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Distribution of Quercus muhlenbergii in Indiana

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During the years of the journal's publication, the Butler University Botany Department had an active program of research and student training. 201 bachelor's degrees and 75 master's degrees in Botany were conferred during this period. Thirty-five of these graduates went on to earn doctorates at other institutions.

The Botany Department attracted many notable faculty members and students. Distinguished faculty, in addition to Cain and Friesner , included John E. Potzger, a forest ecologist and palynologist, Willard Nelson Clute, co-founder of the American Fern Society, Marion T. Hall, former director of the Morton Arboretum, C. Mervin Palmer, Rex Webster, and John Pelton. Some of the former undergraduate and master's students who made active contributions to the fields of botany and ecology include Dwight. W. Billings, Fay Kenoyer Daily, William A. Daily, Rexford Daudenmire, Francis Hueber, Frank McCormick, Scott McCoy, Robert Petty, Potzger, Helene Starcs, and Theodore Sperry. Cain, Daubenmire, Potzger, and Billings served as Presidents of the Ecological Society of America.

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DISTRIBUTION OF QUERCUS MUHLENBERGII IN INDIANA*

By WM. REYNOLDS AND J. E. POTZGER

In a complex forest association such as found in Indiana one is confronted with interesting distribution patterns of some species. These same species may to some degree all associate in the mixed mesophytic forest association. All of them are adapted to the macroclimate but can be segregated from the climax association complex into smaller individual groups by variations of the microclimate. This is determined by physiographic conditions which may modify aerial and edaphic factors. Potzger (5) has discussed this phenomenon as operative in distribution of sugar maple, beech and white oak. Potzger and Friesner (6) referred to it in *Quercus rubra* and *Q. velutina*. All of these segregations are, of course, due to modifications of the macroclimate in more or less limited areas. It is quite obvious that identical soil and physiographic factors in Indiana and northern Michigan, let us say, could not involve segregation of the same genera and species with small variations in the edaphic and aerial factors because of the major selection of species by the macroclimate, or generalized climate, which is greatly different in the two locations.

When control of species is due to multiple factors it is practically impossible to discern the control by customary field methods, even though the response of species is so definite that a sharp line may separate the two types of habitat and the characteristic trees growing there. Over the greater part of Indiana *Quercus muhlenbergii* is a minor associate in the mixed mesophytic forest complex, low in abundance and in fidelity in similar stands. Deam (2) discusses this characteristic of the species when he says, "It is rare or an infrequent tree in practically all parts of its range." While it expresses itself in such manner in most forests of Indiana, it behaves very differently in the Whitewater and the Laughery Creek locations. In this region, especially on south and steep north-facing slopes it plays a very

* This is contribution 239 of the Butler University Botanical Laboratory. We thank the owners of the forests studied for permission to carry out the survey on their property.

prominent part in the more mesophytic aspect of the oak-hickory forest type, forming there a *Quercus muhlenbergii-Q. rubra* association. This unusual change in the chinquapin oak from subordinate to co-dominant control in the crown cover in a limited geographical location marked by outcrops of Ordovician and Silurian limestone aroused our interest. This study is an attempt to investigate the association more in detail.

GEOLOGY AND SOIL OF THE REGION

The preferred habitat of *Quercus muhlenbergii* appeared to be slopes with limestone outcrops, for that reason we will consider briefly only the geology of the rock outcrops. While all four counties (Fayette, Franklin, Ripley and Ohio) were influenced by either Illinoian or both Illinoian and Early Wisconsin glaciation, the leached soils of Illinoian as well as the less leached soils of Wisconsin glaciation are apparently closed to the chinquapin oak and some of its associates. The Cincinnati Arch is of great significance in the area because this uplift brought the Ordovician and Silurian limestones sufficiently close to the surface to enable stream cutting to expose them. The soil on the slopes is thin, and slabs of limestone are embedded in the soil or they lie in chaotic profusion on the surface, making walking on the slopes a difficult matter. In places where less fracturing of the strata has taken place solution lines have developed, producing a layered effect in the rock strata. Whitewater River and Laughery Creek are the major control of the cutting action in their own valleys as well as in all small and larger tributary valleys. The geologic history is strikingly similar in the four counties, since all came under the modifying influence of the Cincinnati Arch.

