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EFFECTS OF MATURITY CHANGES ON NONDESTRUCTIVE MEASUREMENTS OF CITRUS
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Effects of Maturity Changes On Nondestructive Measurements Of Citrus Fruit Quality

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Effects of Maturity Changes on Nondestructive Measurements of Citrus Fruit Quality

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SUMMARY

Studies on Hamlin and Valencia oranges and Marsh grapefruit were conducted during three seasons, beginning in the fall before Hamlin oranges were mature and continuing to the end of the season for each variety. Data were obtained on changes by a number of nondestructive measurements. These included measurements of color by light transmission, firmness, weight, size, and specific gravity. Destructive measurements were internal color, weight, seeds, juice content, soluble solids, and acid analysis. Twenty-eight measurements were made on each individual fruit in the 20-fruit samples.

Statistical analysis showed significant differences among tests in each series in nearly all observations. Fruit weight, size, juice content, and soluble solids increased, and chlorophyll level, firmness, percentage of rind and percentage of acid decreased. Some differences among varieties in the pattern of change were noted, and differences among seasons were apparent in some variables including fruit size, chorophyll, number of seeds, percentage of acid, and solids-to-acid ratio.

INTRODUCTION

Findings from previous research on maturity changes in citrus fruit (*20, 21*) have served as a basis for establishing regulations for grades and standards for Florida citrus fruits.[1] These regulations have enabled the industry to make great advances in improving fruit quality. However, occasional problems still occur because of the range in quality within fruit lots. These problems are more apparent at the start of each season and are particularly serious in shipments of fresh fruit. Although a low quality fruit may pass the present grading system and be unnoticed in a processed product, such fruit may be quite apparent to the consumer of fresh fruit.

This study was undertaken to determine the potential application of newer procedures in the evaluation of citrus fruit quality.

[1] Italic numbers in parentheses refer to Literature Cited, p. 40.

Nondestructive measurements as well as standard chemical analyses and several other measurements were included to provide a broad base for evaluation. Only changes occurring during the season are reported here. Relationships between various measurements will be evaluated in a separate report.

Changes occur slowly in mature citrus fruits, but with the long harvest period these changes may be considerable. Increases in weight were found in Washington Navel (*9, 12*), Hamlin (*21, 48, 54*), Valencia (*2, 13, 33, 36, 43, 48*), Murcott (*34*), and Shamouti (*19*) oranges, and in Marsh (*20, 42, 46, 54*), Duncan (*20*), and Ruby Red (*29*) grapefruit. Changes in volume were comparable to changes in weight (*24, 42, 48*). Similar increases in diameter or circumference were reported for Washington Navel (*9, 12*), Hamlin (*21*), Valencia (*2, 13, 33, 36*), Murcott (*34*), and Shamouti (*19*) oranges and for Marsh (*20, 42*) and Duncan (*20*) grapefruit. Changes in these measurements were greatest early in the season with smaller, if any, changes occurring later. Some decreases occasionally were indicated, particularly in overmature fruit.

The specific gravity of oranges did not change with increasing maturity. Results for Valencia included values of 0.98-1.00 (*51*), 0.89-0.95 (*63*), 0.92-0.94 (*56*), Washington Navel 0.87-0.92 (*63*), 0.93-0.97 (*56*), Pinapple 0.995 (*51*), and Shamouti 0.95 (*19*) oranges. Stout (*60*) in a study on freeze-damaged oranges reported a range of 0.55 to 1.10 in specific gravity for Valencia oranges with the lower values resulting from freeze damage. With Marsh grapefruit, a decrease from 0.87 to 0.73 was reported with increasing maturity (*27*). Other researchers reported values of 0.87 (*51*), 0.79-0.82 (*56*), 0.81-0.85 (*60*), 0.68-0.76 (*24*) for Marsh, 0.82 (*24*) for Redblush, and 0.86 (*51*) for Silver Cluster grapefruit, with no indication of a seasonal change in mature fruit. On an unidentified grapefruit, specific gravities of 0.83 to 0.93 were reported for the intact fruit and 1.00 to 1.11 for the peeled fruit (*35*).

Most of the research on citrus fruit maturity has been limited to changes in chemical analyses. Of these, increases in sugar or soluble solids with maturity have been found in Hamlin (*21, 37, 38, 48*), Valencia (*2, 13, 33, 36, 38, 48, 51, 55*), Murcott (*34*), Washington Navel (*3, 12, 38*), and other varieties of oranges (*21, 33, 37, 38*). At the same time, decreases in total acid content of the juice were found in Hamlin (*21, 37, 38, 48, 54*), Valencia (*2, 12, 33, 36, 38, 43, 48, 51, 55*), Murcott (*34*), and Washington Navel (*3, 12, 38*) oranges. These changes resulted in increased solids-to-acid ratios in Hamlin (*21, 37, 48*), Valencia (*12, 13, 36, 48, 55*), Murcott (*34*), and Washington Navel (*3, 12*) oranges.

In grapefruit analyses, changes were much smaller and less consistent. Some increase in soluble solids was generally found early in the season with little subsequent change in Marsh (*20, 24, 42, 46*) and a seedling (*22*). A decrease in soluble solids was found in Ruby Red (*29*) but no change was found in Redblush (*24*). Data on acid content showed similar variability with results ranging from little change to a decrease. Changes in solids-to-acid ratio were slight or showed some increase in Marsh *(20, 24, 42, 46)*, Ruby Red (*29*), Redblush (*24*), and a seedling (*22*) grapefruit. Apparently, at least part of the variability of results reported was related to differences in the length or part of the season during which fruit was sampled.

Changes in juice content generally followed changes in fruit weight (*18. 34*). The percentage of juice in fruit has varied, however. With Valencia oranges, juice content has ranged from little if any change (*21, 51, 55*) to some increase (*36*) with increasing maturity, while slight increases were reported for Hamlin (*21, 48*) and Murcott (*34*) and a decrease for Navel oranges (*55*). With grapefruit, results varied from no change to an increase, especially early in the season, for Marsh (*20, 23, 42, 46*) and an increase for Redblush (*24*).

The importance of fruit analysis is shown by the use of various combinations of soluble solids, acid, and ratio as the basis for maturity standards in the major citrus areas. Other factors, including fruit color and juice content, are also sometimes used. The value of chemical analyses is shown by their relation to acceptability of fruit in flavor tests *(20, 21. 28, 30, 31)*. However, there have been problems in using these factors as measures of maturity and quality (*21, 30*).

Packers of citrus fruits have been concerned with color for a long time, primarily in relation to removing chlorophyll in degreening. Miller, Winston, and Schomer (*39*) used pigment extraction to follow changes in several varieties of oranges during the season. They found that chlorophyll disappeared between September and November, with the loss occurring earlier in the season in Parson Brown than in Valencia oranges. At the same time carotenoids in the rind increased but these did not reach a maximum level until March. Carotenoids in the juice also were found to increase in Parson Brown and Hamlin oranges (*37, 38*). Stearns and Young (*52*) found that temperatures of 55° F. or below were associated with rapid changes in rind color. At higher temperatures, changes were slower. Responses on Hamlin, Parson Brown, and Pineapple oranges were similar. The rind of Marsh and Duncan grapefruit changed color more gradually with less response to low temperatures. More recent studies with Valencia oranges under controlled conditions showed similar effects of low temperature in improving fruit color (*14, 64, 65*). Chlorophyll levels were lower and carotenoids higher at 7° C. (45° F.) night temperature than 20° C. (68° F.). In this variety, chlorophyll was found to decrease from November to June, while carotenoids, particularly xanthophylls, increased.

Electronic color measurements using reflected light are being used for sorting fruit. In 1953 an experimental sorter successfully sorted lemons (*41*). Today, a similar commercial machine is used to sort most of the lemon crop (*1*). Machines are also extensively used to sort cherries (*58, 59*).

The development of light transmittance instruments provides a promising approach to measuring color of intact fruit *(6, 40)*. Changes in pigments with maturity have been followed in tomatoes (*7*), peaches

(*6, 45, 47*), cherries (*61*), apricots (*44*), plums (*15, 45*), and apples (*6*). Correlations of 0.92 to 0.97 have been obtained between instrument measurements and chlorophyll content of apples (*6, 62*) and 0.94 to 0.96 in peaches (*6, 47*). Some internal defects, including water core of apples (*6, 8, 10, 16*), hollow heart of potato (*4, 6*), and bruising of cherries (*61*), have also been detected by this method. A sorter based on light transmittance shows promise on apples (*62*).

In oranges, greener fruit have lower solids than more orange fruit (*49, 50*). Using a horticultural spectrophotometer, both wavelength of peak transmittance (*32, 34*) and chlorophyll level (*32*) were found to be correlated with flavor and soluble solids in Murcott Honey oranges. The difference meter (*6*) is better adapted to rapid laboratory measurements of specific characteristics such as chlorophyll. Changes in this pigment are readily followed in intact oranges and grapefruit during maturation and as a result of degreening (*25*). This measurement was of considerable value in following changes in color-sorted oranges during degreening (*17, 26*).

MATERIALS AND METHODS

Studies were made during the 1964-65, 1965-66, and 1966-67 seasons. For convenience in the following discussions, these will be referred to as the 1964, 1965, and 1966 seasons. Hamlin and Valencia oranges and Marsh grapefruit were tested. Trees of both varieties of oranges were on rough lemon rootstock, while the grapefruit trees were on sweet orange. All trees were of mature, bearing age. The same trees were used for all samples taken within a season, and the same or adjacent trees were used for all seasons.

Fruit was obtained at 2-week intervals each season. Tests started on September 14, 1964, and ran until February 1, 1965, for Hamlin oranges and until May 24, 1965, for Valencia oranges and Marsh grapefruit. During the 1965 and 1966 seasons, the same series of tests were conducted, but calendar dates were 1 and 2 days earlier than the 1964 tests.

Random samples of 20 fruit each were taken from washed fruit. Any fruit that was scarred or discolored was excluded. The samples were then numbered for individual fruit records. The following series of observations was made on each fruit.

Nondestructive Measurements

Weight: Data on intact fruit size measured in grams.

Volume: Size of intact fruit as measured by water displacement, recorded as grams of water displaced.

Fruit specific gravity: Weight/volume of intact fruit.

Length: Size of fruit as measured along axis from stem to stylar end, in centimeters.

Diameter: Size of fruit as measured across fruit at right angles to the axis, in centimeters.

Form: Fruit length/diameter;

this was used as an indication of fruit shape.

Compression: Fruit firmness as measured by a compression instrument (ASCO "Firmnessmeter") (*18*). This instrument uses an arbitrary scale of 0 to 100 to measure deformation from an applied stress weight. A reading of 50 means a reduction of approximately 0.28 cm. in circumference of a fruit. For these tests, a prestress weight of 1,000 grams and a test weight of 2,000 grams were used for oranges and 1,500 and 3,000 grams for grapefruit. A stress time of 10 seconds was used, and the stress was applied using a metal-link belt.

Chlorophyll—DP: Chlorophyll measurements in intact fruit were obtained with a light-transmittance difference meter (*6, 25*) using the direct path (DP) sample presentation system (*25*). In the DP system, the light beam was restricted to a 1 1/8-inch-diameter path on entering and leaving the fruit. The path of the beam was oriented parallel to the axis of the fruit from stem to stylar end. Measurements were made using monochromatic light from second order interference filters and a photomultiplier (Dumont 6911). The lamp voltage was set at 0.4 scale (11.5 volts), and calibration was based on screens of known density. Chlorophyll measurements were made as the difference in optical density ($\triangle OD$) between wavelengths of 695 and 740 nanometers (nm.).

Chlorophyll—IS: Chlorophyll measurements in intact fruit as indicated by the light-transmittance difference meter with an integrating-sphere (IS) sample system (*25*). Here the light beam was restricted on entering the fruit, as in the DP system, but it could leave in any direction. Entrance to the fruit was through the stylar end. Filters and calibrations were the same as for the DP system. Data were recorded as $\triangle OD$ 695-740 nm.

Chlorophyll reflectances: Chlorophyll measurements on the surface of intact fruit were obtained using a reflectance attachment (*5*) for the difference meter. With this system, a single reading per fruit was taken of an area three-fourths of an inch in diameter along the equator of the fruit. The same instrument calibration procedures were used as for above measurements. Data were recorded as relative reflectance 695-740 nm. As a check, readings of a calibrated orange color plate were made during each test. This plate with Hunter color values of Rd=34.2, a_R = +31.6, b_R = +34.8 gave a relative reflectance of 0.258 to 0.282 with this attachment and chlorophyll filters. This observation was made only during the 1966 season.

Water band—DP: Measurements of waterband absorption at 760 nm. using the difference meter and DP sample system calibrated as described above. Data were recorded as $\triangle OD$ 760-811 nm. The water-band measurement has been effective in detecting water core in intact apples. Although spectral curves have not shown evidence of any similar absorbance response in citrus, this measurement was included because of known changes in structure during maturation.

Water band—IS: Water-band measurements of intact fruit were made using the IS system on the difference meter. Calibration was the same as for the DP system. Data were recorded as $\triangle OD$ 760-811 nm.

Destructive Measurements

Chlorophyll—peeled: Chlorophyll levels of the peeled fruit were made using the difference meter calibrated with the DP system. The fruit was peeled, removing the flavedo and as much of the albedo as practical. Data were recorded as $\triangle OD$ 695–740 nm. During the 1966 season, all measurements of peeled fruit were obtained only in odd-numbered tests.

Water band—peeled: Waterband measurements of the peeled fruit were made using the difference meter calibrated with the DP system. The fruit was peeled as described for chlorophyll, and data were recorded as $\triangle OD$ 760–811 nm.

Peeled weight: Weight in grams of the peeled fruit.

Peeled volume: Size of the peeled fruit recorded as grams of water displaced.

Peeled specific gravity: Peeled weight/volume of peeled fruit.

Rind weight: Difference between weight of intact fruit and peeled fruit in grams.

Rind volume: Difference between volume of intact fruit and peeled fruit in grams.

Rind specific gravity: Rind weight/rind volume.

Percent rind: Percent of weight of intact fruit represented by weight of rind.

Number of seeds: Number of typical seeds of the variety. Because of the range in size of mature seeds, those smaller than normal were recorded as 0.5 of a normal seed. These observations were obtained during the 1965 and 1966 seasons only.

Juice weight: Weight in grams of juice as extracted with a handpress.

Percent juice: Percent of weight of intact fruit represented by weight of juice.

Analytical Measurements

Percent soluble solids: Sugar content of the juice as determined by a refractometer, calculated as sucrose.

Percent acid: Acid content of the juice determined by titration with 0.4095 normal sodium hydroxide (N NaOH) and phenophthalin indicator. This was calibrated as citric acid.

Solids/acid ratio: Ratio of percentage of soluble solids to percentage of acid in the juice.

Weight solids: Weight of juice times percentage of soluble solids, recorded as grams of soluble solids in the juice per fruit.

Field Temperature

A recorder was kept in the field throughout each of the seasons to obtain continuous records of temperature. The recording station was placed near the grapefruit test trees 3 feet off the ground. During the first season, a second station was placed near the orange trees. Although these stations were about one-half mile apart, the temperatures recorded were nearly identical. In successive seasons, therefore, only the grapefruit station was used. During the 1965 season, a freeze occurred on January 31, 1966. All oranges harvested on this date for test 11 and all Valencia oranges used in later tests, therefore, may have had some injury. No evidence of injury was found in any sample of Marsh grapefruit.

The time of bloom for each variety varied somewhat among the three crop seasons. For the 1964, 1965, and 1966 seasons, the peak periods of bloom for Hamlin oranges were March 9–23, March 15–26, and March 11–April 1; for Valencia oranges, March 16–23, March 18–April 1, and March 14–April 1; and for Marsh grapefruit, March 16–23, March 22–April 1, and March 18–April 1.

Florida regulations for citrus maturity include requirements for minimum color and juice as well as minimum levels for soluble solids and solids-to-acid ratio in the juice. In this report, only the analytical requirements are considered, since they are usually the most critical factors in determining maturity.

The data obtained in these studies were analyzed statistically to evaluate the differences among tests. Although 19 tests were run each season (11 for Hamlin), fewer observations were available in several instances because of losses from various causes. Most of those losses were in the first three tests of the 1964 season. Since this complicated computer analyses, these three tests were omitted from the analyses although available data were presented in the figures.

RESULTS AND DISCUSSION

Nondestructive Measurements

Weight

Increases in fruit weight with maturity were found in all three seasons and in each of the varieties studied (fig. 1). These increases in weight tended to be more rapid during the fall, with little change in Valencia oranges later in the season. The differences among tests were significant within each season for each variety (appendix table 1). In 1964, the supply of Marsh grapefruit for testing was not adequate, and because of sampling variability, the data showed a decline in the size of fruit tested near the end of the season. The increases in weight found here support similar results found with these and other citrus varieties (*2, 9, 12, 19, 20, 21, 29, 34, 36, 48*). Both Hamlin and Valencia oranges showed lower fruit weights in the 1966 season which on the Hamlin trees was associated with a heavy crop.

Volume

Changes in fruit volume (not shown) closely followed those for fruit weight, supporting earlier reports (*24, 42, 48*).

