Anatomical Aspects of Avocado Stems and Their Relation to Rooting

By

RICARDO E. GOMEZ

A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL
OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLOIRDA
1971

ACKNOWLEDGMENTS

The author expresses his appreciation to Drs. James Soule and Simon E. Malo for their guidance, assistance and interest during the planning and completion of this investigation. Appreciation is also extended to Drs. R. C. Smith and R. H. Biggs for their constructive criticisms and suggestions in the interpretation and preparation of the manuscripts, to Drs. R. A. Conover and A. H. Krezdorn for their support and friendly guidance.

Eternal thanks are extended to his wife for her moral support and the typing of this manuscript.

The author also wishes to extend his appreciation to the Agricultural Research and Education Center Homestead and to the Center for Tropical Agriculture for providing financial assistance which made this study possible.

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ANATOMICAL ASPECTS OF AVOCADO STEMS
AND THEIR RELATION TO ROOTING

By

Ricardo E. Gomez

December, 1971

Chairman: James Soule
Co-Chairman: Simon E. Malo
Major Department: Fruit Crops

Avocado rootstocks of known parentage are desirable for research and commercial uses. Present stocks are seedlings, which are variable. This investigation was undertaken to determine whether avocado cultivars commonly grown in Florida could be propagated as air layers and to investigate anatomical aspects of stems which influence the rooting of cuttings.

Air layers were put on June 17, September 9, November 11, 1969, and March 10, April 15, and June 24, 1970. Cultivars were 'Pollock', 'Booth 7', 'Booth 8', 'Hickson', and 'Taylor' and 2 Mexican seedlings. The last had the highest percentage rooting while 'Pollock' and 'Booth 7' has the lowest percentage. 'Booth 8', 'Hickson' and 'Taylor' were intermediate. Air layers made in June and April required the shortest period for rooting and the ones in November the longest time.

Six contiguous growth flushes from the terminal end of a branch, as well as the eighth and tenth, were collected from 'Waldin', 'Pollock', 'Catalina', 'Booth 7', 'Booth 8', 'Hickson', 'Lula', 'Taylor', 'Gainesville' (parent tree), 'Brogdon', 'Mexicola', and the 2 Mexican seedling trees.

Material was cut into 0 5 cm lengths, killed in FAA and softened in glycerol-alcohol colution. Sections 35 μ thick were cut on a sliding microtome and treated with phloroglucinol-HCl or IKI. Photomicrographs were made of selected sections.

General details of stem anatomy corroborated earlier reports. Series of sections made progressively from the terminal toward the proximal end revealed that as the stem grows in diameter the fiber-sclereid ring starts to break down, especially when the phloem rays begin to diverge. Etiolated stems were found to have less lignification of cells than non-etiolated. It was also found, that the frequency of the fiber bundles and the sclereid connection was greatest for West Indian cultivars and least for Mexican seedling trees. Guatemalan cultivars and hybrid types were intermediate. The fact that avocados of Mexican origin generally root better than those of the West Indian race is recognized and has been supported by the air-layering experiments described above.

The origin of adventitious roots in most plants is in the periphery of the cambial zone, consequently it is reasonable to presume that if a barrier of fibers and sclereids is present, the race having the lower degree of lignification should root best. This has been shown to be true of the Mexican race as compared to the West Indian cultivars.

INTRODUCTION

Vegetative reproduction by graftage has long been used successfully for many tropical fruit crops. Commercial plantings of avocado (*Persea americana* Mill.) in many parts of the world utilize plants grafted on seedling stocks. These stocks are highly variable; therefore, possible stock-scion interactions can not be readily evaluated. Genetically uniform rootstocks would permit nutritional studies and other useful investigations from which a larger and more uniform production of fruits might be obtained. Propagation of avocado stocks by means of cuttings and air layerage has been attempted in California (44, 45, 58, 59), Israel (72, 81), and Florida (47, 48, 50, 56) but success thus far has been limited mainly to cultivars of the Mexican race.

Objectives of the present investigation were to determine whether avocado cultivars commonly grown in South Florida could be propagated by air layering and to study anatomical aspects of stems which might influence the rooting of cuttings of different cultivars or races.

LITERATURE REVIEW

Avocado, unlike cultivars of some important horticultural crops such as citrus and mango, does not exhibit polyembryony. Vegetative reproduction of avocado by means of cuttings and layers has been widely studied (8, 16, 22, 27, 28, 29, 32, 33, 34, 35, 36, 41, 42, 44, 45, 47, 48, 50, 56, 58, 59, 66, 67, 72, 81, 82).

The nutritive status of the stock plant greatly influences the development of roots and shoots (3, 13, 33, 36, 50, 59, 63, 68, 73, 80). Special consideration has been given to the relative amounts of carbohydrates and nitrogen (N). Starring (74) observed that cuttings taken from tomato plants which had a high carbohydrate and low N content rooted better than plants with low carbohydrate and high N. This is true with other species of plants (34, 51, 60, 74). However, Haun and Cornell (37) noted that cuttings of geranium (*Pelargonium hortorum* Bailey cv. *Ricard*) grown under high N had larger and more numerous roots, but fewer cuttings rooted when compared to cuttings from low N regimes. Carbohydrate and N levels can be used to predict the rooting capabilities in some plants (34). Young (82) reported that cuttings taken from avocado trees under medium and high N regimes retained their leaves for a longer period of time when those from low N regimes. Rodrigues and Ryan (65) have reported the carbohydrate content in avocado shoots and Cameron and Borst (9) starch in 6-year old Mexican seedling trees; Bingham (5) and Embleton *et al*. (17, 18) the N content of leaves of avocado. High carbohydrate levels may be required to sustain the cutting until they root (34) since rooting requires several months (47, 48).

Application of growth-promoting substances is a common practice in commercial rooting of cuttings of many species. Initiation of adventitious roots may be controlled by the level of auxin within the tissue or by a balance between auxin and other compounds (25). Very high concentrations of auxin are sometimes needed to enhance rooting in plants (49, 71, 79). Most experiments involving rooting of avocado cuttings have used concentrations varying from 0 to 500 and up to 4,000 parts per million (ppm) (36, 45, 47, 48, 58, 81), or considerably lower than the 10,000 to 30,000 ppm used for rooting of tea and certain other plants (20, 34).

Cuttings from young avocado seedlings root faster and with a higher percentage of success than those from more mature plants (22, 33, 45, 81). Gillespie (28) obtained sections from a 4-year old Mexican seedling that had been cut back to 30 cm. He made 3 cuttings from each section and found that the basal cutting rooted the fastest, and the terminal the slowest. Contrary to this, Ya'Acob and Kadman (81) and Platt and Frolich (58) reported that terminal cuttings rooted better. Leal and Krezdorn (48) using immature stem tips of 'Gainesville' (a Mexican race seedling) obtained 90% rooting after 7 months. Ryan et al. (66) observed that 'Hass' avocado cuttings had not rooted after 7 months. T. J. Anderson of Mulberry, Florida, air layered the top branches (10-15 cm diameter) of 'Winter Mexican' avocado and obtained rooting after 1 year.[1] Sen et al. (70) ringed 1, 2, and 3-year old shoots on a 35-year old mango

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[1] Personal observation by the author.

in June and after 40 days detached them. Indolebutyric acid was applied as a dip (2,000 ppm) and as a powder (5,000 ppm) before planting. The 3-year old wood gave the highest percentage of rooting.

Adventitious roots may arise from pre-existing primordia or be newly formed in the vicinity of differentiating vascular tissues (1, 2, 4, 10, 11, 12, 15, 20, 30, 31, 62, 73, 78). In young stems, root primordia are formed from interfascicular parenchyma cells while in older stems they may be derived from a vascular ray (77).

Etiolation of shoots from which cuttings and air layers are made has proved beneficial in many instances (23, 34, 39, 40, 46, 53, 54, 55, 62, 73) and specifically in avocado (22, 45, 81). Penfound (57) reported that stems of Helianthus and Polygonum growing in full sunlight had a much greater amount of xylem and more and thicker walled fibers and sclereid cells than those in the shade. Priestley (61) found that etiolated stems had a well developed endodermis and concluded that an etiolated stem was somewhat like a root in structure. Bond (6) also reached a similar conclusion with legumes. The added growth in length of etiolated stems was the result of cells being longer rather than being more numerous (7).

Anatomical structure of the stem has been related to the ability of stems to form adventitious roots. Beakbane (4) reported that shoots of difficult-to-root varieties of apples, pears, and other plants are often characterized by a high degree of sclerification (fibers and sclereids) in the phloem. For instance, 'Conference' pear has an almost continuous cylinder of mature, thick-walled fibers which appears in transverse section as a ring of lignified tissue encircling the secondary phloem.

Shy-rooting clones of Hevea brasiliensis have also been found to possess an almost unbroken cylinder or ring of mature lignified elements. Gardner (as reported by Beakbane (4)) found that the rooting capacity of stooled plants diminished as the continuity of the ring increased. Galkin (24) was able to determine the rooting ability of apples by the amount of hard bast fibers in the bark.

The anatomical structure of avocado stems of seedlings of Mexican or Mexican hybrid parentage has been described by Heismann (38) and Schroeder (69). Metcalfe and Chalke (52) have reported the general anatomical characteristics of the family Lauraceae, and Stern (75) has specifically described the xylem anatomy of Lauraceae.

