BARK YIELDS OF 11-YEAR-OLD LOBLOLLY PINE AS INFLUENCED BY COMPETITION CONTROL AND FERTILIZATION [1]

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Abstract. Bolts cut from 11-year-old loblolly pines (*Pinus taeda* L.) were measured to determine the effects of applications of fertilizer and competition control treatments on the amount of pine bark produced. Bark thickness at breast height was not significantly affected by any of the treatments. Regression analysis showed that the dry weight of bark per unit surface area of the bolt increased as the volume of the bolt increased. The regressions for unfertilized and fertilized trees were significantly different: the fertilized trees had less bark. Because bark weight is correlated with bole diameter, bolts were placed in 20-mm-wide inside-bark diameter classes. Fertilizer and woody plant control treatments decreased mean bark weight from 71.6 to 59.7 kg m^{-3} of wood for bolts in the 120-mm class and from 72.9 to 62.0 kg m^{-3} for those in the 140-mm class.

Introduction

Weed control and fertilization treatments applied at time of establishment of new plantations increase the growth of southern pines substantially (Bacon and Zedaker 1987, Clason 1984, Schmidtling 1984, Tiarks and Haywood 1986, Zutter and others 1987). This reported growth increase is based on outside-bark diameter measurements and derived volumes and on the implicit assumption that the treatments do not affect the tree shapes or the proportions of bark and wood in the trees. However, cultural treatments do affect the taper of older trees (Shoulders and others 1989). Because bark has relatively little economic value, even small changes in bark-to-wood ratios could cause significant differences in the economics of a cultural treatment.

Because interest has usually centered on determining actual wood volume, most measurements of bark have been of thickness. These measurements have shown that bark thickness changes with d.b.h. (Burton 1962), height (Cochran 1982), and age (Koch 1972). Bark thickness is reduced by fire (MacKinney 1934) and varies with region and soils (Koch 1972). Bark thickness is also difficult to measure accurately (Mesavage 1969) and is highly variable (Judson 1964). Bark weights as a portion of wood volume or weight have been reported but have not been related to silvicultural treatments.

We harvested bolts from a stand of loblolly pine (*Pinus taeda* L.) that had received fertilizer and weed control treatments. We compared bark weights to bolt volumes and surface areas to determine the effects of the treatments on bark yields. We removed the effects of diameter on bark yields by including d.b.h. in regression models and by making comparisons within bolt diameter classes.

Methods

Bolts for taper and bark measurements were collected in an 11-year-old loblolly pine plantation established as part of a fertilizer and competition control experiment (Haywood and Tiarks 1990, Tiarks and Haywood 1986). The study site is in Winn Parish, LA, on moderately well-drained Malbis very fine sandy loam (fine-loamy, siliceous, thermic Plinthic Paleudults). A mature loblolly-shortleaf pine (*P. echinata* Mill.) stand was clearcut and the site intensively prepared by V-blading and root raking. In the winter of 1977-78, 64 loblolly seedlings were planted at a 2.4- by 2.4-m spacing on each of 32 19.5- by 19.5-m plots. The center 16 trees in each plot were designated as measurement subplot trees. To maintain uniform density, all dead seedlings were replaced in September 1978 with container-grown loblolly seedlings.

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Fertilizer, herbaceous plant control, and woody plant control treatments were applied in a 2 by 2 by 2 factorial experiment with a randomized complete block design. The four blocks served as replicates. Fertilizer was hand broadcast in April 1978 at the rate of 112 kg of nitrogen, 49 kg of phosphorus, and 93 kg of potassium per hectare. Woody plant control was accomplished by two herbicide applications. In 1978, low-volatile ester 2,4,5-T [(2,4,5-trichlorophenoxy) acetic acid] was sprayed on all hardwoods after the pines had been covered. In 1979, the few remaining hardwoods were cut off near the ground and their stumps treated with a picloram (4-amino- 3,5,6-trichloro-2-pyridinecarboxylic acid) and 2,4-D [(2,4-dichlorophenoxy) acetic acid] mixture. Herbaceous plant control was achieved by hoeing a 1.14-m radius circle around each pine to remove grasses, grasslike plants, and forbs without damaging pine or hardwood roots. The hoeing was done three times yearly between April and September for the first four growing seasons.

