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Composition and Structure of Planted and Native *Pinus echinata* Mill. Stands in Southwestern Illinois

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ABSTRACT

The woody and ground layer vegetation was sampled in 40 0.04 ha permanent plots in pine plantations (n = 20) and native pine stands (n = 20) in southwestern Illinois. Plantations had significantly higher tree basal area and density, sapling density, and dead standing basal area and density than native stands. Native stands had significantly higher seedling density. There was no difference in ground layer cover or species richness between the plantations and native stands. Plantations were characterized by an overstory of *Pinus echinata*, sapling and seedling strata of mesophytic, shade-tolerant woody species, and ground layer dominated by *Toxicodendron radicans*. Native stands were characterized by a mixed pine-xeric oak overstory, sapling stratum of *Quercus velutina* and *Q. marilandica*, and a seedling and ground layer strata of *Vaccinium pallidum*. Dominance-diversity curves show that few species dominate the vegetation in each stand and that most species found were rare and had low abundances. Diversity indices indicate that pine plantations are less diverse than native stands, though they may contain higher numbers of species. Both plantations and native stands are being succeeded by broadleaf, deciduous species and intensive management, from either canopy thinning or prescribed fire will probably be necessary for these pine-dominated stands to be maintained in Illinois.

INTRODUCTION

Shortleaf pine (*Pinus echinata* Mill.) was planted in southern Illinois in response to large scale land abandonment. Poor farming practices which led to topsoil erosion was the primary cause for abandonment (Chapman 1937). Southern Illinois is the northwestern limit in the central hardwood region for *P. echinata*. Pine Hills in Union County and Piney Creek in Randolph County represent the only two areas with naturally occurring stands in Illinois before European settlement (Weber 1959, Schwegman et al. 1973, Mohlenbrock 1986, Herkert 1991).

Extensive work was done on throughfall and stemflow of precipitation, glaze and ice damage, and productivity under different spacing regimes in *Pinus echinata* plantations in southern Illinois (Boggess and McMillan 1954, Boggess 1956, Boggess and Gilmore 1963). Boggess and Gilmore (1963) found that basal area of pine increased in response to thinning. Shortleaf pine responded favorably to being planted even though southern Illinois is its northern range limit. Gilmore and Gregory (1974) found that Illinois short-leaf pine plantations growth rate falls below that expected of the species within its range as the stands grow older. Planted stands have also been found to have increased mortality and declining basal area growth according to a study on a twenty-nine year-old stand (Burkhart and Gilmore 1967). Arnold and Boggess (1971) found that hardwood seedling density increased with thinning treatments.

Pine Hills Research Natural Area (RNA) has had extensive floristic surveys performed by Mohlenbrock and Voigt (1965) and Poellot (1968). Native pine stands are described as having *Pinus echinata* and *Carya texana* as dominant canopy species (Mohlenbrock and Voigt 1965). *Quercus* and *Carya* spp. are listed as complementary canopy species. The sapling layer has been described as containing *Vaccinium arboreum* and *Vaccinium pallidum (*Mohlenbrock and Voigt 1965). Ashby and Kelting (1963) included pine stands in their black oak community, noting that they occur on steep south- and west-facing upper slopes. They included *Rhododendron prinophyllum* as a major constituent of the sapling layer. Poellot (1968) contradicted the findings of Ashby and Kelting (1963) by stating that well-developed pine stands had a depauperate sapling layer.

The objectives of this study were to determine differences in the structure, composition, and diversity of woody and ground layer vegetation between native and planted *Pinus echinata* stands in southwestern Illinois.

METHODS

Study Areas

Pine Hills RNA is located in Union County in southern Illinois. The area is located in the southern Ozark Hills physiographic division (Schwegman et al. 1973). Native *Pinus echinata* stands are found from the midslope to near the ridge tops, becoming more abundant near the top of the slope (Voigt and Mohlenbrock 1964). Planted pine stands were located within the same Ozark Hills region in Union and Alexander counties. The region is characterized by steep ravines with white oak (*Quercus alba*) and black oak (*Quercus velutina*) being codominants in the canopy. Dissected and exposed cherty and siliceous limestones of Devonian age occur on upland areas, while thick loess tops the ridge crests and covers some of the cherty, gravelly slopes (Schwegman et al. 1973).

