

OPERATIONAL TRIALS OF TECHNIQUES  
TO IMPROVE JACK PINE SPACING

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INFORMATION REPORT O-X-180

CANADIAN FORESTRY SERVICE  
DEPARTMENT OF THE ENVIRONMENT  
JANUARY 1973

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#### ACKNOWLEDGMENTS

The author wishes to acknowledge the fine efforts and able assistance of F.F. Foreman, Forestry Technician, in the conduct of the field work and the preparation of this report. The valuable advice provided by Dr. T.L. Tucker, Forest Economist, is also greatly appreciated.

## ABSTRACT

Operational trials were carried out to determine both the best stage in stand development for conducting spacing treatments and the most efficient method of achieving desirable spacing in young jack pine [*Pinus banksiana* Lamb. (= *P. divaricata* [Ait.] Dumont)] stands. The trials were conducted in three age classes (9, 22, and 33 years) and two methods of treatment were tested in each. Time-motion studies were made to determine the factors affecting productivity and to indicate possible improvements in techniques. Cost comparisons were made between treatments, and for each age class benefit/cost calculations were employed to indicate the state at which spacing operations can be expected to yield the greatest net returns.

The actual cost of spacing was lowest in the 9-year age class, and in spite of the longer time to harvest, the calculated benefit/cost ratio was highest for this class. In the 9-year age class treatment was more efficient with powered brushsaws than with Sandvik axes; in the 22-year age class chainsaws were more efficient than axes; and in the 33-year-old stand, treatment with hypo-hatchets was more efficient than felling with hand tools.

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## INTRODUCTION

To achieve their maximum rate of merchantable volume growth, stands must develop at optimum density.<sup>1</sup> At this density individual stems will develop at their maximum rate, the rotation will be as short as possible, and a tendency toward minimization of harvesting costs will result, with obvious benefits to both the forest manager and the industry.

In view of the rising world demand for wood fiber and the gradual withdrawal of forest areas from wood production across the country, pressure for maximum rates of merchantable volume growth can be anticipated in Canada and other major wood-producing nations. Thus, although density control is not yet widely practised in Canada, it is necessary to recognize those conditions under which it would be feasible, and to develop efficient techniques for achieving it.

In Ontario, the Boreal Forest Region (Rowe 1959) contains extensive stands of young jack pine [*Pinus banksiana* Lamb. (= *P. divaricata* [Ait.] Dumont)], most of which originated naturally after wildfire. Although continuing improvement in fire protection is reducing the size of wildfires, large tracts are now being regenerated artificially by scarification and direct seeding, or by scarification over slash, and the use of these techniques is increasing because of their effectiveness, low cost and ease of application. Understandably, initial stand density is impossible to control in wildfire stands, and it is extremely difficult to control in stands created by the other two techniques. Consequently, unsatisfactory stand density will continue to be a problem.

Previous research provides guidelines for optimum densities in jack pine stands of varying ages, and indicates the silvicultural benefits to be gained by growing stands at these densities (Cayford *et al.* 1967; Staebler 1965). Ideally, proper spacing will be achieved early in the life of a stand (Smith 1967; Burch 1967), but Osborn (1968) notes that "the timing of spacing control must be a compromise between economic and biological factors".

In this study, there were two main objectives: (1) to determine at what stage in the development of a jack pine stand spacing operations can be carried out most economically and (2) to determine the most efficient techniques for treating stands of various ages. For this purpose, a series of trials of spacing techniques was initiated in jack pine stands of different ages and densities.

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<sup>1</sup> For the purpose of this paper, the somewhat theoretical concept of "optimum density" is defined as the minimum number of stems required to utilize the full growth potential of the site.



In order to cover the full range of common conditions, the project includes the beating up of understocked regeneration, precommercial thinning in three age classes, and commercial thinning in stands approaching maturity. However, as work on the first and last conditions is still in progress, this report covers only the trials of precommercial thinning techniques.

## THE STANDS

To make a selection of stands for treatment, several combinations of age, density and stocking were chosen to cover the range of conditions which can normally be expected to occur in a developing forest, and within which treatment is necessary. Preliminary selections were made from inventory data for the districts of White River, Chapleau, and Sudbury, and final choices were based on field sampling.

All sites are typical for jack pine, and are gently rolling, well-drained sand plains of Site Class 2 (Plonski 1960). Further details regarding site and stand conditions are given in Tables 1 and 2, respectively.

## TOOLS AND TECHNIQUES

There is a wide range of small equipment on the market which can be used for the reduction of growing stock. To assess the performance of some of the available tools, a series of small-scale trials was conducted in 1969 by staff of the Great Lakes Forest Research Centre in the stands of Age Classes I and III.

In 1970 operational trials were carried out under piecework contract. The workers were typical of those that forest managers might be expected to hire for the kind of work being done. Piecework rates were set so as to promote maximum productivity. The work in Age Classes I and III was undertaken by untrained general laborers, whereas the treatment of Age Class II was by skilled cutters, experienced in the use of power saws.

A suitable density (or spacing) level was selected for each age class using the research information available. While no claim is made that these are optimal, the selected levels were 1210 trees per acre (6-foot x 6-foot spacing) for Age Class I and 682 trees per acre (8-foot x 8-foot spacing) for Age Classes II and III.

Tools used in the treatments are illustrated in Figures 1 and 2.

Table 1. Site descriptions

Age class	Location	District	Forest section <sup>1</sup>	Site class <sup>2</sup>	Moisture regime <sup>3</sup>	Soil
I ( 9 yr)	Benneweis Twp	Sudbury	B7	2 (est.)	1	Medium sand
II (22 yr)	Panet Twp	Chapleau	B7	2	2	Fine sand
III (33 yr)	Mickey Creek	White River	B8/9	2	2	Fine sand

<sup>1</sup> Rowe (1959)

<sup>2</sup> Plonski (1960)

<sup>3</sup> After Hills (1952)

Table 2. Stand descriptions (before treatment)

Age class	Age (years)	Stocking (percent)	Density (trees/acre)	Diameter range (inches)	Avg. diameter (inches)	Avg. height (feet)	Stand origin
I	9	88 <sup>1</sup>	5330	<1-3	1	6	scarification and aerial seeding
II	22	96 <sup>2</sup>	4220	1-5	2	19	wildfire
III	33	96 <sup>2</sup>	2250	1-6	3	32	wildfire

