ANATOMY OF HAWAIIAN PEPEROMIAS

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INTRODUCTION

The anatomy of the plants comprising the family Piperaceae presents several interesting features not common to other dicotyledonous families. This is especially true of the genus *Peperomia*, which includes several hundred species distributed in tropical and subtropical regions throughout the world.

During 1932-33, while making a taxonomic study of the genus *Peperomia* as represented in Hawaii,[1] the senior author collected and preserved in a 4 per cent formalin solution leaves and parts of stems of several species. No attempt was made to preserve material of all species found. Those collected, however, represent the three subgenera occurring in Hawaii, as follows: subgenus *Micropiper*—*Peperomia reflexa* Dietrich, *P. reflexa* Dietrich variety *parvifolia* C. deCandolle; subgenus *Sphaerocarpidium*—*P. oahuensis* C. deCandolle, *P. latifolia* Miquel, *P. membranacea* Hooker and Arnott, *P. leptostachya* Hooker and Arnott, *P. ellipticibacca* C. deCandolle, *P. Cookiana* C. deCandolle, *P. Cookiana* C. deCandolle variety *flavinerva* (C. deCandolle) Yuncker, *P. sandwicensis* Miquel; subgenus Hawaiiana—*P. lilifolia* C. deCandolle variety *nudilimba* (C. deCandolle) Yuncker, *P. Rockii* C. deCandolle, *P. hirtipetiola* C. deCandolle variety *longilimba* (C. deCandolle) Yuncker, *P. expallescens* C. deCandolle. The species selected are presumably fairly representative of the genus as a whole as it is represented in Hawaii.

Though some work has been done on a few members of the genus, we have been unable to find reference to any study which has ever been made on the anatomy of any of the Hawaiian species. With the exception of *P. reflexa, P. leptostachya,* and perhaps also *P. oahuensis* and *P. membranacea,* the species discussed in this paper are endemic.

Sections 20 to 25 microns of the stems and leaves of each species were cut. They were bleached in chloral hydrate and mounted in balsam for study. Each species is represented by diagrams of

[1] Yuncker, T. G., Revision of the Hawaiian species of Peperomia: B. P. Bishop Mus., Bull. 112, 1933.

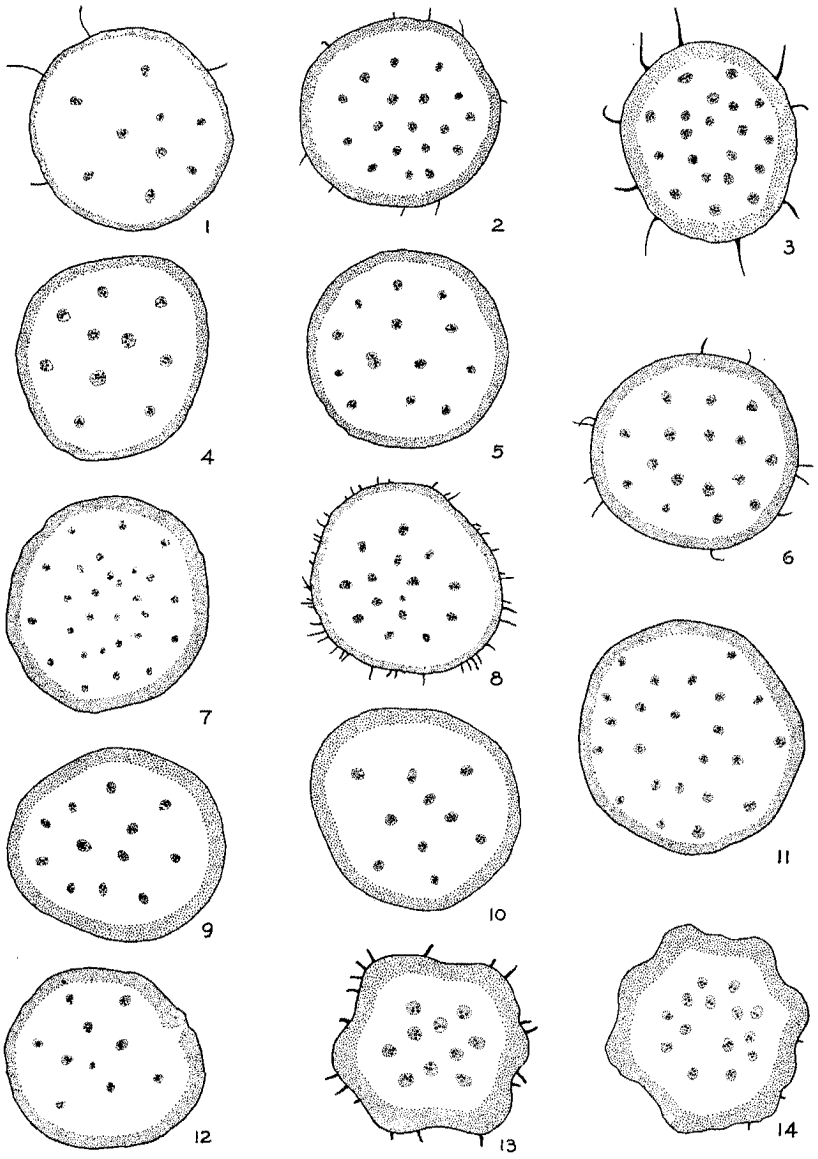
a cross section of an entire stem and of a leaf from the midrib to the margin. Details of the stems and leaves are illustrated in more highly magnified sections which show a vascular bundle and the tissues of the stem and cells from the upper to lower epidermis of the leaf. The diagrammatic drawings were made with the aid of a small Leitz projector and those showing cellular details by means of a Leitz microprojection apparatus. The measurements of the cells and tissues were taken, in the main, from the sections illustrated. Variations in details are to be expected in sections made of other leaves or at different stem levels. In general, the gross anatomical structures of both the leaves and the stems of all the species studied are similar.

