
	Barkai 3	Ashdot 8	West Indian	17	3	126.5
	Barkai 2	Ashdot 8	West Indian	35	3	136.8
Ma'agan Mikha'el	Unknown	Unknown	West Indian	20	5	100.0
	Unknown	Unknown	Mexican	17	5	110.0

3. Variability between avocado tree populations

High variability characterizes each group of avocado trees, originating from the same mother trees, and this is of great importance when assessing the characteristics of the various rootstock/scion combinations. It was found that differences between various avocado tree populations are greater than differences between the individuals comprising each population, but the large differences between individuals, and the variability from this aspect between the various combinations, must be taken into account.

To study the different variability rates, an analysis of tree-yield distribution was made and the standard deviation for each rootstock/ scion combination was calculated for vars. Ettinger and Fuerte in the orchards of Lahavot Haviva and Usha. Parts of the

analysis of distribution, calculated for trees of var. Fuerte in the Lahavot Haviva orchard, are presented in Fig. 1. The data demonstrate various characteristics of the different combinations which are not adequately expressed by the arithmetic mean. The distribution curves of the three outstanding combinations are fairly similar: the tree populations consist of very small groups of poor trees, a small group of mediocre trees, a very large group of satisfactory trees, as well as a substantial group of excellent trees; these evaluations are based on a yield scale as follows (in kg/tree average yield over a period of 5 years): 0-80, 80-160, 160-240, and over 240, respectively. In all cases the rootstock was West Indian. In two other tree groups, also of West Indian stock, but of the Ashdot 7 and Ashdot 8 types, the distribution curve was entirely different, with a large proportion of mediocre trees, and only scant representation of the extreme groups. In tree groups which gave similar yields, distribution curves and standard deviations were of two clear patterns, in accordance with stock race: trees grafted on Mexican Schmidt stock had high variability (standard deviation reached 80) and there was no concentration of trees at any particular yield level. However, trees with West Indian Ashdot 8 stock had a much lower S.D. (56) and most of the trees gave only medium but uniform yields.

These data, and other collected in various orchards, show that tree populations grafted on West Indian stock are more uniform in yield and other characteristics than those grafted on Mexican stock.

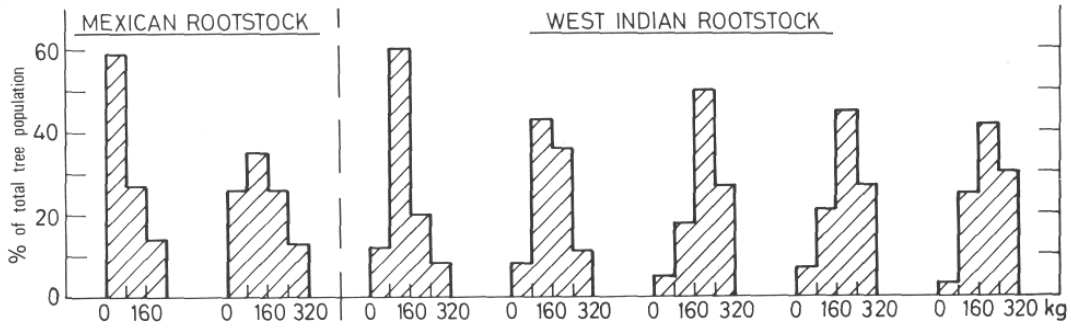
4. Susceptibility of avocado trees to detrimental factors

The survey of plantations frequently included studies of the susceptibility of trees with different rootstocks to various detrimental factors. In the Gat orchard it was found that 'Lula' stock was more susceptible to chlorosis and leaf burn than two other West Indian rootstocks with which it was compared. Of the West Indian rootstocks, Degania 1 stock (originating from tree 'Ashdot 16') was more susceptible than Ashdot 17 stock, particularly at the early stages. These findings were later corroborated in additional orchards. However, it should be noted that in this case no correlation was found between the appearance of the tree and its yield rate, yields being satisfactory and similar in trees with varying degrees of the above mentioned injuries.

The susceptiblity of Nabal rootstock to lime-induced chlorosis, and of Mexican stock to salinity damage, as discovered in Ma'agan Mikha'el, are properties which were known before.

In the Usha orchard lime-induced chlorosis was found in trees grafted on Mexican rootstock, whereas no such cases were found with West Indian stock. However, after a particularly rainy winter, cases of chlorosis and poor foliage growth were found, surprisingly, with West Indian stock, especially with a particular rootstock. Apparently we are not confronted with a general susceptibility of West Indian rootstocks to poor drainage and lack of soil aeration, but only certain rootstocks show susceptibility to this condition. However, our knowledge of the characteristics of this susceptibility is still very limited.

