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# A PILOT STUDY OF A PORTABLE WOOD CHIPPER

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AGRICULTURE - FOREST SERVICE - UPPER DARBY

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# OF A PORTABLE WOOD CHIPPER

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## INTRODUCTION

MUCH OF THE FOREST land in the Northeast--and a great deal of recently abandoned agricultural land--is growing a superabundance of wood fiber in low-value trees. In the forests this fiber can be seen as an excess number of small trees, particularly in young second-growth stands. On agricultural land it can be seen as low-quality woody growth that has become established through misuse of the land. Old-field stands of young and vigorous--but inferior--species such as gray birch, alder, and the like have become a familiar sight in many parts of the region.

Much of this surplus wood benefits neither the land it occupies nor its owners. Its removal is desirable. Early thinning of woodlots is needed to improve the growth and quality of the residual stands. In many places, old-field stands should be clear-cut to convert abandoned farm lands to a better use, either for agricultural use or for growing better tree species.

But both kinds of cutting can be costly. When land is cleared, all material cut must be disposed of. In forest thinnings, the cut material may create a fire hazard for some time if it is left on the ground. And, unfortunately, markets for sapling and pole-size trees are practically nonexistent.

However, there is a growing interest in the use of chipped wood. Chipped wood has long been essential to the pulp and paper industry; it goes into wallboard, roofing materials, and other products as well as paper.

Uses for it have also been found in agriculture. Sawdust and shavings are in demand in some places for bedding and litter for livestock and poultry. Use of chipped wood for mulch also offers possibilities. Orchardists and vegetable growers could use it to retain soil moisture and control unwanted competing growth.

As a soil-amender--broadcast on fields or plowed under, or first composted to speed up natural decay processes--it has a great potential usefulness. It could play a large part in restoring the now deficient organic content of many of our soils. There is also some prospect of its use as a mulch for stabilizing the banks of cuts and fills in road construction. Of course some of these uses are still in the experimental stage.

Another possible use for chipped wood is fuel. Wood chips offer a readily available source of heat. They are already being used in the manufacture of charcoal briquets.

Here, then, is where the recently developed portable wood chipper holds promise of completing the utilization picture. When land is cleared or forest stands are thinned, the portable chipper can be brought in to reduce the cut material to chips. The chips can be scattered on the ground and thus disposed of. Or, with little additional handling, they may be put to some more profitable use.

Organized markets for wood chips have not yet been developed. When they are, the wood chipper can become the key to profitable returns from forest thinnings and land clearing.

Since the portable wood chipper is a fairly new kind of machine, many questions about its operation remain to be answered. To evaluate the worth of this kind of equipment, time and cost studies were made in Connecticut late in 1949, using a standard factory model of one kind of chipper. The findings are contained in this report.

The chipping operations were carried on in conjunction with studies of thinning and clearing operations. The authors will provide information about them on request.

## THE CHIPPER AND ITS OPERATION

THE CHIPPER USED in the study was developed primarily for disposing of brush and orchard prunings, which customarily were burned or lopped and scattered--often a costly

