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Self- and Cross Pollination in Mango

C. Degani, R.J. Knight, R.J. Schnell, S. Gazit

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Self - and Cross-Pollination in Mango

Investigators:
(Principal first)

C. Degani

R.J. Knight

R.J. Schnell

S. Gazit

Affiliated Institute

ARO, The Volcani Center

U.S.D.A.

U.S.D.A.

The Hebrew University

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Chemda Degani

Signature:
Principal Investigator

Dis. Loran.

Signature:
Authorizing Official, Affiliated Institution

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A. ABSTRACT

Bagging inflorescences or caging trees (without bees) of the mango cultivars Irwin, Maya and 15-60 greatly decreased rate of pollination but did not prevent it completely. Thrips are not effective pollinators for mango. 'Irwin', 'Maya' and '15-60' responded differently to self-pollination under controlled pollination conditions. In 'Maya', 99.4% of the fruits produced on trees caged with bees were selfs and there was no significant difference in yield between caged and open-pollinated 'Maya' trees. In 'Irwin', the yield in trees caged with bees was significantly lower than in open-pollinated trees and 98.6% of the regular fruits produced in the cages were selfs. In '15-60' the difference between yield in caged and open-pollinated trees was very large and the few fruits produced in the cages were hybrids.. These results suggest that 'Maya' can set and carry a full crop by self-pollination, while 'Irwin' is partially self-incompatible and '15-60' is self-compatible. The reciprocal effect of 'Maya' and 'Tommy Atkins' on the rate of hybrid percentage was studied in three commercial orchards consisting of two adjacent solid blocks of these cultivars. Rate of hybrids was determined using isozyme markers. Substantial hybrid percentage was found at large distances from the pollenizing cultivar. Studies on outcrossing rates during 'Tommy Atkins' fruit development showed a significant increase of hybrid percentage from the stage of fruitlets to the stage of mature fruit. This indicates selective abscission of selfed 'Tommy Atkins' fruitlets. RAPD markers were developed and used for detecting self- and cross-pollination, genetic relatedness and phylogenetic relationships in mango.

B. OBJECTIVES OF THE ORIGINAL RESEARCH PROPOSAL

- A. To examine the ability of Israeli and Floridian commercial mango cultivars to set and carry a full crop without any cross-pollination under controlled pollination conditions.
- B. To study the effect of different pollen donors on fruit set and yield under orchard conditions, based on the identification of the pollen parent of fruits.
- C. To identify potent pollen parents capable of increasing yields of other cultivars.
- D. To determine the effect of different pollen parents on important fruit traits such as fruit and seed weight.
- E. Methodological objectives (essential for addressing objectives A to D)
 - 1) To find a reliable technique for preventing undersirable pollen transfer between mango trees in the orchard. This simple and basic objective is essential for performing controlled pollinations under orchard conditions and for excluding foreign pollen from caged trees used for producing hybrids in our breeding program.
 - 2) To develop reliable methods for identification of the pollen parent of mango fruitlets and fruits, using isozyme and restriction fragment length polymorphism (RFLP) analyses.

Deviation in methods:

The use of the polymerase chain reaction and RAPD markers had just been reported when the grant was awarded. The decision to switch from RFLP markers to RAPD markers was done because of the ability to generate many more RAPD markers with greater ease and less expense.

C. RELEVANT DATA, METHODOLOGY, RESULTS AND DISCUSSION

C.1. Controlled Pollination Studies (Israel).

Controlled pollination studies were carried out in order to examine the need for insect pollination in mango and the response of commercial cultivars to self- and cross-pollination. In these experiments the rates of pollination and yield were studied. In addition, the male parent of the fruits produced in the cages was identified.

Materials and Methods

Trees of '15-60' (Besor Experimental Station, 1992) 'Irwin' and 'Maya' (Volcani Center, Bet Dagan, 1993) were caged as follows: (a) four trees without pollinating insects (six for 'Maya') (b) four trees with beehives (c) four trees with flowering pollenizer and bees (three for '15-60'). 'Kent' seedlings served as a pollenizer for 'Maya', and 'Lili' seedlings as a pollenizer for 'Irwin'. Trees of the cultivars 19-21, 19-55 and 12-37 served as pollenizers for '15/60'. In addition, four open-pollinated trees were used as control for each cultivar..

