# Stand Dynamics and Plant Associates of Loblolly Pine Plantations to Midrotation after Early Intensive Vegetation Management— A Southeastern United States Regional Study

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**ABSTRACT:** *Increasingly, pine plantations worldwide are grown using early control of woodv and/or herbaceous vegetation. Assuredsustainablepractices require long-term data on pine plantation development detailing patterns and processes to understand both crop-competition dynamics and the role of stand participants in providing multiple attributes such as biodiversity conservation and wildlife habitat. This study examined loblolly pine (*Pinus taeda *L.) plantations across 13 southeastern sites grown for 15 yr with near-complete control of woody, herbaceous, and woody plus herbaceous components during the first 3-5 yr compared to noplantcontrol. This multiple objectiveexperiment (the COMProject) documents standdynamics at the extreme corners of a response surface that encompasses most conditions of woodv and herbaceous competition common to pine plantations in the region. This is the first of two companion reports. After 15 yr, patterns of stand development remained significantly altered by early control treatments and were influenced most by the amounts of hardwoods and shrubs present or controlled. Herbaceous components were more similar across the region. Associatedplants in theseplantations included 68 species of trees, 33 species/genera of shrubs, and 140 genera of herbaceous and semiwoodvplants, woody vines, clubmoss, and ground lichen— 241 total taxa or an estimated 490 total species-more richness than previously reported or assumed. Hardwood rootstock numbers were on average maintained at fairly constant levels from yr I-15 when not controlled, with no initial lag phase evident for reestablishment, indicating prior stand origin. Dynamics of associated vegetation were significantly altered with woody control initially increasing herbaceous cover, while herbaceous control increased hardwood cover and decreased shrub cover. After early herbaceous control, hardwood basel area (BA) was increased by an average of 28%. After rapid early colonization, herbaceousplants began to decline on all treatments aboutyr 8 as pine and/or hardwood canopy cover reached a total of 50–60%, while woody vines continued to increase. By age 15, plant component richness remained significantly changed by early treatments at all locations, most notably fewer tree species after early woody control. South. J. Appl. For. 27(4):00–00.*

*Key* **Words:** *Pinus taeda* L., woody plant control, woody plant competition, hardwood competition, shrub competition, herbaceous plant control, herbaceous competition, forestry herbicides, species richness, plant diversity, biodiversity, tree plantation development, plantation succession.

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The juvenile growth of loblolly pine is accelerated by early herbaceous and longer term woody competition reductions (Cain and Mann 1980, Nelson et al. 198 1, Zutter et al. 1986, Bacon and Zedaker 1987, Glover et al. 1989, Fredericksen et al. 199 1, Haywood 1994, as examples). There are many reports of early increased growth of loblolly pine plantations after competition control; however, there are few reported long-term outcomes after stand closure. Both plant component and pine data are needed to learn fully how stand and site characteristics altercompetition dynamics and how associated stand components provide multi-attributes required for sustainable forestry. Furthermore, to learn how the interaction ofplantation stands and site characteristics alter competition dynamics, it is essential to study both pine and competing plants from many locations established using the same study protocol. To gain a needed regional perspective, strategically located study sites within a range of physiography, topography, and commonly occurring soil sites are required. Such information needs become more urgent when it is realized that pine plantations currently occupying 15% of southeastern forestlands may occupy 26% by 2040 (Wear and Greis 2002).

Current knowledge is limited in the understanding of how competition components of woody and herbaceous vegetation interact to alter long-term plantation development. Important to this understanding is the need to use near-absolute competition control at study locations so that responses to other treatments can be appropriately scaled and compared across sites in relative (site quality equalized), as well as absolute, terms. These data and understandings are needed to guide management refinements aimed towards developing productive sustainable culture as well as baseline data for furthering forest vegetation management science. As awareness and concerns about biodiversity are heightened, data on composition and its alterations by plantation management become critical.

To address some data omissions, a group of investigators with USDA Forest Service, university, and forest industrial cooperators established a region-wide study termed the Competition Omission Monitoring Project (COMProject or COMP) in 1984. This research project employs a unified protocol that continues to examine loblolly pine plantation development relative to four, near-absolute, early competition control treatments(Milleret al. 1987, 1991, 1995a and 1995b, Zutter et al. 1995, Zutter and Miller 1998). The design isolates the influences of the two major competition groups-woody and herbaceous plants-and documents their long-term development and interaction with uniformly established pine. The aim was to study outcomes relevant to intensifying practices of plantation establishment in the region, and to explore the limits of pine plantation productivity following intensive early competition control. This 15 yr analysis of the data and synthesis examines patterns of plantation stand development from both silvicultural and plant successional perspectives, and summarizes results in two companion reports (Miller et al. 2003 *this issue).*

The study objectives examined in this first part of the companion reports are:

1. To describe how early complete control of woody, herbaceous, and woody plus herbaceous vegetation affects patterns of plantation development across the southeastern region.

2. To identify the plant associates in loblolly pine plantations by growth form and track how they are altered in the longer term by intensive control treatments.

This report describes patterns of pine, hardwood, shrub, vine, and herbaceous plant development and their interactions up to midrotation in fully stocked loblolly pine plantations.

## Methods

### Study Sites

A common study design was utilized at 13 plantation sites across four physiographic provinces of the Southeast-the Lower, Middle, and Hilly Coastal Plains and the Piedmont sites located in Louisiana, Arkansas, Mississippi, Tennessee, Alabama, Georgia, and Virginia (Figure 1). Study sites were selected that were on commonly occurring soil series with medium to high productivity for the region (Table 1). Site indices ranged from 57 to 82 (base age 25 yr). Soil physical and nutritional analyses for each site have been previously reported (Miller et al. 1995b). Most sites were upland in topography except for the upper river terrace site at Liberty, MS, the bottomland site at Bainbridge, GA, and the poorly drained flatwood site at Pembroke, GA. Past history of most sites undoubtedly included a period of row crop farming on the more level blocks followed by old-field succession and multiple timber harvests of pine-hardwood stands. Immediately prior to establishment, pine plantations or mixed pine-hardwood stands were harvested. At ten locations, site preparation was by roller-drum chopping and prescribed burning, which stimulated woody resprouts and herbaceous regrowth while eliminating standing trees and shrubs. With similar outcomes, a shear, pile, and bum method was used at Counce, TN, while at Atmore, AL, a complete harvest of fuelwood and pine was used without prescribed burning. The Lower Coastal Plain site near Pembroke, GA was rebedded after a wildfire destroyed a young plantation. The wide distribution of study locations across the region in several physiographic provinces with differing prior stand histories provided a wide array of woody and herbaceous competition conditions for investigation.

University Study establishment, was greatly assisted by Steven A. Knowe, University of Tennessee; Kenneth Xydias, Resource Management Services; Richard D. Iverson, BASF; and Lee Atkins, Timberland Enterprises. Precautions: Use of trade names is for reader's information and does not constitute official endorsement or approval by the USDA to the exclusion of any suitable product or process. Pesticides used improperly can be injurious to humans, animals, and plants. Remember to read the entire herbicide label and use only according to label instructions. Store pesticides in original containers under lock and key out of the reach ofchildren and animals and away from food and feed. Manuscript received May 6, 2002, accepted January 17, 2003. 

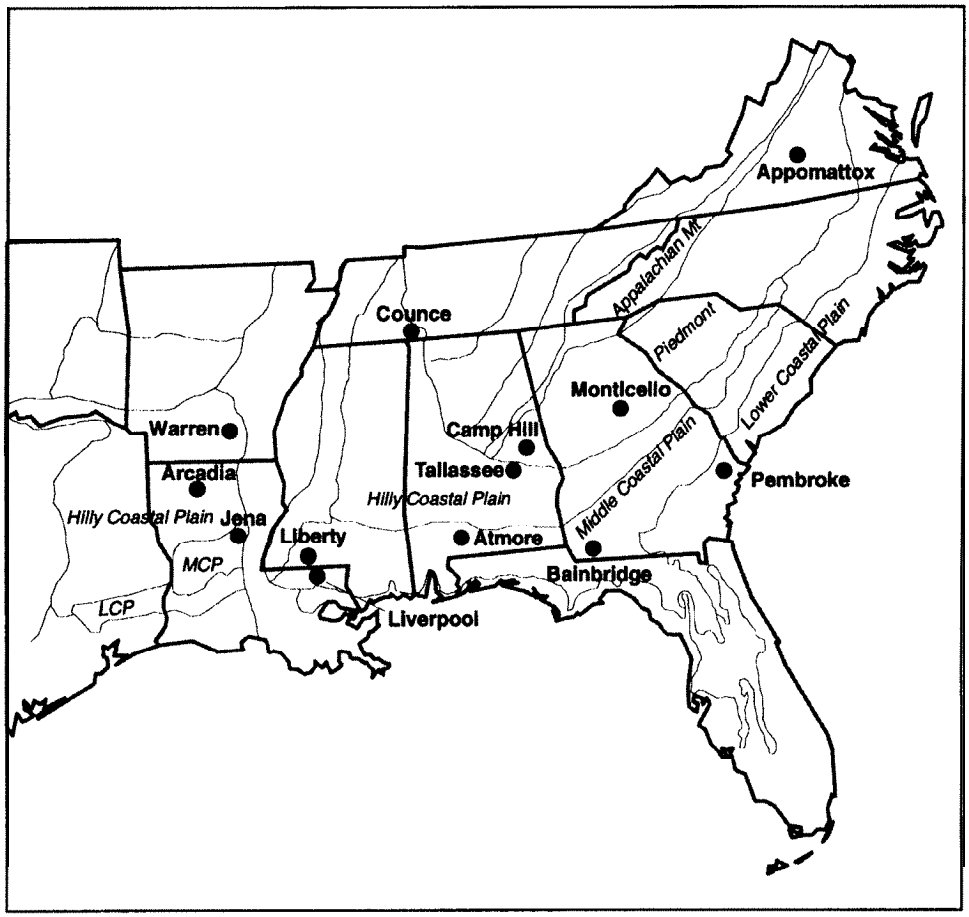


**Figure 1. Competition Omission Monitoring Project study locations relative to physiographic provinces.**

### Experimental Design and Plot Layout

A factorial combination of two woody control treatments (no woody control vs. woody plant elimination) and two herbaceous control treatments (no herbaceous control vs. herbaceous plant elimination) were established in four complete blocks at 11 of the 13 locations. Blocking was by topographic position and/or vegetation composition. At Pembroke, GA, a fifth block was included, and at Bainbridge, GA, a completely randomized design was used in an upper bottomland absent of topographic differences. Treatment plots were generally 0.25 ac in size, and interior measurement plots were 0.09 ac. Precisely measured planting spots on a 9 x 9 ft spacing were used at all but the operationally planted locations of Pembroke, GA and Arcadia, LA. This spacing resulted in 538 trees/ac (565 and 622 trees/ac at the operationally planted locations), with 49 pines in the measurement plots and two border rows surrounding measurement plots.

