Importance of Release for Naturally Seeded and Planted Container Loblolly Pines on a Cutover Site

Michael D. Cain and James P. Barnett

Silviculturalist and project leader, USDA Forest Service, Southern Research Station Monticello, Arkansas, and Pineville, Louisiana

Genetically improved container loblolly pine (Pinus taeda *L.) seedlings were compared to naturally established loblolly seedlings on a cutover pine site. Measurement pines on 6 of 12 plots were released from woody and herbaceous competition in a 61-cm (2 ft) radius around each tree stem. Woody competition was controlled by hand cutting for 5 consecutive years, and herbaceous competition was controlled with herbicides for 4 consecutive years. Competition control increased 6-year survival by 26% for both natural and planted pines. Six years after field establishment, planted pines had a 73% higher volume index than naturally established pines. Large volume gains resulted from release for both regeneration techniques (544% for planted pines and 663% for naturally established pines).* Tree Planters' Notes 45(4):128-136; 1994.

In the management of southern pines, release treatments can alter the competitive balance on regenerated sites and thereby improve the survival and growth of juvenile pines (Cain and Mann 1980, Clason 1984, Haywood 1986). When intensive treatments were applied to control woody and herbaceous vegetation, substantial 5-year growth gains were observed for planted loblolly pines *(Pinus taeda* L.) (Miller and others 1991) and naturally seeded loblolly pines (Cain 1991b). However, results from investigations on plantations are often not directly comparable to those on natural stands because of variations in site, competing species, and treatments.

Many forest landowners may attempt to reduce their establishment expenditures by outplanting improved seedlings where site conditions are less than optimal. These landowners need to know how improved pine seedlings compare to naturally regenerated pine in terms of potential growth following minimal (that is, low-cost) site preparation.

Although the benefits of release are well documented, there is little information on how naturally seeded and planted loblolly pines respond to release treatments applied uniformly within the same research study. Our objectives were (1) to compare loblolly pines established by natural seedfall to outplanted container loblolly pines from a genetically improved seed source in terms of survival and juvenile growth and (2) to determine if control of woody and herbaceous competition produces different responses in naturally established pines than in planted, genetically improved pines. Container seedlings were chosen because they provide an efficient use of genetically improved seed, are quickly produced, and have an extended planting season (Barnett and Brissette 1986).

Methods

Study area. The study was conducted on a 2-ha (5-acre) clearcut on the Crossett Experimental Forest in southern Arkansas (figure 1). The soil was Bude silt loam (Glossaquic Fragiudalf), with a site index of 27m at 50 years for loblolly pine.

Between 1934 and 1969, pines in the study area had been intensively managed using single-tree selection: better pines were exempted from harvest until reach-

Figure 1—*Portion of the 2-ha (5-acre) study area in southern Arkansas at time of study initiation (early spring 1987, 2 years after clearcutting and 1 year after spot treatment with hexazinone herbicide).*

ing a diameter at breast height (dbh) of 46 to 61 cm (18 to 24 in). In the mid-1980's, the site contained an overstocked, uneven-aged stand of loblolly and shortleaf pines *(Pinus echinata* Mill.*)* infested with southern pine beetles *(Dendroctonus frontalis* Zimm.). In summer 1985, trees were clearcut on about 2 ha (5 acres) to salvage approximately 132 m^3/ha (11,000 fbm /acre, Doyle scale) of pine sawlogs killed by bark beetles.

In April 1986, 1 year after clearcutting, the entire area was spot-treated with hexazinone (Velpar® L) at the rate of 3.4 kg ai / ha (3 lb ai / acre) using herbicide spotguns on a 0.9- by 0.9m (3- by 3-ft) grid to control nonpine vegetation. This treatment controlled the larger hardwoods but was less effective on hardwood seedlings, shrubs, and herbaceous vegetation. In summer 1987, a few surviving hardwoods taller than 1.8 m (6 ft) were basally injected with a 50% solution of glyphosate.

