The Influence of Woody and Herbaceous Competition on Early Growth of Naturally Regenerated Loblolly and Shortleaf Pines[1]

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*ABSTRACT. Four levels of competition control were used to study the response of naturally regenerated loblolly and shortleaf pines (*Pinus taeda *L. and* P. echinata *Mill.) in southern Arkansas. Treatments included: (1) Check (no competition control), (2) woody competition control, (3) herbaceous competition control, and (4) total control of nonpine vegetation. Herbaceous plants were controlled for 4 consecutive years, and woody plants were controlled for 5 years. Control of herbaceous vegetation resulted in significant increases in pine height, groundline diameter (GLD), and volume per tree. Control of only woody competition did not improve pine growth compared to untreated checks. After 5 years, pines on total control plots had significantly larger GLDs and significantly more volume per tree compared to pines on any other treatment. Pine growth gains were achieved with herbaceous competition control and total control of nonpine vegetation although these two treatments averaged 4,000 more pines/ac, in trees taller than 5 ft, than the other two treatments. Results of this investigation represent a unique standard of pine growth to which operational treatments might be compared.*

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When lobolly and shortleaf pines (*Pinus taeda* L. and *P. echinata* Mill.) are regenerated on cutover areas by natural or artificial techniques, a number of years elapse between pine establishment and canopy closure. During that time, both woody and herbaceous vegetation compete with the pines for soil moisture, sunlight, growing space, and nutrients. As such, competing vegetation reduces the growth of pine seedlings during this establishment period.

Haywood and Tiarks (1981, 1990) and Tiarks and Haywood (1986) reported that herbaceous rather than woody vegetation is more detrimental to planted loblolly pine growth during the first few years following field establishment. Although the same trents might be expected for naturally regenerated stands of loblolly pine seedlings, only one publication has addressed that topic (Cain 1988).

This study was part of a region-wide investigation entitled Competition Omission Monitoring Project—COMP (Miller et al. 1987). The objectives of that investigation are to: (1) establish a framework of growth response for loblolly pine relative to four competition regimes on major soil types across the region, (2) compare the relative importance of herbaceous versus woody competition as they affect the early and long-term growth of loblolly pine on a wide range of sites, (3) identify the major herbaceous and woody competitors and document early succession, and (4) study the interaction of competition and pine growth on

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insect infestation and disease infection.

Of 14 study locations in that regional project, only the one reported here utilized natural pine regeneration. Both loblolly and shortleaf pines were allowed to invade the study area because the investigation relied entirely on natural seedfall. No effort was made to control pine density during the first 5 years. This course of action permitted the study of natural pine population dynamics at four levels of competition control.

METHODS

Study Area

The study is located within two 5-ac clearcuts on the Crossett Experimental Forest in southern Arkansas. Before clearcutting, these areas contained uneven-aged stands of loblolly and shortleaf pines up to 28 in. diameter breast height (dbh) with about 100 pines/ac and about 9,000 bd ft (Doyle scale) sawlog volume/ac. Hardwoods 1 in. and larger in groundline diameter (GLD) were stem injected with Tordon®101R in the summer of 1980. Prescribed burning with backfires was done in March 1980 on one area and in January 1981 on the other area. Merchantable pines were harvested in spring 1981. The 3-year-old rough on both clearcuts was mowed with a Hydro-ax® to create a uniform height of about 2.5 ft, above established pine seedlings in August 1983, before study installation.

Soils are Bude (Glossaquic Fragiudalf) and Providence (Typic Fragiudalf) silt loams with an estimated site index of 85 to 90 ft for loblolly pine at age 50 years.

Study Establishment and Treatments

Eight treatment plots were established within each 5-ac clearcut. Main plots were 0.25 ac (104 by 104 ft) with 0.1 ac (66 by 66 ft) interior subplots. Treatments were replicated four times in a randomized, complete block design with blocking based on pretreatment stocking of pine regeneration. Each interior subplot contained 10 systematically established, permanent quadrats (circular milacres) for data collection.

