TOPOGRAPHY, ROOTSTOCKS, VARIETIES AND TREE SIZE AS FACTORS IN THE REACTION OF MANGO TREES TO LOW TEMPERATURES.*

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INTRODUCTION

Mango trees are known for their susceptibility to low temperatures. Observations have been made, mainly in India and Florida, on the reaction of different varieties, but there are very few reliable records.

In India, Hayes (5) reports that "some varieties" will withstand 22°F. Singh and Singh (9) report that, for a grass minimum of 25.5°F, vigorous trees suffered less than those of dwarf varieties and that varieties behaved according to the size of their trees, the amount of late growth and some "other" factors. Langra was found relatively resistant and Dasyeri somewhat less so. Jawada (4) found Langra and some other north-Indian varieties more resistant than others.

In Florida, Carmichael (1) recognized size of tree as probably the most decisive factor, with differences between varieties difficult to determine exactly. Kent and Haden were found more resistant than Irwin, Keitt and Palmer. Cobin (2) reports some influence of rootstock. Observations "indicate significance of survival based upon diameter of stock rather than varietal source." Sturrock (10) reports protection of young trees against 26°F by covering the lower parts with sisalcraft + woodshavings. He does not note variety differences. Carmichael (1) notes protection of trees against 22°F by heavy irrigation.

In Israel, Oppenheimer (8) recorded in 1949 in a mixed orchard that Haden trees showed 65% light, 29% medium and 6% heavy damage, Pairee trees 52% light, 42% medium and 6% heavy damage, while an unidentified third variety was very much more susceptible, showing 3% light, 71% medium and 26% heavy damage. In the highest quarter of the orchard 53% of the trees showed light damage, 45% medium and 2% heavy, as against 3% light, 42% medium and 55% heavy damage in the lowest quarter of the orchard.

This paper summarizes the observations made in 1964 in the mango orchard of the Volcani Institute of Agricultural Research. The fact that 23 varieties from widely different climates are planted in this orchard in replications on different parts of a one-direction slope, and that their rootstock, size and yields had been recorded prior to the frost damage, should make these observations of some interest to mango growers.

MATERIALS AND METHODS

1. The Orchard

The mango orchard of the Volcani Institute is situated in the coastal plain of Israel, macro-climatically under nearly identical conditions with those of the Central Meteorological Service.

The orchard was planted on a rather steep northern slope. The highest point is 197 feet
above sea level and the lowest 157 feet. The slope is thus 40 feet in 708—or about 13 inches for each row. Nearby orchards have their lowest point at 141 feet—so that there is air drainage even from the lowest part of the orchard, but this is far from perfect (meter: 60, 48, 12, 216, 0.33, 43).

The orchard was planted in 1956 with rootstocks and budded in situ, mainly in 1956 and 1957. It comprises 705 trees on 6.3 acres.

The soil is a loamy sand. The orchard is irrigated from late spring to the beginning of the winter rainy season. Yields have so far not been high—a mean of 73 lbs. per tree of the main varieties in 1963.

The orchard was laid out for an irrigation trial with 27 plots of 9 trees each—3 varieties on 3 rootstocks. Other varieties have been planted in the guardrows, of them 20 in replicates. The irrigation trial has not yet been started so that in 1963 irrigation was uniform.

2. The Varieties

The mango collection comprises 75 varieties, arranged in four groups:

a. Three varieties—Haden, Maya, Mabroka—are planted in 27 replicates of 3 trees each—81 trees of each variety—for a total of 243 trees.

b. Ten varieties are planted in four replicates of 5 trees each—20 trees of each variety—for a total of 200 trees.

c. Ten additional varieties are planted in four replicates of 3 trees each—12 trees each variety—for a total of 120 trees.

d. 142 trees are budded, in twos and threes, with 52 additional varieties without replications. This collection is located in the uppermost part of the orchard and showed no damage. For both these reasons the records are not included in this paper.

The geographical grouping of the 23 varieties is as follows:

a. Nine varieties are from Florida: Adams, Carrie, Davis-Haden, Edward, Faizanson, Haden, Irwin, Kent and Zill. They need no comment here.

b. Five varieties are local selections: Maya, Menucha, Zrifin, Shepard, 1/15.