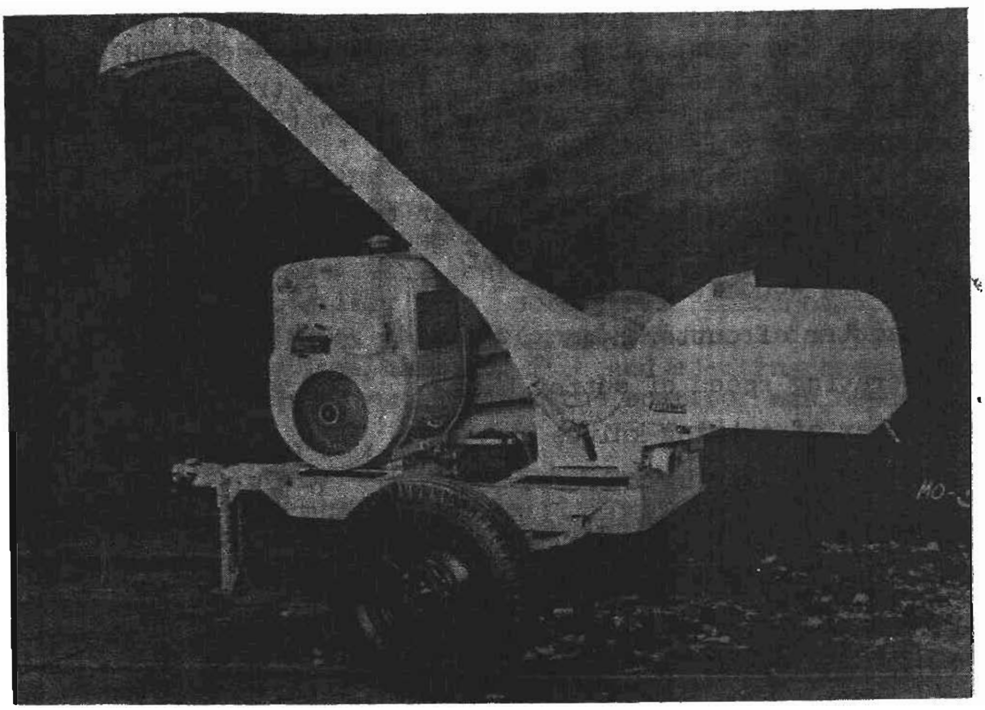

Figure 1.--The wood chipper used in the study. Besides the long delivery chute shown here, a short side-delivery chute was also used.

job. The portable chipper proved convenient and economical for this job, but it appeared that this failed to capitalize on its full potentialities, because the material it produced seemed suitable for further use. Therefore the study was predicated on utilizing the chips rather than merely on investigating another way to dispose of waste wood.

Mounted on a 2-wheel, rubber-tired trailer, the chipper was powered with a 4-cylinder, air-cooled engine. The cutting was done by a drum-type cutter head, a rotating cylinder from which four cutting knives projected. (Most other wood chippers employ a disk-type cutter head in which the knives project from the face of a flat, rotating disk.) The advantage claimed for the drum-type cutter head is that it does not need a blower to eject the chips. This not only results in economy for the purchaser; it also requires less power for the same production capacity.

Two kinds of discharge chutes were supplied with the machine. One was a long chute, projecting forward so it could discharge the chips directly into the truck that towed the chipper. The other was a short elbow (90 degrees) that discharged the chips to the right side.

Specifications of the chipper tested are as follows:

| | | |
|---|---|---|
| 1. | Maximum capacity: diameter of round wood it can chip . . . | 4½ inches |
| 2. | Diameter of cutter head . . . | 9½ inches |
| 3. | Operating speed of cutter head . | 2,200-2,500 r.p.m. |
| 4. | Number of cutting knives . . . | 4 |
| 5. | Length of cutting knives . . . | 6-3/8 inches |
| 6. | Maximum knife setting . . . | 1/4 inch |
| 7. | Minimum knife setting . . . | 1/16 inch |
| 8. | Average power requirement . . | 30-35 hp. |
| 9. | Approximate weight, chipper only . | 415 pounds |
| 10. | Total weight, chipper and power unit, mounted on trailer . . | 1,950 pounds |

Operation of the chipper was rather simple. The engine, which is equipped with a self-starter, was governed

