

# Breeding of Apples for a Subtropical Climate

## II. Analysis of two $F_2$ and Nine Backcross Populations \*

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**Summary.** A report is given on the third phase of a breeding project to produce apples with low chilling requirements and high fruit quality. The selection within two  $F_2$  populations and nine BC populations, with Delicious and Jonathan, is described as to both methods and results. A description is given of three new subtropical apple varieties, MAAYAN, MICHAL and SHLOMIT.

### Introduction

Much work has been done in many countries on the breeding of apples for cold resistance (ZWINTZSCHER 1961) and also, more recently, for late flowering (TYDEMAN 1958), and at least as much work has been done in subtropical countries (WEINBERGER 1961) on the creation of peach varieties suitable for areas with warm winters.

On the other hand, very little planned breeding work has been carried out with the aim of creating apple varieties suitable for warm climates — subtropical apples, as we shall call them hereafter. Selections of locally successful apple types have been made in many countries and states such as: Egypt, Morocco, Tunis, China, Australia, New-Zealand, South Africa, Spain and Portugal, Puerto Rico (ACKERMANN and WINTERS 1966); California (CHANDLER 1967), Palestine (GRASOWSKY and WEITZ 1932), India (HAYS 1953), Tripolitania (MAZZOCCHI and PUCCI 1963), Mississippi (OVERCASH 1960, OVERCASH and MURPHY 1957), Ceylon (SCHMIDT and HERATH 1963). ACKERMANN and WINTERS (1966) have described 36 such types brought together from many warm-climate countries. It is not clear how many of these varieties are the product of planned breeding, but it seems that none of these varieties has so far made its way commercially.

The chilling requirement of northern apple varieties is normally not fully met in lower latitudes and this leads to delayed foliation and unhealthiness of the trees. Delayed foliation can be prevented by chemical treatments, but this has to be well-timed to be effective. This aspect of the problem has been reviewed by SAMISH (1954).

In Israel, one fruit grower has carried out planned crossings following our lead and has released, so far, two varieties. His material has not yet been published, but one of his varieties was included in a report of the USDA (ACKERMANN and WINTERS 1966).

Our breeding program, the latest phase of which is the subject of this article, was conceived with the aim of combining low chilling requirement with the highest obtainable fruit quality. Our hybrids are expected to be suitable for a climate with 200 to

300 hours below 7 °C during the winter months. A first report on our work was published in 1951 (OPPENHEIMER 1951) and a second in 1963 (OPPENHEIMER 1963). A short summary of the early steps is given here, so as to make the story intelligible.

Breeding work was started in 1939. We used as parents a number of local varieties with low chilling requirement but very low fruit quality. The most important among them were one unnamed type from Damascus, and the Palestinian Biari. These we crossed with introduced varieties, such as Astrachan, Calville St. Sauveur (locally called Grand Alexander), Delicious, Jonathan and Lodi.

About 120  $F_1$  trees were grown during the first years. The first  $F_1$  trees fruited in 1943; these, and all  $F_1$  trees fruiting later, gave low-quality fruits.  $F_2$  from free pollination (thus probably mostly sister-brother crosses) were sown between 1943 and 1951. Altogether, about 1300 second generation hybrids were raised. From the 1943, 1944 and 1945 populations five varieties have been released: Vered, Yael, Rahel, Naomi and Tamar. They were described in 1963 (OPPENHEIMER 1963) and three of them are listed by BROOKS and OLMO (1962, 1963).

A lecture on further developments in this breeding project was delivered at the XVIIth International Horticultural Congress in 1966. No Proceedings will be published and only a very short summary was printed (OPPENHEIMER 1966). Some of this material, together with additional observations for 1967, and the final decision as to the release of three varieties and their description will be presented in this article.

### Materials and Procedure

This article describes the behavior of two  $F_2$  populations, seven backcross populations with Delicious and two backcross populations with Jonathan, the procedures followed in their evaluation and the decision to release three new varieties in 1967.