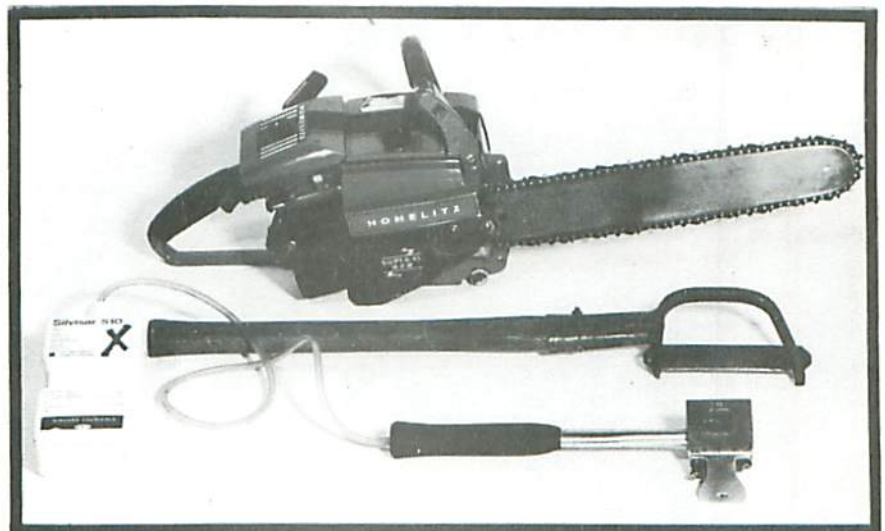
<sup>1</sup> Percent of mil-acre quadrats having at least one tree.

<sup>2</sup> Percent of 1/640-acre quadrats having at least one tree.





*Fig. 1 A brushsaw used in the treatment of Age Class I.*



*Fig. 2 Equipment of the types used in treatment of stands described in this report.*

*Age Class I*

In this age class, two types of equipment were tested, hand tools and brushsaws, both of which are considered to be effective only on small trees (i.e., those up to about 2 inches in diameter at the point of severance). Because of their obvious inefficiency, some of the hand tools (e.g., pruning shears, axes) were not formally tested. Others, such as the Sandvik axe, Woodsman's Pal and Jim Gem axe, were used at the discretion of the individual, but in practice, the Sandvik axe was preferred, and most of the hand cutting was carried out with this tool.

With hand tools, most trees were cut about 1 foot above ground level, the object being to cut below the lowest whorl of living branches. This was considered necessary because live branches remaining on a stump can be expected to turn up and quickly develop into new leaders (Fig. 3). It was evident from the results of preliminary trials that care is required in the timing of thinning operations in young stands. A 7-year-old stand, thinned at the same time as the Benneweis area, had regrown into a dense stand within 2 years of treatment because living lower whorls were growing too close to the ground for easy treatment and were left uncut in most cases. They continued to grow and quickly formed new main stems. Within 3 years it had become difficult, through casual observation, to distinguish these from the stems of the original stand.



*Fig. 3 A cut tree with a living whorl remaining, typical of the condition which will result in a cluster of new stems.*



Because of the disorientation that occurred with repeated bending and standing, no clear pattern of cutting was established. Thinning progressed as regularly as possible, each cutter making his own selection of crop trees.

The three brushsaws used in these trials each had a 10-inch circular blade mounted on a 4-foot shaft and were powered by a 4.5-h.p. gasoline engine. Trees were cut as close to the ground as possible without digging into the soil with the saw blade.

A 6-foot-wide guide swath was first cleared around the perimeter of each trial block of trees. An efficient technique was soon developed in which the operator walked along the uncut edge of the stand in a clockwise direction choosing trees to be left at 6-foot intervals along that edge. At the same time the brushsaw was used in a swathing manner to clear all trees for a distance of 6 feet into the stand. Using this method in a concentric pattern around the block ensured systematic coverage and eliminated time loss due to wandering or uncertainty about tree selection. The trees to be left were rapidly and arbitrarily chosen as the operator moved along, selecting while he cut. The 6-foot swath into the stand could be made rather indiscriminately, since the individual trees to be left on the next round would be found along the uncut edge. Only where density was low or trees of unusual quality were found was it necessary to vary this pattern.

Little difficulty was encountered in the actual cutting, since trees up to 1½ inches in diameter offered little resistance, and could be felled with a scything motion. Even the few trees as large as 3 inches could be handled quite easily, but in these instances it was necessary to concentrate on the individual tree. Several problems were encountered with respect to the equipment itself, the most serious of which occurred in the gear box of the cutting head where the splined end of one of the drive shafts became stripped after only 25 hours of operation. This completely incapacitated the machine. An inspection of the other two machines, after approximately 16 hours of operation on each, showed that it would be only a matter of a few running hours before they would experience a similar breakdown. It is felt, however, that this weakness, along with one or two other minor ones, could be easily corrected by the manufacturer so as to produce a dependable machine which would operate well in this size class of tree.

### *Age Class II*

In this age class average tree size was generally too large for the brushsaw, and chainsaws appeared to be the only feasible alternative to hand cutting. Accordingly, hand cutting (with Sandvik axes) was tested against cutting with chainsaws. With both types of equipment, work was carried out in a concentric pattern and, since low branches

were absent, trees could be cut at a comfortable level (1-2 feet) with no danger of new leaders developing from residual branches. The concentric pattern proved efficient, as it provided a partially cleared area into which the trees could be felled. Some light pruning was carried out to facilitate the thinning operation.

### *Age Class III*

As average diameter at breast height (dbh) was more than 3 inches, it was obvious that felling with hand tools would be inefficient in this age class. Nevertheless, for comparison purposes some hand thinning was carried out with Sandvik axes, but the principal technique was a silvicide treatment in which Silvistar (cacodylic acid) was injected with hypo-hatchets.

In the hand-thinning operation, the unskilled laborers made their own choice of trees to be cut and left, aiming at a residual stand spacing of about 8 feet x 8 feet. Owing to the cutters' lack of experience, tree selection was not entirely satisfactory and there was no clear pattern of cutting. Progress was very slow and this trial was terminated after 5 acres had been thinned.

The high density of the stand (2250 trees/acre) necessitated the establishment of a ground-control system prior to the hypo-hatchet treatment. The control consisted in stringing the area in strips about 20-30 feet wide and paint-marking the trees to be left (at about 8-foot spacing). Treatment was carried out on a strip-by-strip basis, and consisted simply in striking each tree one or more slanting blows with the hypo-hatchet, each blow resulting in the injection of about 1.5 mils of silvicide. One stroke of the hatchet was considered sufficient to kill stems up to 3 inches dbh whereas larger trees received two strokes. Trees less than about 1½ inches in diameter were generally ignored since their meager crowns were below the main canopy, and it was thought that they would not seriously impede the growth of the residual crop trees. In any event, it was difficult to treat these small stems with the hypo-hatchet, because they offered insufficient resistance to cause injection of the silvicide.

