STRUCTURAL ANALYSIS OF A STAND CONTAINING YELLOWWOOD IN SOUTHERN ILLINOIS

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ABSTRACT

An area supporting the only known stand of yellowwood (Cladrastis lutea (Michx. F.) K. Koch) in Illinois was studied using plot sampling techniques to describe and assess its compositional and structural characteristics and to relate these characteristics to the yellowwood population. Stand structural attributes including basal area and density were not related to the structure or population characteristics of the yellowwood. A comparison of the population structure of the yellowwood with the total stand indicates they have similar size-class distribution patterns. Additional investigations revealed that Verticillium albo-atrum is a pathogen which may be affecting the yellowwood. Yellowwood, which is a component of a once more extensive mixed mesophytic forest, appears to be a relic disjunct which is limited in its distribution in Illinois primarily by habitat limitations and possibly by stresses imposed by a pathogen.

INTRODUCTION

Yellowwood (Cladrastis lutea (Michx. F.) K. Koch) is a small deciduous tree which occurs over a relatively restricted range; it extends from western North Carolina into the eastern portion of Tennessee, northern Alabama, Kentucky, southern Indiana, southern Illinois and into north and central Arkansas and southwestern Missouri (Hough 1924, USDA 1974). Throughout the range, which is entirely south of the glacial border, its distribution is discontinuous (USDA 1974). Habitat requirements include moist and well-drained soils which are derived from limestone (Hough 1924, Braun 1950, Arkansas Department of Planning 1974). It often occurs along ravines or stream courses.

Yellowwood is a small tree ranging up to 18 m in height and 0.91 m in diameter (Hough 1924). The species is a component of the mixed

mesophytic forest in the Appalachian Highlands but it may attain greater abundance along the river bluffs in the Western Mesophytic transitional region of central Kentucky and Tennessee. It can occur in all strata although the largest size does not equal that attained by other species in the community. Whittaker (1956) indicates that yellowwood is a character species (sensu Braun-Blanquet) of the cove-hardwood forests in the Great Smoky Mountains.

According to Braun (1950), a number of southern Appalachian Highland endemics which have Asiatic relatives, including yellowwood, are interpreted as Tertiary relics. In fact, the occurrence of yellowwood and other species westward from the Appalachians is thought to be indicative of a once more extensive mixed mesophytic forest. Braun (1950, 1955) has reached the conclusion that the occurrence of yellowwood in the Eocene (Wilcox Flora) indicates that this taxon and other extant Tertiary associates originated in the Interior Highlands.

Yellowwood is found locally in southern Illinois on cherty, well-drained soils derived from dolomitic limestone and is restricted to lower to mid-slopes and ravine or stream bottoms. It is almost universally restricted to northerly facing aspects.

This study was undertaken to 1) describe the vegetation associated with yellowwood, 2) determine the dynamics of the yellowwood population, and 3) to relate the basal area and density of yellowwood to various stand structural parameters.

THE STUDY AREA

The study was conducted in an area (approximately 121.5 ha) which supports the greatest known concentration of yellowwood in southern Illinois. The yellowwood are located on and near Wolf Creek in Alexander County (Secs. 16 & 17, T15S. R2W). As a result of the presence of the yellowwood population and another disjunct species, storax (Styrax grandifolia Ait.), a portion of the study area has been designated a Botanical Area by the U.S. Forest Service, while the remaining portion is under private ownership. Approximately 64 individuals of yellowwood have been located, most of which are mature or decadent although some seedlings and saplings occur. An additional 17 individuals, which were not included in the present study, can be found about 11.3 km east of the Botanical Area.

The area is in the unglaciated foothills in the southern section of the Illinois Salem Plateau of the Ozark uplift (Schwegman 1973). The bedrock geology is primarily of the Bailey Limestone formation of the lower Devonian system (Pryor and Ross 1962). The limestone in this area is novaculite chert which fractures forming beds .30 m to .61 m deep. Covering the chert, is a deposit of Pleistocene loess derived from the Mississippi and former Ohio bottomlands (Pryor and Ross 1962).

