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AVOCADO GROWTH AND DEVELOPMENT[1, 2]

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ABSTRACT

More than 20 commercial avocado varieties grown in the Homestead area of Florida were observed biweekly for over 3 yr. Observations included the number and timing of vegetative flushes and timing of floral development as well as the flower and fruit setting habits of each variety. This report describes the yearly transitions through vegetative growth, rest, and reproduction of avocado.

Avocado (*Persea Americana* Mill.) is a fruit common to the tropics and subtropics. The species consists of three races: Mexican, Guatemalan, and West Indian. The latter and West Indian X Guatemalan hybrids are generally considered best adapted to South Florida's soil and climatic conditions (6). The syncronously dichogamous flowering habit of avocado has been extensively studied and described (4, 8, 15, 16). Venning and Lincoln (19) described the morphology and development of the vegetative axis; however, little information is available on general growth and development patterns of avocados grown in south Florida. This report brings together observations on a number of varieties concerning the phases of growth, rest, flowering, and fruit set of avocados grown in the Homestead area of south Florida. Recent work by Australian and Israeli workers will also be reviewed as it contributes to an understanding of Florida-grown cultivars.

MATERIALS AND METHODS

More than 20 major and minor commercial varieties grown in South Dade County, Florida were observed from 1979 through 1982. All trees were growing on Rockdale soil in commercial groves or at the Agricultural Research and Education Center in Homestead. All trees used for observation were in typical grove spacing with ample water, fertilizer, and daily sunlight on the canopy.

Observations were made biweekly. They include number and timing of vegetative flushes, number of leaves per flush, timing of flowering as well as development and number of inflorescences, and fruit setting habit. Information on all varieties is not complete due to interruption of study by topping and hedging practices; however, whenever possible alternate trees were found. Thus, it is felt the results present enough information to assess the timing and growth characteristics of each variety.

RESULTS AND DISCUSSION

Vegetative growth. Trees of most avocado varieties grow continuously in many respects. They are almost constantly growing throughout the summer months; however, it is important to note that this growth may be active in large or small portions of the canopy at any one time (19). Each branch generally undergoes two to three growth flushes per year beginning with the first which occurs during or near termination of the flowering period. On rare occasions more than three flushes on a branch may occur. Branches that are constantly shaded or are bearing fruit will nearly always produce only one annual vegetative flush, and this flush occurs during flowering. Periods of rest are characterized by non-growing, bract-like leaves and compact internodes at the shoot apices. During a flush each successive leaf expands to a successively larger size along with lengthening internodes until normal leaf size and internode length is reached (19). Each variety produces a characteristic number of normal sized leaves per flush with about 10% branch to branch variability in that number (Table 1). The apical bud rapidly resumes a state of rest at termination of the flush period with an associated transition from normal leaves to leaves reduced in size and finally to the bract-like structures protecting the apical bud. Each flush generally lasts from 3 to 5 wk. A history of this growth pattern is recorded on each branch through leaf and bract scars evident at various internode lengths (19) as described above. One can easily count the number of flushes occurring since last flowering by noting the number of compressed node sections. Development of side branches from axillary buds occurs at compressed nodes as well as at spaced nodes and has been described in detail (19).

Table 1. Number of inflorescences and leaves per flush of avocado reproductive and vegetative growth.

