Effect of controlling herbaceous and woody competing vegetation on wood quality of planted loblolly pine

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Abstract

Southern pine plantations are increasingly established using herbicides to control herbaceous and/or woody competing vegetation to enhance growth, but little is known about the effect on wood quality. A study was established at 13 southern locations in 1984 to examine the effects of complete control of woody, herbaceous, and woody plus herbaceous competition for the first 3 to 5 years on the growth and stand dynamics of loblolly pine (*Pinus taeda* L) plantations. After 15 years, herbaceous plus woody control increased pine merchantable volume per acre by an average of 23 to 121 percent compared to no competition control. Increment cores, 12 mm in diameter, were collected from 36 trees in each of the 4 treatments from each of the 13 locations. X-ray densitometry was used to determine annual growth, proportion of latewood, and specific gravity (SG) of earlywood, latewood, and annual rings. Woody plus herbaceous competition control significantly increased growth at all locations, did not significantly reduce ring SG of earlywood or latewood, and did not significantly affect proportion of latewood in the annual ring. Woody plus herbaceous competition control did significantly increase growth during juvenile wood formation in years 1 to 5 and thus increased the diameter of the juvenile wood core by an average of 19 percent. Cross-sectional weighted proportion of latewood decreased 10 percent and cross-sectional weighted SG decreased 3 percent as a result of increased growth during the juvenility period in trees receiving the woody plus herbaceous control treatment. However, growth gains substantially offset the slight reduction in percent latewood and SG.

Land managers are using herbicide treatments to increase growth of southern pine plantations by controlling competing vegetation. Research has shown that herbicide applications during the first few years after establishment can reduce herbaceous and woody competition and thus significantly increase southern pine growth because of additional moisture and nutrients made available (Cain and Mann 1980, Nelson et al. 1981, Zutter et al. 1986, Glover et al. 1989). However, little information is available on the effects of competition control and rapid early growth on the wood properties. To determine the effect of near complete herbaceous, woody, and herbaceous plus woody competition control for the first 3 to 5 years on loblolly pine (*Pinus taeda* L.) growth and stand dynamics a south-wide study was established by a group of investigators with the forest industry, universities, and USDA Forest Service, Southern Research Station. This south-wide study was established in 1984 and called the Competition Omission Monitoring Project or COMP. This research project employed a unified protocol of four early competition control treatments over a wide range of physiography, topography, and commonly occurring soils (Miller et al. 1991, 2003a, 2003b; Zutter et al. 1995; Zutter and Miller 1998). COMP study results at age 15 (Miller et al. 2003a) showed that with near-complete herbaceous and woody control, pine merchantable stem volume reached 2,350 to 4,415 ft^3/ac by site compared to 1,132 to 2,965 ft^3/ac for the sites receiving no vegetation control. This represents a 23 to 121 percent increase in pine stem growth at age 15 and Miller et al. (2003a) reported that gains increased as hardwoods and shrubs increased on no control plots. Individual COMP pine tree data

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for each of the sites was analyzed by Carpenter (1999) to determine the effect of competition control on stand uniformity. He found that increased component control decreased stand deviations and coefficients of variation of pine to yield more uniform stands.

Juvenile wood is a cylinder of wood surrounding the pith extending the length of all trees and is produced by young cambium in the live active crown (Zobel et al. 1959, Bendtsen and Senft 1986). The number of years the cambium produces juvenile wood at a given height decreases from the northwest to the southeast across the range of loblolly pine. The length of juvenility ranges from 5 to 8 years in the Atlantic Coastal Plain to 9 to 11 years in the Piedmont (Clark and Saucier 1989). The faster a tree grows after planting during the first few years of a rotation, the larger the diameter of the juvenile core in the lower bole. Juvenile wood has a high proportion of earlywood-type tracheids and thus lower specific gravity (SG), thinner cell walls, wider microfibril angles, and less latewood than mature wood. Because of its tracheid characteristics, juvenile wood has lower strength, stiffness, more longitudinal shrinkage, and less radial and tangential shrinkage than mature wood. Wood from young, fast growing pine plantations often has physical and mechanical properties that make it less desirable than older, slower grown wood for structural lumber because of large volumes of low-SG juvenile wood (Pearson and Gilmore 1971, Bendtsen 1986, Bendtsen and Senft 1986, Biblis 1990). Juvenile wood significantly reduces the strength and stiffness of dimension lumber and increases the proportion of lumber down-graded because of drying defects (Pearson and Gilmore 1971). Pulp yield is lower from juvenile wood than mature wood. Paper from juvenile woodpulp will have good tensile, burst, fold, and sheet smoothness but lower tear and opacity than paper from mature wood (Zobel and Blair 1976). Because of the high compaction of juvenile wood, more juvenile wood furnish is required to produce a composite panel compared to that of mature wood. Large volumes of juvenile wood furnish will result in composite panels with lower stiffness and lower dimensional stability than panels made from mature wood (Pugel et al. 2003).