The soils on the slopes are, thus, of post-glacial origin. Long years of leaching has deprived the Illinoian drift of most of its soluble calcium, causing a general acid condition. On the slopes, however, leaching of the limestone outcrops keeps the soils on the alkaline side.

METHODS

Five stands of forest located in Fayette, Franklin, Ripley and Ohio counties were studied for sociological features on basis of ten, twenty or fifty ten-meter-square quadrats. (These represented at least ten per cent of the stands.) Abundance, frequency index, fidelity and stem-size distribution were stressed (table 3). Only one stand is given in detail (table 2); for all others summaries are presented in table 3. The DBH. measurements were made with wooden calipers. At three stands soil samples were taken at surface and 6-inch levels at frequent intervals up the slope (table 1), and field observations were made on the characteristics of the soil. As a whole, the quadrat studies were limited to that section of the slope where *Quercus muhlenbergii* indicated its preferred habitat. Only the stand near Metamora in Franklin County is shown in detail in table 2 as type for the association.

RESULTS

Quercus muhlenbergii is definitely limited to drier slopes, i.e., south-facing or steep north-facing slopes. It was never found invading ridge-tops, these were occupied by white and black oaks and hickories. Conditions are almost identical at all five stands studied, both as to habitat and forest association. The chief associate of *Quercus muhlenbergii* is *Q. rubra*. Consistently associated in a minor way are several species of Carya, *Acer saccharum* and several species of Fraxinus. Ostrya is without doubt the most characteristic second layer tree. Variations in a minor way are indicated by fluctuations between *Acer saccharum* and Fraxinus spp.? or *Quercus alba*. Outstanding by their consistent absence are *Fagus grandifolia* and *Quercus velutina*. *Acer saccharum* shows prolific reproduction but it is usually present only in the small stem sizes. Indirectly this suggests high mortality of the species. The characteristic habitat of the *Quercus muhlenbergii-Q. rubra* association is marked by alkaline soil. The limits of presence of these species of oak harmonize strikingly well with decrease in alkalinity.

Acidity of soil follows a rather uniform pattern, i.e., the zone where the Chinquapin oak thrives best is medium acid at one station (Swain woods) to highly alkaline in all otber stands. Differences in acidity between surface and six-inch soils are small, perhaps not greater than one would expect in multiple samples at the same zone. That the five stations are not identical in habitat factors is indicated by greater or lesser abundance of mesic or xeric associates. More moisture on the steep north-facing slope (compared with south-facing slopes of the region) where the Harting woods is located is indicated by the prominent participation of mesic *Acer saccharum* in the crown control.

DISCUSSION

Very frequently one reads of assumptions that oak-hickory necessarily also refers to xeric conditions in the habitat, but this is not quite correct. Among the oaks *Quercus alba* (to a lesser degree), *Q. rubra* and *Q. muhlenbergii* appear to be just a little less mesophytic than *Acer saccharum*. While *Quercus alba* is facultative, *Q. velutina, Q. montana* and others are obligative indicators of xeric habitats. In the counties included in this study, we seem to deal with an intermediate condition of moisture between the mixed mesophytic climax and oak-hickory habitat sites. In this habitat acidity may constitute a selective factor. As for *Quercus muhlenbergii,* light may operate as an inhibiting factor in the mixed mesophytic forest. In most extensive quadrat studies by Potzger (5) in Monroe County, and by Potzger and Friesner (6) in Monroe, Brown, and Bartholomew counties *Q. muhlenbergii* never appeared at all or just occasionally, but never as dominant. In these same counties *Q. rubra* seldom participated as associate in the oak-hickory forests, but was a frequent co-dominant in the mixed mesophytic climax. Of course, the rock outcrops in these counties are not the pure limestone as those in the Laughery and Whitewater valleys. They are also not arranged as slabs overlying one another as in the Ordovician and Silurian outcrops in eastern Indiana. This slab arrangement may permit accumulation of seepage water along the fracture lines and thus make it a less xeric habitat than that on slopes where the Borden outcrops.