Soils in Pine Hills RNA are composed of the Goss Alford complex. Goss soils are well drained soils being moderately permeable, and are weathered from cherty limestone. Goss series soils are mesic typic paleudalfs (Miles et al. 1979). Alford soils are well drained, moderately permeable soil formed in loess. They are typic hapludalfs (Miles et al. 1979).

Planted stands were composed of a variety of soils including those in the Goss Alford complex. Also included were Haymond silt loam soils which are medium acid, moderately well drained soils. They are moderately permeable, have a moderately high available moisture capacity, and are high in natural fertility (Parks and Fehrenbacher 1968). Muren soils were found in several stands on hillsides and ridges. These soils are found to be moderately permeable, medium in natural fertility, medium to strongly acid, and have high available moisture capacity (Parks and Fehrenbacher 1968).

Southern Illinois has a continental climate featuring hot summers and cold winters (Voigt and Mohlenbrock 1964). Precipitation averages approximately 116.8 cm and ranges from 81.3 to 177.0 cm. There are approximately 200 frost-free days usually ranging between 15 April to 15 October (Miles et al. 1979).

Data Collection

Twenty permanent 0.04 ha plots were sampled in ten native pine stands within Pine Hills RNA., and twenty permanent 0.04 ha plots were sampled in ten planted pine stands within the Ozark Hills region. Plot centers were randomly placed and two plots were sampled within each stand. Pine plantations were located by use of U.S. Forest Service compartment records at the Shawnee National Forest headquarters in Harrisburg, Illinois. Global Positioning System locations for all plots will be archived there in a final report.

All trees ≥ 6.5 cm diameter at breast height (dbh) were measured to the nearest 0.1 cm in each plot. Saplings < 6.5 cm dbh but ≥ 2.5 cm diameter at ground level (dgl) were measured in a 0.004 ha nested subplot. Seedlings < 2.5 cm dgl were counted in a 0.004 ha nested subplot. Ground layer species ≤ 1.5 meters tall were sampled within the 0.04 ha plot and were assigned a cover value according to modified Daubenmire cover classes (Daubenmire 1959, Abrams and Hulbert 1987): 1 = 0-1%, 2 = 2-5%, 3 = 6-25%, 4 = 26-50%, 5 = 51-75%, 6 = 76-95%, 7 = 96-100%. Midpoints of these cover classes were used in data analysis. Overstory canopy cover was measured using a spherical densiometer (Lemmon 1956). The densiometer was leveled at plot center, and the reflection of foliage was tallied in the four cardinal directions with the use of a mask. An average value was then derived for total canopy coverage.

Data Analysis

Tree basal area and density were averaged for species and plot using SAS (SAS 1985). Basal area and density were relativized and summed to determine an importance value (IV_{200}) for each tree species. Sapling and seedling density were averaged by species and plot. Ground layer cover was averaged by species and plot, while frequency was tallied for each species by plot. One tailed t-tests were performed to determine significant ($p \leq 0.05$) differences in woody and ground layer vegetation between native and planted pine stands. A Behrens-Fischer correction factor was used to decrease the inflated type I error rate associated with multiple t-tests (Zar 1999). Dominance-diversity curves were plotted to examine species abundance patterns within each stratum in each stand using Statmost for Windows. Diversity indices were calculated for woody (using IV_{200} for trees and density for saplings and seedlings) and ground layer (using percent cover) vegetation to quantify differences in species abundance and response between planted and native pine stands. The Shannon-Weiner diversity index was calculated using the formula $H' = -\sum p_i * \text{In} p_i$, where p_i is the decimal fraction of the species response measure (IV_{200}, density, or cover) (Peet 1974). Equitability of species response was measured using Pielou's index $J' = H'/S'$, where S = the number of species (Pielou 1966). Hill's family of diversity indices were also calculated and included N_0 (number of species, $N_0 = S$), N_1 (number of abundant species: $N_1 = e^{H'}$, and N_2 (number of very abundant species, $N_2 = 1/\lambda$, where λ is Simpson's diversity index) (Ludwig and Reynolds 1988).

