# PRODUCTION AND COSTS OF THE CHAMBERS DELIMBINATOR IN FIRST THINNING OF PINE PLANTATIONS

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ABSTRACT

Production and quality measures were collected and analyzed for a new chain-flail delimbing machine, Chambers Delimbinator, on two operations in central and southwestern Georgia. The first operation, Logger A, used two skidders and one loader while the second operation, Logger B, used two skidders and two loaders. Logger B with the lower cycle time and larger piece size produced an average of 57.4 tons per hour, while Logger A produced an average of 39.2 tons per hour. With defects defined as a branch greater than 1 inch in length and 1 inch in diameter, the Chambers Delimbinator produced similar delimbing quality for both logging operations with 5.7 defects per stem for Logger A and 7.0 defects per stem for Logger B. The Chambers Delimbinator is well suited to delimbing stems produced from first thinnings of loblolly pine (*Pinus taeda* L.) plantations.

Delimbing is an essential step in the conversion of standing trees to roundwood products. The objective is to remove limbs flush with the bole of the stem, leaving no protruding stubs, without breaking sections of the bole at the base of the limb. Delimbing quality standards are typically higher for sawlogs and veneer grade logs than for pulpwood. However, poor delimbing quality can potentially reduce the quality of chips produced by increasing the percentage of bark, fines, and oversized and undersized chips. Delimbing accounted for 30 percent of the cost of putting radiata pine on board trucks in New Zealand (2) while delimbing and bucking together accounted for 24 percent of on-board costs in Montana (3).

In the southern United States, the most popular delimbing method uses the delimbing gate (4). Grapple skidders back trees into this steel grid and the limbs are broken off as the stem is pushed into it top first. Gates are simple, inexpensive to purchase, require little or no maintenance, and effectively handle multiple stems. However, they often do not remove limbs flush with the bole of the stem, thus requiring that the job be finished with a chainsaw or another delimbing method. They often break the tops of small trees and delimbing quality suffers when the size of the tree is substantially smaller than the grid openings. With the young trees typically removed in first thinnings, limbs are often very flexible and are not as effectively broken by the gate as are more mature trees from other types of harvests.

Pull-through delimbing machines used in conjunction with log loaders are also now a common delimbing method in the South (4). These hydraulically operated devices utilize an inverted grapple with delimbing knives and a topping saw. The loader places stems in the grapple; the grapple arms (knives) are closed around the stem; the loader pulls the stem through the grapple, severing limbs as they strike the knives; and the topping saw is used to remove the unmerchantable top when delimbing reaches the desired top diameter. Most of these units have been purchased to supplement, not replace, delimbing gates. In many cases, they have eliminated the need for people on the ground with chainsaws to finish delimbing after gate delimbing. They are designed to delimb a single stem at a time and therefore their production plummets for the small-size wood removed in first thinnings. Multiple stems can be delimbed in these units, but delimbing quality quickly suffers since not all sides of each stem will be presented to the

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† Forest Products Society Member.

Forest Prod. J. 50(4):81-84.

delimbing knives. This is not as important with pulpwood-sized logs as it is for sawlogs and veneer grade logs.

Chain-flail delimbers first appeared as attachments to skidders or front-end loaders in the early 1970s (9). Stokes (5) studied a chain-flail in a 20-year-old loblolly pine plantation in Alabama and reported production of 3 cunits per hour of stem wood with an average of 2.56 limbs greater than 2 inches remaining on the stem after delimbing. Seventy-five percent of the stems measured had fewer than three limbs following processing. Folkema and Giguere (1) found that mobile chain-flail delimbers working with knuckleboom loaders at the roadside to be effective in Canada. Few chain-flail delimbers mounted on front-end loaders remain in use today. Most are used with difficult-to-delimb species such as sand pine and spruce.

Chain-flail delimbing is most commonly used today in conjunction with in-woods chipping. The majority of those in use in the southern United States are used in first thinnings of pine plantations. This allows production of pulp quality chips in the woods, larger and more uniform truck payloads, and efficient handling of small stems. In addition to removing limbs, bark removal is of similar quality to that expected from fixed installations. Bark content of 1 percent or less is possible when chipping pine and 3 percent or less can be obtained with hardwoods (8, IO). Production rates of 30 to 50 tons of stem wood per hour and annual production of 80,000 to 100,000 tons are common. In addition, fiber recovery is slightly better and far more material remains in the woods as residue. This aids nutrient cycling in the forest and minimizes the debarking residue at the manufacturing facility (7).

