Acidity and Moisture in Tree Bark

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Introduction

Moisture is no doubt the one great controlling environmental factor in the deciduous forest area, which is evident from the major vegetational changes which local physiography or micro-climate induce in this region. Potzger (6) found that environmental variation of north- and south-facing slopes controlled the forest types, i.e., oak-hickory on the more xeric south-facing slopes and beech-maple on the mesic north-facing slopes. In a study of the micro-climate of one of these ridges, the same author (6) found that evaporation losses were 60% greater on south- than north-facing slopes.

Working in the ecotone between forest and prairie along the Missouri River, David Costello reports prairie on west-facing slopes and forest on the east-facing slopes. From this he concludes that the major control factor was difference in moisture induced by the prevailing air currents. These reports are of double significance if one considers that the micro-climatic variation here controls the dominant less sensitive vegetation group and that it operates along a sharply defined narrow border line.

The micro-climatic control ripples in ever narrower circles and ever finer degrees of differentiation into the various strata of a vegetation until it reaches the lower cryptogams. Most sensitive plant indicators of variation in moisture are no doubt the epiphytes. In our climatic regions the only epiphytes of any consequence are the mosses.

One finds frequent reference in the literature to presence or absence of epiphytic mosses on tree trunks, and conjectures are made as to the reason for their absence in certain localities, especially in woodlands or parks in or near cities. Now it is evident that in the water relations of these plants one must take two sources of supply into consideration, i.e., the moisture in the air and the moisture of the bark or substratum. In the latter case, the nature of the bark would play a vital part.

Another environmental factor, which has been stressed by various workers in mosses as vital in ecesis and establishment, is the acidity of the substratum. While this factor has received much consideration in soil, little or nothing has been done to study this factor in tree bark.

It is also quite generally recognized or merely assumed that epiphytic mosses are lacking on trees in city parks and woodlands, and the opinion has been expressed frequently that it was due to toxic substances in the atmosphere about a city, viz., fumes, acids, smoke, CO_2, etc. (2, 8, 9, 1). These toxic features are assumed controls, no experimental evidence having been produced to date in support of the reliability of such conclusions.

The environment is always heterogeneous, and thus it becomes a difficult matter to segregate one factor and call it the controlling factor when the control may be an aggregate effect.

An attempt is made in this paper to consider two environmental factors of epiphytic mosses, i.e., moisture and acidity of tree bark and the variation in these factors due to exposure of the trunk and a comparison of the same factors in an undisturbed forest and a characteristic city woodland on the Butler University campus.

Review of the Literature

The sensitiveness of mosses and lichens to impure conditions of urban districts has long been noticed. Haugsja (2), in studying the effect of atmospheric conditions of urban districts on bryophytes and lichens of trees, noticed that they were very sensitive to smoke. Darbishire (quoted by Watson in 2) said that very few lichens within twenty miles of Manchester bore apothecia. According to Watson (2) "even on the Pennines fertile lichens are very scarce since the prevalent winds bring the smoke from industrial districts, though in a few glens sheltered from such winds some lichens such as *Lecanora polytropa*, *L. varia*, *Cladonia pyxidata*, *Biatora graimlosa*, and *Verrucaria viridula* are occasionally found bearing apothecia." Watson (8), likewise, made a study of the bryophytes and lichens of moorlands in England. He said the bryophytes suffered in a similar way as the lichen from impure atmospheric conditions of an industrial district. The atmospheric conditions had a greater effect on the development of corticicolous epiphytes than on the terrestrial cryptogams. He also mentioned that the trees present, which were somewhat dependent on the soil, were correlated in a degree with the epiphytic mosses that were present. "For example, the smooth bark of the beech is the favorite habitat of some species of *Graphis*, *Arthonia*, etc., though these are not confined to the beech. They have been noted on various trees and have even been found on oaks when they were young and had smooth bark."

Since the lichens were able to reproduce in the areas sheltered from the smoky winds of Manchester, the region in which Darbishire made his study, it seems quite probable that this indicates the presence of greater moisture in that region, and as a result they were able to survive. If smoke had been in the winds, it would have penetrated those sheltered areas just the same as those unprotected. The same drying effect of the prevailing winds would not have been apparent in the sheltered regions, however, and for that reason the moisture content would have been greater.