RESULTS

Pine Plantations

Tree basal area and density were 38.15 (± 5.73) m^2/ha and 1061.3 (± 192.9) stems/ha for pine plantations, respectively (Table 1). *Pinus echinata* had the highest basal area (32.31 ± 6.2 m^2/ha), density (605.0 ± 212.4 stems/ha), and importance values (141.7 out of 200). The most important associated species were *Liriodendron tulipifera*, *Fraxinus americana*, *Ulmus americana*, and *Acer saccharum* (Table 1). A total of 27 woody species were identified in the tree stratum. Sapling density was 1437.5 (± 2145.8) stems/ha and was dominated by *Liriodendron* (787.5 ± 2104.6 stems/ha), *Fagus* (337.5 ± 731.2 stems/ha), and *Ulmus* (237.5 ± 553.0 stems/ha). There were only 8 species identified in the sapling stratum (Table 2). Seedling density was 1437.5 (± 1568.3) stems/ha and was dominated by *Sassafras albidum* (575.0 ± 1517.7 stems/ha), *Ulmus* (212.5 ± 563.6 stems/ha), *Liriodendron* (175.0 ± 526.3 stems/ha), and *Fagus* (162.5 ± 317.0 stems/ha). There were 13 woody species identified in the seedling stratum (Table 2). Average canopy cover was 92.5% ± 3.4%.

Ground layer cover was 28.8 (± 24.2) % and the dominant ground layer species were *Toxicodendron radicans* (18.8 ± 25.2%), *Parthenocissus quinquefolia* (2.4 ± 3.3%), *Polystichum acrostichoides* (1.7 ± 3.4%), and *Lonicera japonica* (1.2 ± 3.5%). A total of 44 species were identified in the ground layer and species richness per plot was 9.3 ± 4.9 (Table 3).

Dead standing basal area and density were 1.25 (± 1.13) m^2/ha and 63.8 (± 49.7) stems/ha, respectively (Table 4). *Pinus echinata* had the highest dead standing basal area (1.13 ± 1.13 m^2/ha) and density (48.8 ± 46.9 stems/ha) values.

Native Pine Stands

Tree basal area and density were 23.67 (± 4.71) m^2/ha and 616.3 (± 115.4) stems/ha in native stands, respectively (Table 1). *Pinus echinata* had the highest basal area (13.80 ± 4.6 m^2/ha), density (255.00 ± 82.96 stems/ha), and importance values (99.7). The most important associated species were *Quercus velutina, Q. marilandica*, and *Q. alba* (Table 1). Native pine stands had significantly lower basal area ($t = -8.74$, $df = 38$, $p < 0.0001$) and density ($t = -8.86$, $df = 38$, $p < 0.0001$) values than plantations. A total of 15 woody species were identified in the tree stratum (Table 1). Sapling density was 300.0 (± 251.3) stems/ha and was dominated by *Quercus velutina* (112.5 ± 221.77stems/ha) and *Q. marilandica* (87.5 ± 233.32 stems/ha). There were only 7 species identified in the sapling stratum (Table 2). Native stands had significantly lower sapling density ($t = 2.35$, $df = 38$, $p < 0.01$) than plantations. Seedling density was 7300 (± 8036.34) stems/ha and was dominated by *Vaccinium pallidum* (4262.5 ± 8504.8 stems/ha), *Pinus echinata* (1637.5 ± 2615.08 stems/ha), *Quercus velutina* (500.0 ± 1135.5 stems/ha), and *Rhododendron prinophyllum* (400.0 ± 1788.9 stems/ha). There were 11 woody species identified in the seedling stratum (Table 2). Native stands had significantly higher seedling density ($t = -3.20$, $df = 38$, $p < 0.01$) than plantations. The average canopy cover was 79.8% ± 4.6%.

Ground layer cover was 25.4 (± 17.8) % and the dominant ground layer species were *Vaccinium pallidum* (15.1 ± 15.8%), *Rhododendron prinophyllum* (1.8 ± 4.7%), and

Danthonia spicata (1.6 ± 3.4%). A total of 40 species were identified in the ground layer and species richness per plot was 9.3 ± 4.5 (Table 3). There was no significant difference in species richness ($t = 1.20$, $df = 38$, $p = 0.50$) and percent cover ($t = 0.79$, $df = 38$, $p = 0.21$) between native stands and plantations.