In 1997, a new type of chain-flail delimber was introduced to the market. The Chambers Delimbinator is a self-contained, towed, chain-flail delimbing unit that is used in conjunction with a log loader at a landing. It is designed to process 4 to 10 trees simultaneously depending on stem size. The stems are pulled by a loader through the front-side feed opening (27 in.) into the chamber, which has an 88-inch-length drum on the top and bottom. The drums are each rigged with 60 12-inch lengths of 5/8-inch hardened chain, which serve as the delimbers. Additional chain surrounds the entrance to the chamber to form a safety curtain. A remote-control unit operates the machine from the loader cab. The Delimbinator is powered by a 8.1-liter John Deere engine and weighs approximately 11 tons.

## Objectives

This study analyzed the performance of the Chambers Delimbinator in first thinnings of southern pine plantations. The objectives were to obtain a measure of the productivity and cost of this machine in typical plantation thinning applications and to begin to assess the quality of the delimbing obtained.

## Methods

The study selected two logging sites in central and southwestern Georgia. Both crews specialized in first commercial thinning of southern pine plantations. Additionally, both crews had a good reputation for their performance with 6 or more months of experience with the Chambers Delimbinator. No experimental design was used for this study due to lack of similar sites needed for replication.

The first logger studied (Logger A) was performing a first thinning in a stand of 15-year old loblolly pine (*Pinus taeda* L.) in Crawford County, Ga., owned by a large forest products company. The harvesting system employed fifth-row thinning, with trees between the rows selectively removed by the machine operator. The harvested trees were piled in the access corridor for removal with grapple skidders. During the study, this crew used two grapple skidders (one full-time and one intermittently) and one feller-buncher. When both skidders were in operation, one skidder would move the piled trees approximately halfway to the landing. The second skidder would then skid the trees the remaining distance to the loader. Once the trees were deposited on the landing, the loader would delimb the stems using the Delimbinator and either load them onto a trailer or add them to a pile of delimbed wood on the ground.

The second logger visited (Logger B) was working on a nonindustrial privately owned tract in Sumter County, Ga. This crew was performing a fifth row with operator selection first thinning of a 15-year-old loblolly pine stand. The stand had similar characteristics to those observed with Logger A, except each tree was more than twice the weight of those for Logger A. However, this crew used two feller-bunchers and two grapple skidders. Each skidder worked in conjunction with a feller-buncher and pulled piles of bunched wood directly to the landing. Additionally, Logger B used two loaders on the same landing. One loader processed the stems through the Delimbinator while the second loader handled all log loading and temporary storage duties.

Elemental time studies were conducted on each logging crew to determine productivity of the Delimbinator. The operating cycle of the loader using the delimber was divided into three primary components:

1. Swing to stems, grasp stems, swing and place on mouth of Delimbinator;
2. Process stems through Delimbinator;
3. Load pile or load truck.

Four additional elements that were only observed occasionally were also recorded:

1. Sort delimbed stems;
2. Pick up stems from delimbed pile;
3. Clean Delimbinator;
4. Clean limbed pile for delimbing.

The loader and Delimbinator of each crew were recorded continuously with a video camera to permit measurement of elapsed times after field data were collected. Some of the time elements just listed were not recorded for Logger B since that operation employed two loaders. Our study focused solely on the loader working with the delimber.

Similar techniques were used at both study sites. Trees that had been felled but not delimbed were skidded to a safe working location as close as possible to the landing. Each tree with an identifying number was then measured and butt diameter, diameter at breast height, height to first live limb, live crown ratio, limb size, number of limb whorls, merchantable height (2-in. top), and total height were recorded for each tree. Measurements were taken as close as possible to the loader to minimize breakage from additional skidding. Once the marked stems had been processed through the Delimbinator, the three measures of delimbing quality were: total length, top-end diameter inside bark, and number of defects. Defect was Considered to be a limb greater than 1 inch in diameter that protruded more than 1 inch away from the stem. Defects were a measure of delimbing quality.