Specific gravity

Specific gravity of intact Valencia fruits (fig. 2) increased at the start of the season. No further changes were found except

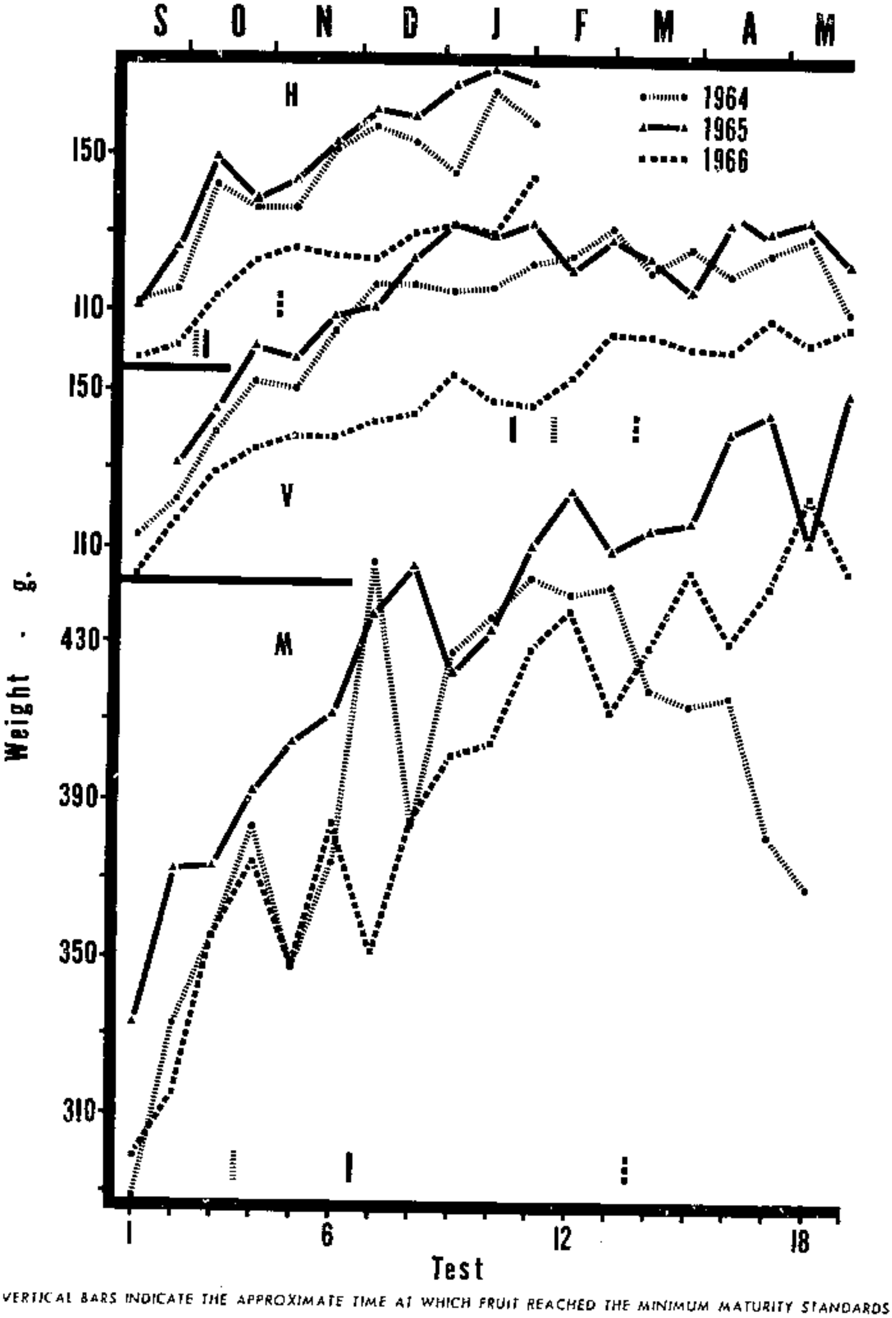

FIGURE 1.—Weight of Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

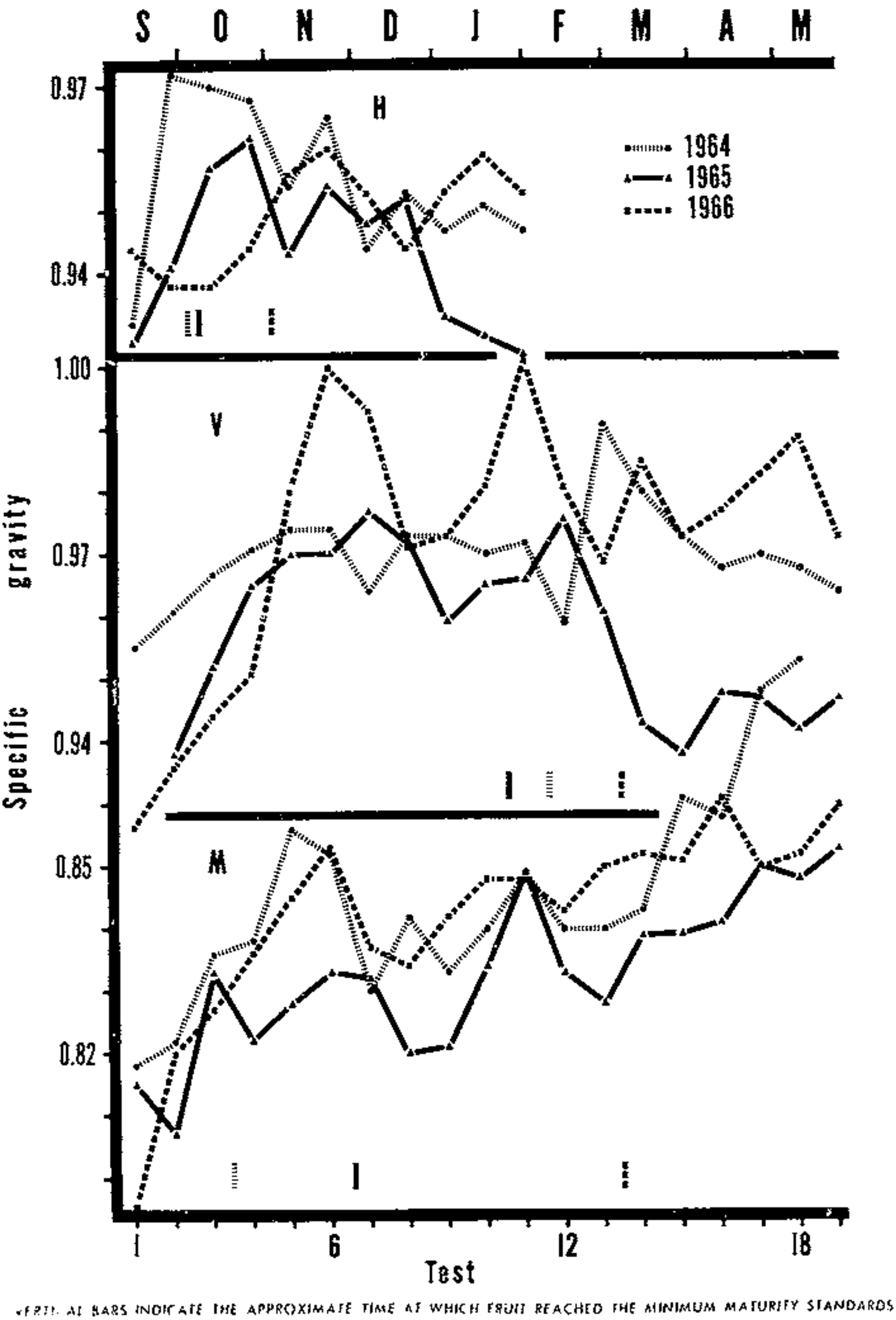

FIGURE 2.—Specific gravity of Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

for the decline in 1965 which resulted from a freeze. The specific gravity of Hamlin oranges was not as consistent from season to season, but in 1964 and 1965 an initial increase was followed by a gradual decline. Marsh grapefruit also showed differences between seasons. In 1964, increases in specific gravity were found at both the start and end of the season, while in 1965 a gradual increase throughout the season was indicated. The values obtained are similar to those previously reported for oranges and grapefruit (*24, 35, 51, 56, 68*).

Length

Seasonal changes in the average length of fruit are shown in figure 3. Again significant increases in fruit size are shown with the greatest increase tending to be during the early part of the season. The smaller size of fruit during the 1966 season, previously noted in the weight of Hamlin and Valencia oranges, is also shown here in fruit length. Marsh grapefruit averaged longer during the 1965 season than in the other seasons.

Diameter

Measurements of fruit diameter (not shown) indicated significant seasonal changes similar to those of length. These results support previous reports of increases in fruit size (*2, 9, 12, 13, 19, 20, 21, 34, 36, 42*). The differences among seasons shown previously for Hamlin and Valencia oranges were also present in these measurements. However, the greater length shown for Marsh in 1965 was not repeated here.

Form

Data on form (length/diameter) of the fruit are presented in figure 4. No consistent trend is evident for Hamlin or Marsh, but significant differences among tests were shown for Valencia. If valid, these findings indicate that the length of the fruit increased more rapidly than the diameter during the season. Decreases in this measurement have been shown in other fruits early in their development (*57*). As an indication of shape, the data show that differences exist among the three varieties. A value near 1.0, as with Hamlin oranges, indicates that the fruit is essentially round. Higher values, as for Valencia, indicate a more elongated shape, while the lower values, as for Marsh, indicate a flatter shape. Consistent differences in the form of the fruit were found among seasons for all varieties. Lower values, indicating flatter fruit, were obtained for Hamlin in 1966, Valencia in 1965, and Marsh in 1964. The results for Hamlin in 1966 may have been associated with the heavy crop and resulting smaller size.

Compression

Significant increases in compression, indicating a softening of fruit with advancing maturity, were shown in all three varieties each season (fig. 5 and table 1). The instrument for measuring compression does not appear to be sensitive or reliable for measuring small differences in firmness. The data do show, however, a number of expected changes. Hamlin oranges either at the same time or at a similar maturity were softer than Valencia oranges. During the first season,

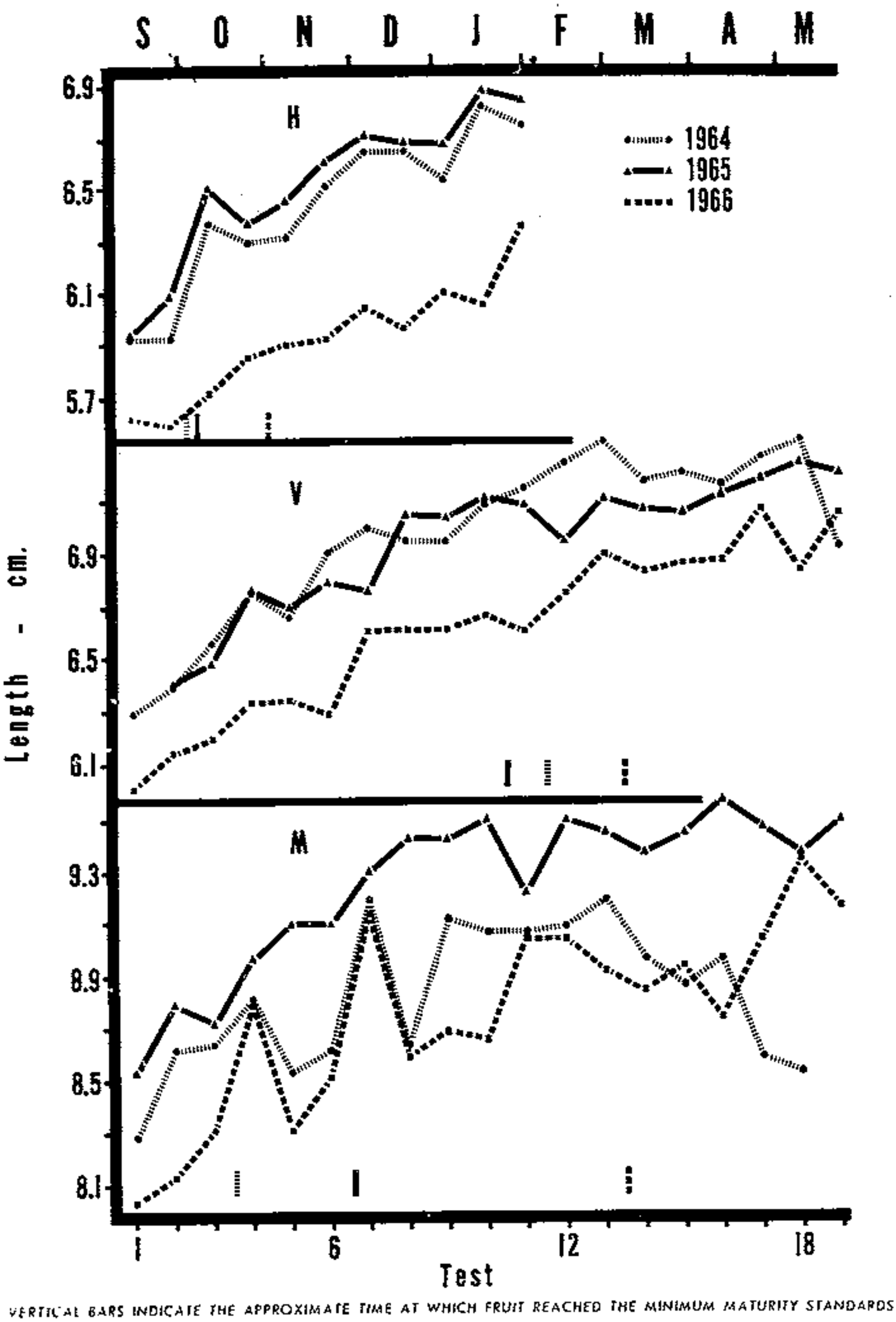

FIGURE 3.—Length of Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

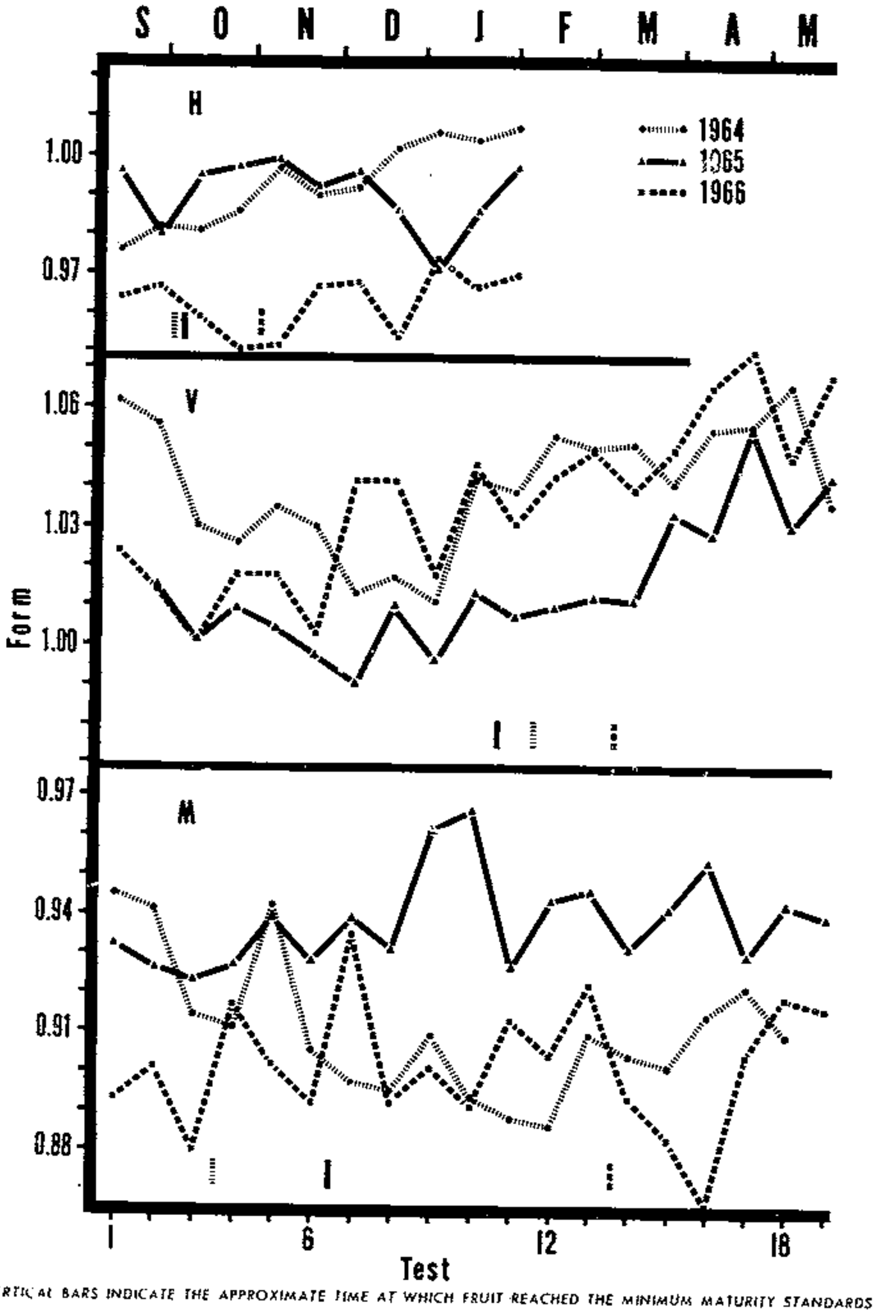

FIGURE 4.—Form (length/diameter) of Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