Dead standing basal area and density were 0.53 ± (0.71) m^2/ha and 20.0 ± (15.4) stems/ha, respectively (Table 4). *Pinus echinata* had the highest basal area (0.28 ± 0.67 m^2/ha) and density (48.8 ± 46.9 stems/ha) values. Native stands had significantly lower standing dead basal area ($t = 2.43$, $df = 38$, $p < 0.01$) and density ($t = 3.77$, $df = 38$, $p < 0.01$) than plantations.

Diversity Relationships

Dominance-diversity curves for woody and ground layer vegetation indicated that each stratum in both plantations and native stands were dominated by a few species, while most species in each stratum had low abundances (Figures 1and 2). *Pinus echinata* was the dominant tree in both stands. *Liriodendron tulipifera* was a subdominant tree in plantations, while *Quercus alba*, *Q. marilandica*, and *Q. velutina* were subdominant trees in native stands. *Liriodendron tulipifera*, *Fagus grandifolia*, and *Ulmus americana* dominated the sapling stratum in plantations, while *Quercus velutina* and *Q. marilandica* dominated native stands. *Sassafras albidum* dominated the seedling stratum in plantations, while *Vaccinium pallidum* and *P. echinata* dominated native stands. *Toxicodendron radicans* was the dominant ground layer species in plantations, and *V. pallidum* dominated native stands (Figure 2).

Plantations tended to have higher species richness (N_0), but lower values for diversity (H'), equitability (J'), abundant species (N_1), and very abundant species (N_2) than native pine stands. Exceptions were in the seedling stratum where plantations had higher diversity values and the sapling stratum where richness was the same for plantations and native stands (Table 5).

DISCUSSION

Woody Vegetation

Planted pine stands had significantly higher density due to planting to produce a cash crop. Greater tree basal area is thought to be attributed to less slope angle than found in native stands, and deeper loess-derived soils in the planted pines. Pines were the canopy dominant in planted stands (32.3 m^2/ha, 605.0 stems/ha), but were not represented in either the sapling or seedling strata. Shade-tolerant mesophytic species such as *Acer saccharum, Fagus grandifolia, Fraxinus americana, Liriodendron tulipifera,* and *Ulmus americana* were the dominants in the sapling and seedling layers of planted stands. These species have begun to replace *P. echinata* in the canopy and understory strata, which has been found in studies of similar even-aged plantations in Arkansas (Cain and Shelton 1994, 1995). The lack of smaller size classes for *P. echinata* indicate that this species will not be represented in the future overstory of these stands. Development of a hardwood understory in the absence of disturbance, in both plantations and natural stands, is well-documented (Blair and Brunett 1976, Cain and Shelton 1994, 1995, Shelton and Cain 1999).

Pine Hills RNA was found to have *Pinus echinata* as the dominant overstory species, while xeric oaks were co-dominants. The seedling layer was found to be dominated by *Vaccinium pallidum*, an ericaceous shrub, and *P. echinata*. In March 1992, a prescribed burn occurred at Pine Hills RNA in 18 of 20 stands sampled, which may account for the high seedling density of *V. pallidum* and *P. echinata*. However, recruitment of *P. echinata* into the larger size classes is not occurring as indicated by seedling density of 1637.5 stems /ha compared to the sapling density of 12.5 stems/ha. Arthur et al. (1998) found that on the Cumberland Plateau in Kentucky repeated cool ground fires would not accomplish maintenance of this species regardless of fire return interval due to lack of canopy removal. Arthur et al. (1998) recommended high intensity disturbances which would form large canopy gaps required by shade-intolerant southern pine species for regeneration. However, Arthur et al. (1998) found that *V. pallidum* responded favorably to single fires. Interspecific competition from the high density (4262.0 stems/ha) of *V. pallidum* is also believed to be a factor in the inability of pine seedlings to survive into the sapling class.