Total height and diameter at breast height (d.b.h.) of the 16 loblolly pine trees in each plot center were measured for the first 10 years. When the pines were 11 years old, the heights and d.b.h. of all living pines on the plots, including those in the border rows, were measured. The measurement data were used to select trees for removal in a thinning operation that would leave 32 living pines per gross plot and 8 evenly spaced, well-formed, crop trees per measurement plot. In each plot, four of the pines identified for thinning and reflecting the diameter distribution of pines on the plot were selected. Whenever possible, trees within the measurement plots were selected, but only if they were from the original planting and not more than one standard deviation smaller in d.b.h. than the mean for the plot. Where this was not possible, trees from the inside border row and having d.b.h. within one standard deviation of the measurement plot d.b.h. mean were selected. Because we preferred to leave good trees in the measurement plots, we took about half of the sample trees from the border rows.

After the sample trees were felled, sample bolts were cut from their main stems at heights of 0 to 1, 1 to 2, and 3 to 4 m. These bolts were debarked by hand and the ovendry weight of the bark from each bolt was recorded. The top-end and bottom-end diameters of each debarked bolt were measured with a tape.

Single bark thickness was calculated by taking half of the difference between the d.b.h. of the standing tree and the d.b.h. calculated from the upper and lower diameters of the debarked bolt representing the 1-m to 2-m height. Because bark thickness varies around the circumference of the tree (Mesavage 1969), this method should give better results than does a bark gauge. The surface area and volume of each bolt were calculated from the upper and lower diameters of the bolt and assuming a truncated cone. These results were used to calculate the dry bark weight per unit volume of wood and dry bark weight per unit surface area of the debarked bole. The significance of effects of the treatments on bark thickness was tested by analysis of variance. Linear regression was used to describe the relationship between dry weight of bark per unit surface area and volume of wood. After the bolt data were separated by 20-mm bolt-diameter classes, general linear model regression was used to analyze the effects of the treatments on bark weight per unit of wood volume and bark weight per unit of surface area.

Results and Discussion

Heights and Diameters

Fertilization and herbaceous plant control significantly increased the height of the trees harvested (table 1). The two treatments increased height by 0.8 and 0.6 m, respectively. Only fertilization significantly affected d.b.h. The application of fertilizer at planting resulted in an increase of about 5 percent in d.b.h. at age 11.

Sample trees were selected to represent the diameter distribution of the stand, so it is not surprising that the treatments affected the d.b.h. of the sample trees as much as it affected d.b.h. for the stand (Haywood and Tiarks 1990). The average d.b.h. of the sample trees was about 10 mm larger than average d.b.h. for the stand, but the difference was uniform across all treatments. Average height of the sample trees was about 0.3 m greater than that of the stand (Haywood and Tiarks 1990). The height response to fertilizer application was slightly larger in the sample trees than in the stand, indicating that there was a small bias in sampling.

Table 1. *Effect of fertilization and vegetation control on the height, diameter, and single-bark thickness of loblolly pines harvested at age 11.*

Treatment Effect	Number of plots	Mean height	Mean d.b.h.	Single bark thickness
		(m)	(mm)	(mm)
Main effect treatment comparisons from the analysis of variance				
Fertilizer	16	13.2	165	12
		0.01 [1]	0.01	0.49
No fertilizer	16	12.4	157	12
Herbaceous plant control	16	13.1	163	12
		0.01	0.17	0.76
No herbaceous plant control	16	12.5	159	12
Woody plant control	16	12.9	163	12
		0.30	0.16	0.64
No woody plant control	16	12.7	159	12
Treatment averages				
No fertilizer				
No plant control	4	12.5	154	13
Woody plant control	4	11.7	153	11
Herbaceous plant control	4	12.4	157	12
Woody + herbaceous control	4	13.0	163	12
Fertilizer				
No plant control	4	12.5	158	11
Woody plant control	4	13.1	170	13
Herbaceous plant control	4	13.3	165	13
Woody + herbaceous control	4	13.7	166	12

[1] *For each paired comparison, the probability of a greater F-value is given. Prob. of F $\leq$ 0.05 is significant for this research.*

Bark Thickness

The average single-bark thickness was 12.1 mm and ranged from 3.3 to 22.5 mm with a standard deviation of 3.5 mm. While the observed range is large, Judson (1964) reported a range of about 5 to 30 mm for trees averaging 180 mm in d.b.h. The fertilization and weeding treatments did not significantly affect the bark thickness. Bark thickness increased with d.b.h. according to the relationship:

$$BT = 0.108 \times d.o.b. - 5.3$$

where d.o.b. is diameter outside bark at breast height in mm and BT is single-bark thickness in mm. The equation is highly significant (Probability $>F$ = 0.001), but the r^2 is only 0.29. The slope of the equation is higher than that reported by others (Koch 1972), but our data are based on a smaller range of d.b.h. Burton (1962) reported a slope of 0.078 based on 326 trees with d.b.h. ranging from about 40 to 250 mm.

