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# *PINUS TAEDA* L. RESPONSE TO FERTILIZATION, HERBACEOUS PLANT CONTROL, AND WOODY PLANT CONTROL

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## ABSTRACT

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On an intensively prepared site, a complete fertilizer applied at planting, and control of herbaceous and woody plants for the first 4 years, increased *Pinus taeda* L. volume at age 5 to 25.9 $m^3$/ha compared to 11.8 $m^3$/ha without the treatments. The fertilizer and competition control factors affected pine growth independently of each other, and so their effects are additive. Herbaceous plant control was the most effective treatment, increasing pine volume by 63%. Declining dry weights of herbaceous plant material indicated that pine was dominant by age 6, so more responses from herbaceous plant control are not expected. Woody plant control did not significantly increase pine volume until the fifth year because the intensive site preparation retarded the development of the woody competition. The fertilizer contained nitrogen, phosphorus, and potassium, but analysis of pine foliage indicates phosphorus was the element causing the response of pine to fertilizer. By the sixth season, the herbaceous and woody plant material contained 31% of the nitrogen and potassium applied as fertilizer. The competing material also contained 7% of the phosphorus applied in the fertilizer. This showed that competitors can be major utilizers of fertilizer applied to pines.

## INTRODUCTION

A pine plantation can be established with a high probability of getting a well-stocked stand with minimal hardwood competition in the first year by using fire and hardwood injection prior to harvesting the previous stand or by using intensive site preparation. Additional cultural treatments that promote rapid growth of newly planted pine are herbaceous vegetation control and fertilizer. But proper utilization of vegetation control and fertilization requires knowledge about the growth response of pines to the treatments, the effect of applying the treatments individually or together, and the manner in which the response to the treatments changes with time during the early phase of the rotation. Because competing vegetation in pine plantations utilizes fertilizer meant for pines, it is also necessary to study the uptake of the nutrients by the competition in order to discover the amount of nutrients not available to the pines if there is no control.

This study was established to find how much pine growth is limited by herbaceous or woody plant competition in a new plantation and to evaluate how fertilization interacts with competition control on sites that have received intensive site preparation.

## METHODS

The study was established in Winn Parish, Louisiana, on the upper Coastal Plain. The soil is moderately well drained Malbis very fine sandy loam (fine-loamy, siliceous, thermic Plinthic Paleudults) with a 7% westward slope. Before clearcutting, the site supported a mature loblolly (*Pinus taeda* L.)—shortleaf (*P. echinata* Mill.) pine stand containing a dense, mixed-hardwood understory (5—20 cm in dbh) that numbered about 5000 stems/ha. There were only a few larger hardwood stems. Typical species were southern red oak (*Quercus falcata* Michx. var. *falcata*), post oak (*Q. stellata* Wangenh.), hickory (*Carya* spp.), and blackgum (*Nyssa sylvatica* Marsh.).

Residual stems were sheared in early September 1977 with a tractor-mounted V-Blade[1] and the site was root-raked to about a 10-cm depth, which tore out most of the large hardwood roots. All windrows were piled away from the study area. Uniformly graded, bare-root 1-0 loblolly pine seedlings were hand planted at 2.44 × 2.44 m spacing during the winter of 1977—1978 on 19.5 × 19.5 m plots with the measurement plots consisting of the 16 center trees. Dead seedlings were replaced with containerized seedlings in September 1978 to maintain uniform density but replacement trees were not measured.

The experiment was designed as a 2 × 2 × 2 factorial with fertilizer, woody plant control, and herbaceous plant control as factors replicated four times in a randomized complete block design. For the fertilization treatment, 112 kg of nitrogen, 49 kg of phosphorus, and 93 kg of potassium per hectare were applied by hand as a granular fertilizer (13—13—13) in April 1978. Woody plant control consisted of treating all woody vegetation with herbicides[2]. In 1978 a low volatile ester of 2,4,5-T [(2,4,5-trichlorophenoxy) acetic acid] was used as a directed spray. In 1979 the few remaining woody plants were cut off near the ground and the stumps treated with a picloram (4-amino-3,5,6-trichloropicolinic acid) and 2,4-D [(2,4-dichlorophenoxy) acetic acid] mixture. Visual observation after treatment indicated the herbicides did not injure the pines. Herbaceous plant control

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[1]Mention of trade names is solely to identify materials used and does not imply endorsement by the U.S. Department of Agriculture.

