SEASONAL AND CUMULATIVE LOBLOLLY PINE DEVELOPMENT UNDER TWO STAND DENSITY AND FERTILITY LEVELS [1]

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Abstract. An 8-year-old loblolly pine (*Pinus taeda* L.) stand was subjected to two cultural treatments for examination of seasonal and cumulative pine development. In the first treatment, pine density was either reduced by removal cutting to 296 trees per acre, at a 12- by 12-ft spacing, or left uncut with an original density of 1,210 trees per acre at a 6- by 6-ft spacing. In the second treatment, either no fertilizer was applied, or diammonium phosphate was broadcast at 134 lbs of P and 120 lbs of N per acre. Competing vegetation was controlled on all plots. Pine heights and diameters were measured in the spring, summer, fall, and winter of the 9th through 11th growing seasons. Plots that had undergone removal cutting had less spring height growth in the 9th and 10th growing seasons than the uncut plots, with no significant affect in the 11th season. Cutting increased diameter growth throughout each spring and summer, but basal area per acre increment failed to keep pace with the uncut plots. Fertilization increased height growth, beginning in the 10th growing season, and fertilization increased diameter and basal area per acre growth each year, especially on the cut plots. Fertilization of cut plots was more beneficial than cutting alone. Removal cutting alone resulted in less height and basal area growth than the other treatment combinations in the 9th through 11th growing seasons.

Introduction

The ability of fertilization to increase volume increment in pole- to sawlog-sized loblolly pine (*Pinus taeda* L.) stands is greatly dependent on the initial stand basal area per acre (Moehring 1966, Wells and others 1976, Windsor and Reines 1973). Therefore, the fertilization of stands that had undergone removal cutting (thinning) is often much more beneficial for increasing diameter and height increment than either fertilization or cutting alone (Jones and Broerman 1977). The cumulative effect is to increase net volume (and value) per tree left after removal cutting as fertilization acts to speed up site reoccupancy (Ballard 1981, Ballard and others 1981).

Clearly, the use of removal cutting and fertilization influences stand development as determined by yearly measurements. However, the question of when during the growing season does the effect of cultural treatments occur remained. In this study, loblolly pine height and diameter measurements were made periodically over several years to determine: (1) when growth responses to removal cutting and fertilization might occur during the growing season and (2) the cumulative growth responses to cultural practices over several growing seasons.

Methods

The Study Area

The 2.8-acre site, located in Rapides Parish, Louisiana, is a gently sloping Beauregard silt loam (Plinthaquic Paleudults, fine-silty, siliceous, thermic) soil. Soil drainage is adequate, and slope is sufficient that water does not pond. The site was planted with loblolly pine seedlings at a 6- by 6-ft (1.8- by 1.8-m) spacing in May 1981. The planting stock was containerized seedlings that had been grown in Styrofoam® blocks for 14 weeks. Over 97 percent of the planted trees survived through 1987, when this study was initiated. The 3 percent that did not survive did not create any openings in the stand canopy. Loblolly pine was the dominant vegetation as measured by basal area per acre, frequency of occurrence, and occupancy of the canopy. Diameters of all pine trees in the stand were measured in September 1987, and, based on these data, it was determined that diameter classes of pine trees were uniformily distributed across the site.

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Plot Establishment

In April 1988, the understory hardwood trees, shrubs, brush (including *Rubus* spp. and *Smilax* spp.), and herbaceous plants were cut with a tractor drawn, rotary mower. Twelve research plots were established with each plot containing 13 rows of 13 trees each (0.14 acre or 0.06 ha plots).

Treatments, Tree, and Plot Selection

Treatments were randomly assigned to the 12 plots in a 2 by 2 factorial arrangement with 3 replications as follows:

1. Removal cutting. Plot density was either reduced to 296 trees per acre or left uncut with an original density of 1,210 trees per acre.
2. Fertilization. No fertilizer was applied, or diammonium phosphate was broadcast at 667 lb/acre [134 lb/acre (150 kg/ha) of P and 120 lb/acre (134 kg/ha) of N]. This choice and rate of fertilizer was based on prior knowledge of loblolly pine responses to fertilization on a Beauregard silt loam soil (Tiarks 1982).