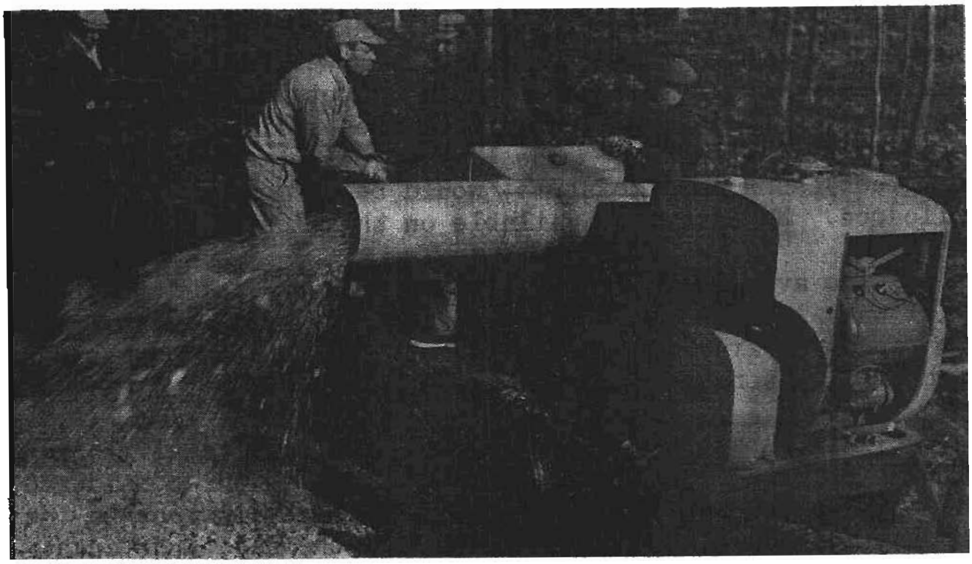

Figure 2.--The chipper in operation. Easy to operate, it produced an average of more than 1½ tons of chips per hour.

for the proper chipping speed: about 2,500 r.p.m. To feed the wood in, the operator stood slightly to one side of the feed apron and, holding the wood horizontally, merely moved it in until it came into contact with the cutting knives. These knives, rotating at a peripheral speed of 5,500 to 6,500 feet per minute, then performed the three functions of drawing the wood in, chipping it, and ejecting the chips. Usually no further attention from the operator was needed.

## PRODUCTIVE CAPACITY

THE TOTAL VOLUME of chips produced, 6,373 cubic feet, was determined by measuring the cubic capacity of the trucks in which the chips were loaded. Of the total volume produced, slightly more than 30 percent was weighted to establish volume-weight relationships.

The volume and weight production data are expressed in terms of green, unshaken chips. There would probably be some reduction in the volume of a truckload of chips after they had been hauled some distance. However, inspection of several 200-cubic-foot loads hauled about 10 miles, partly over unpaved roads, indicated that the shrinkage in volume was barely discernible. The loss of weight that occurs as the green chips lose moisture would be of much greater significance. No data are available on this loss.

The average hourly output of chips for the entire trial was 1.64 tons per hour--approximately 194 cubic feet. The range was from an average low of 1.37 tons to an average high of 2.01 tons per hour.

This output was figured on the basis of total <u>elapsed time</u>. Elapsed time for any one working day was considered the interval between starting the chipping operations in the morning and shutting down at the end of the day, not counting time taken for lunch and rest periods. The total elapsed time in the chipping study was approximately 33 hours.

<u>Productive time</u> was the period when the chipper was running at operating speed and the crew were feeding wood in or were picking wood up and carrying it to the chipper.

<u>Nonproductive time</u> included only those periods when the chipper was shut down because of machine failure, moving the chipper, refueling, and caring for the cutting knives. To operate the chipper efficiently on a large job, it probably would have been necessary to have one man spend an additional hour daily on maintaining the machine. This is not included in nonproductive time; it is considered an element of normal operating cost.

Time records were kept to the nearest minute. For the entire trial, the breakdown is as follows:

| | Minutes | Percent |
|---|---|---|
| Elapsed time | 1,969 | 100.0 |
| Productive time | 1,620 | 82.2 |
| Nonproductive time | 349 | 17.8 |

A breakdown of the nonproductive time is shown in table 1. Some lost time was also caused by plugging of the delivery chutes, due to poor design or a drop in power.

Table 1.--Elements of nonproductive time

| Cause | Shutdowns | Nonproductive time[1] | |
|---|---|---|---|
| | Number | Minutes | Percent |
| Moving chipper | 21 | 128 | 6.5 |
| Sharpening knives | 4 | 92 | 4.7 |
| Refueling | 3 | 11 | .6 |
| Feed-plate retractor spring off | 10 | 26 | 1.3 |
| Feed-plate retractor spring broken | 4 | 14 | .7 |
| Chip caught under feed plate | 5 | 6 | .3 |
| Miscellaneous | 5 | 72 | 3.7 |
| Total | 52 | 349 | 17.8 |

[1] Percentage is based on total elapsed operating time, 1,969 minutes.

Since this fault in the machine can be corrected, the time lost was not included in nonproductive time.