MATERIAL AND METHODS

Air Layers

Air layers were made at the University of Florida Agricultural Research and Education Center Homestead, Homestead, Florida. Plants of West Indian (WI), Guatemalan (G), and Mexican (M) germplasm were used in this study. There were 2 plants each of 'Pollock" (WI) (64), 'Booth 7' (WI x G), 'Booth 8' (WI x G), 'Hickson' (WI x G), 'Taylor' (G) and 2 Mexican race seedling trees designated M 1 and M 2. Ten air layers per variety were applied on June 17, September 9, and November 11, 1969, and March 10, April 15 and June 24, 1970. Branches 1 to 2 cm in diameter were girdled and a strip of bark 2 to 3 cm wide was removed. Moist sphagnum moss was placed around the branch at the ringed area and wrapped with heavy-duty aluminum foil. Experiments simulated commercial conditions. Individual air layers were examined for the appearance of roots on the dates when new air layers were applied and on September 30, 1970, and February 9, 1971, 36 to 518 days after propagation. Branches were examined periodically and reringed at the same place if a callus bridge was found. Percentage rooting was calculated from the number rooted after subtracting those lost from wind or cultural damage.

Anatomical Studies

Avocados used for microscopic examination were 'Waldin', 'Pollock', 'Catalina' (WI), 'Booth 7', 'Booth 8', 'Hickson', 'Lula', (M x WI), 'Taylor', 'Gainesville'[1], 'Brogdon' (M x WI), 'Mexicola' (M), and the 2 Mexican seedling trees (M 1 and M 2). Observations were made on 3 other species, Persea scheideana Nees, Phoebe mexicana Meissn., and Licaria triandra (Sw.) Kostern. Six continuous growth flushes as well as the eighth and tenth from the terminal end of the branch were collected from the avocado cultivars and seedlings, while a random sample was taken from each of the other 3 species. Material was cut into pieces approximately 0.5 cm in all dimensions. Tissues were killed in formalin-acetic acid-95% alcohol solution (FAA; 5,5,45 v:v:v), as described by Childs et al. (14), and softened for at least one month in glycerol-50% alcohol (1:1, v:v) (21). Sections were cut at 35 μ on a sliding microtome and treated with phloroglucinol-HCl (43). Some sections were treated with iodine-potassium iodide (IKI) solution to determine the presence of starch. Photomicrographs were made of selected sections. Line drawings were made to aid in the identification of tissues or zones.

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[1] Material for sections was obtained from parent tree, a Mexican seedling.

RESULTS AND DISCUSSION

Air Layers

Average percentage rooting of all cultivars and seedlings is shown in Fig. 1. A decrease in rooting is apparent in September and November. Three distinct groups appear if the data from the cultivars are separated (Figs. 2 and 3): Mexican seedlings (M 1 and M 2); 'Hickson' and 'Taylor'; and 'Booth 7' and 'Pollock'. 'Booth 8' does not fit into any of the groups but does resemble 'Hickson' and 'Taylor' with a time displacement of about five months. Apparently, the cultivars or seedlings of a race behave similarly as to rooting. West Indian-Guatemalan hybrids may behave like the race of either parent, as 'Booth 7', or unlike either one, as 'Booth 8'.

The Mexican trees had the highest percentage of rooting throughout the year, 75 to 100%, 'Booth 7' and 'Pollock' had the lowest percentages, 22 to 60%, and 'Hickson' and 'Taylor' were intermediate, from 13 to 80% (Table 1). Rooting of 'Booth 8' varied from 38 to 88%. The Guatemalan group had a marked decrease in rooting in the fall.

An important factor in determining the feasibility of air layering avocados is the time required for rooting to take place. The time for initial rooting to take place is shown in Table 1 and the number of days to maximum rooting, in Table 2.

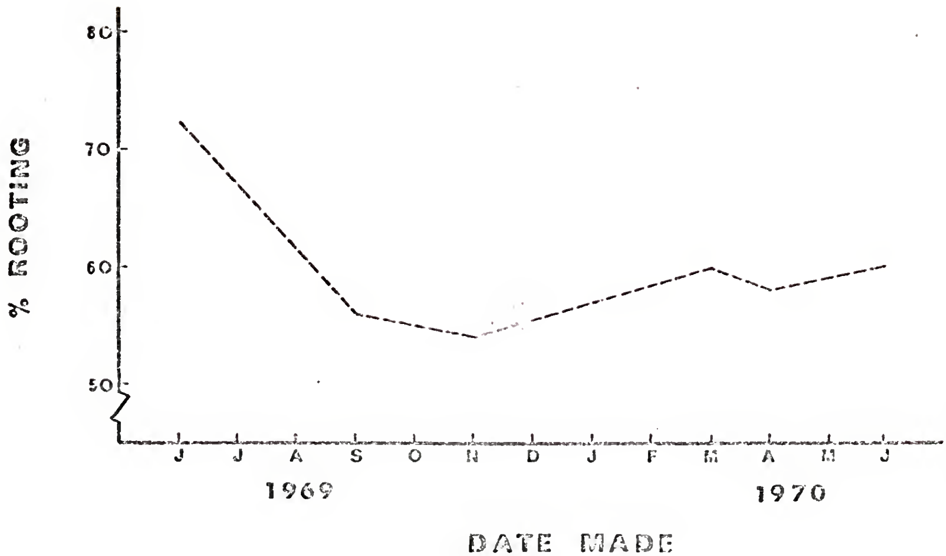


Fig. 1. Rooting of air layers of all avocado cultivars and seedling trees.

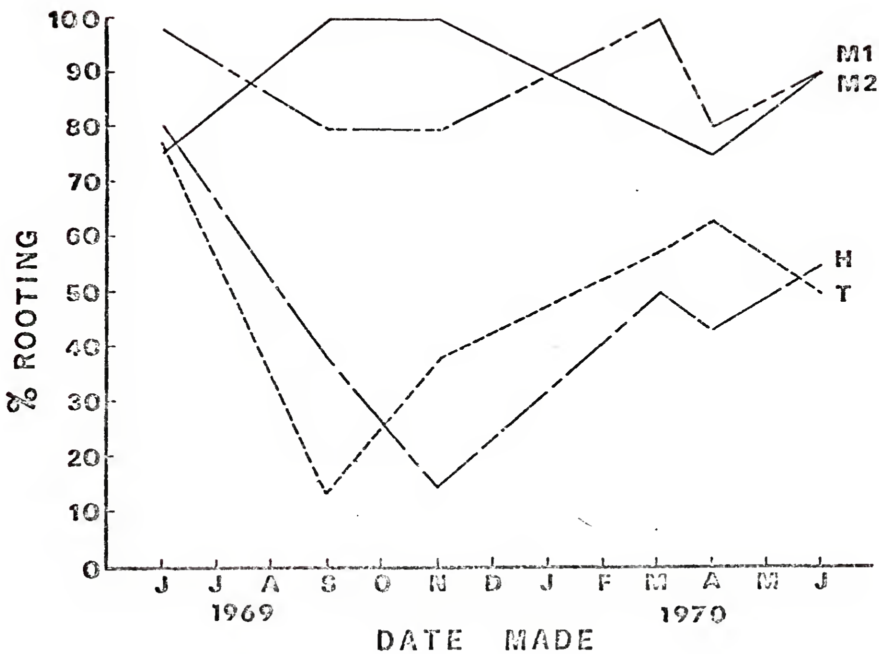


Fig. 2. Rooting of air-layered Mexican seedling trees (M 1 and M 2), Hickson (H), and Taylor (T) avocados.

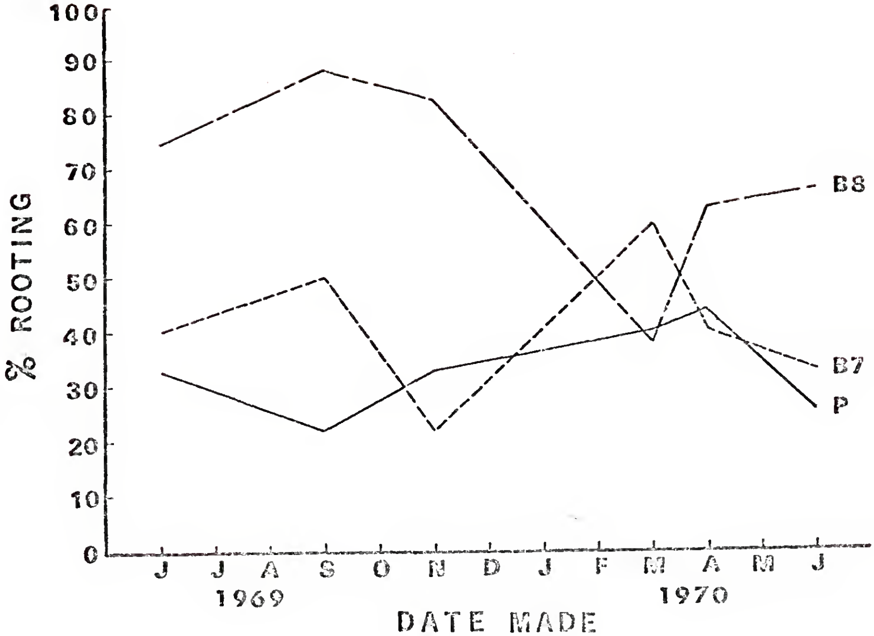


Fig. 3. Rooting of air-layered Booth 8 (B 8), Booth 7 (B 7), and Pollock (P) avocados.

