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The Stomata and Palisade Cells of Leaves

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THE STOMATA AND PALISADE CELLS OF LEAVES.

BY F. C. STEWART.

The name stomata (sing. stoma) has been applied to the elliptical apertures in the epidermis of leaves and other green parts of plants. The stoma is a modified epidermal cell and consists of a rift and guradian cells (usually two in number). The guardian cells are rightly named for it is their function to regulate the amount of evaporation from the leaf by opening and closing the rift. Unlike ordinary epidermal cells, the guardian cells contain chlorophyll, and for that reason they were once thought to belong to the parenchyma.

Goodale[1] says, "Stomata belong especially to green organs exposed to the air, but they have been detected on all superficial parts of the plant with the exception of roots." As authority he cites De Bary, who found stomata on the tubers of the potato, on the perianth and anthers of *Lilium bulbiferum* and on the pistil and seed coat of the Canna. In the higher plants they occur for the most part on the leaves. In the majority of Monocotyledons[2] they are found on both sides of the leaf, but in Dicotyledons they are seldom found on the upper surface except in leaves which present both sides to the sun. In some *Coniferæ*[3] there are more stomata on the upper than on the under surface. They are entirely absent from the leaves of submerged water-plants, and appear only on the upper surface of floating leaves.

In regard to arrangement, there seems to be no general law except in a few orders, viz: in *Equisetaceæ*, *Coniferæ* and *Gramineæ*. Since the object of the stomata is to bring the interior of the leaf into communication with the outside they world, are so placed as to communicate directly with the intercellular passages. Their arrangement, therefore, depends upon the internal structure of the leaf. The rift is a narrow ellipse whose major axis is generally the major axis of the stoma as a whole. (*Portulacca oleracea* is an exception.) Outside of the orders above named, the stomata are found scattered irregularly over the surface of the leaf, and with their axes pointing in every conceivable direction.

Being together with the lenticels, the aerators of plants, their number and size are thought to bear an important relation to the behavior of plants. In general, the plants of arid regions have few and small stomata, while water plants and plants native to moist climates have numerous and large stomata. This rule has a great many preplexing exceptions, and we are forced to acknowledge that we

[1] Goodale's Physiological Botany, p. 70.
[2] Thome's Struct. and Phys. Bot., Eng. Translation, Bennett, p. 61.
[3] Gray's Struct. Bot., p. 90.

really have but little exact knowledge of these curious little plant valves. The number of stomata on a square inch of leaf surface is surprising. It varies all the way from a few thousands up to hundreds of thousands. However, all computations of stomata are only approximations. The number varies on different portions of the same leaf, and the difference is often great. To get even an approximation it is necessary to take sections from different portions of several leaves and get an average. For an example of this variation take the Duchess apple. Counts were made on different parts of three leaves with the following results:

LEAF I.... { 29 stomata in field of microscope.
26 " " "
20 " " "
34 " " "

LEAF II... { 30 stomata in field of microscope.
30 " " "
27 " " "
28 " " "

LEAF III.. { 26 stomata in field of microscope.
38 " " "

A difference of one stoma in the field makes a difference of over 5000 on a square inch. Thus it is seen that the number in the Oldenburg (Duchess of Oldenburg) varies from about 120,000 to 200,000, while we get as an average 150 000 per square inch. From the table below it will be seen that this is about the average number in the varieties of apples examined by me. Prof. Bessey[4] found from 150.000 to 200,000 and Mr. Wellman[5] observed about the same number, while Lindley[6] gives but 24,000.

To obtain accurate measurements of stomata is even more difficult than to obtain their number. They are so very small and it is so difficult to get them always under the same conditions. In this work, also, we must make a large number of measurements and take the average. Stomata on the same leaf vary considerably in size and somewhat in shape. While the majority are elliptical in outline, some circular ones will be found. In some species they are rectangular. To show how stomata vary in size in leaves of the same tree we will again take the Oldenburg apple. Stomata were measured on three leaves.

The largest, the smallest and intermediate sizes were taken. L. stands for length and W. for width:

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[4]Iowa Hort. Report, 1879, p. 131.