STEMS

Epidermis. The epidermal cells of all the species examined are more or less uniformly rectangular in shape, as viewed in cross section, and they range in size from about 10 by 15 microns in *P. reflexa* variety *parvifolia* up to about 30 by 80 microns in *P. membranacea.* A definite amount of cutinization in the epidermis of *P. reflexa* and *P. reflexa* variety *parvifolia* results in cells of a slightly different shape from that in the other species. In *P. reflexa* the radial as well as the outer walls show considerable cutinization, but in *P. reflexa* variety *parvifolia* there is no cutinization of the radial walls. In the other species studied, the cuticle is thin and not especially conspicuous, excepting in *P. lilifolia* variety *nudilimba,* which exhibits cuticle to a somewhat less extent than *P. reflexa.*

Trichomes. Excepting *P. oahuensis* and *P. membranacea,* which are wholly glabrous, all the species discussed in this paper have hairs on the stems. In some of the species, however, the stems are hairy above but glabrate below, and the figured sections of some of these species are from the lower glabrate region and do not illustrate the hairs. The hairs are all multicellular and uniseriate, with the number of cells ranging from as few as 2 in *P. reflexa* to as many as 35 in *P. hirtipetiola* variety *longilimba.* The hairs are all slender and gradually taper from the base to a more or less acute apex. In length they range from about 0.1 mm in *P. reflexa* to 2.1 mm in *P. hirtipetiola* variety *longilimba.*

Collenchyma. All the stems show a definite and conspicuous layer of collenchymatous cells immediately beneath the epidermis.



FIGURES 1-14.—Diagrams of stems: 1, *P. Cookiana* (× 7); 2, *P. Cookiana* variety *flavinerva* (× 4.5); 3, *P. hirtipetiola* variety *longilimba* (× 2); 4, *P. oahuensis* (× 8); 5, *P. expallescens* (× 5); 6, *P. ellipticibacca* (× 4); 7, *P. Rockii* (× 2); 8, *P. leptostachya* (× 7); 9, *P. sandwicensis* (× 5); 10, *P. membranacea* (× 6); 11, *P. lilifolia* variety *nudilimba* (× 2.5); 12, *P. latifolia* (× 5); 13, *P. reflexa* variety *parvifolia* (× 21); 14, *P. reflexa* (× 12).

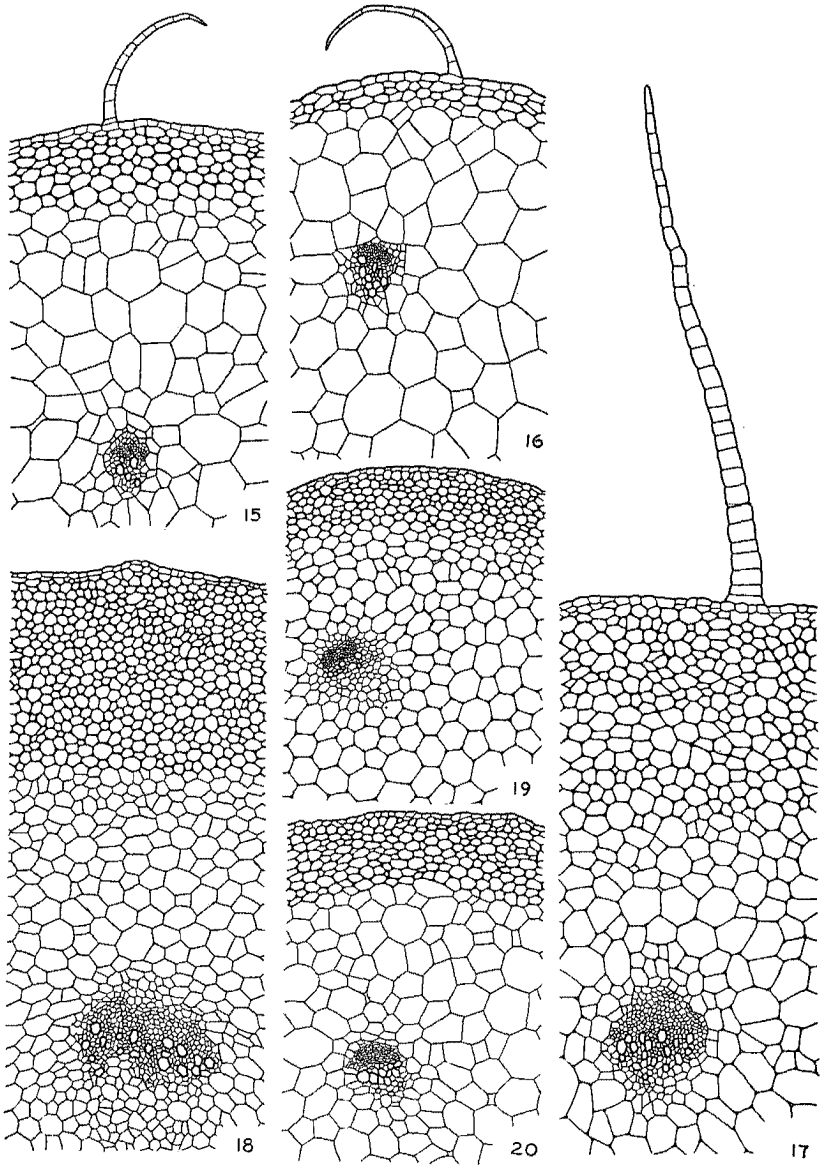
This layer ranges in thickness from 2 or 3 cells in *P. Cookiana* to 23 in *P. Rockii.* In *P. Cookiana* and *P. leptostachya* the collenchyma occupies only about one twelfth to one fourteenth of the diameter of the stem; in *P. reflexa* and *P. hirtipetiola* variety *longilimba* it occupies about one fifth of the diameter. The cells are similar in shape in the different species, but exhibit a wide variation in size.

Hydathodes. Hydathodes, less abundant but similar in structure to those on the leaves, were found in the epidermis of the stems of all the species.