Maya is grown commercially. Its fruit is rather similar to that of Haden, but the tree is somewhat larger. Menucha and Shepard are Haden seedlings selected by a private grower. Zrifin is also grown commercially. It forms a large and prolific tree, but the fruit is less well coloured than Haden. 1/15 is the newest selection of the Volcani Institute. The original tree is very large, extremely prolific and has large, well-coloured fruits. The variety was budded for the first time in this orchard and the yield of the young trees has so far been small.

c. Six varieties have been introduced from Egypt (3):

Alfonso, Pairee, Mabroka, Gaillour, Mistikawi, Bullock’s Heart—but at least the first two, and very probably the first four, are Indian varieties.

d. Langra and Dasher have been introduced directly from India, and Gedong directly from Indonesia.

3. The Freeze

During the period between the end of December 1963 and the end of January 1964, several periods of very low temperatures were recorded in all areas of Israel. The lowest temperatures occurred on December 28 and January 21, but in both cases the freeze lasted several nights.

The following figures are given, in degrees F., for the Main Station of the Central Meteorological Service:

<table>
<thead>
<tr>
<th>Date</th>
<th>Screen Minimum</th>
<th>Screen at 8 a.m.</th>
<th>Grass Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec. 28, 1963</td>
<td>29.5</td>
<td>33.8</td>
<td>27.3</td>
</tr>
<tr>
<td>Jan. 21, 1964</td>
<td>28.4</td>
<td>30.7</td>
<td>26.6</td>
</tr>
</tbody>
</table>

No records were taken in the orchard during the first freeze. In January the following grass minima (degrees F.) were recorded:

Near the lowest row: 24.8; near the middle of the orchard: 26.6 to 27.7. Near the top: 26.6 to 27.5. No records of the duration of the low temperatures are available. Temperatures at tree height, but not in a screen, were about 2 degrees higher than the grass minima.

4. The Records

Immediately after the freezes and continuously during the spring and summer of 1964, records were taken on the amount of damage to every tree in the orchard. For the purpose of this paper the records were summarized late in July.
For the slightly damaged trees the amount of damage was apparent at an early date, but recovery of the severely damaged trees was slow and in many cases branches died back after new growth had appeared on them. For a few of the worst trees the final position is still somewhat doubtful.

We recorded the damage in 9 degrees:
1. less than 10% of leaves scorched.
2. 10-20% of leaves scorched.
3. 20-50% of leaves scorched, some damage to young shoots, new growth from 2nd or 3rd node.
4. 20-50% of leaves scorched, some damage to larger shoots; or, over 50% of leaves scorched, little damage to shoots.
5. over 50% of leaves scorched, young shoots killed, new growth from branches.
6. over 50% of leaves scorched, most branches killed, new growth high from stem.
7. over 50% of leaves scorched, stem damaged, new growth well above bud union.
8. over 50% of leaves scorched, stem killed to near bud union, scion alive.
9. scion killed.

We decided to use such a relatively large number of degrees, because rating the trees must always be somewhat subjective, and the higher the number of degrees, the less important becomes an error of one degree.

A very small number of trees (see below) were excluded because of extreme weakness.

In addition to the records of tree damage, we have the yield records for every tree, as well as measurements of tree size (6, 7).

RESULTS

1. Topoclimatic Influence

As described above, the orchard is located on a rather steep slope. Thus air drainage—at least of the higher part of the orchard—is good.

Some of this influence is confounded with that of varieties and will be discussed later. But topoclimatic influence can be seen in isolation by the results from the 27 plots of the three main varieties.

The influence of topoclimate is extremely clear. Damage to trees in the highest part of the orchard is very light. In fact, all trees there show normal growth and yield. Of the variety collection planted in this part of the orchard, above row 25, only one tree—of the south Indian variety Banganapalle—was severely damaged.

<table>
<thead>
<tr>
<th>Table 1. Mean degree of damage for trees of the three main varieties in different parts of the orchard.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>37/39</td>
</tr>
<tr>
<td>32/34</td>
</tr>
<tr>
<td>22/24</td>
</tr>
<tr>
<td>17/19</td>
</tr>
<tr>
<td>12/14</td>
</tr>
<tr>
<td>7/9</td>
</tr>
<tr>
<td>2/4</td>
</tr>
</tbody>
</table>

2. Influence of Rootstock

The three main varieties are budded, as split-plots, on three different rootstock populations. There are therefore 27 x 3 = 81 trees budded on each of the three. The rootstocks are Sabre from South Africa and two local selections.

The mean damage ratings are:
- on Sabre - 3.0; on 14.6 - 3.1; on 14.7 - 3.2.