Several variables seemed to affect production. These factors, which appear to be inherent in any chipping operation, included the following: Knife setting, size of raw material, size of chip produced, species of wood chipped, size of operating crew, efficiency of crew, method of piling the wood in preparation for chipping, and weather and ground conditions.

## Knife setting

The production rates indicate that knife setting has considerable influence on the output of chips: the coarser the setting, the greater the output (table 2). The volume production rate varied in about the same ratio as chip thickness, which in turn depends on knife setting.

The weight of chips per cubic foot is also influenced by knife setting. The coarse--i.e., thicker--chips averaged 1 pound heavier, 6 percent more per cubic foot than the fine chips.

These data are from approximately 90 percent of the total elapsed operating time. For both knife settings tested, there was a fairly uniform distribution of species, sizes, and type of material--i.e., limbed and unlimbed trees--that was chipped.

Table 2.--Effect of knife setting on production

| Knife setting (inches) | Production per elapsed hour | | Chip weight per cubic foot | Total volume of chips produced[1] | |
|---|---|---|---|---|---|
| | Cubic feet | Tons | Pounds | Cubic feet | Percent |
| 3/32 | 165.5 | 1.37 | 16.6 | 2,641.0 | 41.4 |
| 1/8 | 228.5 | 2.01 | 17.6 | 3,340.5 | 52.4 |

[1] Percentage is based on total production of study, 6,373 cubic feet.

## Size of wood chipped

Diameter.--To test the effect of the size of wood on production, unlimbed hardwood saplings were graded into piles of 1-, 2-, 3-, and 4-inch diameter classes, measured at breast height. Chipping times were related to the cubic volume of chips produced from each class. The knife setting was constant--3/32 inch--and the species distribution was fairly uniform.

Data on the effect of size of wood chipped were based on a yield of 10.3 percent of the total volume of chips produced in the study. From this sampling, it appeared the chipper was most effective in the middle diameters: 2- and 3-inch material (table 3).

Length.--The effect of length of material was evaluated only through observation. When comparatively short wood--only 5 or 6 feet long--was chipped, it was often drawn into the chipper before another piece could be fed in, and some loss of production time resulted. But when wood was fed in constantly, which is possible with longer material, there was little loss in production time. However, some time was lost in chipping the longest and heaviest pieces, because they were difficult to maneuver into the chipper.

Table 3.--Effect of size of material on production

| Size of material | | Production per elapsed hour | | Chip weight per cubic foot | Total volume of chips produced | |
|---|---|---|---|---|---|---|
| Diameter (inches) | Length (feet) | | | | | |
| | | Cubic feet | Tons | Pounds | Cubic feet | Percent |
| 1 | 15 | 190.0 | 1.66 | 17.5 | 169.2 | 2.7 |
| 2 | 20 | 236.0 | 2.07 | 17.5 | 240.1 | 3.8 |
| 3 | 25 | 204.0 | 1.79 | 17.5 | 174.5 | 2.7 |
| 4 | 30 | 155.0 | 1.36 | 17.5 | 69.3 | 1.1 |

The low production rate with the 4-inch material is partly a reflection of this; but mostly it is due to the fact that hardwood material of this size seldom fed itself into the chipper automatically. The operator usually had to push the wood in by hand and re-engage it with the cutter several times until the larger part was chipped off. This difficulty became more apparent as the knives lost their keenness.

In chipping this relatively large material, the crew found it was apparently best to feed it in small end first. The production rate was better this way, because the chipper usually drew the wood in automatically until its diameter capacity was reached; then the leftover bolt of wood was discarded. Obviously the trees had to be limbed before they could be chipped this way--regardless of type of chip produced. However, this method did present a hazard: there was danger that the branch stubs might scratch the operator or catch on his clothing and pull him toward the chipper. No accidents occurred, but one man lost a glove.

## Type of chip produced

Two different types of chips were produced: fairly large chips suitable for use as mulch and similar uses, and finer fragments such as could be used for cattle bedding.