Ground parenchyma. The ground parenchyma, in which are scattered the vascular bundles, is composed of parenchymatous cells of varying shapes and sizes. In *P. reflexa* and *P. leptostachya* well-defined and comparatively large intercellular spaces are present. In the other species, however, the intercellular spaces are lacking or, if present, are very small. Crystals of calcium oxalate are scattered throughout the ground parenchyma of most of the species. The crystals, which vary greatly in abundance in the different species, are for the most part of the druse type, but simple crystals are not uncommon. Starch grains, found throughout the cells of the ground parenchyma of all species, vary considerably in abundance. In *P. oahuensis* cells were found which are similiar to the mucilage canals referred to by Solereder.[2]

Vascular bundles. In all the stems studied there is an outer more or less well-defined but irregular ring of vascular bundles surrounding an irregularly arranged central group of bundles. The bundles of the peripheral ring are foliar; the inner bundles are either basic central bundles or foliar bundles from leaves several nodes above the point where the section was made. The vascular bundles are surrounded by small, closely packed parenchyma cells. Solereder states that in some species each vascular bundle is either surrounded by an endodermis or else there is a semicircular endodermis around the bast, but in none of the species which we studied was any definite single layer found. The size and number of the bundles vary in sections taken from different internodes of the same stems as well as between the stems of different species. The tracheal tubes are mostly of the scalariform type, the annular and spiral types

[2] Solereder, Hans, Systematic anatomy of the dicotyledons, vol. 2, trans. by Boodle and Fritsch, Oxford, 1908.



FIGURES 15-20.—Details of stems (× 38) : 15, *P. Cookiana* variety *flavinerva;* 16, *P. Cookiana;* 17, *P. hirtipetiola* variety *longilimba;* 18, *P. Rockii;* 19, *P. oahuensis;* 20, *P. expallescens.*

being less common. No pitted vessels were found in any of the material studied. Cambium was also lacking.

LEAVES

The leaves vary considerably in thickness and amount of mechanical tissue present. *P. reflexa* has the thickest leaves, *P. membranacea* the thinnest. The mechanical tissue is represented by layers of collenchymatous cells beneath the major veins. Some species, especially *P. reflexa* and *P. membranacea,* lack mechanical tissue, but the other species studied show varying amounts.

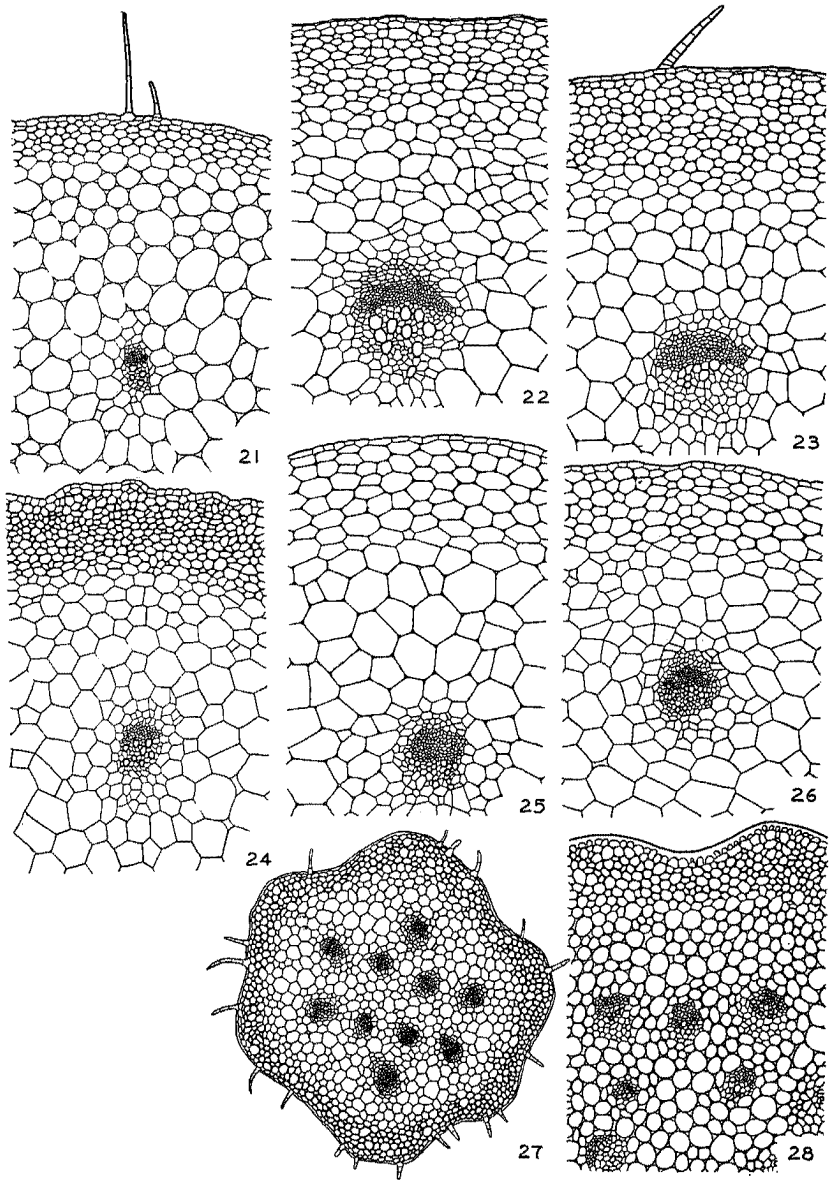
Epidermis. The epidermal cells are, in the main, uniform in shape. *P. sandwicensis* exhibits the largest cells on the average, *P. lilifolia* variety *nudilimba* the smallest. The cuticle is thin for all the species, with the exception of *P. reflexa* and *P. reflexa* variety *parvifolia,* which exhibit a well-defined and comparatively thick cuticle. Stomata were found only on the lower epidermis, excepting in *P. lepotostachya,* where a small number were also found in the upper epidermis.

Trichomes. All species except *P. oahuensis* and *P. membranacea* are provided with epidermal hairs. Though resembling the stem hairs in general, many of the leaf hairs, as in *P. expallescens,* are terminally rounded and blunt instead of acute.

Hydathodes. Hydathodes are found on both surfaces of the leaves of all species. They consist of three cells: *a,* a basal cell belonging to the epidermis; *b,* a short stalk cell; and *c,* a hemispherical, spherical, or saclike terminal cell, which in most leaves lies on the same level as the epidermal cells.