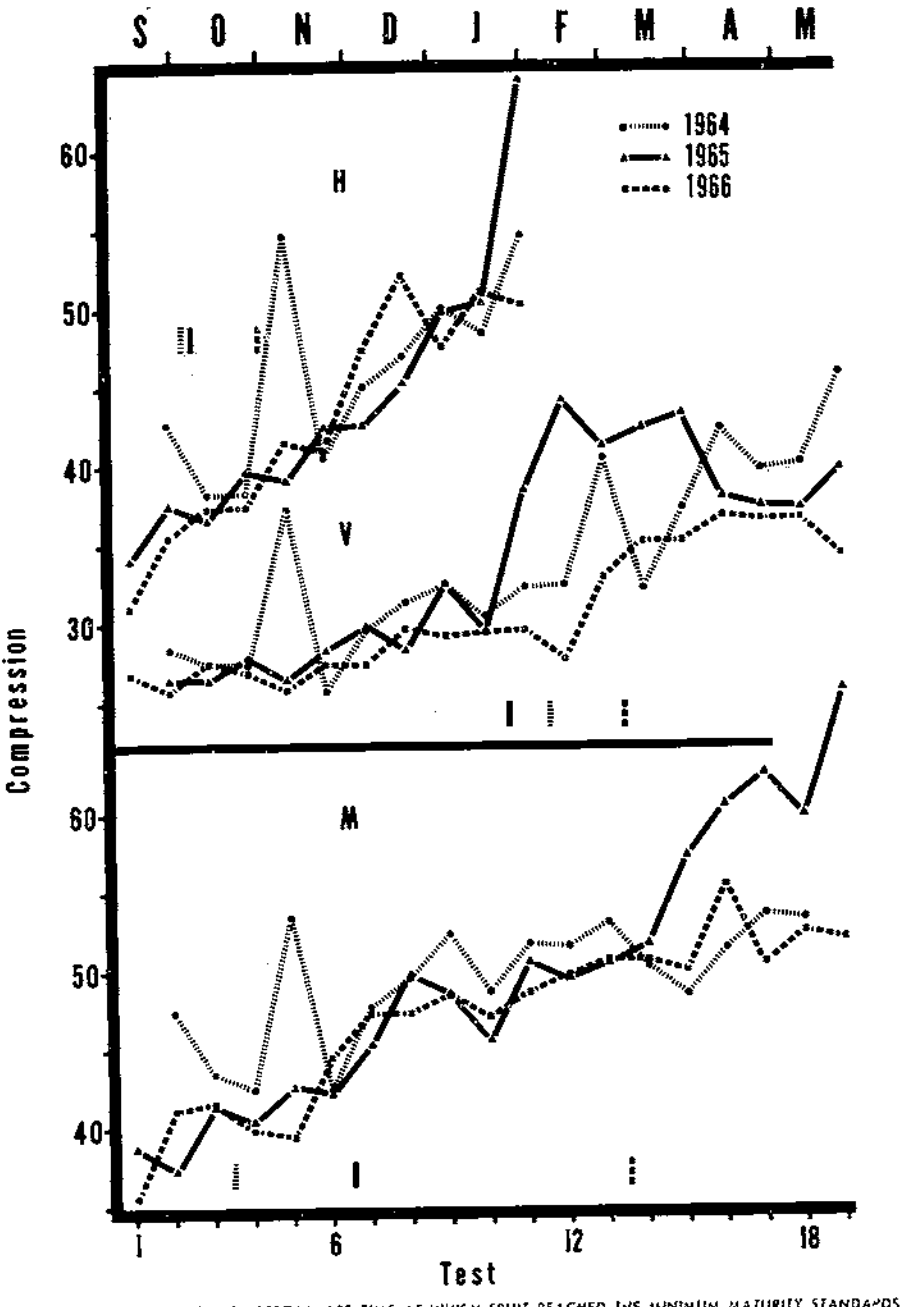

FIGURE 5.—Compression of Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons. Compression values of 50 indicate a reduction in circumference of approximately 0.28 cm.

because of a machine breakdown, test 5 was delayed. When measurements were finally made, the readings were high, indicating a softening of the fruit. A freeze at the end of January 1966 affected oranges beginning in test 11. Both Valencia and Hamlin were softened, but Valencia oranges sampled after test 15 again had normal firmness. Marsh grapefruit, on the other hand, did not show any evidence of injury at the time and the softening that showed up in later tests was probably the result of advanced maturity.

Chlorophyll—DP

Changes in chlorophyll, as measured by a difference meter using the direct-path (DP) system, were significant in each season for each of the three varieties (fig. 6). Each variety had a consistent pattern of change; Hamlin showed an early, rapid loss of chlorophyll, while the change occurred later in Valencias. Marsh grapefurit began changing early in the season, but the rate was slower than for the oranges. No seasonal variation was evident with Valencias, but Hamlin oranges were nearly a month late in changing during the 1966 season. Marsh grapefruit dropped to a lower chlorophyll level in 1966 than in the previous seasons. Both Marsh grapefruit and Valencia oranges showed some regreening in 1964. Since most of the chlorophyll in citrus is in the flavedo, these differences can be seen, although the instrument can detect smaller differences than are visible.

Hamlin oranges still had a high chlorophyll level when they first met the internal quality legal standards. This level was relatively constant from season to season, even though the time of legal maturity varied. By the time Valencia oranges were mature, the chlorophyll level had become minimal. Marsh grapefruit, on the other hand, showed marked differences among seasons in time of legal maturity. These differences were associated with various chlorophyll levels.

Chlorophyll—IS

Results using the integrating-sphere (IS) system in measuring chlorophyll (fig. 7) were similar to those using the DP system. Differences within each season were significant, and differences among seasons for Hamlin oranges and Marsh grapefruit were again evident. Changes in chlorophyll resulting from regreening were not as apparent, however. The changes in pigment indicated here agree with results of chemical extractions (*39*) and also support earlier work on light transmittance with citrus fruits (*34*). These results indicate that changes in chlorophyll can be followed in intact fruit. This procedure has been used successfully in other studies (*17, 25, 26*).

Chlorophyll—reflectance

Results from the reflectance measurements of chlorophyll in the rind during the 1966 season (fig. 8) were similar to the comparable light-transmittance data (figs. 6 and 7). Since most of the chlorophyll is in the flavedo, this similarity was expected. Changes in chlorophyll should be comparable in most parts of the fruit, but the actual levels may differ because the chlorophyll is not

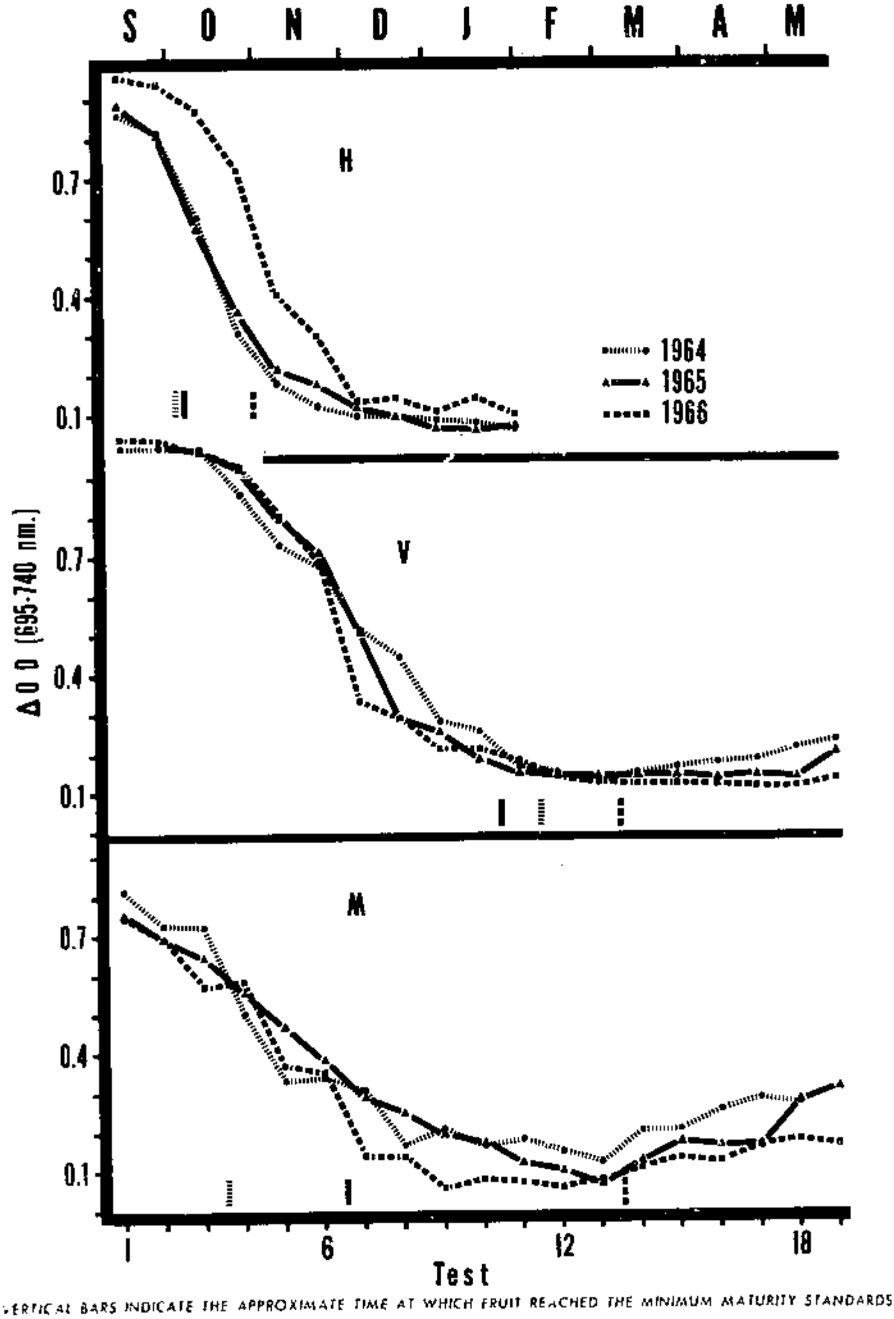

FIGURE 6.—Direct-path (DP) chlorophyll measurements of Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

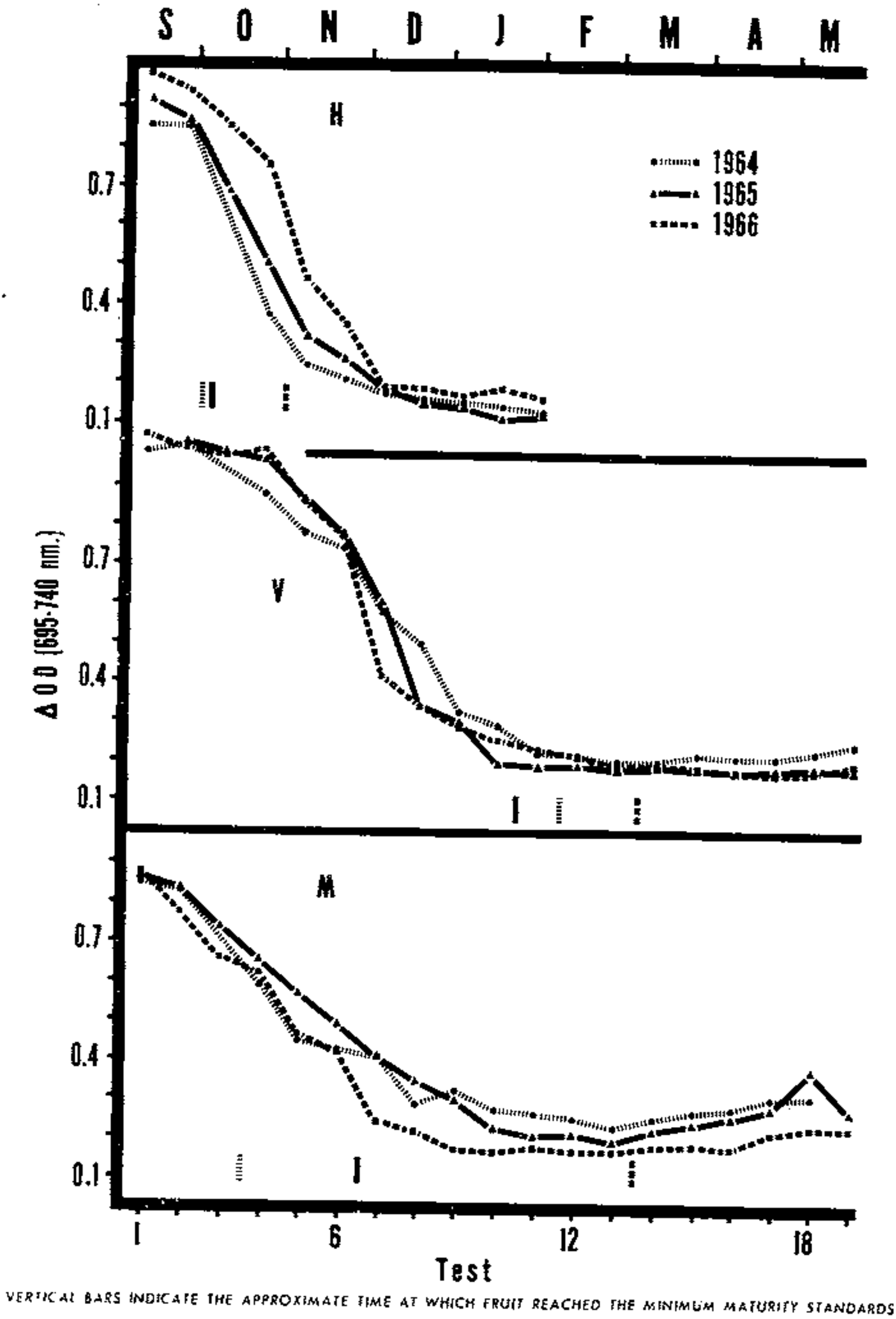

FIGURE 7.—Integrating sphere (IS) chlorophyll measurements of Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

usually distributed uniformly. Because of this, consistent orientation of the fruit reduces measurement variability with either procedure. In practice, light transmittance with the integrating-sphere unit should respond to chlorophyll in a larger part of the rind and, therefore, give a better reading than reflectance.

Water band—DP

Changes in the water-band measurement using the DP system were small, as shown in figure 9. Although there was much fluctuation, some seasonal trend is evident, particularly during the first two seasons, and differences within each season were significant.

Water band—IS

As shown in figure 10, the IS system gave lower but much more consistent readings than the DP system. The same pattern of response is shown by both sys-

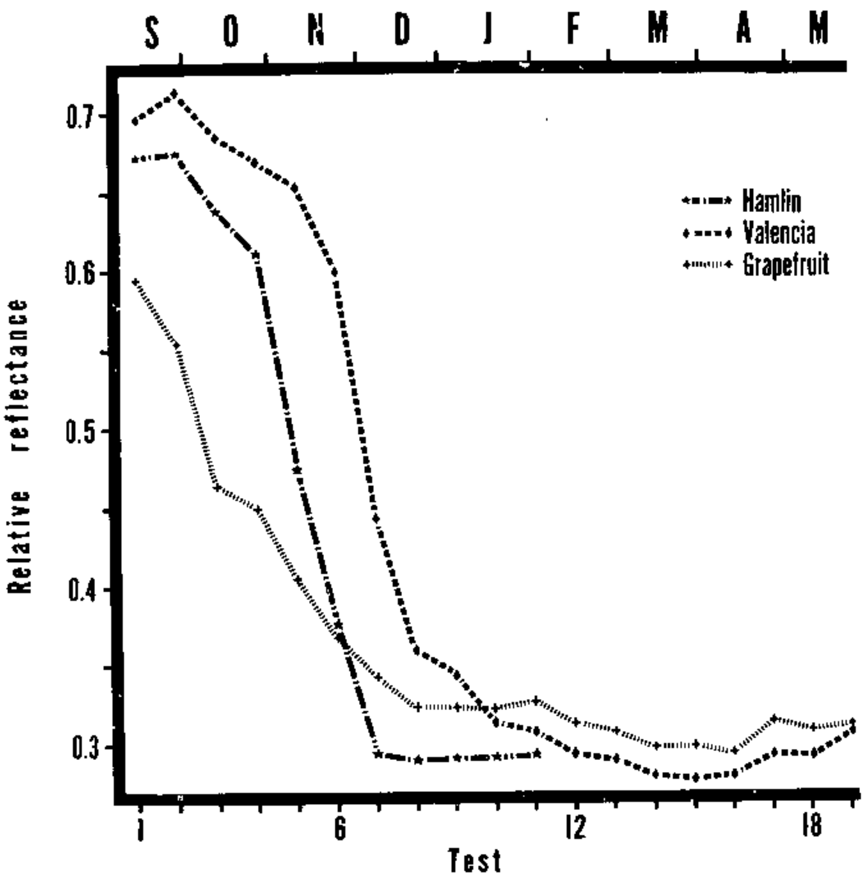

FIGURE 8.—Reflectance chlorophyll measurements of Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1966 season.