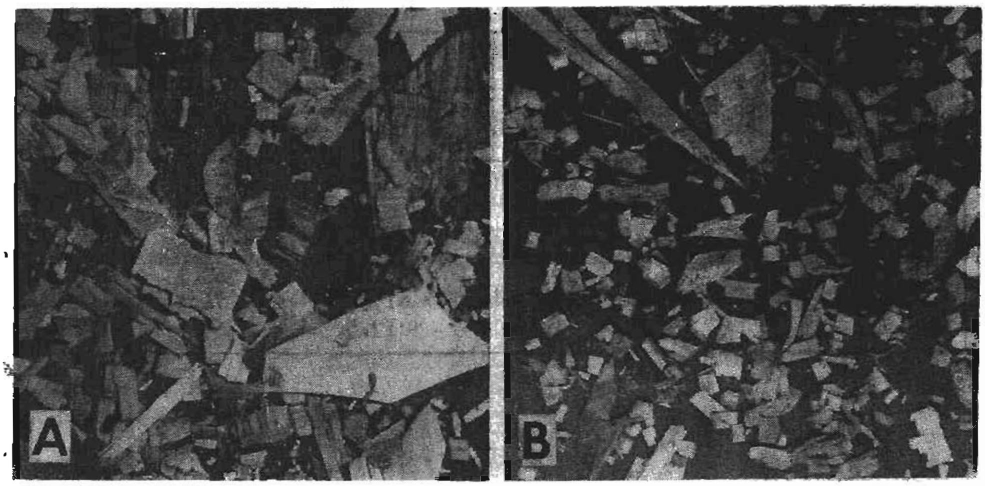


Figure 3.--The two kinds of chips produced. A larger chips, suitable for mulch. B, finer chips, produced by using toothed knives. These are considered rather coarse for good bedding, but probably could be used. The chips are shown here approximately one-half actual size.

The type of chip to be produced determined whether the material should be limbed. Chips from unlimbed trees contain twiggy material, some of it several inches long. This almost splinter-like stuff would certainly be undesirable in cattle bedding, and probably in any pulping process. Chips intended for these uses should be produced from limbed polewood, free of slender branches and twigs. For other uses, however, such as mulch and soil amenders, the presence of twiggy material may be beneficial.

The larger chips were produced by using four straight knives in the cutter head. Two settings were used: 1/8 inch and 3/32 inch.

For producing chips that could be used for cattle bedding, a set of two serrated knives was provided. These had the same dimensions as the straight knives, but the cutting edges were milled into a series of teeth 3/16 inch square. These two toothed knives were mounted in the cutter head alternately with two straight knives, the toothed knives set higher. The toothed knives were set at 1/8 inch, the straight knives at 3/32 inch, although other combinations are possible. In action, each toothed knife rakes a series of narrow strips from the wood and the straight knife behind it planes off most of the ridges that are left.

Unfortunately, through defect in design or manufacture, or by overloading this type of knife, several teeth were broken off after less than 2 hours' operation, precluding any further use of these knives. Therefore production data with the toothed knives is limited. Production results are shown in table 4.

Table 4.--Effect of type of chip on production

| Type of chip | Knife setting | Production per elapsed hour | | Chip weight per cubic foot | Total volume of chips produced[1] | |
|---|---|---|---|---|---|---|
| | Inches | Cubic feet | Tons | Pounds | Cubic feet | Percent |
| Bedding | 3/32 x 1/8 | 173.0 | 1.37 | 15.9 | 392.0 | 6.2 |
| Mulch | 1/8 | 220.0 | 1.93 | 17.6 | 3,607.5 | 56.6 |
| Mulch | 3/32 | 159.0 | 1.32 | 16.5 | 1,130.4 | 17.8 |

[1] Percentage is based on total production of study, 6,373 cubic feet.

In theory, it would seem that the use of toothed knives would markedly cut down the production rate; but it did not. This is accounted for in part by the fact that wood chipped by the toothed knives expanded more than wood chipped with straight knives. Oak chips produced with 1/8-inch straight-knife setting weighed 20.0 pounds per cubic foot; oak chips produced with toothed knives weighed

18.2 pounds per cubic foot. Comparable weights of red maple chips were 16.5 pounds and 13.6 pounds.

When the toothed knives were used, the chipping operation seemed much smoother than the rather violent action evident when only straight knives were used. Besides, larger pieces of wood did not appreciably slow down the speed of the cutter head; so chips were produced at a fairly uniform rate. This, plus the greater bulk of the rather fluffy chips, evidently compensated for the theoretical loss in production due to use of toothed knives.