Hypoderm. The fleshy part of the leaves of all the species consists of water-storage tissue or "hypoderm" and chlorenchyma tissue. The hypoderm is located just beneath the upper epidermis and is made up of a varying number of layers of large, thin-walled cells, which exhibit great variation in size and have the smallest cells adjacent to the epidermis. Solereder states that according to Pfitzer

> The hypoderm in *Peperomia* is developed from a single-layered epidermis. In some cases, viz., when cell division and growth take place equally in the individual layers of the entire integumental tissue, this mode of origin can still be recognized in the mature leaf, the cells of the epidermis and those of the hypodermal layers being arranged in rows at right angles to the surface of the leaf as seen in a transverse section.



FIGURES 21-28.—Details of stems (× 38): 21, *P. leptostachya;* 22, *P. lilifolia* variety *nudilimba;* 23, *P. ellipticibacca;* 24, *P. sandwicensis;* 25, *P. membranacea;* 26, *P. latifolia;* 27, *P. reflexa* variety *parvifolia;* 28, *P. reflexa.*

This arrangement can be seen best in *P. reflexa* variety *parvifolia* (fig. 55) and *P. Cookiana* (fig. 47). In the majority of the species studied, however, the growth and cell division did not take place equally, hence this mode or origin is not so obvious. The thickness of the hypoderm varies from 1 or 2 layers of cells in *P. hirtipetiola* variety *longilimba* to 9 or 10 layers in *P. reflexa* variety *parvifolia.* Mucilage glands are found in a few species.

Chlorenchyma. The chlorenchyma tissue is of two types: *a,* small, closely packed cells, densely filled with chloroplasts and probably to be considered as a modified palisade tissue; *b,* larger, more loosely arranged cells with fewer chloroplasts. These two layers of tissue are designated in this paper respectively as "dense chlorenchyma" and as "spongy chlorenchyma." The dense chlorenchyma layer lies just beneath the hypoderm and consists of one to three layers of cells. The loose chlorenchyma lies between the dense chlorenchyma and the lower epidermis. In cross section and as observed under low magnification the dense chlorenchyma appears as a dark line separating the hypoderm from the spongy chlorenchyma.

SPECIFIC ANALYSES

Peperomia reflexa (figs. 14, 28, 36, 43, 56).

Stems

The stems are small and fluted and sparingly puberulent with hairs 0.1 to 0.2 mm in length. The epidermal cells, which are heavily cutinized on the radial as well as on the outer surface, range in size from 15 by 20 to 40 by 40 microns. The collenchymatous tissue consists of five to seven layers of cells which range in size from 15 by 20 to 40 by 55 microns. The cells of the ground parenchyma appear circular in cross section and range from 30 to 100 microns in diameter. The intercellular spaces are large and numerous. No crystals were found. The vascular bundles are small and surrounded by small, closely packed parenchyma cells.

Leaves

The leaves are succulent, have little or no mechanical tissue, and are about 1.3 mm thick. The cells of the epidermis show heavy cuticularization and range from 20 by 25 to 30 by 60 microns. The cells of the hypoderm range in size from 30 by 40 to 190 by 230 microns and form 6 to 8 layers of cells or approximately two thirds of the total leaf tissue. The dense chlorenchyma consists of two or three layers of cells, the average size of which is 30 by 40 microns. The cells of the spongy chlorenchyma range from 35 to 105 microns in diameter. Both hydathodes and mucilage glands are present.

Peperomia reflexa variety **parvifolia** (figs. 13, 27, 38, 44, 55).

Stems

The epidermal cells, which are cutinized only on the outer surface, range in size from 10 by 15 to 20 by 30 microns. The epidermal hairs consist of only two or three cells and range from 0.1 to 0.2 mm in length. The cells of the collenchymatous tissue are arranged in only four or five layers and range in size from 10 by 15 to 45 by 50 microns. Though there is considerable difference between the sizes of the stems of this variety and those of *P. reflexa*, the proportion of collenchyma to the rest of the stem is about the same in both. The cells of the ground parenchyma are closely packed and range from 25 to 70 microns in diameter. No crystals were found. The vascular bundles are comparatively small.

Leaves

The epidermal cells, which are not as heavily cuticularized as in *P. reflexa*, range in size from 15 by 30 to 20 by 60 microns. The epidermal hairs consist of two or three cells and range from 0.1 to 0.2 mm in length. The guard cells of the stomata are unique in that they protrude beyond the surface of the leaf. The cells of the hypoderm measure from 30 by 45 to 175 by 300 microns and are arranged in rows at right angles to the leaf surface to form 6 to 10 layers. The hypoderm occupies approximately four fifths of the total leaf tissue. The cells of the dense chlorenchyma average 25 by 35 microns in size and form two or, more rarely, one or three layers. The cells of the spongy chlorenchyma range from 30 to 60 microns in diameter.

Peperomia oahuensis (figs. 4, 19, 32, 46, 59).

Stems

The epidermal cells measure from 10 by 25 to 25 by 45 microns. Hairs are lacking. The collenchymatous tissue occupies 7 to 9 layers of cells, which measure from 15 by 20 to 40 by 55 microns. The ground parenchyma cells measure from 40 to 140 microns in diameter and are polygonal in shape with slightly rounded corners. Large simple crystals are abundant. The vascular bundles are surrounded by several layers of small, thin-walled, closely packed parenchyma cells.

