According to Hendershott (4), oranges generally cooled approximately to 24° before ice crystals first formed, the fruit temperature then rises to around 28°, and it stays there as the fruit continues to form ice. It takes several hours for fruit to freeze solid. Injury is in direct proportion to the number and the length of time that ice crystals are present in the fruit. Thus, by turning on a wind machine at an early hour and allowing it to run until 9:00 o'clock or later in the morning, the total time that fruit would be at a freezing temperature is reduced. This in turn will markedly reduce the amount of cold injury. Thus, on cold nights when temperatures will be critical for a long period of time, there will be marked advantage to turning on wind machines at a relatively high temperature and allowing them to run into the daylight hours. On the other hand, if conditions are not such that fruit will be below 26° for four or more hours, cold protection is probably unnecessary.

There can be no hard and fast rule as to the temperature at which a machine should be started. This must be a decision to be made for each individual location, for the temperatures that are expected to occur, and for the type of fruit or foliage that is to be protected.

Conclusions

1. Wind machines as presently being sold in Florida are effective for frost protection in Florida citrus groves.
2. For maximum effective coverage in a square 10 acre grove, wind machines should be located no more than 100 feet from the northwest corner of the block. It is probable that maximum coverage in the block would be obtained if the machine were placed at the extreme northwest corner.
3. Dual headed machines, unless the propellers are operated in tandem rather than opposite directions, probably cover very little, if any, greater area than a single headed machine, but the area covered probably has increased cold protection.
4. When heaters are used in conjunction with wind machines, they should be placed in those places within the wind machine's area which are apt to be the coldest.
5. The time at which a wind machine should be started must be determined specifically for each location and is a function of whether fruit or foliage is to be protected, and upon the expected intensity and duration of cold. Under extremely severe cold conditions, machines should be started when air temperatures are above 32° and the machines should be run until temperatures have returned to above 35° in the morning.

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RELATION OF COLOR TO QUALITY IN MURCOTT HONEY ORANGES

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Thirty-eight samples of Murcott Honey oranges grown on each of four rootstocks were analyzed monthly throughout two seasons, 1959-60 and 1960-61. Relative chlorophyll absorption, peak wavelength of transmittance, Hunter "a" value, total solids (total soluble solids, principally sugars), total acid (calculated as citric acid), and solids-to-acid ratio were determined. Chlorophyll absorption, peak wavelength of transmittance, and Hunter "a" value changed progressively as greenness dis-

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appeared and orange color increased, as total solids and solids-to-acid ratio increased and as total acid decreased over each season.

Chlorophyll absorption, peak wavelength, and Hunter "a" value were highly correlated to consumer acceptance measured by taste tests. Correlations between the solids-to-acid ratio and taste were not as good.

This indicates that color measurements might aid in evaluating fruit quality as determined by consumer acceptance tests. Color determinations are non-destructive and could be applied to individual fruit for close measurements.

Introduction

Quality in citrus fruit has long been measured empirically by determining total solids and total acid of the juice *(5)*. A ratio of these determinations is the generally accepted measure of quality in citrus fruit *(4, 5, 14)*. Rind color and volume of juice are also factors in maturity requirements.

A study of other methods of determining citrus fruit quality was made on the Murcott Honey orange (hereinafter called Murcott). Seasonal changes in fruit color and quality were studied in relation to changes in physical characteristics and chemical analyses. The acreage of this variety has increased greatly in the last decade because of its excellent internal quality, shipability, fine appearance, and demand as a gift-box fruit at a premium price.

The general characteristics of the Murcott were reported by Deszyck and Ting *(3)*, Long and Sunday *(12)*, and Morse *(13)*. The relation of citrus juice color to quality and consumer acceptance was studied by Barron and Olsen *(1)*, Huggart and Wenzel *(6, 7)*, and Long and Sunday *(12)*. They found that the Hunter Color and Color-Difference Meter values changed as the fruit matured. Long and Childs *(9)* found that "rind color inversion" of Temple oranges showing "stylar-end greening" accompanied inversion of the internal physiological gradients. Since both color and quality change as the Murcott matures, the relationship between these factors was further investigated.

Materials and Methods

Color Measurements.—The color of an object is evaluated by the color of light that is reflected from the surface. The rind color of a Murcott changes progressively from green to yellow to orange as the fruit matures. The flesh color and juice color change from a light yellow to a deep orange color.