Pinus echinata is considered a seral species whose persistence in all but the poorest sites is dependant on high disturbance intensity (Daubenmire 1978, Smith and Linnartz 1980). Native pine stands in southern Illinois are remnant populations found only on very dry, steep slopes with gravelly soil. Several studies in the central hardwood region have concluded that intense disturbance will be required to maintain *P. echinata* as an overstory dominant (Schibig and Chester 1988, Fralish et al. 1993, Franklin et al. 1993). *Pinus echinata* was being replaced by xeric *Quercus* species at Land Between the Lakes in Kentucky and Tennessee and it was predicted that this dominance type will be lost from this region without major disturbances such as fire or logging (Fralish et al. 1993, Franklin et al. 1993). Pines were also found to be poorly represented in forests in east Texas and major catastrophic disturbances were thought to be important for maintaining pine-dominated forests in this region (Harcombe and Marks 1978, Glitzenstein et al. 1986). Cain and Shelton (1994) stated that without catastrophic disturbance, mixed hardwoods would replace pines as the dominant vegetation in pine-hardwood forests in southern Arkansas. Shelton and Cain (1999) found that two environmental requirements necessary for sustaining pine reproduction are that overstory basal areas should not exceed 17 m^2/ha and pine reproduction should not be overtopped by hardwoods. Lack of pine reproduction is thought to be due to shade-intolerance, competition from both the overstory and understory strata, and is considered to be a widespread phenomenon in southern pines (Blair and Brunett 1976, Cain and Shelton 1994, 1995, Shelton and Cain 1999).

Ground Layer

No significant differences were found between the planted and native pine stands in either ground layer species richness or percent cover. Pine Hills RNA was thought to have a low species richness and cover due to the poor site location of the pine stands. The cherty, gravelly soil was thought to have restricted growth to xeric species due to lower water holding capacity. Close (1996) found that herbaceous species richness followed a moisture gradient with higher species richness in mesic sites and lower species richness in xeric sites. High density of *Vaccinium pallidum* stems (15.1 % cover) was thought to be a limiting factor to herbaceous plants by outcompeting herbs for limited resources. Arthur et al. (1998) found an increase in both species richness in the herbaceous layer and stems of *Vaccinium pallidum* in pine stands which had been recently burned. It is thought by the authors that if Pine Hills RNA experienced a similar initial increase in species richness due to prescribed burning that it has returned to its original state prior to the burn. Cover values were thought to have increased for *V. pallidum* as a result of sprouting after the prescribed burn. Several other studies have also noted an increase in *V. pallidum* following fire (Reiners 1965, Matlack et al. 1993).

Ashby and Kelting (1963) found the dominant ground layer grasses in pine stands at Pine Hills to be *Andropogon* (*Schizachyrium*) *scoparium, A. gerardii* and *Sorghastrum nutans*. Their study noted that grass cover was less evident under ericaceous shrubs. These shade-intolerant, C_4 grasses were not observed in the native pine stands in the present study. It is believed that increased canopy coverage is responsible for the suppression of these prairie species.

Plantation species richness and cover were thought to have been reduced due to the presence of woody, shade-tolerant vines such as *Toxicodendron radicans*, *Parthenocissus quinquefolia*, and *Lonicera japonica*. These shade-tolerant species are thought to be thriving in the closed canopy of the planted stands. *Toxicodendron radicans* and *Parthenocissus quinquefolia* have been found to be the dominant ground layer species in dry to dry-mesic forests with closed canopies in southern Illinois (Grahame 1996, Shimp 1996, McCoy 1997).

Greater pine mortality in plantations in southern Illinois may be linked to past presence of *Heterobasidion* annosum (*Fomes annosus*), a fungus responsible for trunk and root rot (Gilmore and Gregory 1974). High stem density increases susceptibility to this disease due to increased stress from intraspecific competition. Gilmore and Gregory (1974) thought that this fungus was increasing in Illinois and would make silvicultural thinning of pine stands an undesirable management practice. Future study should examine the actual effect of this fungus on pine mortality in southern Illinois.

No significant difference was found in ground layer between planted and native pine stands in species richness or ground layer cover. Diversity indices show that plantations were less diverse than native stands although they may contain more species. Both stand types were thought to be succeeding to broadleaf deciduous species and intensive management would probably be necessary for the long term maintenance of these pine stands in Illinois.

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Table 1. Tree basal area (m^2/ha ± standard deviation), density (stems/ha ± standard deviation), and importance value (IV_{200}) in pine plantations and native pine stands in the Ozark Hills of southwestern Illinois.