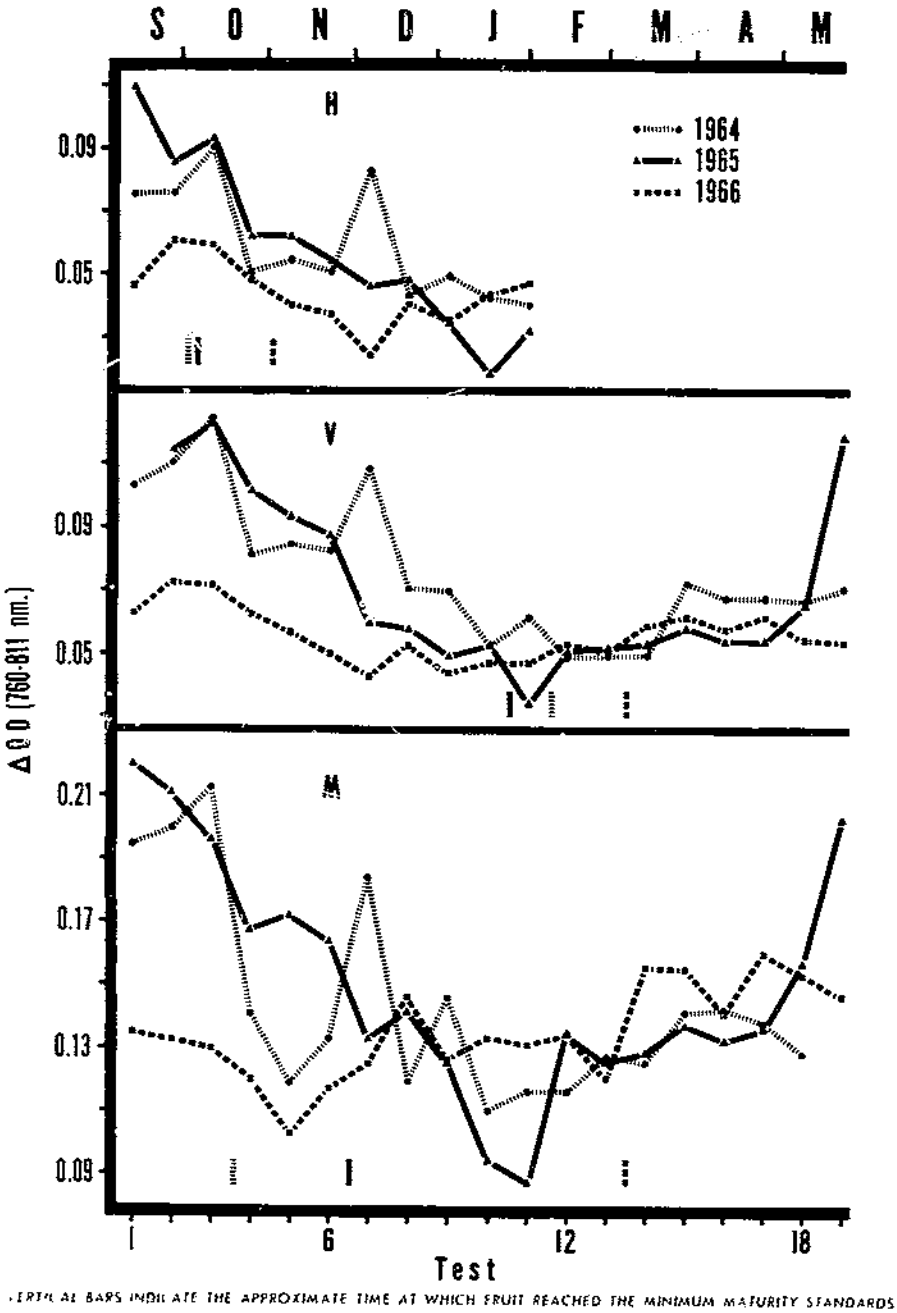

FIGURE 9.—Direct path (DP) water-band measurements of Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

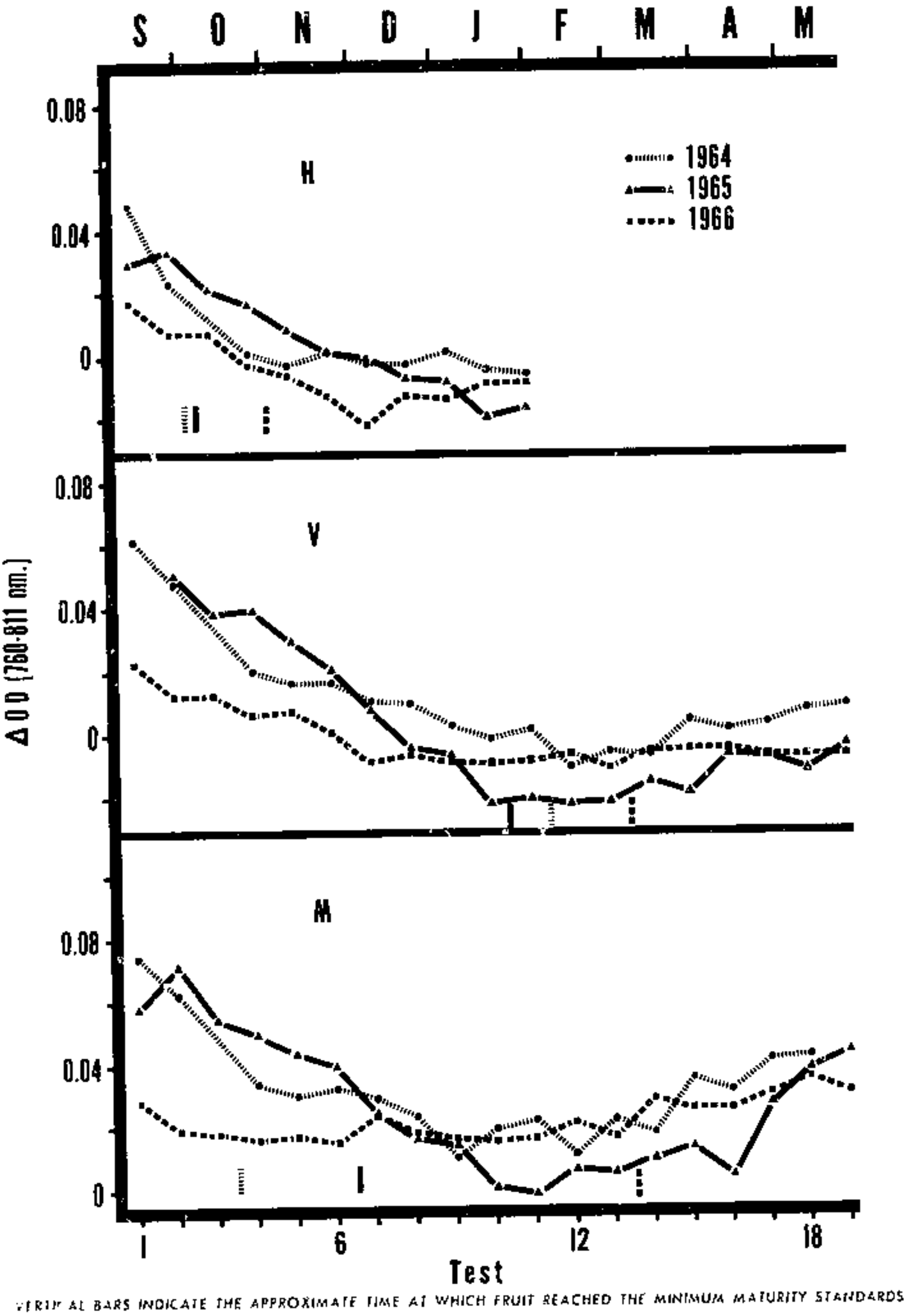

FIGURE 10.—Integrating sphere (IS) water-band measurements of Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

tems for all three varieties. In each variety results for the third season were initially lower and changes less than for the other seasons. Some increase is shown near the end of the season, especially for Marsh grapefruit. These changes were frequently comparable to changes in compression (fig. 5), indicating some relationship between this measurement and structural changes that occur in the maturing fruit. However, a comparison of results for Hamlin and Valencia oranges shows little difference, although the seasons of maturity are totally different for these varieties.

Destructive Measurements

Chlorophyll—peeled

Significant decreases were found in the chlorophyll level in the vesicles of peeled oranges (fig. 11). This decrease occurred later in the season in Valencia than in Hamlin oranges, as in the intact fruit. Changes in grapefruit were inconsistent. As in previous chlorophyll measurements, seasonal differences were found for Hamlin but not Valencia oranges. The low values early in the 1964 season for Marsh grapefruit have not been explained.

Water band—peeled

Changes in the water-band measurements of peeled fruit are shown in figure 12. Differences were smaller and more erratic than with the DP system on intact fruit (fig. 9). In some seasons there was a trend to lower readings with advancing maturity, but more commonly there was little consistent change, although significant differences within each season were present.

Peeled weight

As shown in figure 13, the weight of peeled fruit followed closely the weight of the intact fruit (fig. 1). Again increases were more rapid early in the season, and the fruit, especially the oranges, tended to be smaller in the 1966 season.

Peeled volume

The volume of the peeled fruit (not shown) followed closely the changes in weight of the peeled fruit, and the same comments apply.

Peeled specific gravity

Changes in the specific gravity of the peeled fruit (fig. 14) were small and frequently insignificant. A significant increase during 1966 was shown for Valencia. A trend toward a decreased specific gravity was present for Marsh in 1964 and 1965. Decreases were also evident for both Hamlin and Valencia at the end of the 1965 season. These decreases were related to decreases in fruit specific gravity noted earlier. The specific gravity of 1.0–1.1 for peeled grapefruit, reported by Longfield, Smith, and Gray (*35*), is slightly higher than found for Marsh here. As with the intact fruit, the specific gravity for peeled oranges was higher than for the grapefruit.

Rind weight

As shown in figure 15, changes

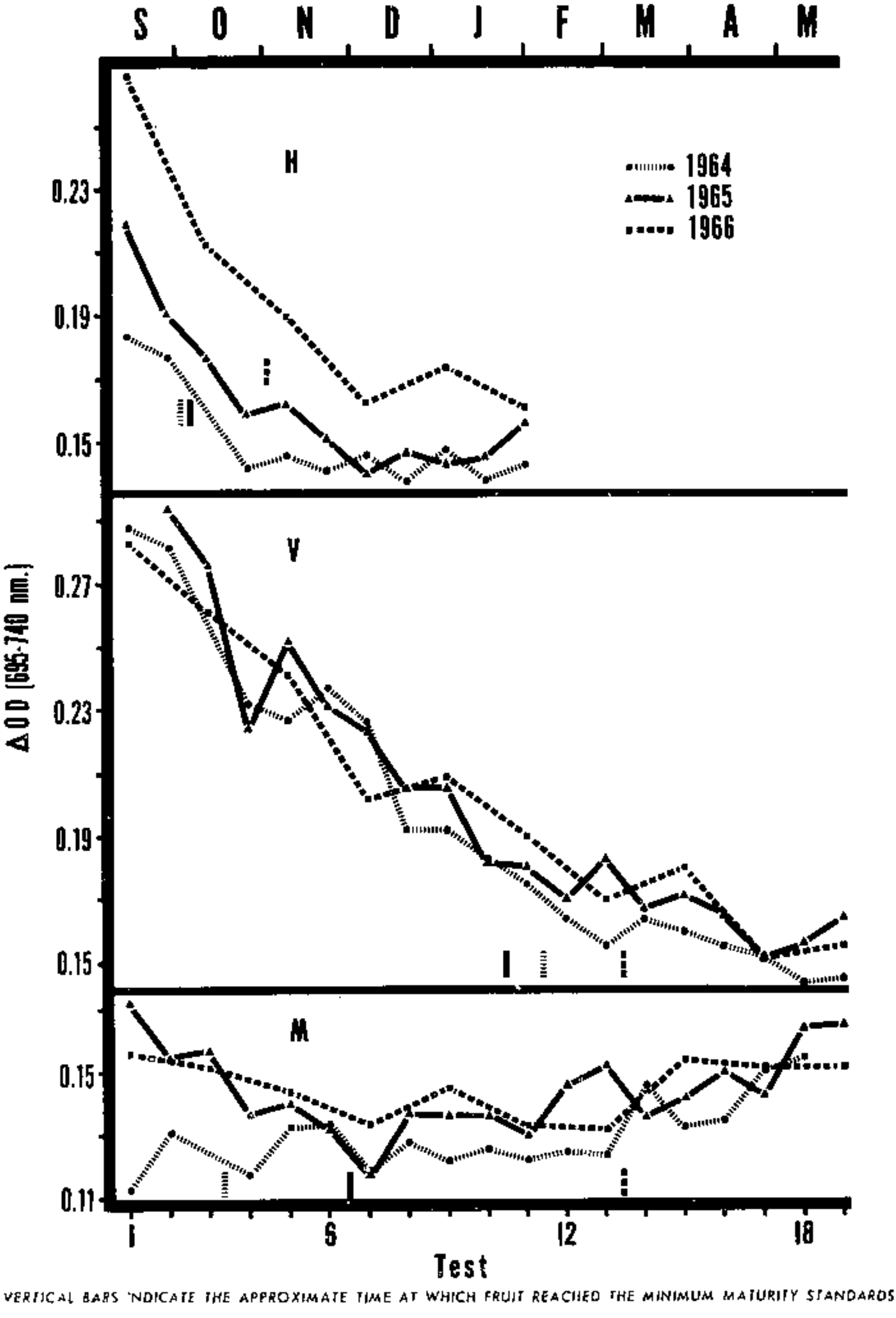

FIGURE 11.—Chlorophyll measurements (DP) of peeled Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

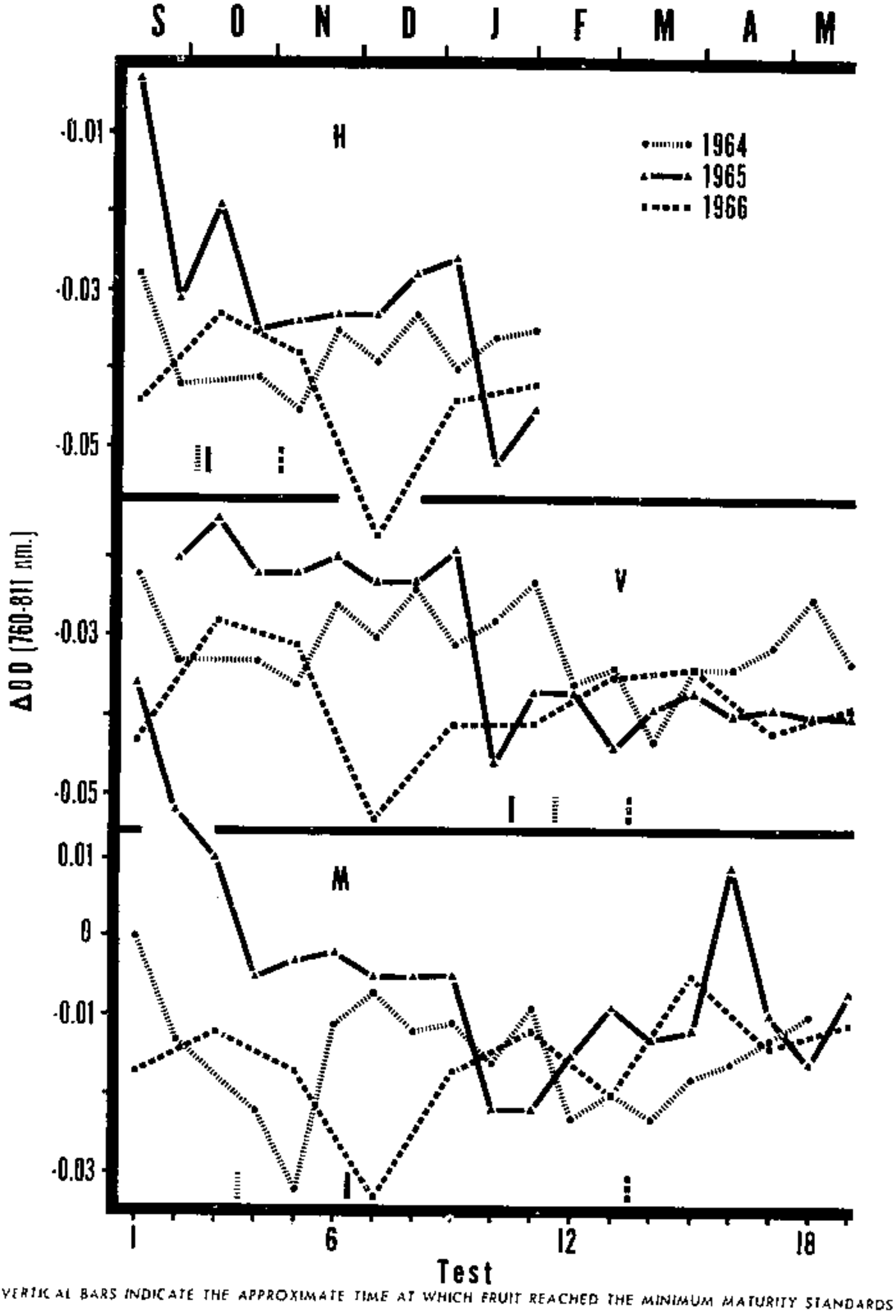

FIGURE 12.—Water-band measurement (DP) of peeled Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