At most sites, two 1-O loblolly pine seedlings (regraded on site for larger size) were planted at each spot, 10–12 in. apart. First-generation genetically improved seedlings were used at all locations. After the first growing season, double-planted seedlings were thinned to one per spot using randomly generated codes. Only single seedlings were planted at Pembroke, GA; Arcadia, LA; and Liberty, MS. Measurement trees were permanently tagged. Double planting was used to minimize the variation attributable to first-year survival and the resulting long-term variation that occurs with unequal stocking. Adequate survival resulted in stocking levels comparable across locations except at Liberty, where the woody control treatment was the only site/treatment that averaged fewer than 400 trees/ac at age 5 (Miller et al. 1991). Volunteer pines were repeatedly removed from all locations except Appomattox, VA, where Virginia pine (*Pinus virginiana* Mill.) was left on woody competition plots since it is a common woody competitor in this area.

### Establishment of Competition Situations

Four treatments, or competition situations, wereestablished and maintained as follows:

1. *No Control (resulting in mixed herbaceous-woody* competition)-After initial site preparation, no further treatments were applied except for tree injection at selected locations of scattered large residual hardwoods using triciopyr (Garlon).

2. *Woody Control (resulting in mainly herbaceous competition)*—Foliar and basal sprays as well as basal wipes (minimize nontarget plant damage) were applied to control hardwoods and shrubs during the first 3-5 yr. A single preplant and multiple postplant applications per year were made usually with directed sprays ofglyphosate

**Table 1. Study sites location and description.**

| Location | Series | Soil classification |
|---|---|---|
| Low hardwood BA | | |
| Jena, LA<br>*N31°40'27"*<br>*W92°10'39"* | Ruston | Fine-loamy, siliceous, Thermic Typic Paleudults |
| Counce, TN<br>*N35°9'52"*<br>*W87°58'17"* | Silerton | Fine-silty, siliceous, Thermic Typic Paleudults |
| Warren, AU<br>*N33°36'5"*<br>*W92°11'51"* | Saffell<br>Stough | Loamy-skeletal, siliceous, Thermic Typic Hapludults<br>Coarse-loamy, siliceous, Thermic Fragiaquic Paleudults |
| Monticello, GA<br>*N33°17'37"*<br>*W83°30'41"* | Davidson | Fine, kaolinitic, Thermic Rhodic Kandiudults |
| High hardwood BA | | |
| Liverpool, LA<br>*N30°55'7"*<br>*W90°43'27"* | Tangi | Fine-silty, siliceous, Thermic Typic Fragiudults |
| Arcadia, LA<br>*N32°26'56"*<br>*W92°57'22"* | Sacul | Fine, mixed, Thermic Aquic Hapludults |
| Liberty, MS<br>*N31°4'49"*<br>*W90°50'41"* | Cahaba | Fine-loamy, siliceous, Thermic Typic Hapludults |
| Bainbridge, GA<br>*N30°48'56"*<br>*W84°37'24"* | Orangeburg<br>Esto | Fine-loamy, kaolinitic, Thermic Typic Kandiudults<br>Fine, kaolinitic, Thermic Typic Kandiudults |
| Camp Hill, AL<br>*N32°49'42"*<br>*W85°35'48"* | Cecil<br>Pacolet | Fine, kaolinitic, Thermic Typic Kanhapludults<br>Fine, kaolinitic, Thermic Typic Kanhapludults |
| Tallassee, AL<br>*N32°31'38"*<br>*W85°48'42"* | Cowarts | Fine-loamy, kaolinitic, Thermic Typic Kanhapludults |
| Appomattox, VA<br>*N37°28'17"*<br>*W78°47'17"* | Cecil<br>Cullen<br>Iredell | Fine, kaolinitic, Thermic Typic Kanhapludults<br>Very-fine, kaolinitic, Thermic Typic Hapludults<br>Fine, mixed, Thermic Oxyaquic Vertic Hapludalfs |
| High shrubs | | |
| Pembroke, GA<br>*N32°7'48"*<br>*W81°35'26"* | Mascotte<br>Pelham | Sandy, siliceous, Thermic Ultic Alaquods<br>Loamy, siliceous, Thermic Arenic Paleaquults |
| Atmore, AL<br>*N31°15'27"*<br>*W87°17'17"* | Orangeburg | Fine-loamy, kaolinitic, Thermic Typic Kandiudults |

(Roundup), triclopyr, and picloram (Tordon), or basal wipes using triclopyr, a penetrant, and diesel fuel. After planting, only herbicides with no soil activity were used to minimize any potential damage to herbaceous plants and measurement pines.

3. *Herbaceous Control (resulting in mainly woody* competition)-Pre-emergent applications ofsulfometuron (Oust at 3-6 oz/ac) were applied annually for the first 2-5 yr (most often for 4 yr) to control forbs, grasses, and woody vines. After the first year, either glyphosate (Roundup at 18 oz/ac) or oxyfluorfen (Goal at 0.6 gal/ac) were commonly added to a mix with sulfometuron for broader control. At Bainbridge, GA and Liverpool, LA, sethoxydim (Poast) was broadcast-sprayed for grass control in the second year. One to 5 times per year during the first 3-5 growing seasons, shielded directed sprays of glyphosate (Roundup 2% solution) were applied to perennial grasses, resistant forbs, and vines.

4. *Woody and Herbaceous Control (denoted as W+H Control) resulting in elimination of all competition-A* combination of the treatments discussed above were used to control both woody and herbaceous competition during the first 3-5 yr.

Season-long eradication of woody or herbaceous components was approached in the first and second year, but rarely completely achieved (Miller et al. 1987). Late summer herbaceous regrowth often occurred after effective early and midsummer applications, and is reflected in the late summer data (but probably had little influence on season-long pine growth). Significant reductions were made and desired competition situations were obtained with persistent applications at most locations, especially by yr 3. Herbaceous

control treatments were applied for 3-5 yr, while control persisted for several more years on most sites (Miller et al. 1995b). With careful applications, only minimal pine injury was observed with these treatments, being comparable to repeated operational applications, Sulfometuron (Oust) has since been shown to inhibit root growth of loblolly pine seedlings (Barnes et al. 1990), while significant early pine growth indicated inhibition was not enough to prohibit an overall positive response to herbaceous plant control (Miller et al. 1991 and widely observed operationally as well).

**Measurements and Calculations**

Pines were measured for total height (nearest 0.1 ft) in yr l-1 1 and 15. Diameters at breast height (dbh)weremeasured to the nearest 0.1 in. from yr 3-l 1 and 15. Basal area (BA) was calculated by summing the stem area at breast height for all surviving trees. All hardwood rootstock stems, exceeding 4.5 ft in height within each interior measurement plot, were recorded after growing seasons 5, 8, 11, and 15 by species, dbh class (0.5 in. classes) and height class (i.e., classes were 1 ft intervals through 12 ft and 5 ft intervals thereafter). Hardwood BA and sum of stem heights were calculated for each plot.

Within each interior measurement plot, three 9 x 18-ft sample plots were systematically established, with the comers at pine planting spots. This 0.01 ac sample per 0.09 ac measurement plot yielded a 12% sample. All hardwood and shrub rootstocks taller than 0.5 ft within each sample plot were recorded by species and height class (same height classes as hardwoods) in September of yr l-5, 8, 11, and 15. A single rootstock was delineated as a hardwood or shrub plant judged to originate from a common central root system with one or more stems. A combined woody competition variable for hardwoods and shrubs was calculated by adding the sum of stem heights for hardwoods (from measurement plot estimates) and the sum of rootstock heights for shrubs (from sample plot estimates)---termed "sum of woody heights" (similar to that recommended by Knowe 199 1).

For cover estimates, the three 9 x 18 ft sample plots were each halved to yield six 9 x 9 ft subplots per measurement plot. In September for yr l-l l and 15, cover was visually estimated within each subplot for total and component herbaceous cover. Herbaceous components were: forbs, grasses and grass-likes, woody vines, and semiwoody plants [e.g., blackberry and dewberry (*Rubus*) and St. John's-wort *(Hypericum)]*. In this study, woody vines and semiwoody plants were included within "herbaceous cover." Starting in yr 2, visual estimates were added for "total woody cover" and for planted "pine cover."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 loo-permitting finer cover estimates at the extremes.

On each 9 x 9 ft subplot in the No Control and Woody Control treatments, cover for the dominant genera of herbaceous plants (including woody vines and semiwoody plants) was also estimated using the above cover classes. Any genus covering more than 16% of the plot (the 20% class) was recorded and cover estimated-referred to as "prevalent genera." At least three genera were recorded per 9 x 9 ft subplot regardless of coverage, unless only one or two genera were present. In yr 15, all genera of herbaceous plants were recorded on all treatments.

**Analyses**

Three plots out of the 2 12 total plots were deleted from the dataset before analysis due to past land use practices that yielded exceptionallypoorproductivity, asouthempine beetle infestation, or excessive ice damage (one each at Camp Hill, AL; Monticello, GA; and Appomattox, VA, respectively). Also, two blocks affected by wildfire were deleted at the Tallassee, AL location.

To aid in summarization and interpretation, locations weregrouped into woody competition categories. Groupings were developed using SAS Cluster Analysis based on yr 15 hardwood BA and shrub sum of rootstock heights (Figure 2). Three woody competition categories clearly delineated were: Low Hardwood BA (four sites), High Hardwood BA (seven locations), and High Shrub (two locations). These groupings were not discemable until yr 15, although a retrospective examination showed that Low Hardwood BA and High Shrub locations had fewer than 1,800 hardwood rootstocks/ acatyr 1.