Four competition control treatments were initiated during the 1984 growing season and were maintained as follows:

1. **Check.** The 3-year-old rough was mowed to a height of 2.5 ft with no additional treatment of the woody or herbaceous components.
2. **Woody control.** All standing and sprouting hardwoods, shrubs, and woody vines were controlled by single-stem herbicide treatments for 5 consecutive years. Control was achieved by basal wipes with wick applicators using triclopyr (10% Garlon®4E) in diesel fuel the first year. During the last 4 years, 10% Garlon was applied as a basal wipe in combination with a surfactant, crop oil, and water. Generally, two treatments were required per growing season.
3. **Herbaceous control.** Forbs, grasses, semiwoody plants, and vines were controlled using preemergent and postemergent herbicides in water solutions for 4 consecutive years. Sulfometuron (Oust®) was broadcast sprayed at 3.75 oz a.i./ac for preemergent control of forbs and annual grasses during each of the first 4 years. Sethoxydim (Poast®) was broadcast sprayed at 0.75 or 1.5 lb a.i./ac during the first 3 years for grass control. At one to three times per growing season, shielded directed sprays of glyphosate (Roundup®) were applied as 2% solutions during the first 4 years to control herbaceous plants that were resistant to Oust and Poast.
4. **Total control.** A combination of herbicides, as previously described for woody control and herbaceous control, was applied to all nonpine vegetation. Woody plants were controlled for 5 consecutive years and herbaceous vegetation was controlled for 4 consecutive years.

Measurements and Data Analysis

Before treatment and annually at the end of each treatment period, pine seedlings were counted by 1 ft height classes on each of the 10 milacres per plot for calculation of density and percent stocking. After the first year of treatment (1984), 50 pine seedlings—90% loblolly—were selected on each interior subplot and tagged for identification. Taller seedlings were chosen when possible, but spacing, seedling quality, and the absence of insects and disease were considerations also. At the time of selection, some seedlings were as small as 0.04 in. GLD and 0.2 ft tall. Survivors were measured annually for total height to 0.1 ft and GLD to 0.04 in. In the fifth year, height-to-live-crown and crown width were measured to 0.1 ft on a subsample of 17 trees per plot. Stems and branches of all surviving measurement pines were examined annually for the presence of fusiform rust, *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme,* and growth flushes were examined for tipmoth, *Rhyacionia frustrana* (Comst.).

Competition levels of woody and herbaceous species were assessed annually in late summer. Woody rootstocks were counted by species and by 1 ft height classes on each milacre quadrat. Percent groundcover of herbaceous vegetation (grasses, forbs, vines, and semiwoody plants) was determined by ocular estimation to the nearest 10% within each milacre. Herbaceous genera that covered more than 15% of a milacre were identified and recorded.

Analysis of variance was used to evaluate treatment differences in competing vegetation; stocking and density of the pine seedling population; survival, live-crown ratio, and crown widths of measurement pines. Analysis of covariance was used to evaluate pine growth and fifth-year means for GLD, height, and volume of tagged seedlings using initial GLD, height, and volume respectively as the covariates. An expression of volume for surviving measurement seedlings was calculated from: Volume index = Σ(total height)$(GLD)^2$. Duncan's Multiple Range Test was used to partition mean differences between treatments in analysis of variance. Fisher's Protected LSD Test was used to isolate mean differences in analysis of covariance. Percent data were analyzed following arcsine $\sqrt{proportion}$ transformation. All analyses were carried out at the 0.05 level of significance.

RESULTS AND DISCUSSION

Competing Vegetation

Herbaceous species were more difficult to control, requiring nearly three times the herbicide needed for control of woody plants. Herbicide usage during the 5-year control effort totaled about 4, 12, and 16 lb a.i./ac respectively for the woody control, herbaceous control, and total control treatments. The most prominent herbaceous vegetation types were grasses and vines for all treatments during the 5-year period. In the fifth year, the frequency of occurrence for the seven predominant herbaceous genera was: *Lonicera japonica* Thunb. (78%), *Uniola* spp. (28%), *Rubus* spp. (20%), *Panicum* spp. (16%), *Andropogon* spp. (12%), *Vitis* spp. (12%), and *Smilax* spp. (11%).