Study design and treatment. A completely randomized statistical design was used, with three replications of four treatments: natural pine seedlings (N), natural pine seedlings plus release (N / R), planted container pine seedlings (P), and planted container pine seedlings plus release (P/R). "Release" refers here to freeing a tree from immediate competition by eliminating vegetation that overtopped or closely surrounded the tree in a 61-cm (2-ft) radius around its stem. For the purpose of this investigation, "seedlings" had a dbh of less than 1.5 cm (0.6 in), and "saplings" had a dbh greater than or equal to 1.5 cm (0.6 in) but less than 9.1 cm (3.6 in).

Each of 12 plots measured 28.4 by 28.4 m (93.3 by 93.3 ft), with 19.2- by 19.2-m (63- by 63-ft) interior subplots. Individual plots accommodated 121 planting spots for crop pines on a 2.7- by 2.7-in (9- by 9-ft) spacing. The 49 crop pines on interior subplots were used as measurement trees. The two regeneration techniques-natural seeding and planting seedlingswere randomly assigned to each of six plots.

Loblolly pine seeds for the container stock were obtained from the Kisatchie National Forest Seed Orchard in central Louisiana, but the original clone selections were from a northern Louisiana source. The open-pollinated seeds were from a bulk orchard lot that had been collected in 1984 before the seed orchard was rogued. The expected genetic gain was about 5% over nursery-run stock.

In mid-September 1986, seeds for the planting stock were sown in Ray-Leach Stubby Cells® filled with a 1:1 peat-vermiculite medium. Greenhouse cultural treatments followed guidelines described by Barnett and Brissette (1986). Because the seedlings were grown during winter, development was slow and the stock was about 26 weeks old when outplanted in early April 1987. At outplanting, pine shoot length averaged 11.6 cm (0.38 ft) and groundline diameter (gld) averaged 2.5 mm (0.1 in). The seedlings were considered small because the recommended shoot length of container loblolly pine seedlings is 15 to 20 cm (0.5 to 0.7 ft) at outplanting (Barnett and Brissette 1986). Although smaller than recommended, container seedlings had a distinct height advantage over natural pine seedlings that had just begun to germinate from seed (figure 2).

Natural pines dropped seeds onto the study area from autumn 1986 through winter 1987. An estimate of natural pine seed production was obtained from 0.2-m^2 (2.2-ft^2) seed collection traps. One trap was placed 0.6 m (2 ft) above ground at the center of each 0.08-ha (0.2-acre) plot. Seed counts were made weekly from October 1986 through February 1987. The seedcrop

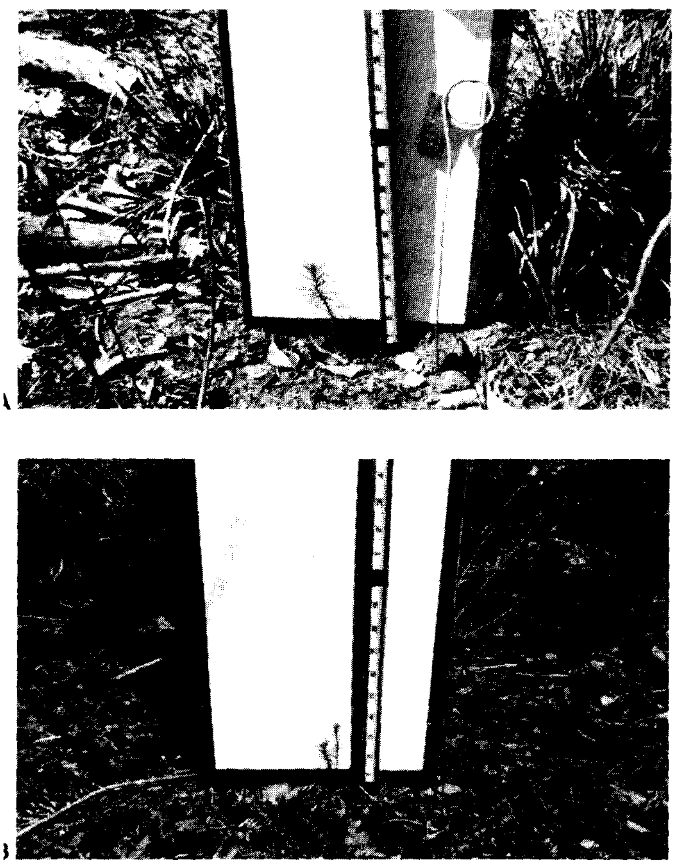

Figure 2—*Container loblolly pine seedling (A) shortly after outplanting in April 1987, and natural loblolly pine seedling (B) from the 1986-87 seedcrop, photographed in April 1987.*

