THE INFLUENCE OF ROOTSTOCKS ON THE TEXTURE AND FLAVOR OF ORANGE FRUITS*

IN the South Australian State Irrigated Experiment Orchard, at Berri, a trial of various citrus stocks was inaugurated in 1913. The stocks used consisted of seedlings of Sweet Orange, Rough Lemon—sometimes called Citronelle—Seville or Sour Orange, Pomelo, and *Poncirus* (Citrus) *trifoliata*—the deciduous orange tree of Japan.

Five plants of each of the above stocks were budded to Washington, Thompson's, Buckeye, Nugget, and Navelencia, as representing navel varieties. Mediterranean Sweet and Valencia Late were used to represent the seed-bearing sweet oranges, whilst Dancy's Tangierine was adopted as the Mandarine type in the trials.

No special attempt was made to secure seedlings from trees of particular merit for rootstocks, but only healthy well-grown seedlings of the various species were utilised in the nursery.

The budwood, however, was all taken from trees, the habits of growth and fruiting of which had been under observation for some years in the State Orchard, at Adelaide, where the work of propagating the trees was conducted. In each instance the same tree yielded the budwood which was used of that particular variety for working over its quota on each kind of stock.

The full range of varieties quoted above as having been worked on Sweet Orange and Rough Lemon stocks was planted out in 1913. Those on Seville and Pomelo rootstocks were set out in 1915, and the final lot, consisting of three trees only of each variety on the Trifoliate orange, was planted out in 1922.

The plot of land devoted to these trials is composed of the very coarse reddish sandy pine ridge loam characteristic of the Murray Valley. It ranges between 2 ft. to 4 ft. in depth over a rubbly marl. The surface is slightly sloping towards the east, and on the whole it is well drained and admirably adapted for citricultural purposes.

At the time of making the juice tests outlined herein the trees on the Sweet Orange and Rough Lemon stocks had fruited over a period of 14 years, with the exception of the Valencia Late, which had borne for 12 years only.

The trees worked on Seville and Pomelo stocks had cropped from 10 to 12 seasons, whilst the whole series growing on the Trifoliate stocks had seven years of cropping recorded to their credit.

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* By George Quin, Chief Horticultural Instructor, Department of Agriculture of South Australia in Bulletin No. 276.

These facts as to the origin and ages of the trees are briefly stated to indicate that at least some of the important factors which might make for varying qualities in the fruits had been much reduced, if not wholly eliminated. Such matters as the relative affinities displayed between the different rootstocks and scion varieties worked on them, or the comparative habits of growth and branch developments, or quantitative yields of oranges are not for the present under review, excepting to remark, in passing, that without exception the trees are normally healthy, thriving, and yielding well.

In planning the research conducted during the orange harvesting season of 1931, trees were selected from which fruits were gathered at fortnightly intervals extending from May 22nd to July 31st in the cases of the Washington and Thompson's Navels, from August 28th to October 23rd in that of the Mediterranean Sweet, and from August 28th, 1931, to February 26th, 1932, the Valencia Late fruits were harvested. The two rootstocks on which the Washington and Thompson's Navel fruits were produced were Sweet Orange and Rough Lemon, whilst those of Mediterranean Sweet and Valencia Late were taken from trees worked on Sweet Orange, Rough Lemon, Pomelo, and *C. trifoliata* respectively.

The procedure adopted consisted of gathering 12 oranges fortnightly from each selected tree. Six of these gauged from $2\frac{1}{2}$ in. to $2\frac{3}{4}$ in. in diameter, representing the smaller fruits, and the other half dozen gauged 3 in. to $3\frac{1}{2}$ in. in diameter, thus placing them among the larger sizes. As the season advanced it became impossible to adhere exactly to these sizes in so far as the Mediterranean Sweet and Valencia Late sorts were concerned. Owing to the shortage of crop on the selected trees of Mediterranean Sweet worked on both *C. trifoliata* and Pomelo, slight variations and estimates had to be made, which can also be noted in lists containing the working data.

Each orange when cut from the tree had a label enclosed in its wrapper giving full particulars of its origin and grade. The whole series of sizes and varieties were then carefully packed and forwarded to the office of the Horticultural Branch Department, in Adelaide, for testing. The whole of the analytical work and calculations were conducted by Mr. E. W. Pritchard, Agricultural Botanist, who is a skilled analyst and associate of the Australian Chemical Institute. Each half dozen fruits was weighed, and each orange halved equatorially prior to the halves being rotated under hand pressure on a fluted conical glass lemon squeezer until no more juice could be released from the pulp. The juices of the six fruits were then blended and strained through a wire gauze sieve having 24 meshes to the inch, and weighed, thus giving the data for calculating the percentage of juice by weight to the total weight of the whole oranges. As the acids and sugars dissolved in the juicy pulp of an orange are the principal factors which make for a balanced and attractive flavor in the fruit, these alone were determined. The former by titrations with N/10 soda solution, and the latter estimated from readings of the scale on the Brix hydrometer. Using a few drops of phenolphthalein solution in the juice as an indicator of changing color, the number of cubic centimetres of the soda solution required to neutralize 10 c. cs. of the blended juices was determined. If the percentage of acidity as citric acid is desired, it may be ascertained by multiplying the number of c. cs. of the soda solution by ·07.