Variety	Inflorescences per reproductive flush	Leaves per vegetative flush
Booth 7	5.8 ± 0.3 (3)[z]	6.9 ± 0.3 (1)
Booth 8	7.4 ± 0.4 (3)	10.4 ± 0.8 (2)
Brookslate	9.3 ± 0.6 (1)	6.0 ± 0.3 (1)
Collinson	5.6 ± 0.3 (1)	7.2 ± 0.3 (2)
Dwarf Lula	5.9 ± 0.4 (1)	8.1 ± 0.4 (2)
Fuchs	—[y]	8.2 ± 0.6 (2)
Fuerte	6.1 ± 0.5 (1)	7.2 ± 0.3 (2)
Hall	9.5 ± 0.6 (1)	6.1 ± 0.4 (1)
Hardee	9.6 ± 0.6 (2)	12.5 ± 2.6 (1)
Hass	8.6 ± 0.6 (1)	7.1 ± 0.2 (1)
Itzamna	6.9 ± 0.7 (1)	7.1 ± 0.6 (1)
Kosel	11.9 ± 0.9 (1)	5.0 ± 0.2 (2)
Lula	6.3 ± 0.5 (3)	6.5 ± 0.3 (2)
Mexicola	5.6 ± 0.4 (1)	8.6 ± 0.3 (2)
Nadir	9.0 ± 0.5 (1)	9.2 ± 0.5 (1)
Peterson	8.6 ± 0.9 (5)	17.5 ± 4.3 (2)
Pollock	11.6 ± 0.5 (3)	6.6 ± 0.2 (2)
Ruehle	6.7 ± 0.4 (2)	9.8 ± 0.9 (2)
Simmonds	11.1 ± 2.6 (3)	10.7 ± 0.6 (2)
Taylor	6.8 ± 0.3 (3)	5.5 ± 0.3 (2)
Tower II	10.4 ± 0.3 (1)	—
Waldin	10.5 ± 0.4 (3)	10.9 ± 0.8 (2)
Winter Mexican	6.7 ± 0.5 (1)	6.4 ± 0.3 (1)

[z]Each datum is the calculated mean ± SE of 20 branches times the number of observation seasons indicated in parentheses.
[y]Not determined.

Vegetative flushes begin to occur on all active branches of a tree synchronously near the climax of flowering which occurs in March or April. As stated above, later flushes occur on only portions of the tree at any one time throughout the summer and early fall. Some varieties are more synchronous with this growth than others. Fig. 1 depicts the vegetative phases (saw tooth lines) of tree growth. If vegetative growth is depicted to be constant (such as 'Ruehle') then it indicates that growth was occurring on at least a few branches at each observation. If, on the other hand, vegetative growth appears to come in bursts (such as 'Nadir'), then it implies generally synchronous growth throughout the tree during growth periods. Portions of trees may be active throughout the summer ending in September and early October before all the buds enter a rest period.

Reproductive growth. The next growth flush to develop produces inflorescences. This occurs in late November to January through March and April in South Florida (Fig. 1). The reproductive stimulus must occur throughout the tree because all developing axillary buds are flowering type. Furthermore, inflorescence buds have been observed to develop even on scaffolding branches of 'Booth 8' trees which were tip pruned during its early flowering period. The timing of floral development varies with variety and to some extent with the weather, most likely the average daily temperature. Variation also occurs within the canopy. The upper and sun side of the trees generally flower first. Buttrose and Alexander (1) demonstrated that 'Fuerte' avocado floral initiation was correlated with both low temperature and, more importantly, short day length. It is not clear at this time how important each of these factors is in floral initiation of Florida grown cultivars. Inflorescence development, however, does not begin here until late November and December which coincides with our shortest days of the year. The day length in the Homestead area is 11 hr, 12 min on November 1 and decreases to 10 hr, 32 min by December 20, the shortest day length of the year (Nautical Almanac Office, U. S. Naval Observatory, Washington, D. C., 20390). Since vegetative growth in many cultivars is active in October it is likely that if trees are responding to day length they should be responding to those day lengths that occur after completion of vegetative growth which would be approximately 11 hr or less.

Inflorescence development has been described anatomically (7, 9, 10). Reese (7) noted floral development of 'Lula' and 'Nabal' trees grown in the Orlando area began in early December and occurred approximately 3 wk later in the Homestead area; however, by February the developmental differences between trees grown in the two locations were nominal. The solid lines in Fig. 1 indicate the period of inflorescence development begins in most commercial varieties grown in the Homestead area in late November through January. Inflorescence development can be described in discrete stages summarized in Table 2 with examples in Fig. 2. The number of inflorescences which develop on a shoot does not appear to be correlated with the number of leaves in each flush (Table 1). Reproductive development in different varieties may proceed at different rates (Fig. 1). Fig. 3 depicts both the rate of development and the observed progress of inflorescences through the various developmental stages. Some varieties such as 'Pollock' progress in time through the stages in a relatively linear fashion. Others such as 'Booth 7' tend to lag in development of the early stages through February. The timing of reproductive development may vary seasonally as much as a month; however, the trends characteristic of each variety appear to be preserved.

