

ECOLOGIC FOLIAR ANATOMY OF SOME PLANTS COMMON TO ILLINOIS AND NORTH CAROLINA.

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Botanical literature contains many reports of studies on leaf structure and the variations observed in different species of the same region or in the same species of two or more markedly different habitats. But very few studies have been made of the foliar anatomy of species common to widely separated regions. The purpose of this paper is to discuss the amount and kind of modification appearing in leaves of the same species collected from Illinois and North Carolina and to correlate so far as possible any variations found with the meteorological conditions existing during the growth and maturing of these leaves.

Collections of leaves were made at Pink Beds, Pisgah National Forest, North Carolina, during the month of August, 1926, and in the vicinity of Urbana, Champaign County, Illinois, in September, 1926. In all cases the specimens were taken as nearly as possible from the south periphery of the plants. The following species were included in the investigation. *Liriodendron tulipifera*, *Quercus alba*, *Acer rubrum*, *Robinia pseudo-acacia*, *Sassafras variifolium*, *Solanum carolinense*, *Plantago lanceolata*, *Hamamelis virginiana*, *Cornus florida*, *Castanea dentata*, *Prunella vulgaris*, *Juglans nigra*, *Rumex acetosella*, *Pyrus malus*, and *Rhododendron maximum*. Pieces from several leaves of each species were imbedded, cut, and stained with Bismarck brown. The sections were studied microscopically and measurements of the parts were made by means of a filar micrometer and carefully checked on various days in order to eliminate personal error as far as possible.

The Pink Beds habitat in North Carolina is situated at an altitude of about 3200 feet in the chestnut-tulip tree climax association. Champaign County, Illinois, on the other hand, is only about 700 feet in altitude and is located in the transition zone between forest and prairie. The climax community in the vicinity of Urbana is a hard maple-red oak association. Table I gives the comparative meteorological conditions of the two habi-

tats from July, 1925, to July, 1926, inclusive. It is readily seen from this table that for the year 1925-26 the North Carolina habitat exhibited the more xeric conditions.

TABLE I.¹

		Mean temperature	Saturation Deficit	Total Precipitation
1925				
July	Ill.....	77.6	.351	1.14
	N. C.....	74.5	.302	0.77
Aug.	Ill.....	74.8	.200	3.42
	N. C.....	72.0	.301	0.22
Sept.	Ill.....	73.0	.255	5.69
	N. C.....	73.6	.255	1.92
Oct.	Ill.....	45.6	.061	4.16
	N. C.....	53.6	.125	2.74
Nov.	Ill.....	38.6	.108	2.81
	N. C.....	43.6	.082	2.43
Dec.	Ill.....	26.6	.023	1.19
	N. C.....	36.6	.068	1.10
1926				
Jan.	Ill.....	28.1	.020	1.86
	N. C.....	37.0	.069	3.39
Feb.	Ill.....	33.5	.030	2.98
	N. C.....	40.4	.090	2.50
Mar.	Ill.....	33.5	.037	2.75
	N. C.....	39.6	.080	3.04
Apr.	Ill.....	45.4	.087	4.01
	N. C.....	52.0	.177	1.68
May	Ill.....	65.7	.256	2.34
	N. C.....	63.0	.257	2.37
June	Ill.....	69.4	.275	3.60
	N. C.....	68.0	.219	1.85
July	Ill.....	77.9	.351	4.38
	N. C.....	72.8	.266	4.48
Mean for March, April and May, 1926				
	Ill.....	43.2	.126	9.10
	N. C.....	51.5	.171	7.09

Table II presents the criteria selected for a comparative study of the leaves of the fifteen species from the two habitats. The figures represent the thickness in microns of the leaf parts indicated. These data, with the exception of those for the cuticles, are shown graphically in figures 1 and 2.

An examination of the data presented in Table II reveals that thirteen of the fifteen species show greater leaf thickness in North Carolina than in Illinois, the exceptions being *Acer rubrum* and *Robinia pseudo-acacia*. One of these, *Acer rubrum*, has a thicker palisade layer in North Carolina but *Robinia pseu-*

¹ The authors are indebted to the U. S. Dept. Agr. Weather Bureau, Asheville, N. C., and the Weather Bureau at the University of Illinois for the data given in this table.

TABLE II.