During the flowering season 50 flowers, about 2 to 4 days old, were sampled every week from each tree. Rate of effective pollination was determined using the method of Martin (1959) as modified by Rahat (1970).

At harvest time the number of mature fruits produced on the caged and control trees was measured. For each treatment in the caged trees up to fifty fruits were sampled and their seeds were husked and individually planted in 750 ml plastic pots containing peat moss mixed with polystyrene flaks (1:1 v/v) and a slow-release fertilizer. Seedlings were grown in a greenhouse (18°/28°C, night/day). Leaf extracts of the seedlings were analyzed for isocitrate dehydrogenase (IDH), phosphoglucumutase (PGM), phosphoglucose isomerase (PGI) and triosephosphate isomerase (TPI), according to Degani et al., 1990.

Results and Discussion

a) Rate of pollination

Results of rate of pollination in caged and open-pollinated (control) trees of the mango cultivars '15-60', 'Irwin' and 'Maya' are shown in Fig. 1.

In '15-60', the rate of pollination in the control trees was 15% at the peak of the pollination season. Furthermore, in '15-60' trees caged with bees, the rate of pollination was almost nil. It seems that this cultivar has a specific pollination problem.

In order to compare between the rates of pollination of 'Irwin' and 'Maya' the mean rate of pollination for each treatment during the season were determined. The results are shown in Table 1.

Table 1. Mean percentage of pollinated flowers in caged and control trees of 'Irwin' and 'Maya' during the flowering season (Bet Dagan, 1993).

Treatment	Percentate of pollinated flowers ^z	
	Irwin	Maya
Control	53 a	67 A
Caged + bees + pollenizer	13 b	45 AB
Caged with bees	24 b	38 BC
Caged without bees	12 b	19 C

^z Result within a column followed by different letters differ significantly by Tukey's test.

In both cultivars the rates of pollination in the control trees were higher than in the caged trees. In 'Maya', rates of pollination in the various treatments and the control were higher than those in 'Irwin'.

Fig. 1. Rate of pollination in caged and open pollinated mango trees

b) Yield

The mean number of fruits produced on the caged and open-pollinated trees of '15-60', 'Irwin' and 'Maya' is represented in Fig. 2. In '15-60' the difference between the number of fruits per open-pollinated tree and the number of fruits per caged tree was very large. In the 'Irwin' trees caged with bees, the amount of regular fruits (weight >300 gr, regular seed) was significantly lower than that in the control trees, but significantly higher than that in trees caged without insects. In 'Maya' the difference in yield between trees caged with bees and the open-pollinated trees was not significant. These results suggest that 'Maya' is self-fruitful, while 'Irwin' is partially self-incompatible and '15-60' is self-incompatible.

c) Outcrossing rates in the caged trees

The male parent of the fruits produced on the caged trees was determined by isozyme analysis. The enzyme systems used were as follows: for 'Maya': IDH and TPI; for 'Irwin': IDH and PGM, and for '15-60': PGM, PGI and TPI. The results are presented in Table 2.

Table 2. Rates of outcrossed fruits in the caged trees.

Cultivar	Treatment	Mean No. of seedlings/tree	Hybrids ^z (%)
15-60	With bees	3.3	100.0 a
	With bees and pollenizer	3.7	91.0 a
	Without bees	8.8	93.0 a
Irwin	With bees	35	1.4 a
	With bees and pollenizer	37	3.4 a
	Without bees	6	8.3 a
Maya	With bees	44	0.6 a
	With bees and pollenizer	43	0.0 a
	With flies	34	1.5 a
	Without bees	17	5.9 a

^z Results for a given cultivar having a common letter do not differ significantly.

Fig. 2. Number of fruits produced on the caged trees.