averaged over 740,000 seeds / ha (300,000 seeds / acre), with 75% judged potentially viable when tested with the seed cutting test described by Bonner (1974). The 1985-86 seedcrop from the previous winter had been judged a failure, with only 7,400 potentially viable seeds/ha (3,000 seeds/acre) (Cain 1991a). An average seed year for loblolly pine is expected to produce from 74,000 to 198,000 viable seeds/ ha (30,000 to 80,000 seeds/ acre), so the 1986-87 seedcrop appeared to be outstanding.

In early summer 1987, 49 natural seedlings were selected as measurement trees and tagged for identification on each of the 6 interior plots where the growth of natural pine regeneration was monitored. Their selection was based on seedling quality and spacing. The tallest first-year seedlings were usually chosen if their terminal buds were intact, although other quality criteria were used as well-for example, the presence of dark green needles and absence of insects, disease, and mechanical damage. A total of 294 natural pine seedlings and 294 planted pine seedlings were tagged for measurement. All other natural pine seedlings were left undisturbed.

Beginning in the 1987 growing season, measurement pines were released from woody and herbaceous competition on three planted plots and three naturally seeded plots (table 1). With machetes, woody vegetation was cut below pine height in a 61-cm (2-ft) radius around preselected pines. Then, within the same 61-cm (2-ft) radius, sulfometuron methyl was applied at 0.26 kg ai / ha (3.75 oz ai / acre) and glyphosate was applied at 0.76 kg ai / ha (0.68 lb ai /acre) to control herbaceous vegetation (figure 3). The herbicides were dispersed as water solutions at the rate of 103 L/ha (11 gal/ acre) using backpack sprayers, and pines were shielded at time of treatment. Cutting was always done before herbicide was applied. Sulfometuron was the principal herbicide used because of pine's tolerance to it; glyphosate was included only in the 3rd and 4th growing seasons to control broomsedge *(Andropogon virginicus* L.), which is resistant to sulfometuron. Some volunteer natural pine seedlings became established within the 61-cm (2-ft) treatment radius after the first year of release but were not intentionally eliminated until the dormant season of the 4th year because they were considered no great impediment to the growth of crop pines.

Measurements and data analysis. After the first year of field establishment, measurement tree heights were taken to the nearest 3 cm (0.1 ft), and gld was measured to the nearest 1 mm (0.04 in). Total heights and gld's were remeasured, using the same degree of accuracy, on all surviving measurement pines at the end of the 3rd, 4th, 5th, and 6th growing seasons. As an estimate of tree volume, total height x gld^2- was calculated and reported as volume index. At each inventory, dbh measurements were taken to the nearest 1 mm (0.04 in) on all crop trees taller than

Table 1 -*Pine release treatments applied during first 5 years after field establishment*

Time of release	Type of release: Manual cutting	Sulfometuron	Glyphosate
1987			
Spring	o	"	"
Summer	+	+	o
1988			
Spring	+	+	o
Summer	+	+	o
1989			
Spring	+	+	o
Summer	+	+	+
1990			
Spring	+	o	+
Summer	+	"	"
1991			
Spring	o	"	"
Summer	+	"	"

Note: += treatment applied;o = no treatment. Spring treatments were applied in April, summer treatments in June or July.

1.37 m (4.5 ft). After 6 growing seasons, height-to-live-crown was measured to the nearest 3 cm (0.1 ft) on all surviving crop trees, and crown widths were measured to the nearest 3 cm (0.1 ft) at the widest axis and perpendicular to that axis on a random sample of 15 pines per plot.

