Early Plant Succession in Loblolly Pine Plantations as Affected by Vegetation Management

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ABSTRACT. *A common study design has been used at 13 locations across the South to examine loblolly pine* (Pinus taeda *L.) plantations established using four vegetation control treatments after mechanical site preparation: (a) No Control, (b) Woody Control, (c) Herbaceous Controlfor 4 yr, and (d) Total Control. This research, the Competition Omission Monitoring Project (COMP), is monitoring both pine growth and plant succession. During the first 8 yr, the cover of herbaceous components and prevalent genera, along with pine, woody (nonpine), and total herbaceous cover were estimated annually in September. Stem numbers and heights of arborescent and nonarborescent woody species were measured during the first 5 yr and yr 8.*

There were 101 prevalent genera of herbaceous plants and 76 species/genera of woody plants present on the study sites, with a core group common to most. Herbaceous cover was rapidly reestablished on No Control and Woody Control treatments, with greater than 80% cover in the first year. After the first year, herbaceous cover steadily declined on No Control plots and was sustained when woody plants were eliminated. In general, grasses dominated the herbaceous layer (mainly Andropogon *and* Panicum *spp.) with cover peaking in yr 4. Woody control increased the actual cover of both grasses andforbs, but only the relative proportion of forbs, which peaked in yr 1–2. Woody control also increased the actual cover of vines and semiwoodies (mainly nontargeted* Rubus *spp.) by yr 6-8, but only the relative cover of semiwoodies. Development of the pine canopy cover was similar with woody and herbaceous control, but pine heights were greater with herbaceous control. Interestingly, herbaceous control did not increase total woody cover until year 8, but the proportion of arborescent tree to nonarborescent shrub cover was increased. Most arborescent species and rootstocks became established in the first year. South. J. Appl. For. 19(3): 109–126.*

Intensive forest management is often cited as a major contributor to the loss of species from forest communities (Probst and Crow 1991, Salwasser 1990, Norse et al. 1986). Although change in the species composition of forests is a natural consequence of succession, the management of forest ecosystems to increase the production of certain species inevitably leads to shifts in the relative abundance of coexisting species (Hunter 1990, Westman 1990). A prevalent objective of vegetation management (or forest weed control) is to alter species composition and relative abundance to

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favor crop trees. Although most vegetation management treatments accomplish this goal, the magnitude and direction of species changes are not always identical or predictable. Wide ranges in diversity effects have been observed as a result of vegetation management, and their magnitude is dependent on the intensity of biotic control and abiotic habitat manipulation (Robinson 1978, Conde et al. 1983a, 1983b, Zutter and Zedaker 1988, Hansen et al. 199 1).

Diversity and species maintenance are coming under increased regulatory control on both public and private forestland (Salwasser 1990). In the future, increases in crop tree growth and yield may not only have to be sufficient to justify the expenditures for vegetation management, but may be weighed against changes in the amenity values of wildlife and noncrop species maintenance as well. As a result, there is an increasing need to understand the impacts of woody and herbaceous plant control on species abundance and relative dominance over time. To assess these impacts, as well as the influence of vegetation management on loblolly pine growth, a group of investigators initiated a unified study in 1984, called the Competition Omission Monitoring Project or COMP (Miller et al. 1987). A prior report in *SJAF* focused on the 5 yr pine response and relative competition levels (Miller et al. 199 1). This report summarizes the first 8 yr of successional dynamics.

An objective of COMP is to describe secondary plant succession as it is altered by the vegetation management treatments of complete woody control and complete herbaceous control as compared to no control and complete control. The 13 plantation sites in COMP established from Louisiana to Virginia (Figure 1) provide a limited but unique network of locations for documenting such trends within loblolly pine plantations in the Southeast, The test treatments permit us to examine the development of herbaceous and woody associations independently and collectively. It is believed that an understanding of secondary succession in these extreme treatment situations should establish bounds of possible trends for management areas where complete component control is not achieved. Herbicide treatments for woody and herbaceous plant control were applied in 1992 to about 552,000 ac of forest lands in the Southeast with increasing use projected (Fallis 1993).

This is the first study to document early succession in plantations over a wide number of locations for the central portion of the southern forest region dominated by loblolly pine. Prior reports have focused on the longleaf pine type (Pessin 1933), Florida slash pine (Grelen 1962, Burns and Hebb 1972, Ballet al. 1981,Condeetal. 1983a, 1983b, Neary et al. 1990), Texas pine-hardwood forests (Stransky et al. 1986), and scattered reportings of wildlife forage production (Wolters and Schmidtling 1975, Lewis et al. 1984, Blake et al. 1987). Other investigations have also examined vegetative response in loblolly plantations due to vegetation management treatments at selected sites (Zutter et al. 1987, Zutter and Zedaker 1988, Locasio et al. 199 1).

Results in this report address the following practical questions about forest plant succession, soil exposure, and floristic richness in intensively managed loblolly pine plantations:

- How do vegetation control treatments alter early loblolly pine canopy development?
- How does herbaceous control influence hardwood and shrub development?
- How does woody control influence herbaceous cover development?
- To what degree and duration may areas be unoccupied or uncovered by vegetation following moderately intensive mechanical site preparation, like chopping and burning, and supplemental control treatments?

a How does woody plant control alter herbaceous component dynamics?

- What herbaceous plant genera occurred in these pine plantations and did woody control treatments alter their occurrence?
- What are the early successional trends of the most common herbaceous plants in pine plantations?
- What are the early establishment patterns of woody plants after moderately intensive mechanical site preparation, like chopping and burning?
- How does herbaceous control alter woody plant development and dynamics?
- What woody plant species occurred in these loblolly pine plantations and did herbaceous control treatments alter their occurrence?

These are thought to be common questions asked by and to forest resource managers regarding the impacts of vegeta-

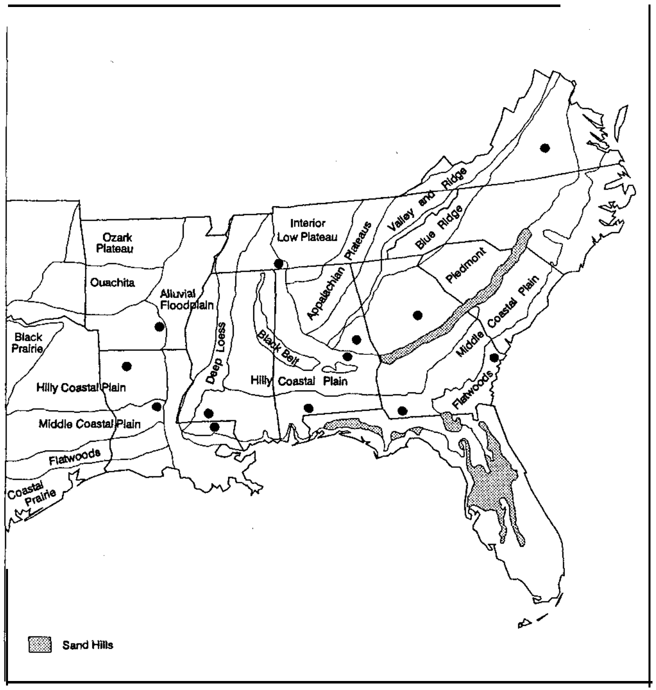

Figure 1. COMP plantation study locations relative to physiographic provinces (map recently complied by J.H. Miller and K.S. Robinson based on Landsat imagery and other sources).

tion management on stand development and associated flora. These findings should also provide a knowledge base for more detailed studies of succession and species diversity in southern pine plantations.

Methods

Study locations ranged in latitude from 30.5°–37.2°N and longitude from 78.5°–93.0°W (Table I). Average annual precipitation ranged by location from 40-60 in. for the 8 yr studied, while March through November amounts ranged from 26-43 in. Frost-free days typically vary from 270 days in the south to 160 days in Virginia. The soils for the most part are Ultisols that are low in bases and have subsurface horizons with clay accumulations, interspersed with recent alluvium. Vegetation of the region has developed until recently (last 200 yr) with frequent burning and extensive cultivation for 8,000+ yr by Native Americans during an interglacial warming period (Bartram 1940, Cronin et al. 198 1, Van Lear and Waldrop 1989, Doolittle 1992). All study locations probably were cultivated in the past 200 yr.

Detailed methods of COMP have been presented in previous reports by Miller and others (1987, 1991) and are only reviewed here with appropriate elaborations. Common criteria for site selection and a common study design (with some differences) were used at the 13 plantation locations, which accommodated pooling of data across all locations to study regional trends. Major site and treatment similarities were:

- Most study sites were located on prevalent soil types of the region.
- Prior stand conditions, harvesting and site preparation methods were typical for the region and similar to each other. Roller-drum chopping and prescribed burning were used at 10 locations, while either windrowing, rebedding, or complete biomass harvesting was used at the other three locations. All site preparation was performed during the growing season before study establishment and usually incorporated burning.
- A common pine planting density of 538 trees/ac was used, except at two locations (565 and 622 trees/ac).

General characteristics of individual study sites are presented in Table 1 and their locations relative to physiographic provinces are shown in Figure 1.

Immediately before and after planting the following competition control treatments were imposed:

1. No Control.
2. Woody Control for 5 yr.
3. Herbaceous Control for 4 yr.
4. Total Control (both woody and herbaceous plant control combining 2 and 3).

These four treatments yield vegetation situations that are the corner extremes of a response surface that encompasses most competition conditions common to young plantations. Treatments 1 and 2 were used to study herbaceous succession with and without the woody component, and similarly, treatments 1 and 3 were used to document woody plant succession with and without the herbaceous component. Semiwoody plants (e.g., *Rubus* spp.) were considered here as herbaceous. In this unique approach, secondary succession was being documented as selective control treatments were being applied, unlike traditional ecological studies following a discrete, singular disturbance.

The four treatments were established at the 13 locations using a randomized complete block design with 4 replications, with 2 exceptions. A fifth block was added at the only Flatwoods Coastal Plain site near Pembroke (GA) and a completely random design was used at Bainbridge (GA). Treatment plots were 0.25 ac and measurement plots were 0.09 ac. Loblolly pines were double planted (12 in. apart) on a 9 x 9 ft spacing, except at two operationally planted locations (Table 1). After the first growing season, pines were randomly thinned to one per spot, which assured uniform pine densities.

Woody plant control after pine planting was achieved by using nonsoil active herbicides-Garlon (triclopyr) and Roundup (glyphosate). Applications were by directed basal and foliar sprays and basal wipes. These herbicides and methods minimized damage to nontarget herbaceous plants. The same methods were used to control volunteer shortleaf (*Pinus echinata* Mill.) and loblolly pines on all plots. Virginia pines (*Pinus virginiana* Mill.) at Appomattox (VA) were not controlled due to their prevalence on regeneration sites in the Piedmont of Virginia.

Herbaceous control treatments relied mainly upon annual broadcast applications of the pre-emergent herbicide Oust (sulfometuron) and shielded directed sprays of Roundup. Pre-establishment screening trials identified Oust rates that resulted in minimal damage to planted conifers, hardwoods, and shrubs. Treatment impacts to nontarget plants decreased greatly during the first 3 yr as control conditions were reached and nontarget plants grew larger. Vine suppression was attempted at half the locations, mainly in the first 3 yr on Woody Control plots, using directed sprays. Vines were cut also from pines for accurate diameter measurements and to minimize pine canopy interference. Thus, vine development was suppressed, but only partially during the first 3 yr.