Means designated by different letters differ significantly by Tukey's test, $P=0.05$

In trees of 'Irwin' and 'Maya' caged with bees, most of the fruits produced were selfs. However, a definite percentage of hybrid fruits were produced in trees caged with bees and without bees. In trees of '15-60' caged with bees and without bees a very small number of fruits was produced but most of them were hybrids (91%-100%). These results point to the penetration of foreign pollen into the cages.

It is noteworthy that when 'Maya' trees were caged with 'Lili' flowering seedlings, the expected hybrid fruits were not produced at all (Table 2). In 'Irwin', caging trees with 'Kent' flowering seedlings produced a very low percentage of hybrids (3.4%). The low efficiency of flowering seedlings as pollenizers might be due to i) negligible number of inflorescences on the seedlings compared to that on the tree ii) termination of seedlings flowering before rate of pollination in the tree reached its peak iii) seedlings are much shorter than adult trees and should have been raised from the ground, to be close to tree inflorescences.

C.2. Thrips as Potential Pollinators of Mango (Israel).

In the controlled pollination studies carried out in the Besor Experimental Station (1992), '15-60' trees were caged within screenhouses (15 mesh) without bees. Although this caging is supposed to exclude the entrance of bees and flies into the screenhouse, fruit-set did occur to a small extent and most of the fruits produced were identified as hybrids by isozyme analysis (Table 2). This raised the question whether thrips which are capable of penetrating through the small holes of the net are the insects that transferred the foreign pollen into the screenhouses and thus mediated pollination in '15-60' flowers. In order to explore this possibility the presence of different thrip species was monitored in caged and open pollinated mango trees. In addition, thrips visiting the mango flowers were trapped and the number of mango pollen grains attached to their bodies was measured.

Materials and Methods

Trees of 'Irwin' and 'Maya' (four trees for each cultivar) and '15-60' (two trees) were caged within screenhouses (15 mesh). The species and number of thrips visiting inflorescences of caged and open-pollinated 'Irwin', 'Maya', and '15-60' trees was monitored. Twice a week, during the flowering and fruit-set season (26 April to 8 June) eight inflorescences were shaken and the collected thrips were counted.

The pistil of mango flowers was smeared with glue and using a stereomicroscope the collected flowers were examined for the presence of thrips or thrips-damaged flowers.

The collected thrips were dried and the presence of pollen grains attached to their bodies was determined using scanning electron microscope.

Results and Discussion

The change in number of thrips visiting mango inflorescences during the flowering and fruit-set season is shown in fig. 3. In all three cultivars, the total number of thrips increased towards the peak of flowering and then decreased. After the thrips were counted, the different thrip species were identified. Results are shown in figures 4 to 6.

Among the 230 female thrips and 50 male thrips examined, 4% of the female thrips were found with pollen grains adhered to their bodies. Similarly it was found by Spencer and Kennard (1955) that 2.8% of the adult thrips carried attached mango pollen grains. Furthermore, in most of the flowers examined not a single thrip could be found in the pistil. It seems that thrips are not effective pollinators for mango. Thrips might play a role as pollinators of mango in cases where efficient pollinators are absent, as was found in other plants (Baker and Cruden, 1991). In Besor experimental station, a large population of thrips was found. This suggests that cross-pollination in the

Fig. 3. Number of thrips in inflorescences of caged and open-pollinated mango trees.

Fig. 4. Number of different thrip species collected from inflorescences of caged and open-pollinated 'Irwin' trees.

* Termination of flowering

Fig. 5. Number of different thrip species collected from inflorescences in caged and open-pollinated 'Maya' trees.

* Termination of flowering

Fig. 6. Number of different thrip species collected from inflorescences of caged and open-pollinated '15-60' trees.

'15-60' trees caged without bees, was due at least partly, to transfer of foreign pollen by the thrips through the net.

C.3. Pollen Parent Effect on Outcrossing Rate in Mango Commercial Orchards (Israel).