Measurement pines were judged as free-to-grow if the terminal leader was not overtopped by the foliage of competing vegetation. If pines were overtopped, then the competing species was recorded. Estimates of natural pine and woody rootstock densities and quadrat stocking were obtained from an inventory of 9 temporary 4-m^2 (1-milacre) circular quadrats (10% sample) that were systematically located on each interior plot. The most recent inventory for assessing population dynamics of natural pine and hardwood rootstocks was conducted 6 years after site preparation with hexazinone.

Analysis of variance for a completely randomized design was used to evaluate treatment effects on pine survival and overtopped status. Percentage values for survival and overtopped status were compared among treatments following arcsine transformation. Sizes of measurement pines were first subjected to analysis of covariance, with first-year sizes as covariates. Because covariates proved nonsignificant, all variables were reanalyzed by analysis of variance. Statistically significant treatment differences ($P < 0.05$) were tested by orthogonal contrasts as follows: N vs. N/R; P vs. P/R; and N+N/R vs. P+P/R

Cost of release was determined from the average number of worker-hours required to manually cut the woody competition and to chemically treat the herbaceous vegetation in a 61-cm (2-ft) radius around 1,500 pines/ha (607 pines/acre). Whenever treatments were applied, records were maintained of the time required to cut the hardwoods and spray the herbicides on a plot-by-plot basis. The cost of unskilled labor was based on a minimum wage of $4.25 / hr. Herbicide costs were based on 1992 retail prices: $351 / kg ($159/lb) for sulfometuron and $29/L ($111/gal) for glyphosate. Release treatments were applied by USDA Forest Service personnel to assure quality control.

Results

Pine response to treatments. After 6 growing seasons, release treatments had improved survival of crop pines by 26% on both naturally regenerated plots ($P = 0.0079$) and planted plots ($P = 0.0175$) (table 2). There was no difference in pine survival between the two regeneration techniques ($P = 0.4930$).

Table 2 -*Survival and overtopped status of measurement pines 6 years after field establishment*

Treatment comparisons	% survival	(PR > F)[a]	Overtopped status (%)	(PR > F)[a]
Natural	71		64.5	
		0.0079		0.0001
Natural/Release	97		2.2	
Planted	69		59.5	
		0.0175		0.0003
Planted/Release	95		7.3	
N + N/R	84		33.4	
		0.4930		1.0000
P + P/R	82		33.4	
Mean square error	0.0374		0.0140	

[a] The probability of obtaining a larger F-ratio under the null hypothesis. Orthogonal contrasts are natural vs. natural/release, planted vs. planted/release, and N + N/R vs. P + P/R.

Of nonreleased pines still alive after 6 years, 60% or more were overtopped by competing vegetation, regardless of regeneration technique (table 2). One year after the final release treatment, 98% of survivors on released natural plots and 93% of survivors on released planted plots were judged free-to-grow (table 2).

As a result of competition control, mean increases ($P < 0.01$) in height over 6 years were 2.07 m (6.79 ft) on natural pine plots and 2.40 m (7.87 ft) on planted pine plots (table 3). After 6 growing seasons, planted pines were 13% taller ($P = 0.0065$) than naturally regenerated pines.

Release resulted in average gains for natural pines of 157% in dbh and 183% in gld ($P < 0.01$), and for planted pines of 125% in dbh and 159% in gld ($P < 0.01$) (table 3). Six years after field establishment, planted pines were 28% larger ($P < 0.01$) in gld and 32% larger ($P < 0.01$) in dbh than natural pines.

After 6 growing seasons, mean differences in volume index per tree between release treatments averaged 0.03 m^3 (1.00 ft^3) ($P < 0.01$) on natural pine plots and 0.05 m^3 (1.65 ft^3) ($P < 0.01$) on planted pine plots (table 3). Planted pines had 73% more ($P < 0.01$) volume than naturally regenerated pines.

