GROWTH OF YOUNG PINE STANDS WITH FERTILIZATION ALONE VERSUS FERTILIZATION PLUS VEGETATION CONTROL

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Abstract—Fertilization and vegetation control are two useful silvicultural tools available to forest managers. Fertilization directly adds nutrients, and vegetation control indirectly improves nutrient and water availability to the crop species. In young pine stands that have not fully captured the site, there has been concern that adding fertilizer will stimulate competing vegetation, which will then outcompete the pines and result in slower pine growth. To determine if this is a valid concern, we tested the hypothesis that there is no difference in pine growth in young stands when applying fertilizer alone or with vegetation control. We installed two treatments at 11 sites with two replications at each site in pine stands across the Southeastern United States. Treatments were fertilization (120 and 12 pounds per acre of elemental nitrogen and phosphorus, respectively, applied every 2 years) and fertilization plus complete sustained vegetation control. Other elements were added if foliar nutrient analysis indicated that they were limiting. Stand age at installation ranged from 2 to 6 years old. Eight years after treatment initiation, no differences in growth were found between the fertilized and fertilized plus vegetation control treatments for diameter, height, basal area, volume, or mortality. Fertilization likely stimulated foliage development, which increased growth and shaded out competing vegetation. However, our results may be influenced by the relatively high rates of nitrogen and phosphorus and additional nutrients added if necessary. In previous studies where one-time applications of 200 and 25 pounds per acre elemental nitrogen and phosphorus, respectively, were added, growth improved when adding vegetation control along with the fertilizer.

INTRODUCTION

Loblolly pine (*Pinus taeda* L.) stands in the Southeastern United States typically have low leaf area levels as a result of nutrient (primarily nitrogen) limitations (Vose and others 1994). These limitations have been ameliorated with mid-rotation applications of 200 and 25 pounds per acre elemental nitrogen and phosphorus, respectively, which result in responses averaging 55 cubic feet per acre per year for 8 years (Fox and others 2007). When one-time vegetation control was applied at the same time as fertilization in mid-rotation loblolly pine stands, treatment responses were additive, indicating that limiting resources other than nitrogen and phosphorus were being ameliorated by the vegetation control treatment (Albaugh and others 2012). However, of the examined sites, a positive response was more common when adding nutrients than when conducting vegetation control. It is likely that in these nutrient-limited mid-rotation stands, the addition of nutrients increased leaf area index such that the additional leaf area shaded out the competing vegetation.

The success in adding nutrients to mid-rotation stands led to an interest in fertilizing younger stands to capture the site more quickly, increase stand productivity, and potentially reduce rotation length. Vegetation control has been included from time of planting with good results. For example, in a regional study, Miller and others (2003) found height gains ranging from 7 to 10 feet at 7 years of age in response to complete sustained herbaceous and woody vegetation control for a range of sites with differing amounts and types of competing vegetation. At age 4 at a site in north-central Florida, fertilization and vegetation control produced similar levels of response when applied alone in loblolly pine stands beginning at planting and additive responses when applied together (Colbert and others 1990). However, in a regional study with similar treatments, there was considerable variation in treatment response, where some sites showed only vegetation control effects at age 5 and others showed only fertilizer effects through age 7 (Will and others 2002). These studies indicated that fertilization could increase growth in young stands, but there was still concern that, at an operational scale, the application of

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fertilizers to young stands which have not fully captured the site would result in competing vegetation taking up these additional nutrients and suppressing rather than improving pine growth.

With this background, our interest was to determine if fertilizer could be applied to young pine stands without stimulating the competing vegetation such that pine growth was reduced. Consequently, we tested the hypothesis that growth as a result of fertilizer and fertilizer plus vegetation control treatments in young pine stands would be the same.

