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Cultural Treatments Influence Hardwood Growth and Foliar Nutrient Concentration on a Minor Stream Bottom Site

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SUMMARY

Seedlings or cuttings of nine species of hardwoods were planted on a minor stream bottom (Aeric Fluvaquents) in southeast Arkansas and mowed or disked several times annually for 4 years. Disking to eliminate competition significantly increased heights and diameters of all, and survival of some, species. Soil nitrogen, organic matter, and pH were significantly lowered in disked plots than in mowed. Cultural treatments did not affect soil phosphorus, potassium, calcium, and magnesium. More water was available for tree growth where all competition from other vegetation was removed.

On disked plots, trees had significantly higher foliar nitrogen concentrations than trees on mowed plots. Cultural treatments did not affect foliar concentrations of phosphorus, potassium, calcium, and magnesium. Foliar nitrogen level for most species was below the 2.0-percent level recommended for the best growth of cottonwood and sycamore, indicating more research with other species on different sites is needed before minimal foliar nutrient concentrations are determined.

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INTRODUCTION

Most hardwoods grown in plantations are shade intolerant, and sites must be intensively managed to eliminate competition from weeds, vines, and grasses. However, quantitative data on the effects of intensity and duration of cultural treatments on soil nutrient availability and uptake, soil moisture, tree growth, and survival are lacking for plantations. Nevertheless, forest managers are practicing intensive plantation management of hardwoods due to the demand for quality logs for veneer, lumber, and specialties. The expanding use of hardwoods for pulp and fuel also adds to this increased demand. This paper reports on soil and foliar nutrient levels, soil moisture, and growth and survival of nine hardwoods as influenced by two intensities of cultural treatment: mow and disk.

METHODS

The study site occupied about 20 acres near Monticello, Arkansas. The site recently had been cleared of a natural mixed hardwood-pine stand and prepared for planting by shearing, root raking, and disking. It is in a minor stream bottom that transects pine uplands. The soil is classified Arkabutla, a member of the fine-silty, mixed, acid, thermic family of Aeric Fluvaquents. These somewhat poorly drained soils, formed in silty alluvium, have dark-brown silt loam A horizons (surface layers) and dark-brown silty clay loam upper B horizons (subsoils) underlain by light brownish-gray silt loam. Estimated site indices for bottomland hardwoods range from 95 feet at age 50 for green ash (*Fraxinus pennsylvanica* Marsh.) to 110 feet at age 30 for cottonwood (*Populus deltoides* Bartr. ex Marsh.).

A split-plot design was used. Five blocks (3 acres each) were laid out and split into two 1.5-acre plots. One of two cultural treatments, mowing or disking, was randomly assigned to each plot. Plots were then divided into nine rows (subplots), 10 feet apart and approximately 550 feet long. One of the nine hardwood species was randomly assigned to each row. Seedlings or cuttings were planted at 10-foot intervals within rows, giving a 10- by 10-foot spacing. Rows were planted perpendicular to the contour to assure that all species were planted on bottoms, slopes, and ridges typical of minor stream bottoms. A 15-foot turn row around each major plot facilitated disking and mowing.

Because of lack of space, only one control plot (no mowing or disking), approximately 100 by 1,100 feet, was installed across the south end of the study area. It was not included in any statistical analyses of the mowed and disked treatments, but was included in tables for comparison. Four rows, parallel to the mowed and disked rows, were planted in a randomized complete block design with 10 seedlings or cottonwood cuttings per species per row. Measurements in the control plot were the same as in the treatment plots. Each row was considered a replication, and statistical analyses were made to compare performance of each species within the control plot.

Plots were disked or mowed at 3- to 4-week intervals from late April through early September the first growing season, and at 4- to 6-week intervals during the same time period in years 2, 3, and 4. Treatments were applied five times the first year, four times the second year, and three times in years 3 and 4.