Within each regeneration technique, crown widths of released pines averaged more than twice ($P < 0.01$) the width of nonreleased pines, and crown widths on planted pines were 23% larger ($P < 0.01$) than on

Table 3 -*Mean size of surviving measurement pines 6 years after field establishment*

Treatment comparisons	Total height (m)	Gld (mm)	Dbh (mm)	Volume index (m^3)	Crown width (m)	Live-crown ratio (%)
Mean size						
Natural	2.36	27.9	19.8	0.0043	0.68	51
Natural/Release	4.43	79.0	50.8	0.0328	1.62	70
Plante d	2.64	37.8	28.4	0.0086	0.87	53
Planted/Release	5.04	98.0	64.0	0.0554	1.95	65
N + N/R	3.40	53.3	35.3	0.0185	1.15	61
P + P/R	3.84	68.1	46.5	0.0320	1.41	59
Mean square error	4.52E-02	28.6451	13.8817	2.70E-05	9.64E-03	7.00E-04
Probabilities of a greater F-value						
Natural vs. Natural/Release	<0.0001	<0.0001	<0.0001	0.0002	<0.0001	<0.0001
Planted vs. Planted/Release	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
N+N/R vs. P + P/R	0.0065	0.0015	0.0010	0.0021	0.0019	0.0957

naturally regenerated pines (table 3). With release, live-crown ratios were 12% and 19% larger (P < 0.01) for planted and natural pines, respectively. However, there was no difference (P > 0.05) in live-crown ratio between the two regeneration techniques (table 3).

Six years after the hexazinone treatment, density of natural pine regeneration averaged 16,360 stems/ ha (6,621/acre) for seedlings and 1,601 stems/ ha (648/acre) for saplings. Quadrat stocking for these natural pines ranged from 33% for saplings to 88%> for seedlings.

The tallest 247 pines per hectare. To better assess treatment efficacy, it is often desirable to look at how the tallest 247 trees/ha (100/acre) respond. For these pines, periodic growth in height, gld, and volume index was better (P < 0.01) with release than without, and differences increased with time (figure 4). Within 2 years of field establishment, growth of dominant released natural pines surpassed that of dominant planted pines where there was no release (figure 4). However, as a group, planted pines outperformed naturally regenerated pines by the equivalent of a half year's growth or more at age 5 to 6 years.

Diameter distributions for the tallest trees at age 6 are illustrated in figure 5. Released pines of both regeneration types reached pulpwood size (9.1 cm, or 3.6 in, in dbh) by age 6. Nonreleased pines, however, did not reach pulpwood size, regardless of regeneration technique.

Competing vegetation. Species that overtopped surviving pines on nonreleased plots 6 years after establishment included eight trees, two shrubs, and three vines (table 4). Japanese honeysuckle *(Lonicera japonica* Thunb.) was the most troublesome competitor, overtopping 49% of surviving pines on natural plots and 45% on planted plots. Trees accounted for less than 11% of individual overtopping competitors, and they overtopped fewer pines overall than did Japanese honeysuckle. The most prolific shrub was American beautyberry *(Callicarpa americana* L.). The original treatment of the site 7 years earlier with hexazinone had failed to adequately control this shrub due to its resistance to this herbicide (McLemore 1983).

Because of minimal site preparation, the area was overgrown with nonpine vegetation. Seven years after clearcutting, and 6 years after hexazinone was applied, woody nonpine species had an average density of 10,845 rootstocks / ha (4,389 / acre) for seedling-size stems and 2,014 stems / ha (815 stems / acre) for saplings. Quadrat stocking averaged 96 and 44%, respectively, for seedling-size and sapling-size hardwood rootstocks. These findings are consistent with results from a study by Cain and Yaussy (1984), which indicated that hardwoods cannot be eradicated from