Pine and competition data were analyzed separately by location using the appropriate analysis of variance (ANOVA) following arcsine squareroot transformations for percent values. The main effects were defined as *woody treatment* (average of Woody Control and W+H Control vs. average of No Control and Herb Control); *herbaceous treatment* (average of Herb Control and W+H Control vs. average of No Control and Woody Control); and the *woody x herbaceous interaction* (average of W+H Control and No Control vs. average of Woody Control and Herb Control). Tukey's HSD was used to separate treatment means for critical examination of selected variables. A 0.05 level of probability for a Type I error was considered significant with all tests, while 0.01 levels were noted. References in the text to effects of woody treatment or herbaceous treatment refer to tests of main effects from the

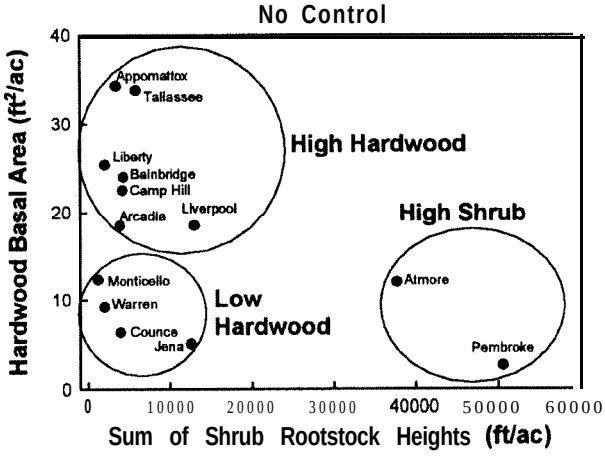


**Figure 2. Study locations grouped by cluster analysis using shrub and hardwood abundance at yr 15.**

ANOVA, whereas references to No Control, Woody Control, Herb Control, or W+H Control refer to the four treatments within the study design. Linear regression analysis was used to examine relationships between pine volume and hardwood BA grown with and without herbaceous competition control. Analyses for homogeneity ofregression coefficients was also calculated using SAS.

## Results

### Hardwood and Shrub Dynamics

The study locations encompassed a wide range of plant competition conditions (Table 2). After 15 growing seasons, hardwood BA on No Control plots averaged 4.9-12.3 $ft^2/ac$ (mean = 8.2 $ft^2/ac$) for Low Hardwood BA sites, 18.5–34.3 $ft^2/ac$

**Table 2. Mean competition attributes at age 15 by vegetation control treatment with sites grouped by woody competition category, and the ANOVA outcomes with main effects and their interaction in bold italics (values are significant differences attributed to treatment and significance of interaction).**

| | Low hardwood BA | | | | | High hardwood BA | | | | | | High shrub | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | Jena | Counce | Warren | Monti- | Liver- | Arcadia | Liberty | Bain- | Camp | Tallassee | Appo- | Pem-broke | Atmore |
| *ANOVA*[1] L | A | TN | AR | cello | pool | LA | MS | bridge | Hill | AL | mattox | GA | AL |
| ***Results*** | MCP[2] | HCP | HCP | GA Pied | LA MCI' | LA HCP | MCP | GA MCP | AL Pied | AL HCP | VA Pied | LCP | MCP |
| | | | | | | Hardwood basal area ($ft^2/ac$) | | | | | | | |
| No | 4.9 | 6.3 | 9.2 | 12.3 | 18.5 | 18.5 | 25.4 | 24.0 | 22.5 | 33.8 | 34.3 | 2.6 | 11.9 |
| Woody | 2.5 | 0.1 | 2.1 | 0.5 | 0.2 | 1.9 | 2.6 | 3.2 | 0.5 | 1.6 | 3.3 | 0.2 | 0.1 |
| Herb | 8.6 | 5.9 | 9.2 | 5.2 | 25. 1 | 29.8 | 30.1 | 33.6 | 33.8 | 42.2 | 41.7 | 3.8 | 23.5 |
| W + H | 0.5 | 0 | 0 | 0 | 0 | 0 | 2.2 | 0.8 | 0.1 | 0 | 0.9 | 0 | 0 |
| ***Woody*** | ***–5.3***** | ***–6.1***** | ***–8.2***** | ***–8.5***** | ***–21.7***** | ***–23.2***** | ***–25.4***** | ***–26.8***** | ***–27.9***** | ***–37.2***** | ***–35.9***** | ***–3.1***** | ***–17.7***** |
| ***Herb*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***–3.8**** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***+5.4***** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***+5.8***** |
| ***W × H*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | * | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ** | ***n.s.*** | * | ***n.s.*** | ** |
| | | | | | | Shrub sum rootstock heights (ft/ac) | | | | | | | |
| No | 12,571 | 3,899 | 1,921 | 1,165 | 13,019 | 3,880 | 2,039 | 4,325 | 4,213 | 4,258 | 3,428 | 50,618 | 37,667 |
| Woody | 1 1,070 | 4,997 | 3,742 | 1,613 | 13,803 | 4,606 | 5,400 | 7,350 | 10,128 | 4,706 | 3,787 | 14,397 | 4,168 |
| Herb | 3,675 | 224 | 179 | 1,501 | 9,255 | I.384 | 3,115 | 1,554 | 2,375 | 2,151 | 919 | 18,902 | 24,828 |
| W + H | 3,585 | 90 | 269 | 381 | 24,178 | 5,740 | 18,060 | 6,117 | 740 | 3,138 | I.390 | 2,904 | 4,549 |
| ***Woody*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***+7,854**** | ***n.s.*** | ***+9,153***** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***–26,110***** | ***–26,889***** |
| ***Herb*** | ***n.s.*** | ***–4,291***** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***+6,868**** | ***n.s.*** | ***–5,613**** | ***n.s.*** | ***n.s.*** | ***–21,605***** | ***n.s.*** |
| ***W × H*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** |
| | | | | | | Herbaceous cover (%) | | | | | | | |
| No | 36 | 31 | 16 | 34 | 14 | 24 | 31 | 32 | 19 | 2 | IO | 8 | 24 |
| Woody | 37 | 49 | 40 | 71 | 32 | 29 | 64 | 55 | 41 | 39 | 34 | 2 | 71 |
| Herb | 4 | 11 | 5 | 2 | 4 | 8 | 21 | 21 | 5 | 4 | 7 | 1 | 5 |
| W + H | 8 | 1 | 1 | 5 | 3 | 5 | 21 | 28 | 2 | 2 | 21 | 1 | 12 |
| ***Woody*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***+20**** | ***n.s.*** | ***n.s.*** | ***+17**** | ***n.s.*** | ***n.s.*** | ***+17***** | ***+19***** | ***n.s.*** | ***+27***** |
| ***Herb*** | ***–31***** | ***–34***** | ***–25***** | ***–49***** | ***–19***** | ***–20***** | ***–27***** | ***–19**** | ***–27***** | ***–17***** | ***n.s.*** | ***–4**** | ***–39***** |
| ***W × H*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | * | ***n.s.*** | * | ***n.s.*** | ** | ** | ***n.s.*** | ***n.s.*** | ***n.s.*** |
| | | | | | | Forb cover (%) | | | | | | | |
| No | 0.3 | 0.4 | 1.3 | 0.4 | 0.0 | 0.1 | 0.0 | 0.3 | 0.3 | 0.0 | 5.3 | 0.1 | 0.2 |
| Woody | 2.0 | 0.4 | 0.4 | 1.1 | 0.4 | 0.1 | 0.9 | 1.0 | 1.0 | 1.9 | 13.7 | 0.2 | 1.2 |
| Herb | 1.0 | 0.4 | 0.4 | 0.6 | 0.3 | 0.1 | 0.0 | 0.1 | 0.4 | 1.0 | 6.5 | 0.1 | 0.0 |
| W + H | 2.0 | 0.5 | 0.1 | 0.4 | 0.8 | 0.5 | 0.1 | 2.2 | 0.7 | 0.1 | 11.8 | 0.1 | 0.1 |
| ***Woody*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***+0.5**** | ***+0.2**** | ***+0.5**** | ***+1.4***** | ***+0.5***** | ***n.s.*** | ***+6.9***** | ***n.s.*** | ***+0.5**** |
| ***Herb*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***+0.2**** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***–0.6***** |
| ***W x H*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | * | ***n.s.*** | * | ***n.s.*** | * | ***n.s.*** | ** | ***n.s.*** | ***n.s.*** | ***n.s.*** |
| | | | | | | Grass cover (%) | | | | | | | |
| No | 0.4 | 0.2 | 7.0 | 8.1 | 0.3 | 0.4 | 0.1 | 3.4 | 0.1 | 0.0 | 2.0 | 3.1 | 0.2 |
| Woody | 0.8 | 0.5 | 18.0 | 44.2 | 0.7 | 2.9 | 2.7 | 16.4 | 3.5 | 3.3 | 3.2 | 1.2 | 2.0 |
| Herb | 0.9 | 0.2 | 4.0 | 0.8 | 0.3 | 0.3 | 0.0 | 0.9 | 0.1 | 1.0 | 2.0 | 0.1 | 0.4 |
| W + H | 0.3 | 0.3 | 0.5 | 0.6 | 0.7 | 0.7 | 0.1 | 4.4 | 0.1 | 0.0 | 2.7 | 0.1 | 0.1 |
| ***Woody*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***+17.9**** | ***+0.4**** | ***+1.4***** | ***+1.4**** | ***+8.2**** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** |
| ***Herb*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***–25.4***** | ***n.s.*** | ***–1.2***** | ***n.s.*** | ***–7.3**** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***–0.8**** |
| ***W × H*** | * | ***n.s.*** | ***n.s.*** | * | ***n.s.*** | ** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | * |

(continued)

**Table 2. (continued)**

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Woody vine cover (%) | | | | | | | | | | | | | |
| No | 25 | 18 | 11 | 23 | 13 | 24 | 31 | 26 | 17 | 2 | 2 | 0.0 | 23 |
| Woody | 24 | 29 | 22 | 19 | 26 | 24 | 61 | 30 | 27 | 8 | 7 | 0.0 | 63 |
| Herb | 3 | 11 | 1 | 1 | 4 | 7 | 21 | 18 | 5 | 3 | 2 | 0.2 | 5 |
| W + H | 5 | 1 | 0 | 5 | 2 | 4 | 21 | 12 | 1 | 2 | 3 | 0.1 | 12 |
| *Woody* | *n. s.* | *n.s.* | *n.s.* | *n.s.* | *n.s.* | *n.s.* | *+15** | *n.s.* | *n.s.* | *n.s.* | *+3*** | *n.s.* | *+23** |
| *Herb* | *–21*** | *–18*** | *–16*** | *–18*** | *–17*** | *–18*** | *–25*** | *–13** | *–19*** | *n.s.* | *–2*** | *n.s.* | *–34*** |
| *W × H* | *n.s.* | *n.s.* | *n.s.* | *n.s.* | *n.s.* | *n.s.* | *n.s.* | *n.s.* | *n.s.* | *n.s.* | * | *n.s.* | *n.s.* |
| Semiwoody cover (%) | | | | | | | | | | | | | |
| No | 7.0 | 11.6 | 0.0 | 1.0 | 0.2 | 0.0 | 0.1 | 0.2 | 0.1 | 0.4 | 3.3 | 3.9 | 0.2 |
| Woody | 14.0 | 19.3 | 0.0 | 3.6 | 5.0 | 3.4 | 0.9 | 0.5 | 4.0 | 30.0 | 10.2 | 0.8 | 1.8 |
| Herb | 0.2 | 0.2 | 0.0 | 0.4 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 2.0 | 0.2 | 0.0 |
| W + H | 0.3 | 0.3 | 0.0 | 0.3 | 0.1 | 0.2 | 2.3 | 2.1 | 0.0 | 0.0 | 6.0 | 0.0 | 0.0 |
| *Woody* | *n.s.* | *n.s.* | *n.s.* | *n.s.* | *+2.4** | *n.s.* | *+1.6** | *+1.5** | *+1.9** | *+14.7** | *+5.4** | *n.s.* | *+0.8*** |
| *Herb* | *–10.3*** | *–15.2*** | *n.s.* | *–1.9*** | *–2.5*** | *n.s.* | *n.s.* | *n. s.* | *–2.0** | *–15.1*** | *n.s.* | *–2.3** | *–1.0*** |
| *W × H* | *n.s.* | *n.s.* | *n.s.* | *n.s.* | * | *n.s.* | *n.s.* | *n.s.* | * | ** | *n.s.* | *n.s.* | ** |