Dry Bark Weights

Bark weight per unit surface area of bolts increased with the volume of the bolt (fig. 1). The larger bolts are on the older parts of the trees so the increased weight per unit surface area is caused by accumulation over time. Fertilization decreased the dry weight of bark per unit surface area from 15 percent for small bolts to 2 percent for the largest bolts measured.

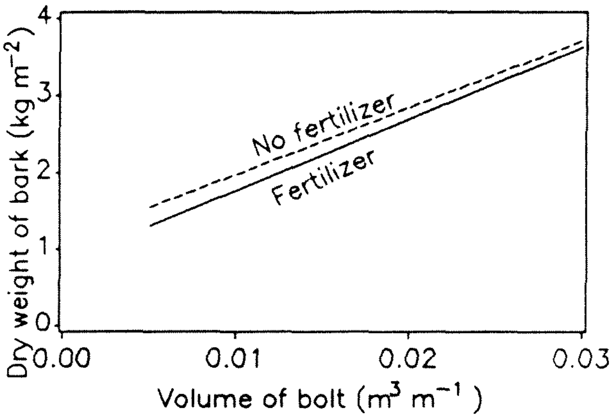

Figure 1. *Effect of fertilizer on the relationship between bolt volume and the weight of dry bark per unit surface area.*

Bolt data were separated by bolt diameter classes to eliminate the effect of diameter on bark weight. Only the 120 and 140 mm classes contained sufficient observations to draw conclusions. The other classes had either too few observations or too many empty cells. Fertilizer decreased the amount of bark on the bolts in both the 120 and 140 mm classes when quantity of bark was expressed either as dry weight of bark per unit of wood volume or as weight of bark per unit surface area (table 2). Woody plant control also decreased the bark yields, but the differences were significant only in the 140-mm bolt class. Volume of wood per unit length of bolt was not affected by the treatments.

Several factors may affect the weight of bark on trees when bark weight is expressed as a function of volume. These factors include the diameter and taper of the bole, bark density, and bark thickness. As the diameter of a bole increases, the ratio of its surface area to its volume decreases. A decrease in taper also decreases the surface area to volume ratio. In the analysis presented here, these effects have been removed by expressing the proportion of bark to wood as weight per unit surface area, and we feel that our data suggest that the treatments are decreasing bark thickness, bark density, or both.

We considered the possibility that because the treatments affect diameter growth, the classes could represent bolts from different heights. Within a given diameter class, the bolts from fertilized trees might be from higher, and thus younger, positions in the boles. However, the distribution of bolt heights within diameter classes was not affected by the fertilizer treatment, eliminating this possibility.

To relate change in bark weights to weight of wood delivered to the mill, we must calculate the change in bark weight of fresh bolts. The average water content of the bark was 124 percent (dry weight basis) and the average wet density of the wood was 1.02 Mg m^{-3}. Using figures for the 140-mm class from table 1, the wet bark weight for the no fertilizer, no woody plant control treatment is 16.0 percent of the total wet weight of the bolt, and the wet bark weight for the fertilized, woody plant control treatment is 13.6 percent of the total wet weight of the bolt.

This study demonstrates that fertilizer and woody plant control, in addition to increasing gross yield 27 percent by weight (Haywood and Tiarks 1990), increases the weight of wood per truck load by 2.8 percent. The waste bark pile would be 15 percent smaller. To verify these results, bark thickness, weight, and density should be measured intensively in other studies in which treatments such as fertilizer and competition control have been applied.

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Table 2. *Effect of fertilization and woody plant control on the weight of bark per unit volume of wood and per unit surface area of the bole. Effect of the treatments on volume of wood within diameter classes is shown for comparison.*

Treatment	n	Bark per unit bole volume ($kg\ m^{-3}$)	Bark per unit bole surface ($kg\ m^{-2}$)	Volume of wood per unit height ($m^3\ m^{-1}$)
			120-mm class	
No fertilizer No woody plant control	35	71.6a	2.14a	0.0112a
Fertilizer No woody plant control	24	63.9b	1.92b	0.0114a
No fertilizer Woody plant control	31	67.8a	2.03a	0.0113a
Fertilizer woody plant control	22	59.7b	1.82b	0.0117a
			140-mm class	
No fertilizer No woody plant control	37	72.9a	2.54a	0.0153a
Fertilizer No woody plant control	42	69.0b	2.39b	0.0151a
No fertilizer Woody plant control	31	69.2b	2.41b	0.0153a
Fertilizer woody plant control	38	62.0c	2.18c	0.0156a

Numbers in the same column and followed by the same letter are not significantly different ($p = 0.05$).