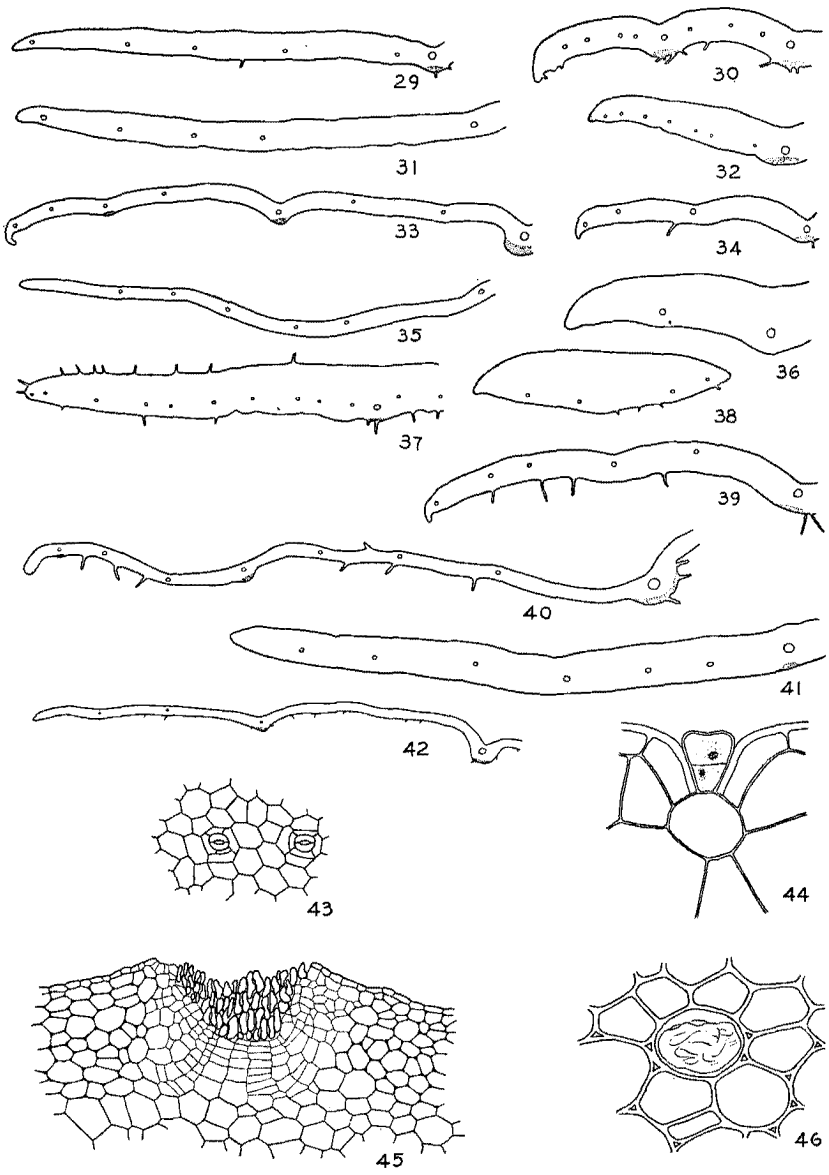
Leaves

The leaves are glabrous and about 0.7 to 0.9 mm thick. Collenchyma is found under the midrib and at the leaf margins. The epidermal cells, which are similar on both surfaces, range in size from 30 by 30 to 40 by 75 microns. The hypoderm is made up of four or five layers of cells which measure from 40 by 40 to 170 by 270 microns and comprises about two thirds of the total leaf tissue. The dense chlorenchyma consists of one or more rarely two layers of cells which average 35 by 45 microns in size. The cells of the spongy chlorenchyma range from 30 to 70 microns in diameter. Hydathodes are abundant, especially on the lower epidermis.

Peperomia latifolia (figs. 12, 26, 39, 45, 57).

Stems

The stems are hirsute above but glabrate below. The sections illustrated are from the lower part of the stem and show no hairs. The hairs, however,



FIGURES 29-46.—Diagrams and details of leaves and stems. 29-42, diagrams of cross sections of leaves: 29, *P. Cookiana* (× 6); 30, *P. ellipticibacca* (× 6); 31, *P. Cookiana* variety *flavinerva* (× 6); 32, *P. oahuensis* (× 6); 33, *P. lilifolia* variety *nudilimba* (× 6); 34, *P. expallescens* (× 6); 35, *P. membranacea* (× 6); 36, *P. reflexa* (× 6); 37, *P. leptostachya* (× 6); 38, *P. reflexa* variety *parvifolia* (× 6); 39, *P. latifolia* (× 6); 40, *P. hirtipetiola* variety *longilimba* (× 6); 41, *P. sandwicensis* (× 6); 42, *P. Rockii* (× 2.5). 43-46, details of leaves and stems: 43, *P. reflexa,* detail of lower epidermis (× 71); 44, *P. reflexa* variety *parvifolia,* detail of hydathode (× 275); 45, *P. latifolia,* detail of lenticel (× 38); 46, *P. oahuensis,* detail of mucilage canal (× 170).

range from 0.35 to 0.75 mm in length. The epidermal cells measure 20 by 35 up to 30 by 60 microns. The collenchymatous tissue consists of six or seven layers of cells which measure from 25 by 30 to 65 by 100 microns. Lenticels which do not protrude above the surface of the epidermis are common in this species. The ring of collenchyma is broken in the region of the lenticel, which would make it appear that the phellogen was formed in the outer part of the ground parenchyma or from the innermost layer of collenchyma. The cells of the ground parenchyma range from 50 to 230 microns in diameter. A comparatively small number of simple crystals were found.

Leaves

The leaves average from 0.5 to 0.6 mm in thickness. Only a small amount of collenchyma was found in the region below the midrib. The cells of both the lower and the upper epidermis are similar and measure from 20 by 30 to 40 by 60 microns. The epidermal hairs are mostly restricted to the lower surface, are sharp-pointed, consist of 13 to 16 cells, and range in length from 0.35 to 0.7 mm. Approximately one half of the leaf tissue is hypoderm which is made up of two or three layers of cells ranging from 30 by 40 to 130 by 160 microns in size. The cells of the spongy parenchyma range from 40 to 100 microns in diameter. The dense chlorenchyma consists of two to three layers of cells averaging about 35 by 50 microns. Hydathodes are abundant, and mucilage glands are found in the hypoderm.

Peperomia membranacea (figs. 10, 25, 35, 53).

Stems

The stems of this species are glabrous. The epidermal cells range from 15 by 40 to 30 by 80 microns. The collenchymatous layer consists of five or six layers of cells measuring 30 by 50 to 90 by 110 microns. The ground parenchyma cells are polygonal in shape and measure from 60 to 240 microns in diameter. Numerous large crystals of both the simple and the druse types were observed. A few of the crystals are located in the innermost cells of the collenchymatous layer. The vascular bundles are surrounded by small, closely packed parenchyma cells.

Leaves

The leaves are comparatively thin, entirely glabrous, and show no evidence of mechanical tissue. The cells of the upper epidermis measure from 20 by 40 to 50 by 90 microns; those of the lower epidermis are slightly larger. The hypoderm consists of one layer or, more rarely, two layers of cells which measure about 80 by 125 microns. The dense chlorenchyma consists of one or rarely two layers of cells which average about 25 by 40 microns. The spongy chlorenchyma is composed of cells commonly more or less horizontally elongated and measuring from 25 by 25 to 60 by 120 microns. Hydathodes are present; their upper cells and also their stalk cells may project above the level of the epidermis.