The main effects of woody treatment (average of Woody Control and W + H Control minus average of No Control and Herb Control), herbaceous treatment (average of Herb Control and W + H Control minus average of No Control and Woody Control), and their interaction (average of W + H Control and No Control minus average of Woody Control and Herb Control).

[2] Physiographic province: LCP = Lower Coastal Plain, MCP = Middle Coastal Plain, HCP = Hilly Coastal Plain, and Pied = Piedmont.

[3] n.s.= nonsignficant at $P = 0.05$ , * = significant at $P < 0.05$, and ** = significant at $P < 0.01$.

(mean = 25.3 $ft^2$/ac) for High Hardwood BA sites, and 2.6-11.9 $ft^2$/ac (mean = 7.3 $ft^2$/ac) for High Shrub sites (Table 2). Hardwood BA after the early woody control treatments remained significantly different after 15 yr at all locations (Table 2). Hardwood BA averaged fewer than 4 $ft^2$/ac on all Woody Controls and was 1 $ft^2$ or fewer on W+H Controls except on the highly productive river-terrace site at Liberty, MS (2.2 $ft^2$/ac). The highest hardwood BA sites were Liberty, MS; Bainbridge, GA; Camp Hill, AL; Tallassee, AL; and Appomattox, VA. Sweetgum *(Liquidambar styraciflua* L.), water oak *(Quercus nigra* L.), southern red oak *(Q. falcate* Michx.), and blackgum *(Nyssa sylvatica* Marsh.) were the most common and dominant hardwoods. Over the 15 yr period, a total of 63 hardwood and 5 pine species were recorded as co-inhabitants of these plantations (Appendix Table 1).

Hardwood BAs were numerically greater on Herb Controls compared to No Controls on High Hardwood and High Shrub sites, although these differences were significant according to ANOVA only at Camp Hill, AL and Atmore, AL. The continued divergence at age 15 between Herb Controls and No Controls (Figure 3) indicates that average hardwood BA on High Hardwood and High Shrub sites was continuing to respond to early herbaceous control treatments. Linear regression of No Control vs. Herb Control across all sites was used to further examine hardwood BA at age 15 to determine whether herbaceous control had resulted in significant increase in hardwood BA at yr 15 (plot not shown). The regression was highly significant with an $R^2$ equal to 0.89 and the resulting equation was: Herb Control Hardwood BA = 0.40 + 1.28 x No Control Hardwood BA. To confirm whether herb control had resulted in an average significant increased hardwood BA, the hypothesis of a slope equal to 1 was tested by SAS. The test indicated that the slope of 1.28 was different than 1 and that hardwood BA on average had been increased with herbaceous control by 28%.

Hardwood rootstock numbers were on average maintained at fairly constant levels on both No and Herb Controls from yr 1-15 (Figure 3), with no initial lag phase evident for reestablishment. Analyses of hardwood rootstock numbers in yr 15 (data not shown) found no significant increases on No Controls vs. Herb Controls. The average pattern of stable rootstock numbers did not occur at all locations, but was evident on the majority of sites. When sites and species were examined individually, recruitment and mortality were continually occurring. Yearly dynamics were evident by the minor peaks shown in Figure 3 that occurred on No Controls at High Hardwood BA sites in yr 3 and 5 where emergence and mortality of sweetgum and water oak seedlings occurred at some locations. Immigration and establishment of the hardwood understory is also evident by the increases in hardwood rootstocks on Woody and W+H Controls after cessation of control, especially on Low and High Hardwood sites. This was more evident in rootstock numbers than was apparent in hardwood BA (Figure 3).

Shrub abundance on No Controls, as sum of rootstock heights, ranged widely across sites from 1,165 ft/ac at Monticello, GA to over 50,000 ft/ac at Pembroke, GA in yr 15 (Table 2). The two High Shrub sites are representatives of the forest type common to the Lower and lower-Middle Coastal Plains. Dominant shrub species at these sites at yr 15 were gallberry [*Ilex glabra* (L.) Gray] at both locations, with yaupon (*Ilex vomitoria* Ait.) at Atmore AL, and blueberry *(Vaccinum)* at Pembroke, GA. These species increased in rootstock numbers and abundance from yr 1 l-15 even under fully developed pine canopies (Figures 3 and 4). On Low and High Hardwood BA sites the common dominant shrubs were winged sumac *(Rhus copallina* L.), blueberry, waxmyrtle [*Morella cerifera* (L.) Small], and American beautyberry (*Callicarpa americana* L.) (Miller et al. 1995a). These species collectively declined as tree canopies developed (Figures 3 and 4). A total of 33 shrub species/genera including the palm,

sawpalmetto [*Serenoa repens* (Bartr.) Small] havebeenrecorded on COMP locations through 15 yr (Appendix Table I).

Shrub rootstock numbers were more variable and dynamic than hardwoods ingeneral on No Controls and Herb Controls, tending to either remain constant, decrease, or increase depending upon woody competition category (Figure 3). Short-term shrub dynamics are indicated by theminorpeak in summed heights in yr 3 on High Shrub sites due to temporary increases in gallberry and those in yr 4 and 8onLowHardwood BA sites due to increases in winged sumac. Shrub abundance was significantly decreased with herbaceous treatments at only two sites in yr 15, while decreases were evident on the majority of sites (Table 2). To further examine whether herbaceous controls resulted in average decreases in shrub abundance at yr 15, linear regression was used with sum-height data for No Controls vs. Herb Controls (plot not shown). The highly significant regression with an $R^2$ equal to 0.86 was: Herb Control Shrub Sum Heights = 61 + 0.47 x No

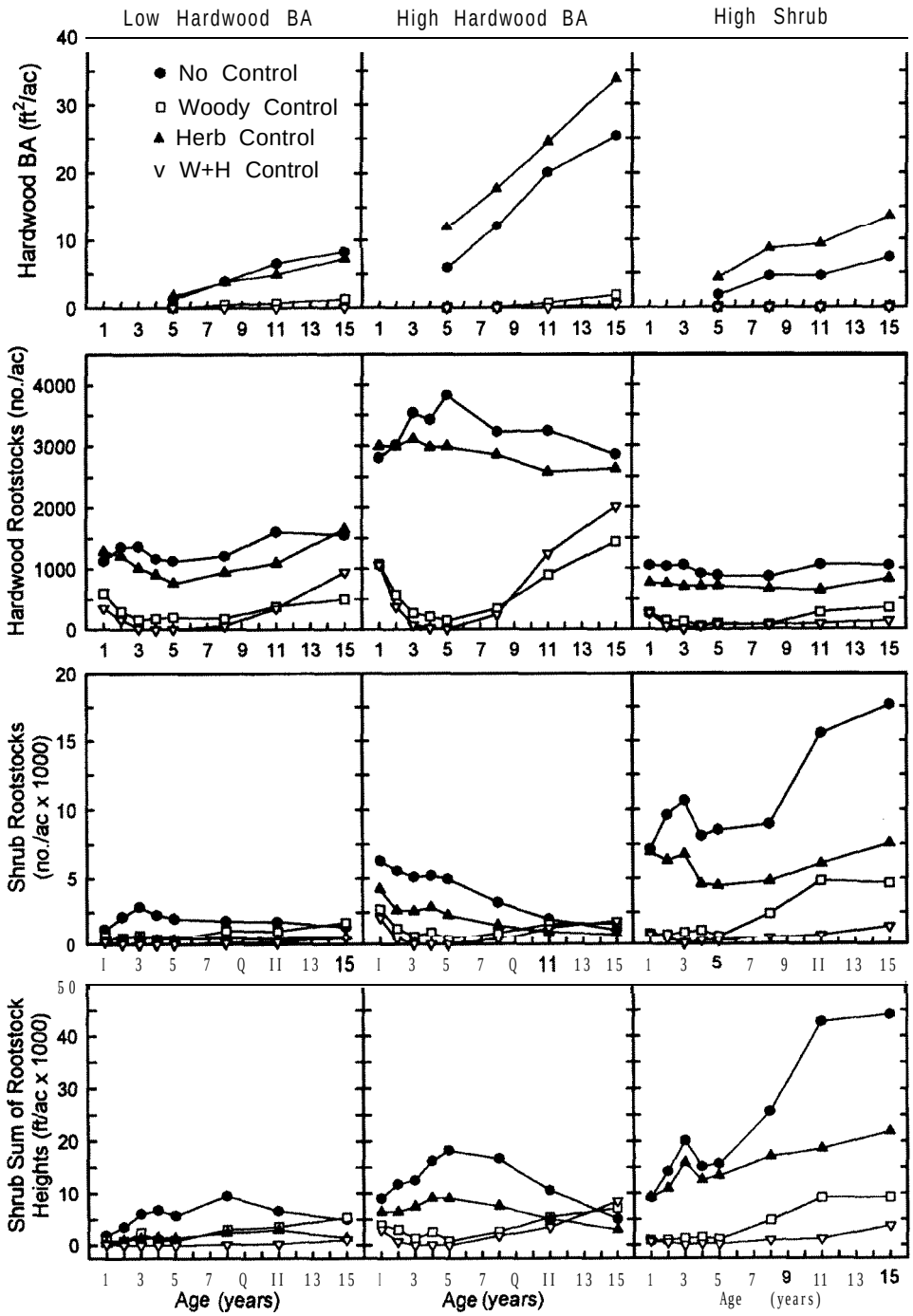


**Figure 3. Average hardwood basal area, rootstocks, shrub rootstocks, and sum of shrub rootstock heights through 15 growing seasons by woody competition category and vegetation control treatment.**

