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# *Fruit Characters in Young Trees of Long-Established Nucellar Lines*

THE VALUE of nucellar embryony for obtaining virus-free lines of citrus was considered by Weathers and Calavan at the First International Citrus Virus Conference (4). At the same time, Cameron *et al.* (2) discussed horticultural aspects of nucellar seedling lines which are being used in California. The need to maintain high fruit quality and trueness to type within citrus varieties makes it important to study critically the fruit characters of lines which may be used commercially. If these characters differ from those of established lines, it should be determined whether the differences are genetic, and therefore permanent, or are continuing manifestations of juvenility. Some citrus virus diseases also affect fruit characters directly or indirectly, and it is useful to know the range of expression of all these effects.

Earlier studies (1) on mature nucellar-line trees of several varieties indicated that in most characters they were equal or superior to their old-line parents. However, certain fruit character differences were still detectable although the lines were then about 35 years old from seed. By 1957 (2), data on young orchard trees repropagated from some of these nucellar lines indicated that some differences were still being expressed. In the present paper we present data taken between 1957 and 1960 on young plantings of the Frost (nucellar) Marsh grapefruit and Washington Navel orange, compared with old lines of these varieties.

Since much California citrus goes to the fresh market, particular attention has been paid to physical characters of the fruit.

## *Materials and Methods*

The data on the Washington Navel oranges are from plantings by commercial growers in Tulare County, where this fruit is marketed from mid-November through February or later. These plantings consisted of one to a few acres of nucellar-line trees, usually with greater acreages of old-line trees nearby. At the McMaster ranch, all trees were planted in 1951 on sweet orange rootstock. At the Chase ranch, nucellar-line trees were planted in 1953 on Troyer citrange rootstock; unrelated old-line trees were planted in 1948 on sour orange. The Johnston trees (all nucellar-line) were planted in 1952 on trifoliate orange, Cleopatra mandarin, and Troyer rootstocks. Except at McMaster's, old-line trees were thus older from planting than trees of the nucellar line.

A sample (usually 20 fruits) was taken from each of 10 trees of each line in each planting early in the season, and sometimes again late in the season. Only healthy-appearing trees carrying relatively good crops were sampled. The fruits were visually graded for physical characters while spread out in groups so that several old-line and nucellar samples could be viewed at once.

Most of the Marsh grapefruit data are from the Coachella Valley, a hot desert area. The plantings varied from a few trees to several acres. At the Price Ranch, nucellar-line trees were planted in 1954 on Cleopatra mandarin and Savage citrange rootstocks. The compared old-line trees had been planted in 1932, apparently on sour orange stock. At the Seaview ranch nucellar trees were planted in 1953 on Troyer rootstock, while the old-line trees were perhaps 30 years of age, on undefined rootstock. In the Scanlon and Brown plantings, all trees were planted in 1956 on rough lemon rootstock.

Ten fruits were usually taken from each tree of each line on 3 sampling dates, for 3 seasons. With the young Scanlon and Brown trees, however, only one sampling was obtained (in April, 1960). Fruit was graded in the same manner as with the oranges.

Chi squares were calculated for all enumeration data. F values were calculated for testing the significance of the differences of peel measurements and juice percentage and composition data from the McMaster ranch and the Scanlon ranch. Because of fewer trees sampled, analyses were not made for these measurement data in the other plantings.

## *Navel Orange Comparisons*

PHYSICAL CHARACTERS.—In the earliest crops of some nucellar-line plantings, considerable numbers of fruits were tapered or rough at the stem end. Data on these and other characters for three seasons at the McMaster ranch and for the 1960 season at the Chase ranch are shown in Table 1. Fruit size has been rather similar between old-line and

TABLE 1. PHYSICAL CHARACTERS OF NUCELLAR- AND OLD-LINE WASHINGTON NAVEL ORANGES[a]

| Line[b] | Year planted | Percentage of fruits with stem end: tapered | Percentage of fruits with stem end: furrowed | Percentage of fruits with: Loose core | Peel thickness (mm) |
|---|---|---|---|---|---|
| | | *McMaster Ranch, 1958* | | | |
| Old | 1951 | 11 | — | 1 | 5.4 |
| Frost nucellar | 1951 | 11 | — | 14** | 5.8** |
| | | *1959* | | | |
| Old | 1951 | 1 | 56 | 0 | 5.5 |
| Frost nucellar | 1951 | 7** | 27** | 4 | 5.7 |
| | | *1960* | | | |
| Old | 1951 | 7 | 25 | 2 | 5.5 |
| Frost nucellar | 1951 | 16** | 6** | 10** | 5.4 |
| | | *Chase Ranch, 1960* | | | |
| Old | 1948 | 9 | 17 | 7 | 6.3 |
| Frost nucellar | 1953 | 21** | 20 | 3 | 6.1 |