Check and woody control plots had from 78 to 92% ground cover from herbaceous plants after the first and fifth years of treatment as compared to an average of only 7 to 18% on herbaceous control or total control plots (Table 1). As the pines and hardwoods grew above herbaceous plants on check plots, their crowns began to close, thereby shading out intolerant species and reducing herbaceous ground cover by 11% during a 4-year period, without the benefit of herbicides (Table 1).

After just 1 year of herbicide treatment, density of woody competition was significantly reduced (Table 1). Repeated herbicide applications during the next 4 years resulted in substantially fewer woody plants on treated plots compared to densities on the same plots after the first year of treatment. The 3,025 woody rootstocks/ac on woody control plots after 5 years is somewhat misleading in terms of competitive influence. A more realistic indicator of woody competition on that treatment was estimated ground cover, which averaged only 1% as compared to 38% on plots without woody control (Table 1).

Based on density, nonarborescent shrubs, rather than arborescent trees, were the predominant woody competitors. After 5 years, nonarborescents comprised 72% of woody rootstocks on check plots, 74% on woody control plots, 61% on herbaceous control plots, and 100% on total control plots. The most prevalent woody competitors at that time were *Callicarpa americana* L., *Rhus copallina* L., and *Vaccinium* spp., and these comprised 70% of all woody species inventoried. Major recurring tree species, in order of prevalence, were *Sassafras albidum* (Nutt.) Nees, *Acer rubrum* L., *Morus rubra* L., *Quercus falcata* Michx., and *Diospyros virginiana* L., but these five species accounted for only 18% of the total. The remaining 12% of woody rootstocks was divided among 18 other species.

Mean height of woody competition was consistent with the type of treatment imposed (Table 1). After 5 years, woody plants on herbaceous control plots averaged over 6 ft tall and were significantly taller than the average height on all other treatments. When shrubs were excluded from analysis, mean fifth-year heights of the arborescent hardwoods averaged 4.6 ft on check plots and 8.0 ft on herbaceous control plots, suggesting that hardwoods showed a positive growth response to herbaceous weed control.

Response of Measurement Pines to Treatment

Of the 50 pine seedlings per plot that were tagged for measurement before the 1985 growing season, 94% survived through the fifth year. There were no differences in mean survival rates between treatments (Table 2).

There were annual growth gains in height, GLD, and volume index for pines on plots where herbaceous vegetation was controlled (Figures 1–3). Compared to pines on untreated check plots during the first 5 years, there was no improvement in growth for pines on plots where only woody species were controlled.

In earlier years, pine growth on herbaceous control and total control plots was similar and, generally, nonsignificant. After 3 years, pines on total control plots achieved statistically significant gains in GLD growth (Figure 2). These gains were still apparent after 5 years and were also reflected in significant volume growth differences between treatments (Figure 3). After only 4 years, pines on plots with herbaceous competition control had achieved a volume index equal to or greater than that of pines on check plots, after 5 years. Mean separations between treatments followed the same pattern regardless of whether all trees or only the tallest 250 pines per acre were plotted (Figures 1–3).

After 5 years, surviving measurement pines on plots with control of herbaceous competition averaged more than 4 ft taller than those pines on check or on woody

Table 1. Competition variables after the first and fifth year of treatment.