The Hunter Color and Color-Difference Meter (referred to hereinafter as the Hunter) was used to measure the color characteristics of the reflected light *(8)*. The Hunter "a" value was found to be most indicative of change with maturation. The Hunter "a" values when plus indicate redness and when minus indicate greenness, the complementary color. Results obtained by Huggart and Wenzell *(6, 7)*, Long and Sunday *(12)*, and Ting, Sites, and Deszyck *(16)* indicate that the "a" value is probably the best measurement of citrus fruit color since the a/b ratio requires calculation.

The amount of light transmitted through an intact fruit was measured by the Horticultural Spectrophotometer (referred to hereinafter as Hortispect) *(2, 15)*. The color spectrum between 425 and 725 mu (millimicrons) was scanned and the optical density recorded by a strip-chart recorder. The wavelength of light that penetrates the fruit in greatest amount (wavelength of peak transmittance) was recorded from the wavelength dial. The relative amount of chlorophyll present was recorded as the difference in light transmittance between 695 and 675 mu. As the chlorophyll disappeared, the transmittance at 675 mu increased.

Fruit Samples.—Plots were sampled monthly from December through April. Each sample consisted of 100 Murcotts, 10 fruit from each of 10 trees grown on rough lemon, sour orange, Cleopatra, or sweet orange rootstock in a previously selected plot. Thirty-eight samples were analyzed during the two seasons. The fruit was picked from the outside of the tree between knee and shoulder height. Twenty-five fruit, typical of the entire lot in color and size, were chosen for chemical analysis, and the fruit was arranged in order of increasing greenness. Fruit number 1, 6, 11, 16, and 21 were used for the color measurements with the Hunter and Hortispect. Two determinations were made with the Hunter near the equator of each fruit. The instrument was standardized with a light yellow tile using a one-inch aperture. One determination was made on fruit with the Hortispect, placing the blossom-end toward the light source. The peak wavelength was read from the wavelength dial, and the chlorophyll absorption determination was read from the strip-chart with a "chart-reader" developed by the author. The determination was calculated as the optical density difference value between 695 and 675 millimicrons. None of the fruit was damaged by the color measurements.

Fruit Analysis. – The 25-fruit sample was weighed, the fruit halved, and the juice extracted with a pressure-type extractor *(4)*. The juice was separated from the seeds and pulp by squeezing it through cheesecloth. The juice volume was measured in a graduated cylinder and then weighed. Total solids of the juice were determined with an Abbe' refractometer, and the readings were corrected for temperature. The total acid of duplicate 25-ml. aliquots

Table 1.--Linear correlation coefficients (r) between color and quality measurements of Murcott Honey oranges

Measurements	"r" value 1/ 1959-60	"r" value 1/ 1960-61
Hunter "a" value:		
Taste	0.98	0.99
Total solids	.83	.78
Percent juice	.66	.36
Total acid	-.55	-.66
Hortispect:		
Chlorophyll absorption--		
Taste	.90	.92
Total solids	.81	.76
Percent juice	.53	.39
Peak wavelength--		
Taste	.94	.96
Total solids	.91	.89
Percent juice	.70	.29
Solids-to-acid ratio:		
Taste	.89	.83
Total acid:		
Taste	-.49	-.73
Total solids:		
Total acid	-.69	-.65
5 percent level of significance	.47	.44
1 percent level of significance	.59	.56

1/ N = 18 in 1959-60, 20 in 1960-61.

was determined by NaOH titration using phenolphthalein as the indicator.

Taste Tests.—The 75 fruit of the taste test sample were cut into halves and two wedges cut from each half for the taste test. Each panel member tasted several slices and reported an average value for the sample. The score card devised by Harding, Sunday and Davis *(4)* was used; a rating of 70 indicates that the fruit was of borderline acceptability. Ratings above 70 indicate higher degrees of consumer acceptance. The size of the panel varied from 29 to 46 people.

Results

Color Values.—The Hunter "a" values were minus in December, became plus in January, and increased during the remainder of the season. These results indicate disappearance of the chlorophyll and the development of a yellow and orange rind color.