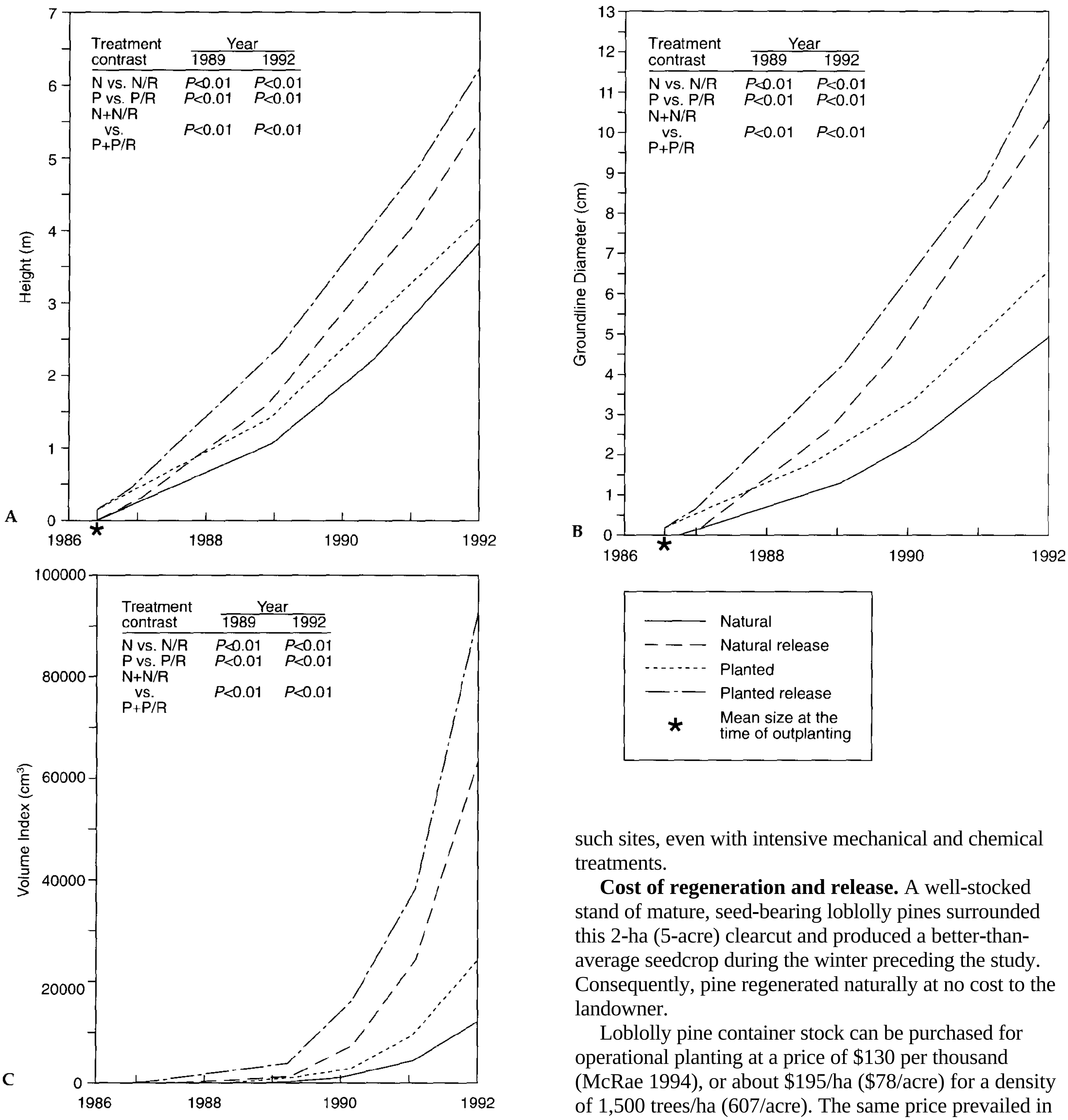

Figure 4—*Periodic growth trends for the tallest 247 pines/ha (100 pines/acre) by regeneration technique, with and without release:* (**A**) *height,* (**B**) *groundline diameter, and* (**C**) *volume index.*

such sites, even with intensive mechanical and chemical treatments.

Cost of regeneration and release. A well-stocked stand of mature, seed-bearing loblolly pines surrounded this 2-ha (5-acre) clearcut and produced a better-than-average seedcrop during the winter preceding the study. Consequently, pine regenerated naturally at no cost to the landowner.

