total cubic-foot volume outside and inside bark are computed:

$$V_{tob} = 0.18658 + 0.00250(10)^2(50) = 12.7 \text{ ft}^3$$

$$V_{tib} = -0.09653 + 0.00210(10)^2(50) = 10.4 \text{ ft}^3$$

Next, the merchantable cubic-foot volume outside bark to a 4-in. top diameter outside bark is calculated using the estimate of V_{tob} and Equation (4) with the appropriate set of coefficients from Table 2:

$$V_4 = 12.7(1 - 0.54583 (4^{3.22011}/10^{3.03262})) = 12.1 \text{ ft}^3$$

The height at which the 6-in. diameter inside bark occurs is computed by applying Equation (11):

$$h = 50 - [1.37724 (10)^{-1.52017}(50)^{0.94915}(6)^{1.51618}] = 24.2 \text{ ft}$$

Finally, the merchantable cubic-foot volume inside bark associated with this portion of the tree can be calculated from the estimate of V_{tib}, Equation (5), and the proper coefficients from Table 2:

$$V_h = 10.4(1 - 0.70499((50 - 24.2)^{2.25108}/50^{2.16787})) = 8.1 \text{ ft}^3$$

The equations presented here can be used to predict total and merchantable cubic-foot volumes for loblolly pine trees grown in cutover site-prepared plantations. They are flexible enough to accommodate changing utilization standards and can also be used as implicit taper functions for predicting upper stem heights and diameters. □

Literature Cited

AVERY, T. E., AND H. E. BURKHART. 1983. Forest measurements. Ed. 3. McGraw-Hill Book Co., New York. 331 p.

BURKHART, H. E. 1977. Cubic-foot volume of loblolly pine to any merchantable top limit. South. J. Appl. For. 1:7–9.

BURKHART, H. E., Q. V. CAO, AND K. D WARE. 1981. A comparison of growth and yield prediction models for loblolly pine. Sch. For. & Wildl. Resour., VPI & SU, Publ. FWS-2-81. 59 p.

BURKHART, H. E., D. C. CLOEREN, AND R. L. AMATEIS. 1985. Yield relationships in unthinned loblolly pine plantations on cutover, site-prepared lands. South. J Appl. For. 9:84–91.

CAO, Q. V., AND H. E. BURKHART. 1980 Cubic-foot volume of loblolly pine to any height limit. South. J. Appl. For. 4:166–168.

FLOWERS, W. J., JR. 1978. Individual tree weight and volume equations for site prepared loblolly pine plantations in the Coastal Plain of the Carolinas, Georgia and North Florida. M.S. thesis, Univ. of Georgia. 53 p.

LEDBETTER, J. R., T. G. MATNEY, AND A. D. SULLIVAN. 1986. Tree profile and volume ratio equations for loblolly pine trees on cutover, site-prepared lands South. J. Appl. For. 10:241–244.

VAN DEUSEN, P. C., A. D. SULLIVAN, AND T. G. MATNEY. 1981. A prediction system for cubic foot volume of loblolly pine applicable through much of its range. South. J. Appl. For. 5:186–189

Pine-Hardwood Mixtures—A New Concept in Regeneration

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*ABSTRACT. Spring felling of standing residuals left after a commercial clearcut, controlled burning the following summer, and hand planting of approximately 450 pine seedlings per acre can produce productive pine-hardwood mixtures on many medium sites in the Southeast. Stand establishment costs are approximately one-half that for conventional pine plantations using intensive site-preparation techniques. These stands have the potential to enhance wildlife, increase forest diversity, improve visual attractiveness, and provide good overall productivity. Early growth of individual pine trees on three study sites was approximately equal to that of pines growing in pure pine plantations of the same age. After 4 growing seasons, 304 to 414 free-to-grow shortleaf pines (*Pinus echinata *Mill.) per acre in the study stands averaged 7.9 to 9.3 feet in total height. Oaks (*Quercus *L. spp.), the predominant hardwood component of the stands, averaged 4.8 to 6.4 feet in total height after 4 years. If correctly applied, this new regeneration technique has the potential to bring many thousands of acres under management that presently are left unattended following harvest.*

South. J. Appl. For. 11(4):192–197.