[5]Iowa Hort. Report, 1873, p. 117.

[6]In his Introduction to Botany, p. 145, Lindley gives the number of stomata in thirty-six species of plants, twenty-eight of which were computed by Thomson.

Leaf I ...	Stoma 1	L. .00109	inches.
		W. .00094	"
	Stoma 2	L. .00109	"
		W. .00078	"
	Stoma 3	L. .00109	"
		W. .00086	"
	Stoma 4	L. .00125	"
		W. .00078	"
Leaf II...	Sto ma 1	L. .00156	"
		W. .00094	"
	Stoma 2	L. .00125	"
		W. .00094	"
	Stoma 3	L. .00094	"
		W. .00094	"
	Stoma 4	L. .00125	"
		W. .00094	"
Leaf III..	Stoma 1	L. .00139	"
		W. .00109	"
	Stoma 2	L. .00094	"
		W. .00078	"
	Stoma 3	L. .00139	"
		W. .00109	"
	Stoma 4	L. .00125	"
		W. .00109	"

The variation indifferent species may be seen in the table. Weiss[7] gives the length and breadth of the stomata in forty species. The least length in his table is .00047 in., the length of the stomata in *Amarantus caudatus;* the least width is .00031 in., in *Morus alba;* the greatest length is .00279 in., in *Lilium bulbiferum;* and the greatest width is .00197 in., in *Arena sativa.* The average length of the stomata in the forty species is .00126 in., and the average breadth is .00091 in.

While studying stomata I also made some observations on palisade cells. The number of rows of palisade cells in each species is given in the table. The number varies from one to four, two being the most common number. Prof. Bessey[8] found from two to four rows in the various varieties of the apple. Except in vertical leaves, palisade tissue is seldom found on the under surface of the leaf. Stomata

[7] Goodale's Phys. Bot., p. 171.

[8] Iowa Hort. Rep't, 1879, p. 132.

are confined mainly to the under surface and palisade cells to the upper surface. The nature of the palisade tissue depends largely upon the amount of light the leaf receives during its growth. Frequently the innermost layer of palisade cells will be incomplete, that is, in places it will be absent, or the cells may be but little different from the ordinary parenchyma cells. In the table, incomplete layers are indicated by the sign +.

The following table gives the results of some observations made during the past summer. It gives the number of rows of palisade cells, the number of stomata per square inch, and the size of the stomata in the species and varieties named. For the species given in the latter part of the table the size of the stomata is not given. Partly dry and partly alcoholic material was used and in these conditions measurements of stomata would be unreliable, and hence are omitted:

TABLE.

SPECIES.	STOMATA PER SQ. INCH.		SIZE OF STOMATA IN INCHES.		PALISADE LAYERS.	
	Upper surface.	Under surface.	Upper surface.	Under surface.	Upper surface.	Under surface.
Sugar pear (*Pyrus communis*)	0	6,768	0	L. .00151 / W. .00119	2+	0
Rutabaga (*Brassica compestris*)	9,024	12,696	0	L. .00119 / W. .00079	.....	.....
Portulacca oleracea	21,150	8,460	L. .00085 / W. .00075	L. .00070 / W. .00092	3	0
Salix laurifolia	0	135,000	0	L. .00150 / W. .00143	2+	0
Prunus pennsylvanica	0	215,000	0	L. .00107 / W. .00059	3	0
Polygonum cuspidatum	0	62,500	0	L. .00381 / W. .00261	2	0
Pontederia cordata	91,000	118,332	L. .00420 / W. .00285	L. .00579 / W. .00266	3	1
Apple (Canada Baldwin) *Pyrus malus*	0	296,000	0	L. .00125 / W. .00094	3	0
Apple (Peffer No. 4) *Pyrus malus*	0	123,332	0	L. .00128 / W. .00086	3	0
Apple (978) *Pyrus malus*	0	32,500	0	L. .00145 / W. .00093	2+	0
Nymphæa reniformis	458,332	0	L. .00094 / W. .00078	0	3	0
Acer nigrum	0	350,000	0	L. .00078 / W. .00073	1	
Pyrus coronaria	0	300,000	0	L. .00100 / W. .00062	3+	0
Crataegus tomentosa, var. *mollis*	.....	.....	0	L. .00102 / W. .00084	.....	.....
Apple (Oldenburg) *Pyrus malus*	0	150,000	0	L. .00124 / W. .00095	2+	0
Sagittaria variabilis	32,500	37,500	L. .00182 / W. .00130	L. .00192 / W. .00156	.....	.....
Virginia Crab	0	153,750	0	L. .00138 / W. .00101	2+	0
6 M (Russian cherry) *Prunus cerasus*	0	160,000	0	L. .00127 / W. .00105	2+	0
12 M (Russian cherry) *Prunus cerasus*	0	142,500	0	L. .00146 / W. .00098	2+	0
Silphium laciniatum	45,000	50,000	L. .00192 / W. .00172	L. .00198 / W. .00156	2	2
Lactuca scariola	120,000	122,000	L. .00101 / W. .00068	L. .00101 / W. .00078	2	2
Populus certinensis	43,750	109,000	L. .00130 / W. .00081	L. .00114 / W. .00070	2	0
Populus tremula	.....	.....	....	.....	2	0