### TIME-MOTION STUDY

For the particular stand conditions included in the trials, the relative efficiency of the various treatments could have been determined simply by recording gross operating times and costs of equipment and supplies. However, it was decided that a more detailed breakdown should be obtained, showing the time required for each of



several elements in a specified treatment. It is hoped that this will increase the value of the study by providing sufficient data to enable the forest manager to estimate the cost of treatment for a broader range of stand conditions. It was felt that the stopwatch method was unworkable for the timing of very short periods (often not more than 1 or 2 seconds) and that a more accurate system was essential.

The use of a cassette-type Super-8 movie camera proved highly successful and, in addition, gave a permanent record of the activity which could be reviewed in detail. During each filming period one or more rolls of film were exposed, providing a representative sample of the various activities. At the same time all downtime or nonproductive time for the entire trial period (with the exception of any that was recorded on film) was determined by stopwatch.

The elapsed time for any designated activity was determined by a frame count of the processed film. An extension of this procedure over the total productive time established the time for each activity and thence the total time over which the trials were conducted. The percentage of time spent on the most time-consuming operations (e.g., walking between trees) was calculated, and this information can be employed by the forest manager as a guide for estimating the operational treatment costs for stands having a wide range of densities.

## RESULTS

Results of the trials conducted will be discussed under three headings: (1) hand tools in all three age classes; (2) special equipment by age class; (3) a cost comparison and an economic comparison of the best treatments in each age class.

The rate used for hired labor in most calculations was the then-current rate (\$2.40 per hour) being paid to manual workers in similar jobs undertaken by the Ontario Department of Lands and Forests (now the Ontario Ministry of Natural Resources). The one exception to this was the somewhat higher rate used in Age Class II where skilled labor was hired, and in the case of the chainsaw treatment, consideration for the saw was included in the wage rate (\$3.50 per hour for wages plus \$1.50 per hour for the saw). Treatment time per acre is presented in order that ever-changing wage rates may be taken into account by the user. Costs for material and maintenance are included where applicable.

Time-study breakdowns for each treatment are considered in the text and full charts are appended (Appendix A, Fig. 9-11) to indicate to the forest manager where the greatest time consumption occurs and, consequently, the greatest labor or cost input. These should be the first areas in which to concentrate attempts to reduce nonessential effort and improve efficiency.



In each treatment the residual stand density was higher than that aimed at, indicating a general reluctance on the part of the cutters and markers to remove too many trees. The impression seemed to be that the stands were being decimated, and the tendency was to leave a tree in a situation where its removal would create a gap greater than the prescribed average spacing. A quite ruthless approach is required on the part of workers if spacing goals are to be attained and greatest benefit is to be derived from the treatment. Post-treatment data for all treatments are presented in Table 3. Costs for each treatment are broken down in Figure 4 to indicate the major inputs required.

#### *Hand Tools (all age classes)*

The results of the work carried out by hand tools are presented and discussed under a single section since one tool, the Sandvik axe, was used for virtually all thinning of this type, and the use of such a tool displays several factors which are interdependent and common to each trial. These are high labor requirements, low productivity and high cost per unit area treated. Even though this is the case there will undoubtedly be occasions when it will be expedient to thin with nonmechanical hand tools. These trials provide a guideline for hand treatment requirements, and comparative data for more efficient methods of achieving the same goal.

Because their high density and small stem diameter enabled a number of trees to be cut quickly and easily from one spot, the blocks of Age Class I were treated quite efficiently in comparison with those of the other two age classes. A productivity rate of slightly better than 1 acre per man-day (8 hours) was achieved. The worker was able to remain in the cutting mode 73.1 percent of the time since he could continue felling stems as he moved forward and did not have to adopt a cut-walk-cut cycle. The recorded time of 16.1 percent in the walking mode was utilized to move from tree group to tree group, to move across openings in the stand, to retrace steps to maintain a continuity of cutting with a minimum of untreated patches left, or to return to the odd untreated patch which did occur. Very little time was required for clearing, selecting, or nonproductive activities. The last appears to be rather close to what could be expected in practice and suggests that worker reaction was not strongly affected by supervision. Non-productive time did not include lunch breaks but included all other stoppages of a personal or work-related nature.

Although stand density in Age Class II decreased from that of the previous age class by some 1100 trees (to 4220), the number of trees to be removed was reduced by only 600 since desired inter-tree spacing had increased from 6 feet to 8 feet. In addition, average stem diameter had increased to more than 2 inches. The combined effect

Table 3. Post-treatment stand, production and cost data

Age class	Treatment	Treated area (acre)	Stocking (percent)	Density (trees/acre)	Average dbh (inches)	Average height (feet)	Desired spacing (feet)	Average spacing A.T. (feet)	Labor (man-hours/acre)	Cost/acre <sup>a</sup> (dollars)
I ( 9 yr)	Hand tools	12.4	80.9	1674 (5330) <sup>b</sup>	1	6	6	5.1	7.66	18.38
	Brushsaw	28.6	79.0	1614	1	6	6	5.2	3.93	15.92
II (22 yr)	Hand tools	1.4	86.3	864 (4220) <sup>b</sup>	2.9	24	8	7.1	27.14	94.99
	Chainsaw	5.0	84.8	862	2.8	23	8	7.1	14.40	72.00
III (33 yr)	Hand tools	5.0	90.7	1159 (2250) <sup>b</sup>	3.2	33	8	6.1	27.60	66.24
	Hypo-hatchet	15.0	88.0	1125	3.3	33	8	6.2	6.91	39.64