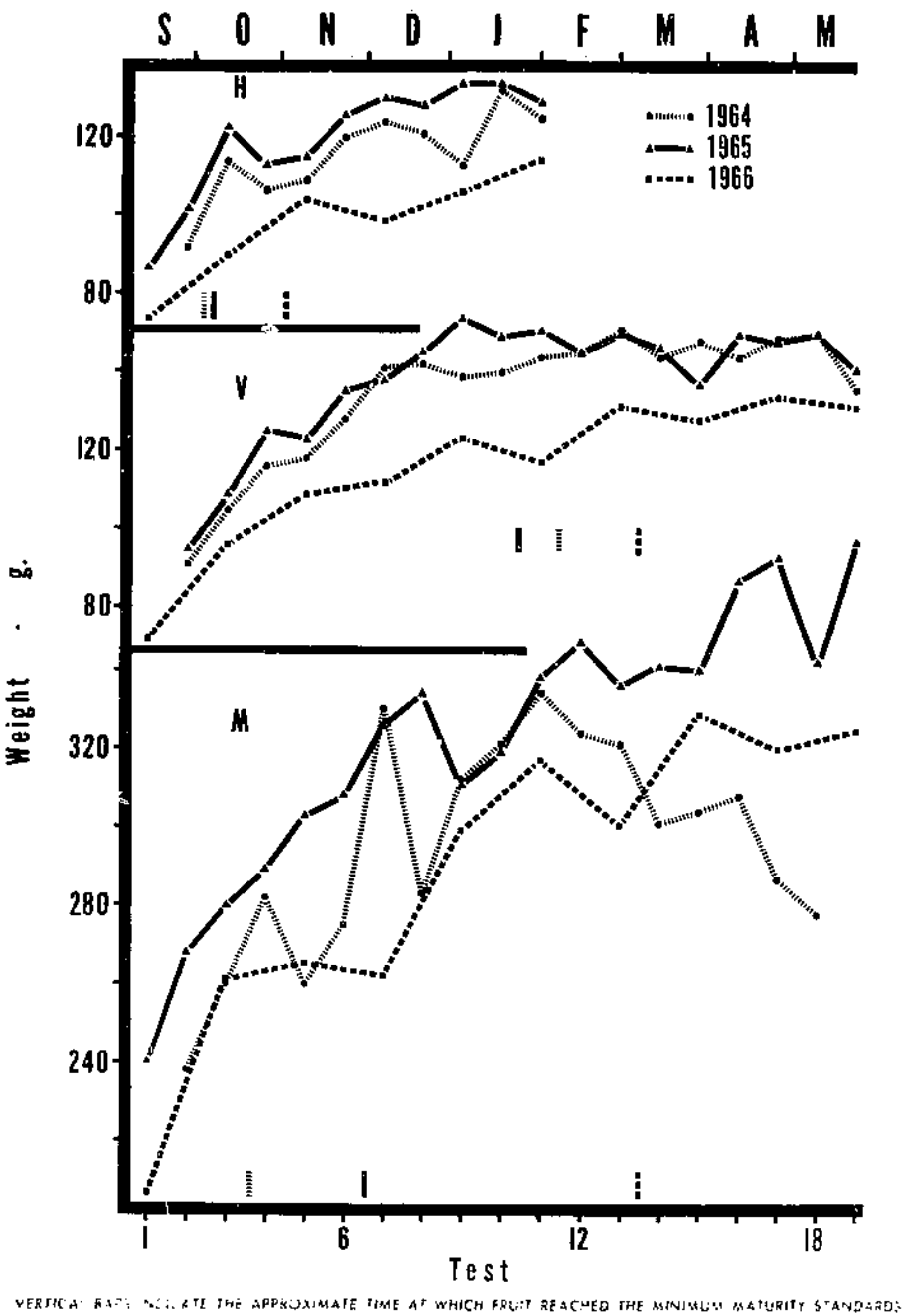

FIGURE 13.—Weight of peeled Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

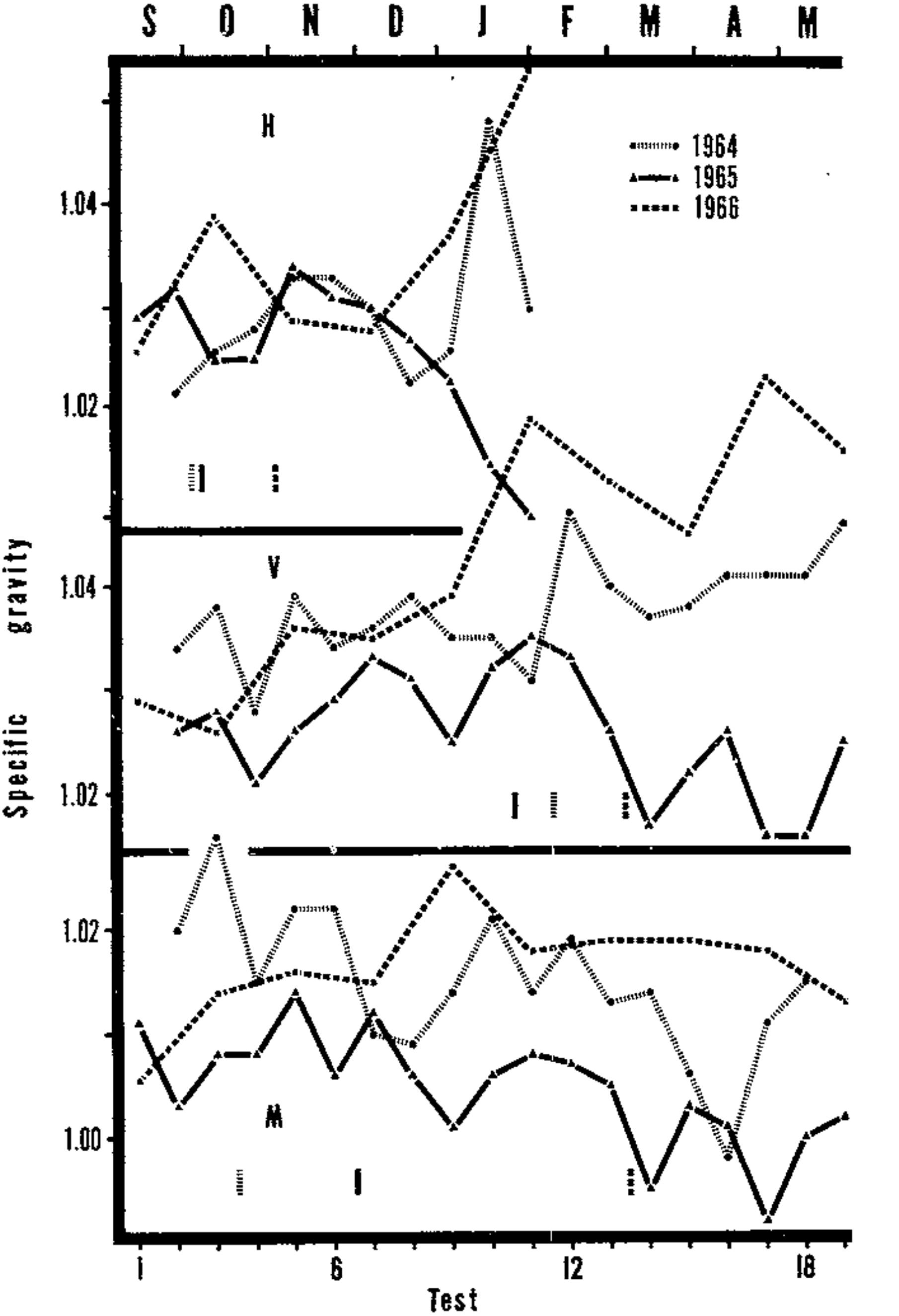

FIGURE 14.—Specific gravity of peeled Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

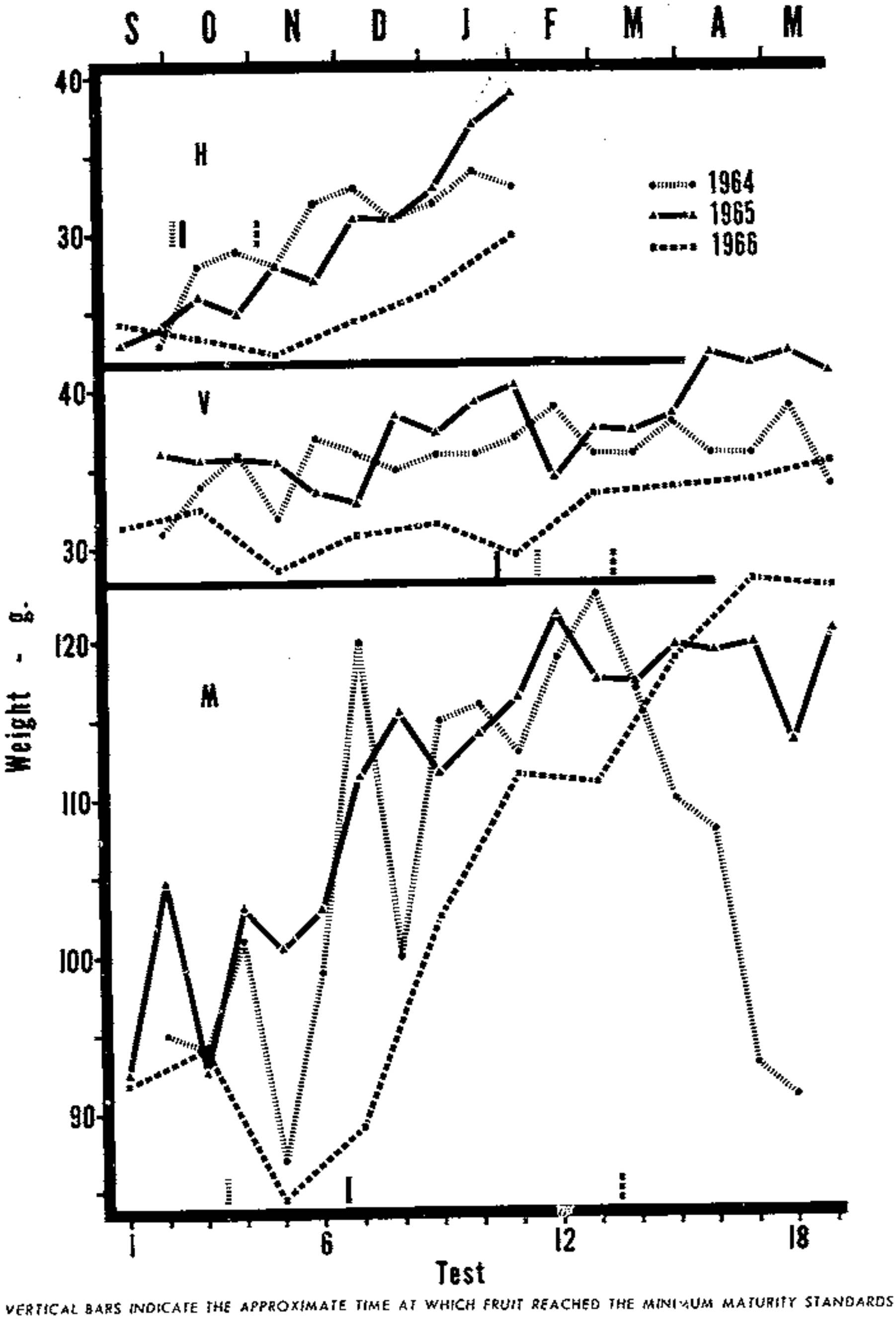

FIGURE 15.—Rind weight of Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

in the weight of rind per intact fruit during the season were much smaller than in the peeled fruit (fig. 13). Significant increases were found in Hamlin oranges, which were greatest during the first two seasons. A trend toward increased rind weight was also shown in Valencia and Marsh fruit. The low weights for Marsh late in the 1964 season were due to the small size of these fruits (figs. 1 and 3).

Rind volume

Changes in rind volume per intact fruit (not shown) were similar to those shown for rind weight. These measurements of rind weight and volume were more variable than the weights of the peeled fruit. Since the data were obtained indirectly through other measurements, the results may be expected to vary from any errors made on these variables.

Percent rind

Data on the percentage of rind in the intact fruit (fig. 16) indicated a decline in the proportion of rind in both Hamlin and Valencia oranges early in the season. Valencia oranges showed no further change, and no differences among seasons were apparent. There was a trend toward an increased proportion of rind in Hamlin oranges near the end of the 1965 and 1966 seasons. In 1965, this increase was associated with higher compression values (softer fruit) (fig. 5). In Marsh grapefruit also, decreases in percent rind were found at the start of the season, but no consistent further change was apparent.

Rind specific gravity

Changes in the specific gravity of the rind (fig. 17) were small although some significant trends were apparent. The 1964 data for Hamlin oranges showed a slight decline with increasing maturity, and similar trends were shown for Valencia during most of the 1964 and 1965 seasons. In contrast, the specific gravity increased slightly for Marsh. The rind of oranges was more dense than that of grapefruit, probably due to the smaller proportion of albedo in orange rind. Valencia rind was also more dense than that of Hamlin oranges.

Number of seeds

Data on the average number of seeds per fruit (fig. 18) showed no significant changes with maturity, as expected. In all varieties fruits contained a wide range in number of seeds. This is indicated by the high coefficient of variability (table 1) and indicates that the variations shown within seasons were due to sampling variation. There was a marked difference in number of seeds between the two seasons with Hamlin oranges. Part of this difference may have been related to the heavier bloom in 1966. Similar seasonal differences in number of seeds have been reported for Valencia (*11*). The number of seeds found here in Valencia oranges was similar to that reported (*11*).

Juice weight

Changes in juice weight per fruit (fig. 19) were significant and generally followed those for

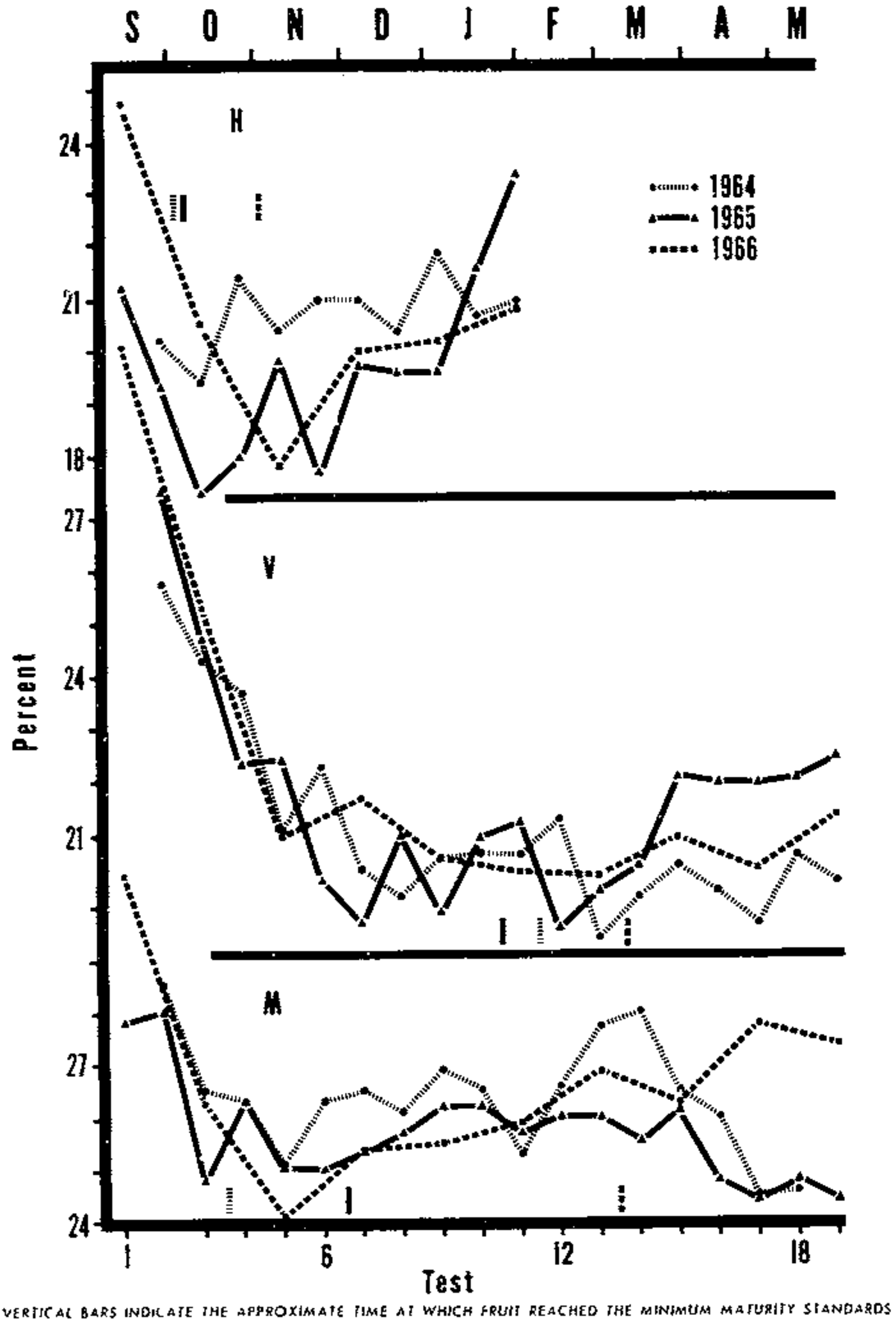

FIGURE 16.—Percentage of rind in Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

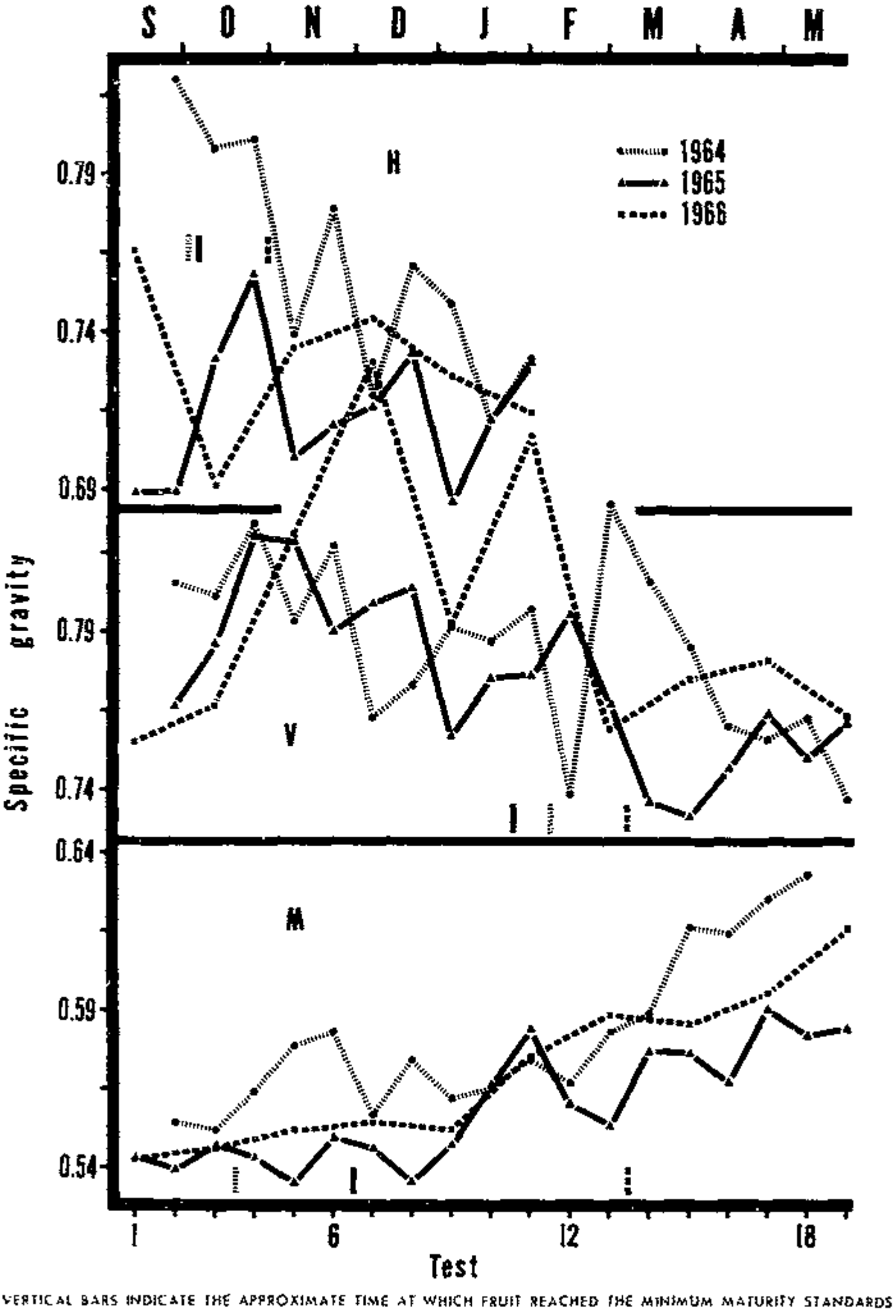

FIGURE 17.—Specific gravity of the rind of Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

intact fruit weight (fig. 1). The major increases occurred during the fall, and lower values were obtained in the 1966 season than in 1964 and 1965. Some decline in juice weight of Valencia oranges occurred after the January 1966 freeze. The decline shown for Hamlin oranges at the end of the 1965 season was associated with an increase in percent rind previously noted.