Bailey (1) attributed the passing of forest mosses to lumbering. He mentioned that "prior to the last decade one could collect within the city limits most of our forest mosses. Now one must go some distance from the city to find them." He thought the smoky atmosphere was well illustrated in the changed conditions of moss growth in the city parks. The forest mosses in his city park had returned in a deep ravine, however. He noticed particularly *Eurhynchium stoloniferum*, *Hypnum circinale*, *Aulacomnium androgynum*, and *Neckera Douglassii*. This seemed to him to indicate the fact that climatic conditions were very important for moss growth. It seems that the return of mosses to the sheltered ravine is definitely because of the increased moisture conditions and not because of the protection from the impure atmosphere as he had previously indicated.

Mosses are for the most part indicators of soil acidity. Montgomery (5) tested a number of epiphytic mosses, which were acid as well as the soil on which they grew. He concluded that the moisture supply was a very important factor even when the H-ion concentration was suitable. His range of acidity for the habitats showed that mosses were very tolerant or else not so selective. A study has been made on the distribution or selectivity of mosses in relation to H-ion reaction and bark moisture as well as physiographic location by Wilson (7). Both were considered as limiting factors in addition to the physiographic conditions.

In reference to the position of Pleurococcus and mosses on trees, Kraemer (3) found that bark moisture was the chief factor in their distribution. He showed that the customary belief of "compass mosses" was unfounded. Mosses grow not only on the north side but on all sides of the trunks. He found, in a further examination, that "they grew in the greatest profusion on the shelving side of the trees with a slant of 10° to 20°, since in that position the greatest amount of moisture is received and retained."

Kobendza (4), in a study of bryophytic ecology of the Monts de Sainte Croix, found that mosses occurred more frequently on the trunks and branches of the sycamore than on the same parts of the beeches. This he attributed to the way in which the chinks of the sycamore bark caught and retained moisture and humus.

Thus we find that there is a divided opinion as to the causes for distribution of epiphytic mosses. There are those who believe that the bryophytes are only in rural districts because they cannot withstand the impure atmospheric conditions of the city. The other theory is that cryptogams are absent from cities because of insufficient moisture for growth. Since terrestrial mosses do occur in cities where the epiphytic mosses cannot survive, there must be some truth to the "moisture theory."

Methods

For the acidity tests, bark was collected in late winter both at Fort Harrison and the woods on the Butler campus. One sample from each of the twenty following species was collected from the campus trees in tin boxes:[1] *Aesculus glabra, Fraxinus americana, Carya ovata, Acer negundo, Acer saccharinum, Acer saccharum, Acer rubrum, Celtis occidentalis, Fagus grandifolia, Fraxinus quadrangulata, Tsuga canadensis, Populus deltoides, Quercus borealis maxima, Ulmus americana, Ulmus racemosa, Ulmus fulva, Prunus serotina, Pinus sylvestris, Liriodendron tulipifera, Ostrya virginiana.*

The pH was measured with the Youden H-ion apparatus. The bark was shaved off, covered with water, and the reading taken immediately. Three readings were made from each sample. The active acidity of these readings was averaged and the final pH obtained from that average.

At the Fort Harrison reservation, samples were taken from only eighteen species. Those were:

Ulmus fulva, Ulmus racemosa, Ulmus americana, Acer saccharum, Acer saccharinum, Acer negundo, Carya ovata, Fagus grandifolia, Celtis

[1] Nomenclature is that of Gray's Manual, Seventh Edition.

occidentalis, Salix sp., *Prunus serotina, Fraxinus americana, Quercus borealis maxima, Tilia americana, Platanus occidentalis, Aesculus glabra, Quercus alba.*

The bark was weighed immediately after collecting and then dried for four days in an oven at 100° C. The percentage of moisture present was computed as percentage of dry weight of the bark. An average of the three readings was taken for each of the eight species as shown in the tables. Range of variation is given in a special column.

Observations

The acidity readings of the campus woodland species showed that the bark from the trees was all acid. There was some variation in the acidity according to species (Table I). *Ulmus americana, Acer saccharinum,* and *Liriodendron tulipifera* were the most acid with the pH ranging around 5.2. The least acid were *Populus deltoides, Aesculus glabra,* and *Prunus serotina* with a range of pH, 6.55-6.26.

At the Fort Harrison woods, the acidity readings were made from samples of bark taken separately from the north and south sides of the trees. In all but two cases, the bark from the south side of the trunks tested more acid than that of the north side. This comparison is shown (Table II) with *Prunus serotina, Quercus borealis maxima,* and *Carya ovata* having the most acid bark, while those with least acid bark were *Celtis occidentalis, Acer negundo,* and *Ulmus americana.*

The percentage of moisture absorbed was computed on dry weight of the respective bark. The results obtained from eighteen species are also shown (Table III). These readings were based on only one sample for each species. The percentage of absorption ranged from 13.6% for *Carya ovato* to 22.2% for the *Populus deltoides.* Samples were taken from the north and south sides of each tree instead of one sample as in the collections on the campus. The acidity readings were made as described previously. For these tests, the bark was shaved into a test tube with distilled water; then the readings were made after it had soaked for two hours and not immediately as for the readings of the campus samples.