Table 1. Cumulative percentage rooting of air layered avocado cultivars and seedling trees

Cultivar or tree	Month made	Month checked 1969 Sept.	1969 Nov.	1970 March	1970 April	1970 June	1970 Sept.	1971 Feb.
Pollock	June, 1969	0	11	22	33			
	Sept.		0	22				
	Nov.			0	0	22	33	
	March, 1970				0	0	40	
	April					0	44	
	June						0	25
Booth 7	June, 1969	0	30	40	40			
	Sept.		0	50	50	50		
	Nov.			0	0	0	0	22
	March, 1970				0	0	40	60
	April					0	20	40
	June						0	33
Booth 8	June, 1969	25	63	75				
	Sept.		11	66	77	77	77	88
	Nov.			14	33	50	66	83
	March, 1970				0	0	13	38
	April					0	38	63
	June						0	66
Hickson	June, 1969	70	80	80	80			
	Sept.		0	10	38			
	Nov.			0	0	13	13	
	March, 1970				0	0	30	50
	April					0	0	43
	June						0	55
Taylor	June, 1969	0	22	77				
	Sept.		0	0	0	0	0	13
	Nov.			0	0	0	0	38
	March, 1970				0	0	0	57
	April					0	0	63
	June						0	50
Mexican 1	June, 1969	63	88					
	Sept.		0	80				
	Nov.			0	60	70	80	
	March, 1970				0	25	100	
	April					0	60	80
	June						0	90
Mexican 2	June, 1969	50	75					
	Sept.		0	100				
	Nov.			0	0	60	88	100
	March, 1970				0	0	60	80
	April					0	25	75
	June						0	90

Table 2. Number of days to maximum rooting of air layered avocado cultivars and seedling trees

Date made	Cultivars					Seedling trees		Average
	Pollock	Booth 7	Booth 8	Hickson	Taylor	Mexican 1	Mexican 2	
1969								
June 17	301	301	265	301	265	146	146	245
Sept. 9	181	287	518	287	518	181	181	308
Nov. 11	323	455	455	323	455	323	455	398
1970								
March 10	204	336	336	336	336	204	336	300
April 15	167	299	299	299	299	299	299	280
Average	235	336	377	309	375	231	283	

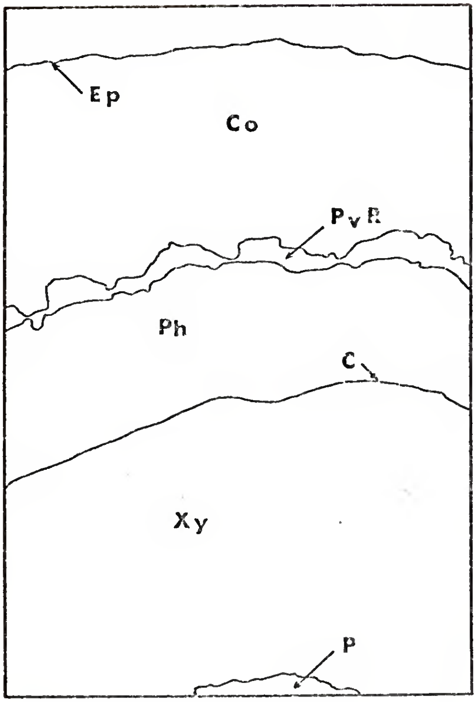
The 2 Mexican seedlings and 'Pollock' rooted in the fewest number of days. Air layers of 'Booth 7' and 'Hickson' were intermediate and 'Taylor' and 'Booth 8' required the longest period for rooting. All avocados except 'Booth 8' and 'Taylor' took longer to root when the air layers were made in November. 'Pollock' was inconsistent in the time required but the others seemed to follow a pattern. 'Pollock' air layers required a shorter time to root, but only a few rooted. Those from Mexican trees also required a shorter time to root and most of the branches rooted.

Average number of days to maximum rooting for all cultivars and seedlings was 398 for air layers made in November, 300 in March, 280 in April, 245 in June, and 308 in September.

Anatomical Studies

General Stem Anatomy

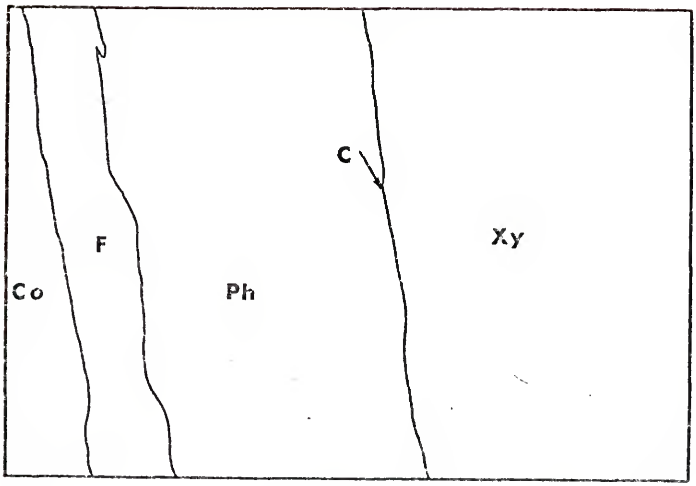
Examination of transverse and tangential sections of second-flush growth (Figs. 4 and 5), showed the following features: Isodiametric parenchyma cells in the pith, primary xylem composed of lines of vessels increasing in size, secondary xylem with scattered vessels (diffuse porous) occurring singly or 2 or more together and prominent unicellular rays, a more or less well defined but irregular cambial layer, a definite continuation of rays, numerous sieve tubes, companion cells, and inclusions in a broad phloem, clusters of fibers connected by sclereids between the phloem and cortex (Figs. 6 and 7), a broad, essentially uniform cortex composed of cells similar to those in the pith, no apparent 'starch sheath' (although some cells contained starch grains (Fig. 8), which correspond to those of the potato (Solanum tuberosum L.) group as described by



A. Line drawing (Ep- epidermis, Co- cortex, PvR- perivascular ring, Ph- phloem, C- cambium, Xy- xylem, P- pith).

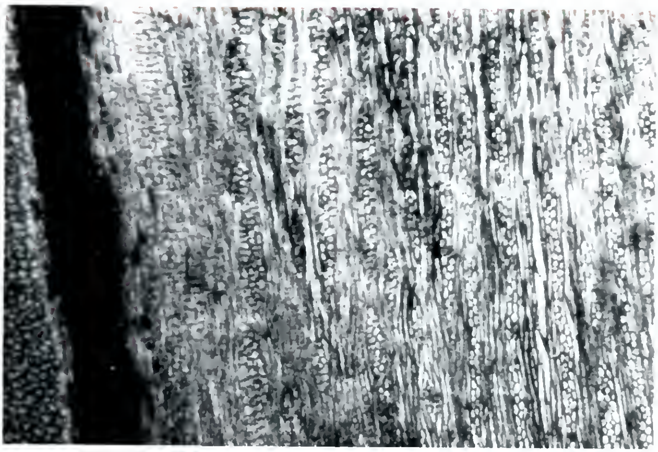
Fig. 4. Transverse section of second-flush Booth 8 avocado

B. Photomicrograph (x 150).

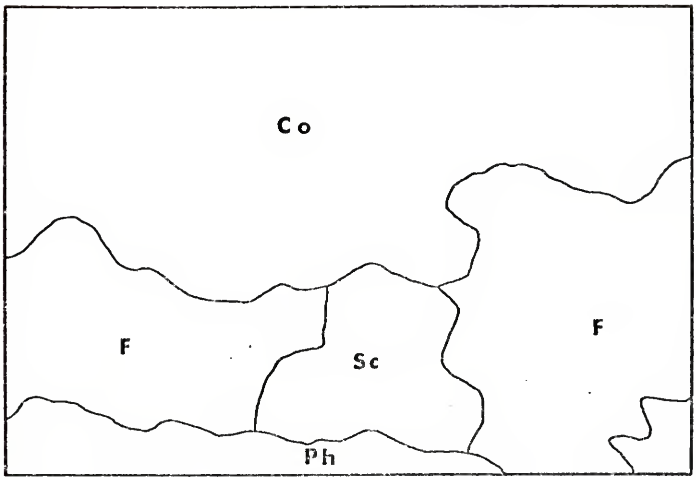


A. Line drawing (Co- cortex, F- fibers, Ph- phloem, C- cambium, Xy- xylem).

Fig. 5. Tangential section of second-flush Hickson avocado.



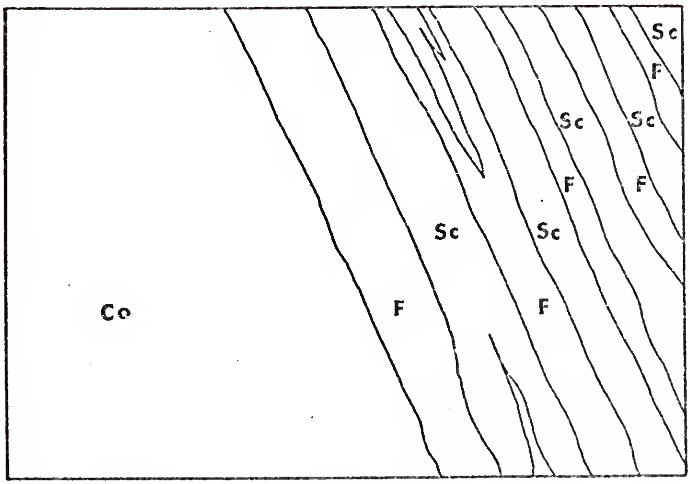
B. Photomicrograph (x 150).



A. Line drawing (Co- cortex, F- fibers, Sc- sclereids, Ph- phloem).

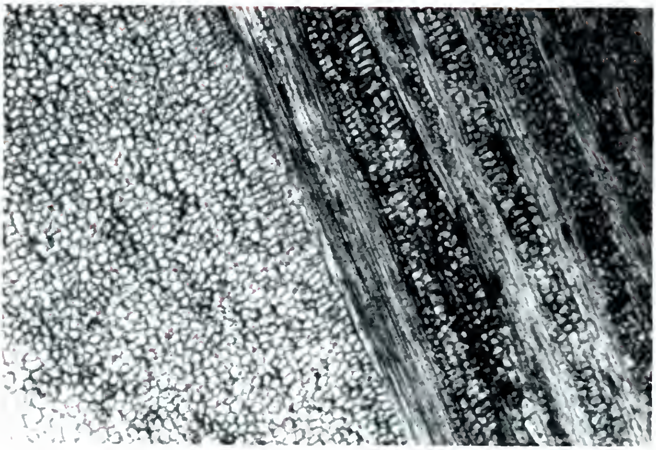
Fig. 6. Transverse section of Booth 7 avocado.