The region-wide COMP study provided the opportunity to determine the effect of herbaceous, woody, and herbaceous plus woody competition control for the first 3 to 5 years on loblolly pine wood quality. This paper reports on the results of sampling the 13 COMP study sites at age 15 to determine the effect of early herbaceous, woody, and herbaceous plus woody competition control on annual ring basal area growth, earlywood and latewood SG, ring SG, percent latewood, length of juvenility, and diameter of the juvenile core.

Procedures

The COMP study was established in 1984 at 13 sites in four physiographic provinces (the Lower, Middle, and Hilly Coastal Plain, and Piedmont) in Alabama, Arkansas, Georgia, Louisiana, Mississippi, Tennessee, and Virginia (**Fig. 1**). Study installations were established on sites with commonly occurring soil series with medium to high productivity for the region. Site indices ranged form 57 to 82 (base age 25 yr). Prior to study plot establishment, mixed pine/hardwoods or pine plantations were harvested in late 1982 or 1983. At 10 study locations, site preparation was by roller-drum chopping and prescribed burning. At Counce, Tennessee, a shear, pile, and burn method of site preparation was used that resulted in

Figure 1. — Location of COMP study sites sampled.

some top-soil removal and displacement into windrows. The Lower Coastal Plain site near Pembroke, Georgia, was rebedded after a wildfire destroyed a young plantation and a complete harvest of fuelwood and pine was used at Atmore, AL. At 11 of the locations, 4 blocks of 4 treatment plots each were established using a factorial, randomized complete block design. At Pembroke, Georgia, a fifth block was included and at Bainbridge, Georgia, a completely randomized design was used. Treatment plots generally measured 0.25 acres and interior measurement plots were 0.09 acres. Eleven of the locations were hand planted at 9- by 9-foot spacing or 538 trees/ac. At Pembroke, Georgia, and Arcadia, Louisana, the trees were machine planted at 565 and 622 trees/ac, respectively.

Four treatments or competition situations were established and maintained at each installation as follows (Miller et al. 1991):

1. No control (NOC) - resulting in mixed herbaceous, woody competition.
2. Woody control (WC) - resulting in herbaceous competition. Foliar and basal sprays as well as basal wipes were applied to control hardwoods and shrubs during the first 3 to 5 years. Post-plant sprays of glyphosate (Roundup) or triclopyr (Garlon) were used, or basal wipes using triclopyr, a penetrant and diesel fuel. Only herbicides without soil activity were used after planting to minimize any seedling damage that could impair subsequent growth response.
3. Herbaceous control (HC) - resulting in mainly woody competition. Pre-emergent applications of sulfometuron (Oust at 306 oz/ac) were applied annually for the first 2 to 5 years (most often 4 yr) to control forbs, grasses, and woody vines.
4. Woody and herbaceous control (W+HC) - resulting in elimination of all competition. A combination of the treatments listed above was used to control both woody and herbaceous competition during the first 2 to 5 years.

The 13 COMP installations were sampled for wood properties after the sites had completed their 15th growing season. Increment cores, 12 mm in diameter, were collected at breast height (4.5 ft aboveground) from 9 trees in each treatment plot within each bock for a total of 36 trees per treatment per location. Trees were selected for boring in proportion to diameter at breast height (DBH) distribution in each plot based on

Table 1. — DBH and total height of trees sampled for wood properties by physiographic region and treatment.