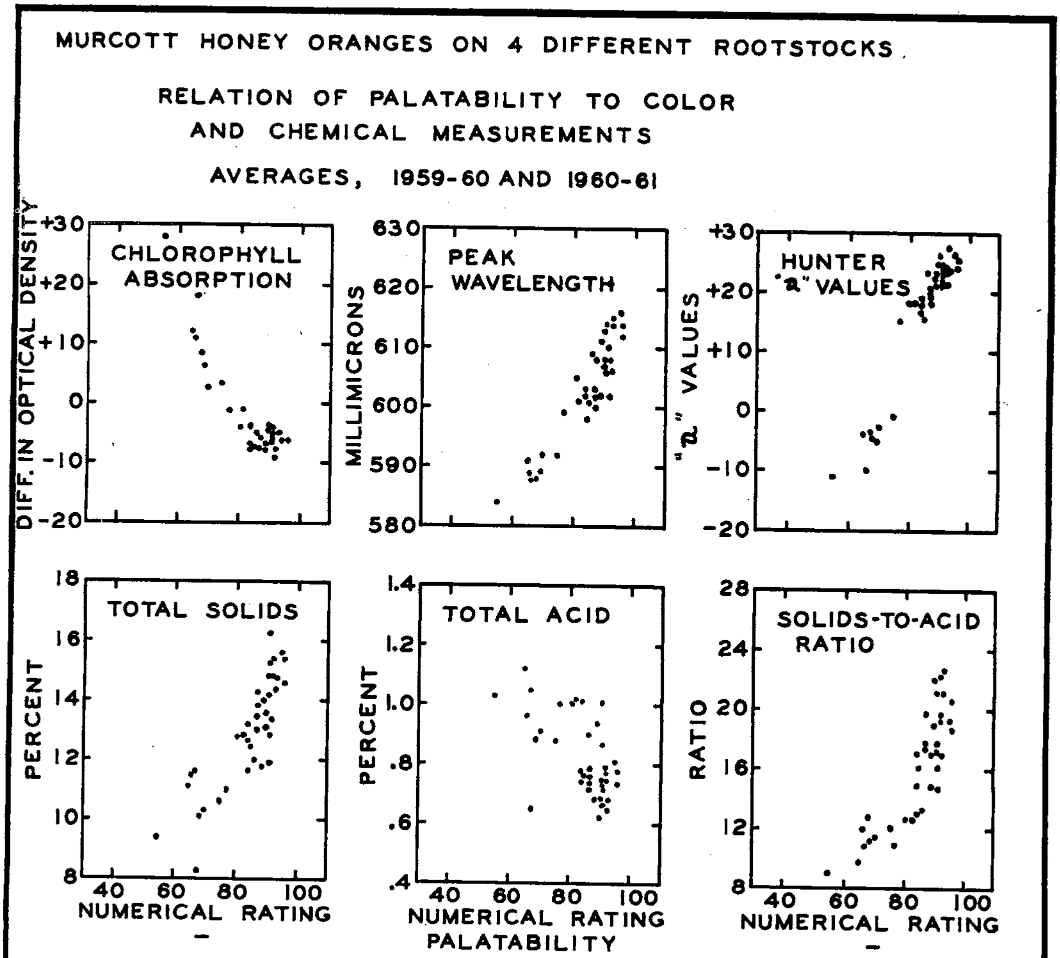

Figure 1.—Relation of palatability to relative chlorophyll absorption, wavelength of peak transmittance, Hunter "a" value, total solids, total acid, and solids-to-acid ratio of Murcott Honey oranges on four rootstocks. (1959-60 and 1960-61)

Hortispect results showed that the absorption due to chlorophyll decreases as the fruit matures. The December samples reflected positive values; the January samples reflected negative values; and these values became increasingly more negative as the season progressed, indicating that the rind degreened almost completely by January. The peak wavelength increased from a low of 584 to 621 mu during the season, December through April.

Juice Analysis.—Analysis of the juice showed that total solids increased greatly between December and January and changed slowly thereafter. Total acid decreased, while the solids-to-acid ratio increased slowly throughout the season. In 1960-61 the fruit was late in maturing.

Taste Tests.—Results of the taste tests indicated that most fruit samples were not acceptable in December. Consumer acceptance of the fruit increased greatly between the December and January samples. The improvement was slower after this period. Fruit were not overripe or dry in April.

Discussion

Previous studies of seasonal changes in Murcotts showed that typical changes occurred in the total solids, total acid, and solids-to-acid ratio *(4, 5, 14)*.

The correlation between consumer acceptance, as measured by taste tests, was better related with the Hunter "a," peak wavelength, and chlorophyll absorption measurements than it was with solids-to-acid ratio, total solids, or total acid (table 1). The scatter diagrams for Hunter "a" values, peak wavelength, and chlorophyll absorption plotted with flavor show less scatter than those for total solids, total acid, and solids-to-acid ratio plotted with taste (fig. 1).

The Hunter values are reduced by rind blemishes such as melanose, russeting, and similar injuries. The amount of the reduction depends upon the intensity and extent of the blemishes. The Hortispect readings were not affected by rind blemishes apparently. Since Florida fruit is usually affected with melanose or russeting, the Hunter "a" value usefulness may be limited.