Treatments[1]	Herbaceous vegetation ground cover		Woody vegetation: Density		Woody vegetation: Total height		Woody vegetation: Ground cover
	1st yr	5th yr	1st yr	5th yr	1st yr	5th yr	5th yr
	(%)		(rootstocks/ac)		(ft)		(%)
Check	89a[2]	78a	15,300a	12,600a	2.4a	3.6a	38a
Woody control	92a	92a	6,200b	3,025bc	1.4b	1.6b	1b
Herbaceous control	13b	7b	15,525a	5,275b	1.9c	6.1c	38a
Total control	8b	18b	8,150b	150c	1.5b	0.5b	0b
Error mean square	27	88	17	5.9×10^6	0.1	0.6	62

[1] Herbaceous species were controlled for 4 consecutive years, and woody species were controlled for 5 years.
[2] Columnar means followed by the same letter are not significantly different at the 0.05 level.

Table 2. Treatment effects on the survival and growth of measurement pines after 5 years.

Treatments	Survival	Height[1]	GLD[1]	Volume index[1]	Live-crown ratio	Crown width
	(%)	(ft)	(in.)	(ft^3)	(%)	(ft)
Check	94a[2]	10.0a	2.36a	0.58a	63a	4.0a
Woody control	91a	10.4a	2.52a	0.72a	68a	4.3a
Herbaceous control	98a	14.7b	3.32b	1.59b	66a	5.2ab
Total control	93a	15.7b	4.00c	2.06c	76b	6.3b
Error mean square	40	0.7	0.08	0.09	10	0.6

[1] Means adjusted for initial size by covariance analysis.
[2] Columnar means followed by the same letter are not significantly different at the 0.05 level.

control plots (Table 2). Mean gains in GLD after 5 years averaged 36% on herbaceous control plots and 64% on total control plots compared to the mean for woody control and check plots. Similarly, measurement pine volume index more than doubled on herbaceous control plots and more than tripled on total control plots compared to mean volume index on the two less intensive treatments (Table 2).

Various forms of damage were monitored annually on measurement pines, but the only two of consequence were the incidence of fusiform rust and pine tip moth.