	Physiographic region			
Control treatment	Lower Coastal Plain	Upper Coastal Plain	Piedmont	Hilly Coastal Plain
	DBH			
	(in)			
None	6.2	7.1	6.9	6.9
Woody	6.7	7.4	7.6	7.3
Herbaceous	6.8	7.4	7.0	7.2
Woody+Herbaceous	6.8	8.0	8.2	7.7
	Total height			
	(ft)			
None	42	51	46	43
Woody	48	51	48	45
Herbaceous	47	54	48	46
Woody+Herbaceous	47	56	52	49

tree measurement collected at age 15. **Table 1** shows average DBH and total height of trees bored for SG analysis. The age-15 tree measurements were used to estimate the pine stem merchantable volume per acre in cunits for trees ≥5.0 inches to a 4-inch diameter outside bark top based on DBH and total height using an equation developed by Clark and Saucier (1990) for planted loblolly pine.

The increment cores were dried, glued to core holders and sawn into 0.078-inch-thick strips. SG of earlywood and latewood from each annual ring for each radial strip was determined at 0.0024-inch intervals using an x-ray densitometer with a resolution of 0.00001. An SG value of 0.48 was used to distinguish earlywood from latewood. The densitometer was calibrated to express SG on a green volume and ovendry weight basis. The cross-sectional area or basal area in square feet of each annual ring at 4.5 feet aboveground was calculated based on ring width measurements collected on the densitometer. The age of demarcation between juvenile and mature wood was determined using the fixed-species definition method. We defined transition from juvenile to mature wood as the year in which ring SG was ≥0.50 and percent latewood was greater than 40 percent for two consecutive annual rings. Cross-sectional SG and proportion of latewood was calculated by weighting each annual ring SG or percent latewood by its annual basal area growth.

Southern pine wood SG is highly correlated with summer precipitation and length of growing season (Clark and Daniels 2004); thus, locations were grouped by climatic and physiographic region to aid in summarization and interpretation. Wood properties data were analyzed for differences among physiographic regions, among treatments, and also run separately for each location using the appropriate analysis of variance (ANOVA). Tukey's HSD test was used to separate treatment means for critical examination of selected variables. A 0.05 level of probability for a Type III error was considered significant with all tests.

Results and discussion

W+HC vegetation control for 3 to 5 years after planting compared to no control increased pine merchantable stem volume significantly after 15 years of growth at all 13 study locations (Miller et al. 2003a). Growth gains associated with HC alone or WC alone were about equal in the Lower Coastal Plain, Upper Coastal Plain, and Hilly Coastal Plain. In the Piedmont, the growth gains associated with WC were higher than those associated with HC. The growth gains associated with WC and HC were generally additive except where control of one group of vegetation enhanced the growth of the other (Miller et al. 2003b). After 15 years, W+HC compared to NOC increased pine merchantable stem volume per acre on average 120 percent in the Lower Coastal Plain, 81 percent in the Upper Coastal Plain, 108 percent in the Piedmont, and 80 percent in the Hilly Coastal Plain (**Fig. 2**). The large increase in growth associated with the W+HC treatments in the Lower Coastal Plain occurred not only because of increases in DBH and height growth but significant increases in the number of trees that grew up into merchantable tree size (5.0 in DBH) by age 15 compared to the NOC treatment.

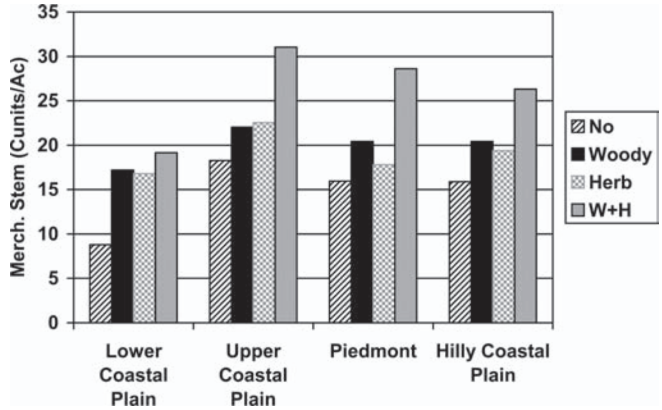

Figure 2. — Effect of woody, herbaceous, and woody plus herbaceous competition control on merchantable stem volume per acre at age 15.