On the cut plots, the trees were removed to leave a 12- by 12-ft spacing by cutting every other row of trees and every other tree in the uncut rows. This left 12 pines on the interior measurement area of each cut plot. Cutting was not done selectively to avoid biasing the comparison of the cut and uncut plots. The purpose of removal cutting was not to improve the population of trees, but rather to compare growth between like populations of trees growing under different management practices. On the uncut plots, 12 trees were systematically selected for collecting height data, rather than measuring the height of every tree.

After tree selection, the plots were randomly assigned treatments. The cutting was done in November 1988, at the end of the eighth growing season. The fertilizer was broadcast in April 1989, at the beginning of the ninth growing season.

Plot Maintenance

The 12 selected trees on each plot were banded with red paint at about 5.5 ft to ensure relocation. All trees on the interior measurement areas were marked with a blue diameter point at d.b.h. for consistent resampling.

An ice storm occurred in February 1989. The ice bent about 28 trees and snapped 2 border trees on the cut plots. Most of the trees restraightened, however, several were no longer usable for height measurements although they were still used for collection of d.b.h. data.

Competition from other plant species is not a factor in this research. Therefore, all remaining large woody vegetation and vines were cut, and the herbaceous and small woody competitors were sprayed with glyphosate in April 1989. The plots were rotary mowed 3 weeks later and retreated with glyphosate later in the growing season to maintain weed control. In 1990, the plots were again sprayed and mowed. In 1991, the vines were again cut and the plots sprayed with glyphosate and a mixture of 2,4-D, dicamba, and dichloroprop and rotary mowed 3 weeks after spraying.

Measurements and Experimental Design

The interior measurement area was that portion of each plot originally occupied by the central 7 rows of 7 trees each (0.04 acre or 0.02 ha). On March 27, 1989, pine tree diameters (of all trees on the interior measurement area) were measured to the nearest 0.1 inch with a diameter tape, and total heights (of the 12 selected trees only) were measured with a clinometer to the nearest 0.5 ft. This measurement provided a baseline covariate for future analyses. The plots were again measured on July 5 and October 2, 1989; March 19, June 13, October 29, and December 14, 1990; and March 8, June 24, September 24, and December 4, 1991.

Data were analyzed by analyses of covariance with the covariate being the original height, diameter, or basal area per acre data (Probability > F-value = 0.05). The dependent variables were the periodic growth differences in the spring, summer, and fall of each year, as well as the cumulative growth differences for the 3-year period. The spring periods were March through July 1989 (100 days), March through June 1990 (86 days), and March through June 1991 (108 days). The summer periods were July through October 1989 (89 days), June through October 1990 (138 days), and June through September 1991 (92 days). The fall periods were October 1989 through March 1990 (168 days), October through December 1990 (46 days), and September through December 1991 (71 days).

Results and Discussion

Plots that had undergone removal cutting had less total height growth than the uncut plots for the 3-year period (fig. 1). However, the effect of cutting on height growth was most pronounced in the spring of the 9th and 10th growing seasons, with no significant influence on height growth in the 11th growing season (table 1). Ginn and others (1989) also reported an early suppression in loblolly pine height growth from reduction in stand density.

Fertilization increased total height growth for the 3-year period, but height growth was not significantly affected by fertilization until the 10th growing season, when height growth was increased on only the uncut plots in spring 1990 (see the removal cutting and fertilization interaction effect in table 1). However, height growth on both the cut and uncut plots was increased in summer 1990 (fig. 1, table 1). Thus, the effect of fertilization on height growth was delayed, whereas the effect of removal cutting on height growth was immediate. However, trees eventually returned to a normal growth pattern on the cut plots.

The cumulative influence of removal cutting and fertilization on pine height growth was additive for the 3-year period (fig. 2). Height growth averaged 8.8, 11.1, 6.1, and 8.5 ft from the 9th through 11th growing seasons on the uncut-unfertilized, uncut-fertilized, cut-unfertilized, and cut-fertilized treatments, respectively.