Within each interior measurement plot, three 9 x 18 ft sample plots were systematically established, with the corners at pine planting spots-a 0.01 ac sample per 0.09 ac measurement plot, yielding a 12% sample. Annually in September of yr l-5 and in yr 8, all woody rootstocks taller than 0.5 ft were recorded by species (genus for some nonarborescents) and height classes. Rootstocks were those judged to originate from the same central root system with one or more stems. Height classes were delineated by 1 ft intervals up to 12 ft and then by 5 ft intervals.

For cover estimates, the three 9 x 18 ft sample plots were halved to yield six 9 x 9 ft subplots per measurement plot. Annually in September for yr 1-8, cover was visually estimated within each subplot for the herbaceous life-forms and

Table 1. Description of study sites.

Location by province	Soil series	Soil classification	Previous stand	Harvest	Site preparation	Regeneration
Flatwoods Coastal Plain						
Pembroke, GA N32°11' W81°34'	Mascotte Pelham	sandy, siliceous, Thermic Ultic Haplaquods loamy. siliceous, Thermic Arenic Paleaquults	6-year-old slash pine planation burned by wildfire	N/A	rebedded 1983	machine planted 7x11 ft Winter 1983-84
Middle Coastal Plain						
Bainbridge, GA N30°51' W84°35'	Orangeburg Esto	fine-loamy, siliceous, Thermic Typic Kandiudults clayey, kaolinitic, Tharmic Typic Kandiudults	mixed loblolly/ shortleaf pine - hardwood	Winter 1982-83	KG blade, chop & burn June 1983	hand planted QxQft Jan 1984
Liberty, MS N31°90' W90°50'	Cahaba Benndale and Latonia	fine-loamy, siliceous, Thermic Typic Hapludults coarse-loamy, siliceous Thermic Typic Kandiudults	mixed loblolly/ shortleaf pine- hardwood	April 1983	chop & burn Summer 1983	hand planted 9 x 9 ft Feb 1984
Atmore, AL N31°90' W86°44'	Orangeburg	fine-loamy, siliceous, Thermic Typic Kandiudults	slash pine plantation with hardwoods	Sept 1983	whole-tree chipped at harvest	hand planted 9 x 9 ft April 1984
Liverpool, LA N30°49' W90°47'	Tangi	fine-silty, siliceous, Thermic Typic Fragiudults	naturally regen- erated loblolly pine-hardwood	Winter- Summer 1983	chop & burn Summer 1983	hand planted 9 x 9 ft Feb 1984
Jena, LA N31°40' w92°50'	Ruston	fine-loamy, siliceous, Thermic Typic Paleudults	mixed pine- hardwood	Fall 1983	chop & burn Summer 1983	hand planted QxQft Jan 1984
Hilly Coastal Plain						
Tallassee, AL N32°26' W85°55'	Cowarts	fine-loamy, siliceous, Thermic Typic Kanhapludults	loblolly pine plantation	Spring 1983	chop & burn late spring - early summer 1983	hand planted 9 x 9 ft Jan 1984
Warren, AR N33°37' W92°51'	Saffell Stough	loamy-skeletal, siliceous, Thermic Typic Hapludults coarse-loamy, siliceous, Thermic Fragiaquic Paleudults	mixed loblolly/ shortleaf pine- hardwood	June 1983	chop & burn Summer 1983	hand planted QxQft Feb 1984
Counce, TN N35°11' W88°91'	Silerton	fine-silty, mixed, Thermic Typic Hapludults	natural mixed pine-hardwood	Winter 1982-83	shear, pile & burn windrows August 1983	hand planted 9 x 9 ft April 1984
Arcadia, LA N32°39' w92°55'	Sacul	clayey, mixed, Thermic Aquic Hapludults	natural loblolly pine-hardwood	1983	chop & burn Summer 1984	machine planted 7 x 10 ft Jan 1985
Piedmont						
Camp Hill, AL N32°48' W85°31'	Cecil Pacolet	clayey, kaolinitic, Thermic Typic Kanhapludults clayey, kaolinitic, Thermic Typic Kanhapludults	natural mixed pine-hardwood	Spring 1983	chop & burn Spring 1983	hand planted 9 x 9 ft Jan 1984
Monticello, GA N33°17' W83°41'	Davidson	clayey, kaolinitic, Thermic Rhodic Kandiudults	natural mixed pine-hardwood	Oct 1982	chop & burn Summer 1983	hand planted QxQft Feb 1984
Appomattox, VA N37°20' W78°48'	Cecil Cullen Iredell	clayey, kaolinitic, Thermic Typic Kanhapludults clayey. mixed, Thermic Typic Hapludults fine, montmorillonitic, Thermic Typic Hapludalfs	natural mixed pine-hardwood	June 1983	chop & burn Summer 1983	hand planted 9 x 9 ft Feb 1984

for any "open area" that had no vegetation at any layer above the area. Plants that were present only in winter, spring, or early summer were missed with this sampling time. The herbaceous life-forms (hereafter referred to as herbaceous components) were as follows: grasses and grass-like plants, forbs, vines, and semiwoody plants (e.g., *Rubus* spp.). Starting in year 2, estimates were added for "total woody cover" and for "planted pine" cover. Beginning in year 5, arborescent (hardwoods) and nonarborescent (shrubs) woody plants were estimated separately. All cover estimations were grouped into one of the following percent classes: 0, 2 (1–5), 10 (6–15), 20 (16–25), 30 (26–35), . . . , 70 (66–75), 80 (76–85), 90 (86–95), 97 (96–99), and 100. This grouping permitted the finer cover estimates that can be made at the extremes. Each site had a different estimator with common procedures used.

On each 9 x 9 ft subplot in the No Control and Woody Control treatments, cover for the dominant genera of herbaceous plants was also estimated using the above cover classes. Any genus present on more than 16% (20% class) of the plot was recorded along with its estimated cover. At least three genera were recorded per 9 x 9 ft plot regardless of coverage, unless only one or two genera were present. These plant genera are referred to as the "prevalent genera," because they usually exceeded 15% cover. For each treatment at a location, dominance values for the prevalent genera were calculated as "mean cover" x "frequency of occurrence" (the proportion of subplots across the site on which the genus occurred (usually $n = 24$)). Thus, dominance in this instance is an estimate of overall coverage. Overall frequency for all study locations (and thus overall dominance) was calculated using either "when prevalent" (locations per year) or "where prevalent" (locations in any year), depending on the discussion point.

Relative cover of each herbaceous component was calculated to determine if the proportion stayed constant or changed when total herbaceous cover changed due to treatment. Relative cover for herbaceous components was calculated as the proportion of the component's cover to the sum of all herbaceous component covers, which often exceeded 100% with multiple layering and intermingled growth.

The majority of locations were measured each year. Cover estimations for one location out of the 13 were missed in yr 1, 3, 6, and 7, and two locations in year 4. For woody measurements, one location was missed in yr 1, 3, 4, and 8. Overall annual means by treatment are the means of treatment means from each location (1 1-1 3 locations for cover involving 264-3 12 sample plots and 12-13 locations for woody measurements involving 144-156 sample plots).

Herbaceous cover and cover of herbaceous components were compared between No Control and Woody Control treatments and total woody cover was compared between No Control and Herbaceous Control treatments via either the paired-t test or Wilcoxon's signed rank test (in case of nonnormality). Tests were performed using treatment means from each location, with $P = 0.05$ as the level of significance.

Results and Discussion

Results are presented relative to the practical questions they address, followed by a general discussion. Pine canopy development is examined first, since this eventually becomes the dominant cover that most influences the succession of the other associated components.

How do vegetation control treatments alter early loblolly pine canopy development?

Pine cover at age 8 as shown in Figure 2 increased as the number of components controlled increased: No Control (41%) < Woody Control (60%) = Herbaceous Control (62%) < Total Control (90%). Pine cover development was similar with Woody Control and Herbaceous Control treatments, even though the cover of other stand components differed greatly. Vertical pine canopy development also increased in total height as the number of components being controlled increased, but there where obvious differences

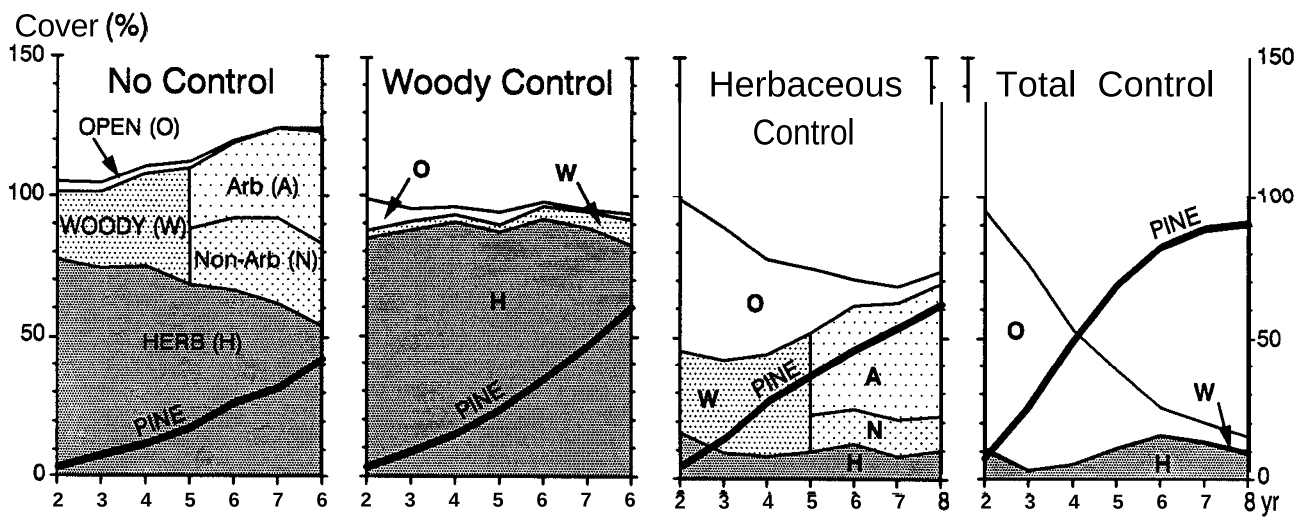

Figure 2. Change over time of mean covers for all locations by component (shown as areas) and pine cover (shown as a line) for the four COMP treatments.

between Woody and Herb Control treatments. At age five, Miller et al. (199 1) noted a mean height of 11.5 ft for No Control, and gains of 1.4, 4.6, and 6.7 ft for Woody Control, Herb Control, and Total Control, respectively. These same trends were still evident with unpublished yr 8 data. Increases in both cover and height of pines are reflective of the dominant position they are assuming in the canopy of all treatments, which is accelerated by vegetation control.

