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Selection of Clonal Avocado Rootstocks in Israel for High Productivity under Different Soil Conditions

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Abstract. **The avocado tree is sensitive to several soil factors, for which rootstocks should be selected. At the same time, avocado yields are relatively low, especially under stress conditions. Since 1982, large-scale selection of clonal rootstocks has been made in Israel, designed to adapt the avocado tree to different soil conditions, while improving productivity. Approximately 160 different clonal rootstocks have been developed, most of which were taken from very productive trees, and subsequently reevaluated in experimental orchards. Updated results of this evaluation are provided.**

The avocado tree was domesticated by the native Indians of Mexico and Central America several thousand years ago. This process took place under the ideal soil and climatic conditions typical of the countries of origin. Even now, soil stress factors such as salinity, alkalinity, lime, and poor aeration; and climatic stress factors, such as extreme temperatures, are rare in much of these countries of origin.

Recently, the avocado was introduced to countries where more extreme and more arid climates prevail. In these countries, the stress factors mentioned above are more pronounced. In many cases, the vegetative development of trees was found to be poor due to soil stress factors, and the productivity low due to climatic factors (Bergh, 1967). The main soil stress factors prevailing in the avocado orchards in Israel and their combinations are as follows: 1. salinity (of irrigation water); 2. alkalinity; 3. lime; 4. lack of aeration; and 5. soil diseases (less significant). Of these salinity is a common problem in association with the other factors and the combination of lack of aeration and soil diseases is also a problem.

The best way to eliminate soil stress problems, and even to permit survival of a given tree type under a particular soil condition, is by the selection and adaptation of rootstocks. According to Hartman and Kester, (1975), "For many plant species, root-stocks are available, which tolerate unfavorable conditions, such as heavy, wet soils.....". Rootstocks for the avocado tree, were selected by Halma (1954), Oppenheimer (1959) and Ben-Ya'acov (1972, 1985, 1986, 1987, 1989). In practical terms, rootstocks in many countries are chosen by nurserymen according to availability of seeds. In Israel, differences were found among different sources of scion and among

seeded rootstock populations with regard to productivity and vegetative development (Ben Ya'acov, 1985, 1987). Significant differences were found not only among the different populations, but also among the trees of a particular population. Gillespie (1954) reported that in a particular orchard where the average annual yield was 80 kg per tree, the average yield for the five best trees was 320 kg.

In the meantime, vegetative propagation of avocado rootstocks became possible (Platt, 1976), permitting propagation and duplication of outstanding trees developed under stress conditions (Ben Ya'acov, 1986, 1989). Again according to Hartman and Kester (1975), "Clonal rootstocks are desirable not only to produce uniformity but, and this is equally important, to preserve special characteristics and specific influences on scion cultivars, such as disease resistance, growth, and flowering habit".

The aim of this project is to select and evaluate clonal avocado rootstocks, adapted for different combinations of soil stress factors, and to produce a better yield under these conditions.

Materials and Methods

Selection of candidate trees. Comparisons began with major seedling-rootstock experiments (Ben Ya'acov, 1972). More than 100,000 trees included in the experiments have been screened. Some trees not included in the experimental system also became candidates. Screening parameters were: accumulated yield, alternation in productivity, tree size, sensitivity to soil factors (leaf burn, chlorosis), and yield calculated per unit area.

Duplicating both root and top. Branch scions were grafted. Afterwards, the rootstock was induced to sprout either by a total removal of the tree down to the graft union, or by other methods. The sprouting root-stock was grafted into mother plantations and in pots. Viroid indexing was conducted during tree development.

Nursery step - the propagation of plants for evaluation. When sufficient propagation material was available, commercial nurseries were asked to prepare enough trees for testing in new plantings.

Evaluation in the orchards. Plants were distributed in orchards under different ecological conditions. The plantings were part of commercial orchards, but planned as experiments by randomized blocks design. The planting system, as well as the follow-up methods, were identical to those described earlier by Ben Ya'acov (1972, 1985, 1987) for the seeded-rootstocks experiments.

Results and Discussion

By screening commercial and experimental orchards in Israel, a few hundred candidate trees were identified. A total of about 160 new promising rootstocks have been obtained.

Table 1 shows typical data on yields in an avocado ('Fuerte') orchard. The range of the yields, accumulated over 4 years, is from 16 to 313 kg per tree. This wide variability enables the selection of 2 or 3 outstanding trees, if their other characteristics are satisfactory. Similar data for the 'Horshim[1] cultivar are in Table 2; the average annual yield for the outstanding tree was 124 kg, compared with the population average of 50 kg. Table 3 shows the relative yield advantage of the outstanding tree for our three most important varieties. In 'Hass' and 'Fuerte[1] the best trees doubled the yield, but in "Ettinger" the additional yield was only 40%.