Although social and economic trends and land use patterns have changed dramatically in the Southeast over the past 40 years, approaches to reforestation have changed very little. Many foresters still promote intensive site preparation and pine plantation management on almost every acre, even though statistics show that nonindustrial owners of small tracts have not bought this approach. Others have promoted natural regeneration techniques with some success (Langdon 1981, McGee 1982). Even so, Ernest (1982) reported that only one acre in nine is purposely regenerated on private lands. Since nonindustrial private owners hold 70 to 80% of all timberland in the South, the majority of stands have no planned regeneration. If the South's forests are to produce the products and benefits the public wants and demands, we must offer landowners new innovative approaches to reforestation (Boyce et al. 1986).

A large number of owners of

small timber tracts have not planted pines because they consider the costs to be prohibitive (Kaiser and Royer 1983). Intensive site preparation and machine planting of pines can cost $200/ac or more (Pehl and Bailey 1983, Straka and Watson 1985). Many landowners cannot afford this, nor are they willing to make investments on the basis of timber production alone. They value their timber, but they are also highly interested in using their woodlands for wildlife, firewood, and esthetics (Royer 1979).

With the possibility of a Southwide growth decline in our forests (Sheffield et al. 1985), it is imperative that we have planned regeneration on as many acres as possible. What is needed is a regeneration system that allows the private nonindustrial owner to grow a significant pine component at a cost he can afford while maintaining his interest in wildlife and other nontimber commodities. The system should provide full stocking and help maintain site productivity. In some cases this can be accomplished through the use of natural regeneration techniques, such as "seed in place." However, there are times when the owner would like to have better control of stocking and be able to take advantage of genetically improved growing stock. A new system has been developed that involves planting genetically improved pine seedlings in stands where natural hardwood regeneration is promoted. In the past 7 years, this technique has been used to successfully regenerate approximately 3,200 acres of cutover lands on the Andrew-Pickens District of the Sumter National Forest to productive pine-hardwood mixtures. This paper describes the technique and gives results of 3 randomly selected 4-year-old shortleaf pine-hardwood stands on the Sumter National Forest that were established using this regeneration method.

The Technique

When stands are harvested, efforts are made to get full utilization for maximum timber benefits and to remove material that would increase the cost of site preparation. Standing residuals greater than 5-ft tall left following the harvest are chainsaw-felled from mid-April to early June. At this time in the Southern Appalachian foothills of South Carolina, most trees are three-quarters to fully leafed out. Time of year is important for this treatment for two reasons: (1) dry leaves and twigs of felled residuals are needed to carry the fire during summer burns, and (2) the severing of stems immediately following early spring flushes of growth reduces carbohydrate reserves in hardwood root stocks. By cutting trees after they have leafed out, twigs and small branches are able to dry more thoroughly through transpirational drying (McMinn 1986), and the depletion of hardwood carbohydrate reserves helps pines gain equal footing in the competition for growing space.

Felled residuals are allowed to dry until early to mid-July. At this time, with the fuel load cured and the nesting season of most game and nongame birds completed, a controlled burn is conducted on the site. The desired burn is a high intensity fire over a moist fuel bed. Following the fire the site should look "black." Some white ashy areas will appear where the fire burned too hot and some small spots may not burn at all. However, these should represent a small portion of the total area. Fuel moisture sticks (Ponderosa pine dowels) are used to determine the correct time to burn. These sticks measure the 10-hour timelag of moisture content in dead fuels ¼- to 1-in. in diameter, and unlike other weather instruments, they reflect all environmental conditions including the effects of daylength and cloudiness (Brown et al. 1977). Fuel moisture sticks are placed both inside and outside the area to be burned approximately 30 days prior to firing and are checked by weighing the dowels on portable scales. Based on experience, broadcast burning in the Southern Appalachians is best accomplished when the moisture sticks are at 13% moisture content outside the burn area and approximately 10% inside the burn area. Guidelines for conducting a safe and effective controlled burn are discussed by Danielovich et al. (1987). Most small nonindustrial owners must depend on consultant foresters or state service foresters to conduct the burning. In South Carolina the cost of burning, as well as the cost of other treatments, is partially defrayed because this regeneration technique is one of three that qualifies for landowner assistance.