In order to study the effect of pollen parents on fruit set and yield under orchard conditions, we located commercial orchards consisting of adjacent solid blocks of 'Maya' and 'Tommy Atkins'. This combination offers a unique opportunity to identify each individual fruit as selfed or outcrossed by TPI isozyme analysis. In this system 'Maya' and 'Tommy Atkins' are homozygous aa and bb, respectively (Degani et al., 1990). Therefore, the reciprocal hybrids of these cultivars are identified by their heterozygous genotype, ab, while 'Maya' and 'Tommy Atkins' self progenies are identified by the aa and bb genotypes respectively.

a) Outcrossing rates in Ramat Magshimim orchard

In Ramat Magshimim, located in the Golan Heights, the cultivars 'Maya' and 'Tommy Atkins' are planted in adjacent blocks. Each block consisted of 18 rows. In addition, few seedlings of the polyembryonic cultivars '1-7', '40-9' and '13-1' were present in the blocks. At harvest, fruits were sampled at four distances from the pollenizer blocks, 50 fruits per row.

Leaf extracts of the seedlings emerged from the seeds were analysed for TPI and IDH according to Degani et al. (1990).

Table 3 presents the isozyme genotypes in these systems for the cultivars present in the plot.

Table 3 Isozyme genotypes of the cultivars planted in Ramat Magshimim orchard.

Cultivar	<i>Tpi</i>	<i>Idh</i>
'Maya'	aa	cc
'Tommy Atkins'	bb	cc
'1-7'	ab	ac
'4-9'	ab	ac
'13-1'	ab	ac

In TPI, 'Maya' and 'Tommy Atkins' are homozygous aa and bb, respectively. Also, both cultivars are homozygous, cc, for IDH. On the other hand the polyembryonic cultivars are heterozygous for TPI and IDH. Seedlings heterozygous for IDH are offspring of the polyembryonic cultivars. Since hybrids in IDH are expected to segregate in a homozygote to heterozygote ratio of 1:1, the actual number of hybrids in IDH should therefore be double the observed number of heterozygous seedlings. The results obtained in 1992 and 1993 are represented in Tables 4 to 6.

Table 4. Outcrossing rates in the 'Maya' block (Ramat Magshimim, 1992)

Distance from 'Tommy Atkins'	Seedlings Germinated	Hybrids (%)	
		Non-'Tommy Atkins' progeny	'Tommy Atkins' progeny ^z
(m)	(no.)		
6	45	9	63 a
30	34	18	54 ab
60	25	0	24 b
108	40	5	34 b

^z Results designated by different letters differ significantly by chi-square test, followed by Bonferroni multiple comparison test.

Table 5. Outcrossing rates in the 'Maya' block (Ramat Magshimim, 1993)

Distance from 'Tommy Atkins' (m)	Seedlings germinated (no.)	Hybrids (%)	
		Non- 'Tommy Atkins' progeny	'Tommy Atkins' progeny
6	44	5	57 a
12	44	9	38 a
24	50	0	52 a
48	47	4	40 a
96	47	13	39 a

Results within a column having a common letter do not differ significantly by chi-square test.

Table 6. Outcrossing rates in 'Tommy Atkins' block (Ramat Magshimim, 1993).

Distance from 'Maya' (m)	Seedlings germinated (no.)	Hybrids (%)	
		Non-'Maya' progeny	'Maya' progeny ^z
6	43	9	79 a
12	44	9	78 a
24	45	22	69 ab
48	41	10	51 bc
96	39	5	24 c

^z Results designated by different letters differ significantly by chi-square test, followed by Bonferroni multiple comparison test.