The material was grown as seedlings, from seeds obtained in the years 1948–51, in special quarters at the Rehovot and Kubeiba campuses of the Volcani Institute of Agricultural Research. The growing conditions in these quarters were rather unfavorable — distances were much too close and the soil was too light for apples. For these reasons evaluation was made for only one character, but this was the deci-

\* Contribution from the Volcani Institute of Agricultural Research (N.U.I.A.) Bet Dagan, Israel. 1967 Series; No. 1227 E.

sive one — of climatic adaptation, especially low chilling requirements.

A first selection was made in 1959 and the selected types were budded at the new Bet Dagan campus of the Institute. The rootstock was Italian Doucin and conditions in the new quarters were favorable.

cially preferable — low, compact, semi-dwarfs — this point was not given much weight in the decision.

*Fertility:* Practically all types were highly productive and some gave too many fruits (and this naturally influences size). For one of the selected

Table 1. *The populations and their numbers at different stages of selection*

Group	Seedlings planted 1950—53	1st selection budded 1959	2nd selection	3rd selection	Released
F/2 Lodi × Biari/4	72	28	8	3	0
Lodi × Biari/6	45	14	1	0	0
BC GRKM 2/18 × Delicious	135	59	28	7	2
Vered × Delicious	11	4	3	1	0
Yael × Delicious	18	4	2	1	0
Lodi/Biari/6 × Delicious	9	2	0	0	0
GRKM 1/12 × Delicious	4	1	1	1	1
Sucari/Astrachan × Delicious	18	3	0	0	0
Biari/Delicious × Delicious	16	0	0	0	0
Biari/Delicious × Jonathan	43	14	1	0	0
Jonathan × Biari/Delicious	91	28	6	1	0
Total	462	157	50	14	3

Table 1 gives the designation of the 11 populations, the number of original seedlings, and the number of budded types after the first selection. In addition, the table shows three points to be discussed later: the 2nd selection, the gradual discarding during the years 1962—1966 of all clearly unsuitable types and the 3rd selection in 1967, showing the few types which need further study and the final selections for release.

The 157 budded trees in the Bet Dagan quarter showed, with very few exceptions, a very satisfactory development. First fruits were obtained in 1961 and selection could be started in 1962. Our decisions are thus based on observations and measurements taken during the five years between 1962 and 1967. As these could be made on single trees only, it was decided as early as 1963 to distribute budwood of a few outstanding types to a small number of reliable collaborators. This was of considerable help in the final decision.

As the first selection in 1959 had excluded practically all climatically non-suitable material, very few additional types had to be discarded for this reason.

Selection was based on a points system which included the following characters: shape of tree, fertility, ripening season, size, shape and color of fruit, firmness during storage, taste at picking time and after two weeks' storage at room temperature, juiciness at picking time and after two weeks, and texture of the fruit flesh. It was very soon found that total score of points alone could not be used as a basis for final judgment. A number of types with a very high general score had decisive shortcomings which would make their commercial production impossible. The final selection was therefore based on a combination of elimination and scoring.

A few remarks shall be added on the basis for the evaluation of the characters:

*Shape of tree:* Very few trees had an absolutely undesirable shape, while some types were commer-

types a mechanical treatment was found necessary to induce early onset of production.

*Ripening season:* Our basic aim was to release early ripening varieties, and thus this point was given great weight. June ripening was preferred to July ripening, and August ripening varieties would have to have an exceptionally high general score to offset their late ripening. Highest marks were given for May ripening, one point less for June and July, one more less for each week in early August and each five days in late August.

*Size:* The fruits of a very great proportion of the hybrids were too small for commercial production and many were discarded after it had been found that even with heavy thinning no fruits of sufficient size could be produced. The lowest commercial size considered by us is 6 cm; full points were given for 85 mm, with 1 point subtracted for each 5 mm less.

*Shape:* Practically none of the hybrids produced fruit of non-acceptable shape and the differences had no great influence on the decision.

*Color:* Lack of color (together with lack of size) led to the greatest number of discards. No type with green fruits, and only one outstanding type with yellow fruits was retained. Some types produced highly colored small fruits and poorly colored large fruits at the same time. A few types with exceptionally good color but rather small fruits are among the group of 3rd selection, with the hope that we still may find a way to enlarge the fruit. Full score was given to fruits 100% red, two points less for 75%, two points less for 50%, and another two points less for 25% colored.