Pine cover increased at a slower rate between yr l-4 where herbaceous vegetation was present on No Control and Woody Control treatments, while the faster early development for Herbaceous Control slowed, becoming linear in yr 4-8. Pine cover expansion in the absence of competition (Total Control) was sigmoid in shape, increasing rapidly in yr 2-6 and slowing to an asymptote of about 90% by year 8. These plots could be considered to have reached stand closure. Likewise, the Herbaceous Control plots had also closed by year 8 (arborescent woody + pine cover > 100%), but Woody Control plots had not. No Control plots had closed only on the heavy hardwood sites at Bainbridge (GA), Tallassee (AL), and Camp Hill (AL).

How does herbaceous control influence hardwood and shrub development?

Differences in total woody cover between No Control and Herbaceous Control were 10% or less over the 8 yr study period. Average woody cover was 3-5% more with Herbaceous Control during yr 1-4, comparable in yr 5, and was 10% less by year 8 (the only significant difference, $P = 0.05$)(Figure 2). With No Control, the proportion of arborescent to nonarborescent woody cover remained fairly constant at about 1: l but was 3: 1 with Herbaceous Control (Figure 2). At yr 5, arborescent hardwood cover was 22% with No Control and 29% with Herbaceous Control, but the basal area of arborescent hardwoods was doubled with Herbaceous Control (Miller et al. 199 1).

Increasing hardwood dominance as a result of herbaceous plant control is consistent with other vegetation management studies (Zutter et al. 1986, Bacon and Zedaker 1987). Herbaceous plants are effective competitors of arborescent plants for nutrients and water (Carter et al. 1984, Zutter et al. 1986). With herbaceous plant control, the normal pattern of secondary succession from a herbaceous-dominated community to one dominated by woody plants as earlier described by Oosting (1942) and Christensen and Peet (198 1) is greatly accelerated.

How does woody control influence herbaceous cover development?

Under the pine canopy of Woody Control plots, herbaceous cover ranged between 80–92% from yr 1-8, while on No Control plots there was a constant decrease in herb cover as pines, hardwoods, and shrubs developed (Figure 2). Thus, removal of woody plants permitted a longer lasting, more complete occupancy of the site by herbaceous plants and prevented the normal herbaceous declines associated with hardwood-shrub development. At year 8, the combined cover of hardwoods, shrubs, and pines averaged 111% with No Control compared to only 70% (60% pine cover) with Woody Control. Adding herbaceous cover to these values reveals sums of cover (pines, woody, and herbs) that were comparable by yr 8, with 160% on No Controls and 152% on Woody Controls. This is evidence of increasing layering and complexity in stand structure with time, which was more evenly distributed among herbaceous, shrub, hardwood, and pine layers with No Control. The perceptible decrease in herb cover in the last 2 yr on Woody Control treatments, from the peak of 92% in yr 6, could be the start of greater decreases as the pine canopy continues to develop and needle litter is accumulated.

To what degree and duration may areas be unoccupied or uncovered by vegetation following moderately intensive mechanical site preparation, like chopping and burning, and supplemental control treatments?

Open area (areas not covered by living vegetation) averaged only 3.3% in the first year with No Controls (mainly chop-and-burn treatments) and averaged 9.8% when Woody Control treatments were added. Herbaceous cover establishment was rapid on these treatments, averaging 84% in the first year with No Control and 80% with Woody Control. Persistent, but decreasing amounts of open area were evident with all treatments over time, which was often a result of residual logs, overturned roots from chopping, and fire ant mounds *(Solenopsis* spp.).

For the more intensive treatments of Herbaceous and Total Control, there were substantial amounts of open area, averaging 47–84%, during the first 3 yr (Figure 2). Even though litter cover was not estimated, field observations confirmed that needle litter completely covered the soil surface of most Total Control plots by yr 5, while litter cover developed somewhat slower with Herbaceous Control. Bare soil comprised most of the open area in the first few yr on Herbaceous and Total Control treatments. Exposure of bare soil likely increased sheet erosion, depending on slope and surface conditions, and the lack of herbaceous vegetation possibly influenced nutrient dynamics (see General Discussion). It should be noted that operational applications of herbicides for herbaceous plant control are usually for only 1 (occasionally 2) yr versus 4 yr and less successful in reducing herbaceous cover than treatments utilized in this study. On many sites, herbaceous control treatments may be banded in 4-5 ft strips over the top of pine rows or applied in spots over individual seedlings, reducing soil exposure by as much as one-half.

How does woody plant control alter herbaceous component dynamics?

Trends in herb component development were similar for both actual and relative cover values between Woody Control and No Control treatments, with minor but significant differences (Figure 3). Grasses and grass-like plants were the most abundant herbaceous component on both treatments, reaching peak levels by year 4 and returning to first-year levels by year 8. Actual peak levels at the different locations occurred between yr 2-6. While actual grass cover was significantly

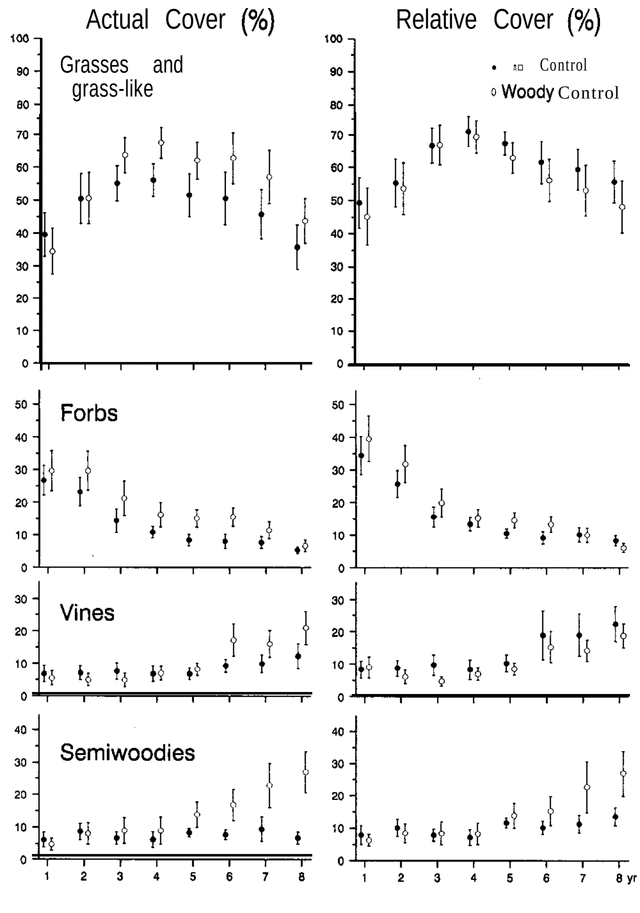

Figure 3. Actual and relative mean cover averaged for all locations and the standard errors (± 1 std. error).

greater with Woody Control treatments from yr 3-7 (P = 0.05), maximum mean differences never exceeded 12% (yr 6). When grass cover was expressed on a relative cover basis (relative to the sum of herbaceous components), it did not differ between the two treatments (Figure 3). Thus, extreme Woody Control treatments did not alter the proportion of grass cover in the herbaceous component.

Average forb cover was greatest in yr 1 with No Control and was sustained for an additional year with Woody Control. Peak forb cover at the various sites was more consistent than grass peaks and occurred in yr l-2 or was characterized by low persistent levels at the more coastal sites. Actual forb cover was significantly greater with Woody Control from yr 3-7, though mean differences only ranged from 5-8%. Relative cover was greatest in yr 1 for both treatments and was significantly different only in yr 5-6 by only 4%. After declining 20–30% in both actual and relative cover over the 8 yr, the lower forb cover levels in yr 8 differed by only 2% between treatments.

Mean cover of vines remained at similar, constant levels on No Control and Woody Control treatments during yr 1-5, partially influenced by the vine suppression treatments that were being applied at about half the sites in yr 1-3, mainly on Woody Control plots. In yr 6, vines began to increase in actual cover, especially where woody plants were controlled. Significant differences in actual cover were noted between treatments by yr 7 and 8 as vine cover with Woody Control exceeded that with No Control. No differences in relative vine cover were noted between the treatments, indicating that relative increases in vine cover were underway on both treatments by year 6. The later increase in vine cover compared to declines for grasses and forbs, may be attributed to the perennial character of major vine species, such as honeysuckle (*Lonicera* spp.) and greenbriar (*Smilax* spp.). Also, a contributing factor may be their ability to occupy and expand in developing pine and hardwood canopies to obtain a more favorable position with regard to light availability.

Among the herbaceous components, semiwoody cover differed most between treatments. Actual and relative covers of semiwoody plants began to increase on Woody Control treatments starting in yr 6 as perennial erect *Rubus* spp. increased in establishment (Figure 4). Recall that *Rubus* spp. was considered to be a herbaceous genus in this study. By age 6, actual cover was significantly greater with Woody Control than with No Control treatments ($P = 0.05$), with differences of 22% by yr 8. Relative cover was significantly greater with Woody Control only in yr 8-a 14% difference. Stable cover levels of semiwoody plants characterized the first 8 yr with No Control, which was probably due to the much greater overstory development with No Control and associated lower light and moisture levels.

What herbaceous plant genera occurred in these pine plantations and did woody control treatments alter their occurrence?

One hundred and one genera of herbaceous plants were recorded: 24 genera of grasses, 58 genera of forbs, 4 genera of semiwoodies, 13 genera of vines, 1 genus of fern, and 1 genus of clubmoss (Table 2). The actual number of genera on the sites likely exceeded 10 1, since each genera had to cover more than 15% of a 9 x 9 ft subplot or be one of the top three genera in coverage to be recorded. In general, the total number of genera (presented at bottom Table 2) was greatest in the first year regardless of treatment and only vines showed an increase in genera during the 8 yr. It is readily evident in Table 2 which genera were early community members and faded, which sustained occupancy, and others that appeared later.

Of the 101 genera recorded, 93 occurred with the No Control treatments and 85 with the Woody Control treatments. Over three-quarters of the genera, 77 total, were common to both treatments. Of the 16 genera unique to No Control, there were 3 grasses and sedges, 9 forbs, 1 semiwoody, and 3 vines. For those 8 genera found only on Woody Control situations, there were 1 grass, 5 forbs, 1 semiwoody, and 1 clubmoss. The greatest numbers of grass genera were in yr 1–4 and of forb genera in year 1. Many genera of forbs were unique to only one location in the first year.