Species tested were cottonwood, sycamore (*Platanus occidentalis* L.), green ash, sweetgum (*Liquidambar styraciflua* L.), sweet pecan (*Carya illinoensis* (Wangenh.) K. Koch), Nuttall oak (*Quercus nuttallii* Palmer), water oak (*Q. nigra* L.), cherrybark oak (*Q. falcata* var. *pagodifolia* Ell.), and yellow-poplar (*Liriodendron tulipifera* L.).

Measurements were made of surface soil moisture and moisture at 1-, 2-, 3-, and 4-foot depths on a volume basis with neutron probes. These measurements

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were made approximately every 2 weeks when climatic and soil conditions permitted. Subsurface measurements were made using aluminum access tubes. There were six tubes located in the disked plots, six in the mowed plots, and two in the control plot.

Soil organic matter (OM), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and pH levels were determined after site preparation but before cultural treatments were started, as well as at the end of each growing season. Samples from the 0- to 6-inch layer were collected at five randomly located points within a cultural treatment without regard to species. Collections were made annually in early September and composited to make one sample per plot. Annual collections were made within 2 feet of the previous year's samples. Samples were air-dried and processed to pass through a 2-mm sieve in preparation for chemical analyses.

The above-ground portion of all understory vegetation was collected every year in early September from two 2- by 2-foot areas on the control plot. Ovendry weights and N, P, K, Ca, and Mg concentrations were determined from composite samples.

Representative foliage samples were collected annually in early September from the midcrown position of each tree in a subplot. Concentrations of N, P, K, Ca, and Mg were determined. Samples were collected at the midcrown position to maintain uniformity in sampling.

All tree foliage and understory vegetation were dried at 70°C and ground in a Wiley mill in preparation for chemical analyses. Nitrogen was determined by a standard semimacro Kjeldahl procedure; P by colorimetry with molybdenum-blue color development; and K, Ca, and Mg by atomic absorption spectrophotometry after samples had been dry ashed and taken up in dilute HCl.

Soil N was determined by a standard semimacro Kjeldahl procedure. Phosphorus was measured with a colorimeter by the Mississippi soil test method (Soil Test Work Group 1974). Concentrations of K, Ca, and Mg were determined by atomic absorption spectrophotometry after extraction in 1 $\underline{N}$ NH_4OAc. Soil pH was measured with a glass electrode in a 1:1 soil/water ratio. Oxidizable OM was determined by chromic acid oxidation and titrations with $Fe(NH_4)_2(SO_4)_2$.

Tree heights, diameters, and survival were measured annually for 4 years. Diameters were measured with calipers at the root collar each year, because some species did not reach 4.5 feet in height until the second or third growing season. Diameters at breast height were measured after the fourth growing season. Heights were measured with an aluminum measuring pole. Effects of treatments on measured variables were tested for significant differences at the 0.05 level of confidence. Comparisons among treatment means were made using Duncan's New Multiple Range Test.

RESULTS AND DISCUSSION

Tree Growth and Survival

Significant species by cultural treatment interactions occurred for tree heights; however, individual species by cultural treatment analyses showed each species was significantly taller in disked than mowed plots (fig. 1). Disking increased heights from 76 percent for yellow-poplar to 160 percent for cherrybark oak over heights of trees in mowed plots. Significant interactions also occurred for cultural treatment by years and for species by years. These are probably a reflection of inherent growth differences between species and differences in yearly rainfall or available soil moisture. Trees were as tall after 2 years in disked plots as after 4 years in mowed plots. If this growth advantage remains, then forest managers could reduce rotation age several years by disking during the first and maybe the second growing seasons. Second-year cultivation had a significant influence on cottonwood growth during the second and third growing seasons, and these benefits were still evident in tree heights and diameters after 5 years (Baker and Blackmon 1978).

Significant cultural treatment by species interaction occurred for diameters at groundline; however, individual species by cultural treatment analyses showed that trees for each species were significantly larger in disked plots than mowed (fig. 2). Disking increased diameters from 86 percent for yellow-poplar to 229 percent for cherrybark oak over diameters of trees in mowed plots. Diameters at breast height after 4 years were 55 percent to 60 percent as large as groundline diameters.