[2]Discussion of pesticides in this paper is not a recommendation of their use and does not imply that uses discussed here are registered.

consisted of careful hoeing of grasses, grasslike plants, and forbs three times yearly between April and September for the first four growing seasons. The hoeing was done within a 1.14-m radius of each planted pine with minimal injury to the woody plants. For erosion control, the treatment intentionally left an undisturbed population of herbaceous plants that covered one-third of the plot area between adjacent trees.

In August of the first four growing seasons and June of the sixth, herbaceous and woody competitors were cut off near the ground on randomly selected 5.95-$m^2$ subplots. A planted pine bounded each corner of the subplot. Subplots were located on the perimeter of main plots with one subplot located on each main plot. A new set of subplots was selected for each sampling. On plots receiving herbaceous plant control, the untreated area between the treated pines was sampled. Samples were bagged separately for determining the over dry weights of competing vegetation by plot. The samples were ground through a 20 mesh screen and stored for nutrient analysis.

Tipmoth (*Rhyacionia* spp.) infested most of the pines on the study area during the first growing season with uniform damage across treatments. In the second and third growing seasons, all pines were treated with 10% carbofuran (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate) pellets at a 15- to 20-g-per-tree rate (Nord, 1978). By the fourth season, all the trees were tall enough to escape tipmoth attack.

Pine height measurements were taken yearly, dbh measurements were taken 4 and 5 years after plantation establishment, and foliar samples were taken at age 5. Total stemwood volume (inside bark) was calculated using Schmitt and Bower's (1970) formula.

The pine foliar and competition samples were digested in sulfuric acid with copper sulfate added as a catalyst. Nitrogen was determined using an ammonia specific electrode (Powers et al., 1981), phosphorus was determined colormetrically (John, 1970), and potassium by atomic absorption spectrophotometry.

Arcsine of pine survival, pine heights for the first 5 years, pine dbh and volume for age 5, woody and herbaceous biomass weights, and the chemical analyses were analyzed using analysis of variance ($P < 0.05$). Two-way and three-way interactions were tested as well as the main effects.

## RESULTS AND DISCUSSION

### *Pines*

There were no significant interactions between the main factors in their effects on pine growth or survival. The cultural treatments had only additive effects on pines so the results are presented as averages of the main factors.

Herbaceous plant control increased pine survival from 78% to 89% at age 4. Neither woody plant control nor fertilization influenced pine survival.

Both fertilization and herbaceous plant control increased pine height at about the same rate until age 2 (Fig. 1). However, fertilizer applied at planting had little effect on the rate of height growth of the pines after age 2. Fertilization did not have a statistically significant effect on height at age 5, although the absolute advantage had increased slightly since age 4. Herbaceous plant control continued to have a significant and increasing effect on pine height through age 5. Although controlling woody plants had not caused a significant increase in height growth through age 5, its effect had increased since age 3. By age 5, the effects of woody plant control and fertilizer on pine height were the same (Table 1) while herbaceous plant control had produced the only significant increase in height. Fertiliza-