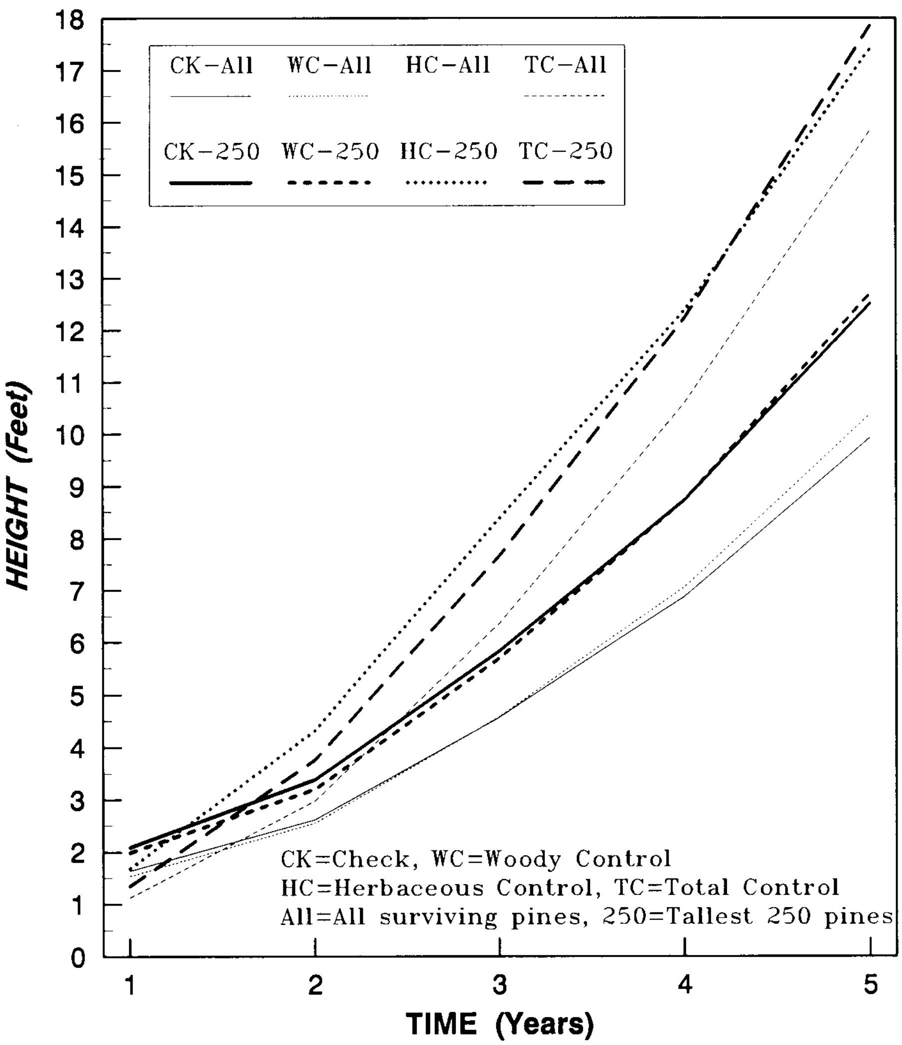

Figure 1. Annual height growth trends for all surviving pines and the tallest 250 pines per acre by method of competition control.

At the end of 5 years, the proportion of pines infected with fusiform rust ranged from 8% on check plots to 13% on total control plots. That difference was considered unimportant because overall there were a greater number of uninfected replacement pines on the total control plots compared to check plots. The highest incidence of tip moth infestation was on check plots after 5 years, averaging 40% of measurement pines. Tip moth infestation of pines on the other three treatments averaged about 25%.

Density and Milacre-Stocking of the Pine Population

When the study was installed, pretreatment pine density averaged 1,338 seedlings/ac with 47% milacre-stocking. A prolific pine seed crop the winter after study installation produced an average of 13,000 pine seedlings/ac with 96% milacre-stocking by the end of the first year of competition control. After 5 years, pine density averaged over 9,000 stems/ac with 95% milacre-stocking (Table 3). There was no difference in milacre-stocking between treatments, but pine density on total control and on herbaceous control plots averaged 4,000 more stems/ac than occurred on check or on woody control plots after 5 years. Intensive control of herbaceous plants exposed a mineral-soil seedbed that was most conducive to pine seedling establishment, survival, and growth. The majority of pine seedlings on check and on woody control plots were 1 to 5 ft tall after 5 years. In contrast, more than 50% of the pine seedlings on total control and on herbaceous control plots averaged taller than 5 ft (Table 3). More pines and larger pines contributed to a significantly higher percentage of pine ground cover on plots where herbaceous species were controlled (Table 3).

On cutover areas, natural regeneration of loblolly and shortleaf pines is considered successful if density averages at least 700 stems/ac at the beginning of the third