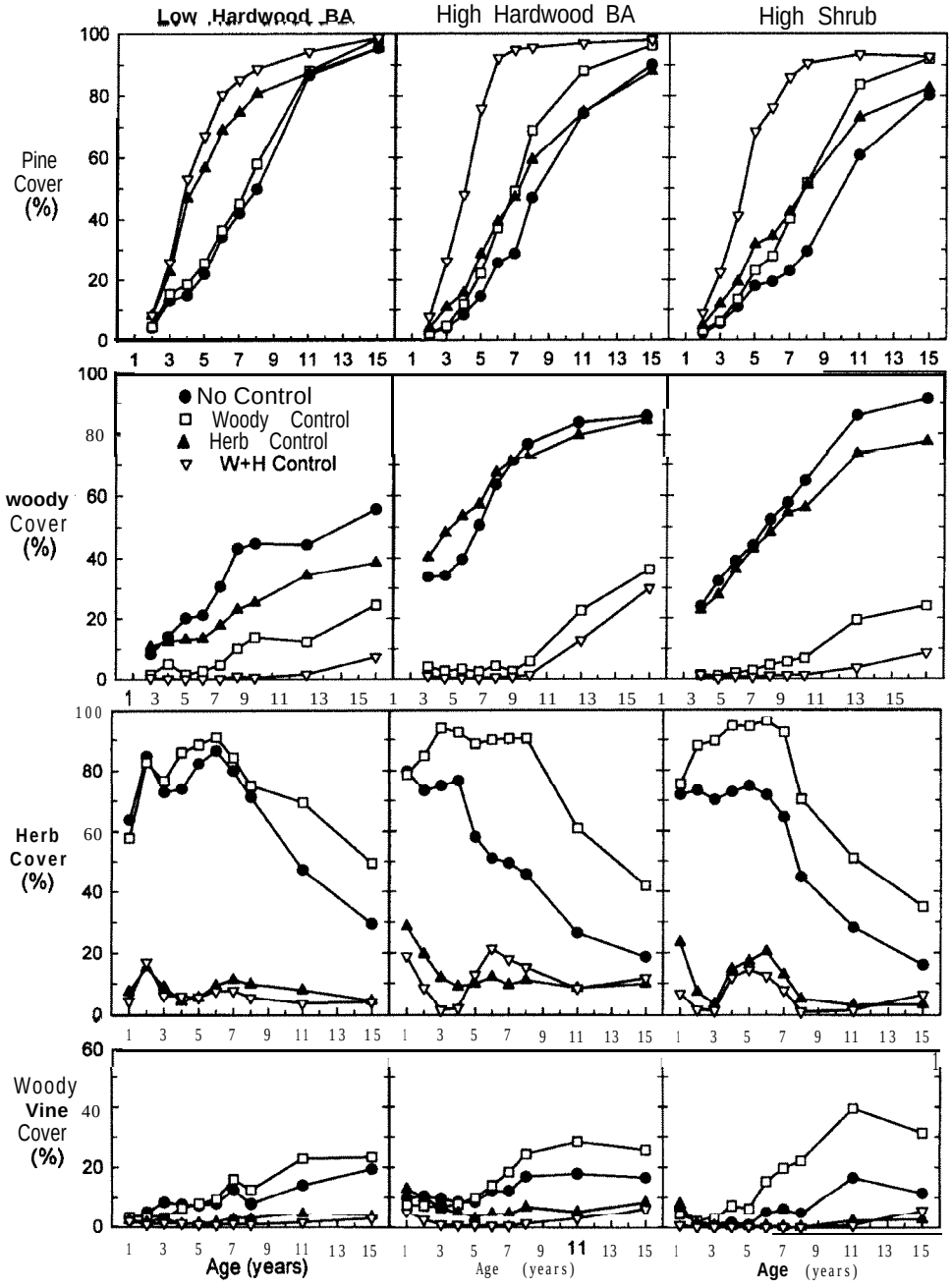


**Figure 4. Cover of loblolly pine, total woody (nonpine), and herbaceous plants (includes woody vines), and woody vines through 15 growing seasons by woody competition category and vegetation control treatment.**

Control Shrub Sum Heights. To confirm whether early herbaceous control had resulted in significantly decreased shrubs the hypothesis of a slope equal to 1 was tested by SAS. The test indicated that the slope of 0.47 was significantly different than 1 and that shrubs on average were 47% less on Herb Controls.

Shrub regrowth commenced slowly on all sites after woody control cessation (Figure 3), most notably on the High Shrub locations as well as the W+H Controls at Liverpool, LA (waxmyrtle dominated) and Liberty, MS (yaupon dominated) (Table 2). Woody control treatments continued to have significantly less abundant shrubs on High Shrub sites at age 15 (Table 2 and Figure 3).

### Pine Canopy Dynamics

Pine canopy cover developed most rapidly on W+H Controls at all locations, especially during the third, fourth, and fifth growing seasons, and exceeded 20%/yr (Figure 4). By yr 15, average pine cover on W+H and Woody Controls approached, but did not reach 100%, while pine cover on all treatments exceeded 80%. No site or treatment reached 100% pine canopy closure, because it was observed that small gaps

continually closed and opened with limb growth and death in the center of planting cells (and with pine mortality). Pine canopies on High Shrub sites closed the least completely, and the stands were more open, which characterizes these "flatwoods" plantations and forests.

On Low Hardwood BA sites, Herb Controls had similar pine canopy development to W+H Controls for the first 3-4 yr, but then began to slow afterward (Figure 4). On these sites by yr 11, average pine cover for Woody and Herb Controls became equal, and then by yr 15 all treatments and sites varied less than 4% in cover and all exceeded 91%. On High Hardwood BA and High Shrub sites, pine canopy development was initially accelerated on Herb Controls, but by yr 7 or 8, pine canopies with Woody Control began to exceed that of Herb Control. By yr 15, Woody Controls equaled W+H Controls (Figure 4). On these same sites by yr 15, average pine canopy cover was 2% or less between Herb and No Controls.

**Component Interactions**

Patterns in woody cover development (combining both hardwood and shrub covers) for No Controls and Herb Controls were similar on High Hardwood BA and High Shrub sites (Figure 4), but shrubs dominated High Shrub sites while hardwoods dominated High Hardwood BA sites (Figure 3). By yr 15, woody cover on No and Herb Controls of High Hardwood and High Shrub sites were similar to pine cover values on these same treatments (Figure 4), indicating the high degree of woody plant participation in these stands. Woody cover regrowth on Woody and W+H Controls commenced slowly after 6-8 yr following the 3-5 yr of control treatments. Regrowth occurred more on Woody Controls than on W+H Controls, but still averaged less than 40% for both treatments on any site at age 15 (Figure 4).

Herbaceous cover remained significantly changed by early control treatments at all locations at yr 15 (Table 2). Early herbaceous control treatments have resulted in an average of 4–49% less herbaceous cover at yr 15, recognizing that interactions are significant at four locations. The majority of these decreases in herbaceous cover were principally due to less vine cover along with varied decreases in semiwoody cover-mainly blackberries (Table 2). In general, woody vines were the most abundant component in the yr 15 understories (including midstory and main canopy occupation), except at Pembroke, GA in the Lower Coastal Plain (Table 2 and Figure 4).

Early woody control resulted in significantly greater yr 15 cover of forbs, grasses, and semiwoody plants (ranging from 0.2–18%), most commonly on High Hardwood BA sites (Table 2). Semiwoodyplants were greater after Woody Control by 2-15% on these High Hardwood sites. Woody Controls resulted in herbaceous covers at levels averaging greater than 80% from yr 2 to yr 7-8 (Figure 4).

There has been an unexpected richness in herbaceous cohabitants in these pine plantations (including woody vines), with 139 genera being identified through 15 growing seasons. There were 42 more genera than reported through the first 8 yr (Miller et al. 1995a) due to the total genera survey in year 15. Herbaceous species/genera included 86 forbs, 30 grasses and grass-likes, 13 woody vines, 4 semiwoodies, 4 ferns, 1 clubmoss, and 1 ground lichen. The common herbaceous generaover the 15 yr have been bluestem grasses *(Andropogon* and *Schizachyrium),* panicgrasses (*Dichanthelium*), goldenrods *(Solidago),* and thoroughworts *(Eupatorium),* while the shade-tolerant spikegrasses (*Chasmanthium*) and nutrushes *(Scleria)* became common across sites after yr 8. A nonnative invasivespecies, Japaneseclimbingfern *[Lygodiumjaponicum* (Thunb. ex Murr.) Sw.] occurred at one location at yr 11, and 5 locations at yr 15, including the first recorded sighting in Virginia.

After reaching peak occupancy by yr 2 and sustained to yr 6-8, herbaceous cover declined through yr 15 on No Controls and Woody Controls (Figure 4). Similar but smaller declines are evident during this same period on Herb and W+H Controls following perceptible small rebounds in cover in yr 4–8 after control cessation. Declines in herbaceous cover coincide with the sizable increases in pine and woody cover, which combined yielded covers from 106–176% for all treatments by yr 15 (Figure 4). During the same time on these treatments, vines increased and maintained occupancy with similar dynamics for the woody competition categories (Figure 4). Vines became reestablished on all Woody and W+H Control plots (Table 2). Dominant woody vine species have remained the same from yr l-8 (Miller et al. 1995a) and are greenbriers *(Smilax),* grapes (*Vitis*), yellow jessamine (*Gelsemium sempervirens* St.-Hil.), and Japanese honeysuckle *(Lonicerajaponica* Thunb.), anonnative invasive that occurred at every location by yr 15.

