DIVERSITY IN TREE SPECIES IN SOUTHEASTERN OHIO *BETULA NIGRA* L. COMMUNITIES

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ABSTRACT

Quantitative data were obtained for arboreal species within 50 lowland forests in southeastern Ohio., Thirty-seven communities were dominated by *Betula nigra* L. and 13 were dominated by *Acer saccharinum* L. The acidic soils collected from *B. nigra* communities contained toxic concentrations of exchangeable aluminum and low concentrations of calcium and magnesium. Tree species diversity (Shannon-Weaver index) and species equitability were inversely related to high concentrations of exchangeable aluminum and hydrogen and directly related to high concentrations of exchangeable calcium and magnesium and an increase in soil pH

INTRODUCTION

Strip mining began in Ohio in 1914 and occurs primarily in unglaciated southeastern Ohio which receives approximately 114 cm of rainfall per year. According to Riley (1960) a majority of the spoil banks created by strip mining in Ohio were left ungraded for a period of 25 years subsequent to 1914. The adverse stream chemistry associated with strip mining is due largely to sulfide-bearing compounds such as pyrite, pyritic shales, and marcasite (Blevins et al, 1970). Sulfuric acid produced from oxidation of these compounds may reach the streams by groundwater or surface runoff. Water draining from rock strata associated with coal seams may contain acid salts of aluminum, iron, and manganese (Struthers 1964).

Betula nigra L. has been found along several streams in southeastern Ohio which carry acid coal mine drainage (McClelland and Ungar 1970, Cribben and Ungar 1974). Braun (1961) and Fritts and Kirkland (1960) reported that *B. nigra* was common along streams draining areas with acid soils in Illinois, but absent along streams draining alkaline soils.

The objectives of this research were to: 1) describe and summarize arboreal species within river bottom communities that had low and high importance values for *B. nigra* including edaphic factors within these southeastern Ohio communities, 2) determine the effects of soil pH and other edaphic factors on tree species diversity and evenness, and 3) determine what effects acid mine drainage has had on succession of arboreal species within river bottom communities in southeastern Ohio.

METHODS AND MATERIALS

During the spring and summer of 1970 and 1971, 50 communities of *Betula nigra* were investigated in southeastern Ohio. Quantitative field data for *B.nigra* and other arboreal species were collected in the 50 communities using the quarter method (Cottam and Curtis 1956). Twenty-five points were established in each community with distance and dbh (diameter at breast height, 1.3 m) recorded for 100 trees. The points were approximately 20 m apart and located along the course of a stream. Trees having stem dbh of 2.54 cm or greater were measured at each point. Relative frequency, relative density, relative dominance, and importance values were calculated using techniques described by Phillips (1959) for all arboreal species in each community. Communities were designated group I if importance values for *B.nigra* exceeded 200. Group II communities had importance values for *B. nigra* that were greater than 100 but less than 200, and group III communities had importance values for *B. nigra* that were less than 100. Quantitative data for each of the 50 communities and their locations were described by Cribben and Ungar (1974).

Tree species diversity was calculated for each river bottom community within groups I, II, and III using the importance value for each arboreal species. Tree species diversity (H') and equitability (J') were determined respectively by formulas of Shannon and Weaver (1949) and Pielou (1969) for each of the 50 communities and were summarized in groups I, II, and III.

Three soil samples were collected at depths of 0-10 cm at each of the 50 river bottom communities, and if *Betula nigra* seedlings occurred at the site, the soil samples were taken near the seedlings. The samples were stored in plastic containers, taken to the laboratory, and air-dried for two weeks. Soil samples were than sifted through a 2 mm sieve and stored in plastic containers.