The most common and dominant grass genera were *Andropogon* and *Panicum* (includes *Dichanthelium),* which occurred at all locations (Table *2). Andropogon* had the greatest overall dominance of any herbaceous genera, with the main species being broomsedge *(Andropogon virginicus* L.). The most prevalent forb genus was *Eupatorium,* occurring on all locations, which was composed mainly of dogfennel

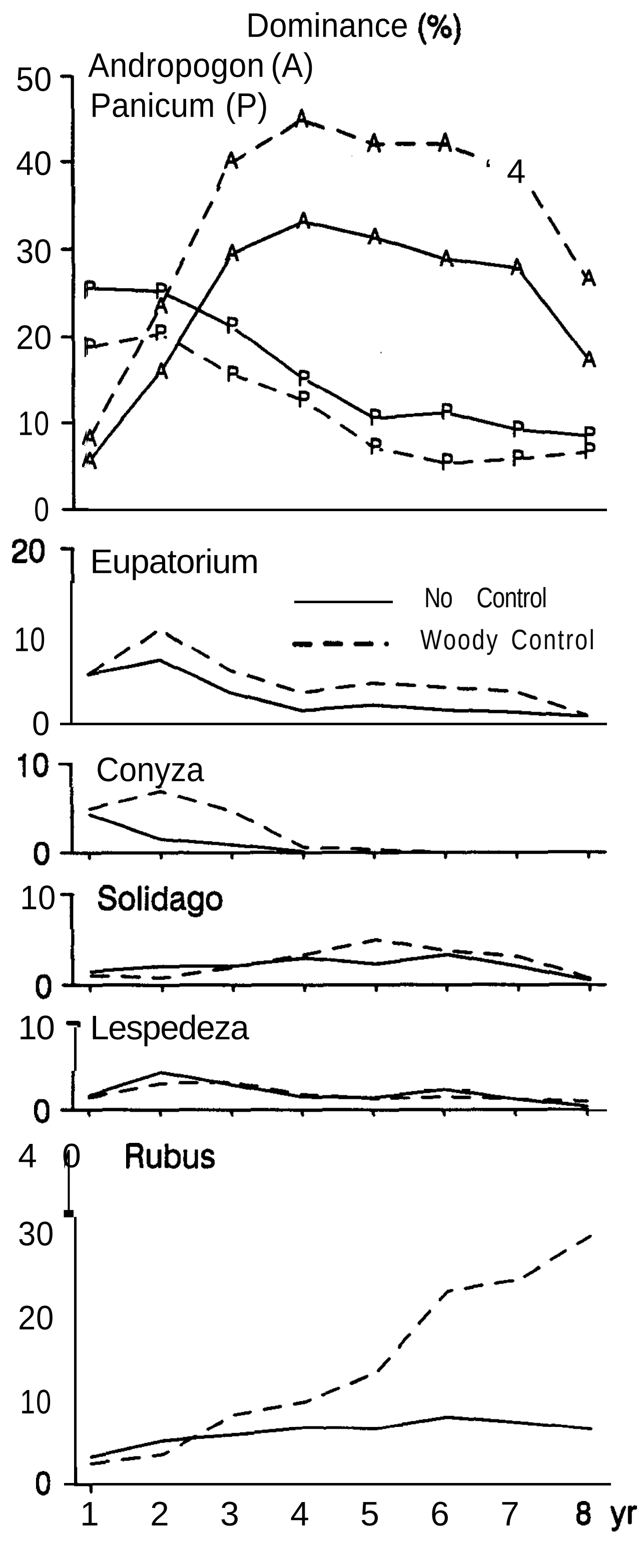

Figure 4. Mean dominance of the prevalent genera over all locations where present, comparing No Control and Woody Control.

(Eupatorium capillifolium [Lam.] Small) in the first 2 yr and perennial broad-leaf *Eupatorium* spp. *(E. album* L., *E. perfoliatum* L., and *E. purpureum* L.) in later years. Goldenrods *(Solidago* spp.) were identified on 83% of the locations, while horseweed *(Conyza canadensis* (L.) Cronquist), leguminous lespedeza *(Lespedeza* spp.), and asters *(Aster* spp.) were prevalent on over half of the locations in any one year. The annual plants, burnweed *(Erechtites hieracifolia* (L.) Raf.) and ragweed *(Ambrosia artemsiifolia* L.), were prevalent on 40% of the locations in the first year, with slightly greater dominance after Woody Control.

Blackberry (*Rubus* spp.) was the most common semiwoody, occurring on all locations (Table 2). It was more dominant with Woody Control and second in overall dominance relative to *Andropogon* spp. by year 8. No vine genera were present at all locations, but honeysuckle *(Lonicera* spp.) and greenbriar *(Smilax* spp.) were prevalent at over two-thirds of the sites. Bracken fern *(Pteridium aquilinum* [L.] Kuhn.) occurred in sufficient cover to be recorded on one-third of the locations by year 8.

The genera of leguminous plants (involved in nitrogen fixation) that occurred on these sites were *Lespedeza, Cassia, Desmodium,* and *Centrosema* (Table 2). Of these, *Lespedeza* and *Cassia* were most widespread, occurring on most locations over the 8 yr.

What were the early successional trends of the most common herbaceous plants?

Figure 4 shows the mean dominance of seven of the most prevalent herbaceous genera, based on the number of locations "where prevalent." Annual panicgrass, dogfennel, horseweed, and lespedezas were early associates that became established immediately after harvesting and site preparation. *Andropogon* spp., perennial broadleaf *Eupatorium* spp., erect *Rubus* spp., and to a lesser degree, *Solidago* spp. started to dominate after yr 3. All of these but *Rubus* spp. began to decline after year *7. Panicum* was the only genus slightly more dominant where woody vegetation was present, while *Lespedeza* dominance was not influenced by woody levels. By year 8, *Rubus* and *Andropogon* were about equal in dominance in the absence of woody (nonpine) vegetation.

Figure 5 shows the mean cover and mean frequency for the four genera that occurred at all locations. In general, their frequency of occurrence had a greater influence on their dominance than their average cover, with all but *Eupatorium* on No Controls being found on an average of at least half of the plots in one or more years, while overall mean cover only ranged from 8–42%. The two grasses responded differently to Woody Control treatments. Both frequency and cover of *Andropogon* were slightly greater with Woody Control, while with *Panicum* both were greater with No Control. *Panicum* dominance was influenced most by frequency, while the mean cover per plot remained constant. Likewise with *Eupatorium,* mean cover was comparable for the two treatments, but the occurrence was more frequent with Woody Control. *Rubus* increased in both frequency and cover over the 8 yr with Woody Control, while only frequency increased with No Control.

Patterns in dominance of specific genera differed greatly by locations. For the two most common genera, *Andropogon* and *Panicum,* trends in dominance at each location and the overall means are shown in Figure 6. *Andropogon* increased in dominance from the first year to the second at all locations

Table 2. Prevalent genera of herbaceous plants for the first 8 yr; the percent of the locations when found and their mean dominance (cover x frequency) when present, for No Control (NC) and Woody Control (WC) treatments (Trt). Names follow Radford et al. (1983) or Grelen and Hughes (1984).

Genera and common name Of principal species	Trt	Percent locations where prevalent								Mean Dominance when present							
		1	2	3	4	6	6	7	8 years	1	2	3	4	5	6	7	8 years
Number of locations sampled:		12	13	12	11	13	12	12	12								
Grasses and grass-like																	
Carex spp.	NC	17								1							
sedge	WC																
Aira spp.	NC	8								2							
hairgrass	WC																
Anthaenantia spp.	NC	8	8							3	5						
green silkyscale	WC	8	8							1	3						
Leptoloma spp.	NC	8	8							1	2						
witchgrass	WC	8	8							1	< 1						
Digitaria spp.	NC	33	8	8	9					3	2	1	4				
crabgrass	WC	33	16		9					4	3		2				
Echinochola spp.	NC	8			9					1			< 1				
barnyardgrass	WC				9								< 1				
Setaria spp.	NC			8								3					
foxtail	WC	8								< 1							
Axonopus spp.	NC	8		8	9					7		4	1				
carpetgrass	WC	8		8	9					2		8	1				
Juncus spp.	NC	8	8				8			1	5				2		
rushes	WC	8	8				8			1	6				2		
Sorghum spp.	NC	8		8	9			8		< 1		< 1	< 1			< 1	
johnsongrass	WC	8	8	8	9					1	1	4	6				
Panicum spp.	NC	92	92	100	100	92	92	92	83	28	27	21	15	11	72	70	10
panicgrass	WC	92	86	92	91	77	76	83	76	20	24	17	14	9	7	7	9
Andropogon opp.	NC	92	92	100	100	700	100	83	83	6	17	29	33	37	29	33	27
broomsedge	WC	92	92	92	100	100	100	83	92	0	26	44	46	42	42	47	29
Cyperus spp.	NC	33	23	17	9	15	77	17	25	3	6	1	3	1	7	3	2
nutsedge	WC	33	8	8	0	15	17	17	8	2	< 1	1	6	1	< 1	3	1
Aristida spp.	NC	17	15	8	9	23	8	8	8	2	3	4	3	3	7	8	8
wiregrass	WC	17	16	8	9	23	8	8	8	1	1	2	1	2	2	1	3
Danthonia spp.	NC		8	8	9	8	8	8	8		5	7	6	3	3	1	1
wild oatgrass	WC	8	8	8	0	8	8	8		1	12	10	12	8	7	2	
Sorghastrum spp.	NC	8	8	8	9	8	8	8	17	2	3	3	3	3	3	< 1	1
indiangrass	WC			8	9	8	8		8			2	2	3	4		3
Erianthus spp.	NC					8	8	8	8					< 1	1	< 1	< 1
plumegrass	WC	8		8	9	23	26	17	17	< 1		2	2	4	4	2	4
Paspalum spp.	NC		75	25	18	15	8	8	17		2	1	4	4	6	4	2
paspalumgrass	WC		16	17	27	8	8	8	17		4	4	2	6	6	3	1
Agrostis spp.	NC		8		9						3		1				
bentgrass	WC					16			8					1			1
Tridens spp.	NC			8								3					
purpletopgrass	WC			8								C I					
Rhynchospora spp.	NC			8	9	8		8				2	5	5		8	
beakrush	WC			8	9	8		a				6	4	3		3	
Chasmanthium spp.	NC			8		8	8		77			3		1	3		10
uniolagrass	WC			17			8		17			1			1		2
Poa spp.	NC				9								< 1				
bluegrass	WC																
Eragrostis spp.	NC																
lovegrass	WC				9								< 1				
Number of Genera	NC	74	12	74	74	10	10	10	9								
	WC	13	11	13	14	10	10	8	9								
Forbs																	
Ludwigia spp.	NC	17								1							
seedbox	WC																
Lysimachia opp.	NC	8								1							
loosestrife	WC																
Oxalis spp.	NC	8								1							
woodsorrel	WC																
Lippia spp.	NC																
lippia	WC	8								1							
Crotonopsis *pp.	NC	8								4							
crotonopsis	WC	8								1							
Richardia spp.	NC	8								< 1							
floridapusley	WC	8								6							
Sida spp.	NC	8								< 1							
prickly sida	WC	8								2							
Polygala spp.	NC	8								< 1							
polygala	WC	8								< 1							