Loblolly pine container stock can be purchased for operational planting at a price of $130 per thousand (McRae 1994), or about $195/ha ($78/acre) for a density of 1,500 trees/ha (607/acre). The same price prevailed in 1987, when container pines were outplanted for this study. In Arkansas, bareroot loblolly pine seedlings from an improved seed source can be obtained through the Arkansas State Forestry Commission at a cost of $30 per thousand, or about $45/ha ($18/acre) for a density of 1,500 trees/ha (607 trees / acre).

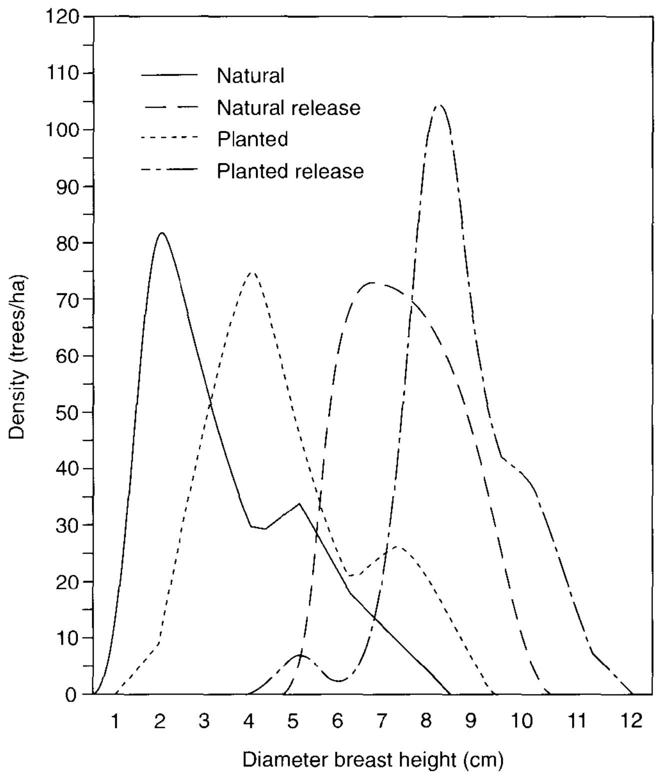

Figure 5—*Diameter distributions for the tallest 247 pines/ha (100 pines/acre) at age 6, by regeneration technique, with and without release.*

Table 4 -Relative proportion of competing species that overtopped surviving measurement pines on nonreleased plots at age 6.

	Pine overtopped (%)	
Overtopping species	Natural	Planted
Trees		
Acer rubrum L.	6.3	7.6
Cornus florida L.	3.0	5.0
Ilex opaca Ait.	—	10.2
Liquidambar styraciflua L.	—	5.4
Prunus serotina Ehrh.	1.6	3.0
Quercus nigra L./*Q. phellos* L.	1.4	4.8
Sassafras albidum (Nutt.) Nees	5.1	1.7
Shrubs		
Callicarpa americana L.	31.9	14.6
Vaccinium L. spp.	1.6	----
Vines		
Gelsemium sempervirens (L.) Ait. f.	—	1.5
Lonicera japonica Thunb.	49.1	44.7
Rubus L. spp.	----	1.5
Total	100.0	100.0

The cost of hand-planting bareroot seedlings on cutover land on the Coastal Plain following less-than-intensive site preparation in 1992 was reportedly $87/ ha ($35 / acre) for a density of 1,500 trees / ha (607 trees / acre) (Belli and others 1993). Because container pine seedlings are easy to hand-plant with conventional bareroot planting tools (Barnett and Brissette 1986), planting costs for container pines should be similar to bareroot planting costs. With seedling costs ranging from $45/ha ($18/acre) for bareroot stock to $195/ha ($78/acre) for container stock, and with planting costs at $87/ha ($35/acre), it costs from $132/ha ($53/acre) to $282/ha ($113/acre) more to plant pine seedlings than to rely on natural pine regeneration.