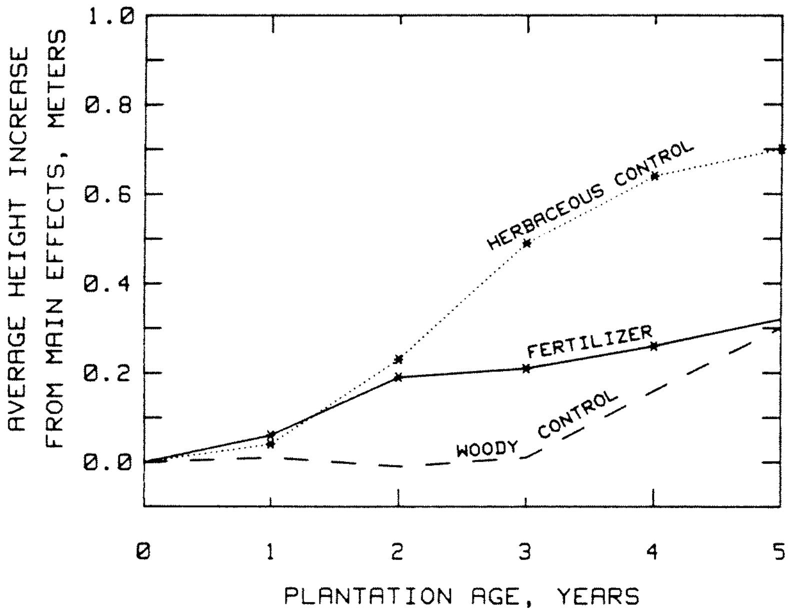


Fig. 1. Effect of fertilization at planting and weed control on pine height for the first 5 years after establishment. Asterisks on a line mean that the difference in the mean was significant in that year ($P < 0.05$).

TABLE 1

Main effect means for each of the three factors for loblolly pine height and diameter at age 5

| Treatment | Height (m) | Dbh (cm) |
|---|---|---|
| Fertilized | 5.2 | 8.2 |
| Unfertilized | 4.9 | 7.4* |
| Woody plant control | 5.2 | 8.1 |
| No woody plant control | 4.9 | 7.6 |
| Herbaceous plant control | 5.4 | 8.4 |
| No herbaceous plant control | 4.7* | 7.2* |

*The difference between two main effect means of height or diameter are significantly different ($P < 0.05$).

tion increased the average diameter by 0.8 cm and herbaceous plant control increased diameter by 1.2 cm. Woody plant control did not significantly affect diameter of the pine.

All three cultural treatments caused a significant increase in volume by age 5 (Fig. 2). Woody plant control was the least effective treatment while fertilizer was only slightly more effective.

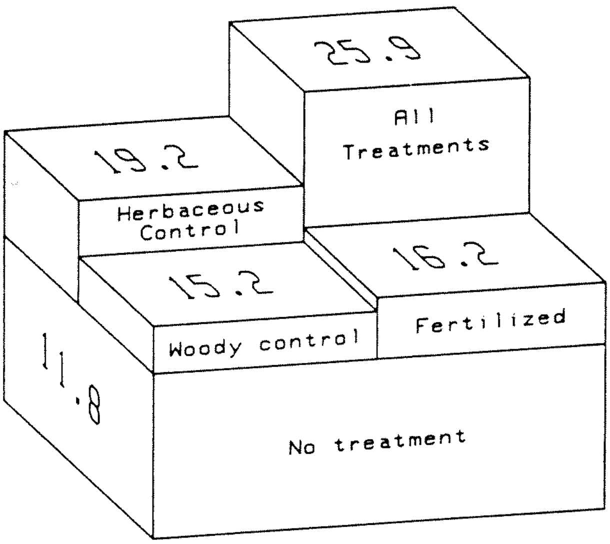


Fig. 2. Total loblolly pine volumes (inside bark), $m^3$/ha at age 5 for no treatment, the average for each major treatment, and for all treatments combined.

The greatest gain in pine volume came from herbaceous plant control on this intensively prepared site. Only 68% of the area around each tree was controlled so even larger volume gains would have been expected if complete control had been used (Tiarks and Haywood, 1981). The gain from herbaceous plant control increased through age 5, but less response is likely in future years because the herbaceous plant competition had decreased by the sixth season. Clason (1978) found that herbaceous plant control applied at age 7 did not increase pine growth. In an older study, the effects of cultivation were no longer significant by age 17 but fertilizer was still increasing growth at age 22 (Schmidtling, 1984).