**Compositional Changes**

At age 15, stand composition was significantly altered in one to all stand components by early control treatments, most notably the tree component (Table 3). Richness of trees species was 2-9 taxa fewer at 12 locations after early woody control and 2-3 taxa fewer at 5 locations after herbaceous control (interactions significant at 2 locations). Total tree richness per location ranged from 8-23 species. There were only 3-10 taxa of shrubs identified per location and six locations had l-2 fewer taxa after herbaceous control. Shrub richnesswaslessaffectedbywoodycontrol withthreelocations having gains or losses of l-2 taxa. The combined taxa of herbaceous, woody vine, and semiwoody plants ranged from 9-38 by location, while woody control treatments had 2-12 more taxa at five locations and herbaceous controls had 4-8 fewer taxa at three locations, with 2 more taxa at a single location (interactions significant at three locations). These changes by component resulted in changes in total stand richness of 4-7 taxa fewer at seven locations after woody control and 2– 10 taxa fewer at seven locations after herbaceous control (interactions significant at three locations). Bainbridge, GA had a net increase of 11 taxa on plots that received woody control. Total stand richness at all locations ranged from 23-65 taxa. The richest site was the bottomland site at Bainbridge, GA, having 65 taxa, and the least total richness was at Pembroke, GA, a High Shrub poorly drained site, with 23 taxa. In general, the highest hardwood sites and High Shrub sites had the least total richness. There were a total of 179 taxa recorded on all locations in yr 15.

**Table 3. Mean plant taxa (and total number) at age 15 by vegetation control treatment with sites grouped by woody competition category, and the ANOVA outcomes with main effects and their interaction in bold italics (values are significant differences attributed to treatment and significance of interaction).**

| | Low hardwood BA | | | | | High hardwood BA | | | | | | High shrub | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Control | Jena | Counce | Warren | Monti-cello | Liver-pool | Arcadia | Liberty | Bain-bridge | Camp Hill | Tallassee | Appo-mattox | Pem-broke | Atmore |
| *ANOVA*[1] | ***LA*** | ***TN*** | AR | GA | LA | LA | MS | GA | AL | AL | VA | GA | AL |
| ***Results*** | MCP[2] | HCP | HCP | Pied | MCP | HCP | MCP | MCP | Pied | HCP | Pied | LCP | MCP |
| **Tree taxa** | | | | | | | | | | | | | |
| No | 11 (14) | 13 (21) | 12 (22) | 9 (14) | 12 (16) | 13 (21) | 14 (17) | 11 (19) | 13 (20) | 8 (11) | 15 (21) | 5 (8) | 10 (13) |
| woody | 10 (19) | 3 (8) | 6 (8) | 4 (7) | 5 (9) | 9 (18) | 11 (15) | 11 (23) | 9 (15) | 5 (7) | 12 (17) | 2 (3) | 3 (6) |
| Herb | 9 (14) | 9 (19) | 9 (12) | 8 (16) | 7 (15) | 13 (20) | 13 (22) | 13 (18) | 13 (18) | 10 (12) | 18 (23) | 3 (4) | 9 (15) |
| W + H | 6 (10) | 2 (5) | 3 (6) | 4 (JO) | 5 (11) | 5 (13) | IO (18) | 9 (16) | 7 (13) | 2 (5) | IO (19) | 1 (2) | 1 (6) |
| ***Woody*** | ***–2**[3]*** | ***–9**** | ***–6**** | ***–5**** | ***–5**** | ***–6**** | ***–3**** | ***n.s.*** | ***–5**** | ***–6**** | ***–6**** | ***–3**** | ***–8**** |
| ***Herb*** | ***–3**** | ***n.s.*** | ***–3**** | ***n.s.*** | ***–3**** | ***n.s.*** | n. s. | ***n.s.*** | ***n.s.*** | ***n.s.*** | n. s. | ***–2**** | ***–2**** |
| ***W × H*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | n. s. | ***n.s.*** | ***n.s.*** | ***n.s.*** | * | * | ***n.s.*** | ***n.s.*** |
| **Shrub taxa** | | | | | | | | | | | | | |
| No | 6 (9) | 2 (4) | 2 (4) | 1 (1) | 4 (4) | 2 (5) | 2 (4) | 3 (6) | 3 (6) | 2 (3) | 3 (6) | 5 (6) | 4 (5) |
| Woody | 5 (7) | 2 (4) | 2 (5) | 3 (4) | 4 (7) | 3 (6) | 4 (4) | 5 (7) | 4 (6) | 2 (2) | 3 (6) | 3 (5) | 4 (6) |
| Herb | 6 (9) | 1 (2) | 1 (4) | 1 (3) | 3 (6) | 2 (6) | 2 (3) | 2 (3) | 2 (4) | 2 (3) | 2 (4) | 4 (7) | 3 (4) |
| W + H | 6 (10) | 1 (2) | 1 (2) | 1 (1) | 4 (5) | 4 (6) | 3 (4) | 4 (7) | 1 (3) | 1 (1) | 2 (4) | 3 (5) | 3 (5) |
| ***Woody*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***+2**** | ***+2**** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***–1**** | ***n.s.*** |
| ***Herb*** | ***n.s.*** | ***–1**** | ***–1**** | ***–1**** | ***n.s.*** | n. s. | ***n.s.*** | ***–1**** | ***–2**** | ***n.s.*** | ***–1**** | ***n.s.*** | ***n.s.*** |
| ***W × H*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** |
| **Herbaceous, woody vine and semiwoody taxa** | | | | | | | | | | | | | |
| No | IO (21) | 8 (15) | 7 (16) | 8 (18) | 8 (13) | 9 (14) | 7 (10) | 11 (23) | 9 (15) | 7 (9) | 7 (20) | 4 (9) | 9 (18) |
| Woody | 10 (19) | 9 (15) | 7 (16) | 8 (17) | 9 (18) | 9 (16) | 11 (20) | 19 (35) | 18 (32) | 9 (12) | 8 (17) | 4 (8) | 14 (22) |
| Herb | 11 (18) | 4 (12) | 5 (14) | IO (20) | 8 (12) | 6 (14) | 5 (10) | 7 (12) | 9 (20) | 8 (12) | —[4] | 3 (8) | 3 (7) |
| W + H | IO (21) | 6 (10) | 6 (13) | 10 (21) | 11 (15) | 9 (14) | 11 (20) | 22 (38) | 11 (20) | 4 (6) | | 2 (5) | 5 (9) |
| ***Woody*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***+2**** | ***n.s.*** | ***+5**** | ***+12**** | ***+6**** | ***n.s.*** | — | ***n.s.*** | ***+4**** |
| ***Herb*** | ***n.s.*** | ***–4**** | ***n.s.*** | ***n.s.*** | n. s. | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***–4**** | ***n.s.*** | — | ***+2**** | ***–8**** |
| ***W × H*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ** | * | * | — | ***n.s.*** | ***n.s.*** |
| **Total taxa** | | | | | | | | | | | | | |
| No | 26 (44) | 22 (40) | 21 (42) | 17 (33) | 23 (33) | 24 (40) | 23 (31) | 26 (48) | 24 (41) | 16 (23) | 19 (27)[5] | 14 (23) | 23 (36) |
| Woody | 25 (45) | 14 (27) | 15 (29) | 15 (28) | 19 (34) | 21 (40) | 26 (39) | 35 (65) | 30 (53) | 15 (21) | 15 (23) | 9 (16) | 21 (34) |
| Herb | 25 (41) | 13 (33) | 15 (30) | 20 (39) | 18 (33) | 22 (40) | 20 (35) | 22 (33) | 24 (42) | 20 (27) | 20 (27) | IO (19) | 15 (26) |
| W + H | 21 (41) | 9 (17) | IO (21) | 15 (32) | 19 (31) | 17 (33) | 24 (42) | 35 (61) | 19 (36) | 7 (12) | 12 (23) | 6 (12) | 9 (20) |
| ***Woody*** | ***n.s.*** | ***–6**** | ***–6**** | ***n.s.*** | ***n.s*** | ***–4**** | ***n.s.*** | ***+11**** | ***n.s*** | ***–7**** | ***–6**** | ***–5**** | ***–4**** |
| ***Herb*** | ***n. s.*** | ***–7**** | ***–6**** | | ***n.s.*** | ***–3**** | ***n.s.*** | ***n.s.*** | ***–2**** | ***n.s.*** | ***n.s.*** | ***–1**** | ***–4**** |
| ***W × H*** | ***n.s.*** | * | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | ***n.s.*** | * | * | ***n.s.*** | ***n.s.*** | ***n.s*** |

The main effects of woody treatment (average of Woody Control and W + H Control minus average of No Control and Herb Control), herbaceous treatment (average of Herb Control and W + H Control minus average of No Control and Woody Control), and their interaction (average of W + H Control and No Control minus average of Woody Control and Herb Control).

[2] Physiographic province: LCP = Lower Coastal Plain, MCP = Middle Coastal Plain, HCP = Hilly Coastal Plain, and Pied = Piedmont.

[3] n.s.= nonsignficant at $P = 0.05$ , * = significant at $P < 0.05$, and ** = significant at $P < 0.01$.

[4] Data not taken at age 15.

[5] Does not include Herbaceous, Woody vine, and Semiwoody.

## Discussion

Study sites were established after pine-hardwood stands had been harvested and the standing portions of hardwoods and shrubs eliminated, with all but one site then prescribe-burned. Most woody and herbaceous species that recolonized these plantations were perennial plants present in the prior stand or soil seed bank along with varying amounts of early annual-biennial plants also from the soil seed bank (Miller et al. 1995a, Leck et al. 1989). This is a similar pattern documented for northern hardwood forests after clearcutting (Bormann and Likens 1979). This pattern of regrowth from residual plants and propagules after disturbance is a modification of the concept of "initial floristics" by Oliver and Larson (1996, p. 145–147), owing that these species did not "invade" but were mostly resident and withstood site preparation. This pattern somewhat differs from old-field succession characterized by Oosting (1958, p. 235-268) as distinct relays of "invading" plant species.

Plant species associated with these pine plantations represent a sizable flora, and most species/genera were common to the majority of study locations across the region (Miller et al. 1995a). Associated plants over the 15 yr include 68 species of

trees, 33 species/genera of shrubs, 86 species/genera of forbs, 30 genera of grasses and grass-likes, 13 species/genera of woody vines, 4 genera of semiwoody plants, 4 species of ferns, and 1 genus each of clubmoss and ground lichen-a total of 241 taxa. There were 179 taxa remaining at age 15. This would yield a conservative estimate of 490 total species. Oosting (1942) identified most of these same genera and species on old-field loblolly pine stands 1-75 yr old in the North Carolina Piedmont. Similarly, most of these species/genera were identified on pine plantation plots treated with site preparation and release herbicides in Central Georgia on stands 11 yr old (Boyd et al. 1995, Miller et al. 1999). It is becoming evident that an association of widely ranging herbaceous and woody plants occurs in pine plantations and mixed forests across most of the southeastern forest region (Miller and Miller 1999). Re-establishment after disturbance greatly depends on residents in prior stands. How this assemblage of plants differs from those inhabiting other forest stand types in the region is yet to be determined owing to the absence of comparable data. Nonnative invasive plants, particularly Japanese honeysuckle, Chinese privet, and Japanese climbing fern, are increasing at many locations.