Habitat controls of forest types are never very easy to discover or to analyze definitely, since multiple factors are underlying. This is especially true when a species of customary minor importance in the association segregates and then expresses itself as an important dominant in a modified aggregate of species from both mesic and xeric habitats. In the present instance it involves *Quercus muhlenbergii, Q. rubra* and species of Fraxinus, Carya and to a lesser degree also *Acer saccharum*, in the region of Ordovician and Silurian limestone outcrops along south-facing slopes. Involuntarily one wonders what the difference might be in these habitats and those of other parts of the state. Auten and Blair (1) say, "Soils affect trees principally through soil air and soil moisture. Seasonal available soil moisture often determines what species will be found in a given forest and their rate of growth."

Such a conclusion may be correct in a general way for trees in agreement with a particular climate, but even in such locations there must be other edaphic factors which limit plant ecesis, especially also as these factors affect germination of the seeds and the seedling stage, or perhaps even absorption of the mature tree. Palmer (4) discovered that Lemanea in Indiana streams was obligatively limited to limestone outcrops of Silurian, Devonian and Upper Mississippian, but he never found the plant on Ordovician outcrops. He was not able to determine the cause of such control which limited growth of the alga to these particular limestone outcrops but he thought that it was the presence of small amounts of certain chemicals in the water dissolved out of the limestones.

From the field observations we can definitely say that *Quercus muhlenbergii* and its associates seem to function as a unit, in agreement with the particular type of habitat which was described in an earlier section of this article. The habitat is apparently too dry for *Fagus grandifolia* and too moist for *Quercus velutina*. Nine of the 14 most common associates show 100 per cent fidelity (table 3), and more species show a high per cent F. I. than would be expected according to Raunkiaer's statement of the law of distribution of species in an association. It is also true that the association follows lines of high alkalinity of soil. However, alkalinity per se, or its influence indirectly on absorption of minerals with its subsequent influence on ecesis of the species represented the field study alone cannot determine. According to the Dominion Forest Service in Ontario (3) *Quercus muhlenbergii* is limited in Ontario, too, to limestone outcrops. As for soil moisture, it appears that the shingled character of the rock strata and loose boulders may retard runoff more effectively than the Borden of Brown and Bartholomew counties. This might well result in an intermediate condition between the habitats controlled by the mixed mesophytic forest association, on the moist side, and the oak-hickory (black and white oaks) on the xeric side.

SUMMARY AND CONCLUSIONS

1. The study is concerned with five stands of forest characterized by a *Quercus muhlenbergii-Q. rubra* association.

2. The stands are located on south-facing and steep north-facing slopes with Ordovician or Silurian limestone outcrops in the Laughery Creek and Whitewater River valleys in Indiana.

3. Soil within the limits of best development of the association is alkaline.

4. The two species of oaks have a high fidelity and frequency.

5. *Quercus muhlenbergii* and *Q. rubra* contribute 39 to 63 per cent of stems 6 inches or over DBH., which is interpreted as of importance in crown control.

6. Small stem-sizes are less abundant for the two oaks than for many of the associates which play a minor role in control of the crown cover.

7. Both *Fagus grandifolia* and *Quercus velutina* seem to be barred from the association. This suggests a soil moisture condition intermediate between the mixed mesophytic and the black oak-white oak-hickory habitats.

8. Apparently both soil moisture and pH exercise controlling influence on selection of members of the association.

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TABLE I

Soil acidity (pH) in various stands of the *Quercus muhlenbergii-Q. rubra* association

Locations	Snrface	6-inch	Descriptions
South-facing slope at Versailles, Ripley Co.			
1. Near foot of slope	7.73		Lower limit of *Quercus muhlenbergii*
2. Fifty fcet above 1	7.68	7.88	Limestone boulders in soil
3. 75 feet above 1	7.76	7.8	Among roots of young Chinquapin oak
4. 150 fect above 1	7.5	7.85	Near upper limits of slope
5. In row of *Q. velutina*	6.58	6.76	Upper rim of slope
6. *Q. alba* and *Q. rubra*	6.33	5.3	On upper slope
7. Abundant young *Q. alba*	4.78	5.43	Flat ridge top
8. Bank of creek	8.17		Seepage water
Whitewater valley, south-facing slope			
1. Lower slope	7.25	7.03	Lower limit of *Quercus muhlenbergii* zone
2. Midslope	7.8	7.48	*Q. muhlenbergii* zone
3. Top of slope	6.88	7.01	Zone of *Q. rubra* and *Acer saccharum*
4. Seepage at foot of slope	7.3		
Fayette County, Stone's Woods			
1. Midslope	7.7	7.96	*Q. muhlenbergii* zone
2. Above *Q. muhlenbergii*	5.5	5.4	Zone of various speeies of oaks
3. Creek water	6.9		
Franklin County, Swain woods			
1. Upper limit *Q. muhlenbergii*	6.85	6.7	
2. Crest of hill	6.15	6.05	No *Q. muhlenbergii*
3. Creek water	7.4		