Table 2 *(continued)*

Coreopsis *pp.	MC	8								1							
coreopsis	WC	8								< 1							
Pluchea spp.	NC	8								1							
pluchea	WC	9								1							
Erechtites spp.	NC	33								4							
fireweed	WC	42	23						8	8	6						< 1
Mecardonia *pp.	NC	8	8							2	9						
mercardonia	WC	9	16							1	2						
Agalinis spp.	NC	8	15	8						2	3	8					
gerardia	WC	9	16	17						2	8	3					
Pyrrhopappus spp.	NC	17			9					12			1				
falsedandelion	WC	26	16		9					12	< 1		< 1				
Euphorbia spp.	MC	8			9					< 1			< 1				
euphorbie	WC				8								< 1				
Acalypha spp.	NC	8			9					< 1			< 1				
three-seeded mercury	WC				9								3				
Phytolacca spp.	NC	8	8							6	2						
pokeweed	WC	26	8	8		8				3	< 1	< 1		< 1			
Gnaphalium opp.	NC	25	8	17						< 1	1	1					
rabbit tobacco, cudweed	WC	9	16		38	8				< 1	< 1		1	< 1			
Helianthus spp.	NC		8	17	27		8				< 1	< 1	1		< 1		
sunflowers	WC	17	8	17	27	8				1	1	2	2	3			
Verbascum spp.	NC	8								< 1							
mullein	WC	8				8				1				< 1			
Conyza *pp.	NC	58	23	25	27					6	5	3	< 1				
horseweed	WC	42	38	42	18	23	8	8		10	14	8	3	1	< 1	< 1	
Polypremum spp.	NC	33	15	8	18	8		8		3	3	3	1	2		< 1	
goldenweed	WC	26	8	8	9			8		2	3	1	1			< 1	
Diodia app.	NC			8	9							< 1	< 1				
poorjoe	WC	17	15	8	18	8	8	8		1	1	< 1	< 1	2	1	3	
Ambrosia rpp.	NC	42	31		9	8				3	1		< 1	< 1			
ragweed	WC	60	31	17	18	8			8	6	2	4	1	< 1			< 1
Eupatorium spp.	NC	83	100	100	82	61	50	58	50	7	7	4	2	4	3	2	2
dogfennel,boneset	WC	92	100	83	82	77	76	87	83	6	11	7	6	6	6	6	1
Solidago spp.	NC	58	69	83	73	77	67	67	50	2	3	2	4	3	5	3	I
goldenrods	WC	68	61	83	84	89	87	87	68	2	1	2	6	7	6	4	1
Lespedeza spp.[1]	NC	25	54	42	45	38	50	25	25	6	7	6	3	3	4	4	1
lespedezas	WC	33	38	60	66	48	50	42	33	4	7	6	3	2	2	2	2
Aster spp.	NC	33	38	50	36	23	25	25	33	2	3	1	1	< 1	< 1	< 1	< 1
asters	WC	33	31	42	46	23	8	17	26	2	4	2	2	1	2	2	1
Heterotheca opp.	NC	17	23	17	9	8	8	8	8	1	1	4	10	6	8	11	5
camphorweed	WC	26	23	8	18	8	8	8	8	1	1	6	6	14	17	9	7
Cassia spp.[1]	NC	25	31	25		8			17	5	7	< 1		1			< 1
partridgepea	WC	8	64	33	27	8	8		8	1	4	1	1	< 1	< 1		1
Fragaria spp.	NC	8	8	8	9	15		8	8	7	7	1	1	< 1		1	< 1
wild strawberry	WC	8	8	8	8	8	17	17	17	8	3	1	< 1	4	4	2	3
Rhexia spp.	NC	8		8	9	8	8	8	8	< 1		< 1	2	1	1	3	2
meadowbeauty	WC	8	8	8	9	8	8	8		< 1	< 1	1	7	6	7	2	
Hibiscus spp.	NC						8		8						1		1
wild cotton, mallow	WC	8	8	8	9	8	8		8	2	3	6	6	3	6		9
Croton spp.	NC	8	8		9				8	10	3		< 1				1
woolly croton	WC	8	8		9		8			6	2		2		< 1		
Lechea spp.	NC	8				8	8	8	8	4				12	16	15	19
pinweed	WC	8				8	8	8	8	4				21	24	26	30
Potentilla spp.	NC					8	8	8	8					< 1	< 1	< 1	< 1
cinquefoil	WC	8				8		9		< 1				1		< 1	
Rudbeckia spp.	NC		8		9	8	8	8	8		< 1		1	2	1	< 1	1
blackeyedsusan	WC		8			8	17				< 1			1	2		
Carduus spp.	NC		8						8		1						< I
thistle	WC					8								1			
Solanum spp.	NC			8								C I					
nightshade	WC		8				26				< 1			< 1			
Monarda spp.	NC		8								< 1						
beebalm	WC		8						8		< 1						< 1
Haplopappus spp.	NC		8								1						
jimmyweed. burrowweed	WC		8								1						
Lobelia spp.	NC		8								1						
cardinalflower	WC		8								3						
Verbena spp.	NC		8								1						
vervain	WC		8								< 1						
Trichostema spp.	NC			8								< 1					
bluecurls	WC			8								3					
Eclipta spp.	NC			8								1					
eclipta	WC			8								2					
Ageratum spp.	NC																
ageratum	WC			8								< 1					
Tephrosia spp.	NC												1				
goat's rue	WC																

Table 2 *(continued)*

Urtica *pp.	NC																
stinging nettle	WC				9								< 1				
Tragia spp.	NC				9		8	8					< 1		< I	< I	
noseburn	WC																
Pycnanthemum spp.	NC					8	8	8	8					4	3	5	2
mountainmint	WC							8	8							1	1
Circaea spp.	NC																
enchanters-nightshade	WC					8								c I			
Salvia spp.	NC																
sage	WC					8								< 1			
Lactuca spp.	NC					8								< 1			
wild lettuce	WC						8								< 1		
Viola spp.	NC						8	8	8						1	< 1	< 1
violet, pansy	WC																
Galium spp.	NC						8	8	8						< 1	< 1	< 1
bedstraw	WC																
Hyssopus spp.	NC						8	8							1	3	
hyssop	WC																
Elephantopus spp.	NC								8								< 1
elephant's foot	WC																
Erysimum spp.	NC																
wormseed mustard	WC								8								< 1
Number of Genera	NC	31	22	17	19	15	16	16	18								
	WC	31	27	19	20	22	16	13	14								
Semiwoodies																	
Ceanothus spp.	NC	8	8							I	<I						
new jersey tea	WC																
Rubus spp.	NC	75	85	100	100	100	100	92	92	5	6	6	7	7	8	8	7
blackberry	WC	67	61	92	91	92	100	92	100	4	6	9	11	15	23	27	29
Hypericum spp.	NC	33	38	8	18	8		8	17	3	1	7	5	7		I	< 1
pineweed, st. john's wort	WC	33	31	26	18	23		8		1	1	1	2	1		< 1	
Desmodium spp. [1]	NC	25	15	8	27	15	8		25	2	4	< 1	< 1	< 1	1		1
tickclover	WC	17	15	a	9		8		33	2	1	< 1	< 1		< 1		2
Number of Genera	NC	4	4	3	3	3	2	2	3								
	WC	3	3	3	3	2	2	2	2								
Vines																	
Ampelopsis spp.	NC	8	15							<I	2						
peppervine	WC	8					8		8	5					< 1		< 1
Lonicera spp.	NC	8	31	50	46	61	58	58	57	4	2	5	2	2	3	3	4
honeysuckle	WC	17	31	26	27	46	68	67	76	3	2	6	2	4	7	7	9
Smilax spp.	NC	33	38	42	73	46	75	75	58	2	2	4	2	4	3	3	6
greenbriar	WC	33	31	42	36	38	42	67	58	2	< 1	3	4	6	7	4	8
Vitis *pp.	NC	17	38	8	36	38	42	33	50	1	I	2	1	I	I	I	1
grape	WC	8	16	8	9	16	8	17	33	< 1	< 1	< 1	1	1	< 1	1	1
Campsis spp.	NC	8		8	9	8	8		17	13		8	7	5	2		3
trumpetcreeper	WC			8	9	8	8		8			7	6	6	6		11
Centrosema spp. [1]	NC	8	8		9		8			3	7		1				
butterflypea	WC	8	8		9		8			3	10		< 1				
Ipomoea spp.	NC	8			9				8	< 1			< 1				< I
morningglory	WC	8	8		9					< 1	< 1		< 1				
Parthenocissus spp.	NC		8		9		8	8	25		I		< 1		< 1	<I	<I
virginia creeper	WC		8						8		1						< 1
Gelsemium spp.	NC			8	18	15	8	25	42			2	2	3	1	4	6
yellow jessamine	WC			8	18	15		17	42			1	4	3		8	8
Berchemia spp.	NO							8	8							< I	I
supplejack	WC																
Passiflora opp.	NC																
maypops	WC							8	8							< 1	< 1
Cocculus spp.	NC								8								< 1
coralbeads	WC																
Toxicodendron spp.	NC								8								< 1
poisonivy	WC																
Number of Genera	NC	7	6	5	8	5	7	6	10								
	WC	6	6	6	7	6	6	6	8								
Fern																	
Pteridium spp.	NC	17	23	17	27	23	77	25	33	1	< 1	1	3	3	3	3	5
brackenfern	WC	8	8	17	36	23	26	26	33	1	1	< 1	1	1	2	2	1
Clubmoss																	
Lycopodium spp.	NC																
clubmoss	WC	8								< 1							
Total **Genera**	NC	57	45	40	45	34	36	35	41								
	WC	66	48	41	46	40	36	29	34								

[1] Symbiotic nitrogen fixer.

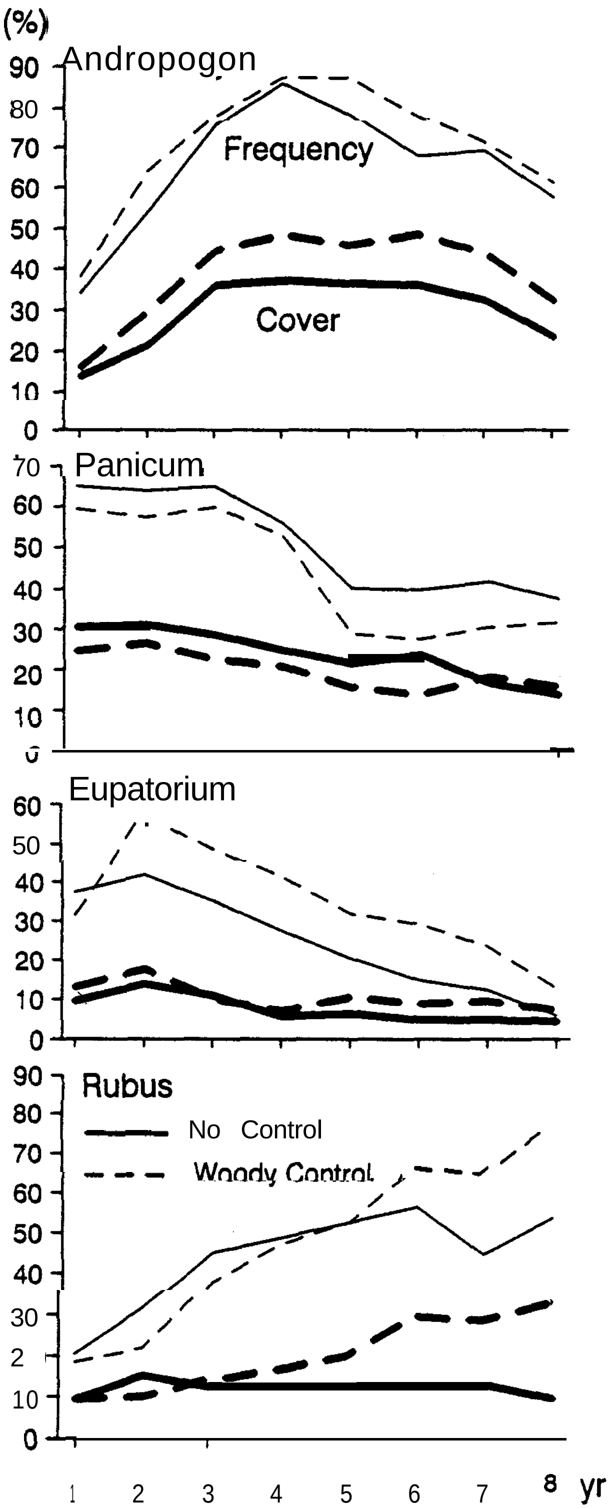

Figure 5. Mean frequency and cover of the four genera that occurred at all locations comparing No Control and Woody Control.