The summer controlled burn provides some important benefits. First, the site is cleared and made accessible for planting. Second, the hardwoods that sprouted in the spring following chainsaw felling have again been knocked back to ground level, and more root carbohydrate reserves have been used up. Early research results indicate that burning does not reduce the number of sprouts, but height of 1-yr-old hardwood sprouts is reduced by 0.5 ft (Danielovich et al. 1987). The black surface of the site following the burn makes green pine seedlings, planted the following winter, show up better, so there is a better planting job. Also, since the fire kills aboveground dormant buds of hardwoods, the sprouts of desirable species that develop the following year are well anchored from below groundline (Augspurger et al. 1987). These sprouts are of good form and have the potential to develop into excellent crop trees along with the pines.

Summer broadcast burning removes approximately 80% of the surface forest floor, but 67% of the root mat remains intact (Danielovich 1986). It is the root mat that is so important for waterholding capacity, which allows young planted pines to survive and grow. It is also the root mat in place that prevents erosion. Danielovich (1986) found that erosion, measured as trapped sediment, did not increase in clearcut and burned areas when compared to clearcut areas alone.

In late winter or early spring following burning, approximately 450 genetically improved pine seedlings are hand planted. Over the past 6 years, loblolly (*Pinus taeda* L.), shortleaf, and some pitch (*P. rigida* Mill.) pines have been planted at 8 × 12 or 10 × 10 ft spacings. White pines (*P. strobus* L.) are planted at a 12 × 12 ft spacing.

Reforestation Costs Using this Technique

The cost of regenerating stands to pine-hardwood mixtures using this technique is about half that for conventional pine plantation establishment. For the years 1983 to 1985, 1,682 ac on the Sumter were treated at an average cost of approximately $90/ac. Average stand size was 32 ac and at least 500 ac were treated each year. A breakdown of costs by year is as follows:

Treatment	1983	1984	1985
	....	$/ac	....
Contract chainsaw felling	18.37	24.37	24.14
Contract fireline construction	7.46	10.14	13.40
USDA Forest Service burning crew (7–10 people, 1 stand/day)	18.24	17.80	18.35
Seedlings (average cost/ac)	16.80	16.20	17.10
Contract planting	23.00	21.50	25.92
Total	83.87	90.01	98.91

Costs were divided almost equally among four items: chainsaw felling, controlled burning, seedling purchases, and labor for hand planting of pines. Burning costs on the Sumter are somewhat higher than would be expected on private lands, but other costs should be representative. Straka and Watson (1985) reported that mechanical site preparation (shear, rake, pile, and disk) in the Piedmont and Coastal Plain of the southern United States averaged $143.26/ac in 1984. The average cost of machine planting in the Piedmont that year was $49.10/ac. If our 1984 seedling cost of $21.50/ac is used, the total cost of intensive site preparation and planting is $213.86/ac, more than double the cost using the pine-hardwood approach.

Shortleaf Pine-Hardwood Mixtures

To illustrate the growth and development of pine-hardwood stands established with this technique, three 4-yr-old shortleaf pine-hardwood stands on the Andrew-Pickens District of the Sumter National Forest were randomly selected for study. These stands had a combination of pines and hardwoods in the overstory prior to harvest. They were located at elevations of approximately 1500 ft and had southern exposures. Based on site trees and general observations, initial stand productivity was judged to be about equal at each site. Site index (base age 50) was estimated to be about 70 for shortleaf pine and about 60 to 70 for white oak. To get a better estimate of site productivity, soil samples were taken at each site. The first stand, referred to as Sandy Ford, had a Saluda soil with a solum (A and B horizons) depth of 16 to 20 in. The second site, called Whetstone, had an Evard soil with a solum depth of 28 to 32 in. The third site, Pine Mountain, had a Walhalla soil with a solum depth of 40 to 49 in. All soils were typic hapludults. Based on soil depth and series, Pine Mountain was estimated to be the most productive and Sandy Ford the least productive.