TABLE—CONTINUED.

SPECIES.	STOMATA PER SQ. INCH.		SIZE OF STOMATA IN INCHES.		PALISADE LAYERS.	
	Upper surface.	Under surface.	Upper surface.	Under surface.	Upper surface.	Under surface.
Acer dasycarpum	0	210,000	0	L. .00057 / W. .00044	1	0
Medicago sativa	105,000	91,000	L. .00088 / W. .00070	L. .00162 / W. .00070	2+	0
Russian Oak (*Quercus robur*, var. *pedunculata*)	0	315,000	0	L. .00119 / W. .00091		0
Mongolian Pear (*Pyrus sinensis*)	0	82.500	0	L. .00177 / W. .00135	2	0
Prunus serotina	0	235,000	0	L. .00115 / W. .00075	2	0
Populus alba					2	0
Lutovka (cherry) *Prunus cerasus*	0	109,165			1+	0
Rosa rugosa					2+	0
Prunus angustifolia	0	150.000			2	2(?)
Celtis occidentalis					1	0
Prunus pumila	0	55,000				
Apricot (Nichol's) *Prunus armeniaca*	0	253,500			2	0
12 M (Pear) *Pyrus communis*	0	33,000			2	0
327 (Apple) *Pyrus malus*	0	90.000			2	0
75 M (Apple) *Pyrus malus*	0	88,000			2	0
Wythe (Apple) *Pyrus malus*	0	197,000			3	0
413 (Apple) *Pyrus malus*	0	150,000			2	0
15 M (Apple) *Pyrus malus*	0	167,500			3	0
Fluke's Wild Crab (*Pyrus loensis*)	0	155,000			2	0
Talman Sweet (*Pyrus malus*)	0	220,000			3	0
Rawle's Janet (*Pyrus malus*)	0	170,000			2	0
Pyrus toringo					2	0

A KEY FOR THE IDENTIFICATION OF THE WEED SEEDS FOUND IN CLOVER SEED.[1]

BY. F C. STEWART.

The identification of weed seeds, though an important matter, is not an easy one. The average person knows Fox-tail, and probably that is about all. Even botanists, who have not given the subject special attention, will be surprised to find how small a number of weed seeds they are able to identify without study.

Outside of systematic works[2] but little has been written on seed characters. What has been written is scattered through Experiment Station Bulletins and Agricultural Reports, and is not in an available form. However, the Germans have done some good work in this line, notably Harz[3] and Nobbe.[4]

A good key for the identification of American weed seeds would be of great

[1]Part of a thesis on THE IMPURITIES OF CLOVER SEED, written for the degree of Bachelor of Science, Iowa Agricultural College.

[2]Gray's Manual of the Botany of the Northern U. S., Chapman's Flora of the Southern States, Coulter's Rocky Mountain Botany, etc.

[3]Landwirtschaftliche Samenkunde, two volumes, Berlin 1885, Paul Parey.

[4]Handbuch der Samenkunde, Berlin, Wilgandt, Hempel and Parey, 1876.