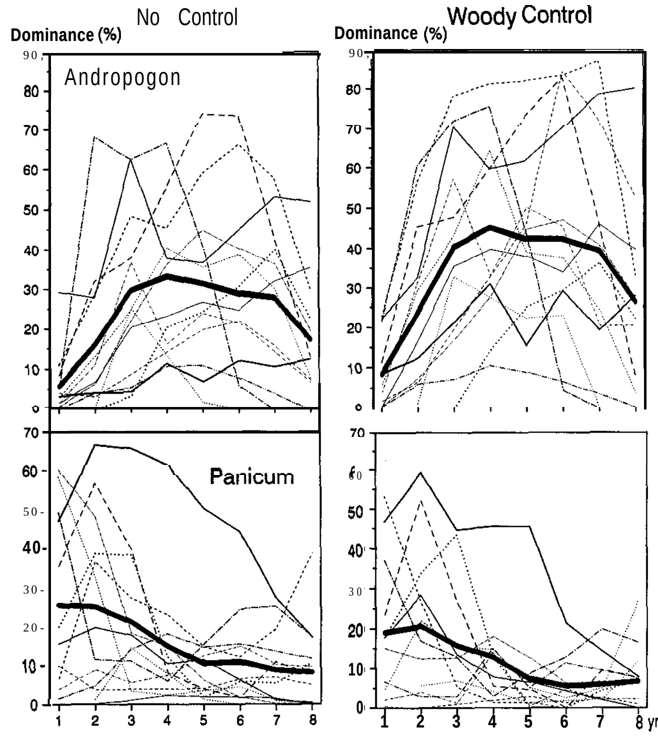

Figure6. Overall mean dominance (dark line) and dominance for each of the 13 locations for *Andropogon* and *Panicum*, *No* Control and Woody Control.

except one, while rapid increases were common from yr l-3. Maximum *Andropogon* levels occurred from yr 2-7 with No Control and from yr 3-7 with Woody Control, and were increased with Woody Control at every location except one. Three locations (solid lines in Figure 6) were still showing increasing trends in *Andropogon* at year 8. *Panicum* increased at 7 locations and decreased at 4 locations between yr 1 and 2, regardless of treatment. (Two locations did not note *Panicum* in these years.) Of the 7 locations with increases, 4 locations had peak levels in year 2. A second peak occurred or the level was still increasing at year 8 at 6 locations with No Control and 9 locations with Woody Control. It is probable that the annual *Panicum* species that characterized the first peak were being replaced by perennial *Panicum* species. By yr 8, *Panicum* of sufficient levels to be recorded had disappeared from No Controls at 5 locations and from Woody Controls at 2 locations. Greater variation in *Panicum* dominance possibly is due to the greater number of annual and perennial *Panicum* species in the region, about 60 total, compared to less than 10 perennial *Andropogon* species.

What are the early establishment patterns of woody plants after moderately intensive site preparation, like chopping and burning?

In the first year following drum chopping and burning (No Control), there were an average of 4,755 nonarborescent rootstockslac (ranging from 359–16,5 14) and 1,852 arborescent rootstocks/ac (471–3,495)(Figure 7). The majority of woody plants were established in the first year, with most nonarborescents probably coming from seed and arborescents from sprouting residual rootstocks (Miller, unpublished data). Relatively few additional species of either type appeared past the second year. Also, volunteer pines (not included in Figure 7) in the first year averaged 118 stems/ac (22-1,098) and increased to 443 stems/ac (67–5,067) in the second year, even with some control measures. The persistent invasion of pines characterized early succession on most sites.

Maximum numbers of nonarborescent woody plants with No Control peaked in year 4 at 5,300 rootstockslac, followed

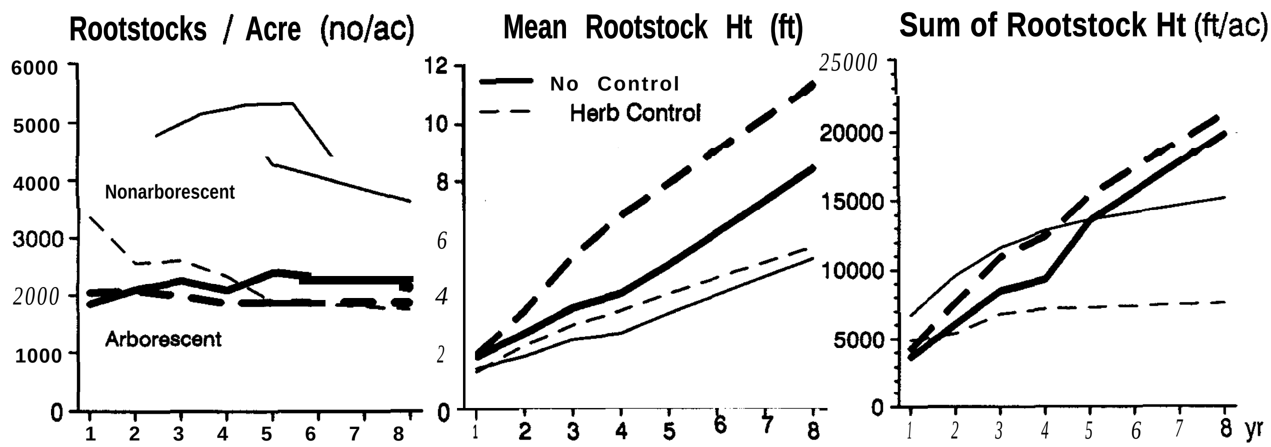

Figure 7. Overall means for density, height, and cumulative size per acre of arborescent and nonarborescent woody plants with No Control and Herbaceous Control treatments.

by a 20% decrease in year 5 and continued slower declines to year 8. Arborescent rootstocks increased slightly to a maximum mean level of 2,400/ac in yr 5, with the actual peak possibly occurring in yr 6 or 7 when data was not collected. Nonarborescent numbers were 2.3-2.5 times those of arborescent woody plants through year 4, declining to only 1.7-1.8 more by yr 8. Average height growth rates on No Control treatments for arborescent rootstocks was greater than nonarborescent rootstocks, 0.7 ft/yr versus 0.4 ft/yr in yr 1–4 and 1.1 ft/yr versus 0.6 ft/yr in yr 4-8, respectively.

The sum of rootstock heights (density weighted by rootstock height) provides a measure of the dominance of woody plants. During the first 4 yr, the sum of the rootstock heights per acre was 3,000–3,500 more for nonarborescent shrubs than arborescent hardwoods, at yr 5 they were equal, and arborescents became 30% more dominant by year 8 with continued divergence. This trend is due to greater height growth rates for arborescents and the declining numbers of nonarborescent shrubs, most notably the sumacs (*Rhus* spp.)(Table 3). The lower position of nonarborescent species in the canopy over time relative to arborescent species and lower light and moisture levels would seem to be a contributing factor to declining numbers of nonarborescent rootstocks.

How does herbaceous control alter woody competition development?

In general, the density of shrubs (nonarborescents) was influenced more by Herbaceous Control than were the density of hardwoods (arborescents) (Figure 7). Arborescent rootstock numbers were comparable in No Control and Herbaceous Control treatments. In contrast, after the first year, shrub rootstock numbers were consistently around 50% lower on Herbaceous Control plots than on No Control plots. The lower number of nonarborescent woody plants with Herbaceous Control may be due to shading by the more rapidly growing, released hardwoods and/or herbicide damage.

Rates of arborescent rootstock height growth were more than doubled during yr 1-4 with Herbaceous Control-O.7 ft/yr without control and 1.6 ft/yr with control. Nonarborescents grew at a rate of 0.4 ft/yr without control compared to 0.5 ft/yr with control. From yr 5-8, arborescent growth was equal between treatments, 1.1 ft/yr, while the height growth for nonarborescents averaged 0.6 ft/yr with No Control and 0.5 ft/yr with Herbaceous Control. Greater early growth resulted in an average of twice the basal area at age 5 of arborescent hardwoods with Herbaceous Control compared to No Control (Miller et al. 1991). Overall by age 5, arborescent hardwoods increased 55% in height after Herbaceous Control, compared to an average of 39% for planted pines.

The slightly lower numbers of arborescent rootstocks with Herbaceous Control grew faster in height for the first 4 yr, resulting in slightly greater levels of summed rootstock heights. In general, sum of arborescent rootstock heights tended to increase linearly (the rate of increase decreasing very slightly from yr 5–8), while nonarborescents increased to yr 3 or 4 and began to level off. Arborescent sum of rootstock heights was only slightly higher with Herbaceous Control while that for nonarborescents was much higher with No Control due to much higher rootstock density on that treatment. Using sum of rootstock heights as a measure of woody dominance, arborescents dominated Herbaceous Control situations from early on while with No Control, nonarborescents dominated in the first few years and arborescent species by yr 7 and 8.

What were the woody plant species in these loblolly pine plantations and did herbaceous control treatments alter their occurrence?

Table 3 shows the 23 nonarborescent and 53 arborescent woody species (genera) identified on the 13 locations, along with the percent of locations on which they were found and the mean density and size-density relations. Because the mean density and mean sum of rootstock heights are averages for all locations, Table 3 presents values for two idealized composite stands relative to treatment, permitting comparisons of relative dominance.

By far the most common and abundant nonarborescent woody species was winged sumac *(Rhus copallina).* Other

Table 3. Nonarborescent and arborescent woody plants for the first 8 yr; the percent of locations when found, overall mean rootstocks per acre, and sum of the rootstock heights per acre (ft/ac), for No Control (NC) and Woody Control (WC) treatments (Trt). Names follow Little (1979) and Radford et al. (1983).