[a]Data from 20 fruits of each of 10 trees of each line in each planting; November picks at McMaster's, December picks at Chase's. Asterisks indicate the 1 per cent level of significance of a difference of a value from the old-line value immediately above it.

[b]McMaster trees on sweet orange rootstock; old-line trees at Chase Ranch on sour stock, nucellar-line on Troyer.

nucellar-line in most samplings, and can scarcely account for differences in other characters. Fruit shape index (the ratio of transverse to longitudinal diameter) has been nearly identical at any one location in any one year, indicating that the nucellar-line fruits are not more elongate than old-line fruits. Despite this there has been a higher percentage of tapering stem ends in nucellar fruit at nearly every sampling. In some comparisons (Table 1) the differences have been significant. The fruit have had slightly rougher stem ends in most samplings. In contrast, furrowing or grooving of the peel at the stem end has seemed to be negatively correlated with tapering and roughness; that is, there has usually been a greater percentage of old-line fruits with furrowing. At the

McMaster planting the differences in furrowing have been significant.

Peel thickness has not been a problem in these nucellar-line plantings. The McMaster data suggest a slight decrease in peel thickness over the 3-year period, and in the other plantings very little difference between lines is evident. A greater tendency to loose cores has been evident in nucellar fruit at McMaster's, with the differences being significant in 1958 and 1960. In two other plantings not shown in Table 1, nucellar-line fruits in 1960 showed percentages of tapered or rough stem ends and core looseness which were in the range of those at the Chase planting. Differences in other characters which would affect the appearance of the fruit have not been consistently found. The effects of location, season, and age of tree on the expression of physical fruit characters have been apparent.

Observations indicated that unfavorable characters in nucellar-line fruits might be accentuated late in the season. Where fruit was available, samples were therefore taken late in the season as well as early. In 1959, stem-end taper, roughness, and core looseness were considerably greater late in the season. There was also a considerable increase in rind thickness at McMaster's in 1959. However, in 1960 there was little change in the incidence of any of the characters except loose core, over the season. Such changes are no doubt mainly due to continued growth of the peel and consequent tendency of the peel and fruit segments to separate. The incidence of unfavorable characters also increased in old-line fruit, but remained lower than with the nucellar-line.

JUICE PERCENTAGE AND COMPOSITION.—Three years of data from the McMaster planting show the nucellar line to be very similar to the McMaster old line in percentage of juice and in total soluble solids. The percentage of acid has been slightly higher in the nucellar line. In 1959, the difference was just significant at the 5 per cent point; in 1958 and 1960 it was not significant. These higher acid values result in slightly lower soluble solids:acid ratios, but the ratios have been well above the required 8:1 at the beginning of each marketing season. At the Johnston planting nucellar-line fruits have always been higher in soluble solids and acid than at McMaster's, and the ratios have always been 9:1 or higher at the beginning of the season.

## *Marsh Grapefruit Comparisons*

PHYSICAL CHARACTERS.—First crops of young trees of the Frost Marsh grapefruit in Coachella Valley, like those of the Washington Navel

orange in Tulare County, have shown certain undesirable fruit characters. Beginning in 1958, data were taken from the Price and Seaview plantings. Young trees of old-line grapefruit were not available in these plantings, so that compared old-line trees are much older from planting than the Frost nucellar trees. The nucellar-line trees have shown consistently higher percentages of tapered and rough stem end fruit than the older old-line trees. They have also shown more fruit with somewhat thick peel at Price's, and the differences in taper and peel thickness have usually been significant. The degree of expression of the characters has definitely declined during the 3 years of sampling. Unlike the Washington Navel oranges, these nucellar-line grapefruits have shown lower average fruit-shape indices, that is, less flattening. With light crops, they have also often shown larger fruit size.