The site preparation applied to the entire study area effectively retarded development of woody plant competition for the first 3 years, and woody plant control did not affect pine growth until the fifth year. However, even on a site with higher levels of initial competition, Cain and Mann (1980) reported that woody competition did not affect pine growth for the first 4 years. Clason (1978) determined that woody plant control can be delayed until age 7 and still give a good response.

Because nitrogen, phosphorus, and potassium were applied together, the nutrient that influenced pine growth most cannot be directly determined. However, the concentrations of nutrients in pine foliage indicates that phosphorus was limiting pine growth on this site. The needles from the fertilized plots had a phosphorus concentration of 1.3 g/kg or 20% more than the unfertilized pines.

The nitrogen concentration of the foliage of the 5-year-old pines averaged 12.5 g/kg. Loblolly stands with foliar nitrogen concentrations above 11 to 12 g/kg are not expected to respond to additional nitrogen (Allen and Ballard, 1982). Also, the fertilizer treatment did not affect the nitrogen concentrations so the nitrogen applied in the fertilizer probably did not increase the pine growth.

Potassium concentration in the pine needles was not increased by the fertilizer or herbaceous plant control treatment. Pines on plots receiving woody plant control had a potassium concentration of 7.6 g/kg which was significantly more than 6.9 g/kg in needles from plots not receiving woody plant control.

Pine response to fertilization, especially where competition is controlled, is depended on the initial fertility of the site. Fertilization on this site gave only a small response even though optimum rates were applied based on previous research. Fertilization and herbaceous plant control treatments did not interact so the effects are additive. On a less fertile site, Tiarks and Haywood (1981) found that fertilization and herbaceous plant control together produced a synergistic response, increasing pine growth much more than the individual treatments indicated.

*Woody plant material*

The intensive site preparation reduced the amount of competition from woody plant material on the experimental area substantially. By age 2, the number of woody stems on the plots without control of woody plants was 12100 stems/ha and averaged 0.5 m in height. The main species were the same as before site preparation (see Methods section). The woody plant control reduced the number of stems to 2650/ha. Main species escaping the control measures were St.-Andrew's-Cross (*Hypericum hypericoides* (L.) *Crantz*), blackberry (*Rubus* spp.), and American beautyberry (*Callicarpa americana* L.).

On plots without plant control, the dry weight of woody plant material developed progressively from 0.3 Mg/ha after one growing season to 4.5 Mg/ha in the sixth year. The woody plant control treatments applied in the first and second years were very effective as the dry weight of woody plant materials never exceeded 0.2 Mg/ha. Fertilization and herbaceous plant control did not affect the growth rate of the woody plants.

The concentrations and amounts of nutrients in woody plant material from only those plots where no woody plants were controlled are shown in Table 2. The quantity of woody plant material collected from plots receiving woody plant control was insufficient to determine nutrient concentrations accurately. The concentration of nitrogen in the material decreased by about 50% between the first and second seasons (Table 2) and then gradually

TABLE 2

Concentration and amounts of nutrients in woody plant material on plots receiving no woody plant control but averaged across all herbaceous control and fertilizer treatment effects

| Season | Nutrient | | | | | |
|---|---|---|---|---|---|---|
| | N | | P | | K | |
| | Conc. (g/kg) | Amount (kg/ha) | Conc. (g/kg) | Amount (kg/ha) | Conc. (g/kg) | Amount (kg/ha) |
| 1 | 16.3 | 4.1 | 0.7 | 0.2 | 7.6 | 1.9 |
| 2 | 8.4 | 6.2 | 0.9 | 0.7 | 5.2 | 3.8 |
| 3 | 6.8 | 9.7 | 0.6 | 0.9 | 3.7 | 13.6 |
| 4 | 7.5 | 19.0 | 0.7 | 1.9 | 5.4 | 13.6 |
| 6 | 5.4 | 25.0 | 0.5 | 2.4 | 4.6 | 23.0 |

decreased to 5.4 g/kg in the sixth season regardless of fertilizer treatment. Concentrations of phosphorus and potassium on the woody material varied seasonally with no evident pattern.