B. Photomicrograph (x 1714).



A. Line drawing (co- cortex, F- fibers, Sc- sclereids).

Fig. 7. Tangential section of Hickson avocado.



B. Photomicrograph (x 150).

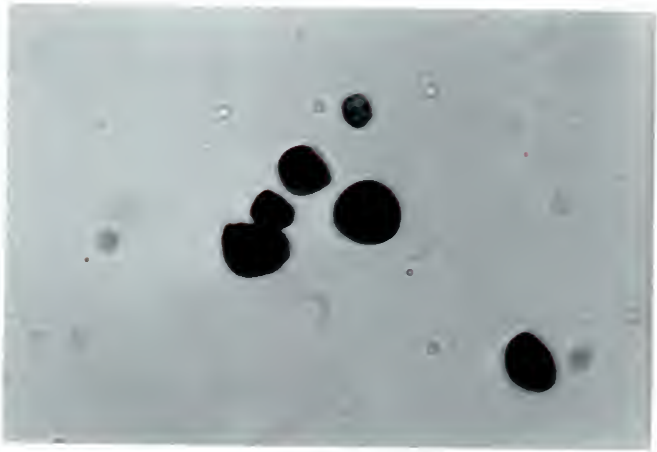


Fig. 8. Typical concentric starch grains of avocado (x 4286).

Esau (19)) and a thick epidermal layer. Etiolated stems of avocado (Fig. 9) differ from the above in that a well defined collenchyma layer is present, fiber bundles are discrete with little or no connection of sclereids, a well defined cambium layer, and a pith which is larger in diameter than in the non-etiolated stem. This is consistent with those plants examined by Penfound (57). Differences were apparent among the cultivars and seedlings in the clusters of fibers and the sclereid connection. These will be described in a later section. Anatomical details noted here corroborated earlier reports on Lauraceae and Persea americana Mill. (38, 52, 69, 75), and were also similar in the other 3 species of Lauraceae examined in this investigation.

Anatomy of Successive Flushes

The gradual expansion of an avocado stem is shown in transverse sections of the first, third through sixth, and eighth flush of 'Booth 8' (Figs. 10, 11, 12, 13, 14, 15, 16). Sections cut about 1 mm from the terminal showed that epidermal hairs (Fig. 10) were abundant, fibers were not lignified (Fig. 11) and little cellular organization occurred. Figures 10 and 11 are serial photomicrographs of a transverse section. Sections of older stem tissues (Figs. 12-16) showed that the progressive expansion of the stem was accompanied by a separation of the fiber bundles and a decrease in the width of the layer of sclereids connecting them. Divergent phloem rays appear in the fourth-flush (Fig. 13). They become more prominent as the stem increases in diameter. There is an almost complete break down of the sclerenchyma ring at the eighth flush (Fig. 16). A transverse section of the sixth-flush of 'Taylor' avocado (Fig. 17) shows a divergent ray, parenchyma type ray cells and a few lignified

Fig. 9. Transverse section of etiolated second-flush Mexicola avocado.

Fig. 10. Transverse section of Booth 8 avocado near the terminal (x 430).

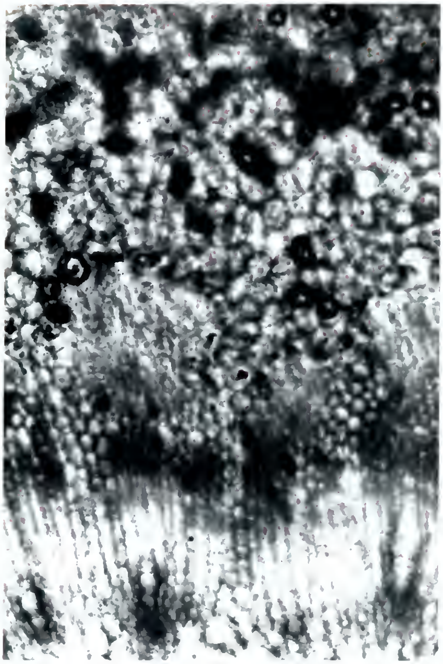
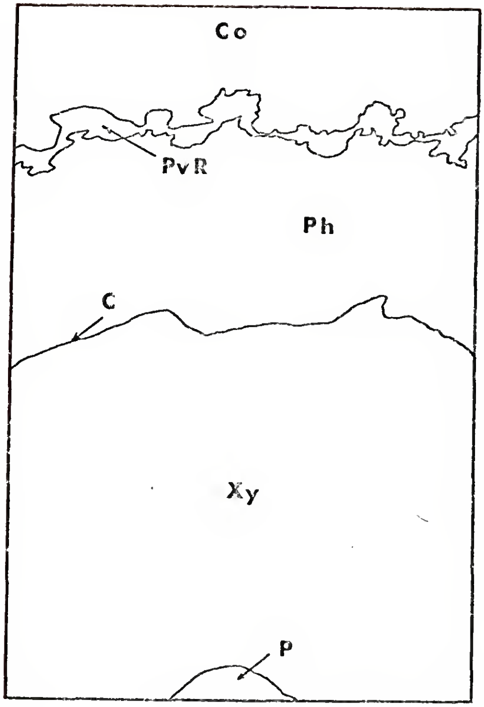
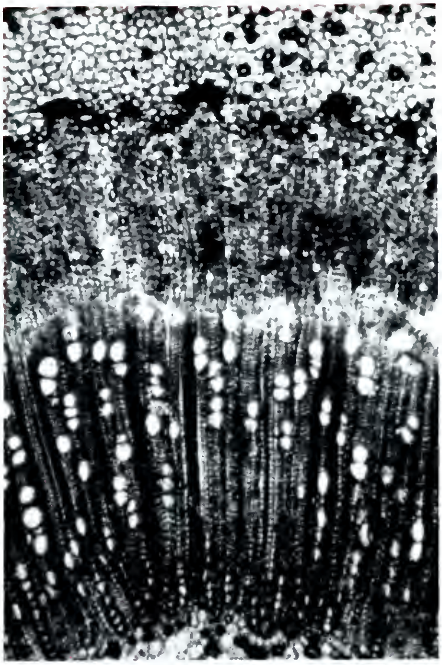


Fig. 11. Transverse section of Booth 8 avocado near the terminal (x 430).

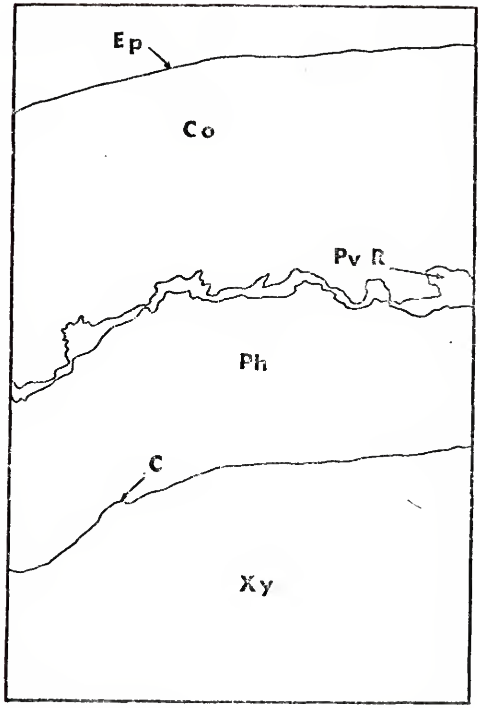


A. Line drawing (Co- cortex, PvR- perivascular ring, Ph- phloem, C- cambium, Xy- xylem, P- pith).

Fig. 12. Transverse section of third-flush Booth 8 avocado.

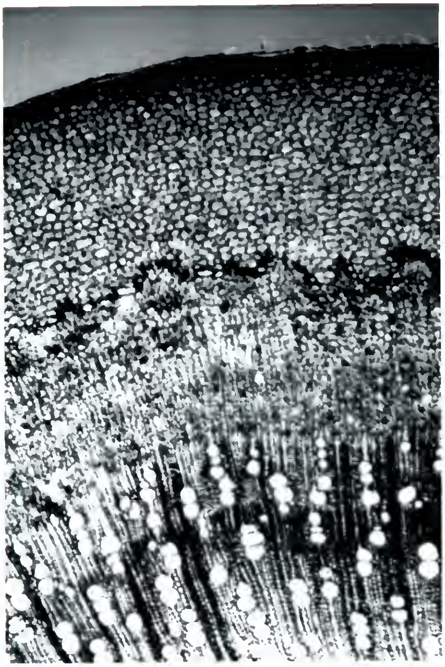


B. Photomicrograph (x 150).

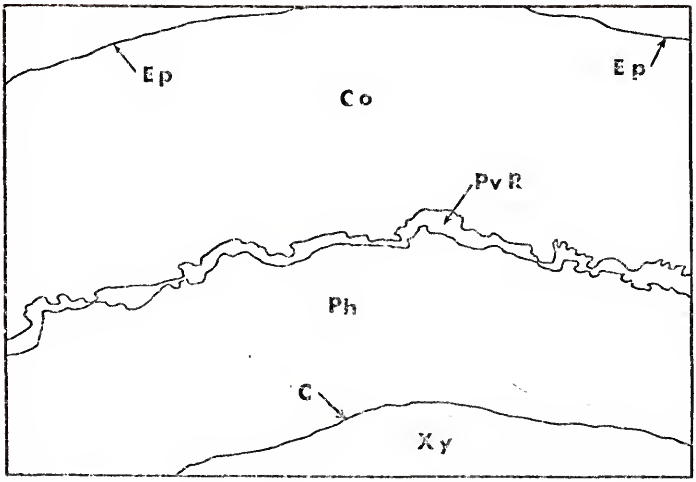


A. Line drawing (Ep- epidermis, Co- cortex, PvR- peri-vascular ring, Ph- phloem, C- cambium, Xy- xylem).

Fig. 13. Transverse section of fourth-flush Booth 8 avocado.