Consistent decline in hybrid percentage with increasing distance from the pollenizer block was not always observed. Thus, in 1992 in the 'Maya' block a decrease in hybrid percentage with increasing distance from 'Tommy

Atkins' block was found (Table 4), while in 1993 such correlation was not found (Table 5). On the other hand, in 1993 in the 'Tommy Atkins' block, we found a gradual decline in hybrid percentage with increasing distance from the 'Maya' block (Table 6). In 1993 in the blocks of both cultivars a substantial percentage of hybrids was found at a distance of 96 m from the pollenizer; 24% and 39% for 'Tommy Atkins' and 'Maya' blocks, respectively (Tables 5 and 6). Consistent with these results are the findings in 'Maya' block in 1992 where we found that a distance of 108 m from 'Tommy Atkins', 34% of the 'Maya' fruits were hybrids (Table 4).

b) Outcrossing rates in Merom Golan orchards

In Merom Golan, located at the Golan Heights, we studied two adjacent blocks of 'Maya' and 'Tommy Atkins'. In 1994 at harvest we sampled fruits at five distances. The germinated seedlings were analysed for TPI. Results are shown in Fig.7. As shown in Fig 7, in the 'Tommy Atkins' block there is a gradual decline in outcrossed fruits from 90% in the row adjacent to 'Maya' to 50% at a distance of 192 m from 'Tommy Atkins'. In the 'Maya' block there is a decline in hybrid fruits from a value of 65% in the row adjacent to 'Tommy Atkins' to 30% at a distance of 96 m from it (Fig. 7). No correlation was found between hybrid percentage and yield.

Although it would be expected that the rate of cross-pollination in the trees remote from the pollenizer cultivar should be much lower than self-pollination, the results in Ramat Magshimim and Merom Golan show that considerable percentage of outcrossed fruits was obtained at large distances from the pollenizer, demonstrating the advantage of outcrossed fruits over selfed ones. Similar results were obtained in 'Hass' avocado where substantial outcrossing rates were obtained at 140 m and 600 m from the pollenizer (Degani et al., 1989, and Vercenar-Gadus and Ellstrand, 1985, respectively).

c) Outcrossing rates during fruit development in Neve-Ur orchard

In Kibbutz Neve-Ur, located in the Jordan Valley, 'Maya' block is planted next to 'Tommy Atkins' block (Fig. 8). Each block has about 25 rows

Fig. 7. Rate of hybrids in 'Tommy Atkin' fruits (exp. 1) and in 'Maya' fruits (exp. 2) in relation to the distance from the reciprocal pollenizer cultivar.

Fig. 8. Schematic map of mango blocks in Neve-Ur orchard.

Sampling

region:

(6m apart), with 15 trees per row (5m apart). At different distances from the 'Maya' block (rows 1, 2, 4, 8 and 16) four uniform 'Tommy Atkins' trees were tagged for each row. At the beginning of May 1994, 20 fruitlets (mean weight 10 gr) were sampled from each tree. At harvest, fruits were sampled from the same trees; 20 fruits per tree.

For isozyme analysis of the fruitlets the endosperm was sucked; an average number of 14 fruitlets per tree were analyzed. Unfortunately, for unknown reason the isozyme analysis of fruitlets sampled from 3 trees failed, and therefore the results obtained for only 17 trees are presented. In mature fruits the seeds were planted and the leafs of the germinated seedlings were analyzed. An average number of 16 seedlings per tree germinated and analyzed for TPI and IDH.

Percentage of hybrids during fruit development.

Fig. 9 presents percentage of hybrids ('Maya' progeny) in 'Tommy Atkins' fruitlets and fruits. For each individual tree there is a remarkable increase in hybrid percentage from the stage of young fruitlets to the stage of mature fruits. In Table 7, the 17 trees were classified into three groups according to hybrid percentage in the fruitlets. For each group there is an increase of 4 to 20 fold in hybrid percentage from early fruit development to mature fruits. These findings clearly show selective abscission in 'Tommy Atkins'. Selfed fruitlets abscised at much higher rate than out crossed ones.

Table 7. Hybrid percentage - 'Maya' progeny- among 'Tommy Atkins' fruitlets and fruits in Neve-Ur orchard 1994. The 17 trees were classified into 3 groups according to hybrid percentage in the fruitlets.