The amount of nutrients taken up by the woody material was not affected by fertilization or herbaceous weed control. The amount of nutrients in the woody material gradually increased, following the same pattern as the total dry weight. By the sixth season, the wood material contained 25.0 kg/ha of nitrogen, 2.4 kg/ha of phosphorus, and 23.0 kg/ha of potassium.

*Herbaceous plant material*

Regardless of treatment, the dry weight of herbaceous plant material increased through the fourth year (Fig. 3). By the sixth year, the total amount had decreased substantially. The herbaceous plant material was not sampled in the fifth year so the year the decline actually started cannot be determined.

Control of herbaceous plants resulted in a 50% reduction in the dry weight of the herbaceous plant material in the first year. In the second year the herbaceous plant control did not significantly reduce the herbaceous plant biomass even though 68% of the area was bare. In the third through the sixth years, the same degree of control reduced the herbaceous plant material by only 40%.

Woody plant control had no effect on the amount of herbaceous plant material during the first four seasons (Fig. 3). In the sixth year the woody plant control and herbaceous plant control interacted. Woody plant control increased the amount of herbaceous plant material from 0.8 to 2.1 Mg/ha on plots not receiving herbaceous plant control. On plots that had received herbaceous plant control, woody plant control had no effect on the remaining herbaceous plant material.

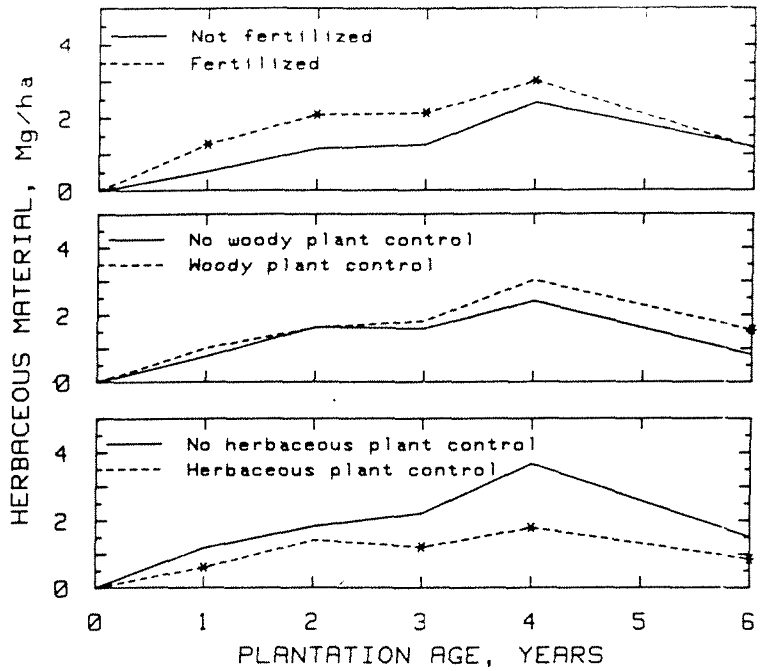


Fig. 3. Influence of the main effects on development of herbaceous plant material. Asterisks on treatment line indicates the treatment had a significant ($P < 0.05$) effect in that year. Data was not collected in the fifth year.

The fertilizer increased herbaceous plant material by about 0.75 Mg/ha regardless of the level of competition control in the first year. The increase was statistically significant. This amount of dry matter increase was maintained through age 4. Fertilization had no effect on the dry weight of herbaceous material by the sixth year.

The application of fertilizer, including nitrogen, never increased the concentration of nitrogen in the herbaceous plant material. The only significant effect of fertilization on nitrogen concentration was a decrease in the second season, but the difference was too small to be of practical importance. Nitrogen concentration in the herbaceous plant material averaged 13.9 g/kg in the first season (Fig. 4) and decreased to 5.2 g/kg by the sixth season.

The concentration of phosphorus in herbaceous plant material on the unfertilized plots was 0.67 g/kg in the first season and then declined to about 0.40 g/kg from the second through sixth seasons (Fig. 4). Fertilizer significantly increased phosphorus in the herbaceous material throughout the sampling period.