*Taste and juiciness:* All types with a tendency to mealiness after 14 days at room temperature were discarded; this sometimes forced us, very reluctantly, to abandon types with very good color and size. On the other hand, due to the heterogeneity of the Israel population, representatives of different taste groups had to be given equal consideration. This point will be made once more in the description of the released varieties.

**Firmness:** A number of very beautiful types had to be discarded on account of extreme softness.

**Texture:** A few otherwise desirable types had very coarse fruit flesh, which made them unpleasant to eat.

In spite of our own earlier observations (OPPENHEIMER 1963) on the necessity (or at least desirability) of growing hybrids on at least two different rootstocks, we did not have the means to do this and all the primary observations were made on Italian Doucin only. Some help was obtained from the fact that practically all the additional trees in commercial orchards were on the locally prominent rootstock — Hashabi.

During the first 25 years all the work was carried out by the senior author; during the last three years most of the testing in Bet Dagan and all the work on the additional trees was carried out by the junior author. Final decisions as to discard or release were made together. Where opinions differed, the decision was delayed.

### Observations and Results

Two general questions should be considered before the results are described: The inheritance of early budbreak and the correlation between this character and the length of the juvenile period.

**Earliness of budbreak:** It does not seem possible from our material to achieve a conclusive genetic analysis of this character, but some idea about its inheritance may be obtained.

The range in time of budbreak among the original seedling populations was very wide — at least seven weeks. The earliest types showed signs of budbreak, according to temperatures of both winter and spring, between the middle of February and the first days in March. Our best types proved their subtropical nature — their very low chilling requirements — by breaking earlier after warm than after cold winters. Quite arbitrarily we counted as “early”, i.e., suitable for our conditions, types which broke bud within three weeks of the earliest types in all (or most) years. Most types behaved consistently, but a few showed more than average variation.

Already in the 1st generation populations a considerable variation was noted with about half of the types classified as “early”. The peak of the curves occurred in the third and fourth weeks in nearly all cases. The distribution of the  $F_2$  populations was not very different from that of the  $F_1$  populations. For the BC populations, we have to rely on our first selection: among 345 BC seedlings, 145 were early enough for selection.

It is clear that the figures cannot be analyzed for numbers of factors concerned, but it seems to

us that dominance of earliness in budbreak may be assumed. The  $F_1$  could have been produced from a recessive foreign parent and a heterozygous local parent, and the BC from types selected for early budbreak with, once again, recessive foreign parents.

**Correlation between early flowering and short juvenile period:** KARNATZ (1965) and VISSER and, VISSER and SCHAAP (1965, 1967) have recently found such a correlation in their material, and recommend early selection. This we have done, and can therefore make no calculations for a possible correlation in our material. Generally, the juvenile period in our material was very short. In an extreme case, fruit was obtained three years after the sowing of the seeds. On the other hand, a few cases were found where early budbreak (and flowering) was present together with a very long juvenile period. In the types later released as Noami and Tamar none or extremely few fruits, respectively, were produced on the seedlings for many years, and only by budding these types on EM 9 rootstocks could they be brought into bearing.

VISSER also reports a correlation between early leaf-fall and early ripening. This would not apply to our material. Our very early ripening types, such as Vered, sometimes retain their leaves even in winter.

Discussion of the results will be arranged into four groups:

- A. the two  $F_2$  populations Lodi  $\times$  Biari;
- B. the two BC populations Biari/Delicious  $\times$  Jonathan and vice versa;
- C. the six small BC populations with Delicious; and
- D. the one relatively large BC population GRKM (Calville St. Sauveur  $\times$  unnamed type from Damascus) 2/18 with Delicious.

The differences between the populations are shown in Table 2.

Shape of tree, fertility and shape of fruit are satisfactory in all groups. Season: groups B and C tend to be late. Size: groups A, B and D contain many small types. Color: A and B are fairly good, group C is the worst. Eating quality (taste, juiciness and texture combined): group A is mostly bad. Firmness: groups A and C are weaker than the others.

