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AVOCADO BREEDING IN ISRAEL

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Summary

The breeding project is aimed at producing new cultivars that significantly over perform present commercial cultivars harvested in the same season. The ideal cultivar is a high-producer under Israeli growing conditions, with high-quality fruit of medium size, a small seed, and high export quality.

The project is based on open pollinations as well as on controlled crosses performed in caged trees with bees as the pollination vector. Some of the hybrids are differentiated from selfs by the use of isozyme, genetic markers. So far about 200 crosses have been made with about 30,000 seedlings.

Analysis of 36 traits of the progeny seedlings resulted in the following conclusions.

1. Girdling is the best method to shorten the juvenile period in the avocado.
2. There are significant statistical differences in flowering age and fruiting age between various progeny populations
3. The time until first flowering is the limiting factor in evaluation of the seedlings.
4. In all the 36 traits tested, no significant differences were detected between grafted and ungrafted seedlings.
5. Parental selection should not be based solely on cultivar performance since a significant non additive genetic variance exist in the avocado.
6. Skin color, flowering group and anise scent are coded by several loci having several alleles in each locus. The various phenotypes probably result from various heterozygous combinations in several loci.

Three selections have been made and released for commercial planting. These are 'Iriet', Adi' and 'Gil'.

The Israeli avocado breeding project started in the early seventies. The breeding plots are located at the Akko Experiment Station in the Western Galilee and at the Agric. Res. Org. in Bet Dagan. Seeds were collected from crosses and selfings by caging trees under a net, using bees as the pollen vector. The harvested seeds were sown in a nursery and one year later transplanted into breeding plots at distances of 4m between double rows of 2 x 1m. The

seedlings were evaluated according to either measurements or visual scoring about 40 traits were evaluated (Lahav et al. 1995).

To distinguish between hybrids and self-pollinated seedlings, the progeny were characterized by isozyme analysis of leaf tissue for the following enzyme systems: leucine aminopeptidase (LAP; EC 3.4.11.1) (Degani et al., 1986), malate dehydrogenase (NIDH; EC 1.1.1.37) (Degani and Gazit, 1984), phos- phoglucoisomerase (PGI; EC 5.3.1.9) (Goldring et al., 1985), phospho-glucomutase (PGM; EC 2.7.5.1.) (Torres et al., 1978) and triosephosphate isomerase (TPI; EC 5.3.1.1) (Goldring et al., 1987).

The most important obstacle in the project is the long juvenile period. We have studied the juvenile period of several progenies and recorded their flowering age and fruiting age.

The mean flowering age ranged between 4.3 years for progeny of 'Rosh- Hanikra 11' x 'Ettinger' and 8.6 years for the self-pollinated progeny of 'Nabal' (Table 1). Flowering age ranged from 3 to 11 years (one record of first flowering after 14 years); fruiting age ranged from 4 to 11 years (one seedling yielded 14 years after planting). The SD in flowering age ranged from 0.6 for the self-pollinated progeny of 'Anaheim' to 2.1 for the progeny of 'Tova' x 'Ettinger'. In fruiting age, the smallest SD was 0.7 for the progeny of 'Anaheim' and 2.0 for the progeny of 'Ettinger' x 'Tova' and 'Tova' x Fuerte'.

Table 1 - Length in years of the juvenile period in 11 avocado progeny populations.

Cross[z]	Progeny (no.)	Flowering age			
		Mean	SD	Range	Flowered (%)
Rosh Hanikra II x Ettinger	51	4.3[y]	0.7	3-7	90.2
Tova x Fuerte	48	5.0	1.5	3-14	91.8
Hass x Fuerte	123	5.8	1.7	3-10	86.1
Ettinger (selfed)	235	5.9	1.1	4-8	70.7
Ettinger x Tova	62	6.2	1.7	3-10	91.9
Tova x Regina	54	6.2	0.9	5-7	88.9
Hass x Ettinger	46	6.4	1.3	4-8	93.6
Anaheim (selfed)	61	6.5	0.6	5-7	68.9
Tova x Ettinger	387	7.0	2.1	3-11	77.4
Horshim x Tova	240	7.5	1.9	4-10	53.3
Nabal (selfed)	85	8.6	1.5	6-10	40.1

Cross	Fruiting age			
	Mean	SD	Range	Flowered (%)
Rosh Hanikra II x Ettinger	5.4[x]	1.0	3-7	62.7
Tova x Fuerte	5.6	2.0	4-14	37.7
Hass x Fuerte	6.3	1.9	4-11	70.8
Ettinger (selfed)	6.9	0.8	5-8	42.1
Ettinger x Tova	7.0	2.0	4-10	83.9
Tova x Regina	6.5	0.8	5-7	79.6
Hass x Ettinger	6.9	1.2	5-8	89.2
Anaheim (selfed)	6.5	0.7	5-7	32.8
Tova x Ettinger	7.0	1.9	3-10	37.7
Horshim x Tova	7.5	1.3	5-9	19.2
Nabal (selfed)	9.4	1.0	7-10	29.4

[z] Order is from low to high mean of flowering age, calculating only for seedling that flowered and yielded during the experiment.

[y] Data refer to the seedlings that flowered during the experiment.

[x] Data refer to ths seedlings that fruited during the experiment.

To assess the impact of the length of the juvenile period (flowering age) on the time needed for the first fruit production (fruit age), the difference between fruiting age and flowering age was calculated for each seedling (Table 2). Referring only to those seedlings that both flowered and fruited, 55% to 95% of the seedlings, first fruiting occurred in the same year as flowering (zero difference). Fewer than 5% of the seedlings showed a difference of 4 to 6 years. About 5% to 35% of the seedlings fruiting either 1 or 2 years after first flowering.