Species or Genera and common names	Trt	Percent locations when found						Rootstocks per acre						Sum of rootstock heights per acre					
		1	2	3	4	6	8	1	2	3	4	6	8	1	2	3	4	5	8
Number of locations sampled:		12	13	12	12	12	12												
Nonarborescent																			
Rhus copallina L.	NC	83	86	92	92	83	83	2407	2759	2667	3018	2039	1092	3848	6614	6639	7324	7407	6970
winged sumac	HC	92	85	83	83	83	76	1868	1280	1176	1248	939	632	2498	2981	3268	4108	3940	3003
Vaccinium spp.	NC	88	77	67	76	76	83	278	277	309	486	387	490	333	404	661	844	783	7338
vaccinium (huckleberry)	HC	58	64	60	87	60	60	270	76	149	192	134	180	321	129	240	346	304	429
Myrica cerifera L. [1]	NC	50	54	68	60	60	42	740	174	767	731	796	267	233	489	636	637	7030	7434
waxmyrtle	HC	42	31	33	42	42	26	82	72	62	48	64	96	127	192	168	171	226	388
Callicarpa americana L.	NC	68	64	68	60	60	60	88	776	160	767	772		121	787	262	330	230	482
American beautyberry	HC	50	48	42	50	33	33	61	42	39	34	26	47	69	86	101	84	80	161
Rhus glabra L.	NC	60	46	33	33	33	77	680	369	174	772	726	22	932	683	428	468	497	78
smooth sumac	HC	42	23	17	26	26	17	179	78	21	62	30	9	303	203	97	179	88	47
Crataegus *pp.	NC	26	39	42	50	68	33	27	66	54	76	62	60	32	80	170	796	764	267
hawthorn	HC	26	39	33	33	33	17	39	19	21	13	17	7	43	38	49	34	24	11
Ilex vomitoria Ait.	NC	26	23	26	26	26	26	6	6	17	28	49	76	16	79	60	84		448
yaupon	HC	33	23	33	26	26	33	26	33	46	26	60	87	48	104	228	123	318	624
Prunus spp.	NC	26	39	33	42	33	26	76	19	28	37	22	21	33	64	97	768	733	766
plum	HC	9	16	9	17	17	17	12	12	6	8	9	15	18	31	21	34	49	114
Baccharis spp.	NC	17	37	42	33	26	26	77	33	776	193	96	738	34	92	717	973	460	1063
baccharis	HC	8	8	8	8		17	11	19	26	28		8	27	73	110	131		39
Ilex glabra (L.) Gray	NC	17	76	77	77	77	77	976	7273	7469	960	906	7 766	7244	7807	2796	7876	2739	3448
gallberry	HC	17	15	17	17	17	17	966	891	1047	880	694	739	1326	1667	2494	1881	2108	2724
viburnum spp.	NC	8	8	8	77	33	8	36	2	9	9	37	2	47	2	9	28	708	6
viburnum (haw)	HC	17	8	8	17	26	17	24	2	4	4	17	7	36	3	8	16	82	46
Ligustrum sinense Lour.	NC	77	76	77	8	8	33	4	3	4	4	4	73	6	9	15	79	79	82
privet	HC		8				17		10				9		10				28
Rosa spp.	NC	77	8	8	8	77	8	4	6	32	28	73	8	4	7	47	46	101	73
rose	HC	8		9		17	8	13		2		6	4	15		4		6	4
Aralia spinosa L.	NC		76	8	77	26	8		7	2	4	77	2		77	4	76	47	22
devils-walkingstick	HC	8					8	4					2	8					29
Lyonia *pp.	NC	8	8	8		8	8	69	92	734		760	763	97	727	223		376	393
lyonia	HC	8	8	8		8	9	18	22	22		26	26	18	30	31		48	69
Styrax grandifolius Ait.	NC	8	8	8				73	9	9				73	9	77			
bigleaf snowbell	HC																		
Rhus typhina L.	NC	8						4						4					
staghorn sumac	HC		8						6						14				
Cyrilla racemiflora L.	NC		8												7				
titi	HC																		
Asimina triloba IL.1 Dunal	NC				8	8	8				2	4	6				4	4	9
pawpaw	HC			8	9					8	2					8	2		
Erythrina spp.	NC			8	8					4	4					9	13		
coralbean	HC			8	8					2	6					2	22		
Serenoa repens	NC																		
saw palmetto	HC				8						6						18		
Halesia *pp.	NC					8						4						9	
silverbell	HC																		
Rhododendron spp.	NC					8						2						4	
azalea	HC	—	—	—	—	—	—												
Number of species (genera)	NC	Ib	77	17	76	18	76												
	HC	14	14	16	14	12	16												
Arborescent																			
Liquidambar styraciflua L.	NC	76	86	83	83	83	83	417	476	682	607	667	494	7063	1777	2462	2673	3298	4866
sweetgum	HC	93	86	92	93	83	93	429	486	488	434	376	432	1104	2218	3390	3829	3972	8228
Quercus nigra L.	NC	58	62	76	67	76	76	273	369	482	398	660	489	469	7770	7970	2732	3923	6876
water oak	HC	87	89	76	83	76	75	191	248		237	367	338	394	981	1918	1911	3601	4778
Quercus falcata Michx.	NC	83	86	83	83	67	76	774	760	787	769	738	96	306	403	679	628	682	928
southern red oak	HC	83	86	83	76	87	67	213	181	187	127	97	101	402	497	901	983	719	1303
Nyssa sylvatica Marsh.	NC	76	77	67	76	83	76	783	174	209	234	209	764	327	498	683	939	997	7272
black tupelo (blackgum)	HC	50	64	60	58	68	42	278	214	209	230	218	202	688	760	1053	1268	1339	1684
Diospyros virginiana L.	NC	67	69	76	76	67	67	176	96	60	76	63	36	204	270	733	230	234	772
persimmon	HC	92	85	76	76	87	97	186	129	126	114	97	110	308	392	644	808	839	768
Acer rubrum L.	NC	60	69	67	76	76	67	56	72	62	76	99	86	737	793	207	296	608	823
red maple	HC	50	64	60	60	58	60	61	102	120	58	106	97	163	422	729	441	974	1268
Quercus stellata Wang.	NC	68	39	77	26	26	42	77	74	46	63	60	49	708	766	727	276	787	284
post oak	HC	67	89	68	50	42	60	62	66	41	68	49	49	101	199	188	288	308	439
Prunus serotina Ehrh.	NC	60	62	60	68	67	76	32	63	41	49	93	69	60	116	723	768	394	678
black cherry	HC	60	39	42	42	42	33	46	26	26	38	24	34	103	81	143	208	198	394

Table 3 *(continued)*

Carya tomentosa (Poir.) Nutt.	NC	50	54	58	68	50	50	39	48	67	73	58	39	66	96	126	173	140	183
mockernut hickory	HC	42	46	60	68	42	42	47	64	63	47	22	28	62	108	126		77	166
Cornus florida L.	NC	25	39	25	33	58	58	80	176	138	93	232	217	153	510	69,	428	,377	2734
dogwood	HC	33	39	33	42	42	58	66	86	36	41	76	69	103	195	164	176	396	466
Quercus alba L.	NC	33	37	33	25	25	77	51	59	38	34	2,	43	773	178	148	158	86'	277
white oak	HC	50	46	60	33	33	26	64	78	24	38	37	47	136	366	171	282	301	632
Sassafras albidum (Nutt.) Nees	NO	42	39	50	25	33	33	78	79	79	64	66	28	IO,	205	249	224	260	159
sassafras	HC	26	39	33	26	42	33	213	212	226	233		140	416	741	,066	1330	1522	1277
Pinus taeda L.	NC	33	23	25	33	25	33	116	438	250	149	132	84	729	686	874	268	266	475
loblolly pine	HC	50	31	17	17	26	33	106	266	146	16	13	11	108	326	978	76	49	66
Liriodendron tulipifera L.	NC	77	23	8	77	2s	25	82	60	2	24	26	47	116	703	17	82	749	357
yellow poplar	HC	17	16	8	17	17	17	92	74	2	30	30	21	136	228	22	129	209	273
Carya glabra (Mill.) Sweet	NC	25	23	17	25	26	25	30	28	19	15	32	30	39	48	73	54	135	170
pignut hickory	HC	17	16	8	17	17	17	13	19	6	16	34	32	19	36	24	66	133	166
Quercus velutina Lam.	NC	17	8		8	8	8	77	16		2	15	20	36	28		73	767	772
black oak	HC	26	8		8	8	8	19	3		2	13	16	34	14		13	108	196
Ulmus alata Michx.	NO	77	23	25	17	17	8	11	17	32	23	7	4	24	40	8,	5,	19	73
winged elm	HC	8	16	17	8		8	0	3	4	2		2	9	6	13	6		13
Ilex opaca Ait.	NC	8	8	8	8	8	8	8	7	8	8	8	6	15	22	34	47	43	58
american holly	HC	17	23	8	8	26	26	6	0	4	4	9	7	7	12	13	19	41	46
Fraxinus pennsylvanica Marsh.	NC			17	8					8	2					2,	8		
green ash	HC	17	23	26	17	26	17	4	6	0	4	6	4	0	0	32	26	60	39
Quercus coccinea Muenchh.	NC	8	8		8	8	8	19	12		15	8	10	49	60		80	110	101
scarlet oak	HC	8	23		17	17	17	13	14		11	6	12	34	48		76	66	180
Quercus laurifolia Michx.	NC	8	8	8	8	8	8	47	28	69	65	39	32	88	84	289	447	325	314
laurel oak	HC	816		8	8	8	8	8	22	17	16	16	6	16	63	96	112	127	64
Quercus phellos L.	NO	17	8	8	8	26	33	7	7	8	8	7	2,	30	22	30	39	45	155
willow oak	HC					8	0					8	2					40	13
Persea borbonia (L.) Spreng.	NC	8	8	8	8	8	8	66	72	76	62	63	73	128	173	322	232	27,	386
redbay	HC	8	16	17	8	17	17	44	67	68	67	66	62	84	174	224	301	320	411
Cercis canadensis L.[1]	NC	8	8		8	8		2	2		2	2		2	2		2	2	
eastern redbud	HC	8	16	6	17	17	17	4	6	2	6	6	9	11	17	11	24	39	148
Celtis occidentalis L.	NC	8	8	8	8	8	8	2	5	30	19	28	26	4	16	77	7,	121	99
hackberry	HC	8	8	17	17	17	17	9	9	21	22	10	17	17	19	99	120	108	133
Sapium sebiferum IL.1 Roxb.	NC	8	8	8	8	8	8	8	3	4	2	2	6	13	10	13	9	11	62
tallowtree	HC	8	8	8		8		2	2	2		2		4	12	19		28	
Oxydendrum arboreum (L.) DC.	NC	8	8		8	8		2	2		2	2		8	9		9	11	
sourwood	HC	8	16		8	8	8	2	7		4	4	6	2	26		22	30	50
Morus spp.	NC			8	8		17			2	2		4			2	2		79
mulberry	HC	8	8		17		8	4	3		4		2	19	19		13		37
Robinia pseudoacacia L.[1]	NO	8	8	8	8			2	3	77	8			4	9	30	22		
black locust	HC																		
Quercus prinus L.	NC	8	8		8		8	2	2		2		2	4	7		77		8
chestnut oak	HC		8		8	8			0		2	2			26		17	16	
Pinus echinata Mill.	NC	8	8	8	8	8		2	5	8	11	9		2	7	15	32	39	
shortleaf pine	HC	8						2						2					
Magnolia virginiana L.	NC																		
sweetbay magnolia	HC	8	8	8	17	8	8	2	2	2	4	2	2	2	3	11	13	13	19
Pinus virginiana Mill.	NC				8	8	8				26	49	24				82	334	245
virginia pine	HC	8			8	8	8	6			37	28	36	6			129	202	469
Salix nigra Marsh.	NC	8	15	8				34	12	6				4,	2,	15			
black willow	HC																		
Juniperus virginiana L.	NC						17						9						22
eastern redcedar	HC	8			8	8	8	2			2	2	6	4			11	13	8
Fagus grandifolia Ehrh.	NC			8						2						6			
american beech	HC	8						2						2					
Ulmus rubra Muhl.	NC	8			8			4			2			4			4		
slippery elm	HC																		
Melia azedarach L.	NC																		
chinaberry	HC	8						2						6					
Albizia julibrissin Durazzini[1]	NC	8						2					4						
mimosa	HC																		
Quercus marilandica Muenchh.	NC		8	8		8	25		2	2		2	11		2	2		2	54
blackjack oak	HC		8				8		2				2		3				37
Castanea pumila (L.) Mill.	NC																		
chinkapin	HC		8		8	8	8		9		2	2	2		14		13	22	22
Hamamelis virginiana L.	NC				77						6						11		
witch-hazel	HC		8	8	8				3	2	6				6	4	9		
Ulmus americana L.	NC		75						3						7				
american elm	HC																		
Quercus virginiana Mill.	NC																		
live oak	HC		8						2						10				
Platanus occidentalis L.	NC			77	8	17	77			4	4	11	6			17	9	49	67
sycamore	HC			8		8	8			2		4	4			28		84	121