Soils associated with the yellowwood include silt loams of the Bodine and Elsah series (Parks and Fehrenbacher 1968) although other soil types occur in the study area. The Bodine Cherty silt loam (Typic Dystrochrept) occurs on 30 to 60% slopes and is shallow and well-drained. This light colored soil develops in silty loess over a cherty substrate. Soil reaction (pH) ranges from 4.5 to 5.5. The Elsah silt loam (Typic Udifluvent) is moderately deep, well drained and occurs over cherty materials on 0 to 4% slopes in narrow ravines or wide stream bottoms. Soil reaction ranges from 6.1 to 7.3.

The climate of Alexander county is humid continental with average daily maximum temperatures in July of 32 C and January average minimum temperatures of -1.1 C. There are about 208 frost free days. Average annual precipitation is slightly in excess of 1143 mm and is relatively well distributed throughout the year (Parks and Fehrenbacher 1968).

Topography is rugged with a relief of about 67.0 m. The area is disected by narrow, steep-sided ravines with slope angles sometimes exceeding 60 percent.

Individual yellowwood trees within the area are generally characterized by poor form, and many show signs of decadence or are dead above but may be sprouting with varying degrees of vigor from the base. In several instances the smaller trees are healthy in appearance. Sprouts from the base of decadent or dead trees vary in size and may occassionally reach sapling size. Upon inspection of the area, the initial impression is that yellowwood is barely maintaining itself or is decreasing in the community.

METHODS AND MATERIALS

To determine the composition and structure of the vegetation associated with the yellowwood, plot sampling techniques were utilized. Thirty-four individuals of yellowwood served as plot center for two concentric circular plots corrected for slope angle (Bryan 1956); the larger 0.04 ha plot was used for sampling trees $\geq$ 6.6 cm dbh (diameter breast high) while in the smaller 0.004 ha plot both seedlings and sprouts $\leq$ 2.54 cm dbh and saplings $>$ 2.54 cm $<$ 6.6 cm dbh were tallied. In addition, number and size of dead yellowwood seedlings and saplings was recorded. Site data included slope position, aspect, and angle and estimates of soil rockiness.

Data were analyzed and summarized on an IBM 360/158 computer located on the campus of Southern Illinois University. Because of the general appearance of the yellowwood, two specimens of plant material, one from an apparently healthy tree and one from an apparently diseased individual were sent to the Plant Pathology Laboratory at the University of Illinois for analyses.

RESULTS

Of the 64 known yellowwood trees ($\geq$6.6 cm dbh) in the study area, 46 were included in the plots sampled. The remaining 18 were not included as they occurred on sites where plots could not be located because of proximity to severely disturbed areas, roads or stream banks. All yellowwood individuals were on north facing slopes on mid-to-lower slopes and ravine bottom positions. Associated soils were invariably rocky with various amounts of chert fragments present.

The general forest composition and structure for the sites that support yellowwood are presented in table 1. On the basis of dominance, the area is a Black Oak-Beech-Sugar Maple type. Sugar maple (Acer saccharum Marsh.) is the predominant overstory species in the sapling layer while ironwood (Ostrya virginiana (Mill) K. Koch) was the most predominant non-overstory species in the sapling layer. The predominant overstory species in the seedling stratum is sugar maple and the predominant non-overstory species is hydrangia (Hydrangea arborescens L.). Density of the trees is 588.1 t/ha and the basal area is 25.9 m^2/ha while the density of saplings and seedlings is 718.57 and 11,136 t/ha, respectively. Of these totals, yellowwood comprises 11.08, 20.21, 5.41 and 4.67 percent of the seedling, sapling and tree density and tree basal area respectively.

A size-class distribution analysis for all stems and for the yellowwood stems is presented in figure 1. Diameters of all stems including seedlings, saplings, and trees were grouped into 5.0 cm size-classes and fit to a negative power curve regression. The negative power curve was used since it is realistic for trees as it does not assume a constant mortality (Hett and Loucks 1971). For all trees the equation is:

$Y = 17{,}794x^{-1.85}$ with an r^2 (calculated on the basis of transformed x and y variables) of 0.95

The equation for the yellowwood is:

$Y = 2473.98x^{-2.03}$ with an r^2 (calculated on the basis of transformed x and y variables) of 0.92

The two correlation coefficients derived from the r^2 values are not significantly different based on a Z test (Zar 1974). The regressions suggest that both the total stand and yellowwood populations approximate a stable size-class distribution. Unfortunately, due to the poor condition of the wood of most of the yellowwood individuals, accurate age determinations could not be made.