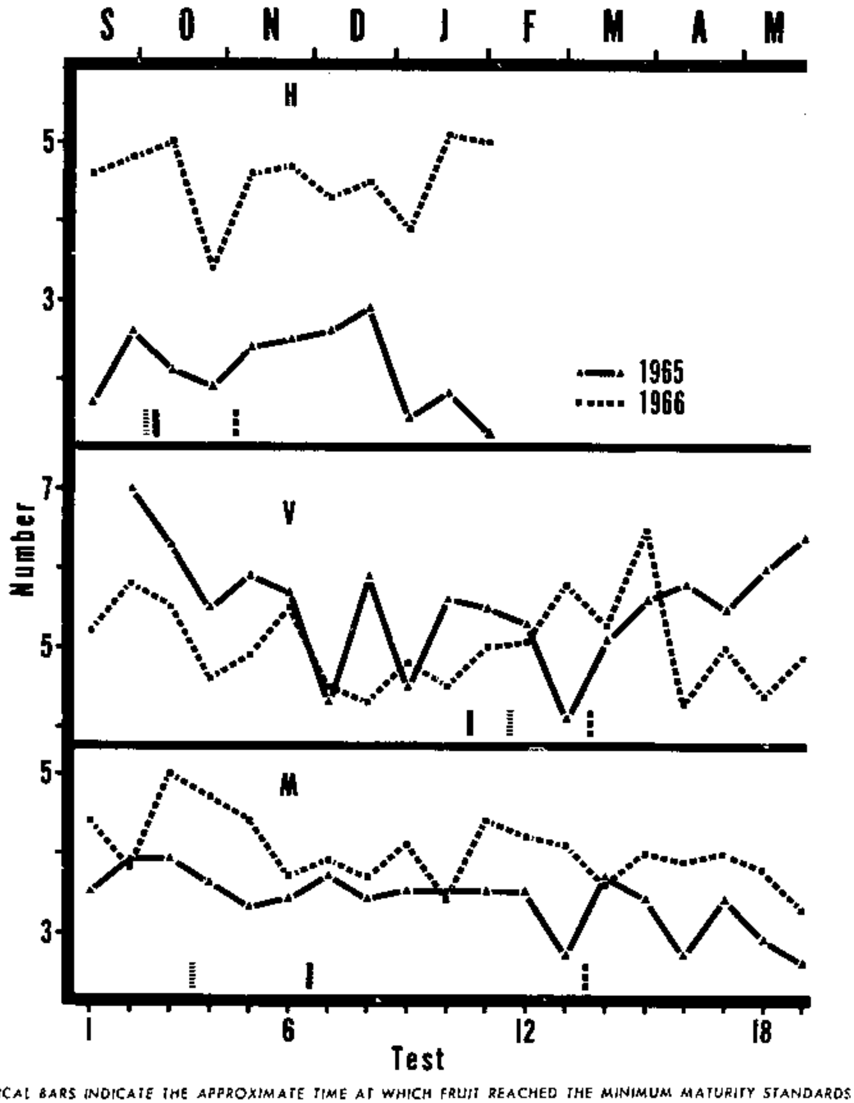

FIGURE 18.—Number of seeds in Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1965 and 1966 seasons.

Data on juice volume were recorded during the 1964 and 1965 seasons also. These values were slightly lower than the associated weight or, as in Hamlin oranges, essentially the same. Since correlations higher than +0.99 were found between these values and juice weight, they were considered duplicate measurements and discontinued.

Percent juice

As shown in figure 20, most changes in percentage of juice occurred early in the season. These changes were significant within each season, and they are in general agreement with published results on these and other citrus varieties (*20, 21, 24, 36, 42, 48, 55*). These tests were initiated before any of the fruits were of marketable maturity, and the results indicated that a maximum juice content might be reached before legal maturity with little further change occurring. The percentage of juice in Valencia oranges was highest during the 1964 season and in 1965 there was a decline after the freeze. A decline was also apparent in Hamlin oranges in 1965.

Analytical Measurements

Percent soluble solids

In Hamlin and Valencia oranges, significant increases in soluble solids were found each season (fig. 21). No seasonal differences were evident during most of the season in either variety. After the freeze in 1965, however, little increase in solids content was evident in Valencia oranges. The decline in Hamlin oranges in 1965 began before the freeze and, when considered with some of the other changes, appeared to be due to the overmaturity of this fruit. When these changes were disregarded, solids increased at a constant rate in Hamlin, and initially in Valencia oranges. Later increases were more gradual in the mature Valencia fruit. These increases in soluble solids agree with published results for oranges (*2, 12, 21, 34, 36, 48*).

Maturity changes were not evident in Marsh grapefruit in 1966, while decreases in solids were found during 1964 and 1965. Although increases in soluble solids early in the season have been reported (*20, 22, 42, 46*), decreases have been found later in the season (*27, 42, 60*), as well as throughout the season (*29*). The results shown here, therefore, are not unusual for Marsh grapefruit.

Percent acid

Decreases in the acid content of fruit during the season were greater in Hamlin and Valencia oranges (fig. 22), and the rate of change declined during maturation. These results are similar to those previously reported for oranges (*2, 12, 21, 34, 36, 48, 55*). The changes were small in Marsh grapefruit and limited in 1966 to the end of the season. Similar decreases in acid content were reported in previous studies of grapefruit (*20, 22, 24, 29, 42*). In 1966 acid levels tended to be higher compared with the two previous seasons, particularly in Hamlin oranges.

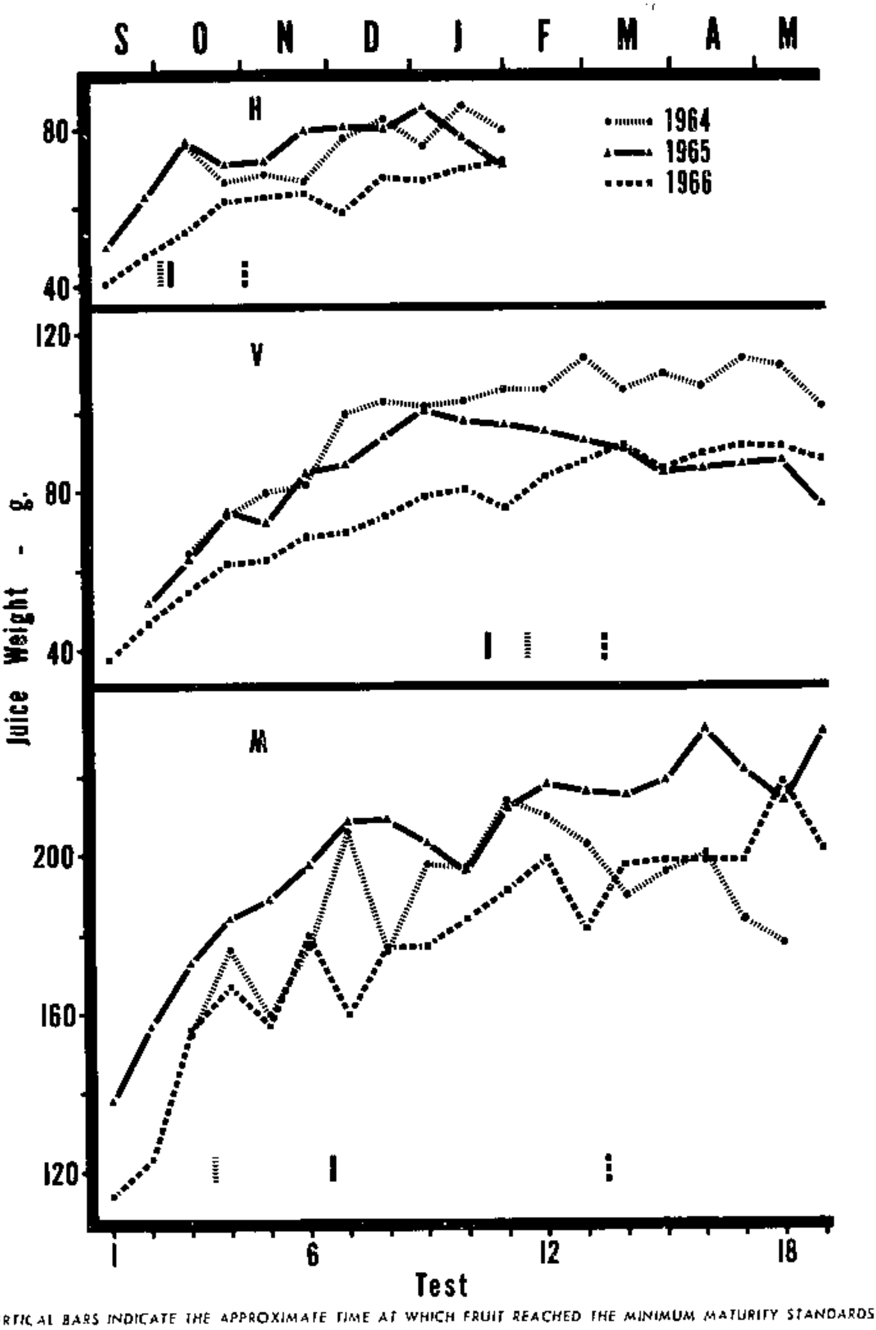

FIGURE 19.—Juice weight in Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

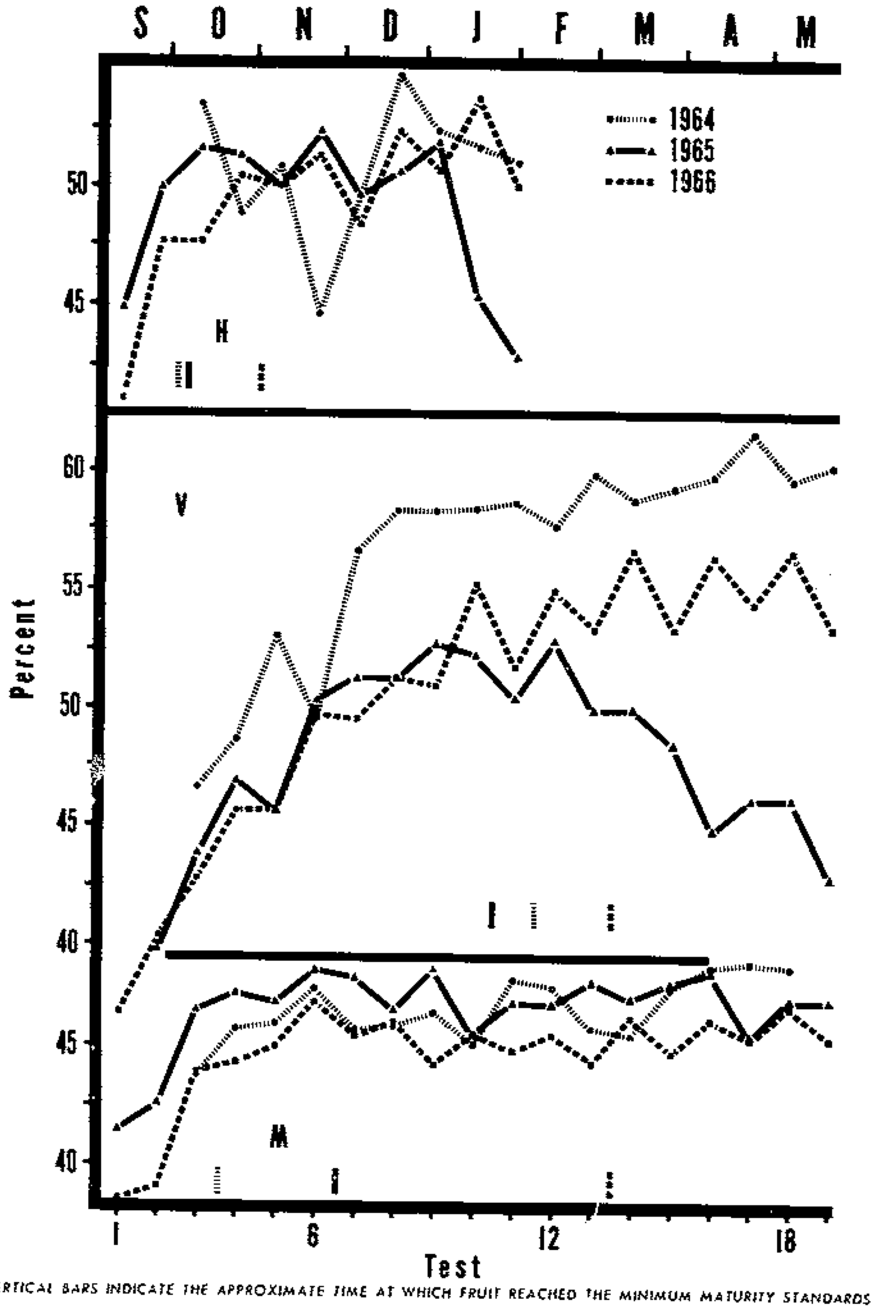

FIGURE 20.—Percentage of juice in Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

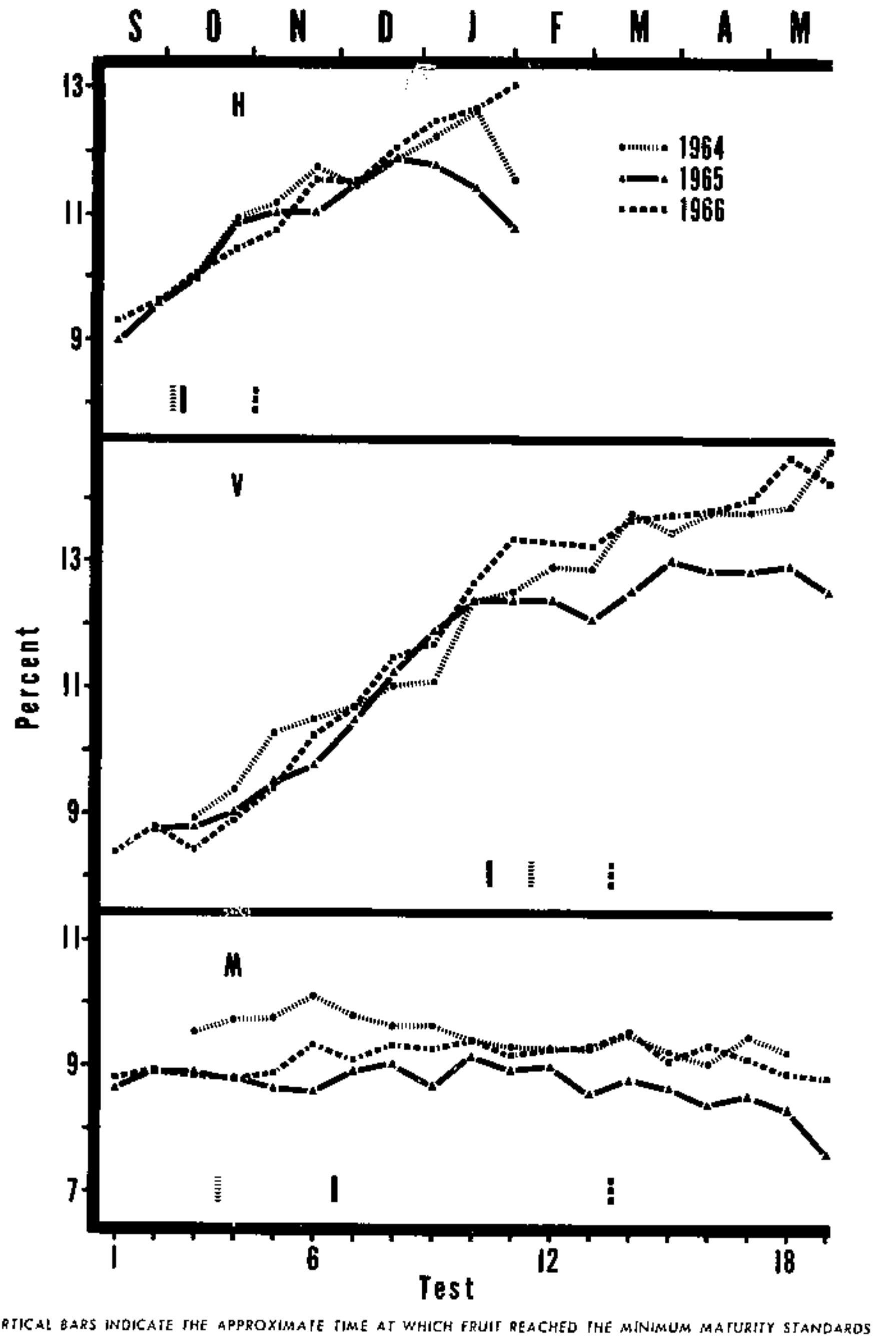

FIGURE 21.—Percentage of soluble solids in Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