Nuttall oak, cottonwood, and sweet pecan had significantly greater survival in disked plots than in mowed. The other six species were not affected by treatment. Even though cottonwood and sweet pecan did better in disked plots, survival was unsatisfactory (43 percent). After 4 years, survival of other species in disked plots ranged from 67 percent for yellow-poplar to 96 percent for sycamore. Competition was primarily from weeds and grasses rather than from vines, which are common on many hardwood sites. Weeds and grasses slowed growth in mowed plots; this competition was not severe enough to cause mortality.

In the control plot, sycamore and sweetgum had significantly higher survival than cottonwood and sweet pecan. Other species were intermediate with no significant differences among them in survival. Green ash, sycamore, yellow-poplar, and sweetgum were larger than cottonwood and sweet pecan in terms of height and diameter growth. Oaks were intermediate with no significant differences among them. Low survival and poor growth rates of cottonwood and sweet

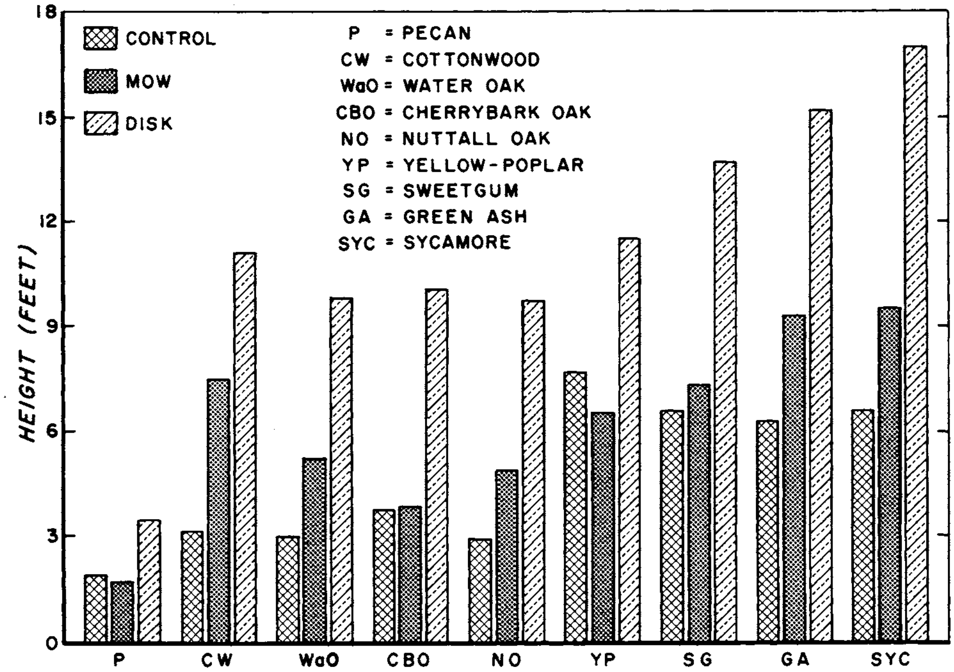

Figure 1. — *Average heights by species and cultural treatment after four growing seasons.*