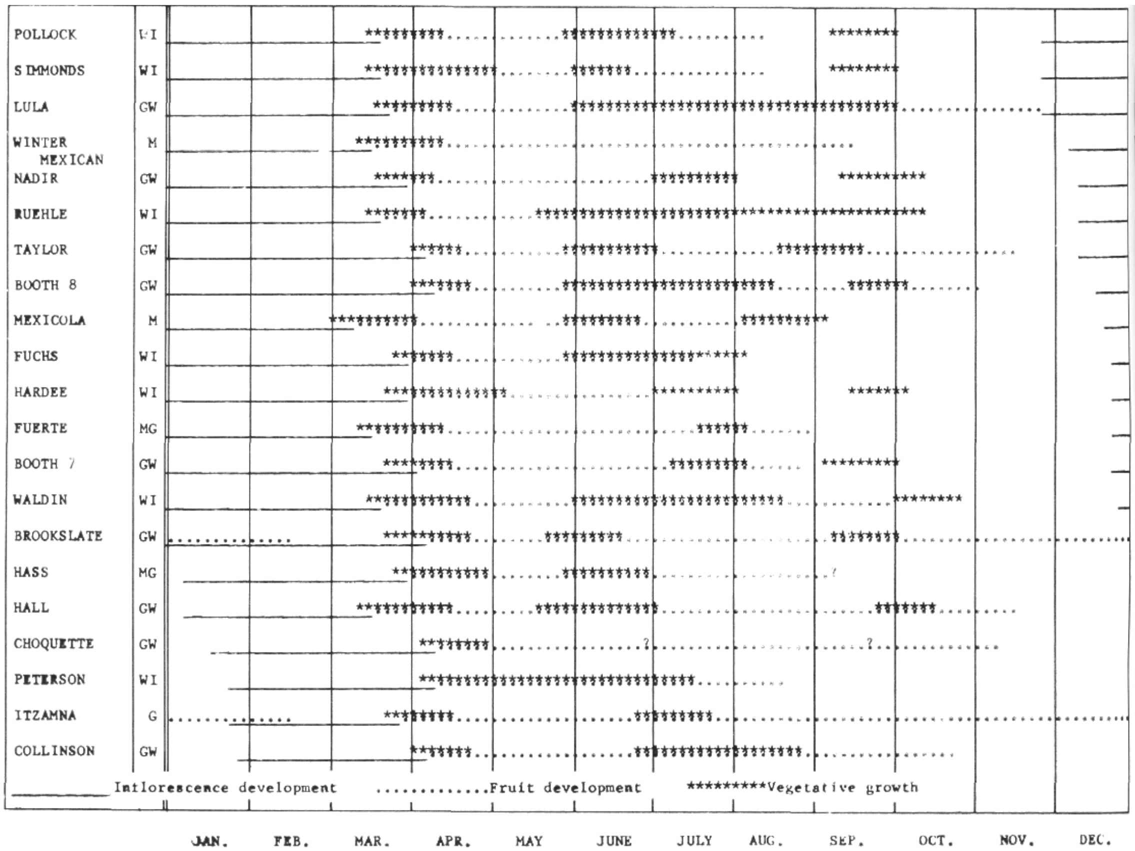

Fig. 1. Growth and development of avocado varieties. Each variety was observed one to three seasons. WI = West Indian; GW = Guatemalan x West Indian hybrid; M = Mexican; MG = Mexican x Guatemalan hybrid.