		Leaf thickness	Palisade	Spongy parenchyma	Upper epidermis	Lower epidermis	Upper cuticle	Lower cuticle
1. <i>Liriodendron tulipifera</i>	Ill.	93.3	25.5	42.5	8.5	8.0	4.2	2.7
	N. C.	180.2	59.5	68.0	12.7	11.6	4.8	3.9
2. <i>Quercus alba</i>	Ill.	136.0	59.5	51.0	14.7	12.75	3.62	2.72
	N. C.	153.0	68.0	51.0	16.1	11.64	4.67	3.23
3. <i>Acer rubrum</i>	Ill.	123.0	51.0	42.5	15.72	12.75	4.62	2.97
	N. C.	109.0	55.25	28.5	16.15	11.0	5.1	3.4
4. <i>Robinia pseudo-acacia</i>	Ill.	136.0	59.5	42.5	16.1	11.6	4.25	3.48
	N. C.	119.0	40.0	46.75	17.0	12.3	5.52	3.9
5. <i>Sassafras variifolium</i>	Ill.	127.0	51.0	44.0	13.45	11.05	4.25	3.97
	N. C.	144.0	68.0	34.0	15.72	12.75	5.35	3.4
6. <i>Solanum carolinense</i>	Ill.	127.0	51.0	51.0	12.75	11.05	4.33	3.4
	N. C.	160.0	68.0	59.0	13.17	12.07	4.5	4.25
7. <i>Plantago lanceolata</i>	Ill.	144.0	42.5	68.0	17.5	15.6	3.8	4.2
	N. C.	187.5	68.0	76.5	20.4	19.5	4.93	4.25
8. <i>Hamamelis virginiana</i>	Ill.	153.0	68.0	51.0	12.75	12.32	4.25	3.82
	N. C.	178.5	85.0	68.0	13.17	12.58	4.93	4.25
9. <i>Cornus florida</i>	Ill.	110.5	34.0	51.0	11.9	10.2	3.48	2.97
	N. C.	153.0	51.0	76.0	15.43	12.58	4.84	3.4
10. <i>Castanea dentata</i>	Ill.	136.0	68.0	38.25	15.3	13.43	4.2	3.4
	N. C.	144.5	76.5	36.0	17.0	13.1	5.1	3.9
11. <i>Prunella vulgaris</i>	Ill.	174.25	68.0	68.0	17.0	15.3	3.4	2.5
	N. C.	204.0	85.0	76.5	25.5	22.7	3.8	3.3
12. <i>Juglans nigra</i>	Ill.	93.0	51.0	25.5	8.5	4.5	2.5	2.1
	N. C.	140.2	68.0	51.0	14.4	8.5	4.2	2.8
13. <i>Rumex acetosella</i>	Ill.	195.5	85.0	89.0	21.2	17.0	4.2	3.4
	N. C.	229.0	76.5	93.5	25.5	21.2	5.5	4.0
14. <i>Pyrus malus</i>	Ill.	178.5	85.0	68.0	13.6	11.9	3.2	2.5
	N. C.	182.7	76.0	68.0	14.4	12.3	5.1	4.4
15. <i>Rhododendron maximum</i>	Ill.	314.5	140.2	136.0	16.57	12.75	5.52	2.55
	N. C.	365.0	170.0	153.0	27.0	17.0	8.0	5.0

do-acacia and also *Rumex acetosella* and *Pyrus malus* have more palisade in Illinois. The upper epidermis and the upper and lower cuticles of all fifteen species are constantly thicker in North Carolina, and this is true of the lower epidermis as well except that in *Quercus alba* and *Acer rubrum* this part is thicker in Illinois. The maximum amount of variation is found in the leaf of *Liriodendron tulipifera* which is nearly twice as thick in North Carolina as in Illinois. It is undoubtedly true that just as great differences could be found between sun and shade leaves on the same tree in either North Carolina or Illinois but that does not diminish the significance of the data here presented since, as previously stated, all leaves used in this study were collected from exposed positions on the south peripheries of the plants.

Table I presents the mean temperature, saturation deficits and precipitation for the thirteen months beginning with July, 1925, and ending with July, 1926. During this period the leaves used in the present investigation were formed and developed to maturity. The term "saturation deficit" expresses "the lack of vapor pressure, or the difference between the existing vapor

pressure and that which the atmosphere would contain at the current temperature if the space were saturated with water vapor." The saturation deficit has been found to be far more accurate for ecological purposes than relative humidity since it gives a direct measure of the capacity of the atmosphere for more vapor and thus, to a certain degree, "a measure of the rate at which evaporation will take place."