In addition to the above chemical and physical determinations the texture of the pulp of each lot was recorded by the use of the letters S. for "satisfactory," M. for "moderately raggy or fibrous," and R. for "very raggy or fibrous". A palate test was also used by setting up a scale of impressions indicated as under, V.S. very sour, S. sour, T. tart, T. Mod. moderately tart, Sw. sweet, and V.Sw. very sweet. Each sample of mixed juices was submitted to three or four persons at random for tasting, and the majority agreement recorded as to which term should apply.

The standard of maturity originally adopted in several Australian States was founded on the acidity thus determined from the mixed juices of five oranges selected at random. When not more than 23 c. cs. of N/10 soda solution were required to neutralize the acids in 10 c. cs. of the juice the fruits were deemed to be palatable and wholesome. It was found, however, that fruits containing greater acidity were often made palatable by the presence of a high percentage of sugar in the juice, and conversely oranges with low acidity could, owing to the paucity of sugars in their juices, appear very sour to the palate. Further, when acids and sugars are both very low in the juice the oranges usually become insipid to the taste. In the tests under review this feature was more particularly in evidence in the juices of Thompson's Navel fruits from trees grown on Rough Lemon rootstocks. There may be numerous other reasons for the occurrence of these variations in the proportions of the principal factors which make for palatability in an orange, but the data obtained thus far would seem to indicate that the kind of rootstock used may yet prove a not inconsiderable cause in securing both juiciness and good flavour.

One fact pointed out by other investigators is consistently emphasised by the figures presented in these studies—excepting in those relating to the Valencia Late—and that is, that quite irrespective of variety of orange or of the kind of rootstock used, under ordinary conditions the comparative sizes of the oranges on a tree afford an indication of their respective advances towards maturity. In other words, the juice of an average small orange—up till mid-harvest period at any rate—may be calculated to contain a higher percentage of acid than the large one picked from the same tree and at the same time.

ACIDITY

The fruits of Thompson's Navel, when grown on the Sweet Orange rootstock, displayed appreciably greater acidity than those from trees worked on the Rough Lemon. In the small sized fruits it ranged from the equivalent of 15·6 c. cs. to 12 c. cs., with an average through the testing period of 13·71 c. cs. of the soda solution. In the large fruits a variation of from 16·5 c. cs. to 9·8 c. cs., with a season's average of 13·15 c. cs. was recorded. The fruits of this variety, when worked on the Rough Lemon stock, showed in the smaller sizes a range from 13·8 c. cs. to 9·6 c. cs., with an average of 11·28 c.cs., whilst the large oranges extended from 14·3 c.cs. to 8·9 c.cs., with an average of 11·21 c.cs.

In the case of the Washington Navel on Sweet Orange rootstock, the small fruits extended from 18·2 c.cs. to 12·0 c.cs., averaging 15·3 c.cs., with the large sized fruits showing from 18·7 c.cs. to 11·2 c.cs., or an average through the season of 14·5 c.cs. The fruits of this variety worked

on Rough Lemon ranged in the smaller sizes from 15·3 c.cs. to 11·0 c.cs., averaging 13·18 c.cs., and in the larger sizes from 15·2 c.cs. to 10·4 c.cs., or an average of 13·01 c.cs.

When the data from the small and large fruits of Thompson's Navel worked on Sweet Orange are aggregated their average acidity is equal to 13·43 c.cs., and the oranges grown on trees of this variety worked on Rough Lemon rootstocks averaged 11·25 c.cs. Making similar aggregations of the fruits of Washington Navel grown on Sweet Orange rootstocks an average equal to 14·90 c.cs., and from fruits of this variety grown on Rough Lemon rootstocks the acidity stated in terms of c.cs. of N/10 soda solution is only 13·10. It would appear from the above that the acidity in the fruits from Thompson's Navel trees grown on Rough Lemon stocks is approximately 16·25 per cent. lower than that in fruits of the same variety when grown on Sweet Orange seedling stocks. In the case of Washington Navel the acidity in fruits produced on Rough Lemon rootstocks is calculated to be 12·08 per cent. less than in those grown on the Sweet Orange rootstocks. It will be noted that the first lot examined was not necessarily the most acid in the season's work, neither was the decline in acidity found to follow any regular graduations from fortnight to fortnight, excepting in Valencia Late fruits.