Floral anthesis (stages 8 and 9) of most varieties begins from late March to early April (Figs. 1 and 2). Flowering can be classified into A and B classes according to Stout (15) and others (4, 8, 16). This classification extends across racial lines. The importance of pollinators has been stressed (3); however, some question still remains as to the relative importance of potential pollinators in Florida.

Table 2. Description of various stages in avocado reproductive development.

Stage	Description
0	bud in rest, bracts closed with no sign of growth
1	first indication of bud development, bracts show signs of opening
2	obvious bud growth, bracts open showing developing inflorescence bud
3	bud assumes spherical shape as inflorescences begin enlarging
4	bud becomes angular, continued enlargement of inflorescences
5	first observable elongation of primary peduncles
6	continued elongation of primary peduncles. First observable elongation of secondary peduncles
7	continued elongation of inflorescence and development of flowers
8	first opening of flowers
9	maximum flower opening

Ambient temperature appears to be an important factor in the function of both flowers and pollen. Sedgley and co-workers (11, 14) reported low temperatures (17°C or 62°F day and 12°C or 52°F night) inhibited pollen tube growth and greatly delayed normal female opening and male anthesis times in both 'Fuerte' and 'Hass'. These low temperatures resulted in little or no fertilization and no subsequent fruit set. High temperatures 33°C or 91°F day 28°C or 81°F night) produced normal flowering but enhanced abscission of flowers and fruitlets. Abnormal pollen tube growth was also noted. Ideal conditions of 25°C (77°F) day and 20°C (68°F) night resulted in optimum performance of both flowers and pollen. Complexing with these potential problems is the observation by both Sedgley (13) and Tomer *et al.*, (17, 18) that a varietal dependent proportion of ovules are abnormal. These workers (11, 18) and others (5), however suggest that under ideal temperature conditions with available pollinators, the number of fertilized flowers does not limit yield. That is, more flowers are fertilized than will set fruit. Conditions controlling subsequent fruit set are apparently more important.

During the early period of flowering, leaf senescence begins in most varieties. The extent of leaf yellowing and fall is varietal dependent with some varieties such as 'Lula' being almost completely deciduous, losing nearly all of their leaves within a week of senescence onset and others such as 'Peterson' losing few leaves. Preliminary experiments conducted on 'Booth 8' strongly suggest that leaf senescence is controlled by the presence of flowers. Trees from which stage 4 to 5 flower buds were removed retained all leaves without any sign of senescence. Leaves from plants which were allowed to flower normally became yellow and fell from the tree.

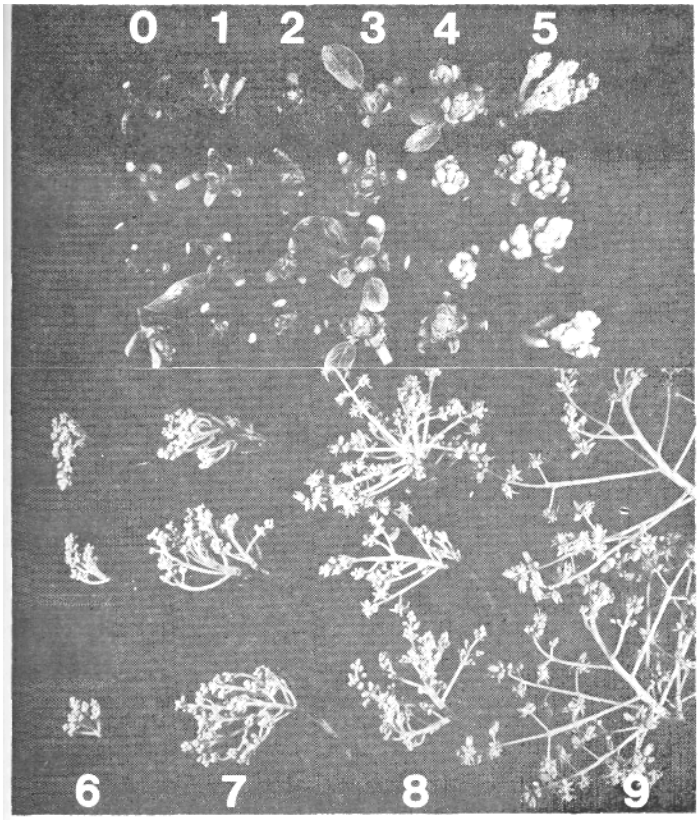

Fig. 2. Developmental stages of avocado inflorescences. See Table 2 for description of each stage.