Soils were analyzed for pH and exchangeable calcium, magnesium, potassium, hydrogen, and aluminum concentrations. The pH was measured with a Beckman Expandomatic pH meter using a 1:1 soil-water mixture. These values varied only ± 0.2 from the field moisture measurements of pH. Exchangeable potassium, calcium, and magnesium were extracted with 1N ammonium acetate and exchangeable aluminum and hydrogen were extracted with 1N potassium chloride using methods of Black (1965). Exchangeable aluminum and hydrogen were determined by titrating with 0.1N sodium hydroxide and 0.1N hydrochloric acid, and exchangeable calcium and magnesium were determined using an EDTA titration method (Black 1965). Exchangeable potassium was determined using a Coleman Flame Photometer as described by Black (1965). All edaphic factors were summarized for communities belonging to groups I, II, and III.

T-values were obtained using the computer program T-Nu at the Ohio University Computer Center, Athens, Ohio. Correlation coefficients were determined using the computer program Correl at the Montclair State College Computer Center, Upper Montclair, New Jersey. This program produced a matrix with nine variables which included species number, diversity, equitability, pH, and exchangeable concentrations of aluminum, calcium, magnesium, hydrogen, and potassium. All programs were run on an IBM system/360 model 44 computer.

RESULTS

River bottom communities belonging to group I were especially evident along the Moxahala and Raccoon Creeks, streams which have been subjected to heavy acid mine drainage from areas that have been extensively strip mined. The 15 group I communities contained a total of 25 arboreal species and averaged six arboreal species per community. Group I communities were dominated by *Betula nigra* (Table I). *Betula nigra* and *Ulmus americana* were the only species with importance values greater than 10.0 (Table I). Thirteen species had importance values less than 2.0 (Table I). A median soil pH of 3.8 and relatively high concentrations of exchangeable aluminum and hydrogen resulted in extremely acid soils within the group I communities (Table II). These soils also contained relatively low concentrations of exchangeable calcium and magnesium (Table II). The stage of succession represented by the Group I communities was characterized by relatively low diversity, low species equitability and low productivity (Table II).

The majority of the group II communities were located on the Raccoon Creek. The 22 group II communities contained a total of 29 arboreal species and averaged eight arboreal species per community. *Betula nigra* was the dominant species in the group II communities (Table III). *Betula nigra, Acer saccharinum, Ulmus americana, Platanus occidentalis, Carpinus caroliniana,* and *Salix nigra* had importance values greater than 10.0 (Table III). With the exception of *B. nigra,* importance values of these species were greater than in the group I communities. Soil pH was higher in the group II communities with lower concentrations of exchangeable hydrogen when compared to the group I communities (Table II). However, concentrations of exchangeable aluminum, calcium, magnesium, and potassium were similar to concentrations in the group I communities (Table II). Soil factors within these group II

TABLE I

Summary of Relative Frequency (RF), Relative Density (RD), Relative Dominance (RDo), and Importance Value (IV) for Arboreal Species Greater than 2.54 cm for 15 Ohio Group I Communities.

SPECIES	RF %	RD %	RDo %	IV
Betula nigra L.	64.6	83.2	85.7	233.5
Ulmus americana L.	5.7	2.7	2.5	10.9
Alnus serrulata (Ait) Willd.	5.7	3.1	0.2	9.0
Acer saccharinum L.	3.6	1.9	2.1	7.6
Platanus occidentalis L.	1.7	0.7	3.8	6.2
Acer rubrum L.	2.2	0.9	0.9	4.0
Prunus serotina Ehrh.	2.2	1.1	0.5	3.8
Acer saccharum Marsh.	2.2	1.0	0.4	3.6
Quercus borealis Michx.	1.9	0.8	0.6	3.3
Salix nigra Marsh.	1.4	0.5	1.1	3.0
Acer negundo L.	1.5	0.7	0.6	2.8
Fraxinus americana L.	1.4	0.6	0.4	2.4
Carya cordiformis (Wang) K. Koch	0.9	0.5	0.3	1.7
Carpinus caroliniana Walt.	1.0	0.5	0.1	1.6
Asimina triloba (L.) Dunal	1.0	0.5	0.0	1.5
Populus grandidentata Michx.	0.7	0.4	0.0	1.1
Quercus imbricaria Michx.	0.3	0.1	0.4	0.8
Populus deltoides Marsh.	0.2	0.1	0.3	0.6
Liriodendron tulipifera L.	0.3	0.1	0.1	0.5
Aesculus octandra Marsh.	0.3	0.1	0.0	0.4
Pyrus malus L.	0.3	0.1	0.0	0.4
Cornus florida L.	0.3	0.1	0.0	0.4
Carya ovata (Mill.) K. Koch	0.2	0.1	0.0	0.3
Morus rubra L.	0.2	0.1	0.0	0.3
Nyssa sylvatica Marsh.	0.2	0.1	0.0	0.3
TOTAL	100.0	100.0	100.0	300.0