3. Differences between Varieties

a. The three main varieties

As we have 27 replications of each of these three varieties, the comparison may be said to be as exact as possible under orchard conditions. Mean tree sizes and mean yields show, up till now, no significant differences. Mabroka trees are slightly denser, and Maya trees slightly larger than those of Haden.

The mean damage rate for all 27 replicates are: Haden 3.30; Maya 3.05; Mabroka 2.95.

If we take only 20 replicates from the lower 2/3 of the orchard so as to make the figures comparable with the 20 other varieties, we find: Haden 3.95; Maya 3.53; Mabroka 3.25.

If we take only the lowest 8 plots, we find: Haden 5.87; Maya 5.13; Mabroka 4.16.

The number of seriously damaged trees—grade 6 or worse—is: Haden 10; Maya 11; Mabroka 3.

The results show that Mabroka is somewhat more prone to light (leaf) damage; but apparently considerably more resistant to or protected against heavy (branch and stem) damage.

b. The 20 additional varieties

Comparison is considerably more difficult and less reliable for this group. In addition, two sub-groups differ in one minor and one major aspect:

The minor: In the second sub-group there are only three trees in each replication as against five in the first sub-group. And here we had to discard in two cases two trees out of three for extreme (and uncharacteristic) weakness.
The major replicates in the first sub-group are planted in the columns, i.e., with the slope, and thus we have at every height-level eight varieties under very similar topographical conditions. Conversely, in the second sub-group the replicates are planted within the rows, i.e., against the slope, and thus in every row only four varieties are in the same topographical condition. We have been able to rectify this position somewhat by using double rows with eight varieties—but this naturally cannot be done for rows 1 and 25.

The mean degrees of damage of the 10 varieties of the first sub-group (without taking into account their place in the orchard) are: 1/15-2.5; Zrifin-3.2; Zill-3.4; Adams-3.4; Pairee-3.7; Menucha-3.9; Shepard-4.5; Faizanson-5.0; Gedong-5.6; Kent-5.7.

By taking into account the position values, the picture is only very slightly changed: Pairee advances from 5th to 2nd place. Kent advances from last place to 8th.

The mean degrees of damage of the 10 varieties of the second sub-group (as above) are: Bullock’s Heart-2.4; Langra-2.8; Mistikawi-3.7; Davis-Haden-4.4; Carrie-4.8; Gailour-5.0 Dasher-5.1; Alfonso-5.2; Edward-5.7; Irwin-5.8.

Taking into account the position value, by using not the original blocks of five rows, but pairs of adjacent rows from two blocks (5, 6; 10, 11; 15, 16; 20, 21) the comparison becomes truer and a change of order might have become apparent. It is thus rather astonishing that this procedure revealed no real change. The varieties can be classified into five groups:

1. Bullock’s Heart and Langra; Mistikawi; Davis-Haden; Carrie, Gailour, Dasher and Alfonso; Edward and Irwin.

4. Size and yield of trees in their relation to frost damage

Table 2 shows degrees of damage (as above) against size of tree in meters, as measured in November 1962 for all 23 varieties:

With the exception of a few cases, to be discussed below, we find a rather perfect negative correlation between vigour of tree and degree of cold damage. However, if we take the 180 trees of the three main varieties in the lower 20 rows and try to find the degree of correlation within the variety, the picture is rather different. No significant correlation can be found, but a trend remains, and will be given here:

Haden: 43 trees of degree 2 to 4 had a mean size of 2.58

Table 2. Mean size of tree and mean degree of damage

<table>
<thead>
<tr>
<th>Variety</th>
<th>Mean size of tree</th>
<th>Mean degree of damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edward</td>
<td>1.77</td>
<td>5.7</td>
</tr>
<tr>
<td>Alfonso</td>
<td>1.81</td>
<td>5.2</td>
</tr>
<tr>
<td>Irwin</td>
<td>1.82</td>
<td>5.8</td>
</tr>
<tr>
<td>Kent</td>
<td>1.91</td>
<td>5.7</td>
</tr>
<tr>
<td>Dasher</td>
<td>1.93</td>
<td>5.1</td>
</tr>
<tr>
<td>Faizanson</td>
<td>1.94</td>
<td>5.0</td>
</tr>
<tr>
<td>Carrie</td>
<td>2.12</td>
<td>4.8</td>
</tr>
<tr>
<td>Gailour</td>
<td>2.21</td>
<td>5.0</td>
</tr>
<tr>
<td>Davis-Haden</td>
<td>2.43</td>
<td>4.6</td>
</tr>
<tr>
<td>Gedong</td>
<td>2.43</td>
<td>5.6</td>
</tr>
<tr>
<td>Shepard</td>
<td>2.47</td>
<td>4.5</td>
</tr>
<tr>
<td>Menucha</td>
<td>2.51</td>
<td>3.95</td>
</tr>
<tr>
<td>Mabroka</td>
<td>2.55</td>
<td>3.3</td>
</tr>
<tr>
<td>Mistikawi</td>
<td>2.70</td>
<td>3.7</td>
</tr>
<tr>
<td>Adams</td>
<td>2.70</td>
<td>3.4</td>
</tr>
<tr>
<td>Mabroka</td>
<td>2.71</td>
<td>3.25</td>
</tr>
<tr>
<td>Zrilin</td>
<td>2.72</td>
<td>3.6</td>
</tr>
<tr>
<td>Pairee</td>
<td>2.79</td>
<td>3.7</td>
</tr>
<tr>
<td>Maya</td>
<td>2.79</td>
<td>3.53</td>
</tr>
<tr>
<td>Zrilin</td>
<td>2.92</td>
<td>3.2</td>
</tr>
<tr>
<td>Bullock’s Heart</td>
<td>3.02</td>
<td>2.8</td>
</tr>
<tr>
<td>Langra</td>
<td>3.07</td>
<td>2.8</td>
</tr>
<tr>
<td>1/15</td>
<td>3.09</td>
<td>2.5</td>
</tr>
</tbody>
</table>

16 trees of degree 5 and worse had a mean size of 2.36

Maya: 49 trees of degree 2 to 4 had a mean size of 2.83

11 trees of degree 5 and worse had a mean size of 2.64

Mabroka: 52 trees of degree 2 to 4 had a mean size of 2.67

7 trees of degree 5 and worse had a mean size of 2.86

There is some influence confounded in these figures of the fact that soil tends to be lighter in the middle part of the orchard, thus trees smaller.

If we take the 70 trees of the three varieties in the two lowest blocks (2 were not measured because they were too small and both were degree 9) we get:

37 trees of degree 3 and 4 have tree size 2.95

16 trees of degree 5 and 6 have tree size 2.78

17 trees of degree 7 and worse have tree size 2.40

And finally taking only the 23 trees of the lowest block:

8 trees with degree 3 and 4 have tree size 2.35

12 trees with degree 5 and 6 have tree size 2.91

14 trees with degree 7 and worse have tree size 2.60

In mango trees there is a fairly high correlation between size of tree and yield (8). Thus it is to be expected that the trees which showed relatively less damage in the winter of 1963/64 would have had a relatively higher yield in the summer of 1963 than their less fortunate brothers.
Table 3. Degree of damage and mean yield (kg)

<table>
<thead>
<tr>
<th>Degree of damage</th>
<th>Varieties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Haden</td>
</tr>
<tr>
<td>1-2</td>
<td>42</td>
</tr>
<tr>
<td>3-4</td>
<td>31</td>
</tr>
<tr>
<td>5-7</td>
<td>26</td>
</tr>
<tr>
<td>8 or worse</td>
<td>10</td>
</tr>
</tbody>
</table>

We had expected that, for the same size, trees with higher yields—and thus less reserves—would have been more damaged. But the records do not show this.

Discussion and Conclusions

There is no doubt that we have found within one orchard of 500 trees in 25 rows and within a collection of 23 varieties considerable differences in the degree of damage to trees of different varieties.

The questions which arise from these observations are the following:
1. How far are we justified in speaking of specific sensibility or resistance of a given variety to low temperatures? Is this reaction only due to the different sizes of the tree and the different amounts of "microclimatic" protection that a tree can give to itself, or are we justified to assume some additional factors?
2. What are the practical lessons—if any—which can be drawn from these observations?