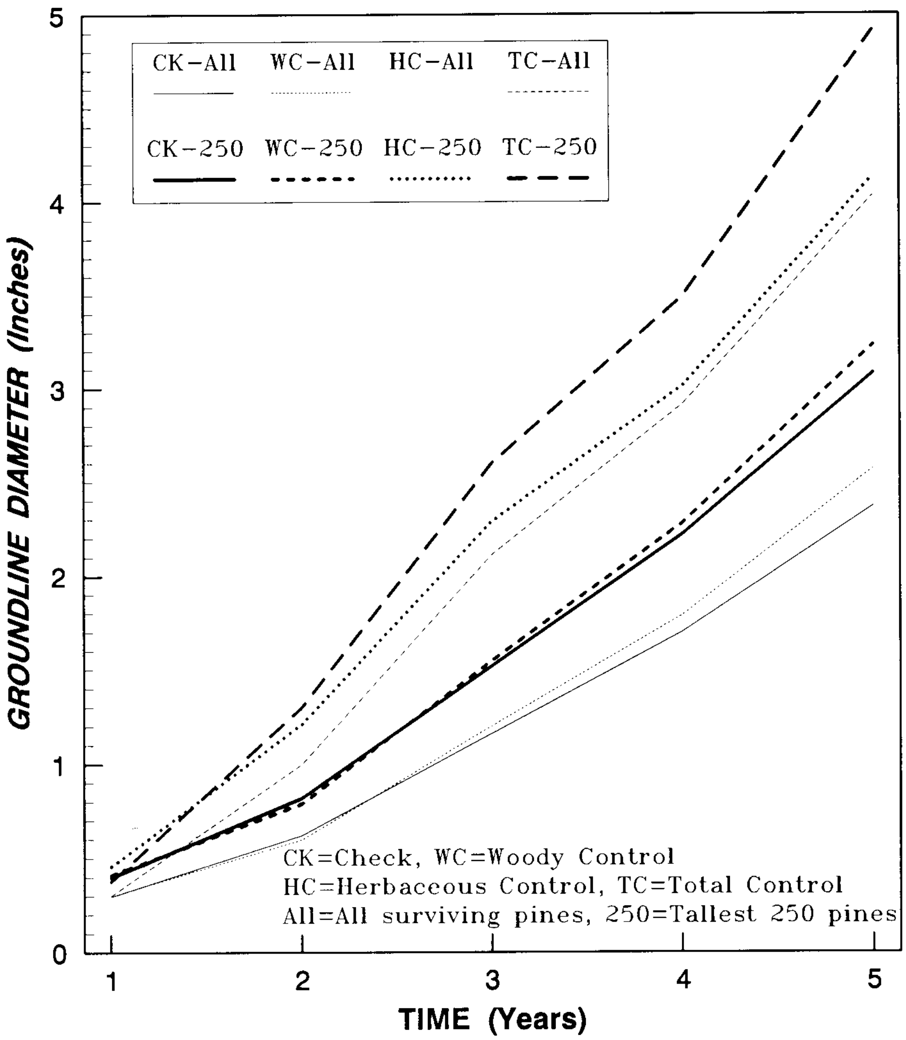

Figure 2. Annual groundline diameter growth trends for all surviving pines and the tallest 250 pines per acre by method of competition control.

year (Grano 1967), and milacre-stocking is at least 60% (Trousdell 1963). Based on those criteria, these cutover sites were well-stocked with pine regeneration after 5 years, but not necessarily overstocked. Within that 5-year period, significant gains in pine growth were achieved on plots where herbaceous competition was controlled in spite of the fact that those same plots averaged almost 4,000 more pines/ac than the two less intensive treatments.

Such high densities suggest that precommercial thinning would be required in accordance with published recommendations. For example, Mann and Lohrey (1974) reported that loblolly and shortleaf pine stands with more than 5,000 trees/ac should be precommercially thinned. They also noted that, before considering precommercial thinning, dominants in the stand should be expected to have less than a 35% live-crown ratio at the time of the first commercial thinning. Given their first criterion, all treatments in the present investigation would require precommercial thinning. Given their second criterion, precommercial thinning might be questionable because surviving measurement pines (dominants) in all four treatments had live-crown ratios that averaged more than 60% or nearly 30% above the recommended minimum (Table 2). Live-crown ratios in excess of 35% can persist in dense loblolly-shortleaf pine stands where dominants have attained pulpwood size. For example, Cain (1990) reported that, 16 years after intensive site preparation, loblolly and shortleaf pine crop trees in an unthinned natural stand had live-crown ratios of 38% to 47% even though pine density averaged 2,650 stems/ac.

Besides having larger live-crown ratios, measurement pines on plots with the highest pine densities and control of herbaceous vegetation also had considerably larger crown widths (Table 2). Therefore, published recommendations for precommercial thinning may not be applicable in dense natural loblolly-shortleaf pine stands where there has been intensive control of nonpine vegetation.