Table 4 summarizes the 168 different rootstocks that were selected. Approximately 100 of these were from under outstanding grafted trees of commercial varieties, and the other 60 from trees resistant either to lime and salinity or to root-rot.

Evaluation of the rootstocks and rootstock/scion combination. Throughout the period 1979-1987, approximately 350 field experiments were established to evaluate the new selected rootstocks, the different sources of scion, and the specific stionic combinations (Table 5).

In each experiment, surveys of leaf burn (salinity damage) and chlorosis (iron deficiency) were made whenever such symptoms were manifested (Kadman and Ben Ya'acov, 1982). In Table 6, the leaf burn surveys show that seedling and clonal rootstocks could be either resistant or sensitive, and that symptoms varied strikingly between years.

Salinity affects productivity as well. Table 7 presents data on the productivity of 'Ettinger' trees grafted on Mexican versus West Indian rootstocks. Where the irrigation water had a chloride content of 100 ppm, there was little difference in productivity between the two rootstock races. But under saline conditions, the Mexican rootstock produced about half the average production of West Indian.

Orchard experiments continue until the age of 10 or 11, including six or seven crops. Thus, many experiments planted during the first period (1979-1982) are now in their final years and will be summarized shortly. Meanwhile, the best known rootstocks for each cultivar under given ecological conditions, have already been recommended for new plantings.

Conclusions

1. Developed avocado industries are shifting to clonal root-stocks. Over one million such trees have been planted already.
2. In Israel, approximately 160 different clonal rootstocks are being carefully monitored and evaluated for different soil conditions. Ten of them have already been released commercially.
3. The clonal orchards show good vegetative development and precocity. Mostly, they bear more fruit than regular (seeded rootstocks) orchards.

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Table 1. Total yield (kg) of individual 'Fuerte' trees - 4 years in "Gat" orchard.

Tree	Row				
	1	2	3	4	5
1	281	247	137	247	100
2	229	33	80	153	27
3	193	188	193	59	38
4	79	120	130	162	123
5	293	173	134	16	43
6	120	168	142	53	33
7	186	89	207	178	47
8	313	89	117	115	66
9	280	16	22	245	200
10	89	160	114	154	105
11	215	163	78	67	69
12	104	40	102	142	75

Table 2. Average annual yield for two scion/rootstocks combinations of the 'Horshim[1] cultivar planted at Shefaim in 1969.

Rootstock Combination	No. of Trees	Year						Yield (kg)	
		74	75	76	77	78	79	Total	Average
1	24	27.3	66.8	37.2	71.0	62.2	5.6	320	53
2	37	11.7	53.9	30.3	74.2	65.5	63.9	300	50
2	1	80.0	117.0	80.8	160.0	135.0	171.0	744	124

Table 3. The superiority of outstanding trees in three avocado cultivars. Total production (kg) to the age of 10 years.

	Cultivar		
	Fuerte	Ettinger	Hass
Average of trees of the same rootstock/scion combination	300	400	400
The best trees of the same rootstock/scion combination	600	560	790
% of additional yield	100%	40%	98%

Table 4. Clonal Avocado Rootstocks in Israel.

	Race		
Original Grafted Scion Cultivar	West Indian	Mexican	Total
Fuerte	24	33	57
Ettinger	11	20	31
Hass	5	5	10
Horshim	4	1	5
Wurtz	1	1	
Nabal	2	1	3
Resistant to lime and salinity	17	14	31
Resistant to *Phytophthora cinnamomi*	28	2	30
		TOTAL	168

Table 5. Experiments with clonal rootstocks planted 1979 to 1987.

Scion Cultivar	Rootstock Race	Number of Trees	Number of Experiments
Fuerte	Mexican	10,553	57
	West Indian	20,260	107
Hass	Mexican	5,237	31
	West Indian	10,554	54
Ettinger	Mexican	7,744	52
	West Indian	7,927	52
TOTAL	Mexican	23,534	140
	West Indian	38,741	213
	TOTAL	62,275	353

Table 6. Nordia experiment, planted 1983. Rate of leaf burn, 'Horshim' variety.

Rootstock		Number of trees	Burn rating (0 (none) to 3 Survey Date	
Name	Type		Jan. 1986	Feb. 1987
Shmidt	Seedling	21	1.71	0.76
Nachalat	Seedling	21	0.76	0.14
Nabal	Seedling	22	0.18	0.18
VC 78	Clonal	22	1.54	0.64
VC 78	Clonal	21	1.47	0.67
VC 78	Clonal	22	1.86	0.91
VC 51	Clonal	22	0.81	0.09

Table 7. Comparison of two rootstock races in two orchards (‘Ettinger’ type).

		Orchard	
	Rootstock	Ein-Ha'choresh	Hama'apil
Salinity of irrigation water (ppm Cl)	--------	100	300
Accumulated yield to 9 years (kg/tree)	VC 51 (West Indian)	251	196
	VV 57 (Mexican)	225	106