Removal cutting immediately increased diameter growth of the remaining trees for the 3-year period (fig. 1). This positive growth response to cutting was significant in every measurement season, except fall 1990 and 1991 [(Probability > F-value = 0.0708 and 0.1333, respectively (table 1)].

Fertilization significantly increased seasonal diameter growth in summer 1989 and 1990 and spring 1991 (fig. 1, table 1). Other studies have shown that initial stand basal area greatly influences pine tree responses to fertilization (Moehring 1966, Wells and others 1976, Windsor and Reines 1973) and fertilization of stands that had undergone removal cutting is often more beneficial than either fertilization or density reduction alone (Jones and Boerman 1977). This was demonstrated by a significant cutting and fertilizer interaction effect on diameter growth for the 3-year period (table 1), with fertilization having little cumulative effect on diameter growth on the uncut plots (figs. 1, 2). Diameter growth for the 3-year period averaged 0.5, 0.6, 1.4, and 2.1 inches on the uncut-unfertilized, uncut-fertilized, cut-unfertilized, and cut-fertilized treatments, respectively.

Plots that had undergone removal cutting had less cumulative basal area per acre growth than the uncut plots at a Probability > F-value = 0.0682 (table 1), and the uncut and cut treatments averaged a 36.5 and 29.5 ft^2 gain in basal area per acre for the 3-year period, respectively (fig. 1). Fertilization increased cumulative basal area growth, especially on the cut plots (fig. 2), but there was no significant cutting and fertilization interaction effect in the cumulative basal area per acre analysis [Probability > F-value = 0.1745 (table 1)]. The 3-year gain in basal area was 34, 39, 23, and 36 ft^2 per acre on the uncut-unfertilized, uncut-fertilized, cut-unfertilized, and cut-fertilized treatments, respectively.

To conclude, the negative effect of removal cutting on subsequent loblolly pine height growth was limited to the first 2 years after treatment. The positive response of removal cutting on diameter growth was immediate and continual through the 3-year period. Fertilization increased diameter growth only on the cut plots and had more influence on basal area per acre increment on the cut than uncut plots. Therefore, on infertile silt loam soils, fertilization of cut or thinned stands is the best management practice. Removal cutting alone is not recommended because of the effect on height and basal area per acre increment.