In the Scanlon and Brown plantings, where all trees were young, both lines had generally greater percentages of fruit with poor physical characters than did the older plantings. However, the nucellar-line trees had higher percentages of such fruits than the old line. The differences in incidence of core hollowness and thick peel were significant. The nucellar-line trees also had lighter relative crops and larger fruit size.

One older Frost Marsh tree, planted in 1933 at the Citrus Experiment Station at Riverside, has been studied for several years in comparison with one old-line companion tree and some other old-line trees from another bud source of Marsh. The Frost Marsh tree and its companion are planted side by side, on sour rootstock, in a variety orchard. The trees of the other old line, on sweet stock, are part of a long-time fertilizer experiment, in treatments where favorable conditions have been maintained. The physical characters of the fruit of the Frost Marsh and its companion tree have been very similar, but the characters of the fertilizer-experiment trees have been somewhat better. At present, it is not known whether the difference is due to environment or to a genetic difference in the Frost Marsh.

JUICE PERCENTAGE AND COMPOSITION.—Fruit composition tests have been made for several years from the grapefruit trees discussed above. The older trees, at Riverside, have not shown consistent differences in percentage of juice or total soluble solids. Acidity, however, has been slightly lower in the Frost Marsh tree in most assays. In the Coachella Valley, from 1958 to 1960, the percentages of juice and soluble solids in the nucellar line have improved as the trees gained age. Percentages of acid have regularly been lower than in the older old-line trees. At the

Price and Seaview Ranches, old-line and nucellar fruit were rather similar in percentages of juice and soluble solids; acids were slightly lower in the nucellar line. At the Scanlon and Brown ranches, where all trees were only 4 years from planting, fruit composition characters were poor in both lines. Soluble solids in the nucellar line were equal to those in the old line, and acid was slightly lower in the nucellar line. Percentage of juice was also lower, but this is probably due to the lighter crops of larger-size fruit. Analyses of the data from the Scanlon Ranch indicate that the differences in percentage of juice, percentage of acid, and soluble solids:acid ratio are significant at the 1 per cent level.

## *Discussion*

The reasons for the observed differences in fruit characters are not entirely clear. Because of greater vigor, it can be expected that newly repropagated trees of either old or young lines will produce fruit inferior to that of older trees. This undoubtedly accounts for some of the differences found. However, the higher numbers of these fruits from nucellar-line trees when both lines are of the same age from recent planting suggests that effects of nucellar juvenility are still operating. The facts that two different citrus varieties exhibit these tendencies, and that physical characters seem to be improving with tree age and heavier crops, fit this supposition. Older trees of these lines at Riverside have differed little from compared old lines in these characters. Although the two nucellar lines had not been often repropagated until about 1950, it is surprising that such a degree of juvenility could still be discernible.

Unfavorable fruit characters have been more prominent in the grapefruit than in the navel orange. This has been correlated with extremely vigorous growth of the young grapefruit trees, and with slowness to come into heavy bearing.

Genetic differences may yet be found in either nucellar line. The slightly lower acid in the nucellar Marsh is suggestive of such a difference.

The contribution of the several rootstocks to differences between lines cannot be adequately evaluated. However, the vigorous growth of the nucellar lines on Troyer appears to have accentuated adverse fruit characters. Since differences were present even when the rootstock was the same for both lines, rootstock does not appear to be the primary factor involved.

Symptoms suggestive of stubborn disease have recently been observed

in some Frost Marsh trees in California. This disease has not been proved absent in the trees reported here, but they have been among the most vigorous in the plantings and the fruit characters discussed are not ones presently associated with stubborn disease.

The adverse characters noted in the 2 varieties have not been prominent in recent plantings of nucellar Valencia oranges and lemons. Similarly, nucellar Red Blush grapefruit lines in California do not seem to show these characters. Cooper *et al.* (3) state that in Texas the fruit size, shape, and quality of 8-year-old seedlings of Webb Red Blush grapefruit are essentially as good as in budded old-line trees.

More data are needed on the performance of nucellar lines of all the major varieties. Data are being taken at Riverside on a 1954 planting of additional Washington Navel lines originated by Dr. H. B. Frost, and on seedlings from the same lines. Dr. W. P. Bitters is also establishing nucellar lines of many of the better-known strains of Washington Navel.

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