Table 2- Distribution of the differences in years between flowering age and fruiting age in 11 avocado progeny populations

	Number of years between flowering age and yield age						
Cross	0	1	2	3	4	5	Significance of the average
Rosh Hanikra II x Ettinger	54.9[y]	17.6	17.6	9.8	0.0	0.0	a[x]
Tova x Fuerte	77.1	8.3	4.2	6.2	0.0	0.0	ab
Hass x Fuerte	76.4	6.5	11.4	0.8	2.4	1.6	ab
Ettinger (selfed)	74.5	6.8	13.6	4.2	0.9	9.9	abc
Ettinger x Tova	58.1	17.7	12.9	6.5	3.2	1.6	a
Tova x Regina	83.3	13.0	3.7	0.0	0.0	0.0	bcd
Hass x Ettinger	73.9	13.0	10.9	2.2	0.0	0.0	abcd
Anaheim (selfed)	95.1	4.9	0.0	0.0	0.0	0.0	d
Tova x Ettinger	91.2	1.6	5.7	0.5	0.5	0.5	bcd
Horshim x Tova	92.9	3.3	1.3	1.3	0.8	0.4	bcd
Nabal (selfed)	91.8	4.7	3.5	0.0	0.0	0.0	cd

[y] Percentage of the progeny

[x] Progeny having a common letter do not differ significantly.

The juvenile period was shortened by the use of autumn girdling (Lahav et al., 1986). Girdling improved each of the measured parameters, and the earlier the girdling, the greater the effect (Table 3). The earliest (September) girdling increased the proportion of seedlings flowering from 47% to about 100%; nearly tripled the flowering intensity (from rating 1.0 to 2.7); highly increased the proportion of seedlings setting fruit (10.8% vs. 65.4%); and, perhaps most significantly of all, resulted in a 7-fold increase in number of fruits per tree (1.3 vs. 9.3). In breeding evaluation, one fruit is of little or no value, but 9 fruit permit a significant appraisal.

Table 3 - Effect of girdling date on flowering and fruit set of avocado seedlings[z]

Date of girdling	No. seedlings	Seedlings flowered (% of total)	Flowering intensity[y]	Seedlings that set fruit (% of total)	Average no fruit per seedling
12 Sept. 1983	73	99.2 a[x]	2.7 a	65.4 a	9.3 a
18 Oct. 1983	64	93.7 a	2.3 b	54.8 ab	6.3 ab
22 Nov. 1983	43	90.9 ab	2.0 b	42.6 ab	4.7 ab
5 Jan. 1984	27	61.4 b	1.0 c	14.9 c	1.3 c
Ungirdled control	74	47.3 b	1.0 c	14.9 c	1.3 c

[z] All values are least-square means.

[x] Within column, means separated by Tukey-Kramer test, P=0.05

[y] Flowering intensity ranked from 1 = very little to 5 = profuse.

The findings in this experiment agreed with our previous observations of differences in the length of the juvenile period among various crosses (Table 4). Selfed 'Rincon' seedlings rated highest in all 4 parameters measured. 'Tova' x 'Regina' rated lowest in the flowering comparisons, while 'Ettinger' x 'Fuerte' seedlings rated lowest in number of fruit. No significant interaction was found between seedling origin and girdling date for any of the parameters studied.

Table 4- Effect of parentage of the flowering and fruit set of avocado seedlings[z].

Cross	No seedlings	Seedlings flowered (% of total)	Flowering intensity[y]	Seedlings that set fruit (% of total)	Average no.fruits per seedling
Rincon (selfed)	17	99.9 a[x]	2.9 a	80.1 a	9.0 a
Ettinger x Hass	20	86.9 ab	2.1 b	60.2 ab	8.4 a
Hass x Ettinger	37	79.5 ab	1.8 bc	56.2 ab	7.8 a
Ettinger x Wurtz	27	66.8 bc	1.3 cd	26.6 bc	5.6 ab
Tova x Irving	62	74.2 b	1.5 bc	48.2 abc	5.2 ab
Ettinger x Rosh Hanikra	7	99.9 a	2.3 ab	39.5 abc	2.1 ab
Tova x Regina	76	42.2 c	1.0 d	21.0 c	1.9 b
Ettinger x Pinkerton	25	78.9 ab	1.5 bc	34.6 bc	1.6 b
Ettinger x Fuerte	10	80.3 ab	1.8 bc	5.0 c	0.5 b

[z] See note to table 3.

Most fruit-tree breeding projects utilize the selection of the best performing nonjuvenile 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 stage. Therefore we have studied the potential effect of grafting on the performance of avocado seedlings.

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 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 5). For the remaining ten traits a significant interaction was detected between the performance of the original seedlings and that of their grafted trees (Table 6).

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 performance 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. In this study no significant rootstock effect on productivity was found. In all the cases the differences between the seedlings and their grafted duplicates was relatively small in relation to the 2 to 7 degrees of evaluation.

Table 5 - Avocado traits in which significant main effect differenc 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
Lengh 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

Table 6 - Avocado traits in which significant seedlding x graft interactions were detected.

Trait	Seedling average	Graft average	F value	P
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

Three cultivars have been selected in the project. 'Iriet' (Lahav et al., 1989) a relatively small tree, pear shaped fruit with black slightly pebbly peel with gloss. Fruit weight 300-500 g. Harvest season February to May; 'Adi' (Lahav et al., 1992) strongly resembles Hass but light green in color. Average weight 230 g, seed size less than 10%. Long harvest season from November to April. 'Gil' (Lahav et al., 1995) pear shaped with a short neck, the skin is black slightly pimpled with medium gloss. Average weight 300 g. Harvest season January to March.

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