Relationships between structural parameters, ie. basal area and density, of the stand and those of the yellowwood were compared using stepwise multiple regression. Basal area per plot of either the living or dead yellowwood was the criterion (dependent variable) and total plot density and basal area of all species excluding yellowwood were the

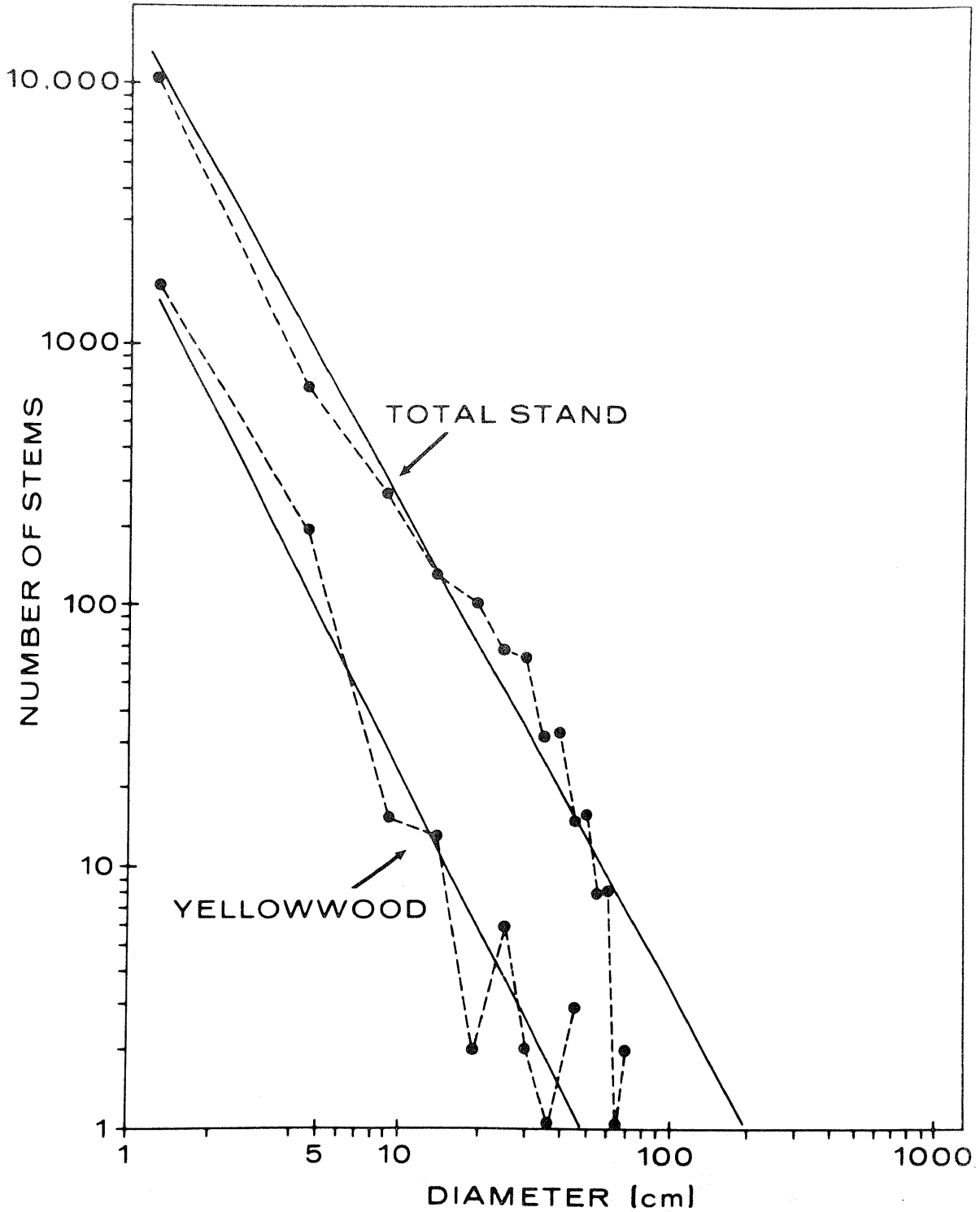

Fig. 1. Size-class analysis of the yellowwood population and total stand. Solid lines are derived from the negative power curve regression; dashed lines represent observed values.