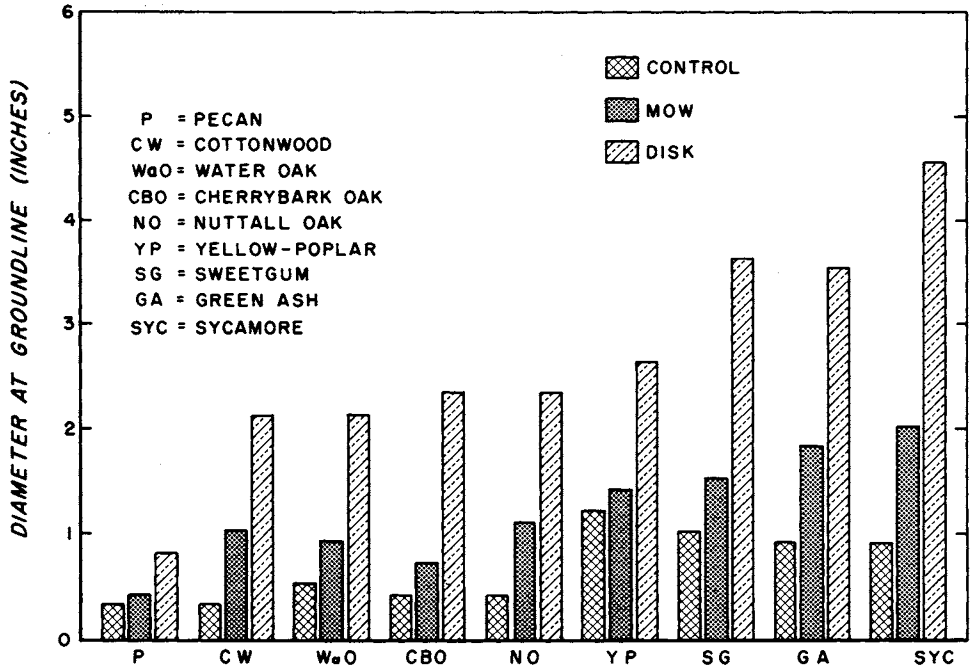

Figure 2. — *Average diameters at groundline by species and cultural treatment after four growing seasons.*

pecan indicate their unsuitability for planting on this site. Survival and growth of mowed plots and the control were very similar. Kennedy's (1981) results showed no differences in growth and survival of trees in mowed and control plots.

Trees compete strongly with weeds and grasses for moisture, nutrients, and sunlight. Annual dry-weight production of weeds and grasses in the control plot averaged 4.2 tons per acre. Nutrient concentrations of understory vegetation were: N, 0.64 percent; P, 0.07 percent; K, 0.30 percent; Ca, 0.28 percent; Mg, 0.12 percent. Better tree growth in disked plots than in mowed and control plots (figs. 1 and 2) indicated that disking eliminated the competition, resulting in more available water and nutrients for seedlings. Competition apparently still existed, whether weeds and grasses were mowed or not mowed.

Foliar Nutrients

Cultural treatments did not affect foliar concentrations of P, K, Ca, and Mg (table 1). The cultural treatment by species interaction for N was significant, so individual analyses by species were made. Green ash, water oak, sweet pecan, cottonwood, and sweetgum had higher foliar N concentrations in disked plots than mowed, but cultural treatments did not affect foliar N concentrations in cherrybark oak, sycamore, Nuttall oak, or yellow-poplar. Although cultural treatments did not significantly affect foliar concentrations of any nutrient element except N, assuming foliar weights are proportional to D^2 or D^2H, then 3 to 12 times more of each nutrient was accumulated in trees in disked plots than in mowed. Except for N, trees in the control plot had about the same nutrient concentrations as those in mowed plots.

The higher foliar N levels in trees in disked plots probably resulted from reduction in competition for the available soil N and conditions that were more favorable for the breakdown of organic matter. Researchers (Blackmon and White 1972, Carter and White 1971) have suggested a minimum nitrogen foliage level of 2 percent for best growth in several species of poplars. The 2 percent N level for good growth in sycamore has also been suggested (Norris and others 1980). Results of our research suggest that trees of several species, including sycamore, can have good growth when foliar N concentrations are below the 2 percent level.

Over the 4 years of this study, foliar P, Ca, and Mg remained relatively stable regardless of cultural treatment. Foliar N and Mg decreased with age in disked plots but was relatively stable in mowed plots. Lower N and Mg concentrations in tree foliage in disked plots probably resulted from dilution.

