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Growth Measurement as an Indication of Avocado Maturity

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ABSTRACT. Fruit growth of avocado *(Persea americana* Mill.) fruit measured by the increase in length, diameter, and volume was initially rapid, but later slowed to a linear growth. Linear extrapolation to zero from growth rate in the descending portion gave a definite point indicating that physiological maturity had occurred. In many cases, this physiological maturity date correlated well with horticultural maturity date determined by taste-panel analysis.

Horticultural maturity in many fruits is generally related to physiological maturity, the stage when physical growth is virtually complete. Growth of fruits measured by length, diameter, volume, weight, etc., during development often shows a characteristic pattern.

Schroeder (4) showed a sigmoid growth curve for avocado fruit. Length and diameter increased slowly just after fruit set but increased rapidly during warmer months. Growth in both dimensions slowed as cool weather approached. Growth, observed accurately and continuously with a dial gauge, consisted of a series of diurnal fluctuations instead of a smooth curve (6). Maximum fruit size was attained early in the day. During the day, water moved from fruit to leaves due to transpiration, resulting in reduced fruit size.

Most fruits go through intensive cell division during the first weeks after pollination, after which cell division ceases. Cell division in avocados is unique because it proceeds as long as a fruit is attached to the tree (5). Thus, growth is due to both cell division and cell enlargement. After the avocado fruit reaches about half of its ultimate size, cell division and subsequent enlargement of these cells are responsible for growth because mature cells no longer enlarge (3).

Robertson (2) divided the sigmoid growth curve of avocado fruit into 3 stages. The 1st stage was one of slow growth, during which 90% abscission occurred. Fruit growth was rapid during the 2nd stage, when 80% of the development took place and a great number of cell divisions occurred. Physiological maturation proceeded during the 3rd stage, in which the seed matured and the rate of cell division decreased. This pattern was the same for many cultivars, but the lengths of each stage differed among cultivars.

The purpose of this study was to relate the nature of the changes in growth to horticultural maturity based on taste testing.

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Table 1. Comparison of dates of acceptable taste and change in length growth rate.

Cultivar	Location	No. years	Date of change in growth rate	Date of acceptable taste	Difference in date
Bacon	Irvine	1	Nov. 3	Nov. 3	0
	Santa Barbara	1	Dec. 24	Dec. 14	+10
	San Marcos	1	Nov. 28	Nov. 16	+12
	Santa Paula	1	Dec. 11	Nov. 29	+12
	Valley Center	2	Nov. 16	Nov. 16	0
Fuerte	Fallbrook	4	Nov. 9	Nov. 3	+ 6
	Highland Valley	1	Nov. 9	Nov. 12	− 3
	Irvine	5	Nov. 1	Nov. 4	− 3
	San Marcos	1	Nov. 6	Oct. 28	+ 9
	Santa Paula	1	Nov. 14	Nov. 10	+ 4
	Valley Center	1	Nov. 18	Nov. 28	−10
Hass	Irvine	1	Oct. 31	Nov. 27	−27
Zutano	Corona	2	Nov. 3	Dec. 2	−29
	Fallbrook	5	Nov. 21	Nov. 18	+ 3
	Highland Valley	1	Nov. 23	Nov. 22	+ 1
	Irvine	3	Nov. 8	Nov. 10	− 2
	Lindcove	1	Oct. 28	Oct. 19	+ 9
	Porterville	1	Oct. 19	Oct. 25	− 6
	Valley Center	1	Oct. 26	Nov. 27	− 1

Materials and Methods

In early July 4 avocado trees at each sampling location (Table 1) were tagged for growth studies. Fruit were not tagged immediately after anthesis because of the high abscission rate of the very small fruit. In early July, differences in fruit size were apparent, presumably due to different times of pollination. By dividing the fruit on a tree into 3 size categories (small, medium, and large) for subsequent measurement, consistent growth data were obtained.

The lengths and diameters of these fruit were measured with a vernier caliper in the morning (10 AM to 12 noon) every 2 weeks. Fruit volume was measured by water displacement, but since these measurements were difficult to make in the field, fruit volume was also calculated from the measurements of length and diameter, using an appropriate adjustment to the formula of an ellipsoid. The adjustment factor for each cultivar was obtained by measuring the volume, the length, and the diameter of 20 fruit: it represents the ratio of the measured volume to the volume calculated from the formula.

Growth rates were calculated by dividing the difference in measurement between 2 measuring dates by the number of days in the interval. A maturity date based on the growth-rate curve was obtained by extrapolating a linear regression line from the descending growth rate to the date axis.

Fruit from other trees in each location were collected, ripened, and subjected to taste-panel analysis to determine horticultural maturity dates (1). These dates were compared with the dates of physiological maturity based on the growth-rate curves.

Results and Discussion

For each parameter, only the last half of a sigmoid growth curve was plotted because growth measurements were not made during the very early part of the season (Fig. 1).