Moisture Content of the Bark

The samples collected from the campus trees were also used to measure the percentage of moisture absorption. The bark was dried for four days in an electric oven at 100° C. Next, it was weighed and placed into a saturated atmosphere for eight days. After reweighing, the percentage of moisture absorbed was computed on the dry weight of the bark for each species.

In April, a collection was again made from three trees each of the same species at the Fort Harrison woods and the campus for the purpose of determining the amount of moisture present in the bark. Samples were taken from both north and south exposures of the trunks. At the time of collecting there had been a five-day rainless period. At Fort Harrison, samples were also taken from beech and maple located in a protected ravine.

The average moisture present in the bark was derived from samples from three trees of each species, both on the campus and at Fort Harrison. In every case, the average moisture was greater on the north side than on the south side. These readings are compared (Table IV). In all but two readings, the moisture on the north side of the trees at Fort Harrison was greater than on the same side of the same species on the Butler campus, and likewise, the south side over the south side. The range in percentage of moisture content for the different species is shown (Table V). There is considerable variation in moisture content for different trees of the same species probably because of location, exposure, and different densities of bark.

Discussion

Plants are an expression of the environment where they grow, and at times these habitat control factors are so sensitive that it is difficult to point with certainty to any one factor and stamp it the controlling factor.

Water is without doubt one of the most important environmental factors. This is especially sensitively expressed in epiphytes where the less stable water content of the atmosphere is the major source of supply. It is a matter of common knowledge that in our region epiphytic mosses are primarily on the north side of trees, seemingly limited by a sharp control. The trees of open city woods and along streets are almost devoid of epiphytic mosses. The question of what factor controls this distribution of epiphytic mosses on trees now arises. Opinions vary. Some think it is difference in moisture; others say it is a difference in acidity. As for trees in cities, the absence of mosses is commonly attributed to toxic conditions caused by smoke and soot in the environs of the city.

The present study concerned itself with two of these environmental factors of epiphytic mosses, viz., moisture and acidity. Since bark of trees is the substratum for these mosses, it was the substrat which was examined for acidity, moisture content, and hygroscopic qualities.

Let us first consider the problem of moisture. This problem involves two phases, i.e., variation in loss of water due to environmental differences and differences in absorptive potentialities of barks. The season when this study had to be carried out prevented atmometer observations on variation in water loss due to exposure. So the characteristics of the bark as water-holding substrata were examined.

TABLE I.—Acidity of Tree Bark for the Butler Campus Species

SPECIES	pH	SPECIES	pH
Aesculus glabra	6.28	Populus deltoides	6.55
Fraxinus americana	6.18	Quercus borealis max	5.61
Carya ovata	6.16	Ulmus americana	5.20
Acer negundo	6.43	Ulmus racemosa	5.44
Acer saccharinum	5.22	Ulmus fulva	5.97
Fagus grandifolia	5.65	Prunus serotina	6.26
Celtis occidentalis	6.14	Acer saccharum	6.16
Acer rubrum	5.58	Pinus sylvestris	6.19
Fraxinus quadrangulata	5.68	Liriodendron tulipifera	5.20
Tsuga canadensis	6.03	Ostrya virginiana	5.82

TABLE II.—Acidity of Bark from Trees at Fort Harrison

Species	Acidity South	Acidity North	Species	Acidity South	Acidity North
Ulmus fulva	4.84	5.17	Celtis occidentalis	6.29	6.38
Ulmus racemosa	5.84	6.16	Salix	5.23	6.12
Ulmus americana	6.24	5.77	Prunus serotina	3.80	3.81
Acer saccharum	4.76	5.06	Fraxinus americana	5.44	5.5
Acer saccharinum	5.10	5.20	Quercus borealis max	4.45	4.405
Acer negundo	6.24	5.87	Tilia americana	5.46	6.06
Carya ovata	4.50	5.10	Platanus occidentalis	4.96	5.36
Fagus grandifolia	4.64	5.22	Aesculus glabra	5.39	....
			Quercus alba	4.62	...