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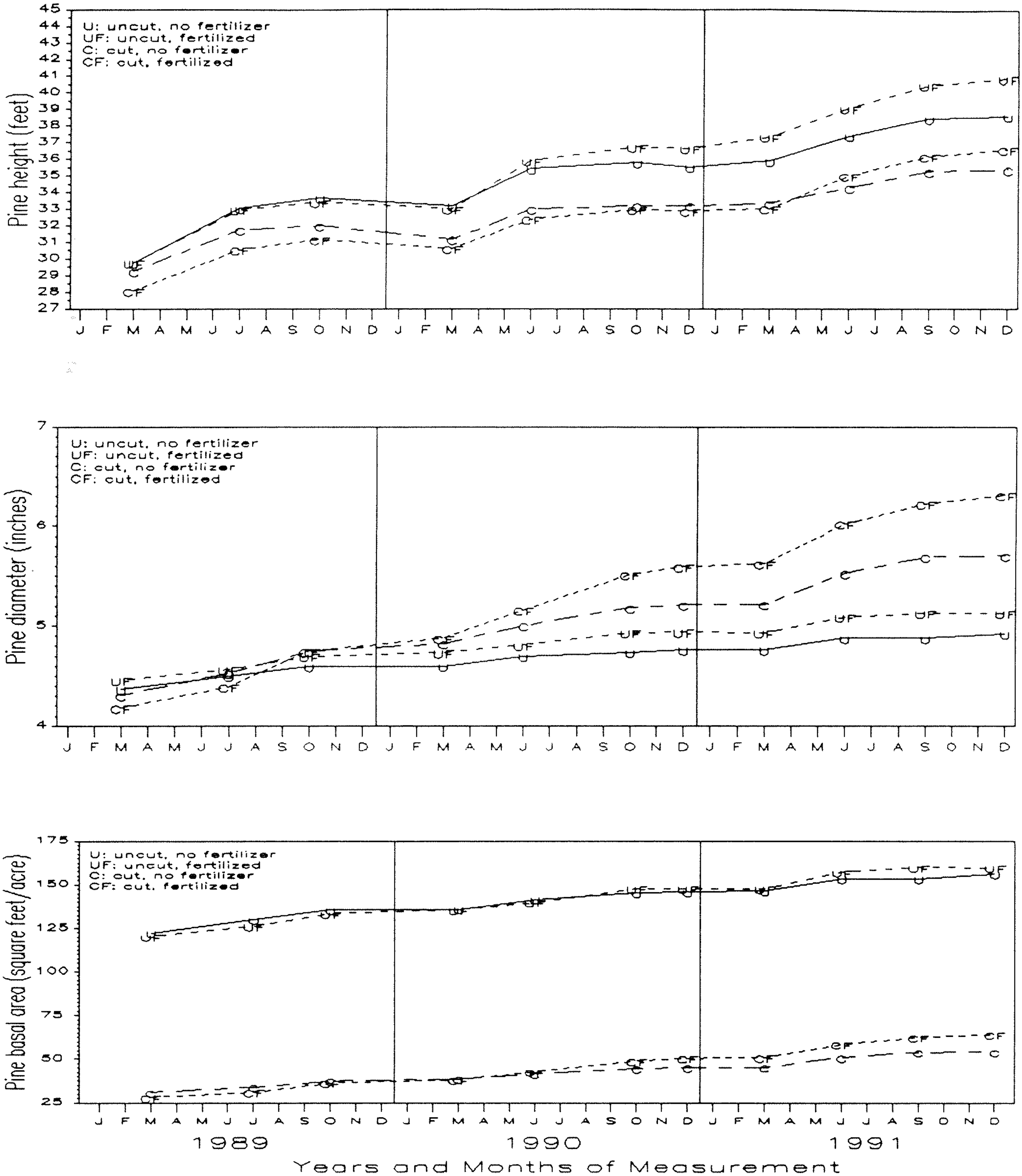

Figure 1. ***Total loblolly pine height (top), diameter (middle), and basal area per acre (bottom) in the 9th through 11th growing seasons.***

Table 1. *Probability of a greater F-value for the main effect treatments and interaction term when comparing seasonal and cumulative height, diameter, and basal area per acre growth of loblolly pine in the 9th through 11th growing seasons.* [1]

Variable Response	(Probability > F-value) 9th growing season Spring	Summer	Fall	10th growing season Spring	Summer	Fall	11th growing season Spring	Summer	Fall	Cumulative 3-year growth
Height growth										
Removal cut	.0042	.6832	----[2]	.0013	.2905	.4172	.5124	.5335	.9550	.0002
Fertilizer	.6114	.5813	----	.1421	.0055	.8574	.0120	.3737	.0256	.0007
Cut x fert.[3]	.8882	.1506	----	.0343	.9839	.9265	.0594	.6867	.7762	.8758
Diameter growth										
Removal cut	.0075	.0001	.0202	.0012	.0001	.0708	.0001	.0007	.1333	.0001
Fertilizer	.3643	.0046	.0627	.1653	.0002	.3964	.0145	.1381	.5226	.0051
Cut x fert.[3]	.7190	.0507	.9345	.0382	.0692	.0785	.3446	.9345	.0328	.0312
Basal area/acre growth										
Removal cut	.0376	.0908	.8027	.3736	.8376	.5710	.0098	.1410	.5073	.0682
Fertilizer	.0985	.0080	.0008	.9515	.0003	.7297	.0013	.0454	.2019	.0067
Cut x fert.[3]	.2558	.8308	.0660	.1554	.3328	.1691	.4618	.2643	.0018	.1745

[1] Probabilities are from analysis of covariance with the initial height, diameter, and basal area per acre data, taken in March 1989, as the covariate. The accepted level of significance was Probability > F-value = 0.05.
[2] Average pine heights were reduced on all treatments. No analysis was made.
[3] The removal cutting by fertilization interaction.