The WC, HC, and W+HC treatments resulted in increased annual ring basal area growth during the first 4 to 6 years after planting compared to the NOC treatment in all physiographic regions (**Fig. 3**). Generally after ring 6, the annual ring basal area growth was about the same for all treatments within each region. However, the significant gain in cumulative basal area growth resulting from the W+HC treatment continued through age 15 for all physiographic regions (**Fig. 4**). In the Lower Coastal Plain, the increased growth associated with the HC and WC also continued through age 15 and in the Upper Coastal Plain and Piedmont the increased growth associated with WC continued through age 15.

Plots of annual ring earlywood SG over rings from the pith show earlywood SG did not vary with vegetation control treatment and was generally linear from pith to bark within a physiographic region (**Fig. 5**). Average basal area weighted earlywood SG, however, was significantly higher in the Lower Coastal Plain compared to that in the other regions (**Table 2**). Plots of annual ring latewood SG show no effect by vegetation control on latewood SG within a region. Average basal area weighted latewood SG was significantly higher in the Lower Coastal Plain and significantly lower in the Hilly Coastal Plain (**Table 2**). Plots of the proportion of annual ring in latewood show no effect by vegetation control treatments on percent latewood within any of the physiographic regions (**Fig. 5**). The proportion of annual ring in latewood increased

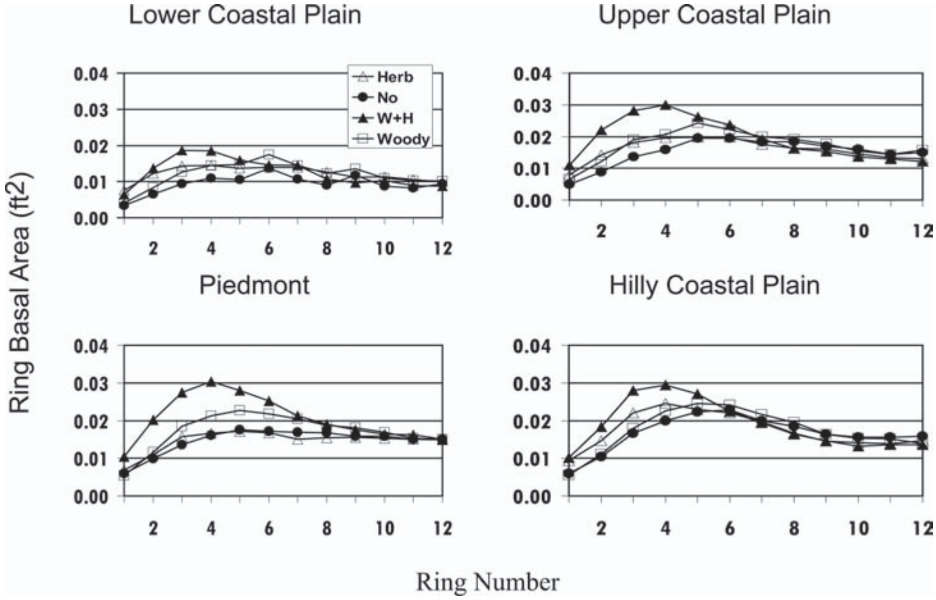

Figure 3. — Effect of woody, herbaceous, and woody plus herbaceous competition control on annual ring basal area growth by physiographic region.