About the time the flowers are in their maximum activity, growth of the apex resumes vegetatively. Once this vegetative flush ceases, the tree resumes the sporadic vegetative growth flushes through the summer months as described earlier.

Fruit set. Fruit set habits of cultivars grown in Florida can be described as one of two distinct types. Table 3 lists varieties which typically fall into each class. Type 1 habit has a heavy initial fruit set. It is estimated that 20 to 30% of the flowers will develop into small fruitlets. All fruitlets which become larger than 5 mm in diameter are fertilized as indicated by developing cotyledons. The fruitlets are then systematically lost from the tree over time until a final percentage of the original fruit are left to harvest (Fig. 4). This percentage may range from 1 to 7 *%.* Fig. 4 also demonstrates the lack of a "June drop" as has been described in apples. It may well be that the "June drop" referred to by many growers is the time when the fruit become large enough to be heard when they strike the ground. Representations of this type habit notably include 'Peterson' and 'Simmonds' as well as California varieties, 'Hass' and 'Fuerte'. Loss of these developing fruitlets is mediated by spontaneous deterioration of the seed coat (10). This rapidly deteriorating tissue produces ethylene gas which causes fruit separation from the tree. It is clear that yield in Type I varieties is not dependent upon fertilization processes but upon factors, at present unknown, which cause deterioration of developing fruitlet seed coats.