The general outline and fundamental structure of most leaves are developed while the leaf is yet minute within the bud. Later growth consists in increase of cell size and the maturation of the mesophyll. If the leaves under study were fully developed in August and September of 1926, they were laid down as embryonic structures in 1925. The mean monthly temperatures were higher in North Carolina than in Illinois in eight of the thirteen months treated in Table I. In nine of the thirteen months the precipitation was less in North Carolina than in Illinois, while the saturation deficits show a drier atmosphere in North Carolina in eight of the thirteen months.

It may be concluded from such data that the leaves collected in North Carolina developed under more xeric conditions than those collected in Illinois. If we consider March, April and May of 1926 as the months of cell enlargement and maturation of the mesophyll after the swelling and bursting of the buds, we are again confronted with more xeric conditions in North Carolina. The differences between the habitats are in no case very great but they are great enough to be of significance in the development of plastic organs, and it is interesting to note that the amount of variation in thickness of the various leaf parts is proportional to the amount of difference in weather conditions in the two habitats.

In addition to the factors already discussed the differences in altitude between the two habitats is of some importance since the illumination at an altitude of 3200 feet would presumably be more intense than at 700 feet. Higher light values, by increasing assimilation, tend to cause an increase in assimilative parts such as chloroplasts and palisade cells. This in turn increases transpiration and necessitates adaptations in leaf structure to meet the more xeric conditions.

An increase in thickness of leaf parts is, of course, only an indication of xerism, the cuticle being the most conclusive indicator, while primary significance lies in the entire plant structure. Species are plastic in varying degrees and respond in dif-

ferent ways to the same stimulus, and the data presented in this paper would be of conclusive significance only after comparison with similar studies in several successive years.

Summary and Conclusions.

1. The present investigation is a detailed microscopical study of the foliar anatomy of fifteen species common to the widely separated habitats of Illinois and North Carolina.

2. Thirteen of the fifteen species studied show a greater leaf thickness in the North Carolina habitat.

3. *Liriodendron tulipifera* shows the maximum variation of thickness between the two habitats in mesophyll, palisade and sponge tissues.

4. The protective structures, as a whole, show a higher degree of development in the North Carolina specimens.

5. The weather conditions existing during the period of the formation and development of the leaf tissues characterize the eastern habitat as a more xeric region than the western habitat.

6. The amount of variation in leaf thickness is in agreement with the amount of difference in weather conditions in North Carolina and Illinois.