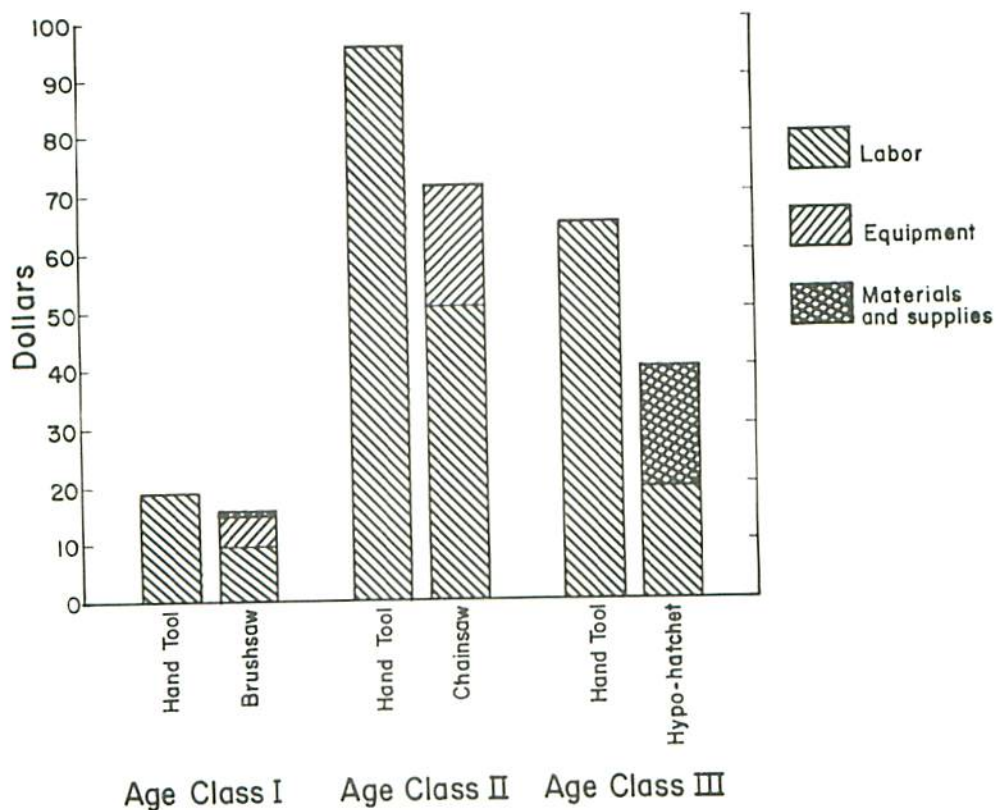
<sup>a</sup> Including equipment, materials and supplies.<sup>b</sup> Pretreatment density (trees/acre).

Fig. 4 Total cost per acre and cost breakdown for each spacing treatment.



was to cause work time to soar to 27.14 hours per acre even with more skilled laborers on the job. While "cutting" remained the predominant time element at 50.8 percent, much more time (22.3 percent) was required to clear the felled trees and remove the light brush which existed as an understory. Some pruning was required to gain access to trees to be removed or to allow freedom of movement when actually felling a tree, and this occupied 13.4 percent of the time. This was offset by a large decrease in walking time (to 4.7 percent), partially accounted for by the concentric operating pattern used. Little time was wasted in moving from tree to tree since the worker was always aware of the direction in which work was to progress and could orient himself accordingly at all times. However, in Age Class II, thinning with hand tools was obviously so slow that the trial was terminated after only 1.4 acres had been treated.

In Age Class III productivity remained very low. While the spacing objective was the same as in Age Class II (8 feet), stand density was reduced by 2000 stems per acre. This should have increased productivity, but felling of trees became much more difficult because of increases in diameter, height, and crown dimensions. The workers' lack of experience was apparent since clearing (i.e., any manoeuvring or handling of the tree after severing) made up 52.4 percent of the overall work time. Cutting, on the other hand, dropped to 26.5 percent, a somewhat surprising fact since the workers had considerable difficulty in cutting the larger trees (4 inches plus) and never really did master the use of the Sandvik. Walking required 14.6 percent of the time, largely because the cutters were allowed to proceed through the area as they saw fit, and this resulted in some unnecessary wandering. It is considered that, in this case, the small amount of time spent in non-productive activities (1.1 percent) reflects an attempt on the part of the cutters to work harder while being observed. Because of low productivity, work was terminated after 5.0 acres had been thinned.

### *Special Equipment*

#### (a) Age Class I (Brushsaw)

It is unlikely that one brand of brushsaw will perform the actual cutting operation more efficiently than another since they all employ the same principle, i.e., a rotating sawblade on the end of a long shaft. However, the particular brand used on this trial was prone to incapacitating breakdowns in the gear box, a defect largely responsible for the fact that machine downtime approached 15 percent of the total available operating time. This is an area in which considerable improvement could be made. Personal downtime was only 4.7 percent, a quite justifiable amount since the machines, while not particularly heavy in themselves, are fatiguing to use for prolonged periods of time. Trees of this size tend to fall like stalks of corn and no concerted effort is required to clear them from the work site. They are small enough that they can be walked over and therefore very little time was spent in slash handling.

Cutting was the major time consumer (57.6 percent) while walking accounted for 20.2 percent. Walking was often coincident with cutting, and as long as the operator was in position to fell trees he was considered to be in the cutting mode.

Productivity achieved a rate of 1 acre every 3.93 hours. To arrive at a cost of operation it was assumed that brushsaws would be rented without operator and, in addition to the \$2.40-per-hour labor rate, certain maintenance costs would be incurred. The total cost of brushsaw treatment consisted of the following elements:

Labor	-	\$ 2.40 /hour
Machine rental	-	\$ 1.30 /hour <sup>1</sup>
Fuel and blade maintenance	-	\$ 0.35 /hour
<hr/>		
Total	-	\$ 4.05 /hour

$$\text{Cost per acre} = \$4.05 \times 3.93 = \$15.92$$

It was further assumed that major repairs would be the responsibility of the renting agencies and therefore no allowance was made for this. On the long-term rental of several units a more favorable rate could undoubtedly be obtained and the total cost per acre somewhat reduced.

An ample supply of blades (3-4 per machine) is required since blades need to be sharpened after each day of use and, although this particular area was relatively stone-free, blades could be dulled immediately if any stone surface was contacted.

Contrary to reports received on past treatments with brushsaws, we saw no major safety problems although the possibilities were well recognized. The length of the shaft is such that there appeared to be little danger of the operator's cutting himself, even if he stumbled or fell while the saw was running. If due caution is practised the operator can be quite certain of his safety. The real danger lies in having other people in the vicinity. For this reason each operator was given a separate block in which to work, and observers were instructed to remain well back from the operator or his intended line of travel. A major hazard is the continual roar of the engine which is situated just behind the operator's head. If the machines are to be used operationally it is strongly recommended that ear protectors be worn, a practice quite common in Scandinavia where brushsaws are widely used for spacing control.

Stand conditions of Age Class I before and after treatment by brushsaw are illustrated in Figures 5 and 6.

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<sup>1</sup> Ontario Department of Highways (now the Ontario Department of Transport and Communication) rate for powersaw rental.