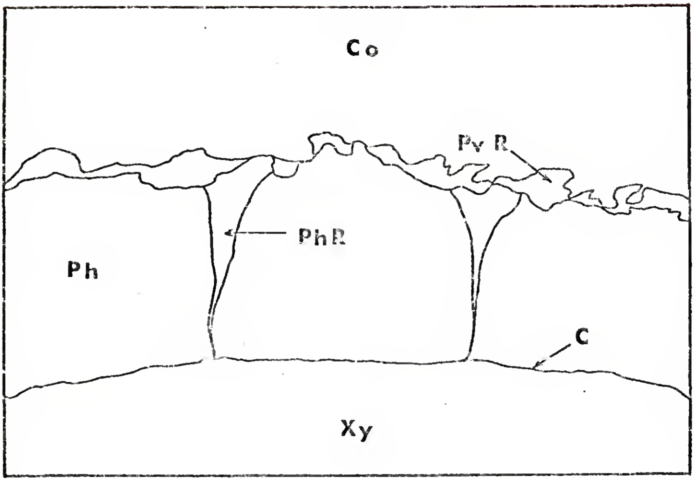
B. Photomicrograph (x 150).



A. Line drawing (Ep- epidermis, Co- cortex, PvR- perivascular ring, Ph- phloem, C- cambium, Xy- xylem).

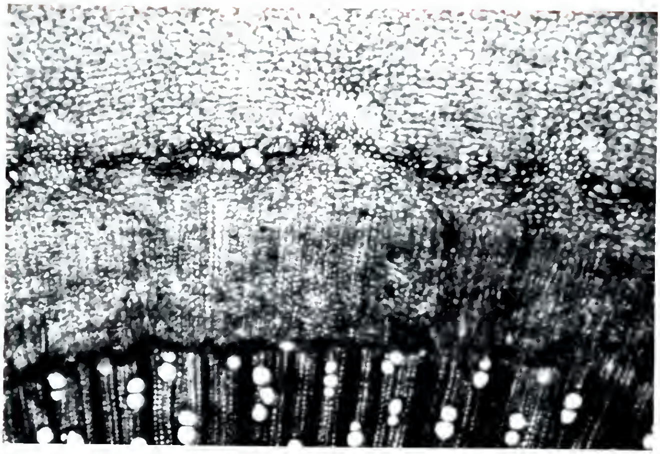
Fig. 14. Transverse section of fifth-flush Booth 8 avocado.

B. Photomicrograph (x 150).

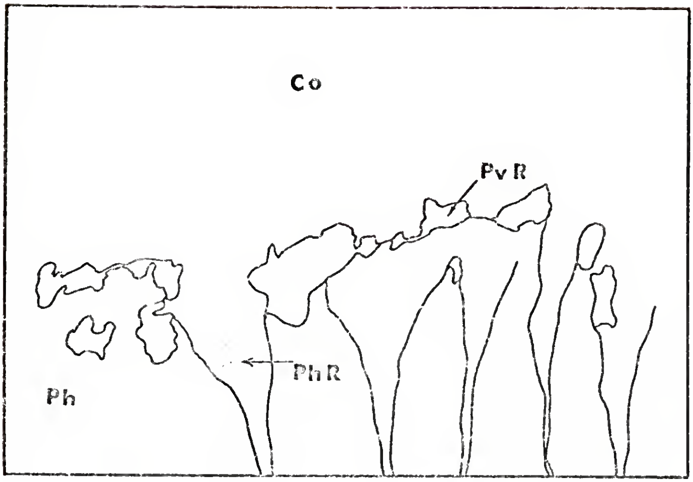


A. Line drawing (Co- cortex, PvR- perivascular ring, Ph- phloem, PhR- phloem ray, C- cambium, Xy- xylem).

Fig. 15. Transverse section of sixth-flush Booth 8 avocado.



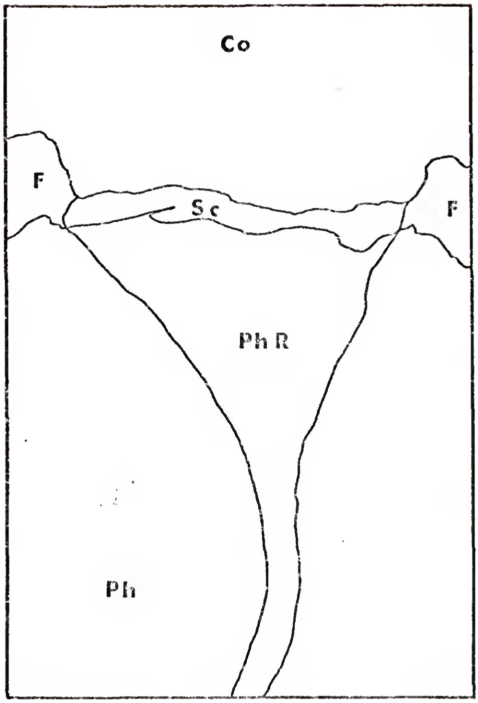
B. Photomicrograph (x 150).



A. Line drawing (Co- cortex, PvR- perivascular ring, Ph- phloem, PhR- phloem ray).

Fig. 16. Transverse section of eighth-flush Booth 8 avocado.

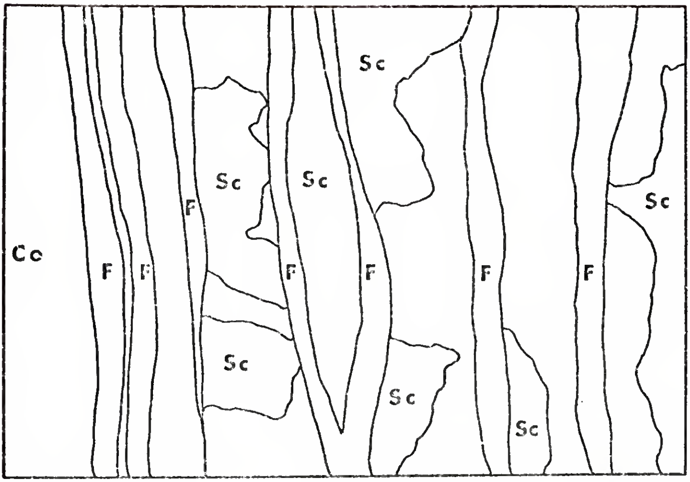
B. Photomicrograph (x 150).



A. Line drawing (Co- cortex, F- fibers, Sc- sclereids, PhR- phloem ray, Ph- phloem).

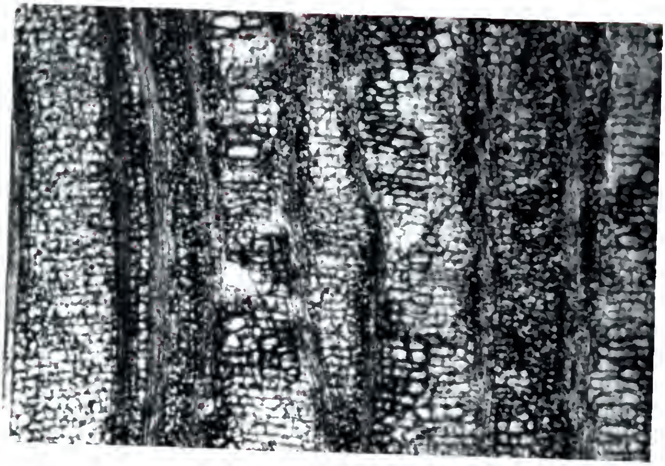
Fig. 17. Transverse section of sixth-flush Taylor avocado.

B. Photomicrograph (x 430).

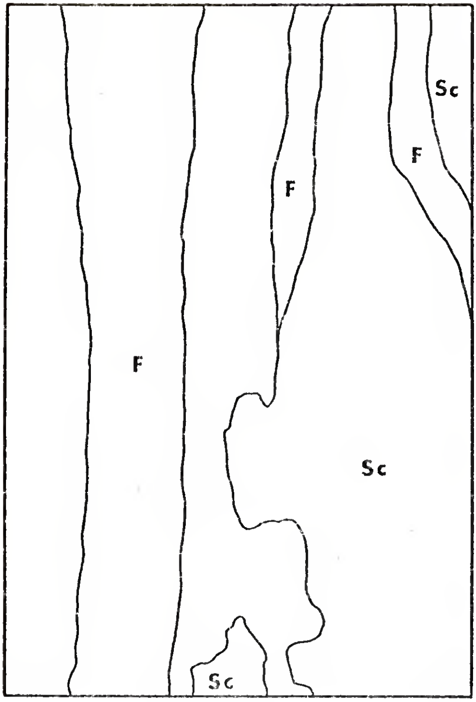


A. Line drawing (Co- cortex, F- fibers, Sc- sclereids).

Fig. 18. Tangential section of sixth-flush Booth 8 avocado.