Peperomia ellipticibacca (figs. 6, 23, 30, 49).

Stems

The stems are densely hirsute with slender, rusty-brown hairs ranging from 0.4 to 1 mm in length. The epidermal cells range from 15 by 25 to 25

by 60 microns. The collenchyma cells measure from 25 by 35 to 100 by 100 microns and form as many as 12 or 15 layers. The cells of the ground parenchyma vary considerably in size, ranging from 60 to 280 microns in diameter. Small intercellular spaces are numerous. The crystals are scattered throughout the ground parenchyma and are predominatingly of the simple type. The vascular bundles are surrounded by small, closely packed parenchyma cells.

Leaves

The leaves are approximately 0.7 mm thick. Small amounts of collenchyma tissue are found just beneath the midrib and each of the larger veins. The cells of the upper epidermis measure 15 by 35 to 50 by 75 microns; those of the lower epidermis are slightly smaller. The epidermal hairs are stout, blunt-tipped, measure from 0.4 to 0.9 mm in length, and are confined largely to the lower epidermis. The leaf tissue is almost equally divided between the chlorenchyma and the hypoderm, which consists of three or four layers of cells which measure from 20 by 40 to 150 by 250 microns. The dense chlorenchyma tissue consists of two or three layers of elongated cells about 30 by 45 microns in size. The cells of the spongy parenchyma measure from 30 to 70 microns in diameter. Hydathodes are present but not numerous.

Peperomia Cookiana (figs. 1, 16, 29. 47).

Stems

The stems are densely hirsute. The hairs are slender, composed of as many as eight cells, and range in length from 0.6 to 1.3 mm. The epidermal cells are more or less uniform in shape and size and measure about 20 by 50 microns. The cells of the ground parenchyma range from 40 to 250 microns in diameter. Crystals of the druse type are abundant. The vascular bundles are surrounded by small parenchymatous cells.

Leaves

The leaves are about 0.5 mm thick, with a small amount of collenchyma tissue below the midrib. The cells of both the lower and upper epidermis are similar and measure from 20 by 40 to 50 by 90 microns. The epidermal hairs are stoutish and range from 0.6 to 1.5 mm long. The hypoderm is composed of three or four layers of cells, which range in size from 25 by 80 to 160 by 200 microns and which make up approximately three fifths of the total leaf tissue. The dense chlorenchyma consists of two rows of slightly elongated, closely packed cells which average 40 by 50 microns. The loose parenchyma cells vary from 30 to 70 microns in diameter. Hydathodes are numerous.

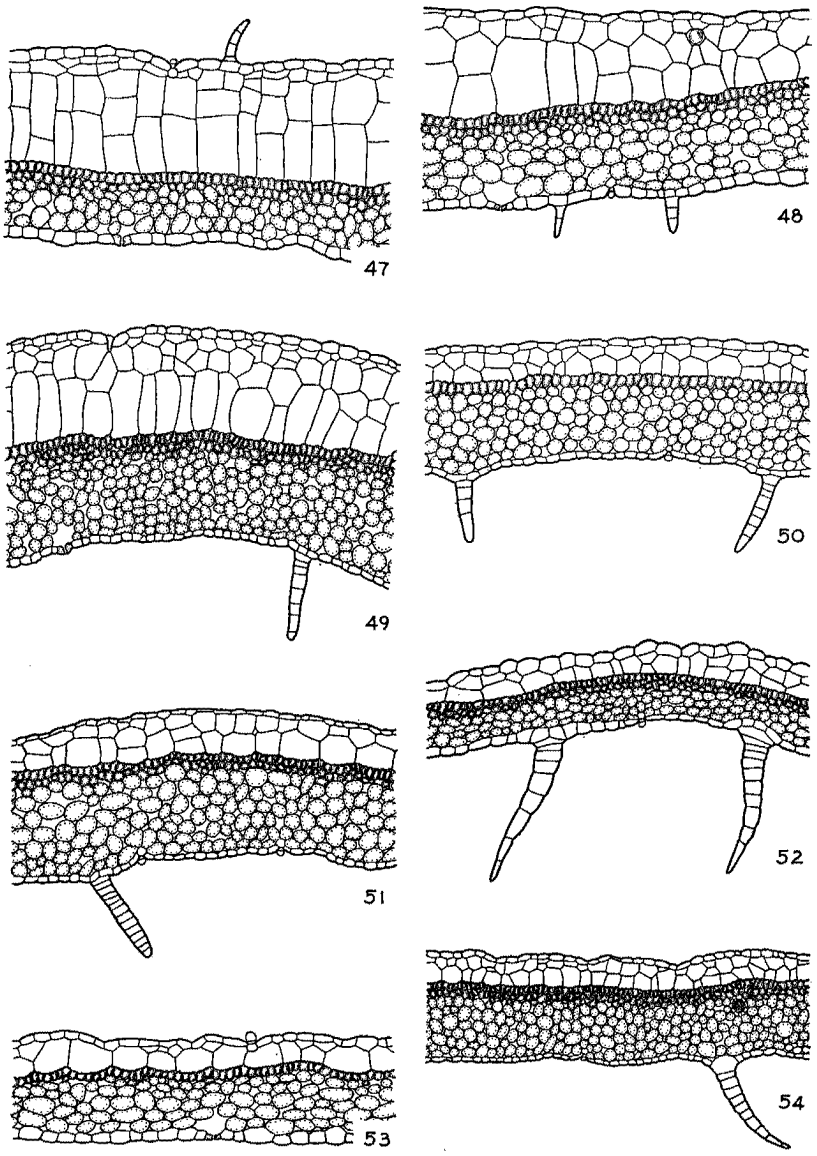
Peperomia Cookiana variety **flavinerva** (figs. 2, 15, 31, 48).