MANAGEMENT IMPLICATIONS

Operationally and historically, control of only the woody component has been given priority in southern pine management. It has generally been assumed that only hardwood competitors need to be controlled in accordance with the stages of natural plant succession that occur in old fields (Oosting 1956). In that process, abandoned agricultural fields, that are bordered by seed-bearing pines, naturally regenerate with pines coincidentally with herbaceous plants. But in the absence of disturbance, the pines can eventually be displaced by more aggressive shade-tolerant hardwoods. In the present investigation, however, herbaceous vegetation was found to reduce both height and diameter growth of natural pine regeneration within 5 to 7 years after seedling establishment.

Although there were impressive pine growth gains on plots with herbaceous vegetation control, surviving measurement pines on check plots averaged 10 ft in height after 5 years and exceeded the mean height of woody competitors by more than 6 ft. One long-term research study, located less than 1 mile from the present investigation, showed that small clearcuts of about 5 ac will natu-

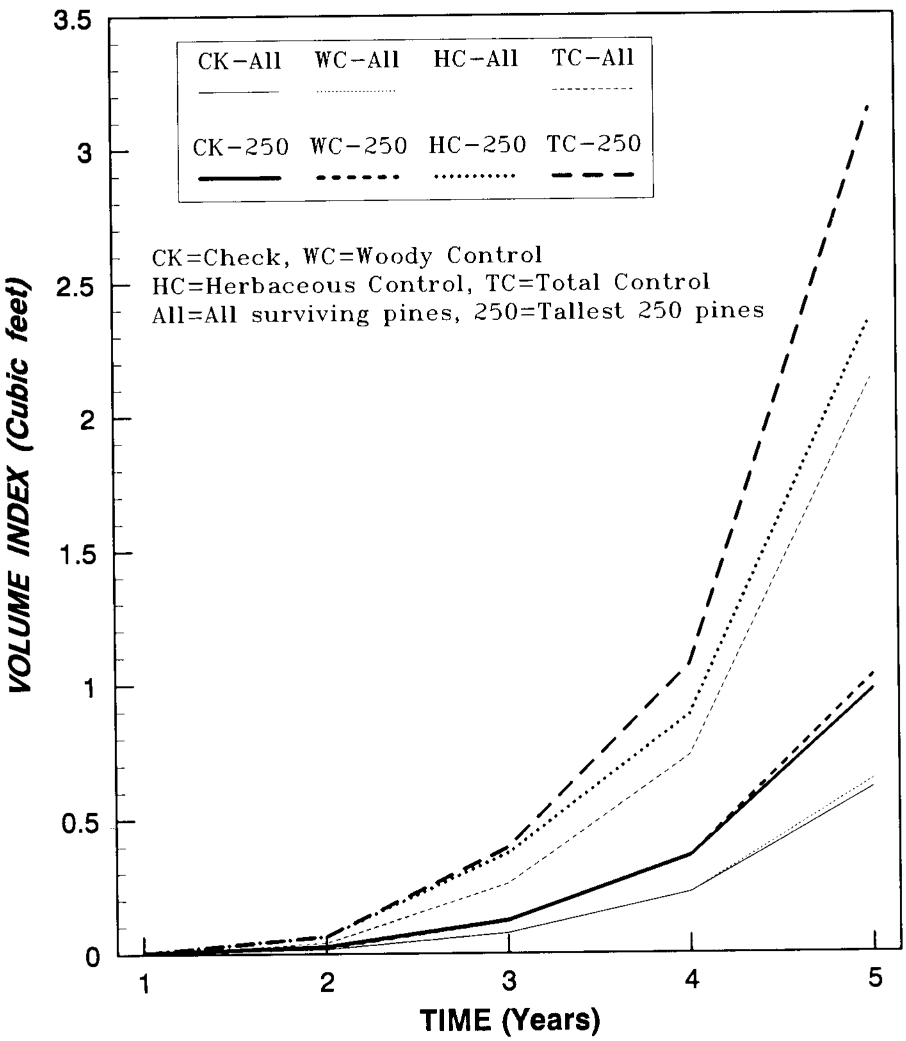

Figure 3. Annual volume growth trends for all surviving pines and the tallest 250 pines per acre by method of competition control.

rally regenerate with pines that seed in from bordering loblolly and shortleaf pine seed trees and will develop into well-stocked stands of sawlog-size pines even with low-intensity site preparation and without followup control of competition (Baker and Murphy 1982).