The costs of release treatments (table 1) were as follows: wages for manual cutting were $0.05 /tree; wages for herbicide application were $0.03 / tree; the cost of sulfometuron was $0.08 /tree; and the cost of glyphosate was $0.03 /tree. Costs do not include the purchase price of handtools or backpack sprayers.

Discussion

Planted container stock outperformed pines of natural origin in this investigation, and pines that were released from woody and herbaceous competition in a 61-cm (2-ft) radius around each stem exhibited more vigor and better growth than those that were not released, regardless of regeneration technique. According to Baker and Langdon (1990), diameter growth of individual loblolly pines generally increases as crown surface area and crown ratio increase, with optimal diameter growth in trees with at least 40% live-crown ratio. A mortality rate of 30% for crop pines that were not released during the first 6 years after field establishment is attributed mainly to dense shading from overtopping vegetation, primarily American beautyberry and Japanese honeysuckle.

Adequate density and quadrat stocking of pine regeneration was achieved by natural seeding across a 2-ha (5-acre) clearcut without the benefit of intensive site preparation. In the absence of release, less than half of the dominant natural pines were judged free-to-grow after 6 years. But pines were so dense that there seemed to be no immediate need for release. One longterm research study conducted less than 0.8 km (0.5 mile) from the site of this study showed that small clearcuts of about 2 ha (5 acres) will naturally regenerate with seed from bordering loblolly and shortleaf pine seed trees; despite low-intensity site preparation, and even without followup control of competition, well-stocked stands of sawlog-size pines will develop on these sites (Baker and Murphy 1982). Still, the present study shows that release treatments can substantially improve pine yields through age 6.

Release treatments in a 61-cm (2-ft) radius around 1,500 pines/ha (607 pines/ acre) had little impact on density and quadrat stocking of woody vegetation because the treatments were restricted to 18% of the plot area. Spot treatments for pine release are often more advantageous than band or total control treatments because more vegetation remains to stabilize soil, improve landscape appearance, and provide food and cover for wildlife (Yeiser and Barnett 1991). In an evaluation of spot size for controlling herbaceous vegetation to improve the growth and survival of recently planted loblolly pines, Dougherty and Lowery (1991) noted that from an environmental standpoint it was important to treat the smallest area needed to provide the desired response. However, there are disadvantages to spot treatments compared to broadcast treatments: costs are often higher because of intensive labor requirements, and workers usually are exposed to increased amounts of herbicides.

Natural regeneration of loblolly pines is still a viable alternative to planting and is especially desirable for landowners who prefer low-cost establishment. We do not suggest that the costs associated with 5 years of intensive competition control on small plots are operationally feasible. However, chemical release may be operationally achieved by ground application with backpack sprayers. According to Belli and others (1993), the cost of such treatment on the Coastal Plain in 1992 was $119/ha ($48/acre).

Further research is needed to determine if operational spot release will improve the growth of natural and planted loblolly pines. In an evaluation of the long-term effect of weed treatments on stand growth, Busby (1992) reported that single spot treatments of sulfometuron in a 53-cm (1.75ft) radius around loblolly pines provided economically efficient control of herbaceous weeds (regardless of rate of application) for all combinations of site and planting density. In this study, costs for spot treating 1,730 trees/ha (700 trees/ acre) with 0.28 kg (4 oz) ai of sulfometuron were about $60/ha ($24/acre) on cutover sites.

Data from the present investigation suggest that container loblolly pines from a genetically improved seed source that are outplanted on areas with minimal site preparation will equal or exceed the growth of naturally established pines. To maximize survival and growth potential of genetically improved planting stock on good sites, some degree of herbaceous and woody competition control seems justified during the first few years after pine establishment. When using loblolly pine container stock on an operational basis, outplanted seedlings should be larger than those used in this study (Barnett 1991). The general rule for southern pine planting stock is that the higher the morphological grade or the larger the seedling, the better survival and growth will be (Wakeley 1954).

Address correspondence to Michael D. Cain, USDA Forest Service, Southern Research Station, Monticello, AR 71656.

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