SUGARS (AS SUCROSE)

It will be noticed from the accompanying tables of figures that the total sugar contents of the Thompson and Washington Navel oranges varied only very slightly throughout the 10 weeks from May 22nd to July 31st, though they are consistently higher in fruits from trees of both varieties when worked on the Sweet Orange rootstocks. In all cases, irrespective of variety or stock, the smaller navel fruits consistently displayed a slightly higher percentage of sugar content than was found in the larger sizes.

The average percentage of sugar found in Thompson's Navel fruits of small and large sizes grown on Sweet Orange stocks was 12·24, and when taken from trees on Rough Lemon 11·14 per cent. Washington Navels of both sizes produced on Sweet Orange stocks an average percentage of 11·15, and from similar fruits grown on Rough Lemon stocks the average percentage was 10·85.

JUICE (PERCENTAGE BY WEIGHT OF WHOLE FRUIT)

With one exception in each of the series the percentage of juice by weight to that of the whole fruits was slightly lower in the small sized oranges, but these differences were negligible. In each instance, however, fruits of both varieties carried more juice when grown on Sweet Orange stocks than on the Rough Lemon.

The Thompson's Navels on Sweet Orange stocks averaged 34·80 per cent. as against 33·23 per cent. from fruits produced on Rough Lemon stocks, whilst the Washington Navels displayed averages of 41·75 per cent. on Sweet Orange and 40·65 per cent. on Rough Lemon stocks.

Of the eight series of tests made with these two navel varieties the fruits in five of them, which were gathered on May 22nd, displayed the highest percentage of juice found throughout the series. Of the Thompson's Navel one each of these extra juicy lots was grown on Orange and Lemon stocks respectively, whilst in the case of the Washington Navel two were grown on trees worked on Orange and one on Lemon rootstock.

PALATE DETERMINATIONS

The larger sized fruits of Thompson's Navel grown on trees on Sweet Orange stocks were classed as "sweet" on June 5th, but the smaller sizes did not reach this condition until the third picking on June 19th—a fortnight later.

On the Rough Lemon stocks fruits of this variety, both small and large, were classed as "sweet" on May 22nd.

The larger sized Washington Navels grown on Orange rootstocks were deemed to be "sweet" on June 19th, but the smaller sizes were not classed as "sweet" until a fortnight later, that is, on July 3rd. The smaller fruits grown on Rough Lemon rootstocks were declared "sweet" to the palate when tasted on May 22nd, but were more consistently so four weeks later, when the larger sized oranges were classed as "sweet" on June 19th. It will be seen, therefore, that Thompson's Navel oranges of various sizes taken from trees on Rough Lemon stocks are classed as "sweet" from two to four weeks earlier than when this sort was produced on Sweet Orange stocks.

The Washington Navel fruits from trees on Rough Lemon stocks could be declared consistently sweet on June 19th, and the larger sizes from trees on Sweet Orange stocks from June 19th also, but the smaller sized fruits did not reach this condition until July 3rd—a fortnight later.

TEXTURE OF PULP

The texture of the pulp is gauged from the comparative proportions and coarseness of the "raggy" fibrous tissues which envelop and separate the juice sacs. This ragginess appears to be frequently an evidence of "dryness", or lack of juice in the pulp. In the case of Thompson's Navel fruits—which have an unenviable reputation for developing ragginess—the orange rootstock would appear to exercise an appreciable influence towards the reduction of this undesirable quality in the pulp as compared with similar fruits from trees of the variety when growing on Rough Lemon rootstocks. The pulp of the fruits of Washington Navels, whether taken from trees worked on Sweet Orange or Rough Lemon, in none of these tests were classed other than as "satisfactory," which implies the absence of anything other than normal development of the essential fibrous tissues found in and around the edible pulp of the orange.

Taking the average throughout the season of the acidity, sugar and weight of juices found in the small and large fruits combined, the following table enables a comparison to be drawn between the effects of the two rootstocks on the principal constituents of the Washington Navel and Thompson's Navel oranges:

	Sweet Orange Stocks	Rough Lemon Stocks
Acid—	c. cs.	c. cs.
Washington Navel	14·90	13·09
Thompson's Navel	13·43	11·24
Sugar—	per cent.	per cent.
Washington Navel	11·15	10·85
Thompson's Navel	12·24	11·14
Juice—	per cent.	per cent.
Washington Navel	41·75	40·65
Thompson's Navel	34·80	33·23