*Fig. 5* Brushsaw treatment of the overly dense condition typical of the Age Class I stand.



*Fig. 6* A portion of the Age Class I stand after treatment by brushsaw.



## (b) Age Class II (Chainsaw)

Although the trees of this size presented no difficulty for the chainsaw, labor input soared over that required in Age Class I. The answer lies primarily in the fact that the method of operation had changed from swathing to individual tree treatment, resulting in a labor and machine-rental requirement of 14.40 hours, at a cost of \$72. per acre. Only 28.4 percent of the time was spent in cutting. Clearing proved to be the big hindrance to progress. Maintaining the concentric orientation provided as much opportunity as possible for felling into open areas, but hangups still occurred and time amounting to 36.9 percent of the total was required for clearing. Nonproductive time (16.3 percent) was evenly divided between personal downtime and downtime due to the equipment. The latter, however, was only for maintenance items such as refueling and sharpening of chains. No time was lost because of saw breakdown.

This treatment resulted in a potentially dangerous fire condition. Such large volumes of slash were created that walking on the ground was virtually impossible, and it was necessary to step from one felled tree to another to move about. The fire hazard will likely remain for several years, and this represents another serious drawback of treatment in this age class. Figure 7 demonstrates the post-treatment condition and the large amount of slash remaining. The person in the figure is standing on slash some 2 feet off the ground.



*Fig. 7 A portion of the Age Class II stand after treatment by chainsaw.*

(c) Age Class III (Hypo-hatchet)

Three distinct operations were required in the hypo-hatchet treatment: stringing, tree marking and treating. The first two control operations were found to be necessary for the orderly progress of the treatment itself. It was assumed that these control operations would not be carried out by the labor hired to treat the trees, but would be assigned to regular staff of the organization initiating the work. For this reason a higher wage rate (\$3.20 per hour) was used to calculate the cost of stringing and marking.

Stringing of the blocks was carried out very quickly and required only 0.45 hours per acre. During marking and subsequent treating it was necessary to walk the entire area to select the trees to be left as crop trees. (Pretreatment stand condition is illustrated in Figure 8.)



*Fig. 8 Overly dense stand condition typical of the Age Class III treatment area.*



A zig-zag pattern back and forth across the strung strip was adopted because of its efficiency, with trees being marked to give an approximate 8-foot spacing. It was to be expected, then, that walking would be the most time-consuming function (56.3 percent). Since the purpose of marking was to choose crop trees, it is not surprising that the markers spent 11.4 percent of their time in the selection process. This percentage could have been higher except that it was possible to do much of the stem selection while moving between trees, in which case the time was assigned to walking. Approximately two spray cans of paint were used per acre (at an approximate cost of \$2.70) and 3.17 hours of labor were required (at a cost of \$10.14), making a total marking cost of \$12.84 per acre.

With the crop trees preselected it was rather a simple task for the labor crew to identify trees to be left and inject the silvicide (cacodylic acid) into each of the unmarked trees. As in the marking, the major portion of time (51.2 percent) was utilized in the "walking" element. Treating time was also high at 40.2 percent. Several trees could often be reached from the same ground position and it was not always necessary to approach each tree individually. Some additional selecting of trees was carried out by the crew where two trees that were very close together had been marked or where a poor tree had been marked beside a good tree.

In treating approximately 1100 trees per acre at 1-2 cuts per tree depending on size, an average of 3.6 U.S. quarts of herbicide (at \$4.85 per quart) were required per acre. Some 3.29 man-hours per acre were necessary to complete the job for a total treatment cost of \$25.36 per acre.

The cost summary for the entire job is as follows:

Stringing	- \$ 1.44
Marking	- \$ 12.84
Treatment	- <u>\$ 25.36</u>
Total cost per acre	- \$ 39.64

If marking could be eliminated, the cost of treatment would be significantly reduced. In this case, however, it was felt that quality of treatment would also be reduced without preselection of crop trees. In fact it would then be very difficult for either the worker or the supervisor to determine if treatment in progress was too heavy or too light. A follow-up assessment in 1970 showed that mortality of treated trees was total.

A definite advantage is to be gained when trees remain *in situ* after treatment, as the dead trees deteriorate slowly and do not constitute a serious fire hazard. This is a very different condition than that produced by any of the foregoing spacing methods, all of which entail the felling of trees.

A minor annoyance associated with the use of this silvicide is a garlic-like flavor in the mouth (apparently resulting from absorption of certain elements by the skin) and a similar odor when clothing which has been splashed by the material becomes moistened. This is most disagreeable to other persons, and even when the soiled material has been washed several times, the odor tends to linger.

## DISCUSSION

### *General Cost Comparisons*

In all age classes the cost of treatment by hand was higher than that of the alternative method. The only hand treatment that could be considered competitive is the Sandvik treatment in Age Class I for which the cost differential (in favor of brushsaw treatment) was only \$2.46 per acre. In the case of Age Class I, the analysis of the brushsaw treatment will provide a close approximation of the costs of treatment by hand. In Age Classes I and II, labor input for the hand treatment was approximately double that for the mechanical method. However, owing to the extra costs associated with operating power equipment, the difference in the total cost was less than this, and in Age Class I it is conceivable that the cost difference would be virtually eliminated with lower initial stand densities. In this event the choice of method becomes a function of availability of equipment and labor and the time allowed to complete the job. As stand density increases, however, it can be expected that the cost advantage in favor of the brushsaw would also increase. In Age Class III a fourfold increase in labor input resulted in a doubling of cost per acre, reflecting the very significant cost of materials required for the hypo-hatchet operation.

### *Response to Thinning*

Although numerous studies have been carried out to determine the effects of thinning upon the height, diameter and volume growth of jack pine, few of the treated stands have been assessed at maturity, the only time when the impact of thinning can be fully determined. These studies have usually indicated that, at harvest, merchantable volumes obtained from a thinned stand should be greater than those from an unthinned stand (Cayford 1961; Waldron and Cayford 1961; Cayford 1964). Without more evidence of the extent to which the last is true, it is assumed for the following analysis that the merchantable yields from the treated stands will be the same as those from unmanaged stands (as read from Normal Yield Tables for Ontario, Plonski 1960).