TABLE III.—Percentage of Water Absorbed by Dry Bark of Campus Trees

SPECIES	% absorbed	SPECIES	% absorbed
Aesculus glabra	18.9	Populus deltoides	22.2
Fraxinus americana	18.8	Quercus borealis max	16.7
Carya ovata	13.6	Ulmus americana	18.2
Acer negundo	22.8	Ulmus fulva	19.0
Acer saccharinum	18.1	Ulmus racemosa	21.6
Fagus grandifolia	18.8	Prunus serotina	16.3
Celtis occidentalis	16.4	Acer saccharum	19.0
Acer rubrum	15.0	Pinus sylvestris	40.1
Fraxinus quadrangulata	19.6	Liriodendron tulip	20.6
Tsuga canadensis	18.8	Ostrya virginiana	22.0

Naturally, the presence of mosses in the protected forest at Fort Harrison and the absence in the open, much-disturbed woodland on the Butler campus invited a comparison which brought out rather interesting features. In bark of all trees (Table IV) but *Ulmus fulva* and *Ulmus racemosa*, the moisture content was greater at Fort Harrison than on the Butler campus. On the north side of trees, the excess ranged from .9% in *Ulmus fulva* to 5.17% in *Fraxinus americana*, while the excess on the south side ranged from .25% in *Aesculus glabra* to 4.3% in *Acer saccharinum* for the trees of the Fort Harrison reservation over those from the Butler campus. There is, thus, a slightly higher difference on north than south exposures. These results become even more significant if we consider that Marion County had an exceptionally wet season with rainfall several inches above normal, clouded skies for most of the spring and winter season, and low temperatures. Only five rainless days had intervened between the last shower and the collecting of the bark. One can readily picture the magnified differences during seasons of high evaporation and low precipitation.

One very significant feature in this study was that the amount of moisture present in bark on the south side of trees at Fort Harrison, where mosses are absent, equalled approximately that of the bark on the north side of trees on the Butler campus. This indicates that moisture, varying with micro-climatic differences, is the control of the absence or the presence of mosses on trees. Kraemer (3) attributed the distribution of epiphytic mosses entirely to the presence of moisture and considers the belief erroneous that mosses grow in general on the north side of trees. He says that, because the shelving side of the tree collects and holds more moisture, the mosses occur there most abundantly whether that be the north or the south side.

Wind action probably accounts for the difference in moisture content of the Fort Harrison and Butler trees. The differences in moisture content of bark on the north and south sides is shown (Table IV). In the city woodland, there is not that protective layer of shrubs or small trees either within or at the edge of the woods so that the wind is allowed a free sweep. Such a drying effect is also apparent in open rural woodlands. J. E. Potzger observed in an open woodland forest in Michigan that mosses were present only at the very base of the roots. Kobendza (4) correlates the presence of mosses and the kinds of epiphytic mosses on trees with the kind and quality of the bark. He holds that moisture was the chief factor involved. In his study of bryophytic ecology of the Monte de Sainte Croix, he found mosses more abundant on sycamores than on the same parts of beeches. He explained that the chinks of the sycamore bark caught and retained moisture and humus, which made the growth of mosses possible.

Table IV.—Percentage of Moisture in Bark

Species	Butler Campus Average			Fort Harrison Average			Camparison	
	South	North	Excess N—S	South	North	Excess N—S	Excess N/N	of S/S
Fraxinus americana	8.83%	13.03%	4.20%	10.6%	18.5%	7.90%	5.17	1.77
Aesculus glabra	10.15%	13.86%	3.71%	9.9%	15.8%	5.90%	1.94	0.25
Fagus grandifolia	8.30%	9.77%	1.47%	11.12%	11.64%	0.54%	1.87	2.82
Ulmus racemosa	11.6%	14.2%	2.60%	11.0%	11.10%	0.10%	3.10	....
Ulmus fulva	12.0%	15.4%	3.4%	11.47%	16.3%	4.83%	0.90	....
Ulmus americana	8.93%	12.8%	3.89%	10.35%	14.4%	3.05%	1.60	1.42
Acer saccharum	10.0%	12.86%	2.86%	11.30%	15.73%	4.43%	2.87	1.30
Acer saccharinum	12.0%	12.16%	0.16%	12.93%	16.46%	3.53%	0.93	4.30