## Species chipped

A limited test was made of the effect of species on production rate. Four species were chipped: Red maple, red oak, scarlet oak, and white oak. The wood was limbed, and other controllable variables were eliminated. Approximately 15.6 percent of the total volume produced was chipped in this test of the effect of species.

Table 5.--Effect of species on production

| Species | Production per elapsed hour | | Chip weight per cubic foot | Total volume of chips produced[1] | |
|---|---|---|---|---|---|
| | Cubic feet | Tons | Pounds | Cubic feet | Percent |
| Red maple | 195.0 | 1.46 | 14.9 | 456.2 | 7.2 |
| Oaks | 193.5 | 1.83 | 19.0 | 534.4 | 8.4 |

[1] Percentage is based on total production of study, 6,373 cubic feet.

The results (table 5) indicate that the species factor may be unimportant with respect to volume production of chips, regardless of physical differences among woods; the chipper had enough power to overcome such differences. Of course there is significant difference in specific gravity between red maple and the oaks. This accounts for the greater weight of the oak chips produced.

## Size of crew

When the chips were being ejected into the bed of a truck, a 3-man crew was found to be best. One man had to be in the truck at nearly all times to level off the load as it built up. Two men were needed to feed the chipper. They were usually able to keep it supplied continually at a rate that could be kept up throughout a working day.

Figure 4.--Chipping unlimbed brush directly into a truck. Notice the piles of brush along the road. A 3-man crew was found to be most efficient.

It was found that with three men feeding the chipper, one was idle part of the time awaiting his turn to feed in the wood. They simply got in one another's way.

## Efficiency of crew

Much of the time the 3-man crew consisted of the writers and one assistant, none of whom had any but a very brief previous experience with wood chippers.

Although feeding the chipper is a simple matter, a few days' experience developed certain useful knacks that made possible a steadier output of chips. For example, we found that pole wood could be fed in either end first; so there was no need for turning pieces end for end if they were reversed in the piles. Likewise, in feeding in small brush, we soon found that the whiplike slender branches could whip about and inflict a painful blow as the brush was drawn into the chipper. Some means of protecting the eyes should be provided when chipping brush.

The crew naturally became more efficient as the study progressed. As they gained experience there were fewer and shorter delays in feeding the chipper, and the production of chips became more uniform throughout the day.

## Method of piling wood

Four different methods of piling the wood to be chipped were used, as follows:

1. In windrows along access road, butt ends together, material oriented at 45-degree angle to access road.
2. In piles, at 45 degrees to access road.
3. In piles, at right angles to access road.
4. In piles, parallel to access road.

The unlimbed material was piled with the butts all pointing the same way. Limbed material would go through the chipper either end first; so limbed poles were piled without regard to which way the butts pointed.

There was less lost motion when the wood piles pointed directly at the feed opening of the chipper. Therefore, the position of the chipper in the road determines whether the piles should be at right angles to the road or in some other position. The position of the chipper depended largely on which delivery chute was used and how the chips were being disposed of.

Actually, careful piling of the material was more important than the orientation of the pile. Many times the chipper was without wood for periods of perhaps 20 seconds while the feeding crew wrestled with a stick to free it from the pile. Careful piling would minimize this source of lost time considerably.

In theory, having the wood available from both sides of the road would be the most convenient for the chipper operators. Each man could then draw wood from a separate pile without interfering with the other.

It was found important to have a clear working space between the pile of wood and the chipper. The space should be at least equal to the length of the longest piece of wood in the pile.

Although care and method of piling are important to achieving maximum production efficiency, they are not critical factors. Compared to knife setting and size of wood, their significance is negligible.

## Weather and ground conditions

A record of general weather conditions--precipitation, average temperature, and the like--was kept for each working day. It was a minor factor in affecting production. As in other out-door work, the general effect of inclement weather was to slow operations by making the work harder and more hazardous.