Group A — Biari  $\times$  Lodi — two  $F_2$  populations from trees 4 and 6.

117 seedlings, 42 trees budded in 1959, nine retained after 2nd selection during 1962–1966. Out of these, six were discarded in 1967, due mainly to lack of size and eating quality, and this in spite of some of them being among the most beautiful fruits in the whole orchard.

Table 2. Mean scores in grading for important characters in 1967 (before 3rd selection)

Group	Number of trees	Tree shape	Fertility	Season	Fruits				
					Size	Shape	Color	Eating quality	Firmness
A	9	4.6	6.4	6.8	2.4	6.3	4.0	3.7	4.4
B	7	5.6	6.4	4.5	2.0	6.0	3.7	5.8	6.4
C	6	4.5	6.3	4.5	4.3	6.2	2.3	4.9	4.5
D	28	5.0	6.0	6.4	2.4	5.3	3.0	5.6	5.0

Three types have been retained for further observations, and none were released. The percentage of maximum points given these types during the last three years (not all types gave enough fruits for testing in all years) was:

Type	1965	1966	1967
2.48	—	70	71
3.3	—	—	69
3.14	89	62	63

A few remarks about these types:

2.48 — Rather large fruit of good color, suitable ripening time, good taste, firm, and of good keeping quality.

It has not yet been released for two reasons — no additional trees have come into bearing and the fruit from the original tree has a coarse texture and is not pleasant to eat. This may be a question of finding the best time of picking, and for this and other trials we need more fruit.

3.3 — Very early ripening, nice looking and fairly tasty fruit. The fruit is too small for commercial production, but the type may be suitable for home-garden growing.

3.14 — Still earlier ripening, and may be an improvement on Vered. Fruits are either too small for commercial production but with good color and taste, or of acceptable size but with lower quality. This type will have to be grown under other conditions so as to find out whether it is possible to obtain a suitable combination of size, color and taste.

Group B — *Two BC populations of Biari/Delicious × Jonathan and vice versa.*

134 seedlings, 42 trees budded in 1959, seven retained after 2nd selection during 1962–1966, all but one discarded in 1967, none released so far.

Many of these types have obtained rather high scores because of their good color, eating quality, storage life and productivity. The one major problem for which nearly all have had to be discarded — and it is still doubtful if even the one will finally remain — is lack of size. As is well known from breeding programs in other countries, Jonathan hybrids tend to be too small for commercial production, and this is the case here also. Even with rigorous thinning it has not been possible to obtain more than size 5 fruit with most types.

The one remaining type is:

6.13 — Scores: 1956, 86%; 1966, 67%; and 1967, 71%.

It flowers and ripens later than desirable, but would still be a very valuable deep-red fruit of good taste, eating and keeping quality for its season in August, if large enough fruit could be produced. Only in 1966 was the minimum size of 60 mm first obtained after rigorous thinning. So far, we have only the one tree in Bet Dagan. Trees will have to be grown on commercial-size plots before a decision on the release of this type can be made.

Group C — *Six small BC populations with Delicious.*

66 seedlings, 14 trees budded in 1959, six kept after 2nd selection during 1962–1966. Of these six, one has been released and two (or even three) others seem to be promising. This seems a rather good return from such a very small outlay.

The % scores of three types:

Type	1965	1966	1967
8.6	—	60	60
8.11	88	67	64
10.7	—	73	70

8.6 — (Vered × Delicious): A very good and very prolific tree, with rather large, well shaped fruits, resembling the Calville St. Sauveur parent of Vered. Ripens in July. The fruit has no color and is somewhat coarse, so that it would probably be only a cooking apple. It is doubtful if such an addition to the present collection is needed.

8.11 — (Yael × Delicious): This tree has for a number of years given extremely high yields of large fruit which ripens rather late and keeps extremely well. We have not yet been able to get a clear picture of its quality, and much work will have to be done before a decision becomes possible.