Potassium in the herbaceous plant material was not affected by any of the cultural treatments. The concentration of potassium declined steadily throughout the sampling period from 14.7 to 3.4 g/kg (Fig. 4).

The amount of nutrients taken up by the herbaceous plant material on an area basis followed the same trend with time as the total dry weight of the herbaceous plant competition, gradually increasing until the fourth season and then declining. The fertilizer did not interact with the plant control factors. The effect of phosphorus was still significant in the fourth season, but by age 6 fertilization had lost even this effect on the nutrient content of the herbaceous plant material.

At age 6, woody and herbaceous plant control interacted in their effects on the nutrient content of the herbaceous material. Woody plant control by itself allowed the herbaceous material to take up about twice as much nutrient (Table 3) as the other plant control treatments. However, the difference of 5 kg/ha of nitrogen, 0.4 kg/ha of phosphorus and 2.5 kg/ha of potassium were small in comparison to the total nutrient pool.

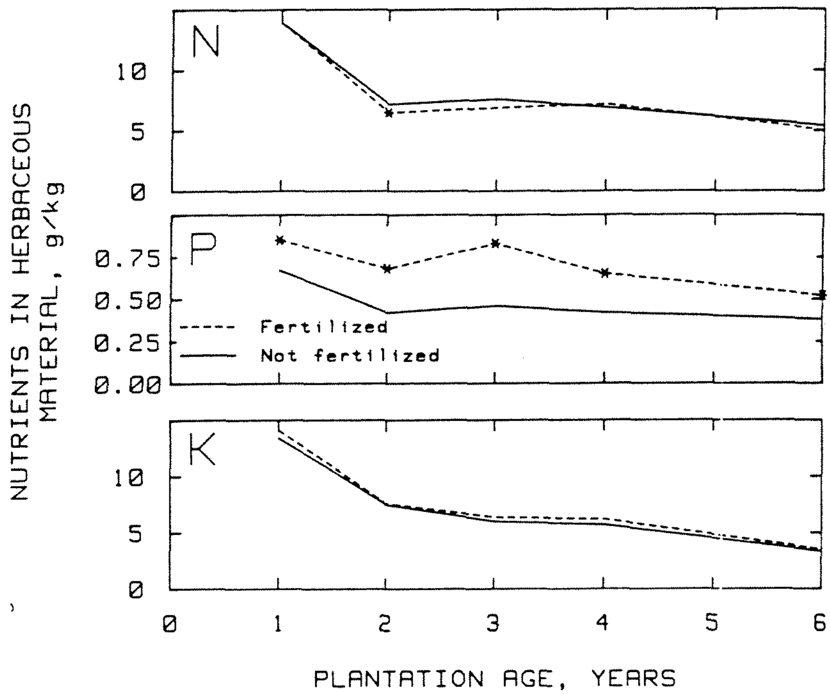


Fig. 4. Influence of fertilization and time on the concentration of nutrients in herbaceous plant material. Asterisks on treatment line indicates that fertilizer had a significant ($P < 0.05$) effect on that nutrient content in that year. Data was not collected in the fifth year.

TABLE 3

Influence of competition control on quantity of nutrients in herbaceous material collected in the sixth season averaged across both fertilizer levels

| Weed control | N (kg/ha) | P (kg/ha) | K (kg/ha) |
|---|---|---|---|
| None | 4.2 a[a] | 0.36 a | 2.6 a |
| Woody controlled | 9.6 b | 0.84 b | 5.4 b |
| Herbaceous controlled | 4.0 a | 0.35 a | 2.5 a |
| Both controlled | 4.7 a | 0.43 a | 3.2 a |

[a]Numbers in a column followed by the same letter are not significantly different ($P < 0.05$).

## CONCLUSIONS

(1) Herbaceous plant control is necessary for the first 4 years after loblolly pine establishment for maximum pine growth.

(2) Pines will respond to phosphorus fertilization at planting on some sites even without control of competing plants.

(3) Woody plant competition control can be delayed for the first 3 or 4 years provided the site has received intensive and effective site preparation.

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