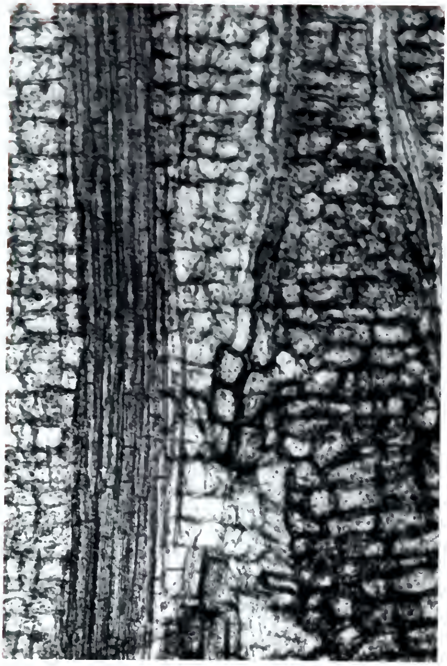


B. Photomicrograph (x 150).

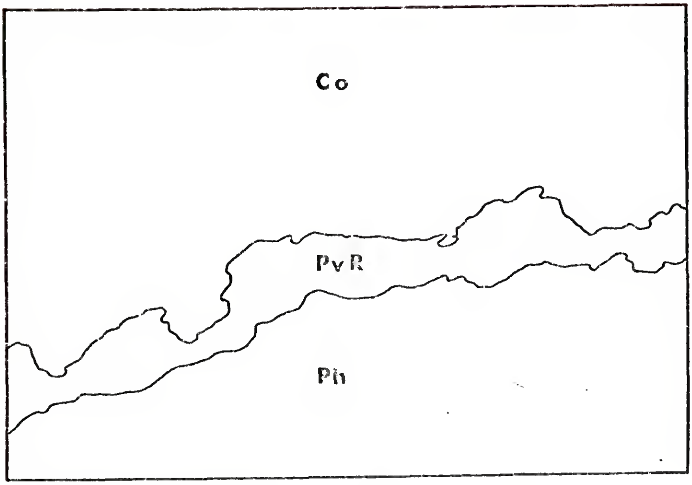


A. Line drawing (F- fibers, Sc- sclereids).

Fig. 19. Tangential section of sixth-flush Booth 8 avocado.

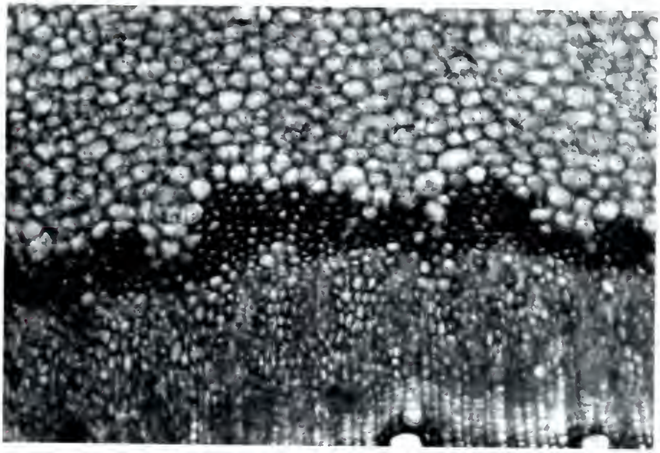


B. Photomicrograph (x 430).

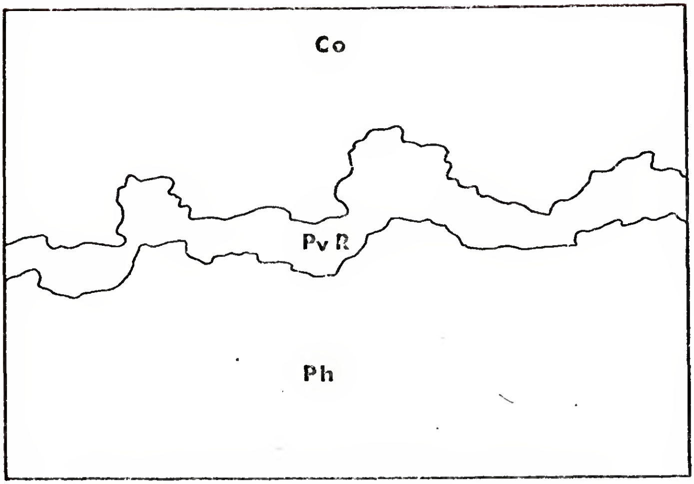


A. Line drawing (Co- cortex, PvR- perivascular ring, Ph- phloem).

Fig. 20. Transverse section of first-flush Hickson avocado.

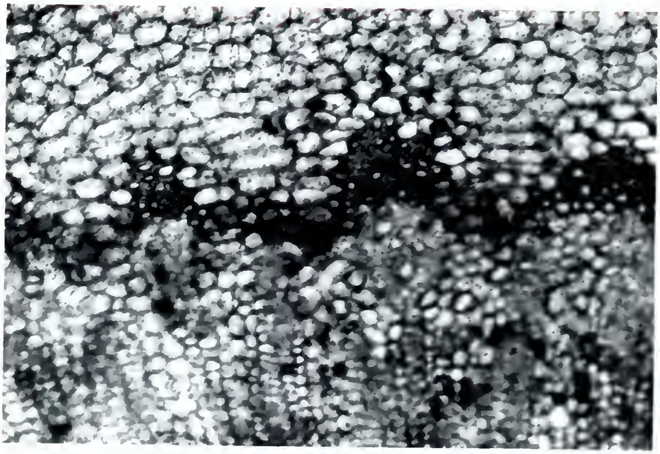


B. Photomicrograph (x 430).

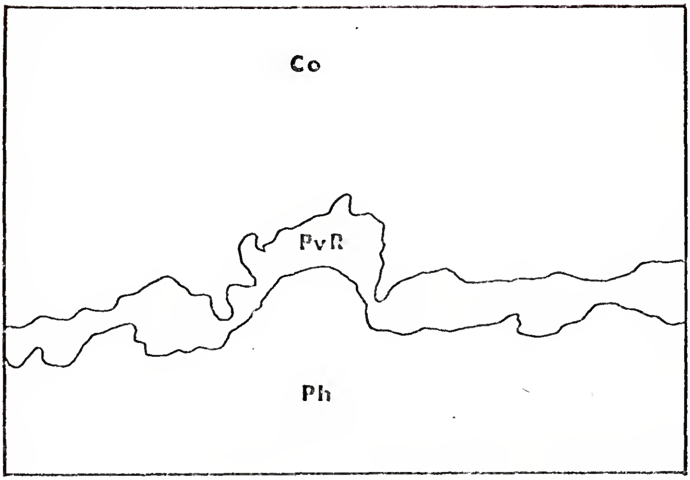


A. Line Drawing (Co- cortex, PvR- perivascular ring, Ph- phloem).

Fig. 21. Transverse section of second-flush Hickson avocado.

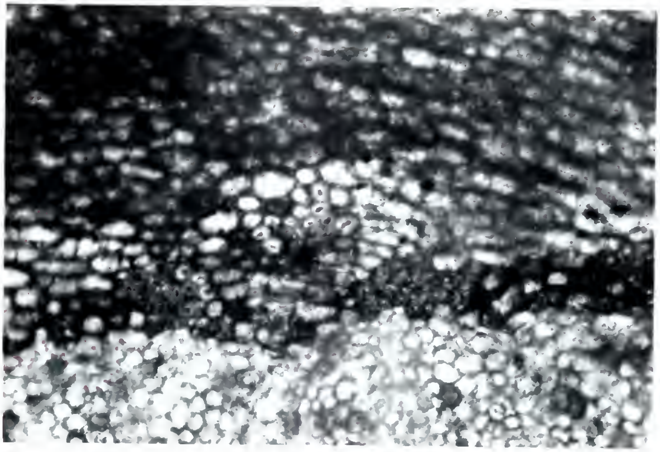


B. Photomicrograph (x 430).

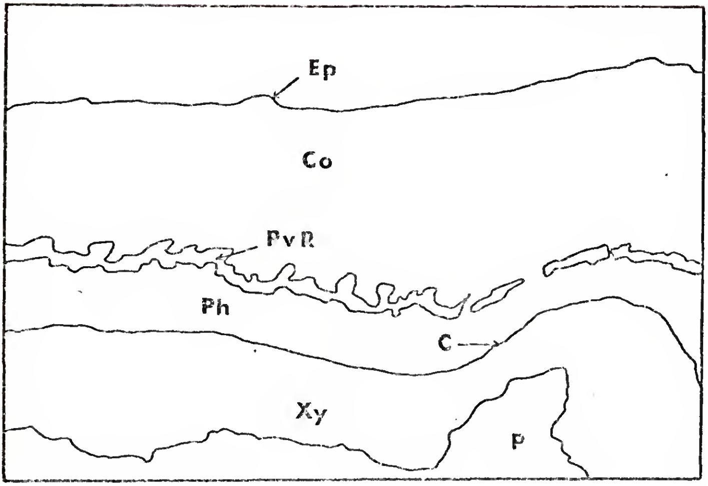


A. Line drawing (Co- cortex, PvR- perivascular ring, Ph- phloem).

Fig. 22. Transverse section of third-flush Hickson avocado.