The 23 varieties fall into four groups, according to size of tree and degree of damage:

a. Three varieties with large trees and low mean degree of damage:
   Bullock's Heart, I/15 and Langra.
   Bullock's Heart is a very poor producer. The fruit is rather unattractive and, in spite of its good taste, can certainly not be grown commercially. Langra is the standard variety of northern India. It gives fair to good yields and the fruit has a good taste. But it lacks colour, a severe drawback for marketing both in Florida and Israel. I/15 has fruits of very good shape and colour, but the young trees have so far been rather disappointing in their yields.

b. The three standard varieties and six others form the second group. They rank in hardness from high to low: Zrifi, Mabroka, Zill, Adams, Maya, Pairee, Mistikawi, Menucha, Haden. But these differences are probably of little practical importance. Zill may be the best candidate for commercial production, but it is doubtful whether it will replace the standard varieties.

c. Four additional varieties—Davis-Haden, Shepard, Carrie and Gailour—are probably somewhat more tender than our standard varieties. Shepard has very beautiful fruits and Gailour superior taste, but neither will be grown commercially.

d. Seven varieties have been found very susceptible to low temperatures: Alfonso, Dasher, Fanzanson, Gedong, Kent, Edward and Irwin. Most of them form very small trees. Gedong has a medium sized tree, is rather prolific, extremely early and of good taste. Its tenderness is probably due to its tropical origin. Commercially, Irwin and Kent are very desirable varieties, but if they can be grown at all commercially in Israel, they will have to be planted only in extremely favourable locations.

We have, tentatively, reached the following conclusions:
1. All dwarfing varieties are very susceptible to low temperatures.
2. Only the varieties with very large trees are more resistant than our standard varieties.
3. There seems to be some specific difference in hardiness among the varieties with medium sized trees—especially Gedong is more tender than might have been expected from its size.
4. There is no variety in our collection which can be expected to be more hardy than our standard varieties and has, at the same time, all the other qualities needed in a commercial variety. The only possible candidate is our new selection I/15, if its trees will give sufficiently high yields on reaching maturity.

Summary

1. Observations are reported on the relative frost damage rating of 23 mango varieties, planted in replications in a young orchard in Israel.
2. The lowest temperature recorded in the orchard was 25°F.
3. The collection includes 5 local selections, 9 varieties from Florida and 9 Indian, Indonesian and Egyptian varieties.
4. The differences between the highest and the lowest part of the orchard were found to be highly significant.
5. No influence of rootstock on frost damage rating could be detected.
6. Larger trees suffered generally less frost damage than smaller trees, but the correlation is not highly significant within the three main varieties.
7. All dwarf varieties were found to be extremely susceptible to low-temperature damage.
8. The three most resistant varieties all have large to very large trees.
9. There may be some specific resistance factor, in addition to size of tree, related to the likelihood of low temperatures in the country of their selection; the variety Langra from northern India is very much more frosthardy than the variety Gedong from Indonesia.

LITERATURE CITED

EFFECT OF NURSERY STOCK SIZE ON PEACH YIELDS

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The rapid expansion of peach acreage in Florida has increased the demand for nursery trees to the extent that purchasers often overlook certain quality factors in order to obtain trees. Also, many Florida nurserymen are propagating peach trees for the first time without fully understanding the quality factors involved. Tree size is frequently used in determining price and needs to be related to its potential value in terms of production.

Savage and Cowart (2) reported that nursery tree size had no important effect on peach yields in Georgia. However, in one study, severe spring freezes completely destroyed the crops until the fifth growing season so that no data on early production were obtained.

Nursery peach tree grades are based on height and diameter (4). Within the usual grades the larger trees bring the highest price because it is thought that they may become the most productive.

PROCEDURE

These data were not derived from an experiment explicitly designed to study size of nursery stock. Data were utilized from fertility experiments, where growth response to nutrient levels was determined by trunk diameters. Measurements were made 4 inches above the bud union. Except where noted, June-budded trees were planted at random without regard for size. The orchards were divided into blocks (replications) for fertilizer treatments which were made at random without regard for tree size. Later the trees were grouped by sizes. Therefore, tree size was obtained without regard to location or fertilization.

Yield differences were measured under the same circumstances. Yield responses were obtained from another experiment, using the 'Flordawon' variety (1). Total yields were obtained for each tree. Growth was measured on 'Flordawon,' 'Tejon' and 'Early Amber.'

RESULTS AND DISCUSSION

Tree Size. The small trees did not attain the same size as the larger trees during the first year in the orchard (Table 1). The trees remained in their same size class despite a wide variation in fertilization. Growth response of these trees admittedly was poor during the first year, since well grown trees in Florida will increase about one inch per year during the first 4 or 5 years.

Second year growth in the orchard is shown in Table 2. These trees made better growth dur-