No trees sampled	No. fruitlets examined	No. fruits examined	Hybrid percentage	
			fruitlets	fruits
6	81	104	3	68
7	109	112	14	77
4	57	57	22	79

Fig. 9. Percentage of 'Maya' progeny among fruitlets and fruits of 17 'Tommy Atkins' trees examined. Trees are presented in the order of increase in hybrid percentage in fruitlets (Neve-Ur, 1994).

Effect of the distance from 'Maya' on hybrid percentage

The percentage of hybrids in 'Tommy Atkins' fruitlets and fruits was determined at four distances from 'Maya' and the results are shown in Fig.10. The rates of hybrids in fruitlets decline from a value of 19% at the row adjacent to 'Maya', to 5% at row 16. The high rate of hybrids among fruitlets from row 8 might be due to the effect of a 'Maya' branch bursted on 'Tommy Atkins' tree which originally was grafted on 'Maya' tree in row 11. Hybrid percentage in mature fruits ranged from 82%-86% at the first two rows adjacent to 'Maya' to 50% at row 16. The high percentage of hybrids at a distance of 96m demonstrate that outcrossed fruitlets have higher chance of survival than selfs. The advantage of outcrossed fruitlets is probably related to the fact that in selfed progeny the embryo and endosperm are less vigorous than in outcrossed progeny due to inbreeding depression (Charlesworth and Charlesworth, 1987; Sedgley and Griffin, 1980).

No correlation was found between hybrid percentage and yield. This might be due to the formation of selfed 'Tommy Atkins' fruitlets in quite high proportions and their capability to reach maturity whenever they are not subject to strong competition with outcrossed fruitlets. When fruit-set is low or abscission is particularly massive due to environmental stresses, the advantage of outcrossed fruitlets might be expressed in increase of yield.

C.5. The effect of Pollen Parent on Fruit and Seed Weight (Israel).

In 'Tommy Atkins' and 'Maya' no correlation was found between the pollen source and the weight of the fruits (Table 8). In the 'Tommy Atkins' block at Merom Golan it was found that hybrid fruits originated from 'Maya', contained seeds which were significantly heavier than those of their corresponding selfed fruits. However, in the 'Tommy Atkins' block at the Neve-Ur, the difference in the weight of seeds between hybrid and selfed fruit was not significant.

Fig. 10. Hybrid percentage in 'Tommy Atkins' fruitlets and fruits in relation to the distance from 'Maya' block (Neve-Ur, 1994).

Table 8. Fruit and seed weight in selfed and outcrossed 'Tommy Atkins' and 'Maya' fruit

Orchard Location	Fruit type	Fruit (No.)	Fruit (g)	Seed (g)
'Tommy Atkins'				
Neve Ur	Selfed	68	267 a	17.3 a ^z
	Outcrossed	169	256 a	16.8 a
Merom Golan	Selfed	53	291 a	17.1 a
	Outcrossed	198	298 a	19.5 b
'Maya'				
Merom Golan	Selfed	92	231 a	15.4 a
	Outcrossed	66	232 a	16.0 a

Results within columns followed by different letters differ significantly by t test, $P=0.05$.

C.6. Development and use of RAPD markers (U.S.A)

Randomly Amplified Polymorphic DNA (RAPD) markers were developed and their use for detecting self- and cross-pollination, genetic relatedness, and phylogenetic relationships in mango was investigated. Three separate sets of experiments were used to determine the suitability of RAPD markers.

Experiment 1, nine *Mangifera* species were analyzed using ten selected primers that produced 109 usable bands which were scored as present or absent. Analysis was conducted using UPGMA and principal coordinate analysis (PCA). RAPD generated clusters did not always agree with the taxonomic classification based on phenotypic traits. When the two subsections of the

genus were analyzed separately, the classification more closely agreed with the traditional taxonomic analysis (Schnell and Knight, 1993).