10.7 — *Shlomit*. Parentage: (GRKM 1/12 × Delicious). The mother tree on which the BC with Delicious was made was a  $F_2$  tree from the same cross as Vered (Calville St. Sauveur × Damascus), but from another  $F_1$  tree. This is the  $F_2$  tree which was mentioned above as producing its first fruit after three years. The fruit was large and early, but of rather low quality.

*Budbreak:* Between the end of February and the middle of March.

*Beginning of flowering:* The same.

*The tree and its yields:* Medium, upright tree, bearing early, on spurs. Seems to be very prolific.

*Ripening time:* Beginning of June to middle of July.

*Fruit:* Fairly large (6–8 cm) and sometimes even too large. Form, round to conic. Partly, but not very fully rose colored. Very good aroma, taste sweet, with some but relatively little acid. May be taken as a sweeter Golden Delicious. This type of fruit taste is preferred by most non-European people. The fruit is firm enough but has melting flesh which keeps in good condition at room temperatures for at least ten days. Can be kept in cold storage for at least two months.

*Tree 10.7* was found to be outstanding in every year, even if scoring was sometimes not recorded due to the small number of fruits.

Group D — *BC population GRMK 2/18 with Delicious.*

The mother tree of this population is a sister of Vered, chosen for good color and taste, but not released because of too-small fruit.

135 seedlings, 59 trees budded in 1959, 28 retained during the period of 2nd selection 1962–1966, seven retained after 3rd selection — two of which have been released.

% scores of the seven types:

Type	1965	1966	1967
4.8	84	—	63
4.11	90	—	66
4.26	91	73	70
4.31	—	—	65
5.1	—	75	54
5.7	—	65	59
5.12	98	74	72

Table 3. *Scores of individual trees in 1967 (1966)*

Type	Tree shape	Fertility	Season	Fruit			Taste after 14 days	Juiciness after 14 days	Firmness	Texture
				Size	Shape	Color				
5.12	6	7	7	4	5	4	6	5	5	7
4.26	7	7	7	3	5	3	6	5	7	7
4.8	5	5	7	3	6	2	4	4	7	7
4.11	5	5	7	3	6	1	5	5	7	7
4.31	7	7	5	1	6	6	5	5	7	7
5.1 (1966)	7	5	7	3	7	8	5	6	7	7
(1967)	7	7	5	3	7	4	2	1	4	5
5.7 (1966)	7	7	5	5	5	4	5	3	5	5
(1967)	7	7	4	3	5	3	5	3	5	5
4.9	6	6	5	2	7	7	2	1	3	7
4.24	8	8	5	4	6	1	5	5	5	7
5.6	7	7	7	3	5	6	2	1	5	7

Table 3 shows partial scores in 1967 for the two releases, for the five other promising and for comparison also for three discarded types. For the two types 5.1 and 5.7 we have added also the scores for 1966 because they are much higher and represent the reason for keeping these types for additional observations.

Type 4.9 had to be discarded, in spite of its excellent color, due to lack of size, firmness and taste. Type 4.24, in spite of many good points, was discarded due to lack of color; type 5.6 was discarded due to its tendency to mealiness.

The five candidates and the two new varieties will now be described.

4.8 — This type has a fairly high general score, with some deficiency in color and size of the fruits on the original tree. It remains a candidate on account of its much better showing in a commercial orchard.

4.11 — This type did not look promising during its first years of fruiting and gave no yield in 1966; thus we have only three years of observations. Nevertheless, the type looks promising and is by far the best of the *yellow* apples in our populations. Besides its lack of red color, and therefore low score for this trait, its fruit is not large, but just reaches the commercial minimum of 60 mm. We shall have to grow more trees so as to obtain the reaction of the market. If a yellow fruit will prove acceptable to the consumer in June and early July, the type will probably be released.

4.31 — In spite of its very good color, this type was not deemed promising until this year, on account of its small size and rather late ripening. If we shall find it possible to release the Jonathan BC 6.13 we shall need a second variety flowering at the same time as pollinizer, and 4.31 is the most probable candidate. We shall have to find out during the next few years if the size of the fruits can be sufficiently improved by proper thinning.