Of greater significance from the industry's point of view is the increase in average stand diameter which almost invariably occurs as a result of thinning. Various researchers have shown increases in periodic and current annual increment ranging from 0.03 inches to 0.07 inches (Wilson 1952; Waldron and Cayford 1961; Cayford 1961; Cayford 1963,



unpublished progress report; Cayford 1964). It is to be expected that these increases will vary depending on the age and density of the stand and the intensity of treatment, as well as climatic and site differences. However, for the purpose of calculating the growth of the treated stands, the increase in periodic annual diameter increment was conservatively estimated at 0.04 inches for all three age classes. It was also assumed that increased growth will accumulate at this rate only from the age at thinning to the age at which the stand returns to "normal" density (as defined by Plonski 1960). At that time growth rates will revert to those of the "normal" stand.

Using the increment increase indicated above (0.04 inches), Table 4 illustrates the projected effect upon the average diameter of the stands treated in this study. In the case of Age Class I, response to thinning will cease at a stand age of 29 years. The effect on the following calculations of not having reached the spacing objectives then becomes readily evident. This is particularly true in Age Class III where the response period as read from the normal yield table is less than 5 years. However, it is considered that a thinning of the intensity achieved in this age class will produce a response for at least 5 years.

Recent studies have illustrated the impact of volume per tree (i.e., tree diameter) upon the cost of producing a cunit of wood. Hannula (1970) reported that daily production of lodgepole pine (*Pinus contorta* Dougl.) increased by an average of 3.7 cords (3.14 cunits) per two-man crew for each 1-inch increase in average butt diameter of tree-length material up to 11 inches. Williams (1971) demonstrated similar effects of tree size on direct costs of producing wood in eastern Canada. In addition, recent tests of harvesting machines, conducted by the Pulp and Paper Research Institute of Canada, have shown startling improvements in efficiency as volume per tree increased. The effect of increasing diameter on wood costs is shown in Table 5.



Table 4. Effect of thinning on diameter increment (increase over increment of unthinned stems)

Age class	Age at thinning in 1970 (years)	Period of increased growth due to thinning <sup>a</sup> (years)	Estimated periodic annual increment increase (inches)	Estimated total diameter increment increase over period (inches)
I	9	20	.04	.8
II	22	20	.04	.8
III	33	5 <sup>b</sup>	.04	.2

<sup>a</sup> Jack pine, Site Class 2, Plonski 1960.

<sup>b</sup> The response period is considered to be not less than 5 years.

Table 5. Harvesting cost per cunit, at roadside (dollars)

Avg. dbh of trees harvested (inches)	Cost/cunit <sup>a</sup> (northwestern)	Cost/cunit <sup>b</sup> (PPRIC)	Cost/cunit <sup>c</sup> (eastern Canada)
5.0	11.33	6.95	20.00
6.0	8.55	4.60	14.00
7.0	7.11	3.15	11.00
8.0	5.86	2.50	9.00
9.0	5.52	2.10	8.00

<sup>a</sup> Cost per cord from report converted to cost per cunit ( $\times \frac{100}{85}$ ).  
Butt diameters converted to diameter at breast height  
by reducing butt diameter 1 inch.

<sup>b</sup> Diameters obtained by relating volume per tree from PPRIC report  
to volumes for 60-foot trees in Ontario Department of Lands and  
Forests (now the Ontario Ministry of Natural Resources) standard  
volume tables.

<sup>c</sup> Volumes derived using same tables as for 2.

The large differences between columns suggest that different cost elements were included in the original calculation. However, this does not invalidate the fact that within each column costs decrease rapidly with increasing average diameter. These reductions are indicated in Table 6.

Table 6. Reduction in harvesting cost to be gained through a 1-inch increase in diameter of the average tree

Dbh change (inches)	Reduction in cost per cunit					
	Northwestern		PPRIC		Eastern Canada	
	\$	%	\$	%	\$	%
5-6	2.78	24.5	2.35	33.8	6.00	30.0
6-7	1.44	16.8	1.45	31.5	3.00	21.4
7-8	1.25	17.6	.65	20.6	2.00	18.2
8-9	.34	5.8	.40	16.0	1.00	11.1

In a fully stocked stand the average diameter of jack pine at 60 years of age on Site Class 2 is 6.2 inches (Plonski 1960). This diameter was increased by the amounts indicated in Table 4, and the results are shown in Table 7 along with the reductions in harvesting costs per cunit resulting from the increased diameters. However, if production costs continue to rise, the savings resulting from increased tree size will be even greater. Assuming that harvesting costs continue to rise at an annual rate of 1.23 percent as in the past decade (Williams 1971), potential reductions in cost per cunit are also given. Only the eastern Canada values are used in this calculation since they are based on an extensive sample and should adequately represent the existing situation. While the data in Table 7 are typical of pulpwood costs, they should be equally valid for the production of sawtimber, because of similarities in harvesting methods.

### *Economic Comparison of Mechanical Treatments*

With the foregoing as background, an economic comparison of thinning in the three age classes was made by discounting the potential reductions in harvesting costs to the time of thinning. To avoid the problem of selecting an acceptable interest rate, the internal rate of return was calculated for each age class.

Table 7. Effect of increased average tree diameter on harvesting costs per cunit

Age class	Dbh of average tree at age 60, unthinned stand (inches)	Dbh of average tree at age 60, thinned stand <sup>a</sup> (inches)	Years to harvest	Reduction in cost/cunit <sup>b</sup> (1970 dollars)	Potential reduction in cost/cunit <sup>c</sup> at harvest (dollars)
I	6.2	7.0	51	2.30 <sup>d</sup>	4.29
II	6.2	7.0	38	2.30	3.66
III	6.2	6.4	27	0.70	0.97

<sup>a</sup> From Table 4.

<sup>b</sup> Due to corresponding diameter increase (trees processed to roadside).

<sup>c</sup> Due to corresponding diameter increase and compounded to harvest age at 1.23 percent per annum (13 percent per 10-year period).

<sup>d</sup> Derived from eastern Canada data of Table 6.



Table 8 shows the internal rate of return on the cost of thinning in each age class.

Table 8. Internal rate of return from thinning (in percent)

Site class	Merchantable volume/acre at 60 years <sup>a</sup> (cunits)	Age class		
		I (15.92) <sup>b</sup>	II (72.00) <sup>b</sup>	III (39.64) <sup>b</sup>
3	14.8	2.7	-0.8	-3.8
2	23.1	3.6	+0.4	-2.1
1	31.8	4.3	1.3	-0.9

<sup>a</sup> From Plonski 1960.

<sup>b</sup> Cost per acre of thinning, in dollars.

Although all stands treated in these trials were in Site Class 2, the above table contains data for Site Classes 1 and 3, simply to illustrate the effect of varying yield on the internal rate of return. It is obvious that treatment of Age Class I produces the most favorable rates of return, and these rates increase as site quality (yield) improves. Evidently the lower treatment cost in Age Class I is more than sufficient to offset the shorter interest periods enjoyed by Age Classes II and III.