Linear correlation between two factors is more significant as its coefficient (r) increases from 0 toward 0.99. These coefficients were highest between Hunter "a" value and taste (table 1), slightly less for peak wavelength, and still less for chlorophyll absorption. Consumer acceptance was more highly correlated with each of these characteristics, however, than it was with total solids, solids-to-acid ratio, and total acid. Correlations betweeen total acid or percent juice and taste were sometimes not statistically significant (table 1). These results are substantiated by those that were obtained graphically (fig. 1).

Some variation between fruits occurred because fruit sets over a period of two weeks or longer and because fruit samples were collected randomly and were not selected for uniform color.

Color measurements by the Hunter or Hortispect do not damage the fruit. The measurement could be applied to each fruit.

Light transmittance and light reflectance have been used for grading eggs (blood spots), separating brown and white eggs, determining weevil and smut content of grains, and studying color and quality of deciduous fruit *(2, 15)*. Whether the transmittance or the reflectance methods are practical in "color grading" of citrus fruits for quality remains to be proven.

Based upon the results obtained: (1) Larger correlation coefficients for color measurements, and (2) less scatter in the diagrams in figure 1, it would appear that a more thorough investigation of the relation of internal quality and color of citrus fruit should be made.

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A COMPARATIVE EVALUATION OF ROOTSTOCKS FOR VALENCIA AND PARSON BROWN ORANGES ON LAKELAND FINE SAND

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While the search for new rootstocks of superior performance and adaptability continues unabated it is important that the rootstocks now commonly used be critically re-evaluated, not simply in terms of boxes of fruit produced but also as to pounds of solids produced. The rootstocks in the experiment here reported have, with one exception, been used commercially for many years and much has been learned by experience regarding their performance and characteristics. However, a valid comparative evaluation of these rootstocks is not possible from scattered commercial plantings because of differences in location, soil, age of trees, budwood source, and cultural practices. The present work evaluates the commonly-used rootstocks in a single uniform planting under strictly comparable conditions over a 17-year period.

An extensive literature exists on the many effects of citrus rootstocks, not only on the growth and productivity of the scion variety (1), but also on various fruit characteristics including size, color, and chemical composition (4). A review of the literature, even as it may relate to this experiment, would be not only impractical but unprofitable because of differences between the rootstocks and scions here included and those reported elsewhere. There have been two earlier publications on this experimental planting which contribute to the overall study (2, 3).

Procedures

Stock and scion varieties.—The test planting consisted of 2 sweet orange scion varieties—Valencia and Parson Brown—both old-line selections carrying one or more citrus viruses. Both were budded on 7 rootstocks: Sour orange No. 3 (a selected tree at Eustis), sour orange-A (commercial seed), Rough lemon (commercial seed), Duncan grapefruit[1] (a selected tree at Eustis), Cleopatra mandarin (a selected tree in the USDA variety collection at Orlando), Rusk citrange (USDA planting at Glen St. Mary, Florida), and sweet orange (variety Parson Brown). In addition to these budded trees, some of the same Parson Brown seedlings which were used as rootstocks were included in the experiment as unbudded nucellar seedlings. The trees were planted in the test block near Tavares, Florida, in the fall of 1942.

Experimental design and soil type.—The 2 scion varieties on each rootstock were planted in 3-tree plots randomized within blocks for each variety. The blocks were replicated 13 times. The soil, a fairly good grade of Lakeland fine sand with the clay layer 6 to 8 feet below the surface, had no previous history of cultivation. The test planting received uniform and adequate fertilization, pest control, and soil management but no irrigation. Despite some soil variability within the area, the large number of replications generally lent statistical significance to relatively small differences in growth, yield, and other performance data.

Data collected. — Tree size was measured every year for the first 5 years and subsequently about every other year. Relative tree size is

[1] The tree which supplied the seed for these grapefruit stocks is listed in USDA records as "Bowen" grapefruit. E. M. Savage, now retired from the U. S. Department of Agriculture, recalls that his father, Frank Savage, secured buds about 75 years ago from a block of seedy grapefruit from the Bowen grove 7 miles northeast of Eustis, Florida. This block of grapefruit produced well and was considered to be somewhat earlier in fruit maturity than other seedy grapefruit in the area. Frank Savage propagated a number of trees from these buds and planted them in his home grove at Eustis where some of the trees are still thriving. He called these trees "Bowen" grapefruit to designate the budwood source, and the name has carried over into USDA records. In early hybridization work, these trees were used as a parent in crosses which produced many of the tangelos and also trifoliate-orange hybrids. Recently we carefully compared the "Bowen" with the Duncan grapefruit as to fruit character, number of seeds, and seed characteristics and were unable to find any points of difference. In this report, therefore, we have used the name Duncan rather than perpetuate confusion by calling this variety Bowen grapefruit.