FIGURE 1. TREE DISTRIBUTION BY YIELD (var. Fuerte), LEHAVOT HAVIVA ORCHARD



SCION: / ROOTSTOCK:	LEVINSKI GIVAT-HAIM	LEVINSON 6 SCHMIDT	BARKAI 7 ASHDOT 8	BARKAI 5 ASHDOT 7	LEVINSON 9 ASHDOT 2	BARKAI 6 ASHDOT 16	LEVINSON 9 ASHDOT 9
AVG. TREE YIELD (kg (over 5 yr. period)	78.7	138.3	132.1	160.9	192.6	197.5	209.1
MIN. YIELD/TREE	3.0	2.0	11.0	40.0	2.0	43.0	78.0
MAX. YIELD/TREE	195.0	337.0	257.0	330.0	280.0	401.0	370.0
NUMBER OF TREES	22	77	25	84	22	89	36
S.D.	56.75	78.97	56.12	65.08	65.25	73.28	65.42

5. Selection of outstanding mother-trees

The collection of data on fruit-bearing orchards made it possible to locate (potentially) outstanding mother-trees; in five of the six orchards included in the survey, tree lots of outstanding Fuerte trees were chosen; generally these were the outstanding specimens of the most favored rootstock/scion combination. In three of the orchards several of the outstanding trees have already been designated as scion mother trees for propagation and there is good reason to suppose that the extensive use of this selected propagation material will contribute to increasing yields of avocado orchards.

SUMMARY AND CONCLUSIONS

The summary and analysis of the data collected in six fruit-bearing avocado orchards show the considerable influence of propagation material source on tree productivity and development rate. The effects were those of rootstocks as well as of scion and also specific rootstock/ scion combinations.

Of the many graftwood sources investigated, a number of low-productivity sources were isolated and their further use was consequently eliminated. However, some outstanding graftwood sources were also located and a series of mother trees was established which will make the wider use of these excellent sources possible.

Distinct differences in the productivity of different scion sources were found with the Fuerte and Ettinger varieties but not with var. Hass. In vars. Fuerte and Ettinger considerable differences were also found between rootstock sources in the influence they exert on productivity, but these differences were not related to the properties of the horticultural race—Mexican or West Indian—but rather of the individual characteristics

of each particular rootstock or a specific rootstock/ scion combination. In three orchards which were composed of both Mexican and West Indian stock (but whose scion source was not shared by the rootstocks of the two strains), particularly high yields were obtained in several tree lots having West Indian rootstock. However, in the same orchards tree lots with West Indian rootstock were also found in the mediocre and low-bearing combinations.

The survey findings showed that Fuerte, Hass and Ettinger trees, grafted on West Indian stock, give satisfactory yields although such combinations were not usual in the past. It follows that it is now possible to cultivate trees of these varieties in areas which are unsuitable for

Mexican rootstock in view of the salinity of the irrigation water or the high lime content of the soil. Indeed, the conclusions inferred from this research have been applied in practice for a few years throughout Israel.

In several cases in which the effect of stock source on yield was noted with var. Hass, it was found that this effect was the outcome of stock source effect on tree size; it appears that with var. Hass, in contrast to vars. Fuerte and Ettinger, there is a positive correlation between tree size and tree productivity.

Differences in tree development that were found between various combinations of rootstock and scion were established on the basis of trunk circumference measurements. However, in vars. Ettinger and Fuerte trunk circumference was not related in fruitfulness.

In one of the orchards differences were found in the size of the tree vertical projection, between the various rootstock/scion combinations. The calculation of yield per area unit brought about significant changes in the evaluation of productivity of the various tree combinations.

It was found that the distribution of individual trees, in accordance -with their yield rate, is dissimilar for different stock/scion combinations and that the shape of the distribution curve should be considered an important element characterizing the combination.

The high variability rate in avocado tree populations should not preclude distinguishing between productivity rates of the various stock and scion sources, in which differences are even greater.

Trees grafted on West Indian stock were more uniform than those grafted on Mexican stock.

Differences were also found in susceptibility to various detrimental soil conditions, between different rootstocks. These data, in addition to those collected in the series of planned experiments (1), permit the rejection of various rootstocks for specific soil conditions and facilitate an order of preference between different stocks in each race and between the races.

CONCLUSIONS FOR THE CONTINUATION OF THE RESEARCH: The existence of considerable differences between various propagation sources with regard to productivity, encourages us to continue with the selection of rootstocks and scion

sources, as is indeed being done within the framework of a large-scale research scheme (1).

PRACTICAL MEASURES: Several scion sources were rejected for further use, after they were found to be of low productivity. The use of susceptible rootstocks was limited to suitable conditions only. A list was compiled of outstanding trees which are already relied upon, or will be in the near future, as an important source of propagating material.

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