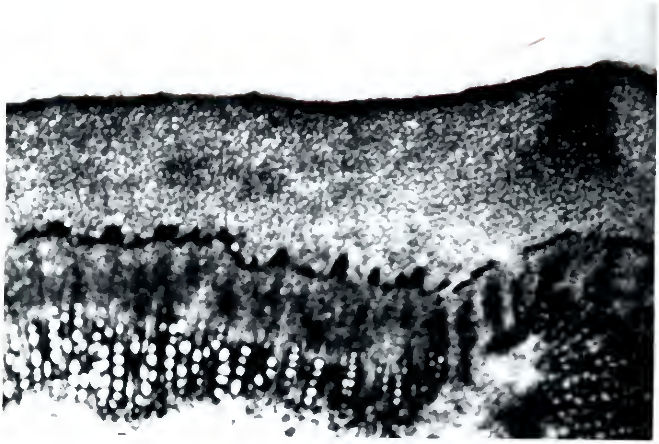


B. Photomicrograph (x 430).

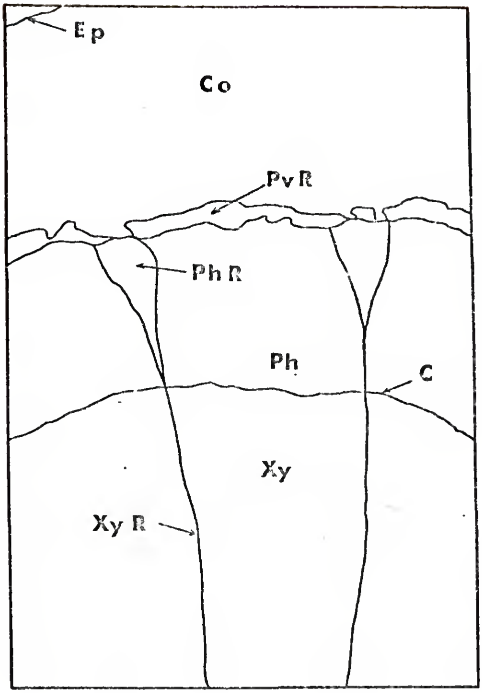


A. Line drawing (Ep- epidermis, Co- cortex, PvR perivascular ring, Ph- phloem, C- cambium, Xy- xylem, P- pith).

Fig. 23. Transverse section of first-flush Taylor avocado.

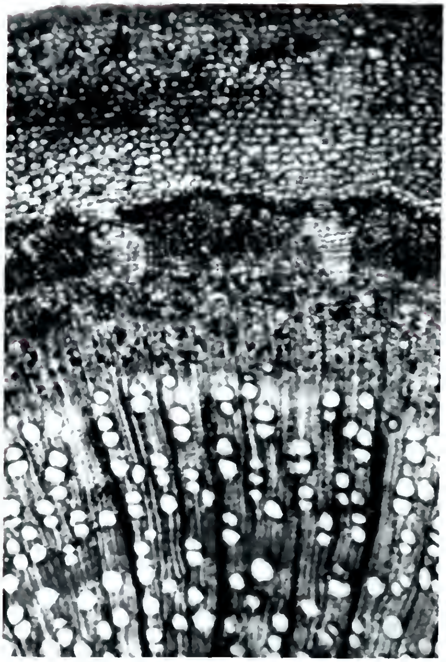


B. Photomicrograph (x 150).



A. Line drawing (Ep- epidermis, Co- cortex, PvR- perivascular ring, PhR- phloem ray, Ph- phloem, C- cambium, Xy- xylem, XyR- xylem ray).

Fig. 24. Transverse section of fifth-flush Taylor avocado.



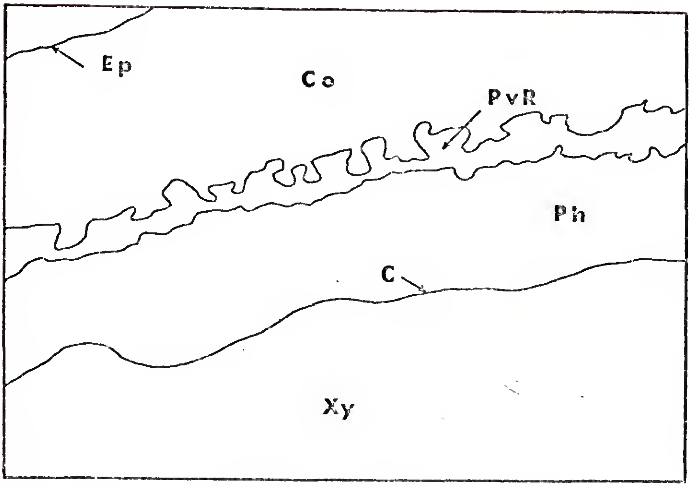
B. Photomicrograph (x 150).

cells across the broad end of the ray. It may be noted in tangential sections of the sixth-flush of 'Booth 8' (Figs. 18 and 19) that the lignified cells connecting the fibers are not as compact or as continuous as those in Fig. 7. The separation of fiber bundles and decrease in thickness and continuity of the ring is clearly noted in transverse sections of contiguous flushes of 'Hickson' (Figs. 20, 21 and 22). The separation of bundles and discontinuity of the fiber ring is even more apparent in non-contiguous growth flushes of 'Taylor' (Figs. 23 and 24).

Anatomy of Cultivars

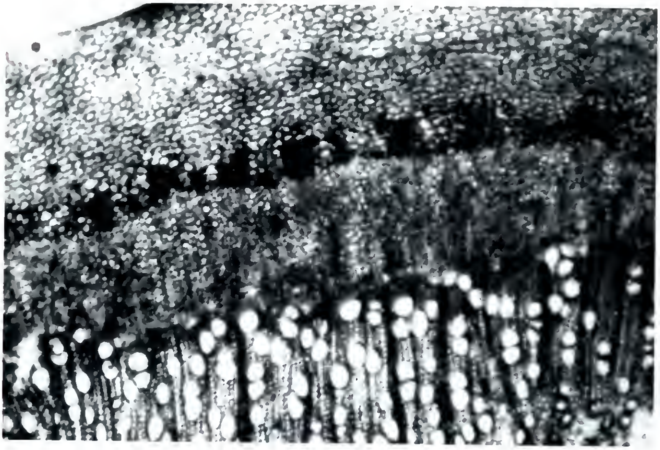
Transverse sections of the second-flush of 'Pollock', 'Booth 7', 'Booth 8', 'Taylor' and 'Gainesville' avocado are shown in Figs. 25, 26 27, 28, and 29, respectively. These cultivars and seedling ('Gainesville') were chosen as representative of those examined since all follow more or less closely the same structural pattern. It was evident from these sections that the fiber bundles were larger, closer together, and definitely interconnected by more sclerenchyma cells in the West Indian cultivar (Fig. 25) than those of the other races or hybrids. 'Gainesville' (Fig. 29) appeared to have the most loosely organized ring. 'Taylor' (Fig. 28) was intermediate. 'Booth 7' (Fig. 26) was similar to the West Indian type, while 'Booth 8' (Fig. 27) resembled the Guatemalan parent rather than the West Indian.

The discontinuity of the perivascular sclerenchyma ring, divergence of the rays and separation of the fiber bundles found in sections examined in the present study were consistent with Esau's (19) model for the thickening of a dicotyledonous stem. The parenchyma type ray cells may be capable of reverting to meristematic characteristics and give rise to root initials. Etiolated stems resemble the apical portion of the

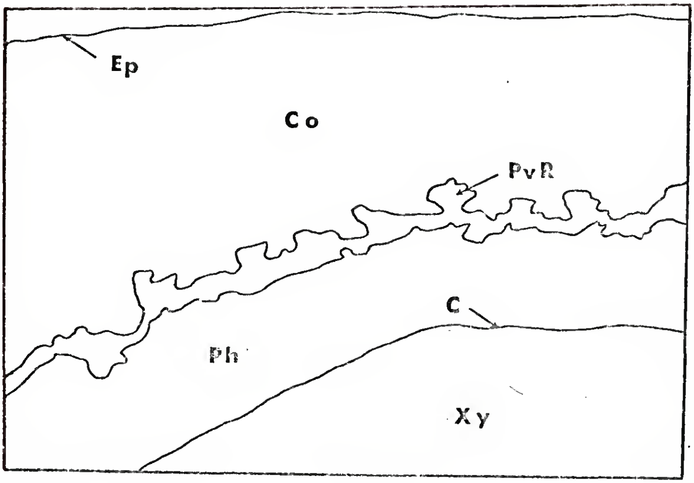


A. Line drawing (Ep- epidermis, Co- cortex, PvR- perivascular ring, Ph- phloem, C- cambium, Xy- xylem).

Fig. 25. Transverse section of second-flush Pollock avocado.

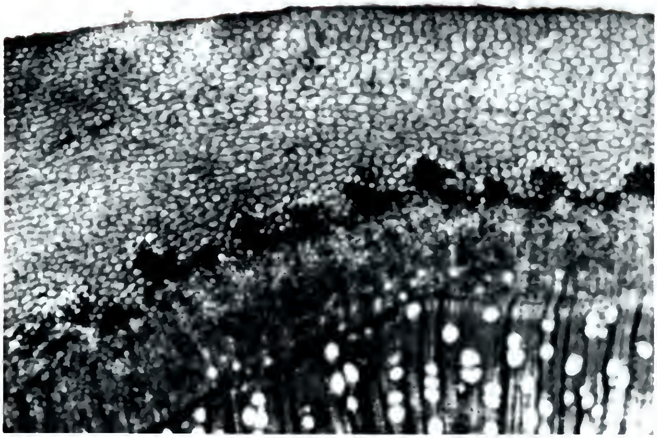


B. Photomicrograph (x 150).

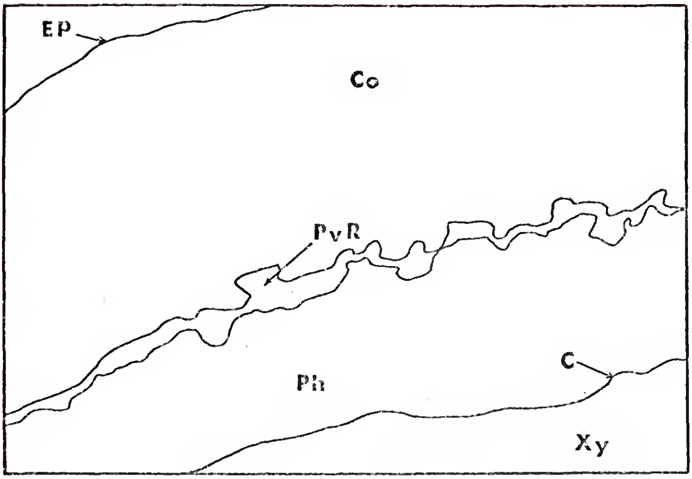


A. Line drawing (Ep- epidermis, Co- cortex, PvR- perivascular ring, Ph- phloem, C- cambium, Xy- xylem).

Fig. 26. Transverse section of second-flush Booth 7 avocado.