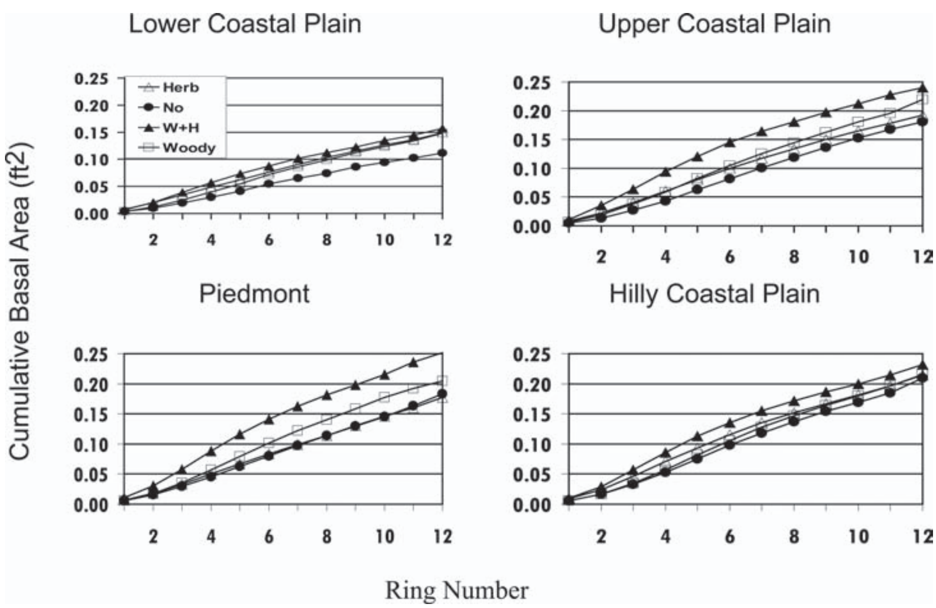

Figure 4. — Effect of woody, herbaceous, and woody plus herbaceous competition control on cumulative basal area growth by physiographic region.

with increasing ring number from pith in all regions. Basal area weighted proportion of latewood was significantly different among the four regions (**Table 2**). Basal area weighted percent latewood was highest in the Lower Coastal Plain and lowest in the Hilly Coastal Plain. The proportion of latewood in the annual ring is highest in the Lower Coastal Plain because the Lower Coastal Plain receives more late summer precipitation and has a long growing season for latewood formation (Clark and Daniels 2004).

Plots of ring SG over rings from the pith show ring SG did not vary with vegetation control treatment within any of the physiographic regions (**Fig. 5**). When ring SG was plotted over rings from the pith, ring SG displayed the normal juvenile/mature wood SG pattern for loblolly pine (Zobel et al. 1959, Bendtsen and Senft 1986) for all treatments and regions. Plots show low-SG crown-formed wood, formed in the first 2 to 5 rings, followed by a rapid increase in SG in the transition zone, followed by high-SG mature wood. Basal area weighted cross-sectional SG was significantly different among the four regions (**Table 2**). Cross-sectional SG is highly correlated with the proportion of latewood and negatively correlated with the diameter of the juvenile core. Cross-sectional SG was highest in the Lower Coastal Plain, 12 percent lower in the Upper Coastal Plain, 15 percent lower in the Piedmont, and 21 percent lower in the Hilly Coastal Plain compared to that in the Lower Coastal Plain.

Based on the criteria used in this study to define the transition from juvenile to mature wood, the vegetation control treatments had no consistent effect on the length of juvenility (**Table 3**). In the Lower Coastal Plain and Piedmont, the W+HC trees displayed 1 additional year of juvenility compared to 1 less year in the Upper Coastal Plain and 2 years less in the Hilly Coastal Plain. Trees in the Lower Coastal Plain were producing mature wood by rings 4 or 5, trees in the Upper Coastal Plain were producing mature wood by rings 7 or 8, trees in the Piedmont were producing mature wood by rings 8 or 9, and trees in the Hilly Coastal Plain were producing mature wood by rings 8 to10.

Basal area weighted earlywood SG was significantly different at only 2 locations (Counce and Warren in the Hilly Coastal Plain) of the 13 study locations for the W+HC treatment compared to the NOC treatment (**Table 4**). Warren and Hill Camp were the only locations where W+HC basal area weighted latewood SG was significantly different from that of the NOC treatment. Basal area weighted latewood SG at Hill Camp was significantly lower than that of the NOC treatment and at Warren the WC, HC, and W+HC basal area weighted latewood SGs were significantly higher than that of the NOC. Average cross-sectional weighted percent latewood for the W+HC treatment was lower for 12 out of 13 locations, but was significantly lower at only 3 locations (**Table 4**). When averaged across all locations, W+HC cross-sectional weighted percent latewood was 10 percent lower than that of the NOC treatment. Cross-sectional weighted SG for the W+HC treatment was lower than that of the NOC treatment for all 13 locations (**Table 4**), but significantly lower at only at 1 location (Pembroke in the Lower Coastal Plain). W+HC cross-