In general when woody plants were omitted, herbaceous components slightly increased, and likewise, when herbs were eliminated, hardwood BA (but not their rootstocks) increased and shrubs decreased. Herbaceous control alone released not onl y the pines but also hardwoods to grow faster resulting in significantly more woody cover by yr 8 (Miller et al. 1995a), a similar response to that reported for the Virginia Piedmont by Bacon and Zedaker (1987). Hardwoods remained midstory to understory in stature on all treatments. The significant decreases in shrubs, and the increases in hardwoods, withearly herbaceous control werereportedon themajorityof sites as early as yr 5 (Miller et al. 1991). Decreases in shrub abundance after early herbaceous control are thought to be due to greater competition from released pines and hardwoods as well as possible injury by the herbicide sulfometuron (Oust).

Shrub abundance was more dynamic than hardwood abundance. Shrub abundance on No Controls and Herb Controls were generally declining by yr 15 from higher levels at yr 5–8 on Low and High Hardwood BA locations, compared to continued increases on High Shrub locations (Figure 3). Pine canopy closure was somewhat less on High Shrub sites, which would permit more sunlight (and rooting space) for shrub development by shade tolerant species-mainly gallberry, blueberry, and yaupon. The shrub component has been a succession of species at all locations, starting with the early occupation and decline by light demanding species—mainly winged sumac and smooth sumac (*Rhus glabra* L.) (Miller et al. 1995a).

Woody cover regrowth after the 3-5 yr of control treatments slowly began in yr 6-8, indicating the resiliency of these woody plant associates as well as a "lag phase for reorganization" described by Bormann and Likens (1979) for New Hampshire hardwood stands. Even with these small plots-many being located within untreated plantations—immigration and reestablishment of hardwoods and shrubs was slow. This result was contrary to that reported by Cain and Yaussy (1984) for an Arkansas site, and may be due to the use of more effective herbicides and application techniques in our study.

Significant increases in herbaceous cover on Woody Controls (compared to No Controls) did not begin until about yr 3 on the High Hardwood and High Shrub sites, which is after the period when herbaceous competition has the greatest effect on pine growth (Miller et al. 1991). Significantlygreater herbaceous cover persisted through 15 yr on the High Hardwood and High Shrub sites, with blackberries being mostly enhanced followed by grasses. Lauer and Glover (1995) and Haywood and Tiarks (1990) also reported positive responses of herbaceous vegetation to woody control on a flatwood site in Florida and a Coastal Plain site in Louisiana, respectivel y. In the current study, herbaceous cover on No and Woody Controls started to decline about yr 8 as pine and/or hardwood canopy cover reached a total of 50–60%. From a study with the same treatments and natural pine regeneration in Arkansas, Cain (1999) reported "ground cover" declines commenced somewhat earlier in yr 6-8. Although being generall y observed, onl y a few others have documented and described the decline of herbaceous cover with woody canopy development in the Southeast (Grelen 1976, Knowe et al. 1992) and in the Pacific Northwest (McDonald 1986). Thus, maintenance of herbaceous cover and enhancement by woody control treatments could likely maintain higher levels of plant diversity since most species richness and diversity resides with herbaceous plants in pine plantations (Boyd et al. 1995, Miller et al. 1999). At age 15 there were 92 genera of herbaceous plants (including woody vines and semiwoody plants) compared to 62 species of trees and 25 genera/species of shrubs. Also, woodycontrol treatmentsgenerallyincreased herbaceous taxa by yr 15, which were significantly greater on five sites.

## Conclusions

Associated flora in these plantations included 241 species/genera of trees, shrubs, forbs, grasses/grass-likes, woody vines, semiwoody plants, and ferns. This is a richer flora than widely acknowledged byplantationopponents. A sizablecore group of plants occurred across the entire region associated with plantations, with nonnative invasive plants increasing in occurrence and abundance. Woody and herbaceous plants were resilient even after multi year and yearl y control treatments which frequently failed to sustain season-long control at most sites indicating the tenacity and power of endemic forest plant communities at this time. Patterns of stand succession differed among locations with either low amounts of hardwoods, high hardwoods, or high shrubs. Herbaceous component levels varied less across the regional sites.

Herbaceous plants rapidly rebounded after initial site preparation to form 60–80% cover in the first year. Herbaceous cover was increased and sustained longer after early woody plant control. Control of hardwoods and shrubs sustained significantly more forb, grass, and semiwoody cover, most frequentlyon high hardwood sites. This herbaceous component then commenced to decline starting about yr 5–8 as combined

pine and hardwood canopies reached a total of 50–60% cover. Occupation amounts by herbaceous plants were generally changed more than their composition by early treatments. Most commonly, woody vines becamethedominant understory component starting in yr 11.

Hardwoods and shrubs remained suppressed on all sites 15 yr after early woody control treatments, which altered not only stand structure but woody composition as well. It is apparent that intensive woody control treatments during establishment cangreatly limit woody species reoccupation through midrotation even in small stands within forested landscapes. Where hardwoods were retained, rootstock numbers remained on average at consistent levels from yr 1-15 through cycles of recruitment and mortality, even with early herbaceous control. Hardwood productivity in these pine plantations was increased by about 28% with complete early herbaceous control. This stimulation of hardwood growth in pine plantations will deserve further scrutiny if hardwood wood values continue to increase. On average, shrub component resiliency following treatment was even less than hardwoods and occupancy generally declined with canopy development except for High Shrub sites, where shrubs continued to increase through yr 15 on all treatments.

This regional study not only provides silvicultural understandings but ecological understanding of patterns and dynamics of pine plantations to midrotation. Plantations of pines planted uniformly in suppressed pre-existing forest communities are projected to increase in the southeastern landscape. More multiple commodity and noncommodity values will be demanded from them and we must learn how these will interact with surrounding forest types, wildlife and human co-inhabitants.

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**Appendix Table 1. Genera and species encountered in study plots grouped by growth form and nomenclature according to Plants Natio nal Database (http://plants.usda.gov).**

| Scientific name | Common name | Scientific name | Common name |
|---|---|---|---|
| Trees | | Trees (continued) | |
| *Acer* ***barbatum*** Michx. | maple, southern sugar | ***Q .michauxii*** Nutt. | oak, swamp chestnut |
| ***A.*** *rubrum* L. | maple, red | ***Q. nigra*** L. | oak , water |
| *Aesculus pavia* L. | buckeye, red | ***Q. pagoda*** Raf. | oak, cherrybark |
| ***Ailanthus*** *altissima* (P. Mill.) Swingle | tree-of-heaven | *Q.* ***hemisphaerica*** Bartr. ex Wild. | oak, Darlington |
| ***Albizia julibrissin*** Durazz. | silktree | ***Q. prinus*** L. | oak, chestnut |
| ***Amelanchier arborea*** (Michx. f.) Fern | servicebeny | *Q.* ***rubra*** L. | oak, northern red |
| *Carpinus* ***caroliniana*** Walt. | American hornbeam | ***Q. shumardii*** Buckl. | oak, shumard |
| ***Carya*** glabra (P.Mill.) Sweet | hickory, pignut | *Q. stellata* Wangenh. | oak , post |
| *C.* ***alba*** (L.) Nutt. ex Ell. | hickory, mockernut | ***Q. veiutina*** Lam. | oak, black |
| ***Castanea pumila*** (L.) P. Mill. | chinkapin | *Q.* ***virginiana*** P. Mill. | oak , live |
| *Celtis* ***laevigata*** Willd. | sugarberry | ***Robinia pseudoacacia*** L. | black locust |
| ***C. occidentalis*** L. | hackberry, common | *Salix* ***nigra*** Marsh. | willow, black |
| ***C.*** *tenuifolia* Nutt. | hackberty, Georgia | ***Sassafras albidum*** (Nutt.) Nees | sassafras |
| ***Cercis*** *canadensis* L. | eastern redbud | *Triadica sebifera* (L.) Small | tallowtree |
| *Cornus florida* L. | flowering dogwood | *Ulmus* ***alata*** Michx. | elm, winged |
| ***Diospyros virginiana*** L. | persimmon | *U.* ***americana*** L. | elm, American |
| *Fagus grandifolia* Ehrh. | American beech | *U.* ***rubra*** Muhl. | elm, slippery |
| *Fraxinus* ***americana*** L. | ash, white | Shrubs | |
| *F. pennsylvanica* Marsh. | ash, green | ***Aralia spinosa*** L. | devil's walkingstick |
| *Frangula* ***caroliniana*** (Walt.) Gray | Carolina buckthorn | ***Asimina*** *parviflora* (Michx.) Dunal | dwarf pawpaw |
| ***Hamamelis virginiana*** L. | witch-hazel | ***Raccharis*** *halimifolia* L. | eastern baccharis |
| *Ilex* ***opaca*** Ait. | American holly | ***Callicarpa americana*** L. | American beautyberry |
| ***Juniperus virginiana*** L. | eastern redcedar | ***Crataegus*** sp. L. | hawthorn |
| ***Liquidambar*** *styraciflua* L. | sweetgum | *Cyrilla racemiflora* L. | titi |
| ***Liriodendron*** *tulipifera* L. | yellow poplar | *Erica* sp. L. | heath |
| ***Magnolia*** *grandiflora* L. | magnolia, southern | ***Erythrina herbacea*** L. | redcardinal |
| *M.* ***virginiana*** L. | magnolia, sweetbay | *Euonymus* ***americana*** L. | strawberry bush |
| *Malus angustifolia* (Ait.) Michx. | southern crab apple | *Gaylussacia* sp. Kunth | huckleberry |
| ***Melia azedarach*** L. | chinaberrytree | *Halesia* sp. Ellis ex L. | silverbell |
| *Morus* ***rubra*** L. | mulberry, red | *Ilex* ***decidua*** Walt. | possumhaw |
| *Morus* ***sp.*** L. | mulberry | *I.* ***glabra*** (L.) Gray | gallberry |
| ***Nyssa sylvatica*** Marsh. | blackgum | ***I. vomitoria*** Ait. | yaupon |
| ***Osmanthus americanus*** (L.) Benth. & Hook. f. ex Gray | devilwood | ***Ligustrum*** *sinense* Lour. | Chinese privet |
| | | ***Lonicera tatarica*** L. | tatarian honeysuckle |
| *Ostrya* ***virginiana*** (P. Mill.) K. Koch | hophornbeam | ***Lyonia*** *ferruginea* (Walt.) Nutt. | staggerbush |
| ***Oxydendrum arboreum*** (L.) DC. | sourwood | ***L. ligustrina*** (L.) DC. | maleberry |
| *Persea* ***borbonia*** (L.) Spreng. | redbay | ***L.*** *lucida* (Lam.) K. Koch | fetterbush |
| *Pinus* ***echinata*** P. Mill. | pine, shortleaf | ***Morella*** *cerifera* (L.) Small | waxmyrtle |
| ***P. elliottii*** Engelm. | pine, slash | ***Rhododendron sp.*** L. | azalea |
| ***P.*** *palustris* P. Mill. | pine, longleaf | ***Rhus copallinum*** L. | sumac, winged |
| *P. taeda* L. | pine, loblolly | ***R. glabra*** L. | sumac, smooth |
| ***P. virginiana*** P. Mill. | pine, Virginia | ***Rosa*** sp. L. | rose |
| *Platanus* ***occidentalis*** L. | American sycamore | *Styrax grandifolius* Ait. | bigleaf snowbell |
| *Prunus* ***americana*** Marsh. | plum, American | ***Toxicodendron*** *vernix* (L.) Kuntze | sumac, poison |
| ***P. serotina*** Ehrh. | black cherry | ***Vaccinium*** *arboreum* Marsh. | farkleberry |
| ***P.*** *umbellata* Ell. | plum, hog | *V.* ***myrsinites*** Lam. | evergreen blueberry |
| *Quercus alba* L. | oak, white | *V. stamineum* L. | deerberry |
| *Q.* ***coccinea*** Muenchh. | oak , scarlet | ***Vaccinium*** sp. L. | blueberry |
| *Q. falcata* Michx. | oak, southern red | ***Viburnum dentatum*** L. | Southern arrowwood |
| ***Q. incana*** Bartr. | oak, bluejack | ***Viburnum*** sp. L. | haw |
| *Q. laurifolia* Michx. | oak , laurel | Palm | |
| *Q.* ***marilandica*** Muenchh. | oak, blackjack | ***Serenoa*** *repens* (Bartr.) Small | saw palmetto |