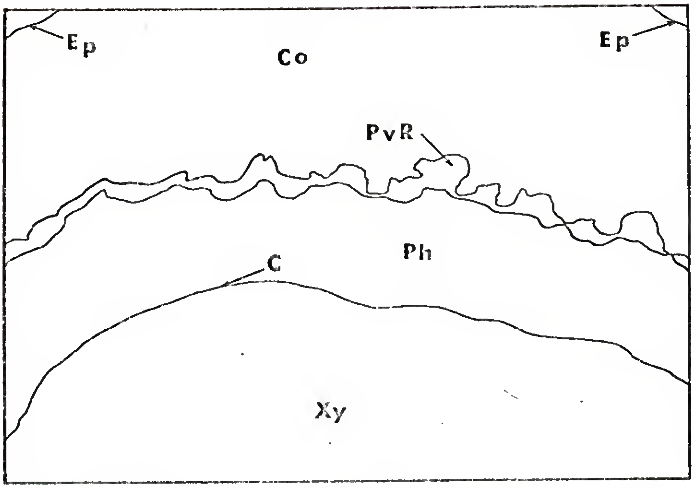
B. Photomicrograph (x 150).



A. Line drawing (Ep- epidermis, Co- cortex, PvR- perivascular ring, Ph- phloem, C- cambium, Xy- xylem).

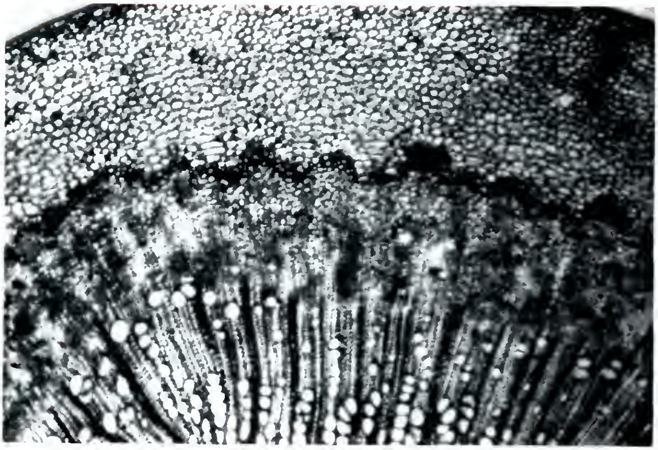
Fig. 27. Transverse section of second-flush Booth 8 avocado.

B. Photomicrograph (x 150).

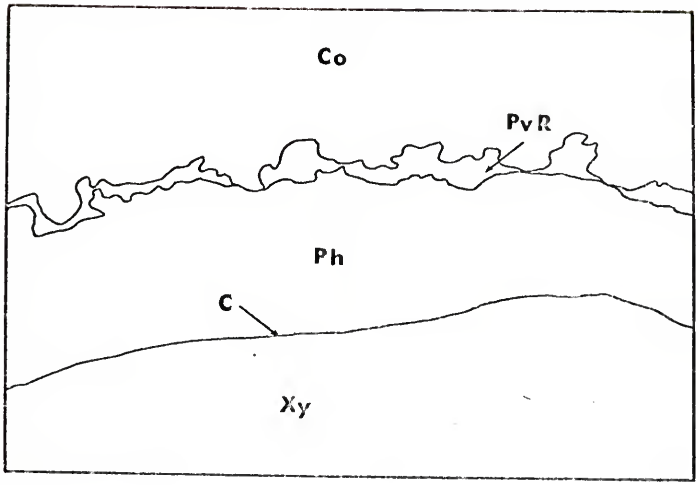


A. Line drawing (Ep- epidermis, Co- cortex, PvR- perivascular ring, Ph- phloem, C- cambium, Xy- xylem).

Fig. 28. Transverse section of second-flush Taylor avocado.



B. Photomicrograph (x 150).



A. Line drawing (Co- cortex, PvR- perivascular ring, Ph- phloem, C- cambium, Xy- xylem).

Fig. 29. Transverse section of second-flush Gainesville avocado.

B. Photomicrograph (x 150).

terminals in the lack of sclereids between the fiber bundles. The above may explain in part why some plants which are difficult to root by cutting are successfully rooted as air layers (34). It may also explain the success in rooting immature 'Gainesville' avocado cuttings, reported by Leal and Krezdorn (48) as well as that of Anderson[1] in rooting 'Winter Mexican' (G x M) 10 to 15 cm in diameter by air layerage.

Many investigators have had success with stimulating rooting with the use of auxins (34). In the case of avocado little success has been obtained with auxin in stimulating rooting. Some have shown promotion, others have not obtained a promotion of rooting (35, 45, 47, 48, 81). This could be due to the cultivars or seedlings used in the tests.

Kadman and Ya'Acob (45) concluded in a review of experiments on avocado propagation that Mexican avocado generally roots better from cuttings than does Guatemalan, while West Indian roots the poorest. This statement would still be true if the sclerenchyma ring were to act as a barrier to root emergence and would explain the results obtained with the air layers reported previously. This is in accord with Beakbane's (4) conclusion that shoots of shy-rooting plants are often characterized by a high degree of sclerification in the phloem and with Galkin (24), who was able to predict rooting ability by measuring the amount of bast fibers. The difference in rooting ability of mature and juvenile types of material may result from the degree of sclerification in the primary phloem being much less in very young material (4). Many years ago, Gardner (26) suggested that anatomical differences existed. Stoutemyer

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[1] Personal observation by the author.

(76) found that tissue from mature and juvenile wood of apples were nearly identical histologically with the exception that the mature phase contained more pericyclic fibers than the juvenile.

SUMMARY AND CONCLUSIONS

General details of stem anatomy corroborated those observed by earlier investigators. Series of sections made in progression down the stem from the terminal revealed that as the stem grows in diameter the fiber-sclereid ring starts to break down, especially when the phloem rays begin to diverge. This was true of 'Waldin', 'Pollock', 'Catalina', 'Booth 7', 'Booth 8', 'Hickson', 'Lula', 'Taylor', 'Gainesville' seedling, 'Brogdon', 'Mexicola', and the 2 Mexican seedling trees. It was found, when the same flush of the cultivars or seedlings was examined, that the frequency of the fiber bundles and the chickness of the sclereid connection was greatest for the West Indian and least for the Mexican. The Guatemalan and hybrids were intermediate. Etiolated shoots have been shown to have a smaller degree of lignification than non-etiolated stems. The origin of adventitious roots in many plants is in the periphery of the cambial zone, therefore, if the sclerenchyma ring acts as a barrier, the race having the lower degree of lignification should root best. Mexican avocados were found to have less lignification than the West Indian.

Air layers were put on June 17, September 9, November 11, 1969 and March 10, April 15, and June 24, 1970. Cultivars tested were 'Pollock', 'Booth 7', 'Booth 8', 'Hickson', and 'Taylor', and 2 Mexican seedling trees. The last had the highest percentage rooting while 'Pollock' and 'Booth 7' had the lowest percentage. 'Hickson' and 'Taylor' were intermediate.

Air layers made in June and April required the shortest period for rooting. The ones made in November took the longest time to root.

The experiments with air layering further exemplifies the differences in rooting ability between races and would still be true if the fiber-sclereid ring acted as a barrier. Mexican avocados were found to have a lower degree of lignification and rooted best while West Indian had the most continuous lignified ring and rooted the poorest.

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BIOGRAPHICAL SKETCH

Ricardo E. Gomez was born July 13, 1938 at Havana, Cuba. In June 1956 he was graduated from Lafayette School in Havana. In April 1966 he received the degree Bachelor of Science in Agriculture with a major in Soils from the University of Florida and received the 1965-66 Kroger Award for high scholarship. In the same year he enrolled in the Graduate School of the University of Florida. In August 1968 he received the degree Master of Science in Agriculture with a major in Soils from the University of Florida. He was a graduate student in the Department of Fruit Crops and held a graduate assistantship provided by the Agricultural Research and Education Center, Homestead and the Center for Tropical Agriculture from 1968 to 1971. He was awarded the degree Doctor of Philosophy in December 1971. He received the T. J. Anderson Memorial Award for 1971 for work in tropical fruits.

He is a member of American Society for Horticultural Science, American Society for Horticultural Science, Tropical Region, Alpha Zeta, Gamma Sigma Delta, and Phi Sigma honorary fraternities.

He is married to the former Maria Martha Callejas of Chinandega, Nicaragua. He is the father of four children, three boys and a girl.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

James Soule

James Soule, Chairman
Professor of Fruit Crops

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

S. E. Malo

Simon E. Malo, Co-Chairman
Associate Horticulturist

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Robert H. Biggs

Robert H. Biggs
Professor of Fruit Crops

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Alfred H. Krezdorn

Alfred H. Krezdorn
Professor and Chairman of Fruit Crops

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Richard C. Smith

Richard C. Smith
Associate Professor of Botany

This dissertation was submitted to the Dean of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

December, 1971

for John E. Reynolds

Dean, College of Agriculture

Dean, Graduate School