This analysis suggests that investments in early spacing control may be justified on the basis of an expected reduction in harvesting costs at maturity. However, it would appear that as a supplementary treatment to aerial seeding, spacing operations may also be justified in terms of stand establishment costs. The cost of planting jack pine is about \$48. per acre, including the cost of stock, while the cost of seeding, including seed, is about \$7. per acre (Scott 1968). (In both instances the cost of site preparation is excluded because it is common to both methods of regeneration.) These trials showed that spacing can be carried out for about \$16. per acre in dense young stands originating from aerial seeding. The resulting stands are equivalent to well-stocked plantations, but their total establishment cost (about \$23. per acre) is considerably less. Thus it would appear that, even allowing for a greater possibility of failure, aerial seeding plus early spacing may be a more efficient method than planting for the regeneration of jack pine.

## SUMMARY AND CONCLUSIONS

Operational trials were undertaken to determine the stage in stand development at which precommercial thinning can be carried out most effectively in dense jack pine stands. Various methods were employed to identify the most efficient technique for use in each of three age classes (9, 22, and 33 years). Hand treatment with Sandvik axes was tested in all three age classes, in comparison with brushsaw treatment in the 9-year class, chainsaw treatment in the 22-year class, and treatment with hypo-hatchets and silvicide in the 33-year class.

In each case the trials were carried out under contract at piecework rates. Time-study and cost data were obtained for each trial, and a benefit/cost analysis was made to indicate the potential returns from thinning in each age class. Treatment methods were described in detail to illustrate some of the difficulties encountered and suggest where improvements could be made.

The cost of treatment was much lower for the 9-year class than for the two older classes. Benefit/cost calculations indicated that the internal rate of return on the thinning investment (as a result of reduced harvesting costs) was highest for the youngest class.



## REFERENCES

- Burch, W. G. 1967. Stocking control in the Douglas fir region - Canada. Proc. West. Reforest. Coord. Comm., Portland, Ore. p. 36-38.
- Cayford, J. H. 1961. Results of a 1927 jack pine thinning in Saskatchewan. Can. Dep. Forest., Forest. Res. Branch Tech. Note No. 107. 13 p.
- Cayford, J. H. 1964. Results of a 1921 jack pine thinning in western Manitoba. Can. Dep. Forest., Forest. Res. Branch Publ. No. 1077. 7 p.
- Cayford, J. H. *et al.* 1967. A review of silvicultural research in jack pine. Can. Dep. Forest. Rural Dev., Forest. Branch Publ. No. 1173. 255 p.
- Hannula, O. 1970. The effect of average stand diameter on tree-length logging costs. Pulp Pap. Mag. Can. 72(2) WS 2577(B-1) 96-100.
- Hills, G. A. 1952. The classification and evaluation of site for forestry. Ont. Dep. Lands Forests. Div. Res. Res. Rep. No. 24.
- Osborn, J. E. 1968. Economics of spacing control. Rep. submitted to Fac. Forest., Univ. B.C., Vancouver. 109 p.
- Plonski, W. L. 1960. Normal yield tables. Ont. Dep. Lands Forests Silv. Bull. No. 2.
- Rowe, J. S. 1959. Forest regions of Canada. Can. Dep. North. Aff. Nat. Res. Forest. Branch Bull. No. 123. 71 p.
- Scott, J. D. 1968. Direct seeding. Can. Pulp Pap. WS 2490 (F-2).
- Smith, J. H. G. 1967. The financial aspect-early stocking control. Proc. West. Reforest. Coord. Comm., Portland, Ore. p. 17-23.
- Staebler, G. R. 1965. Advances in stand improvement. Pap. presented at annu. meet. West. Forest. Conserv. Assoc., Vancouver. 18 p.
- Waldron, R. M. and J. H. Cayford. 1961. Results of a 1936 thinning in a two-storeyed stand of jack pine and black spruce in western Manitoba. Can. Dep. Forest., Forest. Res. Branch Mimeogr. 10 p.

- Williams, N. R. 1971. A decade of wood cost performance for industry east of the Rockies, implication of mechanization. Pulp Pap. Mag. Can. 72(6) WS 2594(B-1) 95-102.
- Wilson, G. M. 1952. Thinning jack pine, Nisbet Forest Reserve, Saskatchewan. Can. Dep. Res. Dev., Forest. Branch Silv. Res. Note No. 99. 24 p.

## APPENDIX



### AGE CLASS I

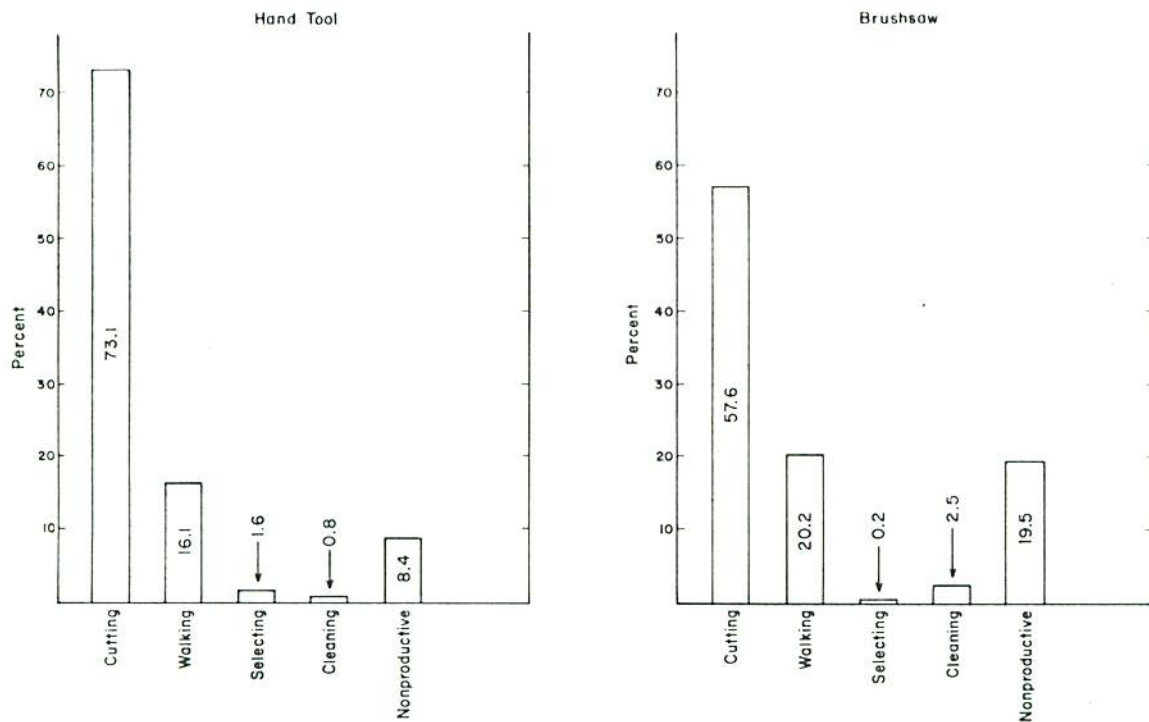


Fig. 9 Time-element breakdowns (in percent) for treatments of Age Class I.