In the winter of 1980, the three stands were harvested. The volume of products removed was low because the stands had been cut over several times prior to this final harvest. Sandy Ford and Whetstone each produced slightly more than 300 cu ft/ac of pine roundwood and 340 to 390 cu ft/ac of hardwood roundwood (Table 1). Pine Mountain had somewhat lower roundwood yields. Whetstone and Pine Mountain also produced a small amount of mostly pine sawtimber. The following spring, after limited free-use firewood removals, standing residuals greater than 5 ft tall were felled. In the summer of 1981 the sites were burned, and the following winter approximately 450 genetically improved shortleaf pines seedlings/ac were planted.

In the winter of 1985–86, four growing seasons after stand establishment, each stand was inventoried to determine species composition, density, and growth of pines and hardwoods. Free-to-grow planted shortleaf pines (those receiving light from above) were tallied in each stand on six 52.5 × 82-ft plots arranged in a 2 × 3 matrix with the long axis running east and west along the contour. Hardwoods were measured on three 10 × 120-ft strips spaced approximately 90 ft apart and arranged perpendicular to the contour of the slope. With sprout clumps of more than one stem, minor suppressed stems in the clump were not counted. Basal diameter and total tree height were measured on each planted pine, species and total tree height were recorded on all hardwoods. With hardwood clumps, only the height of the tallest tree was recorded.

Table 1. Volume of harvested timber at three locations on the Sumter National Forest, 1981.

Location	Pulpwood		Sawtimber[c]	
	Pine[a]	Hardwood[b]	Pine	Hardwood
	....	ft³/ac	....	MFB/ac ....
Sandy Ford	320	340	—	—
Whetstone	310	390	7.8	0.5
Pine Mountain	200	300	3.0	0.2

[a] Pine pulpwood, 5.0″ < dbh < 12.0″.
[b] Hardwood pulpwood, 6.0″ < dbh < 14.0″.
[c] Scribner decimal C.

RESULTS

The three sample stands were inventoried 1 and 4 years after planting to determine survival rates of planted shortleaf pines. After 1 year, survival was 95% at Sandy Ford, 93% at Whetstone, and 98% at Pine Mountain. After 4 years, the number of free-to-grow trees had dropped to 71% at Sandy Ford, 84% at Whetstone, and 91% at Pine Mountain. Even so, there were 304, 356, and 414 free-to-grow pines/ac after 4 years at Sandy Ford, Whetstone, and Pine Mountain, respectively. The first-year survival in the three sample stands was slightly higher than the 88% survival rate for all stands (1,682 acres) installed from 1983 to 1985.

After 4 growing seasons, a detailed inventory of the three stands revealed that a large component of the planted pines had not only survived, but had grown substantially. Average basal diameter ranged from 1.6 to 2.1 in. and average total height ranged from 7 9 to 9.3 ft (Table 2). These growth rates equal or exceed those found in many pure shortleaf or loblolly pine plantations of similar age. Dierauf (1986) reported height growth of 7.0 to 9.0 ft for 4-year-old planted loblolly growing on an upland site in the Piedmont of Virginia.

Significant differences in diameter and height growth occurred between the three stands. Whetstone had significantly larger planted pines than Sandy Ford, and Pine Mountain, in turn, had significantly larger trees than Whetstone (Table 2). These differences are attributable primarily to differences in site productivity and hardwood competition. Sandy Ford had the shallowest soil (solum depth = 16 to 20 in.) and the greatest hardwood competition while Pine Mountain had the deepest soil (solum depth = 40 to 49 in.) and the least hardwood competition.