Table II. Summary of species diversity (H'), evenness (J'), and productivity (basal area, m^2/hectare) including various edaphic factors for Ohio group I, II, and III communities. Mean cation concentrations were expressed in milliequivalents/100 g of soil.

GROUP	H'	J'	BA	pH	Al	Ca	Mg	K	H
I	.3413	.4482	42.4	3.8	2.86	0.62	0.20	0.20	1.33
II	.5882[a]	.6741[a]	80.1[a]	4.7	2.17	0.60	0.17	0.19	0.77[a]
III	.8174[ab]	.7845[ab]	66.5[ab]	5.3	0.78[ab]	1.36[ab]	0.37[ab]	0.25	0.40[ab]

[a]Diversity-evenness values and exchangeable cations were significantly different from group I at the 0.05 level.

[b]Diversity-evenness values and exchangeable cations were significantly different from group II at the 0.05 level.

communities were extreme and comparable to soil factors within the group I communities. Group II communities had significantly greater diversity, species equitability and productivity than group I communities (Table II). The stage of succession represented by the group II communities had a biomass approximately twice that of the group I communities.

The group III communities were located along Wolf, Jonathan, Symmes, Stoney, Big Beaver, South Fork, Rush, and Salt Creeks. These streams had not been subjected to acid mine drainage to the same extent as the Raccoon and Moxahala Creeks. The 13 group III communities contained a total of 39 arboreal species and averaged 11 arboreal species per community. *Acer saccharinum*, was the dominant species in group III communities (Table IV). *Acer saccharinum, Betula nigra, Acer negundo, Platanus occidentalis*, and *Ulmus americana* had importance values greater than 27.0 (Table IV). Soils within the group III communities were less acidic and contained significantly lower concentrations of exchangeable hydrogen and aluminum than the soils within groups I and II communities (Table II). Concentrations of exchangeable calcium and magnesium were significantly higher in the group III communities (Table II). These communities had significantly higher diversity and species equitability than group I and II communities (Table II). The stage of succession represented by the group III communities was characterized by a productivity lower than in the group II communities but higher than in the group I communities (Table II). Certain other species, relatively unimportant in the group I and II communities, were more important in group III (Table IV). These included *Aesculus octandra, Prunus serotina, Liriodendron tulipifera, Ulmus rubra, Fagus grandifolia*, and *Acer saccharum*.

Statistical analysis indicated a direct relationship between diversity (H') and number of species per community ($r = 0.84$; $p = 0.05$), species equitability ($r = 0.86$; $p = 0.05$), exchangeable calcium ($r = 0.36$; $p = 0.05$), exchangeable magnesium ($r = 0.43$; $p = 0.05$), and soil pH ($r = 0.47$; $p = 0.05$). There was an inverse relationship between diversity and exchangeable aluminum ($r = -0.43$; $p = 0.05$) and exchangeable hydrogen ($r = -0.61$; $p = 0.05$).

TABLE III.