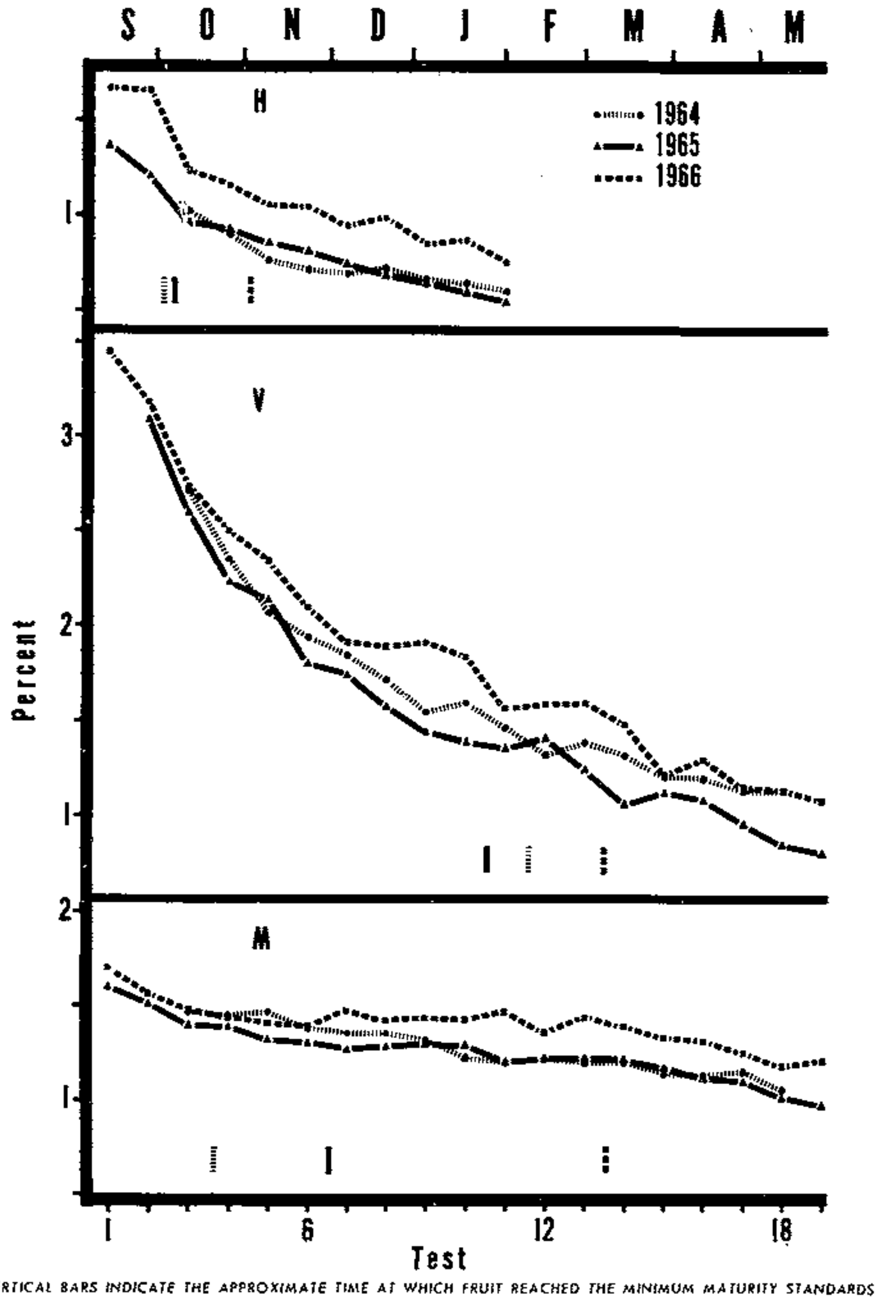

FIGURE 22.—Percentage of acid in Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

Soluble solids—acid ratio

As shown in figure 23, significant increases in solids-to-acid ratio were found for each season for Hamlin and Valencia oranges. A smaller but steady increase was also found for Marsh. These changes during the season are similar to those reported for oranges (*12, 21, 34, 36, 48, 55*) and grapefruit (*20, 22, 24, 29, 42*). The lower ratios shown for 1966, particularly in Hamlin oranges, were the result of the higher levels of acid (fig. 22).

There was a marked difference among seasons in time of legal maturity for Marsh grapefruit. As shown in figures 21 and 22, the 1966 fruit had high acid as well as high solid, which resulted in the lower ratios shown in figure 23. These results did not differ greatly from those in the other seasons. However, these values were close to the minimum standards and, since changes occurred slowly, legal maturity was delayed for several months.

Weight of soluble solids

The weight of soluble solids per fruit increased during maturation (fig. 24), but in mature Marsh grapefruit, there was little change. This combination of early season increase and limited changes reflects the pattern for juice weight (fig. 19) more closely than that for percentage of soluble solids (fig. 21). The differences among seasons are also similar to those for juice weight and are due largely to differences in fruit weight (fig. 1), as well as some variation in percent juice (fig. 20). The decline in soluble solids and juice in Hamlin and Valencia oranges at the end of their 1965 seasons is also apparent here.

Field Temperature

The continuous temperature records obtained in the grove are summarized in figures 25 and 26. The data shown represent *A*, the number of hours below 70° and 65° F. per 2-week period prior to the harvest of each test, and *B*, the cumulative number of hours below these temperatures during the season. Temperatures in this range are the first indication of cooler fall weather. They are also the lowest temperatures that occur early enough to affect the initial changes in citrus color in Florida.

The data for hours below 70° F. (fig. 25) indicated that the fall was cooler during 1964 than during 1965. This difference was not associated with any consistent difference between seasons in the rates of chlorophyll change (figs. 6 and 7). In Hamlin oranges, these changes began later in the 1966 than in the previous season. Since 1965 and 1966 had similar temperature patterns at this time, these factors do not appear to be closely related. Other reports showed more rapid and better color development under cooler conditions (*14, 52, 64, 65*). The results shown here do not necessarily contradict those reports, but do indicate that more work is needed to evaluate the field response to temperature changes and to determine effects such factors as maturity have on the loss of chlorophyll.

Data on cumulative hours

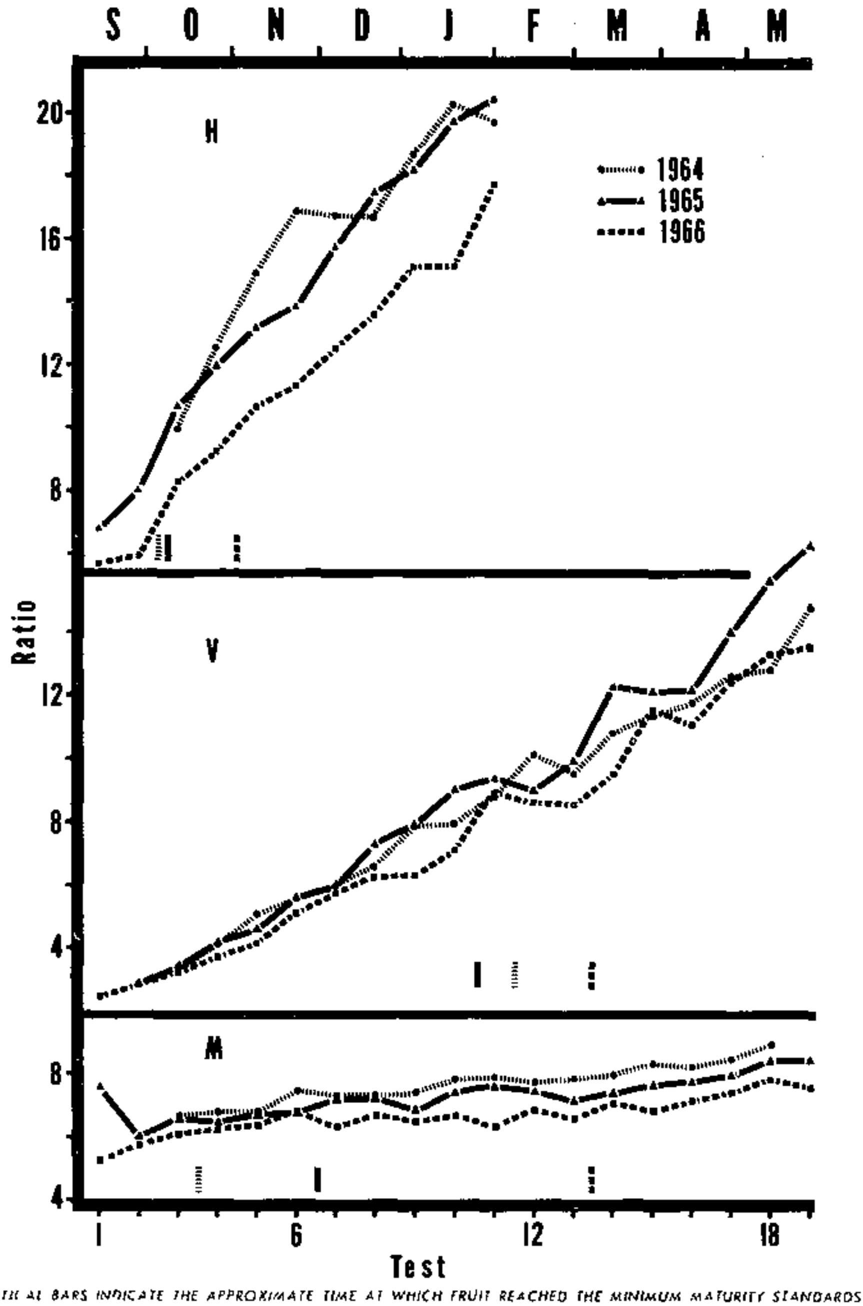

FIGURE 23.—Ratio of soluble solids-to-acid in Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

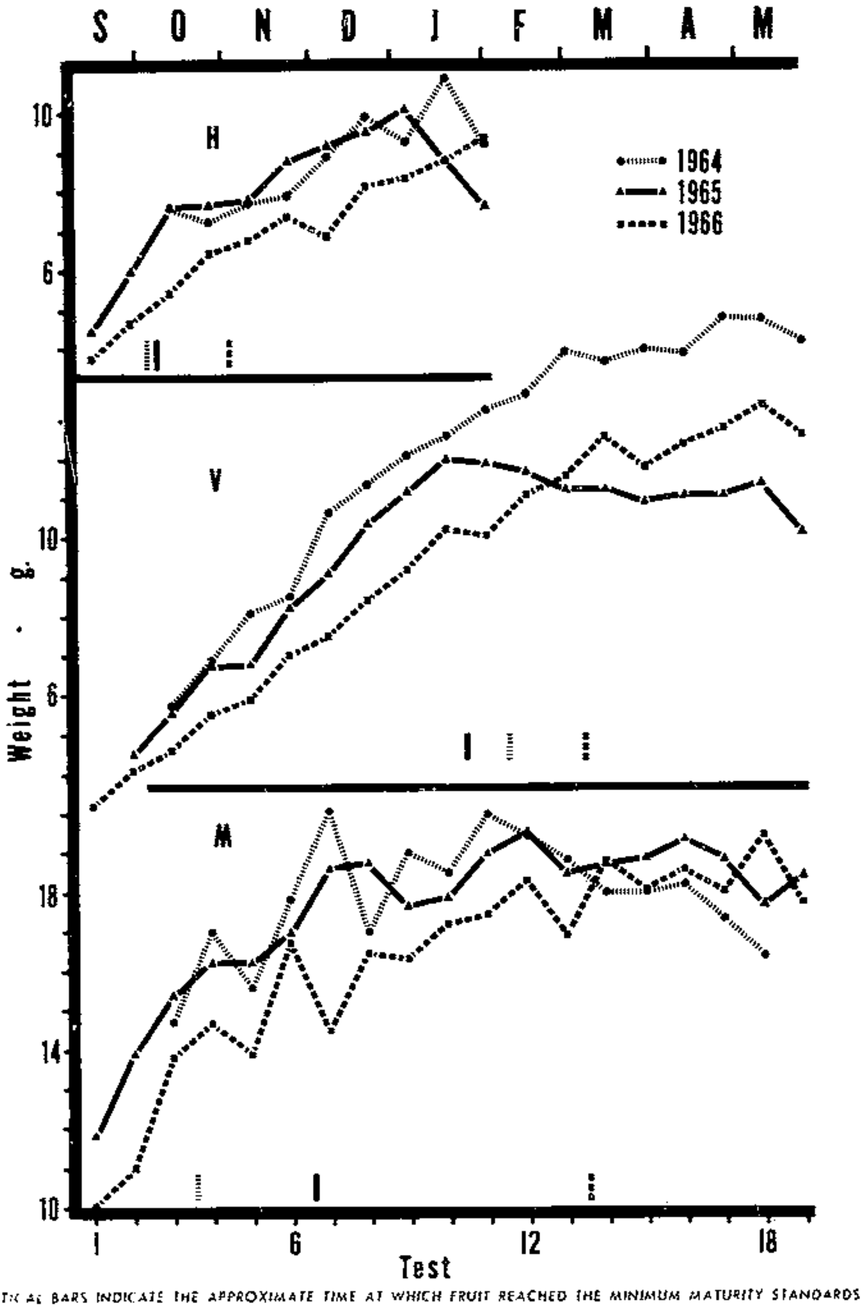

FIGURE 24.—Weight of soluble solids per fruit in Hamlin (H) and Valencia (V) oranges and Marsh (M) grapefruit during the 1964, 1965, and 1966 seasons.

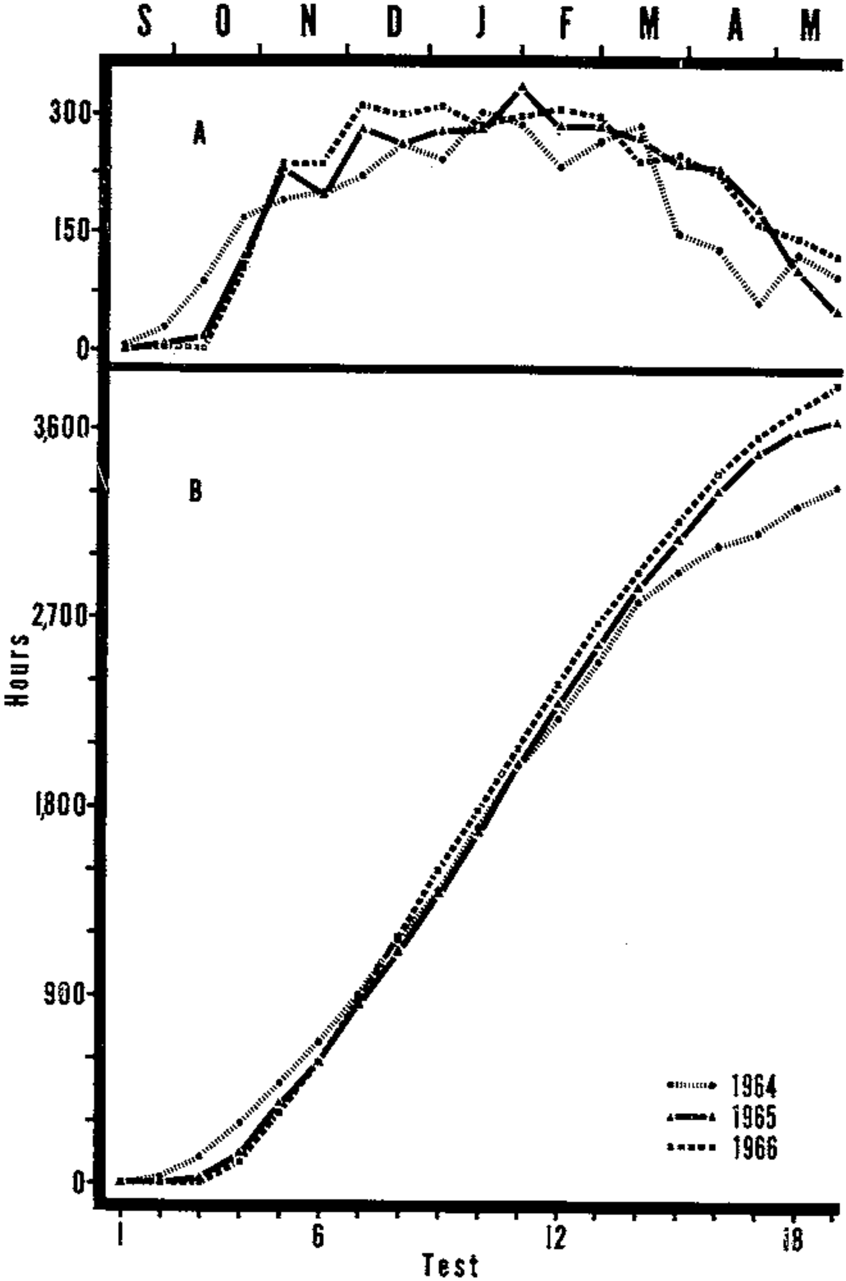

FIGURE 25.—Field temperature. Hours below 70° F. during the 1964, 1965, and 1966 seasons: *A*, Number of hours below 70° during the 2 weeks prior to each harvest; *B*, cumulative hours below 70° during the season.