Species	Pine Plantations (n = 20)			Native Pine Stands (n = 20)		
	Basal Area	Density	IV_{200}	Basal Area	Density	IV_{200}
Acer saccharum	0.59 ± 1.25	51.3 ± 110.2	6.4	0	0	0
Carya glabra	0	0	0	0.11 ± 0.15	13.8 ± 19.0	2.7
Carya texana	0	0	0	0.14 ± 0.37	6.3 ± 16.0	1.6
Cornus florida	0.31 ± 0.57	38.8 ± 60.1	4.5	0.06 ± 0.14	6.3 ± 16.0	1.3
Diospyros virginiana	0.16 ± 3.74	7.5 ± 16.4	1.1	0	0	0
Fagus grandifolia	0.21 ± 0.48	27.5 ± 59.6	3.1	0.03 ± 0.11	1.3 ± 5.6	0.3
Fraxinus americana	0.86 ± 2.27	47.5 ± 104.8	6.7	0	0	0
Liquidambar styraciflua	0.36 ± 0.56	36.3 ± 55.3	4.4	0	0	0
Liriodendron tulipifera	2.05 ± 2.15	112.5 ± 122.1	15.7	0.03 ± 0.14	1.3 ± 5.6	0.3
Nyssa sylvatica	0	0	0	0.19 ± 0.58	15.0 ± 50.3	3.2
Pinus echinata	32.31 ± 6.2	605.0 ± 212.4	141.7	13.80 ± 4.64	255.0 ± 83.0	99.7
Prunus serotina	0.10 ± 0.27	7.5 ± 20.0	1.0	0	0	0
Quercus alba	0.01 ± 0.07	1.3 ± 5.6	0.2	1.21 ± 2.28	51.3 ± 53.5	13.4
Quercus marilandica	0	0	0	1.94 ± 1.77	95.0 ± 86.8	23.6
Quercus rubra	0.01 ± 0.05	8.8 ± 24.7	0.9	0.79 ± 2.15	21.3 ± 38.3	6.8
Quercus velutina	0.02 ± 0.11	1.3 ± 5.6	0.2	5.28 ± 3.95	140.0 ± 105.6	45.0
Sassafras albidum	0.29 ± 0.58	32.5 ± 71.7	3.8	0.01 ± 0.04	1.3 ± 5.6	0.3
Ulmus americana	0.48 ± 0.89	56.3 ± 75.6	6.6	0	0	0
Minor Species[1]	0.39 ± 1.34	27.2 ± 104.0	4.0	0.07 ± 0.27	8.4 ± 39.2	1.8
Totals	38.15 ± 5.73	1061.3 ± 192.9	200.3	23.67 ± 4.71	616.3 ± 115.4	200.0

[1] Minor species include *Acer negundo*, *Acer rubrum*, *Carpinus caroliniana*, *Carya ovata*, *Carya* spp., *Cercis canadensis*, *Crataegus* sp., *Ostrya virginiana*, *Quercus shumardii*, *Quercus* sp., *Tilia americana*, and *Vitis* spp. in plantations and *Amelanchier arborea*, *Carya ovata*, and *Vaccinium arboreum* in native stands.

Table 2. Sapling and seedling density (stems/ha ± standard deviation) in pine plantations and native pine stands in the Ozark Hills of southwestern Illinois.