After 4 growing seasons, the hardwood component of the three stands had developed quite differently. Sandy Ford had more total hardwood sprouts (4,898 stems/ac) than Whetstone (4,400 stems/ac), and substantially more than Pine Mountain (3,626 stems/ac) (Table 3). Species composition also differed substantially among locations. Sandy Ford was dominated by oaks, blackgum (*Nyssa sylvatica* Marsh.), hickory (*Carya* Nutt. spp.), and a mixture of other hardwoods (Table 3). Whetstone had a fairly large oak component, but less hickory and more mixed hardwoods than Sandy Ford. Pine Mountain had very few oaks and hickories but larger numbers of blackgum and yellow-poplar (*Liriodendron tulipifera* L.). Yellow-poplar was almost nonexistent at Sandy Ford and Whetstone. Interestingly, red maple (*Acer rubrum* L.) was a minor component of all three stands. Red maple is generally one of the more serious competitors to more desirable species because it sprouts prolifically and can tie up large amounts of growing space, especially on the better sites. Beck and Hooper (1986) found that red maple in the Southern Appalachians self-thins very slowly and occupies considerable growing space even at stand age 20. Kays et al. (1984) reported that red maple sprouted much less on poor Piedmont sites than on good ones, and less following growing season harvest than following dormant season harvest. Since the three sites in this study were medium in productivity and since the summer burns caused the stands to respond as though they had been harvested in summer, and red maple growth may have been minimized. On the better of the three sites (Pine Mountain), red maple was limited in numbers (162 trees/ac), but had exceptional height growth (10.2 ft) (Table 3).

A comparison of mean tree heights of pines and hardwoods showed that shortleaf pine was significantly taller than all hardwoods and select oaks regardless of location (Table 4). However, when pine heights were compared to the height of hardwoods greater than 5 ft tall, pines were significantly taller than the hardwoods only at Whetstone and Pine Mountain. At Sandy Ford, there was no significant difference in the height of pines and hardwoods greater than 5 ft tall. The 5 ft height was selected to represent dominant and codominant stems.

Table 2. Number of trees sampled and mean (±standard error of mean) stem basal diameters and total heights of planted shortleaf pine four years after planting.[a]

Location	Trees sampled	Mean (±standard error of mean)	
		Basal diameter	Total height
	no.	in.	ft
Sandy Ford	182	1.6 ± .03 a	7.9 ± .13 a
Whetstone	213	1.8 ± .04 b	8.4 ± .14 b
Pine Mountain	248	2.1 ± .03 c	9.3 ± .12 c

[a] Means within columns followed by the same letter are not different at the 0.05 level, Duncan's New Multiple Range Test.

Table 3. Number of trees per acre and average total tree height of hardwoods by species and location four years after regeneration.

Species	Sandy Ford		Whetstone		Pine Mountain	
	Trees/ac	Height (ft)	Trees/ac	Height (ft)	Trees/ac	Height (ft)
Select oak[a]	1,945	6.4	1,409	5.6	298	4.8
Blackgum	1,296	4.7	1,259	4.3	935	4.2
Hickory	474	5.7	150	3.4	262	4.4
Red maple	187	5.9	125	5.4	162	10.2
Yellow-poplar	25	9.6	87	4.4	586	5.3
Other hardwoods	971	7.2	1,370	5.2	1,383	4.7
All hardwoods	4,898	5.8	4,400	4.9	3,626	4.7

[a] Scarlet oak (*Quercus coccinea* Muenchh.), southern red oak (*Q. falcata* Michx.), white oak (*Q. alba* L), post oak (*Q. stellata* Wangenh.), black oak (*Q. velutina* Lam.), chestnut oak (*Q. prinus* L.).

Table 4. Comparison of mean total tree height of shortleaf pines with all hardwoods, hardwoods greater than 5 ft tall, and select oaks by location.

Location	Pine total height	All hardwoods		Hardwoods > 5 ft tall		Select oaks[a]	
		Total height	Difference from pine	Total height	Difference from pine	Total height	Difference from pine
	feet						
Sandy Ford	7.9	5.8	2.1**	7.9	0.0[NS]	6.4	1.5**
Whetstone	8.4	4.9	3.5**	6.9	1.5**	5.6	2.8**
Pine Mountain	9.3	4.8	4.5**	7.0	2.3**	4.8	4.5**

[a] Scarlet oak, southern red oak, white oak, post oak, black oak, chestnut oak.
** Highly significant difference from pine total height, $\alpha = 0.01$.
[NS] Not significantly different from pine total height.