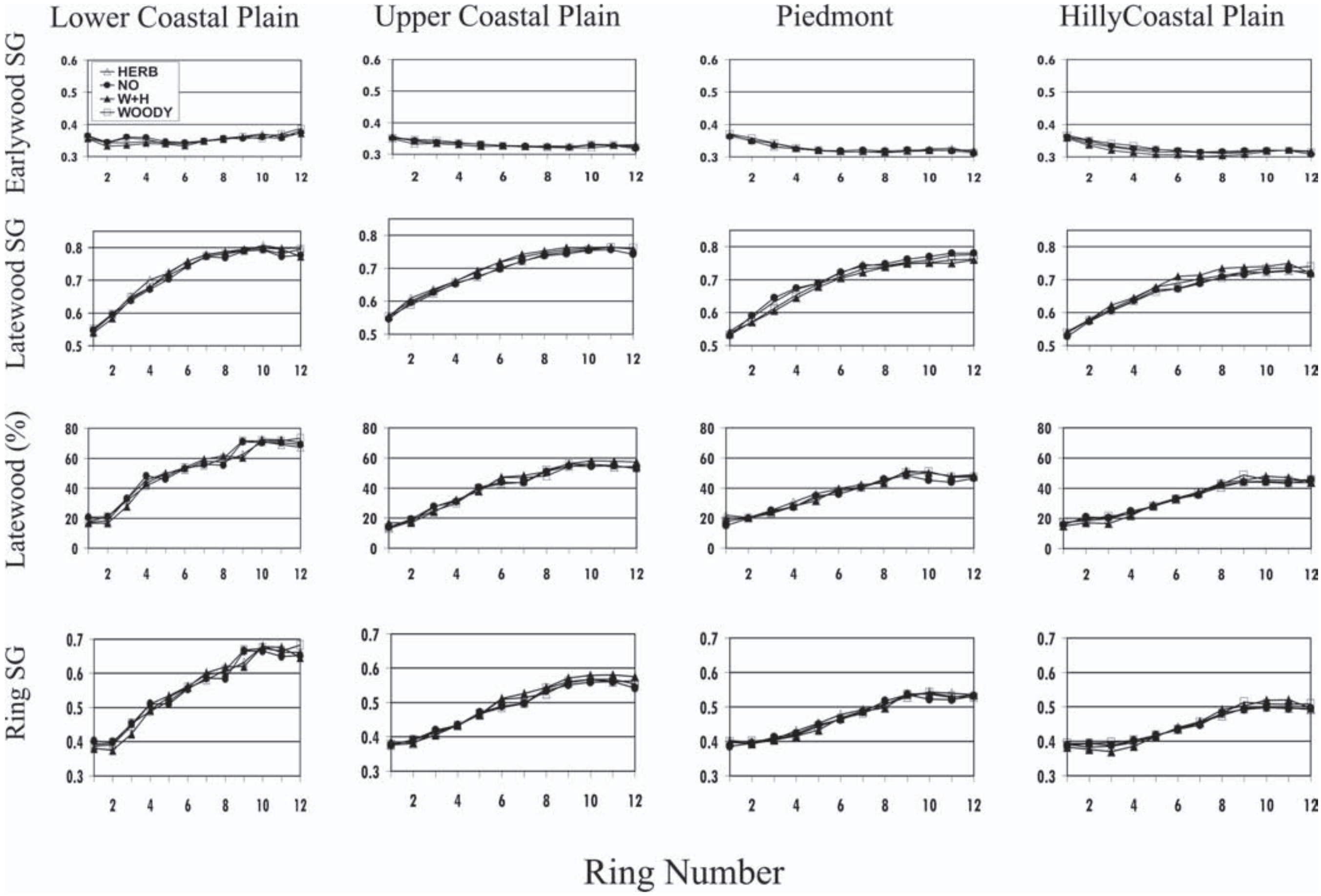

Figure 5. — Effect of woody, herbaceous, and woody plus herbaceous competition control on annual earlywood, latewood, ring SG, and proportion of latewood by physiographic region.

Table 2. — Basal area weighted earlywood, latewood, and cross-section SG, proportion of latewood, and diameter of juvenile core by physiographic region averaged across treatments.[a]

	Physiographic region			
Property	Lower Coastal Plain	Upper Coastal Plain	Piedmont	Hilly Coastal Plain
Earlywood SG	0.348 A	0.329 B	0.326 B	0.322 B
Latewood SG	0.749 A	0.710 B	0.712 B	0.684 C
Cross-sectional SG	0.555 A	0.486 B	0.470 B	0.439 C
Latewood (%)	51 A	41 B	37 C	32 D
Diameter juvenile core (in)	2.5 A	4.4 B	4.7 B	5.4 C

[a]Values across each row followed by a different capital letter are significantly different at the 0.05 level.