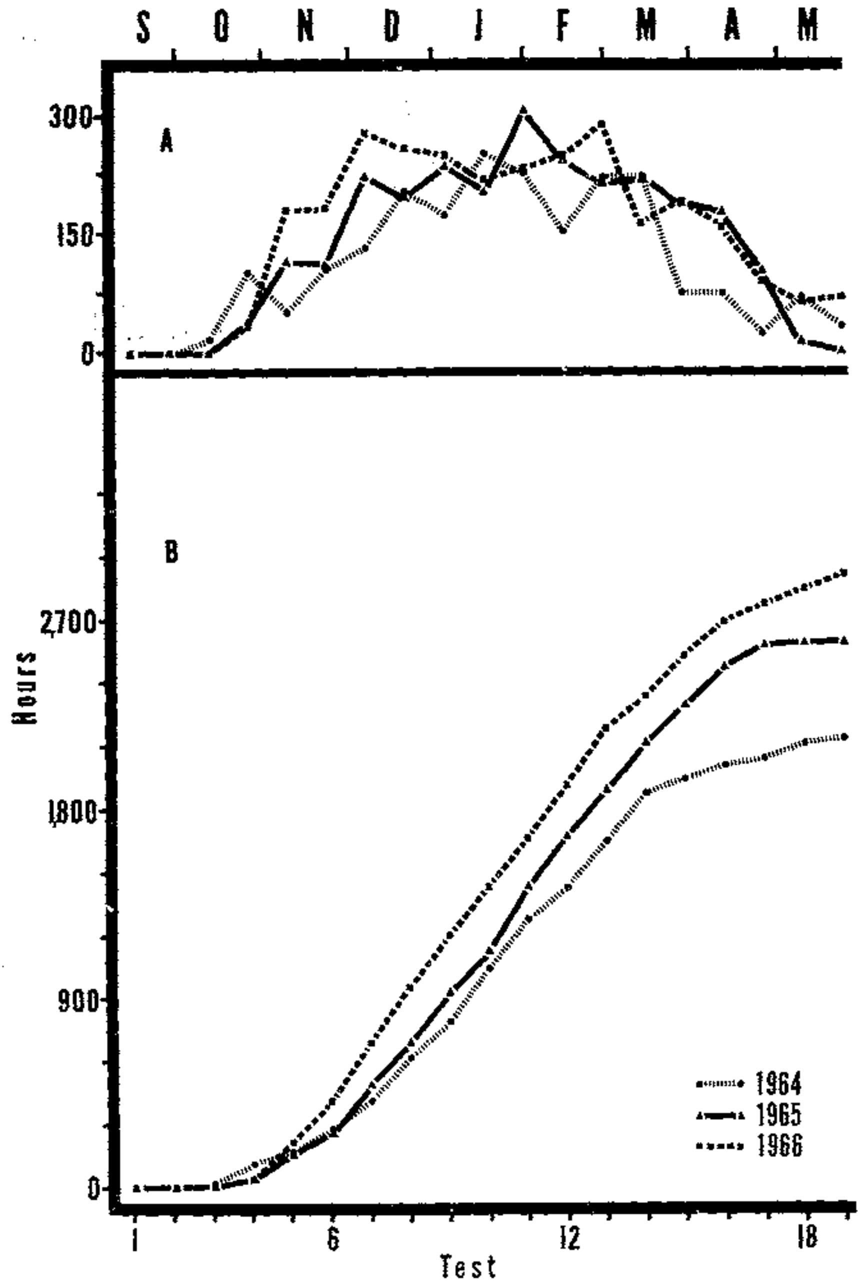

FIGURE 26.—Field temperature. Hours below 65° F. during the 1964, 1965, and 1966 seasons: *A*, Number of hours below 65° during the 2 weeks prior to each harvest; *B*, cumulative hours below 65° during the season.

below 70° and 65° F. (figs. 25, *B* and 26, *B*) indicate a trend toward cooler winters between 1964 and 1966. The data for 70° were approaching the maximum value obtainable and therefore were not as responsive to seasonal differences as the comparable data for hours below 65°. Chlorophyll levels in Marsh grapefruit during the latter part of the season showed a similar trend over the three seasons (fig. 7). This finding supports previous reports of a relationship between low temperature and loss of chlorophyll in citrus (*14, 52, 64, 65*).

The results of these studies show that most of the measured variables have some pattern of seasonal change during the period of observation. This was expected with Valencia oranges and Marsh grapefruit since a long period was studied, including both immature and mature fruit stages. Within each season and variety, significant differences were usually present (table 1). Comparable correlations were also found between changes in these variables and the calendar date as indicated by the test number (table 1). Some of these trends, of course, are more consistent and useful than others. However, the number and extent to which the variables change during the season indicate that correlations may be found that would be useful in quality separations of citrus fruits.

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APPENDIX

TABLE 1.—*Mean squares for tests and error sources for indicated variables with an indication of significance, coefficients of variability, and correlation coefficients between test number and test means* [1]

Measurement and source	Hamlin orange 1964	Hamlin orange 1965	Hamlin orange 1966	Valencia orange 1964	Valencia orange 1965	Valencia orange 1966	Marsh grapefruit 1964	Marsh grapefruit 1965	Marsh grapefruit 1966
Weight:									
Tests	2,221.6**	7,210.8**	3,621.9**	2,808.2**	6,287.0**	6,178.9**	21,995.0**	37,689.0**	45,255.0**
Error	226.8	337.5	191.3	514.2	557.4	322.0	2,227.0	2,989.0	2,835.0
Coefficient of variability	10.0	12.3	11.3	12.9	13.4	12.2	11.7	12.6	13.4
Correlation	.870	.926	.922	.804	.775	.925	.149	.921	.936
Volume:									
Tests	2,815.4**	8,460.5**	3,708.9**	2,945.4**	6,985.3**	5,473.6**	39,473.0**	43,933.0**	50,082.0**
Error	267.1	414.2	219.8	622.1	690.5	380.7	3,967.0	5,445.0	4,983.0
Coefficient of variability	10.4	12.8	11.5	13.7	14.3	12.9	13.0	14.2	14.9
Correlation	.890	.950	.913	.813	.834	.921	.006	.893	.927
Specific gravity:									
Tests	.00158**	.00303**	.00123**	.00104**	.00350**	.00833**	.00479**	.00305**	.00483**
Error	.00022	.00027	.00032	.00028	.00036	.00035	.00055	.00073	.00053
Coefficient of variability	1.56	1.73	2.88	1.73	1.98	1.93	2.76	3.24	2.72
Correlation	−.283	−.353	.647	.264	−.416	.557	.639	.812	.794
Length:									
Tests	0.6908**	1.735**	1.0373**	0.824**	1.226**	1.980**	0.1870**	0.2842**	0.4113**
Error	.0563	.085	.0604	.143	.133	.100	.0302	.0396	.0393
Coefficient of variability	3.61	4.48	4.15	5.34	5.24	4.78	4.96	5.47	5.75
Correlation	.923	.920	.948	.840	.894	.956	−.002	.834	.808
Diameter:									
Tests	0.5120**	1.9153**	1.0025**	0.4119**	0.852**	0.8108**	0.4286**	0.2322**	0.4108**
Error	.0598	.0914	.0638	.0912	.115	.0777	.0337	.0394	.0436
Coefficient of variability	3.71	4.59	4.10	4.44	4.95	4.37	4.75	5.11	5.47
Correlation	.851	.936	.918	.716	.651	.895	.016	.831	.911

TABLE 1.—*Mean squares for tests and error sources for indicated variables with an indication of significance, coefficients of variability, and correlation coefficients between test number and test means* [1]—Continued

Measurement and source	Hamlin orange 1964	Hamlin orange 1965	Hamlin orange 1966	Valencia orange 1964	Valencia orange 1965	Valencia orange 1966	Marsh grapefruit 1964	Marsh grapefruit 1965	Marsh grapefruit 1966
Form:									
Tests	.00151 ns	.00155 ns	.00116 ns	.00530**	.00578**	.00911**	.01850*	.00284**	.01080**
Error	.00080	.00107	.00077	.00099	.00135	.00106	.00878	.00183	.00180
Coefficient of variability	2.84	3.30	2.88	3.04	3.62	3.14	10.4	4.56	4.39
Correlation	.936	−.234	.386	.315	.741	.845	−.072	.344	−.004
Compression:									
Tests	751.9**	1,472.0**	988.3**	660.2**	837.5**	323.6**	251.7**	1,502.2**	550.16**
Error	34.7	27.2	28.5	15.4	29.1	12.3	21.4	24.0	27.4
Coefficient of variability	12.4	11.9	12.5	11.3	15.7	11.5	9.25	9.88	11.6
Correlation	.668	.904	.948	.822	.827	.906	.578	.957	.919
Chlorophyll—DP:									
Tests	.1314**	1.8750**	2.5950**	1.1227**	2.1651**	2.5568**	.1906**	.9090**	1.0395**
Error	.0012	.0020	.0037	.0047	.0027	.0027	.0047	.0037	.0040
Coefficient of variability	27.3	14.3	13.8	20.7	13.5	13.0	27.9	19.8	25.1
Correlation	−.881	−.905	−.936	−.891	−.869	−.890	−.459	−.765	−.752
Chlorophyll—IS:									
Tests	.1281**	1.8924**	2.3057**	1.1189**	2.2287**	2.384**	.1940**	.9893**	1.0673**
Error	.0009	.0017	.0022	.0035	.0022	.002	.0026	.0025	.0019
Coefficient of variability	16.6	10.8	9.97	16.0	11.1	9.95	16.1	12.7	13.2
Correlation	−.877	−.933	−.939	−.899	−.879	−.890	−.722	−.812	−.793
Chlorophyll reflectance:									
Tests	------	------	0.5830**	------	------	0.61183**	------	------	0.15797**
Error	------	------	.0016	------	------	.00089	------	------	.00088
Coefficient of variability	------	------	8.98	------	------	6.98	------	------	8.17
Correlation	------	------	−.933	------	------	−.887	------	------	−.822

Water band—DP:									
Tests	.00371**	.01537**	.00206**	.00496**	.01530**	.00147**	.00659**	.04958**	.00458**
Error	.00009	.00012	.00011	.00017	.00035	.00012	.00041	.00067	.00058
Coefficient of variability	18.0	18.3	24.1	18.8	26.4	19.6	15.3	16.6	18.4
Correlation	−.578	−.950	−.482	−.623	−.440	−.297	−.104	−.142	.647
Water band—IS:									
Tests	.020632**	.030906**	.00266**	.001497**	.03133**	.00175**	.00190**	.02635**	.000828**
Error	.003937	.000048	.00005	.000055	.00004	.00004	.00005	.00007	.000048
Coefficient of variability	48.0	49.7	133.3	166.0	104.0	294.2	25.8	26.8	31.4
Correlation	−.830	−.678	−.773	−.707	−.672	−.743	.232	−.523	.600
Peeled chlorophyll:									
Tests	0.00029**	0.01154**	0.03275**	0.02127**	0.03514**	0.04027**	0.00266**	0.00365**	0.00177**
Error	.00010	.00018	.00022	.00056	.00050	.00042	.00015	.00014	.00017
Coefficient of variability	7.09	8.14	7.68	12.0	11.1	10.1	8.73	8.25	8.87
Correlation	−.767	−.808	−.892	−.950	−.924	−.960	.678	.094	−.007
Peeled water band:									
Tests	.000306**	.02066**	.00190**	.000548**	.00463**	.00099**	.000904**	.00355**	.001041**
Error	.000014	.00002	.00002	.000025	.00003	.00003	.000044	.00007	.000061
Coefficient of variability	9.8	20.6	10.8	15.9	20.9	10.6	41.2	185.8	51.4
Correlation	.021	−.282	−.259	−.265	−.336	−.059	.103	−.594	.412
Peeled weight:									
Tests	1,462.5**	4,360.7**	3,973.7**	2,344.6**	5,189.5**	7,407.6**	10,201.0**	24,285.0**	30,321.0**
Error	163.0	246.0	128.9	322.6	259.6	192.9	1,263.0	1,666.0	1,596.0
Coefficient of variability	10.7	13.1	11.6	12.8	13.7	12.1	11.8	12.7	13.8
Correlation	.791	.851	.922	.783	.713	.892	.192	.919	.908
Peeled volume:									
Tests	1,257.0**	4,374.4**	3,420.5**	2,085.7**	4,966.6**	6,258.6**	10,379.0**	25,538.0**	28,225.0**
Error	172.8	254.8	137.4	320.6	367.0	209.1	1283.0	1728.0	1582.0
Coefficient of variability	11.4	13.6	12.4	13.3	14.2	13.1	12.0	12.9	14.0
Correlation	.793	.870	.912	.772	.735	.876	.226	.927	.916

TABLE 1.—*Mean squares for tests and error sources for indicated variables with an indication of significance, coefficients of variability, and correlation coefficients between test number and test means* [1]—Continued

Measurement and source	Hamlin orange 1964	Hamlin orange 1965	Hamlin orange 1966	Valencia orange 1964	Valencia orange 1965	Valencia orange 1966	Marsh grapefruit 1964	Marsh grapefruit 1965	Marsh grapefruit 1966
Peeled specific gravity:									
Tests	.00112 ns	.00107**	.00205 ns	.00049 ns	.00069*	.00280**	.00084**	.00061**	.00061**
Error	.00068	.00037	.00119	.00032	.00033	.00094	.00017	.00014	.00020
Coefficient of variability	2.53	1.89	3.33	1.72	1.78	2.94	1.28	1.20	1.38
Correlation	.455	−.696	.678	.611	−.411	.882	−.477	−.667	.386
Rind weight:									
Tests	92.29**	550.73**	146.30**	64.69**	174.97**	89.22*	2,655.00**	1,714.70**	4325.2**
Error	15.65	19.51	11.06	33.99	42.70	19.99	2:84	360.50	363.9
Coefficient of variability	12.6	15.0	13.2	16.1	17.3	13.9	15.7	17.1	18.0
Correlation	.884	.958	.786	.494	.758	.698	−.028	.859	.924
Rind volume:									
Tests	350.67**	1009.27**	357.02**	184.87**	491.75**	351.84**	11,302.00**	3,644.00**	7,202.00**
Error	40.18	46.70	34.44	81.34	95.85	49.44	1,212.00	1,703.00	1,615.00
Coefficient of variability	14.9	16.5	16.8	19.3	19.9	17.1	18.8	20.6	21.7
Correlation	.907	.937	.814	.647	.808	.538	−.206	.646	.845
Percent rind:									
Tests	5.12 ns	64.46**	102.64**	26.54**	82.37**	210.17**	20.30**	19.78**	62.09**
Error	3.75	4.30	2.58	2.98	4.92	3.38	5.90	6.29	4.82
Coefficient of variability	9.22	10.5	7.77	8.39	10.3	8.27	9.29	9.77	8.25
Correlation	.499	.594	−.433	−.742	−.305	−.680	−.153	−.577	−.019
Rind specific gravity:									
Tests	.0176**	.0101**	.01305 ns	.0163**	.0137**	.0347**	.01218**	.00677**	.01240**
Error	.0040	.0026	.00669	.0028	.0027	.0057	.00061	.00071	.00076
Coefficient of variability	8.44	7.08	11.2	6.80	6.71	9.50	4.23	4.77	4.84
Correlation	−.827	.174	−.313	−.562	−.667	−.153	.807	.847	.960

Number of seeds:									
Tests	......	5.241^{ns}	5.279^{ns}	......	10.50**	7.314^{ns}	......	2.866^{ns}	3.811^{ns}
Error	......	3.950	4.065	......	4.97	6.021	......	3,697	4.128
Coefficient of variability	......	94.5	44.5	......	40.2	48.5	......	57.1	51.9
Correlation	......	−.280	.106	......	−.135	−.080	......	−.676	−.486
Juice weight:									
Tests	1,106.5**	2,072.9**	1,841.4**	2,963.1**	3,209.9**	5,080.4**	4,729.0**	12,037.0**	14,706.0**
Error	80.0	88.7	54.8	165.2	156.8	97.8	550.0	576.0	483.0
Coefficient of variability	11.8	12.8	12.2	12.7	14.8	13.2	12.3	11.9	12.4
Correlation	.683	.658	.911	.817	.483	.937	.315	.879	.899
Percent juice:									
Tests	180.10**	212.44**	223.55**	277.27**	290.46**	650.62**	27.19**	64.71**	102.48**
Error	11.2	6.94	5.15	5.29	14.02	4.61	4.19	6.13	5.95
Coefficient of variability	6.63	5.36	4.59	4.01	7.81	4.25	4.39	5.32	5.47
Correlation	.190	−.276	.726	.839	−.183	.881	.590	.444	.588
Percent soluble solids:									
Tests	6.001**	17.041**	32.830**	50.288**	51.785**	97.850**	1.591**	1.593**	1.005**
Error	.281	.448	.193	.275	.364	.221	.121	.117	.240
Coefficient of variability	4.54	6.21	3.92	4.25	5.31	3.98	3.67	3.95	5.38
Correlation	.813	.787	.995	.978	.949	.969	.237	−.550	.313
Percent acid:									
Tests	.1560**	1.2580**	1.8443**	2.921**	7.794**	9.291**	.3144**	.4706**	.2823**
Error	.0051	.0063	.0147	.033	.040	.066	.0048	.0114	.0112
Coefficient of variability	10.2	9.49	11.04	12.1	13.0	13.7	5.58	8.60	7.58
Correlation	−.902	−.958	−.924	−.942	−.936	−.950	−.969	−.944	−.851
Ratio—solids-to-acid:									
Tests	127.26**	415.57**	292.83**	197.24**	348.04**	261.04**	7.087**	11.129**	6.950**
Error	2.44	1.67	1.65	1.73	1.76	1.34	.225	.264	.208
Coefficient of variability	9.20	9.14	11.4	14.5	14.8	15.3	6.17	7.23	6.90
Correlation	.946	.994	.989	.994	.989	.990	.951	.933	.903

TABLE 1.—*Mean squares for tests and error sources for indicated variables with an indication of significance, coefficients of variability, and correlation coefficients between test number and test means* [1]—Continued

Measurement and source	Hamlin orange 1964	Hamlin orange 1965	Hamlin orange 1966	Valencia orange 1964	Valencia orange 1965	Valencia orange 1966	Marsh grapefruit 1964	Marsh grapefruit 1965	Marsh grapefruit 1966
Weight soluble solids:									
Tests	29.14**	53.209**	61.852**	155.78**	110.22**	218.48**	32.97**	80.14**	136.74**
Error	1.14	.844	.700	2.09	1.78	1.15	5.37	4.37	4.34
Coefficient of variability	12.0	11.5	12.1	11.4	13.7	11.7	12.8	12.0	12.3
Correlation	.851	.740	.976	.945	.780	.978	.043	.763	.880
Temperature correlations —(hours below): [2]									
70° F.—2 weeks	.956	.939	.853	.152	.178	.072	−.377	.314	.072
70° F.—cumulative	.997	.974	.985	.992	.995	.995	.993	.992	.995
65° F.—2 weeks	.906	.956	.670	−.094	.146	−.347	−.154	.253	−.347
65° F.—cumulative	.982	.950	.999	.985	.988	.990	.988	.984	.990

[1] Statistical significance: ** 1-percent level; * 5-percent level; ns, not significant.

[2] Correlations between test number and temperature data for Valencia oranges and Marsh grapefruit would normally be the same within each season as in 1966. Differences between these varieties shown in 1964 and 1965 were due to differences in number of tests included in the analyses.

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