The data were analyzed using graphical, correlation, and linear regression techniques to identify factors contributing to Delimbinator and loader productivity and the delimbing quality of processed stems. Where causality could not be established for dependent variables, simple statistical measures of location and variability were reported.

Cost per hour and per ton were estimated using cost data obtained from the logging contractors. Variable costs were estimated directly using data provided by the contractors. Fixed costs were estimated using the machine rate approach described by Miyata (5). Production records from the contractors were used to calculate costs per ton and to verify calculated production rates from our time 'studies.

## RESULTS

The mean cycle time for Logger A, who operated a single loader, was 1.16 minutes compared to 0.92 minutes per cycle for Logger B, who had a second loader that was dedicated to operating the dehmbinator (Table 1). The additional cycle time with the single loader operation was spent loading trucks or piling delimbed stems. These additional elements increased the cycle time variability for the single loader operation (49%) compared to the operation using two loaders (36%). Logger A, operating a single loader, handled 7.4 stems per cycle on average with a mean stem diameter at breast height (DBH) of 6.2 inches and a mean stem length of 39 feet. This resulted in an average cycle payload of 0.76 tons per cycle. By comparison, Logger B, operating hvo loaders, handled 3.8 stems per cycle. However, these stems averaged 7.8 inches DBH and 56 feet in length, giving an average cycle payload of 0.88 tons. The combination of larger pieces combined with a shorter cycle time resulted in the two-loader operation producing 57.4 tons per productive hour versus 39.2 tons for the single loader crew.

Several variables were examined to determine if they were useful in explaining cycle time. Of particular interest was the number of stems delimbed per cycle. Several transformations of this variable were explored but no form was found that explained a significant level of the observed variation in cycle time. Given the design of the machine and the method of delimbing, this was not unexpected.

*TABLE 1. — Summary statistics from studies of two logging crews using the Chambers Delimbinator in first thinnings of pine plantations, central Georgia, 1998.*

| Variable | Logger A | Logger B |
|---|---|---|
| No. of loaders | 1 | 2 |
| Cycles timed | 569 | 539 |
| Mean cycle time (min.) | 1.16 | 0.92 |
| Std. Dev. cycle time (min.) | a.57 | 0.33 |
| C.V. cycle time (%) | 49 | 36 |
| Stems per cycle | 7.4 | 3.8 |
| Mean stem DBH (in.) | 6.2 | 7.8 |
| Mean stem height (it.) | 39 | 56 |
| Mean stem weight (lb.) | 205 | 466 |
| Cycle payload (tons) | 0.76 | 0.ss |
| Cycles per prod. hour | 51.8 | 65.2 |
| Hourly production (tons) | 39.2 | 57.3 |

*TABLE 2. — Summary of the quality statistics from studies of two logging crews using the Chambers Delimbinator in first thinnings of pine plantations, central Georgia, 1998.*

| Variable | Logger A | Logger B |
|---|---|---|
| Average top diameter | 2.2 | 2.1 |
| Std. dev. top diameter | .74 | .86 |
| Average recoverable length (%) | so.5 | 84.5 |
| Std. dev. recoverable length (%) | 11.5 | 8.3 |
| Average no. of defects per stem | 5.3 | 7.0 |
| Std. dev. no. of defects per stem | 4.2 | 4.4 |

Both operations produced similar recoverable volume with a merchantable top diameter slightly greater than 2 inches (Table 2). Eoth loggers were able to recover more than 80 percent of the original length. Logger A recovered an average of 80.5 percent of the original length while Logger B with the larger trees recovered 84.5 percent of the original stem length. The average number of defects was similar in both operations with 5.3 defects per stem for Logger A who had the smaller trees. Logger B had more defects, with an average of 7.0 per stem, but had the larger trees.

The larger trees with their larger limbs required more effort to delimb and resulted in more limbs remaining following delimbing. DBH was the only variable measured that showed a significant correlation with the number of defects on a stem (Fig. I). The correlation coefficient ($r$) between DBH and number of defects was 37 percent for Logger A and 47 percent for Logger B. To improve delimbing quality, the stems could be kept in the delimbinator for a longer period of time. However, any quality improvement obtained would come at the expense of lowering production due IO a longer cycle time. Another approach might be to perfonn a rough sort of stems by DBH so that the stems within a given bundle would all be of approximately the same size. When stem sizes are mixed, small stems are effectively delimbed while larger stems with more and larger branches may be missed. Other factors not measured in this study should be examined in future studies. These include the number of logs being processed and the time that each stem or bundle spends in contact with the chains on the quality of delimbing. To adequately evaluate these and other factors, a designed experiment where these variables are controlled would be needed.