Summary of Relative Frequency (RF), Relative Density (RD), Relative Dominance (RDo), and Importance Values (IV) for Arboreal Species Greater than 2.54 cm for 22 Ohio Group II Communities.

SPECIES	RF %	RD %	RDo %	IV
Betula nigra L.	41.5	52.3	58.9	152.7
Acer saccharinum L.	14.8	15.2	24.4	54.4
Ulmus americana L.	8.1	6.8	4.4	19.3
Platanus occidentalis L.	5.4	3.5	5.7	14.6
Carpinus caroliniana Walt.	7.6	5.9	0.8	14.3
Salix nigra Marsh.	5.0	4.2	1.7	10.9
Alnus serrulata (Ait.) Willd	3.7	2.6	0.1	6.4
Asimina triloba (L.) Dunal	2.3	2.4	0.2	4.9
Acer negundo L.	1.9	1.6	0.2	3.7
Quercus borealis Michx.	1.9	1.1	0.7	3.7
Liriodendron tulipifera L.	1.0	0.6	1.0	2.6
Acer saccharum L.	1.1	0.8	0.6	2.5
Prunus serotina Ehrh.	1.2	0.7	0.2	2.1
Fraxinus americana L.	1.0	0.6	0.5	2.1
Sassafras albidum (Nutt.) Nees	0.8	0.5	0.1	1.4
Carya glabra (Mill.) Sweet	0.4	0.3	0.0	0.8
Fagus grandifolia Ehrh.	0.2	0.1	0.3	0.6
Staphylea trifolia L.	0.3	0.3	0.0	0.6
Carva cordiformis (Wang) K. Koch	0.3	0.2	0.0	0.5
Fraxinus pennsylvanica Marsh.	0.3	0.1	0.0	0.4
Aesculus octandra Marsh.	0.2	0.1	0.0	0.3
Cornus amomum Mill.	0.2	0.1	0.0	0.3
Robinia pseudo-acacia L.	0.1	0.0	0.1	0.2
Juglans nigra L.	0.1	0.0	0.0	0.1
Acer rubrum L.	0.1	0.0	0.0	0.1
Celtis occidentalis L.	0.1	0.0	0.0	0.1
Cornus florida L.	0.1	0.0	0.0	0.1
Morus rubra L.	0.1	0.0	0.0	0.1
Quercus alba L.	0.1	0.0	0.0	0.1
Total	100.0	100.0	100.0	300.0

TABLE IV

Summary of Relative Frequency (RF), Relative Density (RD), Relative Dominance (RDo), and Importance Value (IV) for Arboreal Species Greater than 2.54 cm for 13 Ohio Group III Communities.