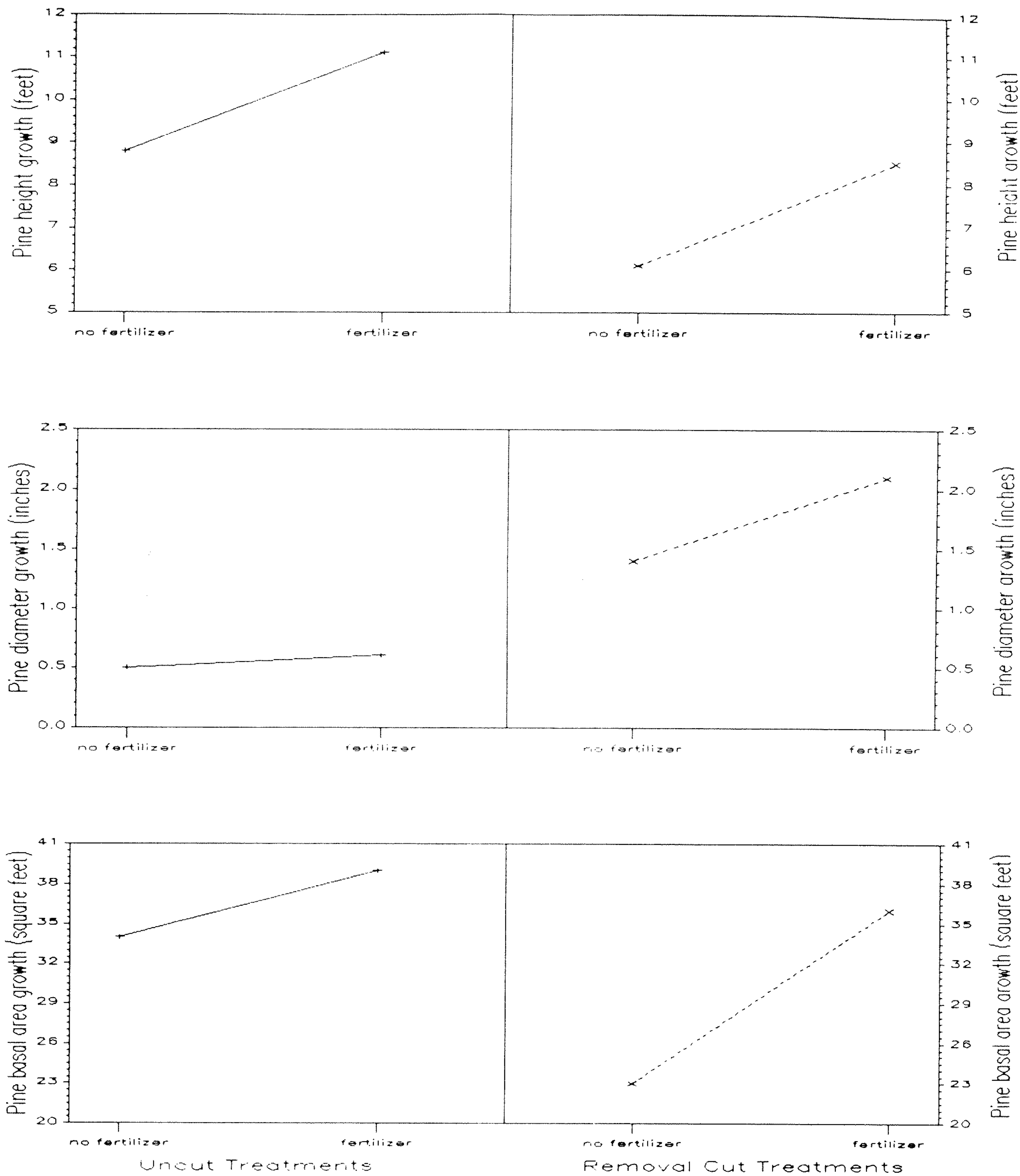

Figure 2. *Three-year-growth response of loblolly pine height (top), diameter (middle), and basal area per acre (bottom) to removal cutting and fertilization.*