# COST OF CHIPPING

THE COST OF OPERATING the chipping machine was calculated at $4.04 per hour, elapsed time. This was based on the labor and machine costs tabulated below:

| | |
|---|---|
| Labor: 3 man-hours at $1.00 . . . . . . . . . | $3.00 |
| Machine costs: | |
| Operation--Gasoline, 3 gallons at 20 cents . | .60 |
| Oil . . . . . . . . . . . . . . | .02 |
| Maintenance--Grinding knives . . . . . . . . | .05 |
| Power unit and trailer . . . . . | .05 |
| Miscellaneous[1] . . . . . . . . | .14 |
| Depreciation--Chipper, $780 in 120 months . . | .04 |
| Knives, $70 in 24 months . . . . | .02 |
| Power unit and trailer, $1,100 in 60 months . . . . . | .12 |
| Total | $4.04 |

From this hourly cost of operation, the unit cost of chipping can be calculated readily as--

$$\frac{\text{Hourly chipping cost}}{\text{Units produced per elapsed hour}} = \text{Cost per unit.}$$

The costs of producing chips are shown in table 6. The data used appear in the preceding tables.

# DISCUSSION

THE WOOD CHIPPER tested was designed primarily as a brush-disposal machine. As such, it probably is a useful piece of equipment for disposing of brush.

[1] INCLUDES ESTIMATED TIME FOR CHANGING AND STONING KNIVES, ADDING FUEL, AND OTHER MAINTENANCE, OUTSIDE OPERATING PERIODS.

Table 6.--Approximate cost of producing chipped wood, loaded in trucks at chipping site

| Type of chip | Knife setting used | Cost per 100 cubic feet woods run | Cost per ton, green | | |
|---|---|---|---|---|---|
| | | | Woods run | Oaks | Maple |
| | Inches | | | | |
| Bedding | 3/32 x 1/8 | $2.33 | $2.93 | $2.56 | $3.43 |
| Mulch | 1/8 | 1.77 | 2.01 | 1.77 | 2.15 |
| Mulch | 3/32 | 2.45 | 2.95 | 2.58 | 3.29 |

However, as new markets for wood chips develop, there will be new possibilities of extending the use of such light, portable chippers beyond that of mere brush disposal. Within the limit of their productive capacity and the limited size of material they can chip, such machines can manufacture chips suitable for several uses, present and proposed.

From the forester's viewpoint, however, a chipper of the size tested is unable to utilize much of the forest waste that still must remain a liability in stands older than those cut in this study. This waste is in the excess low-grade material larger than the chipper can handle, up to the minimum low-grade small sawlog of 8 or 9 inches--wood that formerly supplied the now limited fuel market. It is possible to build larger chippers to utilize this material, but as the size increases so do the costs, and the feature of mobility tends to decrease.

Yet there are many young stands--at a critical age with respect to their future growth and composition--in which much or all the thinned material is within the small chipper's capacity. In managing these stands the small portable chipper could be a very useful tool.

It was observed that the chips produced in this study of the drum chipper did lack uniformity in all dimensions at any knife setting. This condition appears to be characteristic of chips produced by any manually fed drum-type chipper with horizontal intake. A more serious factor, and one inherent in chipping small round wood with any type of chipper, is the presence of bark, which, at least for most chips used for pulp, is rather undesirable. The bark is difficult to separate from the solid wood.

Farmers who have viewed the finest material this chipper could produce feel that it is still too coarse to make good bedding. But, they said, it probably could be used if other litter were not available.

This is one fault that can be overcome. Six-knife machines are being developed that will be able to produce good bedding chips. Changes in the knives of the chipper tested may also gain this end. Since the study was made, using square-toothed knives, the manufacturer has improved the design of the serrated knife. The new knife is fluted instead of square-cut; this gives the teeth more strength.

Another factor that farmers are interested in is the ability of the bedding to pick up moisture. It is possible that green chips cannot do this as well as dry chips. This could be overcome by chipping only air-dry wood, or by drying the chips. Artificial drying, however, would increase the cost and might not be practical.

The wood chips produced by this portable drum-type chipper appear satisfactory for most other uses such as mulch, soil amendment, and fuel. In general, this equipment, in its present state of development, has encouraging possibilities in both forestry and agriculture when the following conditions exist:

1. The wood to be chipped is easily accessible and of small diameter.
2. Chip quality is not important with respect to size, uniformity, or presence of bark.
3. A small initial investment and a low daily operating cost are desirable.