METHODS

We identified 11 sites across the Southeastern United States (table 1) with good operational pine stands that had been site prepared with a mix of chemical or mechanical site preparation. Ten stands were planted in loblolly pine and one (site 11) was in slash pine (*P. elliottii* Engelm.). Stands ranged in age from 2 to 6 years, with Cooperative Research in Forest Fertilization (Jokela and Long 2012) soils groups A, B, C, and E represented. Plots were installed with a measurement plot centered in a larger treatment plot. Measurement plots averaged 0.11 acres and treatment plots averaged 0.45 acres across sites. Between adjacent plots, a minimum buffer of 30 feet was installed. Plots were blocked based on height, basal area, and density to reduce heterogeneity among the plots within and between blocks. There were two blocks per site. Treatments were fertilization (120 and 12 pounds per acre of elemental nitrogen and phosphorus, respectively, applied every 2 years) (F) and fertilization (120 and 12 pounds per acre of elemental nitrogen and phosphorus, respectively, applied every 2 years) plus complete sustained vegetation control (F+VC). Diammonium phosphate, monoammonium phosphate, urea, and coated urea fertilizer sources were used. To prevent nutrient imbalances, additional nutrients were applied to individual sites based on annual foliar nutrient analyses. After 8 years, total applied nutrients were 480 and 48 pounds per acre of elemental nitrogen and phosphorus, respectively. Vegetation control methods were determined for each site and included mechanical (mowing, weed eaters) and chemical control (spot and directed sprays of glyphosate). Diameter at breast height (4.5 feet) and height were measured prior to treatment and annually for 8 years. Individual tree volume was calculated using an over-bark volume equation for unthinned trees (Tasissa and others 1997) as:

$$V = [0.21949 + (0.00238 * D * D * H)] \qquad (1)$$

where

V = individual tree volume in cubic feet per tree
D = diameter at breast height in inches
H = height in feet

The volume increment in year 8 was the volume at the end of year 8 minus the volume prior to treatment.

A mixed model [PROC MIXED (SAS Institute 2002)] was used to test for treatment effects prior to adding

Table 1—Age at initiation, Cooperative Research in Forest Fertilization (CRIFF) soils group, and location for the 11 sites where fertilizer and fertilizer plus complete sustained vegetation control treatments were applied in young pine stands in the Southeastern United States

Site	Age at initiation *(years)*	CRIFF soils group	Latitude	Longitude	County	State
			(decimal degrees)			
1	6	E	32.91	-86.38	Coosa	AL
2	3	E	34.15	-85.38	Floyd	GA
3	3	E	31.13	-94.46	Angelina	TX
4	2	E	33.81	-82.96	Wilkes	GA
5	4	E	32.70	-88.58	Kemper	MS
6	3	A	32.37	-87.84	Marengo	AL
7	5	E	32.68	-84.74	Talbot	GA
8	2	B	30.48	-93.78	Newton	TX
9	4	E	35.28	-79.94	Montgomery	NC
10	6	B	32.55	-89.64	Montgomery	MS
11	3	C	29.65	-83.17	Dixie	FL

the treatments and 8 years after treatments began. We examined height, diameter, and stand volume prior to adding the treatments and height, diameter, and volume increment (volume at 8 years minus volume at year zero divided by 8) 8 years after treatment began. Fixed effects were treatment (F or F+VC), location (11 sites), and treatment by location. Block was a random effect.

Annual volume growth was calculated for each treatment plot for each year as the volume at the end of the year minus volume at the beginning of the period. We used a linear mixed model to develop a regression equation for the volume increment model:

$$VI_{FVC}=VI_F\ S\ VI_F xS \qquad (2)$$

where

VI_{FVC} = annual volume increment for the F+VC treatment (cubic feet per acre per year)

VI_F = annual volume increment for the F treatment (cubic feet per acre per year)

S = site

$VI_F xS$ = the interaction of the annual volume increment for the F treatment and site

Non-significant terms were dropped from the model until all terms were significant. We tested the slope and intercept estimates to see if they were different from 1 and 0, respectively, and estimated the 95 percent confidence intervals around these parameters. All statistical tests were evaluated with alpha equal to 0.05.

RESULTS

No treatment differences were observed for initial diameter, height, and stand volume. Similarly, no treatment differences were found for 8-year diameter, height, or stand volume increment (table 2 and fig. 1). The only significant term in the volume increment model was VI_F. The intercept for the volume increment model was not different from zero but the slope (0.945) was different from 1. However, the 1:1 line fell within the 95 percent confidence intervals around the volume increment model (fig. 2).

DISCUSSION

We accepted our hypothesis that growth as a result of fertilizer and fertilizer plus vegetation control treatments in young loblolly pine stands was the same. There were no treatment differences in initial stand metrics; consequently, the stands were equal at the start of the study. Eight years after treatment, there were still no differences in stand metrics between the two treatments. We did find a slope <1 for the F+VC and F relationship. In this case, a slope <1 indicates that the F plots had a higher annual volume increment than the F+VC. However, the 1:1 line fell within the 95 percent confidence interval around the regression line suggesting that there is little real difference between the two treatments. Site and site-by-volume increment were not significant factors in the regression model. The loblolly and slash pine sites behaved similarly for the relationship between annual volume increment for the F and F+VC treatments.