Experiment 2, 25 accessions of *M. indica* were examined for RAPDs with 80 10-mer random primers. Of the 80 primers screened, 33 did not amplify, 19 were monomorphic, and 28 gave reproducible, polymorphic DNA amplification patterns. Eleven primers were selected for the study. The number of bands generated was primer- and genotype-dependent, and ranged from one to 10. No primers gave unique banding patterns for each of the 25 accessions; however, ten different combinations of two primer banding patterns produced unique fingerprints from each accession. A material half-sib (MHS) family was included among the 25 accessions to see if genetic relationships could be detected. RAPD data were used to generate simple matching coefficients which were analyzed phenetically and by means of PCA. The MHS clustered together in both the phenetic and the PCA while the randomly selected accessions were scattered with no apparent patterns (Schnell et al., 1995).

Experiment 3, progeny arising from caged trees of the cultivars 'Keitt' and 'Kent' were analyzed. In the 'Keitt'-F₁, 110 bands were generated, of which 78 (71%) were repeatable. Of these 78 loci, 23 were variable and segregated 3:1 as expected. In the "Kent-F₁, 141 bands were generated, of which 58 (41%) were not repeatable, two (1.4%) were present in the progeny, but not in the parent, and 81 (57%) were repeatable. Forty-one of these loci were variable; however, only 28 segregated as expected. Apparently, the progeny arising from the caging of 'Keitt' are the result of self-pollination, while those arising from caged 'Kent' contain cross-pollinated and self-pollinated individuals. The two bands found in the 'Kent'-F₁ but not in 'Kent' are reproducible and, along with the 32% anomalously segregating loci indicate that cross-pollination occurred (Schnell et al., to be submitted).

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D. DESCRIPTION OF THE COOPERATION

During the project period, the principal investigators of the cooperating groups visited the laboratories of each other. In July 1992 Dr. Degani visited the SHRS at Miami for three weeks. During this time she became familiar with the RAPD techniques being used for the mango evaluation. In November 1993, Dr. Schnell visited the Volcani Center for three weeks. During this time he became familiar with the research in Dr. Degani's lab, the mango breeding program, and the horticultural program in general at the Volcani Center.

The investigators exchanged genetic material and methodologies and a joint paper was prepared (see list of publications).

E. EVALUATION OF THE RESEARCH PROJECT

1. The efficiency of various bagging methods of mango inflorescences in excluding pollinated insects was studied. No significant difference was found among the various bagging methods (i.e. 15 mesh net bag; 50 mesh net bag' cloth bag' paper pag). Bagging with different types of bags greatly decreased the rate of pollination but did not prevent it completely.
2. Thrips appear to play a minor role in mango pollination.,
3. The cultivars studied in Israel responded differently to self-pollination under controlled pollination conditions. In 'Maya' there was no significant difference in yield between trees caged with bees and open-pollinated trees and almost all fruits obtained in cages were selfs. This demonstrates the ability of 'Maya' to set and carry a full crop by self-pollination. In "Irwin" most of the fruits produced in trees caged with bees were selfs but the yield in caged trees was significantly lower than that in open-pollinate 'Irwin' trees. This suggests that 'Irwin' is partially self-incompatible. In '15-60' the difference between the number of fruits produced in trees caged with bees and open-pollinated trees was very large and the few fruits produced in caged trees were hybrids. These results suggest that 'Irwin' is partially self-incompatible while '15-60' is self-incompatible.

4. Our studies on outcrossing rates during fruit development from the stage of young fruitlets to the stage of mature fruit indicated selective abscission of selfed fruitlets. The advantage of outcrossed fruitlets over selfed ones is also shown by the substantial percentage of hybrid fruits found in large distances from the pollenizing cultivars.
5. Using isozyme analysis we have determined: i) the effect of different pollen parents on outcrossing rate in the orchard. ii) the dependence of hybrid formation on the distance from the pollenizing cultivar, as well as the correlation between yield and hybrid formation. This information should be very useful for designing future planting schemes of mango orchards.
6. We have developed RAPD markers which, along with isozymes are capable to determine selfed vs. outcrossed progeny. RAPD markers were used to determine relatedness and phylogenetic relationships in mango.

F. LIST OF PUBLICATIONS

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