Species	Pine Plantations (n = 20)		Native Pine Stands (n = 20)	
	Sapling Density	Seedling Density	Sapling Density	Seedling Density
Acer saccharum	25.0 ± 77.0	75.0 ± 335.4	0	0
Amelanchier arborea	0	0	0	12.5 ± 55.9
Aralia spinosa	0	0	0	12.5 ± 55.9
Asimina triloba	0	37.5 ± 167.7	0	0
Carya glabra	0	0	25.0 ± 111.8	162.5± 619.2
Carya ovata	0	50.0 ± 223.6	0	0
Carya spp.	12.5 ± 55.9	50.0 ± 153.9	0	0
Carya texana	0	0	12.5 ± 55.9	87.5 ± 233.3
Cornus florida	12.5 ± 55.9	25.0 ± 77.0	0	0
Crataegus sp.	12.5 ± 55.9	0	0	0
Fagus grandifolia	337.5 ± 731.2	162.5 ± 317.0	0	0
Liquidambar styraciflua	0	37.5 ± 122.3	0	0
Liriodendron tulipifera	787.5 ± 2104.6	175.0 ± 526.3	0	0
Pinus echinata	0	0	12.5 ± 77.0	1637.5 ± 2615.1
Prunus americana	12.5 ± 55.9	0	0	0
Quercus alba	0	0	12.5 ± 55.9	0
Quercus marilandica	0	0	87.5 ± 233.3	0
Quercus rubra	0	12.5 ± 55.9	0	0
Quercus sp.	0	12.5 ± 55.9	0	0
Quercus velutina	0	0	112.5 ± 221.8	500.0 ± 1135.6
Rhododendron prinophyllum	0	0	0	400.0 ± 1788.9
Rhus copallina	0	0	0	25.0 ± 111.8
Sassafras albidum	0	575.0 ± 1517.7	0	87.5 ± 391.3
Tilia americana	0	12.5 ± 55.9	0	0
Ulmus americana	237.5 ± 553.0	212.5 ± 563.6	0	0
Vaccinium arboreum	0	0	25.0 ± 77.0	112.5 ± 503.1
Vaccinium pallidum	0	0	0	4262.5 ± 8504.8
Totals	1437.5 ± 2145.8	1437.5 ± 1568.3	300.0 ± 251.3	7300.0 ± 8036.3

Table 3. Frequency and percent cover (± standard deviation) of most important ground layer species in pine plantations and native pine stands in the Ozark Hills of southwestern Illinois.

Species	Pine Plantations (n = 20)		Native Pine Stands (n = 20)	
	Frequency	% Cover	Frequency	% Cover
Amelanchier arborea	0	0	4	0.9 ± 3.5
Antennaria plantaginifolia	0	0	7	0.2 ± 0.2
Asplenium platyneuron	14	0.4 ± 0.2	3	0.1 ± 0.3
Aureolaria flava	0	0	13	0.7 ± 1.0
Campsis radicans	7	0.3 ± 0.7	0	0
Cunila origanoides	0	0	9	0.4 ± 0.7
Danthonia spicata	0	0	18	1.6 ± 3.4
Diarrhena americana	6	0.3 ± 0.7	0	0
Helianthus divaricatus	1	<0.1± 0.2	5	1.3 ± 2.2
Hieracium gronovii	0	0	16	0.4 ± 0.3
Lespedeza hirta	0	0	6	0.2 ± 0.2
Lonicera japonica	4	1.2 ± 3.5	0	0
Parthenocissus quinquefolia	19	2.4 ± 3.3	8	0.2 ± 0.3
Phryma leptostachya	8	0.2 ± 0.3	0	0
Podophyllum peltatum	5	0.2 ± 0.2	0	0
Polystichum acrostichoides	16	1.7 ± 3.4	3	0.1 ± 0.2
Pycnanthemum incanum	0	0	6	0.2 ± 0.2
Rhododendron prinophyllum	0	0	8	1.8 ± 4.7
Rhus copallina	0	0	4	0.2 ± 0.7
Rubus allegheniensis	4	1.0 ± 3.5	0	0
Sanicula canadensis	14	0.4 ± 0.3	0	0
Smilax glauca	11	0.5 ± 0.9	1	0
Solidago ulmifolia	0	0	7	0.2 ± 0.2
Tephrosia virginiana	0	0	6	0.2 ± 0.2
Toxicodendron radicans	18	18.8 ± 25.2	4	0.1 ± 0.2
Vaccinium pallidum	0	0	17	15.1 ± 15.8
Vitis spp.	2	0.1 ± 0.2	7	0.2 ± 0.2
Minor species[1]		1.3		1.3
Totals		28.8 ± 24.2		25.4 ± 17.8

[1]Entire data set for ground layer available from authors upon request.

Table 4. Basal area (m^2/ha ± standard deviation) and density (stems/ha ± standard deviation) of standing dead trees (≥ 6.5 cm dbh) in pine plantations and native pine stands in the Ozark Hills of southwestern Illinois.