(continued)

**Appendix Table 1. (continued)**

| Scientific name | Common name | Scientific name | Common name |
|---|---|---|---|
| Forbs | | Forbs (continued) | |
| *Acalypha* sp. L. | copperleaf | *Pityopsis* sp. Nutt. | golden aster |
| *Agalinis* sp. Raf. | gerardia | *Plantago* sp. L. | plantain |
| *Ageratum* sp. L. | ageratum | *Pluchea* sp. Cass. | pluchea |
| *Ambrosia* sp. L. | ragweed | *Polygala* sp. L. | polygala |
| *Anemone quinequefolia* L. | nightcaps | ***Polygonatum*** *biflorum* (Walt.) Ell. | Solomon's seal |
| ***Arisaema triphyllum*** (L.) Schott | Jack in the pulpit | *Polypremum procumbens* L. | rustweed |
| *Aster* sp. L. | asters | *Potentilla* sp. L. | cinquefoil |
| *Baptisia* sp. Vent. | wild indigo | *Prenanthes* sp. L. | rattlesnakeroot |
| ***Carduus*** sp. L. | thistle | *Pycnanthemum* sp. Michx. | mountainmint |
| *Centrosema* sp. (DC.) Benth. | butterfly pea | *Pyrrhopappus* sp. DC. | falsedandelion |
| ***Chamaecrista*** sp. (L.) Moench | partridgepea | *Rhexia* sp. L. | meadowbeauty |
| *Chimaphila maculata* (L.) Pursh | wintergreen | *Richardia* sp. L. | floridapusley |
| *Circaea* sp. L. | enchanter's nightshade | *Rudbeckia* sp. L. | blackeyedsusan |
| *Conyza* sp. Less. | horseweed | *Salvia* sp. L. | sage |
| *Coreopsis* sp. L. | tickseed | *Scutellaria* sp. L. | skullcap |
| *Croptilon* sp. Raf. | goldenweed | *Senna* sp. P. Mill. | sicklepod |
| *Croton* sp. L. | woolly croton | *Sida* sp. L. | prickly sida |
| *Crotonopsis* sp. G.L. Webster | crotonopsis | *Solanum* sp. L. | nightshade |
| *Dichondra* sp. J.R. & G. Forst. | ponysfoot | *Solidago* sp. L. | goldenrods |
| *Diodia* sp. L. | poorjoe | *Stylosanthes biflora* (L.) B.S.P. | pencilflower |
| ***Duchesnea*** *indica* (Andr.) Focke | Indian mock strawberry | *Tephrosia* sp. Pers. | goat's rue |
| *Eclipta* sp. L. | eclipta | *Tragia* sp. L. | noseburn |
| *Elephantopus* sp. L. | elephant's foot | *Trichostema* sp. L. | bluecurls |
| ***Erechtites*** *hieracifolia* (L.) Raf. ex DC | American burnweed | *Urtica* sp. L. | stinging nettle |
| ***Erysimum*** sp. L. | wallflower | *Verbascum* sp. L. | mullein |
| *Eupatorium* sp. L. | dogfennel, boneset | *Verbena* sp. L. | vervain |
| *Euphorbia* sp. L. | spurge | *Vicia* sp. L | vetch |
| *Euthamia* sp. Nut. ex Cass. | flat-topped goldenrod | *Viola* sp. L. | violet, pansy |
| *Fragaria virginiana* Duchesne | wild strawberry | *Waldsteinia* sp. Willd. | barren strawberry |
| *Galactia* sp. P. Br. | milk pea | Grasses and grass-likes | |
| *Galium* sp. L. | bedstraw | *Agrostis* sp. L. | bentgrass |
| *Gamochaeta* sp. Weddell | everlasting | *Aira* sp. L. | hairgrass |
| *Gnaphalium* sp. L. | rabbit tobacco | *Andropogon* sp. L. | broomsedge |
| *Helianthus* sp. L. | sunflowers | *Anthaenantia* sp. Reauv. | green silkyscale |
| *Heterotheca* sp. Cass. | camphorweed | *Aristida* sp. L. | wiregrass |
| ***Hibiscus*** sp. L. | wild cotton, mallow | ***Arundinaria gigantea*** (Walt.) Muhl. | switchcane |
| *Hyssopus* sp. L. | hyssopus | *Axonopus* sp. Beauv. | carpetgrass |
| *Ipomoea* sp. L. | morningglory | *Carex* sp. L. | sedge |
| *Iris verna* L. | dwarf violet iris | *Chasmanthium* sp. Link | uniolagrass |
| ***Jacquemontia*** *tamnifolia* (L.) Griseb. | smallflower morningglory | *Cyperus* sp. L. | nutsedge |
| ***Kummerowia*** sp. Schindl. | annual lespedeza | *Danthonia* sp. DC. | wild oatgrass |
| *Lactuca* sp. L. | wild lettuce | ***Dichanthelium*** sp. (A.S. Hitchc. & Chase) Gould | low panicgrass |
| *Lechea* sp. L. | lespedezas | *Digitaria* sp. Haller | crabgrass |
| *Lespedeza* sp. Michx. | | | |
| *Liatris* sp. Gaertn. ex Schreb. | blazing star | *Echinochloa* sp. Beauv. | barnyardgrass |
| *Lippia* sp. L. | lippia | *Eragrostis* sp. von Wolf | lovegrass |
| *Lobelia* sp. L. | lobelia | *Gymnopogon* sp. Beauv. | skeletongrass |
| *Ludwigia* sp. L. | seedbox | *Juncus* sp. L. | rush |
| *Lysimachia quadriflora* L. | yellow loosestrife | ***Microstegium vimineum*** (Trin.) A. Camus | Nepalese browntop |
| *Matelea* sp. Aubl. | Aublet vine | *Panicum* sp. L. | panicgrass |
| ***Mecardonia*** sp. Ruiz & Paviin | mercardonia | *Paspalum* sp. L. | Qaspalumgrass |
| *Mimosa* sp. L. | sensitive briar | *Poa* sp. L. | bluegrass |
| *Mitchella repens* L. | partridge berry | *Rhynchospora* sp. Vahl | beakrush |
| *Monarda* sp. L. | beebalm | *Saccharum* sp. L. | plumegrass |
| *Monotropa* sp. L. | Indianpipe | *Schizachyrium* sp. Nees | bluestem |
| *Oxalis* sp. L. | woodsorrel | *Scleria* sp. Berg. | nutrush |

(continued)

**Appendix Table 1. (continued)**

| Scientific name | Common name | Scientific name | Common name |
|---|---|---|---|
| Grasses and grass-likes (continued) | | Semiwoodies | |
| *Setaria* sp. Beauv. | foxtail | ***Ceanothus*** sp. L | redroot |
| *Sorghastrum* sp. Nash | indiangrass | ***Desmodium*** sp. Desv | tickclover |
| ***Sorghum halepense*** (L.) Pers. | johnsongrass | *Hypericum* sp. L. | St. John's- wort |
| *Sporobolus* sp. ***R.*** Br. | dropseed | *Rubus* sp. L. | blackberry, dewberry |
| *Tridens* sp. Roemer & J.A. Schultes | purpletopgrass | Ferns | |
| Vines | | *Botrychium virginianum* (L.) Sw. | rattlesnake fern |
| ***Ampelopsis*** sp. Michx. | peppervine | *Lygodium* ***japonicum*** (Thunb. ex Murr.) Sw. | Japanese climbing fern |
| ***Berchemia*** *scandens* (Hill) K. Koch | Alabama supplejack | ***Polystichum acrostichoides*** (Michx.) Schott | Christmas fern |
| ***Bignonia capreolata*** L. | crossvine | ***Pteridium aquilinum*** (L.) Kuhn | brackenfern |
| *Campsis* ***radicans*** (L.) Seem. ex Bureau | trumpetcreeper | Clubmoss | |
| *Cocculus carolinus* (L.) DC. | Carolina coralbead | ***Lycopodium*** sp. L. | clubmoss |
| ***Decumaria barbara*** L. | climbing hydrangea | Ground lichen | |
| *Gelsemium sempervirens* St. Hil. | yellow jessamine | ***Cladonia*** sp. P. Browne | reindeer moss |
| ***Lonicera*** sp. L. | honeysuckle | | |
| ***Parthenocissus*** *quinquefolia* (L.) Planch. | Virginia creeper | | |
| *Passiflora* sp. L. | passionflower | | |
| *Smilax* sp. L. | greenbriar | | |
| ***Toxicodendron radicans*** (L.) Kuntze | poison-ivy | | |
| Vitis sp. L. | grape | | |