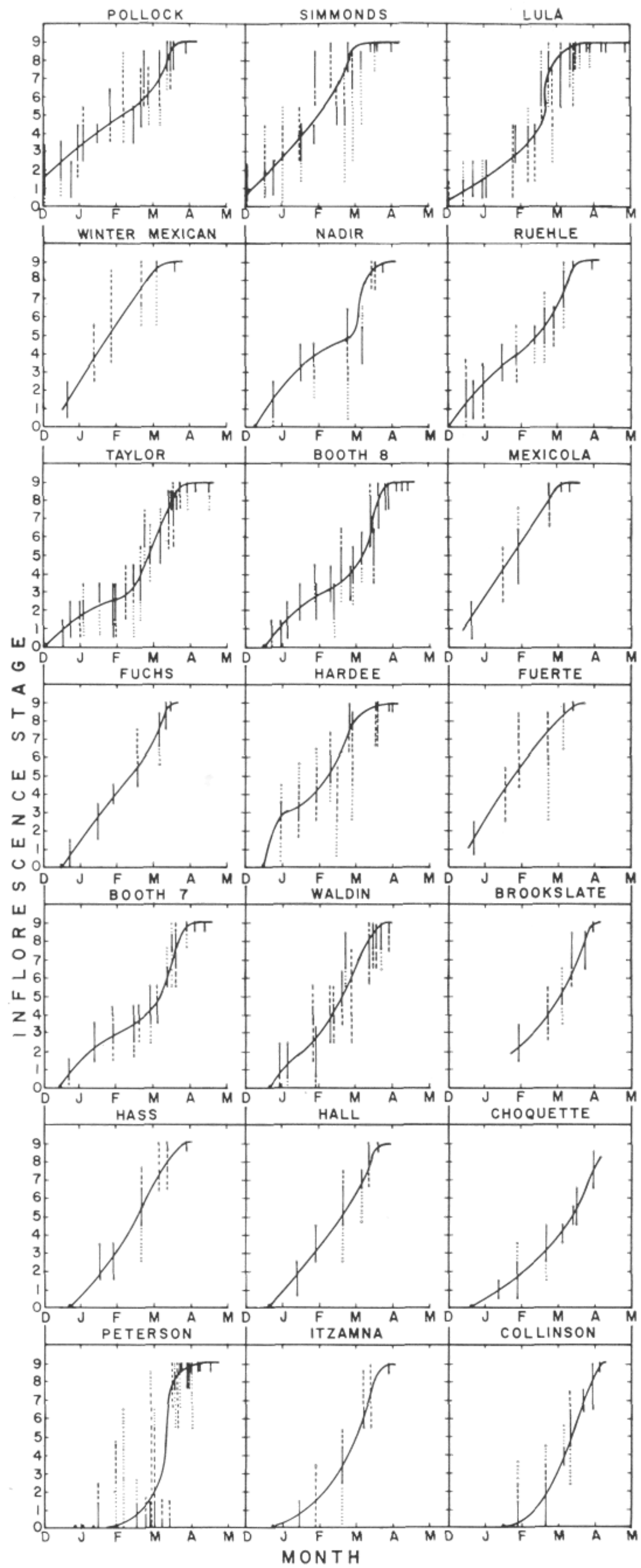

Fig. 3. Transition of avocado inflorescence buds through stages 0-9 during flowering season. Each variety was observed one to three seasons. Each vertical line represents the range and percentage of each stage observed at the indicated time (. . . . , 20%; - - - -, 20% to 40%; ——, >40%.

Table 3. Comparison of setting patterns in avocados grown in South Florida.

Type I heavy initial fruit set, moderate to heavy fruit drop	Type II light initial fruit set, little subsequent fruit drop
Peterson	Pollock
Simmonds	Nadir
Booth 8	Waldin
Hall	Lula
Hass	Booth 7
Dwarf Lula	Fuchs
Ruehle	Taylor
Mexicola	Tower II
Itzamna	Collinson
Winter Mexican	Kosel
Fuerte	Brookslate
Hardee	

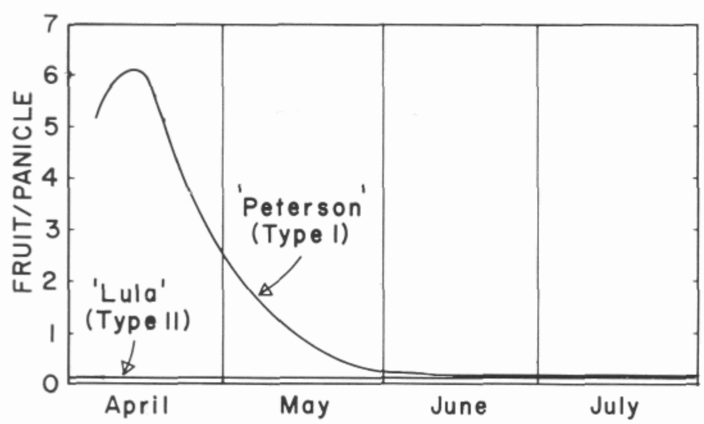

Fig. 4. Fruit set habits of typical Type I and Type II varieties.

Type II fruiting habit is typified by 'Lula' or 'Booth 7'. Few flowers (less than *1%)* initially set fruit, but those that do set initially tend to be retained to maturity (Fig. 4). Preliminary results suggest that nucellus and seed **coat** senescence and associated ethylene production by these tissues are intimately involved in flower loss. A number of factors may be involved in control of fruit set in Type II cultivars. Certainly lack of fertilization of flowers may be a possibility. One may assume that pollinators are just as active in Type II varieties as they are in Type I varieties. Lack of compatibility of pollen from different varieties may be involved and should be examined. The only successful study of such a question was conducted by Sedgley (12) on Australian varieties where she found that the female parent exerted more control over successful ovule penetration by pollen than by the pollen itself. Generally all varieties were equally compatible.

The avocado tree not only produces a delicious fruit but is an interesting plant to study. This paper describes avocado growth and development so that growers and horticulturists can better understand the complexities of the yearly transitions through vegetative growth, rest, and reproduction.

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[2]The author thanks Mr. Bill Krome and M. N. Pal Brooks for access to certain varieties

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