TABLE II

Tabulations of woody species from 50 ten-meter-square quadrats on a south-facing slope into Whitewater valley about 2 miles west of Metamora, Franklin County, Indiana

Species	Below 1 in.	1-2	3-5	6-10	11-15	16-20	Above 20	Total stems	Per cent F. I.
Acer saccharum	34	350	43	3				430	98
Aesculus glabra	12	24	4	2				42	32
Carpinus caroliniana		2						2	2
Carya cordiformis	1	10	1	2				14	20
C. glabra		2	1					3	4
C. ovata	7	35	16	17	8	5		88	84
Celtis occidentalis	1	2						3	4
Cercis canadensis	19	10	2					31	20
Cornus drummondi	48	2						50	20
Crataegus sp.?	4	3	7	1				15	24
Fraxinus americana	9	29	24	13	1			76	66
F. quadrangulata	35	86	20	12	1			154	82
Gymnocladus dioica		4						4	4
Juglans nigra				2	1			3	6
Morus rubra		1						1	2
Ostrya virginiana	23	58	50	5				136	82
Quercus muhlenbergii	3	18	19	18	6	8	3	75	64
Q. rubra		6	20	15	10	3	2	56	64
Tilia americana		1	1					2	2
Ulmus americana	4	4	7	5	5	2		27	42
U. rubra			1	7				8	14
			SHRUBS						
Euonymus atropurpureus	5							5	8
Dirca palustris	7	49						56	6
Rhus radicans	2							2	4
Ribes sp.?	19							19	24
Viburnum prunifolium	10							10	4
Vitis sp.?	9							9	14

TABLE III

Summary of sociological characteristics of 14 species of trees in five stands of *Quercus muhlenbergii-Q. rubra* association in Whitewater and Laughery Creek valleys

Species	Per cent of total stems 6 inches or above DBH.					Per cent F. I.					Average number of stems per 10-meter quadrat 5 inches or less DBH.					Fidelity				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Quercus muhlenbergii	36.7	22.3	16.2	41.0	16.6	90	64	60	100	70	2.3	.8	1.8	5.1	7.2	x	x	x	x	x
Q. rubra	26.5	19.0	31.0	13.7	22.2	90	64	85	60	60	.4	.5	.8	1.0	.4	x	x	x	x	x
Q. alba			28.3	26.0		20		55	60		.3		1.9	2.7		x		x	x	
Carya ovata		19.0	6.7	2.7	8.3	70	84	50	55	40	1.9	1.1	1.1	.3	.5	x	x	x	x	x
Fraxinus amerieana																				
F. lanceolata	1.0	8.9	2.7	4.0	8.3	90	66		90	90	2.6	1.2	1.4	1.7	3.3	x	x	x	x	x
F. quadrangulata		8.2				30	82	35	60	90	.4	2.8	.7	1.7	3.3	x	x	x	x	x
Acer saccharum		1.9	4.0	2.7	31.0	90	98	100	100	100	8.9	8.5	27.0	21.4	9.0	x	x	x	x	x
Aesculus glabra		1.3	4.0		5.5		32	20	40	50		.8	.1	.3	.5		x	x	x	x
Carya cordiformis		1.3	1.3			60	20	50	20		1.6	.2	.5	.3	.5	x	x	x	x	x
C. glabra	4.0			6.8		50	4	25	45	30	1.2	.1	.8	.2	.4	x	x	x	x	x
Ulmus americana		7.6					42					.3					x			
U. rubra	12.2	4.5				90	14	55			12.1		2.6			x	x	x		
Carpinus caroliniana						30	2	10	15	10	1.0		.1	.4	.2	x	x	x	x	x
Ostrya virginiana						100	82	85	100	100	9.0	2.6	4.9	7.5	10.3	x	x	x	x	x