Species	Pine Plantations (n = 20)		Native Pine Stands (n = 20)	
	Basal Area	Density	Basal Area	Density
Cercis canadensis	0.02 ± 0.07	1.3 ± 5.6	0	0
Cornus florida	0.01 ± 0.03	2.5 ± 7.7	0	0
Crataegus sp.	0.03 ± 0.15	1.3 ± 5.6	0	0
Diospyros virginiana	0.02 ± 0.11	2.5 ± 11.2	0	0
Fraxinus americana	0.02 ± 0.05	2.5 ± 7.7	0	0
Juniperus virginiana	0.01 ± 0.04	1.3 ± 5.6	0	0
Liquidambar styraciflua	0.02 ± 0.03	1.3 ± 5.6	0	0
Liriodendron tulipifera	0.01 ± 0.05	1.3 ± 5.6	0	0
Pinus echinata	1.13 ± 1.13	48.8 ± 46.9	0.28 ± 0.67	6.3 ± 11.1
Quercus marilandica	0	0	0.23 ± 0.42	10.0 ± 12.6
Quercus velutina	0	0	0.02 ± 0.05	3.8 ± 9.2
Ulmus americana	0.01 ± 0.01	1.3 ± 5.6	0	0
Totals	1.25 ± 1.13	63.8 ± 49.7	0.53 ± 0.71	20.0 ± 15.4

Table 5. Diversity indices for woody and ground layer vegetation in pine plantations and native pine stands in the Ozark Hills of southwestern Illinois (H´ = Shannon-Weiner Index, J´ = Pielou Equitability Index, N_0 = number of species, N_1 = number of abundant species, N_2 = number of very abundant species).

A. Overstory

Diversity Index	Pine Plantations	Native Pine Stands
H´	1.31	1.51
J´	0.40	0.56
N_0	27	15
N_1	3.71	4.51
N_2	1.96	3.17

B. Saplings

Diversity Index	Pine Plantations	Native Pine Stands
H´	1.16	1.56
J´	0.60	0.68
N_0	7	7
N_1	3.20	4.77
N_2	2.57	3.79

C. Seedlings

Diversity Index	Pine Plantations	Native Pine Stands
H´	1.92	1.27
J´	0.75	0.55
N_0	13	10
N_1	6.85	3.56
N_2	4.63	2.48

D. Ground Layer

Diversity Index	Pine Plantations	Native Pine Stands
H´	1.57	1.83
J´	0.42	0.50
N_0	44	40
N_1	4.83	6.21
N_2	2.41	2.95

Figure 1. Dominance-diversity curves for trees and saplings in plantations (open squares) and native pine stands (solid squares) in southwestern Illinois. Species sequence is from most to least important.

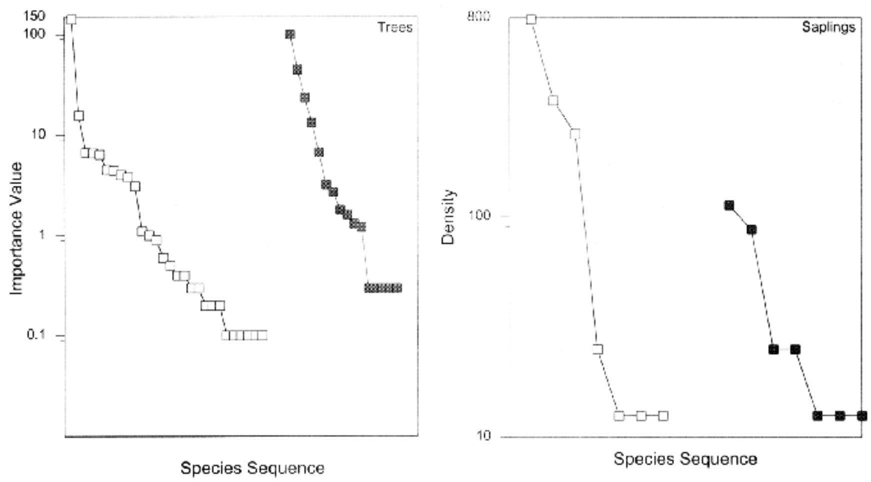

Figure 2. Dominance-diversity curves for seedling and ground layer vegetation in plantations (open squares) and native pine stands (solid squares) in southwestern Illinois. Species sequence is from most to least important.