### AGE CLASS II

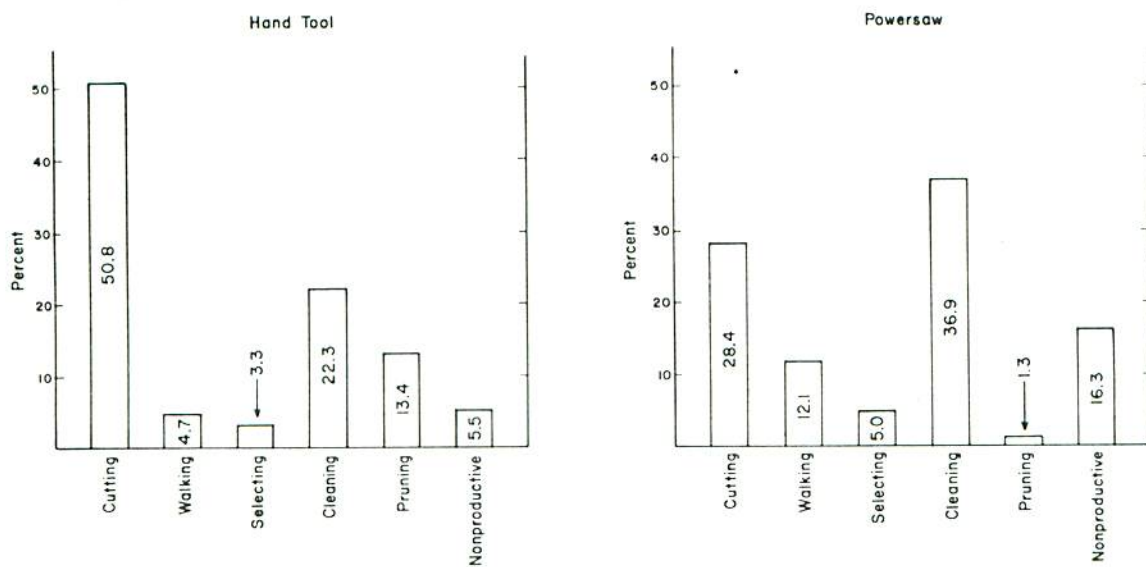
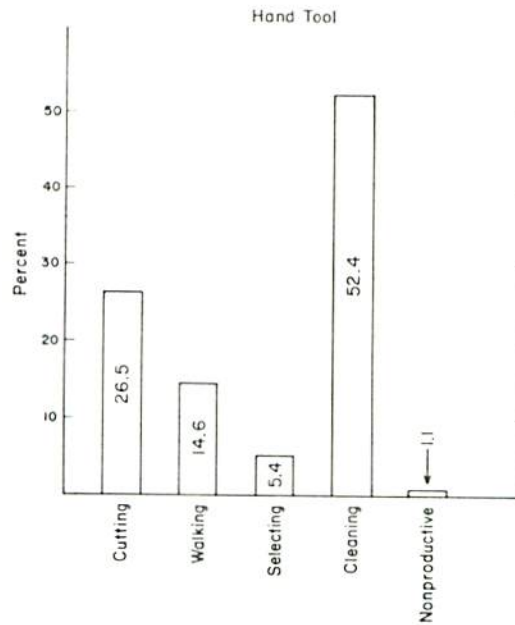


Fig. 10 Time-element breakdowns (in percent) for treatments of Age Class II.

### AGE CLASS III



### HYPO-HATCHET and SILVISAR

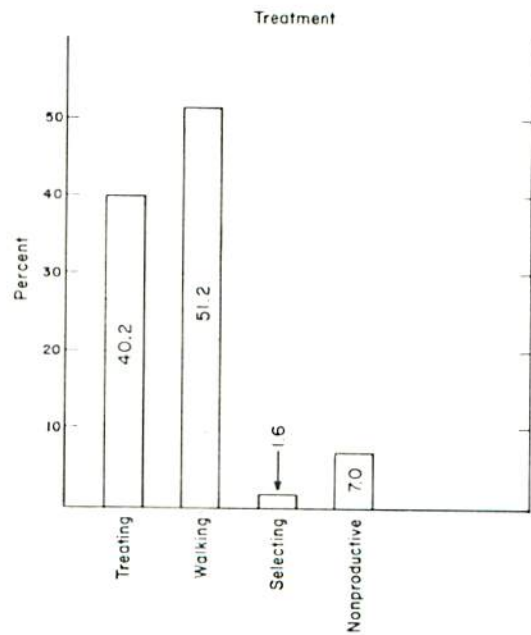
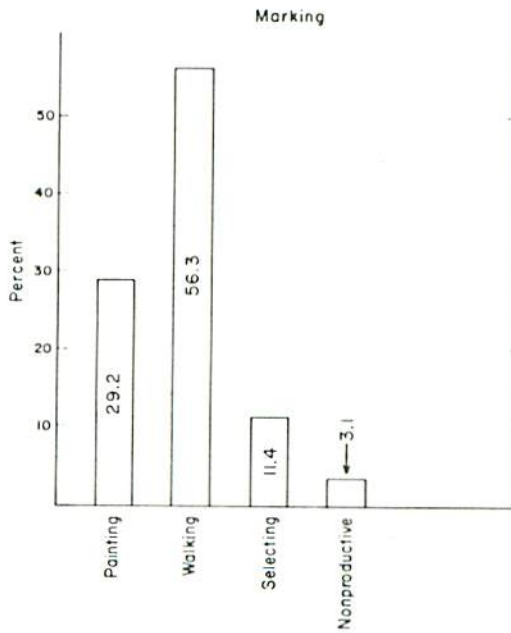


Fig. 11 Time-element breakdowns (in percent) for treatments of Age Class III.