5.1 — This type has been puzzling us for a number of years (see Table 3). In certain years the fruit was excellent and the type attained the highest overall score in 1966. In other years (see score of 1967) it was extremely disappointing. One small orchard has been budded with this type and there, too, the fruit, while highly colored and of good shape, was this year too small and of too poor eating quality and did not find a ready market. While this type

is still a candidate, we suppose that it will finally be dropped.

5.7 — The original tree 5.7 was found in 1962 to be highly promising, but died from root rot during the following winter. Another tree was budded with budwood from the original seedling and has given fruit during the last three seasons. As seen in Table 3, the scores during the last two years have not been highly consistent and it is not yet possible to decide the fate of this type. It ripens a bit too late, is not really large enough, and while of very good taste immediately after picking tends to lose its juiciness too quickly. It now seems probable that we shall decide to discard this type if trials to improve its quality do not succeed.

#### 4.26 — *Michal*<sup>1</sup>.

*Budbreak:* End of February until beginning of March.

*Beginning of flowering:* Middle of March.

*Tree and productivity:* Low, widespread tree; fruits easy to pick, formed both on spurs and on year-old branches. Starts bearing in 3rd year and is highly prolific, as also shown in small commercial plots.

*Ripening season:* Middle of June to end of July.

*Fruit:* Round with rather deep cavities, size 60–70 mm, about one quarter of surface covered with light red coloring; juicy subacid, of the Jonathan taste group — probably the most „European“ of the three varieties; of good aroma and texture; keeps in very good condition for at least two weeks at room temperature during which time it becomes slightly sweeter. In cold storage it keeps for at least two months. The fruit is firm and carries well to the market.

5.12 — *Maayan*<sup>2</sup>. This type has been consistently the best during the seven years of recording, has been very successfully grown in small orchards, and has received a very good reception on the market.

*Budbreak:* End of February to beginning of March.

*Beginning of flowering:* Beginning of March.

*Tree and productivity:* The tree is fairly large and bears on spurs only. The original tree came into full bearing rather late, in the seventh year after

<sup>1</sup> Hebrew girl's name, means brook, the 'a' pronounced as in ar.

<sup>2</sup> Hebrew girl's name, means spring, the 'a' pronounced as in ar.

planting. By having their branches bent, young trees have been induced to early spur production and thus to productivity as early as in the third year.

*Ripening season:* From early June to late July.

*Fruit:* Round fruit of good size, 60–80 mm, covered with strong red color usually over more than half of its surface, very good looking. The fruit flesh is juicy, of very good aroma and texture, sweetish-acid, belonging to the Delicious group, but by most people judged to be of better taste. At room temperature the fruits keep in good condition for at least two weeks, and in cold storage for at least two months. The fruit is firm and carries well to the market.

### Rootstocks

The original trees have been selected as grown on Italian Doucin and thus this rootstock is clearly suitable. All three varieties are being grown in small commercial orchards on the locally prominent rootstock, Hashabi, and seem to do well on it. None of the new varieties has been tested on seedling stock or on any of the Mallings stocks.

### Pollination behavior

Very little is known of this question. We have not yet been able to make conclusive tests, but the little that has been done shows that the new varieties can probably not be relied on to be self-fruitful (in contrast to Vered, which is nearly 100% self-fertile). Thus it will probably be necessary to plant at least two of them together. The standard varieties will, under subtropical conditions, flower weeks later and probably not even overlap. In 1966, all three varieties reached full bloom on the same date (March 15). In 1967, Shlomit reached full bloom on March 28, Maayan on April 4 and Michal on April 9 (due to the very cold spring, flowering was delayed on all fruit trees in 1967). There was sufficient overlapping early in April to bring about effective cross-pollination.

### Zusammenfassung

Es wird über die 3. Phase eines Züchtungsprojektes zur Erzeugung von Äpfeln mit geringem Kältebedürfnis

und guter Fruchtqualität berichtet. Methoden und Ergebnisse der Selektion innerhalb von 2  $F_2$ -Populationen und 9 Rückkreuzungspopulationen mit 'Delicious' und 'Jonathan' werden beschrieben und 3 neue subtropische Apfelsorten, 'Maayan', 'Michal' und 'Shlomit', vorgestellt.

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