Our results were somewhat surprising given the response observed in previous studies where fertilizer and fertilizer plus vegetation control in young stands resulted in an additive treatment response in at least some cases (Colbert and others 1990, Will and others 2002). Fertilization increases leaf area index on nutrient-limited sites, and crown development and expansion can be rapid and extensive (Albaugh and others 2006). Consequently, fertilization alone may eventually stimulate pine leaf area sufficient to shade out competing vegetation. The fertilizer application rate used in our

Table 2—Statistical summary (*p*-values) for growth metrics prior to treatment initiation (initial) and 8 years after treatment initiation for 11 sites in the Southeastern United States where fertilizer and fertilizer plus complete sustained vegetation control treatments were added to young *Pinus taeda* or *P. elliottii* stands

	Effect		
Variable	Treatment	Study	Study x treatment
Initial diameter (inches)	0.310	<0.001	0.541
Initial height (feet)	0.256	<0.001	0.793
Initial stand volume (cubic feet per acre)	0.615	<0.001	0.999
8-year diameter (inches)	0.203	<0.001	0.390
8-year height (feet)	0.121	<0.001	0.714
8-year volume increment (cubic feet per acre per year)	0.386	<0.001	0.990

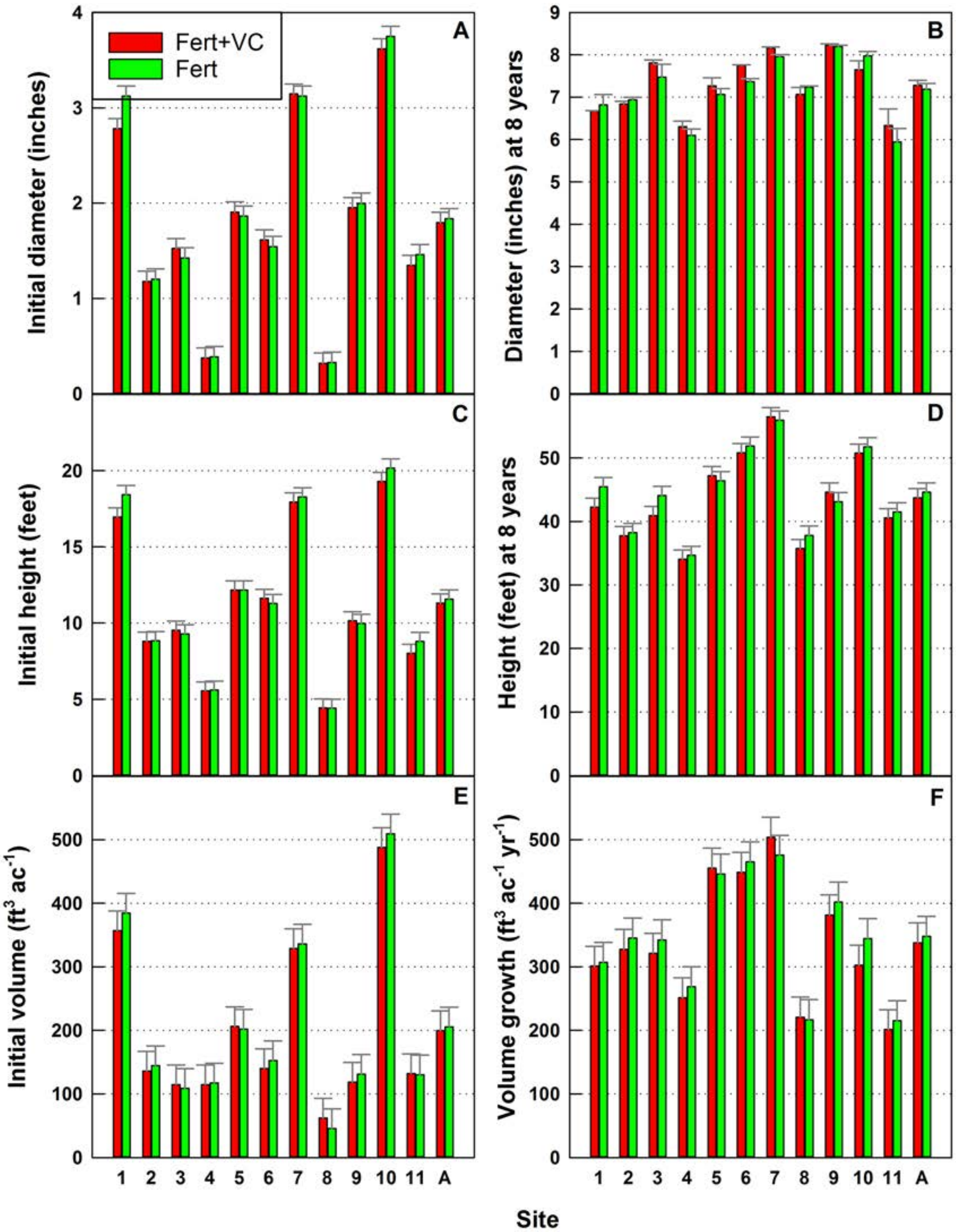

Figure 1—Initial diameter (A), height (C), and stand volume (E) and diameter (B), height (D), and average annual volume increment (F) 8 years after treatment started for the fertilizer only (F) and fertilizer plus vegetation control (F+VC) treatments at 11 sites in the Southeastern United States where fertilizer and fertilizer plus complete sustained vegetation control treatments were applied in young pine stands. Error bars are one standard error; 'A' indicates the average across all 11 sites.

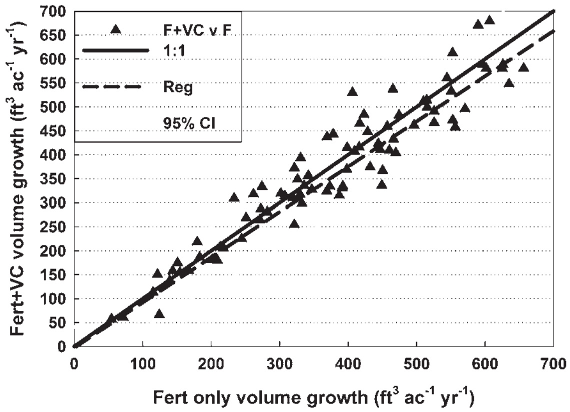

Figure 2—Annual volume growth (cubic feet per acre per year) for 8 years after treatments started for the fertilizer plus vegetation control treatment (F+VC) versus the corresponding fertilizer only treatment (F) at the same site for the 11 sites in the Southeastern United States where fertilizer and fertilizer plus complete sustained vegetation control treatments were applied in young pine stands. Lines shown are the 1:1 line (1:1), the regression (Reg), and plus and minus 95 percent confidence intervals around the regression (95 percent CI).