Soil Nutrients

Soil N, OM, and pH were significantly lower in disked plots than in mowed (table 2). Cultural treatments did not affect P, K, Ca, and Mg. Soil N dropped significantly during the first and second years. During years 3 and 4, N rebounded to the preplant level. This is probably a reflection of less leaf mass production and decomposition of OM from the former forest during the first 2 years. Disking helped incorporate OM into the soil and created conditions more favorable for decomposition than in mowed plots. During years 3 and 4, the trees probably had begun to return enough litter to the soil to offset OM decomposition.

Phosphorus, K, Ca, and Mg were also significantly altered over the 4 years (table 2). Phosphorus was

Table 1. — *Percent foliar nutrient concentrations by species and cultural treatment averaged over the first four growing seasons*

	N			P			K			Ca			Mg		
Species[1]	C[2]	M	D	C	M	D	C	M	D	C	M	D	C	M	D
GA	1.31	1.59	1.90	0.11	0.12	0.11	0.74	0.71	0.76	0.75	0.73	0.76	0.24	0.22	0.22
CBO	1.44	1.57	1.75	.09	.10	.10	.48	.48	.58	.79	.79	.70	.14	.14	.11
WaO	1.41	1.55	1.78	.08	.10	.10	.46	.57	.62	.66	.66	.65	.14	.14	.14
Syc	1.32	1.52	1.72	.10	.11	.11	.57	.62	.64	.85	.84	.75	.23	.22	.22
SG	1.45	1.48	1.61	.13	.12	.11	.48	.47	.53	.87	.91	.90	.34	.31	.28
NO	1.35	1.51	1.91	.09	.10	.10	.54	.52	.59	.54	.56	.57	.13	.12	.11
SP	1.28	1.57	2.05	.12	.11	.12	.45	.49	.51	1.87	1.29	1.47	.48	.32	.27
CW	1.33	1.77	2.32	.11	.14	.13	.64	1.03	1.13	1.43	1.17	1.06	.52	.42	.44
YP	1.55	1.68	1.69	.10	.11	.09	.45	.46	.40	1.39	1.35	1.45	.42	.36	.38
$\bar{X}$	1.38	1.58	1.86	.10	.11	.11	.53	.59	.64	.93	.92	.92	.29	.25	.24

[1] GA = green ash, CBO = cherrybark oak, WaO = water oak, Syc = sycamore, SG = sweetgum, NO = Nuttall oak, SP = sweet pecan, CW = cottonwood, YP = yellow-poplar.
[2] C = Control, M = Mow, D = Disk.

Table 2. — *Nutrient levels in the upper 6 inches of soil by cultural treatment and year*

Cultural treatment	Year[1] 0	1	2	3	4
			N-percent		
Control	0.084	0.077	0.059	0.081	0.101
Mow	.089	.080	.070	.088	.084
Disk	.072	.055	.052	.061	.081
$\bar{X}$	.081a[2]	.068b	.061c	.075a	.083a
			P-ppm		
Control	5.0	6.0	4.0	5.0	5.0
Mow	7.0	6.6	5.6	4.4	2.6
Disk	8.2	6.0	3.6	3.4	3.0
$\bar{X}$	7.6a	6.3a	4.6b	3.9b	2.8c
			K-ppm		
Control	81	58	72	64	50
Mow	92	79	89	76	57
Disk	87	77	82	74	56
$\bar{X}$	90a	78a	85a	75a	57b
			Ca-ppm		
Control	338	375	225	300	300
Mow	503	500	299	480	247
Disk	435	397	322	360	345
$\bar{X}$	469a	449a	310b	420a	296b
			Mg-ppm		
Control	165	150	112	135	63
Mow	197	183	163	176	83
Disk	180	179	171	167	102
$\bar{X}$	189a	181a	167a	172a	93b
			OM-percent		
Control	1.55	1.62	1.42	1.73	2.18
Mow	1.74	1.58	1.48	1.94	1.78
Disk	1.50	0.94	1.30	1.42	1.72
$\bar{X}$	1.62a	1.26b	1.39b	1.68a	1.75a
			pH		
Control	5.58	5.75	5.82	5.70	5.58
Mow	5.70	5.69	5.50	5.77	5.51
Disk	5.46	5.30	5.37	5.65	5.70
$\bar{X}$	5.58a	5.50b	5.44c	5.71a	5.70a

[1] Year 0 is for nutrient levels before cultural treatments were applied; others are after each growing season.