In view of these findings, what might be the justification for operationally implementing intensive competition control in a recently established natural stand of loblolly-shortleaf pine regeneration? Perhaps if density and stocking of established pine seedlings are at or just below the recommended levels for successful natural regeneration and the pine seed source has been removed, then intensive release of the established seedlings could at least maximize pine growth without resorting to site preparation and artificial regeneration. Dubois et al. (1991) reported that the cost of low-intensity site preparation (single chop) plus hand planting was about $110/ac. In contrast, their highest reported cost for chemical release treatments was only $58/ac.

In another scenario, a pine seed source borders a cutover area, but a dense cover of woody and herbaceous vegetation precludes the establishment of pine seedlings. In that case, some form of site disturbance is needed to create the seedbed conditions that are conducive to germination from natural seedfall. The four competition levels, that were maintained for 5 years in the present investigation, provide benchmarks for growth of natural loblolly and shortleaf pine regeneration that can be expected on similar sites in the Upper Coastal Plain. □

Table 3. Fifth-year pine population density, milacre-stocking, and ground cover by treatment.

Treatment	Density: All pines	Density: Pines > 5 ft tall	Milacre-stocking[1]	Ground cover
	--------- (trees/ac) ---------		(%)	(%)
Check	9,450ab[2]	1,975a	98a	19a
Woody control	5,650a	2,050a	82a	20a
Herbaceous control	11,600b	6,125b	100a	57b
Total control	11,275b	5,950b	100a	78c
Error mean square	6.9×10^6	2.0×10^6	245	39

[1] (Number of milacres occupied by pine ÷ total number of milacres) × 100.
[2] Columnar means followed by the same letter are not significantly different at the 0.05 level.

Literature Cited

Baker, J.B., and P.A. Murphy. 1982. Growth and yield following four reproduction cutting methods in loblolly-shortleaf pine stands—a case study. South. J. Appl. For. 6:66–74.

Cain, M.D. 1988. Competition impacts on growth of naturally regenerated loblolly pine seedlings. USDA For. Serv. Res. Note SO-345. 5 p.

Cain, M.D. 1990. Incidental observations on the growth and survival of loblolly and shortleaf pines in an even-aged natural stand. South. J. Appl. For. 14:81–84.

Dubois, M., et al. 1991. Costs and cost trends for forestry practices in the South. For. Farmer 50(3):26–32.

Grano, C.X. 1967. Growing loblolly and shortleaf pine in the Midsouth. USDA Farmers' Bull. 2102. 27 p.

Haywood, J.D., and A.E. Tiarks. 1981. Weed control and fertilization affect young pine growth. Proc. South. Weed Sci. Soc. 34:145–151.

Haywood, J.D., and A.E. Tiarks. 1990. Eleventh-year results of fertilization, herbaceous, and woody plant control in a loblolly pine plantation. South. J. Appl. For. 14:173–177.

MANN, W.F., JR., AND R.E. LOHREY. 1974. Precommercial thinning of southern pines. J. For. 72:557–560.

MILLER, J.H., ET AL. 1987. A region-wide study of loblolly pine seedling growth relative to four competition levels after two growing seasons. P. 581–591 *in* Proc. Fourth Bienn. South. Silv. Res. Conf., USDA For. Serv. Gen. Tech. Rep. SE-42.

OOSTING, H.J. 1956. The study of plant communities. Ed. 5. W.H. Freeman, San Francisco. 440 p.

TIARKS, A.E., AND J.D. HAYWOOD. 1986. *Pinus taeda* L. response to fertilization, herbaceous plant control, and woody plant control. For. Ecol. Manage. 14:103–112.

TROUSDELL, K.B. 1963. Loblolly pine regeneration from seed—what do site preparation and cultural meaures buy? J. For. 61:441–444.