7. Of all the leaf parts, the cuticle is the most conclusive indicator of xeric conditions.

8. Environmental conditions vary from year to year, and plants respond according to the plasticity of the species.

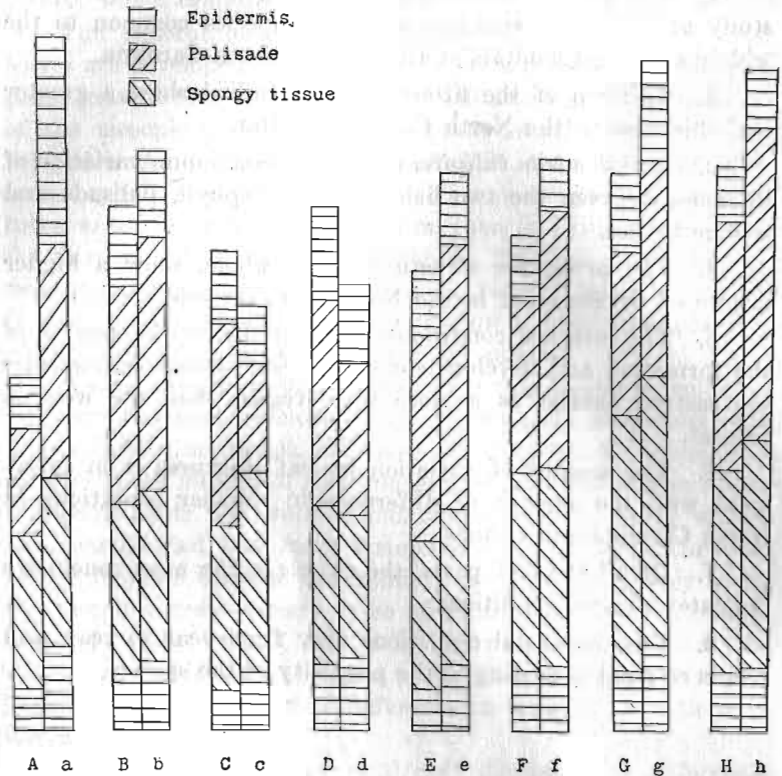


Fig. 1. Schematic representation of cross sections of leaves showing relative proportions of tissues. The large letters indicate Illinois specimens, the small letters North Carolina specimens. A, a=*Liriodendron tulipifera*; B, b=*Quercus alba*; C, c=*Acer rubrum*; D, d=*Robinia pseudo-acacia*; E, e=*Sassafras variifolium*; F, f=*Solanum carolinense*; G, g=*Plantago lanceolata*; H, h=*Hamamelis virginiana*. Scale: 1 inch=30 microns.

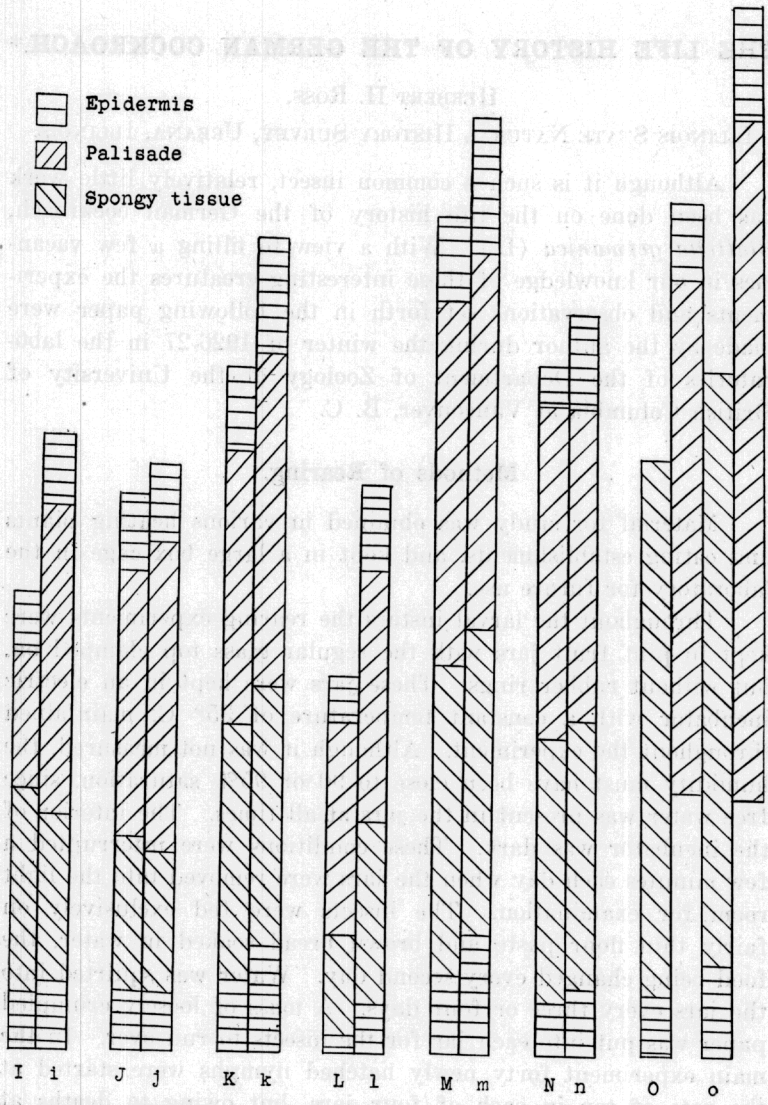


Fig. 2. Schematic representation of cross sections of leaves showing relative proportions of tissues. The large letters indicate Illinois specimens, the small letters North Carolina specimens. L, i=Cornus florida; J, j=Castanea dentata; K, k=Prunella vulgaris; L, l=Juglans nigra; M, m=Rumex acetosella; N, n=Pyrus malus; O, o=Rhododendron maximum. Scale: 1 inch=30 microns.