Table 1. Composition and Structure of a Yellowwood Stand in Southern Illinois.

Species	Seedling Density[1]	Seedling Rel.Den.	Sapling Density	Sapling Rel.Den.	Tree Density	Tree Rel.Den.	Tree Basal Area[2]	Relative Basal Area	IV200
Acer rubrum	72.86	.65	7.16	1.0	4.45	0.76	0.15	0.58	1.34
Acer saccharum	610.33	5.5	334.19	46.51	59.52	10.12	1.93	7.45	17.57
Aesculus glabra	14.57	0.13							
Amelanchier arborescens	14.57	0.13							
Aralia spinosa	7.16	0.06							
Asimina triloba	2026.88	18.20							
Carpinus caroliniana	327.02	2.93	21.73	3.02	15.31	2.60	0.10	0.39	2.99
Carya cordiformis	138.07	1.23			10.13	1.72	0.17	0.66	2.38
Carya glabra	210.69	1.89	36.31	5.05	38.53	6.55	1.05	4.05	10.60
Carya ovalis	21.74	0.20			13.83	2.35	0.49	1.89	4.24
Carya ovata	43.72	0.39	7.16	1.00	29.15	4.96	0.69	2.66	7.62
Carya tomentosa					2.96	0.50	0.05	0.19	0.69
Cladrastis lutea	1235.0	11.08	145.23	20.21	31.86	5.41	1.21	4.67	10.08
Cornus florida	290.72	2.61	14.57	2.03	12.35	2.09	0.08	0.31	2.40
Diospyros virginiana					1.48	0.25	.009	0.03	0.28
Euonymous atropurpurea	50.88	0.46							
Fagus grandifolia	450.53	4.04	7.16	1.00	38.53	6.55	6.19	23.89	30.44
Fraxinus americana	72.62	0.65	14.57	2.03	19.51	3.32	0.32	1.24	4.56
Fraxinus pennsylvanica	29.14	0.26			1.48	0.25	0.18	0.69	0.94
Hydrangea arborescens	2927.69	26.28							
Lindera benzoin	138.07	1.24							
Liquidambar styraciflua	7.16	0.06	7.16	1.00	23.22	3.95	0.95	3.67	7.62
Liriodendron tulipifera	7.16	0.06			13.09	2.23	1.19	4.59	6.82
Magnolia acuminata	58.04	0.52			8.65	1.47	0.55	2.12	3.59
Morus rubra	7.16	0.07	7.16		1.48	0.25	0.03	0.12	0.37
Nyssa sylvatica	36.31	0.33	7.16	1.06	15.31	2.60	0.28	1.08	3.68
Ostrya virginiana	1750.74	15.72	94.35	13.13	31.12	5.29	0.28	1.08	6.37
Platanus occidentalis					0.74	0.13	0.01	0.04	0.17

Table 1. Continued.

Species	Seedling Density[1]	Seedling Rel.Den.	Sapling Density	Sapling Rel.Den.	Tree Density	Tree Rel.Den.	Tree Basal Area[2]	Relative Basal Area	IV200
Prunus lanata	14.57	0.13			1.48	0.25	0.06	0.23	0.48
Prunus serotina	7.16	0.06			2.22	0.38	0.02	0.08	0.46
Quercus alba	29.14	0.26			37.05	6.30	1.69	6.52	12.82
Quercus muhlenbergii					1.48	0.25	0.10	0.39	0.64
Quercus rubra	29.14	0.26			13.83	2.35	0.83	3.20	5.55
Quercus velutina	7.16	0.06			91.64	15.58	5.78	22.31	38.19
Rhus radicans	43.47	0.39							
Rubus spp.	29.14	0.26							
Sassafras albidum	283.31	2.54	14.57	2.03	50.88	8.65	1.06	4.09	12.74
Ulmus alata	7.16	0.07		1.00	3.71	0.63	0.02	0.08	0.71
Ulmus americana					1.48	0.25	0.09	0.35	0.60
Ulmus rubra	123.50	1.11			9.39	1.60	0.33	1.27	2.87
Vaccinium vacillans	7.16	0.06							
Vitis spp.	7.16	0.06			2.22	0.38	0.01	0.04	0.42
Total	11,136.90	99.95	718.48	100.07	588.08	99.97	25.90	99.96	200.23