Table 3 *(continued)*

Carpinus caroliniana Walt.	NC			17	8	17	17	7	3	8	11	37	8	52	99
am. hornbeam (ironwood)	HC					8	8			2	2			6	6
Malus angustifolia (Ait.) Michx.	NC			8	8	17	17	2	3	8	7	8	9	41	89
crab apple	HC				8				11				67		
Quercus shumardii Buckl.	NC														
shumard oak	HC			8				2				2			
Fraxinus americana L.	NC				8				3				13		
white ash	HC														
Aesculus pavia L.	NC														
red buckeye	HC				8				2				6		
Pinus elliottii Engelm.	NC					8				2				4	
slash pine	HC														
Pinus palustris Mill.	NC						8				2				2
longleaf pine	HC														
Amelanchier arborea (Michx. f.) Fem.	NC														
serviceberry	HC						8				2				28
Number of species **(genera)**	NC	32	32	32	38	33	33								
	HC	33	33	27	34	33	36								

[1] Symbiotic nitrogen fixer.

nonarborescents occurring on at least half the locations were huckleberry (*Vaccinium* spp.), waxmyrtle *(Myrica cerifera)*, American beautyberry *(Callicarpaamericana)*, smooth sumac (*Rhus glabra*), and hawthorn (*Crataegus* spp.). Waxmyrtle is the only shrub associated with nitrogen fixation and occurred at 7 sites. Gallberry (*Ilex glabra*) was the dominant nonarborescent species on the two locations where it occurred—Atmore (AL) and Pembroke (GA).

Sweetgum *(Liquidambar styraciflua*) and water oak (*Quercus nigra)* were the most commonly found and most dominant arborescent hardwoods, although not present at the northern locations of Counce (TN) and Appomattox (VA). Eleven other arborescent species occurred on at least half the locations, including southern red oak *(Q. falcata);* black tupelo (*Nyssa sylvatica);* persimmon *(Diosypros virginiana);* red maple (*Acer rubrum*); post oak (Q. *stellata);* black cherry (*Prunus serotina);* mockernut hickory *(Carya tomentosa);* dogwood (*Cornus florida*); white oak (*Q. alba);* sassafras *(Sassafras albidum);* and volunteer loblolly pines. Three woody species recognized for symbiotic nitrogen fixation—eastern redbud *(Cercis canadensis);* black locust *(Robinia pseudoacacia);* and mimosa *(Albizia julibrissin)*-were present only on one or two sites and were infrequent in occurrence.

Of the 23 nonarborescent species, 18 were found on both No Control and Herb Control plots with 4 being unique to No Control and one to Herb Control treatments. Only infrequently occurring nonarborescent species were found on only one treatment. Of the nonarborescent species, only yaupon (*Ilex vomitoria)* appeared to respond positively to Herbaceous Control treatments. For all other 17 nonarborescent species found on both treatments, the sums of the rootstock heights consistently decreased with Herb Control as shown earlier for cover (Table 3).

Of the 53 arborescent species, 38 occurred on both treatments with 8 only on No Control and 7 only on Herb Control. Those unique to one or the other treatment occurred only at one or two locations and most for only 1 yr. Of the 12 most common arborescent hardwoods, 8 showed a positive response to herbaceous control based on summed heights per acre and 4 showed decreases. Persimmon and sassafras showed the greatest proportion of increase following herbaceous competition control.

General Discussion

Overall, it is striking that successional trends at the various locations were so similar across such a broad geographical area, contrasted to some other forest regions. A core of prevalent genera and species were present at most locations, with the dissimilar sites being on the edges of the region—Pembroke (GA), Counce (TN), and Appomattox (VA). *Panicum* and *Andropogon* grasses and *Rubus* dominated herbaceous succession at most sites. There were eight arborescent and two nonarborescent woody species (genera) that occurred at all but one or two locations. While having similar core species, each location had unique patterns of component and plant establishment, and other unique genera and species. Similarities can obviously be attributed to the limited range in environmental conditions within this region-undivided by mountains or bodies of water-and also to the common means of disturbance applied to all sites and the common pine planting density.

The extreme treatments examined made surprisingly minor alterations to the successional patterns at this intensity of study. The sustained coverage of herbaceous plants with Woody Control occurred in similar relative proportions of grasses, forbs, and vines found on No Control. The slight increase in actual forb cover could significantly influence forage quality, nitrogen fixation, and species diversity. It is evident that the sizable increases in blackberry with Woody Control could enhance wildlife food, when fruit is produced (Miller and Witt 1991). Total woody cover did not increase with Herbaceous Control (as did herbaceous cover with Woody Control), but the proportions of trees increased with a decrease in shrubs. Herbaceous control accelerated height growth of hardwoods, shortening the browse-height window, while fruit-bearing shrubs were decreased. However, mast production by the rapidly grown hardwoods should commence sooner.

Besides the obvious component eliminations by treatments (e.g., woody species by Woody Control), it is impossible with this study design to accurately identify specific species that are added or omitted from the stands because of shifts in competition-cooperation balances alone. The 24 herbaceous genera and 5 nonarborescent and 15 arborescent woody species that occurred only on one or the other treatment situation may simply be due to low frequency on study locations, low intensity of sampling, small plot size, and for herbaceous plants, a minimal cover value for recording. These will require closer examination. Only one genera of herbaceous plants was found that contains a species currently listed as threatened, which is *Solidago spithamaea* M.A. Curtis in Tennessee, which should not be influenced by pine management treatments since it only occurs on Blue Ridge Mountain balds (U.S. Fish and Wildlife Service 1992). No threatened or no endangered species were identified on any study plots.

Those plants that take part in symbiotic nitrogen fixation may play an important role in providing nitrogen for the entire stand. Wood et al. (1992) found significant nitrogen increments from preplant conditions at the Tallassee (AL) location when herbaceous vegetation was not controlled. Lespedeza accounted for 1 O-l 5% cover during the first 3 yr on both treatments and waxmyrtle, 10% at age 7 on the No Control treatment and less than 1% on Herb Control treatments. The most common legume at COMP sites was *Lespedeza* spp. that occurred at all sites except Pembroke (GA), while *Cassia* spp. appeared in yr l-2 at all sites except Pembroke and Appomattox (VA). Other plants associated with nitrogen fixation were one semiwoody, one vine, one shrub, and three tree species (footnotes Tables 2 and 3). Of these, it appears that the shrub, waxmyrtle, was most influenced by treatment with decreased occurrence, density, and growth with Herbaceous Control.

The rapid establishment of herbaceous plants following chop-and-burn site preparation has been noted by both Stransky et al. (1986) in Texas and Conde et al. (1983a and b) in Florida. *Andropogon* and *Panicum* were also the major genera of grasses at these outlying locations. The Texas research likewise found that the majority of woody species became established in the first few years. The core arborescent species initially established on COMP sites are mostly those that remain to participate in near-climax stands on upland Coastal Plain sites (Quarterman and Keever 1962). Other comparisons with prior research is difficult because of the unique scope and treatments with COMP.

Summary

The early secondary successional trends across 13 loblolly pine plantations appear to be as follows:

a. Establishment of herbaceous plants was rapid after moderately intensive mechanical site preparation and prescribed burning, averaging greater than 80% cover in the first year, even after Woody Control treatments.

b. During the 8 yr following site preparation, herbaceous cover declined in the absence of other vegetation control treatments. Removal of woody plants (both hardwoods and shrubs) allowed herbaceous cover to remain nearly constant over the same period, being significantly greater than in the presence of hardwoods and shrubs from yr 3 onward.

c. The occurrence and cover of the prevalent genera of herbaceous plants were not drastically changed by complete Woody Control. Grasses (and grass-like) were the most abundant herbaceous plants. On the average, maximum grass cover was reached in yr 4 regardless of treatment. Woody Control resulted in a slight increase in the cover of grasses but not by a greater proportion than the general increase in total herbaceous cover. The most prevalent grass genera were *Andropogon* and *Panicum.* With the control of woody plants, the dominance of *Andropogon* was increased and *Panicum* decreased.

d. On average, forb cover peaked in yr 1 with No Control and was sustained for an additional year with Woody Control. Also, the proportion of forb cover to total herbaceous cover slightly increased with Woody Control. The most common and dominant forb genera were *Eupatorium, Solidago, Conyza*, *Lespedeza*, and *Aster*. *Rubus* steadily increased to become a dominant cover by year 8 on Woody Control treatments. The actual cover of vines was also increasing in yr 6-8 with Woody Control, but not the relative proportion.

e. Total woody cover was not affected by Herbaceous Control treatments; however, basal area and cover of arborescent hardwoods were increased with an associated decrease in shrub cover. Shrub rootstock density was also reduced by herbaceous control while arborescent rootstock density was unaffected.

f. Fifty-three species of arborescent and 23 species of nonarborescent woody plants were identified. Most woody plants were established in the first year. Sweetgum and water oak were the most common and most abundant arborescent hardwoods, while winged sumac was the most common nonarborescent shrub.

It should be remembered that the duration of woody and especially herbaceous control was lengthy. Treatments were extreme in intensity relative to single season, single application operational treatments following site preparation. We would assume that less intensive operational treatments would have less affect on vegetation dynamics than reported here. In addition, the documentation of treatment effects on plant species diversity were also limited due to the recording of only prevalent herbaceous genera, the use of September assessment times, and the limited plot sizes per treatment-location.

This study has made us more aware that the richness of flora that grows and flourishes in pine plantations is at the same moment a heritage and a legacy that must be known and valued to be wisely managed-our shared responsibility.

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