If each clump is considered a single point of competition (one stem), there were 660, 598, and 87 hardwood stems/ac greater than 5 ft tall at Sandy Ford, Whetstone, and Pine Mountain, respectively.

SUMMARY AND IMPLICATIONS

Low intensity site preparation and the culturing of pine-hardwood mixtures can provide many benefits to a wide range of timberland owners. A major benefit is that regeneration costs are reduced by approximately 50%. The regeneration of approximately 3,200 ac of cutover land on the Andrew-Pickens District of the Sumter National Forest averaged about $90/ac whereas intensive site preparation costs often exceed $200/ac (Straka and Watson 1985).

Another benefit is excellent early survival and growth of planted shortleaf pines. First year survival in three sample stands averaged 95%, and the number of free-to-grow trees after 4 growing seasons was 304 to 414 trees/ac. Height growth was also excellent. The average height of planted shortleaf pines after 4 years was 7.9, 8.4, and 9.3 ft in three sample stands. Corresponding basal diameters of trees averaged 1.5, 1.8, and 2.1 in. Height of pine trees was significantly greater than the height of hardwoods except at Sandy Ford, where pine height was no different than the height of hardwoods greater than 5 ft tall.

Although hardwood growth was generally less than for pines, many desirable hardwood species grew well. Oaks, a major hardwood component in two stands, averaged 4.8 to 6.4 ft tall. Yellow-poplar, a major component of the third stand, averaged 5.3 ft tall. Although measurements were not taken on stem form, visually the hardwoods appeared to be well-anchored stems of good form.

The product goal for these stands is small sawtimber and pulpwood for both pines and hardwoods. Since the pines have gained an early competitive edge (Table 4, Figure 1), they are expected to be a major component of the final stand. Quality hardwoods are also expected to contribute to the value of these stands as commercial species of good stem form develop into crop trees.

In addition to the advantages of low cost and good early growth, there are many other potential benefits of pine-hardwood mixtures. By culturing a hardwood component, stand diversity is increased, and wildlife benefits are enhanced. Sprouting hardwoods provide excellent browse for deer and cover for small game such as turkeys and rabbits. The summer burns increase herbaceous vegetation by twofold over nonburn areas (Danielovich et al. 1987), so insects that feed on green leafy vegetation are increased, and small mammals that feed on the vegetation and the insects are increased. By not using heavy equipment during site preparation, and burning over a moist fuel bed, most of the root mat is maintained and erosion is minimized (Danielovich 1986). Over

Figure 1. View of Sandy Ford site four growing seasons after stand establishment. Stand has an average of 304 free-to-grow shortleaf pines/ac that average 7.9 ft in height and 1,945 select oaks/ac that averaged 6.4 ft.

time, this should help maintain site productivity. Genetic gains are realized through the use of genetically improved pine seedlings, and natural selection gains are realized through normal field competition between pines and hardwoods. The pales weevil (*Hylobius pales* Hbst.) is eliminated with this technique, and southern pine beetle (*Dendroctonus fontalis* Zimm.) attacks are reduced because the pine trees are too far apart to support spot spread (Belanger et al. 1983). Finally, mixed stands are generally thought to be visually more attractive than pure pine stands.

The successful use of the pine-hardwood regeneration technique does require attention to certain details. The scheduling of events is seasonally oriented, so chainsaw felling must be conducted in the spring and burning must be conducted in the summer (Abercrombie and Sims 1986). If the work is to be contracted, substantial planning is required to assure that the work in one phase of the operation is completed on time so the next phase can start. With the use of fire, safety and smoke management are concerns, but where favorable burning conditions exist and trained crews are used, these problems can be minimized.

Even though early results are promising, there are some disadvantages of this technique as compared to pure pine management. Based on today's markets, the value of intermediate and harvest cuttings would be reduced because of the lower valued hardwood component. Income from thinnings would also likely be delayed since the first thinning would not occur until the stand reached an age of about 25 years. Fuel reduction burns could not be conducted in the stands until hardwoods reached a size where fire damage would be minimal. Since this technique is new, information is lacking on long term growth and yield and on the type and timing of intermediate cultural treatments. In addition, the technique has been tested only in the Southern Appalachians, so the full range of sites to which it can be applied is yet to be determined.