Table V.—Range in Percentage of Moisture Content

	Butler		Fort Harrison	
	South	North	South	North
Fagus grandifolia	6.9—11.2%	9.3—10.8%	8.2—16.4%	10.02-13.2%
Fraxinus americana	8.4— 9.2%	11.4—14.5%	12.9—15.7%	11.0—22.9%
Aesculus glabra	8.1—12.2%	11.7—15.8%	9.9— 9.9%	12.2—20.5%
Acer Saccharinum	11.6—12.5%	11.3—13.9%	10.7—15.2%	16.0—17.2%
Acer saccharum	9.6—10.5%	10.5—19.5%	9.7—12.8%	14.2—17.2%
Ulmus racemosa	11.3—12.1%	13.5—14.6%	9.9—12.1%	10.9—11.3%
Ulmus americana	7.2—9.9%	8.7—16.5%	10.4—11.3%	10.1—18.7%
Ulmus fulva	12.0—	15.4—	10.3—12.3%	13.2—23.2%

To study additional variations in moisture due to slight micro-climatic differences, two trees, *Fagus grandifolia* and *Acer saccharum*, from a protected ravine at Fort Harrison were included. Not only was the moisture content of the bark on the south side higher than of the trees on the plateau but there was also less difference between the north and south exposures in the ravine.

Apparently there is no doubt that micro-climate is directly related to the presence of mosses. The assumption by certain authors that toxicity is the chief factor in their distribution had been made without sufficient experimental evidence. Darbishire (2) said that fertile lichens, because of the smoke-laden atmosphere, did not appear within twenty miles of Manchester, England, except in a few sheltered ravines. This, I consider, is not a matter of smoke but the lack of moisture due to the warm, drying prevalent winds. Only in those sheltered ravines was there enough moisture for the epiphytes to exist. It could not have been the smoky atmosphere that prevented their appearance, except in glens, because the smoke would have seeped into the sheltered glens the same as it covered the rest of the area. Bailey (1) likewise attributed the return of mosses to a protected ravine in his city park to the sheltered conditions from the city atmosphere. Both of these workers jump at conclusions and overlook micro-climatic differences affecting moisture.

Now let us examine the hygroscopic characteristics of different barks. There was considerable fluctuation in the range of moisture content (Table V). Since samples were taken from three trees of each species, this variation is expected. Again this shows the effect of micro-climate. If the tree were slightly more protected from the sun and wind, it would in all probability have a greater moisture content. Not only the micro-climatic factor but the depth of the bark fissures would explain this fluctuation. Where the fissures were deeper, evaporation would be less.

The dried bark showed specific differences in degree of absorption (Table III). *Pinus sylvestris* absorbed most; *Carya ovata*, the least. In general, the spongy bark absorbed more than the hard bark. It can readily be seen that the ability to absorb moisture from rain and the atmosphere would have a direct bearing on the growth or presence of epiphytic mosses. If the bark were highly hygroscopic, it would be able to replenish the moisture supply from the humidity of the air. It is known that the relative humidity within a forest is from 5% to 10% greater within than in the open area around it. Therefore, those trees within a protected area would be able to absorb more moisture from the area than those same species in an open woodland.

All of the acidity data bring out the fact, however, that bark of trees as a whole is acid in its reaction as *Prunus serotina*, and Quercus species may even be very acid. Not one of the twenty-three species examined in the present study had bark with alkaline or neutral reaction. This leads one to believe that all bark would probably be suitable substrat for epiphytic mosses from the standpoint of acidity and that the real limiting factor is moisture.

Summary

1. Bark of twenty-three species of trees was tested for acidity, moisture content, and hygroscopic potentialities.

2. Areas studied were a typical undisturbed beech-maple woodland on the Fort Harrison Reservation and a typical open woodland on the Butler University campus.

3. Comparisons are made between results from the two type locations.

4. All bark gave an acid reaction.

5. Range of acidity was pH 3.8 to 6.55.

6. In the Fort Harrison sampling, north and south sides were compared.

7. As a whole, bark from south sides was slightly more acid than that from the north side.

8. Bark of trees from Butler campus correlated closely in acidity with that of the Fort Harrison trees.

9. Moisture content was greater in the bark of trees on the Fort Harrison Reservation, both on north and south sides, than of trees on the Butler campus.

10. Moisture content of bark from the south side of trees in the Fort Harrison woods was in most cases comparable to that on the north side of the same species on the Butler campus.

11. The hygroscopic potentiality of porous bark was greater than that of compact bark.

12. *Pinus sylvestris* with an absorption of 40.1% was highest and *Carya ovata* with 13.6% was lowest.

13. Ravine protection tended to obliterate the north and south variation of moisture content of trees on uplands.

14. Apparently, moisture is the chief controlling factor in distribution of epiphytic mosses in this locality.

15. Apparently, epiphytic mosses are absent on trees in urban communities and disturbed rural woodlands because of greater desiccating influences.

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