[1] Density is expressed as individuals per hectare.

[2] Basal area is expressed as m^2 per hectare.

predictors (independent variables). In both regressions there was no significant relationship as only 5.7 percent of the basal area variation in the living yellowwood and 2.2 percent of the variation in basal area of the dead yellowwood was accounted for by the two stand structural attributes. It appears that the stand structure as commonly measured is not related to the structural features of the yellowwood. A biserial correlation coefficient (Ostle 1963) was calculated to determine if the dead yellowwood (dichotomized with the plots containing living yellowwood) correlated with either basal area or density of the plots. Again, no significant relationship was detected.

The results of the analysis of the two specimens sent to the Pathology Laboratory at the University of Illinois suggested that the wilt fungus, Verticillium albo-atrum was a potential pathogen in one individual. The cankers that occur on many of the older trees may be secondary fungal infections to the Verticillium infection (Jacobsen pers. comm.).

DISCUSSION

The overall stand composition and structure is typical for north facing slopes and ravine bottom communities in southern Illinois (Ashby and Kelting 1963, Voigt and Mohlenbrock 1964, Weaver and Ashby 1971). The large importance value of black oak (Quercus velutina Lam.) in the stand reflects the steep mid-slope positions and rocky, well drained soils of some of the plots sampled since it characteristically occurs on those sites in this area. The 42 woody species encountered in the samples reflect the range of environmental conditions from the stream or ravine bottoms to the mid-slope positions. The structural characteristics of the stand compare favorably with other upland forests in this part of Illinois (Ashby 1968, Weaver and Ashby 1971) and in southern Indiana (Schmelz and Lindsey 1965). The basal area and density for the yellowwood stand are lower and higher, respectively than Weaver and Ashby (1971) reported for an old growth upland woods located about 17.3 km to the north of the present study site. The differences are probably due to the greater degree of protection from timber harvesting and to the more favorable site conditions ie. gentler slopes and deeper and less rocky soils in the latter stand.

The mesophytic nature of the yellowwood stand will be perpetuated if the compositional patterns observed and measured in the understory seedling and sapling strata prevail into the overstory as evidenced by the high proportion of sugar maple in these strata. However, predictions such as this should be made with caution as forest composition can be influenced by many factors including climatic shifts, land utilization practices, and influences of fire and disease (see Weaver and Ashby 1971). If large openings in the canopy are not created by the demise of the Beech and other major components of the overstory and if environmental changes are minimal, then sugar maple should continue to increase in importance in the stand.

The high Coefficient of Determination for the negative power curve regression for the total stand may indicate that severe past disturbance (Schmelz and Lindsey 1965) or changes in the size-class distribution as a result of changing regeneration strategies (Robertson 1976) have not occurred in the stand. The reasonable balanced size-class distribution of the yellowwood, which is not significantly different from that for the total stand, suggests that the stand structure is, in itself, not affecting regeneration success of the yellowwood. Also, the lack of significant relationships between stand structural attributes including basal area and density and those for the yellowwood support this conclusion. Thus, the impression that the yellowwood status in the stand is being influenced by the associated species structure is not borne out by these analyses. This is consistent with interpretation of structural position of yellowwood in the Appalachian forests (Braun 1950, Whittaker 1956).