Table 3. — Length of juvenility by physiographic region and treatment.

	Physiographic region			
Control treatment	Lower Coastal Plain	Upper Coastal Plain	Piedmont	Hilly Coastal Plain
	(yr)			
None	3	7	7	9
Woody	4	7	7	8
Herbaceous	3	6	7	8
Woody+Herbaceous	4	6	8	7

sectional weighted SG, averaged across all locations, was 3 percent lower than that of the NOC treatment. Cross-sectional weighted SG and percent latewood were lower in the W+HC trees because these trees grew more rapidly than the NOC trees during the first 4 to 6 years of the rotation (**Fig. 2**) and thus had wide annual rings when the trees are producing a small proportion of latewood and low ring SG during juvenile wood formation. Because the W+HC significantly increased basal area growth during the first 4 to 6 years, the diameter of the juvenile core was significantly larger at 10 of the 13 locations (**Table 4**). On average, the diameter of the juvenile wood core was 19 percent larger in the W+HC trees compared to that of the NOC trees.

When averaged across physiographic regions, cross-sectional weighted earlywood and latewood SG for the W+HC trees were not significantly different than that of the NOC trees (**Table 5**). The cross-sectional SG and percent latewood of the W+HC trees were significantly lower than that of the NOC when averaged across regions and diameter of the juvenile core was significantly larger in the W+HC trees.

Conclusions

Controlling woody plus herbaceous competing vegetation for the first 3 to 5 years after planting increased loblolly pine growth significantly at all study locations. The significant in-

Table 4. — Average loblolly pine cross-sectional weighted wood SG of earlywood, latewood, whole ring, proportion of latewood, and diameter of juvenile wood core by vegetation control treatment with sites grouped by physiographic region.[a]

	Lower Coastal Plain	Upper Coastal Plain					Piedmont			Hilly Coastal Plain		
Control	Pembroke, GA	Bainbridge, GA	Liberty, MS	Tallassee, AL	Atmore, AL	Liverpool, LA	Jenna, LA	Hill Camp, AL	Monticello, GA	Appomattox, VA	Arcadia, LA	Warren, AR	Counce, TN
Earlywood SG													
No	0.354 A	0.353 A	0.319 AB	0.328 A	0.323 A	0.327 AB	0.335 A	0.322 A	0.317 A	0.336 A	0.334 A	0.334 A	0.309 A
Woody	0.350 A	0.349 A	0.331 B	0.337 A	0.322 A	0.327 AB	0.330 A	0.326 A	0.320 A	0.333 A	0.336 A	0.334 A	0.310 A
Herb	0.348 A	0.349 A	0.331 B	0.330 A	0.323 A	0.320 B	0.334 A	0.328 A	0.313 A	0.335 A	0.329 A	0.334 A	0.302 AB
W+H	0.338 A	0.349 A	0.320 AB	0.328 A	0.318 A	0.334 A	0.334 A	0.327 A	0.320 A	0.331 A	0.324 A	0.324 B	0.299 B
Latewood SG													
No	0.747 A	0.706 A	0.711 A	0.702 A	0.733 A	0.711 A	0.684 A	0.721 A	0.733 A	0.709 A	0.687 A	0.647 A	0.698 A
Woody	0.751 A	0.680 B	0.694 A	0.714 A	0.740 A	0.710 A	0.685 A	0.710 A	0.720 A	0.700 A	0.689 A	0.665 B	0.696 A
Herb	0.756 A	0.705 A	0.721 A	0.717 A	0.740 A	0.710 A	0.701 A	0.729 A	0.717 A	0.708 A	0.692 A	0.669 B	0.688 A
W+H	0.741 A	0.713 A	0.715 A	0.693 A	0.730 A	0.705 A	0.704 A	0.686 B	0.713 A	0.695 A	0.700 A	0.677 B	0.700 A
Proportion of annual ring in latewood													
No	54 A	49 A	42 A	42 A	42 A	41 A	41 A	39 A	36 A	37 A	34 AB	34 A	31 A
Woody	53 A	45 A	39 AB	41 A	41 A	36 A	41 A	37 A	37 A	37 A	35 B	34 A	32 A
Herb	50 AB	50 A	41 AB	44 A	40 AB	38 A	35 B	40 A	40 A	39 A	33 AB	31 A	29 A
W+H	47 B	46 A	37 B	41 A	38 B	37 A	36 AB	37 A	37 A	35 A	30 A	31 A	30 A
Ring SG													
No	0.569 A	0.526 A	0.486 A	0.486 A	0.497 A	0.484 A	0.480 A	0.470 AB	0.467 A	0.473 A	0.454 A	0.441 A	0.433 A
Woody	0.56 AB	0.499 A	0.475 A	0.494 A	0.494 A	0.467 A	0.475 A	0.471 AB	0.469 A	0.470 A	0.458 A	0.449 A	0.433 A
Herb	0.557 AB	0.527 A	0.480 A	0.500 A	0.492 A	0.469 A	0.464 A	0.492 A	0.454 A	0.478 A	0.451 A	0.439 A	0.417 A
W+H	0.529 B	0.520 A	0.468 A	0.478 A	0.478 A	0.472 A	0.471 A	0.462	0.458 A	0.459 A	0.438 A	0.434 A	0.422 A
Diameter of juvenile wood core													
No	1.8 A	3.3 A	4.6 A	3.7 A	3.3 A	4.1 A	5.1 A	4.1 A	4.7 A	4.2 A	4.5 A	5.4 A	5.5 AB
Woody	2.7 B	3.5 A	5.2 AB	4.0 AB	4.4 B	4.4 AB	4.9 A	4.5 A	4.8 A	5.2 B	5.1 B	5.6 AB	5.6 A
Herb	2.5 B	3.7 AB	4.7 A	3.1 C	3.7 A	4.8 AB	5.1 A	3.7 A	5.1 A	3.4 C	5.0 AB	6.1 B	5.8 A
W+H	3.2 C	4.3 B	5.6 B	4.2 B	4.6 B	5.2 B	4.9 A	5.8 B	5.3 A	5.7 B	5.7 C	5.9 B	5.1 B