study (120 and 12 pounds per acre of elemental nitrogen and phosphorus, respectively, applied every 2 years) is a relatively large amount of nutrients to add. After 8 years in our study, we had applied more than twice the current operational application recommendation of 200 and 20 pounds per acre of elemental nitrogen and phosphorus, respectively, applied every 8 years. The relatively high rate of nutrient application may have influenced how rapidly crown expansion occurred and consequently how rapidly the competing vegetation was shaded out in both treatments. The sites selected for our study were considered good operational stands in that they would have had good mechanical or chemical site preparation. This factor may have played a role in our results, in that it is possible there was relatively little competing vegetation when the study started and thus there would be little additional response from the vegetation control. Unfortunately, resources were not available to quantify the competing vegetation at any time during the study, so it is impossible to evaluate this potential effect. Similarly, we did not monitor the effectiveness of the vegetation control; it is possible that vegetation control was not very effective which would have resulted in our observed outcome with no difference between the treatments. Alternatively, although care was taken to avoid damage to the pine from the vegetation control treatments, it is possible that the vegetation control treatments had both a beneficial (elimination of competitors, more available resources) and a detrimental effect (from chemical drift or over application) on the pine where the net result was no change.

From our data alone, one would conclude that on many sites, nutrients may be added to young stands without stimulating the competing vegetation such that there is a loss of pine growth. It is likely that there are sites or conditions where competing vegetation control would be required to get a good response when applying fertilization in young stands. However, if the stands have been well managed from the start and an intensive fertilizer regime is applied, there is a good likelihood of a nutrient response without stimulating the competing vegetation. In support of this argument, there is recent evidence that, in mid-rotation stands with relatively low amounts of competing vegetation, almost all applied nitrogen can be found in the trees, soil, or litter layer with very little found in competing vegetation (Raymond 2016), further supporting the results from this study.

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