Stems

The stems are hirsute with hairs similar in structure and size to those of *P. Cookiana.* The epidermal cells range in size from 15 by 40 to 20 by 60 microns. The collenchyma is made up of six to eight layers, the cells of which measure 20 by 30 to 40 by 80 microns. In other respects these stems are similar to those of *P. Cookiana.*

Leaves

The leaves average approximately 0.5 mm in thickness and show no mechanical tissue. The epidermal hairs are similar in size and shape to those



FIGURES 47-54.—Details of cross sections of leaves (× 38): 47, *P. Cookiana;* 48, *P. Cookiana* variety *flavinerva;* 49, *P. ellipticibacca;* 50, *P. Rockii;* 51, *P. expallescens;* 52, *P. hirtipetiola* variety *longilimba;* 53, *P. membranacea;* 54, *P. lilifolia* variety *nudilimba.*

of *P. Cookiana*. The upper epidermis is similar to the lower epidermis, the cells of which measure 15 by 40 to 20 by 60 microns. The hypoderm consists of two or three layers, the cells of which measure from 50 by 60 to 200 by 270 microns, and it makes up approximately half of the entire leaf tissue. The dense chlorenchyma tissue commonly consists of two or, more rarely, three layers of cells which average about 30 by 40 microns. The spongy parenchyma cells range from 40 to 100 microns in diameter. Hydathodes are numerous on both the upper and lower surfaces. Mucilage glands are present but are confined to that region of the hypoderm just beneath the upper epidermis.

Peperomia leptostachya (figs. 8, 21, 37, 58).

Stems

The stems are densely pubescent, with thin, delicate hairs consisting of three or four elongated cells and ranging in length from 0.1 to 0.55 mm. The epidermal cells measure from 10 by 30 to 20 by 40 microns. The collenchymatous tissue consists of four or five layers, the cells of which are but slightly larger than the epidermal cells and measure from 15 by 20 to 35 by 60 microns. The cells of the ground parenchyma appear circular, have large intercellular spaces, and measure from 25 to 90 microns in diameter. No crystals were observed.

Leaves

The leaves of this species are mostly 0.8 to 0.9 mm thick. There is no mechanical tissue except a small amount of collenchyma in the region of the midrib. The leaves are pubescent on both surfaces, with hairs composed of 3 to 7 cells and measuring from 0.07 to 0.4 mm in length. The epidermal cells measure from 20 by 35 to 40 by 70 microns. A small number of stomata were observed in the upper epidermis in addition to those commonly found in the lower epidermis. The hypoderm, which is composed of four layers of cells ranging in size from 20 by 35 to 170 by 360 microns, occupies approximately two thirds of the total leaf tissue. The cells of the dense chlorenchyma, which average about 35 by 50 microns, occupy two or three layers. The cells of the spongy chlorenchyma are but slightly larger, measuring from 40 to 70 microns in diameter.

Peperomia sandwicensis (figs. 9, 24, 41, 60).

Stems

The stems are hirsute above but glabrate below. The hairs range from 0.3 to 0.75 mm in length. The epidermal cells range from 15 by 20 to 25 by 40 microns. The collenchyma is made up of 10 to 14 layers of cells which range from 20 by 20 to 35 by 50 microns. The cells of the ground parenchyma are moderately closely packed, are polygonal in outline, and range from 30 to 60 microns in diameter. The crystals are of the druse type and comparatively few. The vascular bundles are small and surrounded by small, closely packed parenchyma cells.

Leaves

The leaves are without any mechanical tissue except a small amount of collenchyma beneath the midrib. The epidermal cells are similar in shape and size in both the upper and lower epidermis and measure from 30 by 45 to 50 by 85 microns. The hairs are multicellular and blunt-tipped and range from

0.3 to 0.7 mm long. The hypoderm, which occupies one half to three fifths of the total leaf tissue, is composed of 3 to 5 layers of cells ranging in size from 70 by 90 to 245 by 300 microns. The dense chlorenchyma tissue is generally composed of two or, more rarely, one or three layers of cells, which are about 35 by 40 microns. The cells of the spongy chlorenchyma range from 30 to 80 microns in diameter. Hydathodes are not abundant.

Peperomia lilifolia variety **nudilimba** (figs. 11, 22, 33, 54).

Stems

The stems are essentially glabrous. The epidermal cells measure from 10 by 20 to 20 by 50 microns and have a definite cuticle. The collenchymatous tissue consists of 10 or 12 layers of cells which range from 20 by 30 to 60 by 90 microns. The vascular bundles are numerous and comparatively large. The cells of the ground parenchyma range from 60 to 480 microns in diameter. The crystals, which are scattered throughout, are mostly of the druse type with a few scattered simple crystals.

Leaves

The leaves are about 0.4 mm thick. Collenchyma is found beneath the midrib and each of the larger veins. The epidermal cells are similar on both surfaces and measure from 10 by 20 to 25 by 60 microns. The hairs, which resemble those of *P. hirtipetiola* variety *longilimba* in shape and cell arrangement, range from 0.4 to 1 mm. in length. The hypoderm, which makes up about one third of the total leaf tissue, consists of two layers of cells which measure from 15 by 20 to 70 by 80 microns. The cells of the dense chlorenchyma are arranged in two or three layers and average 25 by 30 microns. The spongy chlorenchyma is comparatively compact and is composed of cells ranging from 20 to 65 microns in diameter. Hydathodes are not abundant.