[a]Values for the same variable within a location followed by a different capital letter are significantly different at the 0.05 level.

Table 5. — Basal area weighted earlywood, latewood, and cross-section SG, proportion of latewood, and diameter of juvenile core by treatment averaged across physiographic region.[a]

	Control treatment			
Property	None	Woody	Herbaceous	Woody + herbaceous
Earlywood SG	0.330 AB	0.331A	0.327 B	0.326 B
Latewood SG	0.707 A	0.705 A	0.712 A	0.705 A
Cross-sectional SG	0.482 A	0.479 A	0.478 A	0.468 B
Latewood (%)	40 A	39 A	39 A	37 B
Diameter juvenile core (in)	4.2 A	4.6 B	4.3 A	5.0 C

[a]Values across each row followed by a different capital letter are significantly different at the 0.05 level.

crease in growth of the W+HC trees compared to that of the NOC trees during the first 4 to 6 years after planting resulted in significantly larger trees at age 15. After 15 years, study results show W+HC increased pine merchantable stem volume per acre on average 120 percent in the Lower Coastal Plain, 81 percent in the Upper Coastal Plain, 108 percent in the Piedmont, and 80 percent in the Hilly Coastal Plain compared to NOC. W+HC did not significantly reduce annual ring SG of earlywood or latewood, and did not significantly affect proportion of latewood in the annual ring. The vegetation control treatments had no consistent effect on the length of juvenility. W+HC significantly increased growth during juvenile wood formation in years 1 to 5 and thus significantly increased the diameter of the juvenile wood core by an average of 19 percent. Because of the increased growth during the juvenility period, the basal area weighted proportion of latewood decreased 10 percent and basal area weighted SG decreased 3 percent in the trees receiving the W+HC treatment compared to NOC trees. Growth gains, however, substantially offset the slight reduction in percent latewood and SG.

The herbicide applications in this study were broadcast across the study plots. A good chemical site prep treatment to control hardwoods in a loblolly pine plantation for 2 to 3 years costs about $100 per acre per year in 2004 dollars. A broadcast application of herbicides to control herbaceous vegetation would cost about $60 per acre per year. A banded application of herbicides to control herbaceous vegetation would cost only $35 to 40 per acre per year and provide about 80 percent of the growth response reported in this study.

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