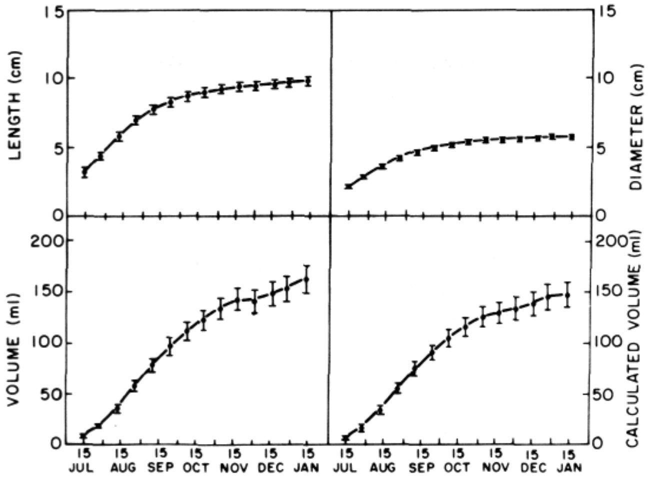

Fig. 1. Growth curves in length, diameter, volume, and calculated volume for 'Fuerte' fruit at Irvine during development. The curves represent the mean values for 18 fruit. Vertical bars are 2 SE. These data, which are representative of a large number of data sets, were collected in 1977.

Length increased rapidly during the summer and then continued slowly in autumn and winter while the fruit became mature. Changes in diameter were smaller but similar in pattern. Volume increased slowly in late July and increased faster in August through September. In mid-November, the increase slowed. The volume measurements by water displacement were the least reproducible and the most difficult to make in the field. Early in the season, this displacement volume was not significantly different from the calculated fruit volume. The pattern of change was similar in both cases. However, as the season progressed, the increase in calculated volume was slightly less than the increase in measured volume.

The growth rate in length for 'Fuerte' fruit at Irvine is shown in the upper portion of Fig. 2. Avocado fruit grew rapidly in August (about 900 (mm/day). As cool weather approached, the rate declined and leveled off at a low and consistent rate after November.

Physiological maturity, which is the completeness of major physical growth, can be estimated by an extrapolation of the linear regression line from the descending curved portion of the growth-rate curve to the date axis (Fig. 2). The point at which the line intersected the date axis was considered to be the point where the final deceleration of the growth rate ceased, and linear growth remained. In Fig. 2, the date based on physiological maturity was November

Estimated maturity dates were compared with dates of acceptable taste as determined by taste-panel analysis (Table 1). Generally, the estimated dates from the growth-rate curves were close to the time of acceptable taste. 'Bacon' and 'Fuerte'

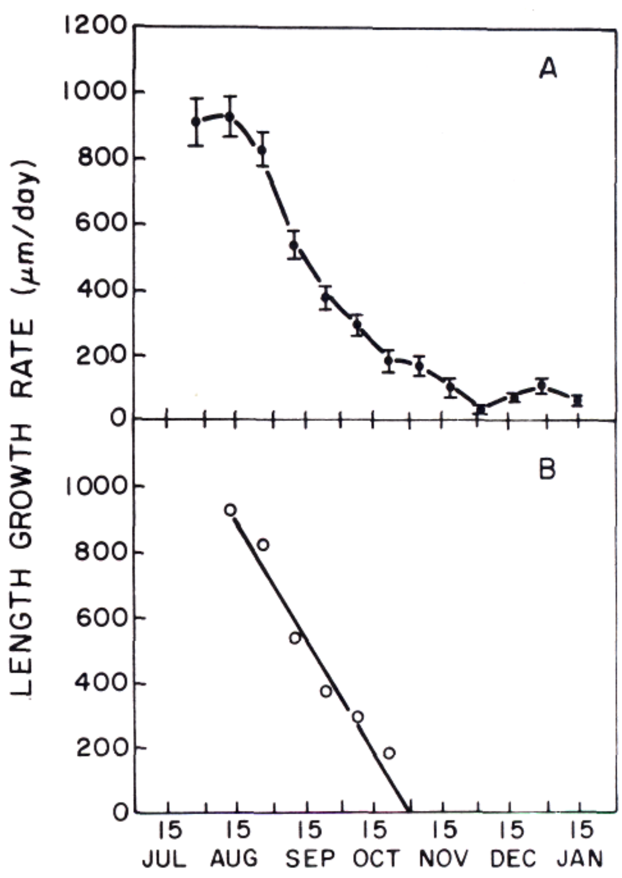

Fig. 2. **A:** Growth-rate curve in length for 'Fuerte' fruit at Irvine. The curves represent the mean values for 18 fruit. Vertical bars are 2 SE. These data, which are representative of a large number of data sets, were collected in 1977. **B:** Regression line during the declining growth-rate period. Physiological maturity date is the point where the line intersects the date axis.

were especially good examples of this relationship. 'Zutano' fruit showed a good relationship between the date of mature taste and the date of change in length growth rate except for the fruit at Corona, which weighed less than those from the other areas. The predicted date from the growth-rate curve for one 'Hass' location occurred about a month earlier than that of acceptable taste. Under present marketing conditions, 'Hass' is not an important cultivar for determining maturity because growers benefit more by holding fruit on the tree until after 'Bacon', 'Fuerte', and 'Zutano' fruit are off the market. Therefore, growth measurements apparently could be used to predict horticultural maturity in many cases. However, percent dry weight shows promise as a simpler and more reliable index of maturity (1).

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