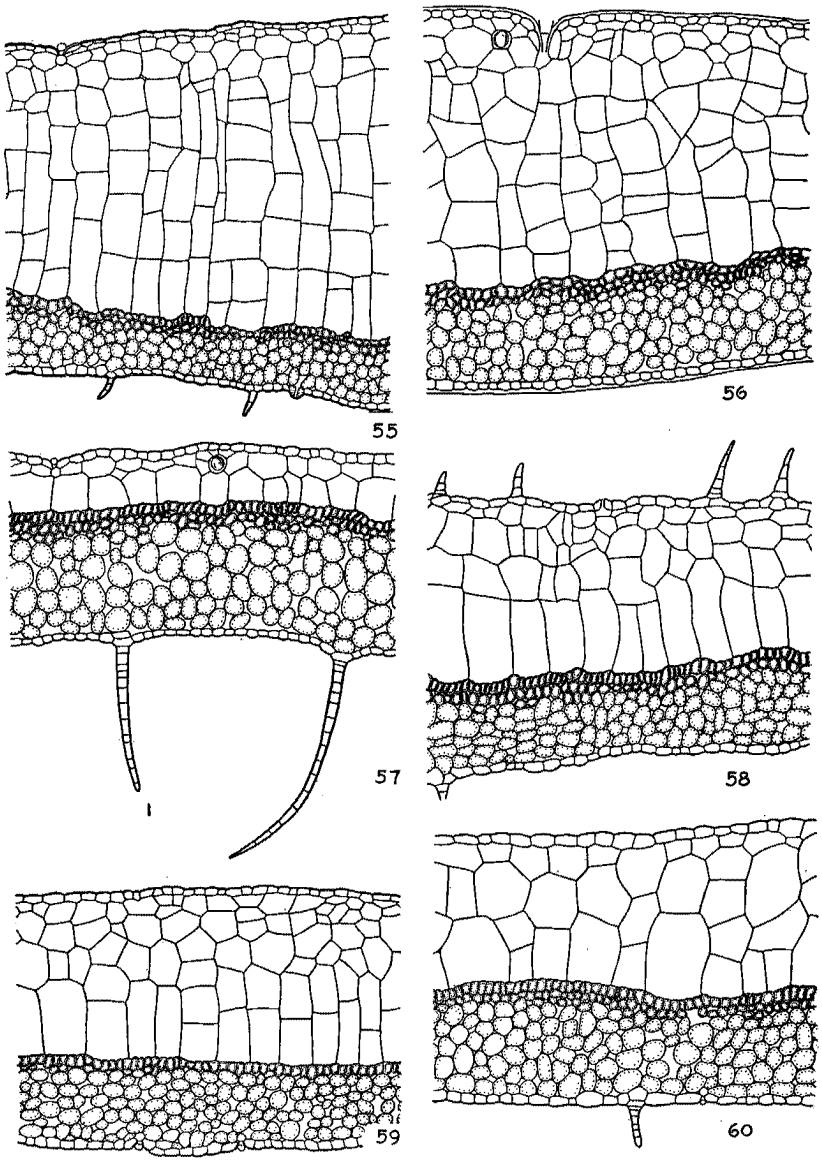
Peperomia Rockii (figs. 7, 18, 42, 50).

Stems

The hairs range in size from 0.3 to 0.7 mm in length but are mostly about 0.5 mm. The epidermal cells range in size from 15 by 20 to 20 by 50 microns. The collenchymatous tissue consists of 22 or 23 layers of cells which appear almost round in cross section and range in size from 10 by 15 to 50 by 60 microns. The cells of the ground parenchyma are closely packed and range from 40 to 120 microns in diameter. No crystals were observed. The vascular bundles are comparatively large.

Leaves

Collenchymatous tissue is present beneath the midrib and larger veins. The cells of both the upper and lower epidermis are similar in shape and size and range from 20 by 30 to 35 by 80 microns. The epidermal hairs range from 0.23 to 0.55 mm in length. The cells of the hypoderm measure from 30 by 45 to 80 by 110 microns and form two layers which occupy one fourth to one third of the total leaf tissue. The dense chlorenchyma consists of only one layer of cells, the average size of which is 35 by 40 microns. The cells of the spongy chlorenchyma range from 40 to 80 microns in diameter. Hydathodes are not abundant.



FIGURES 55-60.—Details of cross sections of leaves (× 38); 55, *P. reflexa* variety *parvifolia;* 56, *P. reflexa;* 57, *P. latifolia;* 58, *P. leptostachya;* 59, *P. oahuensis;* 60, *P. sandwicensis.*

Peperomia hirtipetiola variety **longilimba** (figs. 3, 17, 40, 52).

Stems

The stems are very densely hirsute, with hairs mostly 1 to 2 mm long and made up of 25 to 35 thick-walled cells. The epidermal cells range in size from 15 by 30 to 25 by 50 microns. The cells of the collenchyma, which may form as many as 15 layers, range in size from 30 by 35 to 60 by 100 microns. The cells of the ground parenchyma are closely packed, have small intercellular spaces, and range from 40 to 300 microns in diameter. No crystals were found. The vascular bundles are comparatively large.

Leaves

The leaves are comparatively thin, averaging about 0.3 mm. Collenchymatous tissue is present beneath the midrib and the larger veins. The epidermal cells range from 20 by 35 to 50 by 95 microns. The epidermal hairs are elongated, cone-shaped, multicellular, and range from 0.25 to 1.5 mm in length. The lower cells of the hairs are flat and disc-shaped; those toward the outer end are more elongated. The hypoderm, which makes up about two fifths of the total leaf tissue, is composed of one or two layers of cells that range in size from 35 by 40 to 90 by 140 microns. The cells of the dense chlorenchyma are about 30 by 40 microns and form two layers. The cells of the spongy chlorenchyma range from 25 to 50 microns in diameter. The hydathodes are slightly raised above the level of the epidermis.

Peperomia expallescens (figs. 5, 20, 34, 51).

Stems

The stems are densely hirsute above but glabrate below. The hairs range from 0.7 to 1.4 mm in length. The epidermal cells are comparatively small, ranging from 10 by 30 to 20 by 65 microns. The collenchyma is made up of 10 or 11 layers of comparatively small cells which range from 10 by 20 to 40 by 70 microns. The ground parenchyma consists of medium-sized cells measuring from 50 to 175 microns in diameter and having few intercellular spaces. A small number of simple crystals were found.

Leaves

The leaves are 0.5 to 0.6 mm thick. A small amount of collenchyma is present beneath the midrib. The cells of the upper and lower epidermises are similar in shape and size, ranging from 10 by 30 to 20 by 65 microns. The epidermal hairs—stout, very blunt-tipped, composed of flat, disclike cells—range in length from 0.4 to 1.0 mm and are most abundant on the lower surface. The hypoderm is composed of cells from 40 by 50 to 105 by 140 microns in size and form two or three layers making up about one third of the total leaf tissue. The dense chlorenchyma tissue consists of two or, more rarely, three layers of cells which average about 30 by 40 microns. The cells of the spongy chlorenchyma range from 40 to 70 microns in diameter. Hydathodes are numerous.