A purchase price of $79,500 with an assessed salvage value of 20 percent was used with an economic life of S years. Using straight-line depreciation and 2,000 scheduled machine hours (SMH) per year, this gave a depreciation cost estimate of $13,250 per year resulting in an estimated $6.36/SMH. Inter-

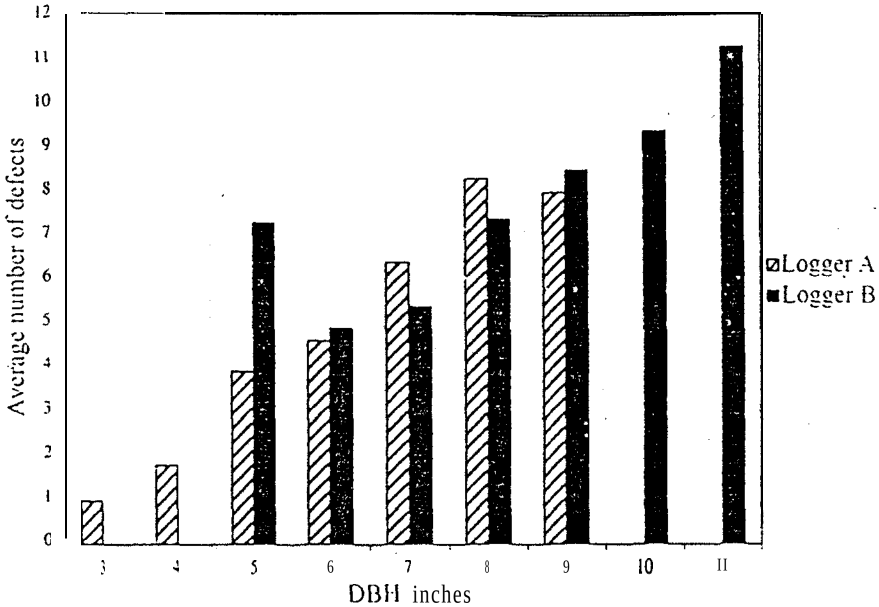


Figure 1. —Relationship between number of defects observed after delimbing with a Chambers Delimbinator and tree DBH on two pine thinning operations in central Georgia, 1998.

est, insurance, and taxes were assumed to total 10 percent of average annual investment and were calculated to be $2.70/SMH. Total fixed costs were estimated at $9.06 SMH. Operating (variable) costs included maintenance and repairs of $1.48 per productive machine hour (PMH), $2.12/PMH for fuel and lubricants, and $1.85/PMH for replacement of flail chains. Chains were assumed to cost $532 per set with an expected life of 400 truckloads or approximately 8 weeks. Total operating cost was estimated at $5.45/PMH. No additional labor is required since the Delimbinator is operated remotely by the loader operator. Using a utilization rate of 90 percent, this gives a total cost per hour for the machine of $15.52/PMH or $13.97/SMH.

Production varied with the two crews depending upon the tract of timber, distances to markets, and production quotas imposed due to market and inventory conditions. Observed production over the last quarter of 1998 and first quarter of 1999 ranged from under 1,000 to over 1,500 tons per week. A weekly production of 1,200 tons or approximately 48 truckloads per week was assumed. Five 8-hour days per week translates into a production of 30 tons/SMH. This is conservative compared to the estimate based on our time study. However, the time study results are based on productive hours, thus ignoring delays. In addition, the contractors do not consider market impacts such as quotas. Using 30 tons/SMH and total hourly costs of $13.97/SMH gives a per unit cost estimate of $0.47/ton.

## CONCLUSIONS

The Chambers Delimbinator is well suited as a delimbing technique for trees removed during first thinnings of pine plantations. The machine handles multiple stems easily and can produce high quality delimbed stems. It is also simple, reliable, and cost effective. Additional work should focus on how to improve the quality of delimbing and the consistency of delimbing quality.

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