The presence of the Verticillium wilt in this population and in other individuals of yellowwood from Illinois (Himelick 1968a, 1968b, 1969) may be an influential factor affecting the distribution and population dynamics of yellowwood in southern Illinois. General symptoms of Verticillium wilt include a wilting and browning of the leaf followed by defoliation and a dieback of stems and branches. The latter symptoms were observed on some individuals within the study area. The former symptoms were not observed as most of the field work was conducted during the fall after leaf fall was completed. Verticillium wilt seems to be most severe along an imaginary line that demarks climatic zone IV and V in Illinois according to Rehder (1940). This line crosses the state in a northeasterly to southwesterly direction about midstate. However, since yellowwood is not present naturally above the glacial border, it is possible that the pathogen may limit this particular host considerably south of the zone of greatest incidence of the disease. It appears that with changing postglacial climates and subsequent restriction to very limited suitable habitat plus the stresses imposed by the pathogen, the range of yellowwood has been limited for a long period of time.

While a limited study such as this does not provide a great deal of information concerning the nature of disjunctions, it does raise the question concerning the status of the yellowwood. An affinity of the Illinois Ozarks to the deciduous forests to the east is suggested by the presence of disjunct taxa, including yellowwood, storax (Voigt and Mohlenbrock 1964, Pusateri 1975), chestnut oak (*Quercus prinus* L.) (Myatt 1975) and azalea (*Rhododendron nudiflorum* Torr.) (Braun 1950, Voigt and Mohlenbrock 1964). In addition, some of the taxa in the yellowwood stand are components of the Mixed Mesophytic Forest such as beech (*Fagus grandifolia* Ehrh.), yellow-poplar (*Liriodendron tulipifera* L.), sugar maple, white oak (*Quercus alba* L.), cucumber-tree (*Magnolia acuminata* L.), American ash (*Fraxinus americana* L.), red maple (*Acer rubrum* L.), black gum (*Nyssa sylvatica* Marsh.) in the overstory and flowering dogwood (*Cornus florida* L.), blue beech (*Carpinus caroliniana* Walt.), ironwood, spicebush (*Lindera benzoin* Blume) and hydrangea in the sapling-shrub stratum. These characteristic species and the pattern of

disjuncts imply a more extensive mixed mesophytic plant assemblege as projected by Braun (1950). She interprets the occurrence of disjuncts near the glacial border as evidence that these species and their associated forests have persisted in their northern locals throughout the Pleistocene to the present.

In direct contrast to the interpretation of Braun (1950, 1955) is that derived from palynological studies by Whitehead (1967, 1972). He contends that "significant southward displacement of biota took place during times of glacial advance." (Whitehead 1972 pg. 127). This was an azonal displacement as no modern counterparts can be found for the patterns observed in the fossil spectra. He suggests that the mixed mesophytic as it presently exists represents a post-glacial shuffling of species assembleges from southern refugia about which we have little information. He also points out that the mixed mesophytic forest, if it had remained in place since the mid-Tertiary as Braun (1950) suggests, would have had to withstand the climatic changes of the Pleistocene.

Recently Delcourt and Delcourt (1975) have presented evidence that during the Pleistocene the Blufflands along the Mississippi provided environmental conditions that permitted numerous migrations of plants into Louisiana from the mixed mesophytic forests to the north. The conditions that allowed such migrations may have been adequate to allow many mixed mesophytic species to exist in the loess covered hills and bluffs of southern Illinois during that period and thus be partially responsible for the pattern of disjunctions observed today.

Considering its present pattern of east-west disjunction along with other taxa mentioned above, yellowwood must have been, in either interpretation, a component of a once more extensive mixed mesophytic forest which, due to environmental changes, has been restricted to limited areas in the Appalachian Mountains. It, therefore, should be considered a relic disjunct. The yellowwood, because of its characteristic habitat requirements, seeds which are not easily dispersed, and its susceptability to Verticillium Wilt, will remain restricted in its distribution. Because of these characteristics it is not likely to occupy more than secondary importance in communities in which it occurs in southern Illinois. Alteration of the communities in which yellowwood occurs to protect or maintain it is not warranted by the results of this study and may, in fact, cause it to be eliminated by increasing competition from opportunistic species or directly from habitat destruction. Additional studies should focus on the extent and role of the Verticillium Wilt in affecting the population dynamics of yellowwood.

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