In spite of these disadvantages, the technique fills a very important need. It provides an option to landowners that are interested in multiple-use management at an affordable price. Maximum timber production per acre may not be realized, but with substantially reduced regeneration costs, the net return on investment could be very attractive. More importantly, many acres that are presently unmanaged could be brought into production, and many nontimber benefits could be enhanced. □

Literature Cited

ABERCROMBIE, J. A., JR., AND D. H. SIMS. 1986. Fell and burn for low-cost site preparation. For. Farmer 46(1):14–17.

AUGSPURGER, M. K., ET AL. 1986. Regeneration of hardwood coppice following clearcutting with and without prescribed fire. P. 89–92 *in* proc. 4th Bienn. So. Silvic. Res. Conf., Atlanta, GA. Southeast. For. Exp. Stn., Asheville, NC.

BECK, D. E., AND R. M. HOOPER. 1986. Development of a Southern Appalachian hardwood stand after clearcutting. South. J. Appl. For. 10:168–172.

BELANGER, R. P., ET AL. 1983. Coping with southern pine beetles. For. Farmer 42(8):8–9.

BOYCE, S. G., ET AL. 1986. Silviculture—the past 30 years, the next 30 years. J. For. 84(6):41–48.

BROWN, J. K., J. A. K. SNELL, AND D. L. BUNNELL. 1977. Handbook for predicting slash weight for western conifers. USDA For. Serv. Intermt. For. & Range Exp. Stn., Gen. Tech. Rep. Int-37. 35 p.

DANIELOVICH. S. J. 1986. High intensity site preparation burning after clearcutting in southern hardwoods—effects on residual vegetation and soil erosion. Thesis, Clemson Univ., Clemson, SC. 67 p.

DANIELOVICH, S. J., ET AL. 1987. Site-preparation burning in South Appalachian logging slash—effects on residual vegetation and hardwood regrowth. P. 91–97 *in* Sixth Central Hwd. For. Conf. Proc., Knoxville, TN.

DIERAUF, T. A. 1986. Loblolly pine release study—Report No. 5. Occas. Rep. 69. Virginia Div. For., Charlottesville. 9 p.

ERNEST, A., JR. 1982. Financing the South's forest development. For. Farmer 41(9):6–7, 32.

KAISER, H. F., AND J. P. ROYER. 1983. Why nonindustrial forest landowners do not invest in pine reforestation. Tree Planters Notes 34(2):8–10.

KAYS, J. S., D. WM. SMITH, AND S. M. ZEDAKER. 1984. Season of harvest and site quality effects on hardwood regeneration in the Virginia Piedmont. P. 137–145 *in* Proc. Third Bienn. So. Silvic. Res. Conf. Atlanta, GA. Southeast. For. Exp. Stn., Asheville, NC.

LANGDON, O. G. 1981. Natural regeneration of loblolly pines: A sound strategy for many forest landowners. South. J. Appl. For. 5(4):170–176.

MCGEE, C. E. 1982. Low quality hardwood stands—opportunities for management in the interior uplands. USDA For. Serv., South For. Exp. Stn. Gen. Tech. Rep. SO-40, New Orleans, LA. 22 p.

MCMINN, J. W. 1986. Transpirational drying of red oaks, sweetgum, and yellow-poplar in the Upper Piedmont of Georgia. For. Prod. J. 36(3):25–27.

PEHL, C. E., AND R. L. BAILEY. 1983. Performance to age ten of a loblolly pine plantation on an intensively prepared site in the Georgia Piedmont. For. Sci. 29(1):96–102.

ROYER, J. 1979. Conclusions from a review of 50 years of small woodlot owner studies. Paper presented at South. For. Econ. Workshop. Duke University, Durham, NC.

SHEFFIELD, R. M., ET AL. 1985. Pine growth reductions in the Southeast. USDA For. Serv. Southeast. For. Exp. Stn. Res. Bull. SE-83. 112 p.

STRAKA, T. J., AND W. F. WATSON. 1985. Costs of forestry practices. For. Farmer Man. 44(5):16–22.