SPECIES	RF %	RD %	RDo %	IV
Acer saccharinum L.	16.4	27.3	20.3	64.0
Betula nigra L.	14.1	19.3	14.1	47.5
Acer negundo L.	14.6	7.9	18.1	40.6
Platanus occidentalis L.	8.4	17.7	7.2	33.3
Ulmus americana L.	12.3	5.0	10.5	27.8
Salix nigra Marsh.	3.1	2.6	2.3	8.0
Aesculus octandra Marsh.	2.1	1.8	1.9	5.8
Ulmus rubra Muhl.	2.1	0.7	2.9	5.7
Carpinus caroliniana Walt.	2.7	0.4	2.3	5.4
Prunus serotina Ehrh.	2.1	1.4	1.6	5.1
Alnus serrulata (Ait.) Willd.	2.3	0.1	2.5	4.9
Acer saccharum Marsh.	1.8	1.4	1.6	4.8
Fagus grandifolia Ehrh.	0.7	3.6	0.5	4.8
Liriodendron tulipifera L.	1.6	1.6	1.0	4.2
Fraxinus pennsylvanica Marsh.	1.8	0.7	1.2	3.7
Gleditsia triacanthos L.	1.6	0.9	1.2	3.7
Fraxinus americana L.	1.6	0.4	1.5	3.5
Acer rubrum L.	1.4	0.7	1.1	3.2
Quercus alba L.	0.1	3.0	0.1	3.2
Rhus typhina L.	1.4	0.1	1.6	3.1
Asimina triloba (L.) Dunal	1.2	0.1	1.3	2.6
Juglans nigra L.	1.2	0.5	0.8	2.5
Robinia pseudo-acacia L.	0.8	0.7	0.7	2.2
Rhus glabra L.	0.8	0.0	1.0	1.8
Populus deltoides Marsh.	0.3	1.1	0.1	1.5
Salix interior Rowlee	0.4	0.5	0.3	1.2
Ailanthus altissima (Mill.) Swing.	0.4	0.3	0.4	1.1
Quercus borealis Michx.	0.5	0.2	0.3	1.0
Cercis canadensis L.	0.4	0.0	0.2	0.6
Sassafras albidum (Nutt.) Nees	0.4	0.0	0.2	0.6
Viburnum prunifolium L.	0.4	0.0	0.2	0.6
Celtis occidentalis L.	0.3	0.0	0.2	0.5
Staphylea trifolia L.	0.1	0.0	0.2	0.3
Cornus amomum Mill.	0.1	0.0	0.1	0.2
Cornus florida L.	0.1	0.0	0.1	0.2
Crataegus spp.	0.1	0.0	0.1	0.2
Maclura pomifera (Raf.) Schneid.	0.1	0.0	0.1	0.2
Morus rubra L.	0.1	0.0	0.1	0.2
Sambucus canadensis L.	0.1	0.0	0.1	0.2
Total	100.0	100.0	100.0	300.0

A direct relationship existed between species equitability (J') and number of species per community ($r = 0.45$; $p = 0.05$), exchangeable calcium ($r = 0.39$; $p = 0.05$), exchangeable magnesium ($r = 0.36$; $p = 0.05$), and soil pH ($r = 0.57$; $p = 0.05$). There was an inverse relationship between species equitability and exchangeable aluminum ($r = -0.48$; $p = 0.05$) and exchangeable hydrogen ($r = -0.68$; $p = 0.05$).

Biomass as measured by basal area (m^2 per hectare) was directly related to species equitability ($r = 0.29$; $p = 0.05$), but not to diversity or any edaphic factor.

DISCUSSION

River bottom communities along the Moxahala and Raccoon Creeks in southeastern Ohio were very low in diversity and species equitability compared with river bottom communities along streams less affected by acid mine drainage. Productivity was lowest in those communities in which the median soil pH was 3.8, somewhat higher in those communities in which the median soil pH was 5.3, but highest in those communities in which the median soil pH was 4.7. This indicated that the most diverse communities did not have the greatest productivity, an observation which has been noted by Whittaker (1965) and McNaughton (1970).

Betula nigra was the dominant river bottom species along streams which carried acid mine drainage, indicating the high degree of tolerance of this species to low soil pH and accompanying extreme edaphic conditions. *Acer saccharinum, Ulmus americana, Platanus occidentalis,* and *Carpinus caroliniana* were also important along these streams and were tolerant of these edaphic conditions. *Acer negundo, Aesculus octandra, Ulmus rubra, Prunus serotina, Liriodendron tulipifera, Acer saccharum,* and *Fagus grandifolia* had low importance values or were absent along streams which were heavily polluted with acid mine water, suggesting a lower degree of tolerance of these species.

Soils collected from communities located along the Moxahala and Raccoon Creeks had pH values below 5.0, which is characteristic of acid mine affected soils. Similar pH values for acidic soils have been reported by Struthers (1964) and Blevins et al. (1970). In contrast the median pH value of 5.3 obtained for soils collected from communities along other streams was indicative of more moderate edaphic conditions within areas less affected by acid mine drainage.