[2] Means of mowed and disked only; means for a given element followed by the same letter are not significantly different at the 0.05 level. Control is shown for comparison only.

highest before planting and at the end of the first growing season. It was lowest after the fourth year, while years 2 and 3 were intermediate and not different from each other. Potassium and Mg levels did not change the first 3 years, but dropped significantly in year 4. Calcium levels were the same before planting and after years 1 and 3. In years 2 and 4, Ca was significantly lower than the other sample times. July and August of the fourth year were the driest months recorded during the study and probably accounted for the lower amounts of P, K, Ca, and Mg measured that year.

Disked plots were significantly lower than mowed in organic matter. This probably resulted from increased decomposition of OM after incorporation into the soil in disked plots. Organic matter was also lower in mowed plots during the first and second years than before planting and after years 3 and 4. This trend was expected because of higher decomposition rates after planting and less leaf fall in years 1 and 2 than later in the life of the plantation. The cultural treatment by year interaction was significant but did not appear as important as the main effects. The interaction was probably caused by the decline in OM in disked plots during the first growing season.

Soil pH was significantly lower in disked than mowed plots and is probably a reflection of the release of organic and inorganic acids during OM decomposition. However, the range from lowest to highest was not wide and probably there were not large enough differences to affect tree growth and survival.

Soil Moisture

Soil moisture content did not differ by cultural treatment. Soil moisture was highest at the beginning of the growing season under all cultural treatments and diminished during the growing season. Evapotranspiration from a fully stocked forest stand in the Gulf South is about one-fourth of an inch per day. Up to 50 percent of the moisture loss in a pine forest stand can be attributed to the hardwood understory (Zahner 1958). In our study, soil moisture absorbed by weeds and grasses in the mowed and control plots was not available for uptake by trees. On disked plots, this loss did not occur because weeds and grasses were destroyed and soil moisture was available for uptake by the trees. Apparently, trees in disked plots absorbed as much water as weeds and grasses in other plots, because no differences in soil mositure content among treatments were detected. Evidently as much as 50 percent more moisture could have been available for uptake by trees in disked plots than in mowed and control plots.

Soil moisture depletion varied by depth during the year. Moisture in the surface and at the 1-foot depth was lowest as the growing season progressed, followed by the 2-foot depth. At the lower depths of 3 and 4 feet, soil moisture remained relatively constant during the growing season, indicating that most roots did not extend below 2 feet, or there was sufficient water movement from lower horizons into this rooting zone to maintain moisture levels.

CONCLUSIONS

One of the major benefits of disking was control of weeds and grasses. By eliminating this competition, disking directly or indirectly increased nutrient concentrations and the amount of soil moisture available for uptake by trees, as evidenced by increased tree growth. Without good site preparation and disking, lower survival and reduced growth of planted trees can be expected.

The study site is considered relatively infertile for hardwoods, because soil nutrients are near or below what is considered to be the minimal level for good tree growth, particularly for P, K, and Ca (Davey 1976). Foliar N for most species was below the 2.0 percent level recommended for good growth in cottonwood and sycamore (Carter and White 1971, Norris and others 1980). However, 4-year growth was good for all species except cottonwood and sweet pecan (which had foliar N concentrations above 2 percent in disked plots). More research is needed with other species, including sycamore, on different sites before minimal foliar nutrient concentrations and soil nutrient levels are determined.

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Influence of cultural treatments on soil and foliar nutrient levels, soil moisture, and growth and survival of nine hardwoods was studied.

Additional keywords: Plantation, soil moisture, soil nutrients, *Fraxinus pennsylvanica, Quercus* spp.

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