Struthers (1964) and Blevins et al. (1970) demonstrated that low soil pH was commonly associated with relatively high concentrations of exchangeable hydrogen and aluminum. Our study supported their findings, in that statistical analysis indicated an inverse relationship did exist between soil pH and concentrations of these exchangeable cations. The soils along acid mine affected streams had concentrations of exchangeable hydrogen and aluminum as high as 1.33 mew/100 g of soil and 2.86 meq/100 g of soil respectively. By contrast the soils along streams not heavily polluted by acid mine drainage had concentrations of 0.40 meq/100 g of soil and 0.78 meq/100 g of soil respectively. Foy (1974a) noted that concentrations of exchangeable aluminum in the soil generally were higher at low pH's, particularly at pH's below 5.0.

Exchangeable calcium and magnesium concentrations were relatively low in the soils most affected by acid mine drainage, but were significantly higher in the soils less affected by acid mine drainage. Low concentrations of these two exchangeable cations is characteristic of acid soils (Blevins et al. 1970).

The toxic effects of aluminum on plant growth have long been known (Hartwell and Pember 1918, Magistrad 1925). Evidence that aluminum is a major growth limiting factor in acid soils was provided by Rorison (1960) who showed that while *Scabiosa columbaria* died in both soil and nutrient solutions with a pH of 4.8 containing aluminum, the species survived in a nutrient solution with a pH of 4.8 containing no aluminum. Clymo (1962) isolated aluminum as a toxic edaphic factor in the growth of *Carex lepidocarpa*. A major factor in the success of a species in acid soil is therefore its degree of aluminum tolerance.

Species differ widely in their tolerance to soil aluminum, and such differences may affect their distribution. Rorison (1969) noted that *Deschampsia flexuosa*, which is extremely tolerant of aluminum, occurred almost exclusively on acid soils, probably because the species grows too slowly to compete with other species on neutral soils. However, the species can tolerate high aluminum concentrations which would eliminate other species from acid soils. The importance of *Betula nigra* along acid mine affected streams in southeastern Ohio may be related to the tolerance of this species to aluminum.

Oosting (1942) reported that *Betula nigra* was a good indicator of secondary succession when occurring in pure stands along streams. He also reported that 14-year old *B. nigra* communities in North Carolina had well-developed overstory trees. The overstory frequencies in these communities were *Betula nigra* (100%), *Platanus occidentalis* (20%), *Salix nigra* (60%), *Pinus taeda* (30%), while understory frequencies were *B. nigra* (100%), *Platanus occidentalis* (50%), *Liquidambar styraciflua* (60%), *Salix nigra* (10%), and *Liriodendron tulipifera* (30%).

In comparison with 14-year old *Betula nigra* communities in North Carolina, we found that a 14-year old site in southeastern Ohio which had been affected by acid mine drainage had overstory frequencies of *B. nigra* (100%), *Fraxinus americana* (16%), *Ulmus americana* (8%), *Alnus serrulata* (12%), *Acer saccharum* (12%), and *Acer saccharinum* (4%). There were few understory species in several 14-year old *B. nigra* communities in Ohio (Cribben, unpublished data). Thus the stage of succession in certain acid mine affected areas in southeastern Ohio differs markedly from the stage of succession described by Oosting (1942).

Margalef (1963), Odum (1969), Whittaker (1970), and Reiners et al. (1971) have indicated that there was a general increase in plant species diversity with succession, at least during the early stages of succession. Some acid mine areas in southeastern Ohio might also increase in species diversity during succession if soil conditions were improved along streams that carry large amounts of acid mine drainage.

High acidity and high aluminum concentrations in acid mine affected soils have provided strong selection pressures in certain southeastern Ohio river bottom communities. These selection pressures might exclude less tolerant species because of the direct and/or synergistic effects of the extreme edaphic conditions existing in these heavily polluted areas. Succession in some Ohio acid mine areas dominated by *Betula nigra* might have been limited to this early stage by these edaphic conditions.

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