A GUIDE TO PLANTING MACHINE OPERATION IN THE BOREAL FOREST OF ONTARIO

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ABSTRACT

This is a basic report containing operational information and guidelines for the forest manager who is confronted with the need to begin mechanizing his planting program. The need to mechanize has arisen from present-day economic and social realities. To date, little background information on the whole field of mechanized regeneration has been available. Inadequate knowledge of the machine types available, how they operate, and where, can lead to improper or inappropriate use and eventual disenchantment. This report can be used to aid in planning the operation and in seeing it through to completion. In a general way, the basic types of machines available and the conditions to which they are suited are outlined. Proper use is stressed and helpful hints gained from 5 years of operational testing of planting machines in the boreal forest are given. Problems such as stumps, slash, residuals and soil type are discussed. Costs should be comparable to those incurred by hand planting.

ACKNOWLEDGEMENTS

I am indebted to F. F. Foreman, Forestry Technician, for his suggestions and valuable assistance in the conduct of field work. I also wish to acknowledge the cooperation of the Ontario Ministry of Natural Resources in Chapleau, Cochrane, Dryden, Terrace Bay and White River in the conduct of the planting machine trials. This report is based on the experience gained from those trials. The participation of Ministry personnel was essential and greatly appreciated.

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INTRODUCTION

Ontario's silvicultural program is being vigorously expanded. An integral part of this expansion is artificial regeneration of cut-over and burned-over land at acreages much higher than those currently being regenerated. In Ontario, hand planting of nursery stock has traditionally been the prime artificial regeneration technique. Over the past decade, hand planting of both bare-root and containerized seedlings has accounted for approximately 83% of the area artificially regenerated (Anon. 1966, 1971, 1974). However, ever-increasing wage rates and chronic regional shortages of seasonally available forest workers will make it difficult, if not impossible, for the forest manager to keep pace with increasing demands for regeneration by using hand-planting methods. It is essential that alternative methods be closely investigated. The dramatic increase in the use of mechanized equipment in the field of logging and the success it has enjoyed suggest that mechanization of reforestation may materially assist in meeting the challenge.

Silversides (1964) summarized terrain conditions in the pulpwood forests in eastern Canada. The sample he used, covering 217,500 km^2 (84,000 sq. miles), principally in the boreal forest (Rowe 1972), showed that 74% of the area was flat to gently rolling (10% to 25% slope), about 78% had less than 15 cm (6 in.) of humus, and about 64% had deep soil (90 cm, or >3 ft). It is assumed that mechanized reforestation will be feasible only on those sites where all three of these favourable conditions occur. These sites probably will not exceed 40% of the total productive forest of eastern Canada. The strategy will be to make use of scarce labour on sites that cannot be mechanically reforested, concentrating our efforts on mechanizing the 40% that is suitable for machine planting.

Americans and Scandinavians have been developing and using a variety of tree-planting machines for some time. However, with the exception of promotional material from manufacturers, little published information on performance is available. That which is available is often not applicable either to Ontario's conditions or to the single-pass site preparation, or to the planting strategy that seems conducive to the greatest overall efficiency of operation.

During the period 1971-1974, the Great Lakes Forest Research Centre (GLFRC), in cooperation with the Ontario Ministry of Natural Resources (OMNR) and under the auspices of the Canada—Ontario Joint Forest Research Committee, conducted field trials on five commercially available planting machines as well as developmental work on an original machine, the Ontario Planter. The trials were set up to determine the ability of each planter to cope with various site conditions in boreal Ontario, to point out areas for design modification that would improve planting quality or production, and to determine efficient and effective operating techniques. Over 162 ha (400 acres) were treated during the course of the trials.

Experience has provided information on the use of specific models of tree planters, some of which has already been presented in reports by Cameron (1975) and Riley (1975). In addition, information was also obtained concerning operating procedures for machine planting in general. The purpose of compiling this report is to provide the potential user of a planting machine with information that will enable him to avoid many of the pitfalls associated with mechanical planting. The report discusses factors common to all mechanical planting operations. It outlines what the user can and should expect in the way of results, and gives basic tips on proper use of the equipment.

Each time an expensive piece of equipment passes over the same piece of ground, costs escalate. In an effort to minimize costs and develop methods that compare favourably with alternative methods of artificial regeneration, site preparation and planting are carried out in a single pass. My comments and observations are based on the single-pass operation.

EQUIPMENT

Three distinct components comprise the effective planting unit: the V blade, the tractor and the planting machine. The components will be dealt with in that order.

i) V Blade

Experience has shown that, regardless of type of planting machine used, planting quality and production efficiency are directly related to preparation of a suitable planting microsite. This can be defined as that area within the operating width of the planting machine's components which is free of debris and, depending on tree species and soil type, either is cleared to mineral soil or retains a thin layer of duff over the mineral soil. To date, this condition has been cheaply and effectively achieved through the use of a front-mounted V blade on the bulldozer pulling the mechanical tree planter.

Use of the V blade has certain advantages over other methods of site preparation which make it suitable for single-pass operations. It is mounted in front of the tractor, eliminating interference with planter hookup. The V shape ensures that the device is self clearing. Ease of operation and ruggedness make this uncomplicated piece of equipment a logical choice for cutover conditions in the boreal forest. Generally, V blades used with mechanical planters have the following features: bunting frame, scalping foot, V blade wings, prong, and means of attachment to tractor (Fig. 1).

The bunting frame which is fitted around the top of the blade is used to knock down or push aside chicots and residuals that may be in

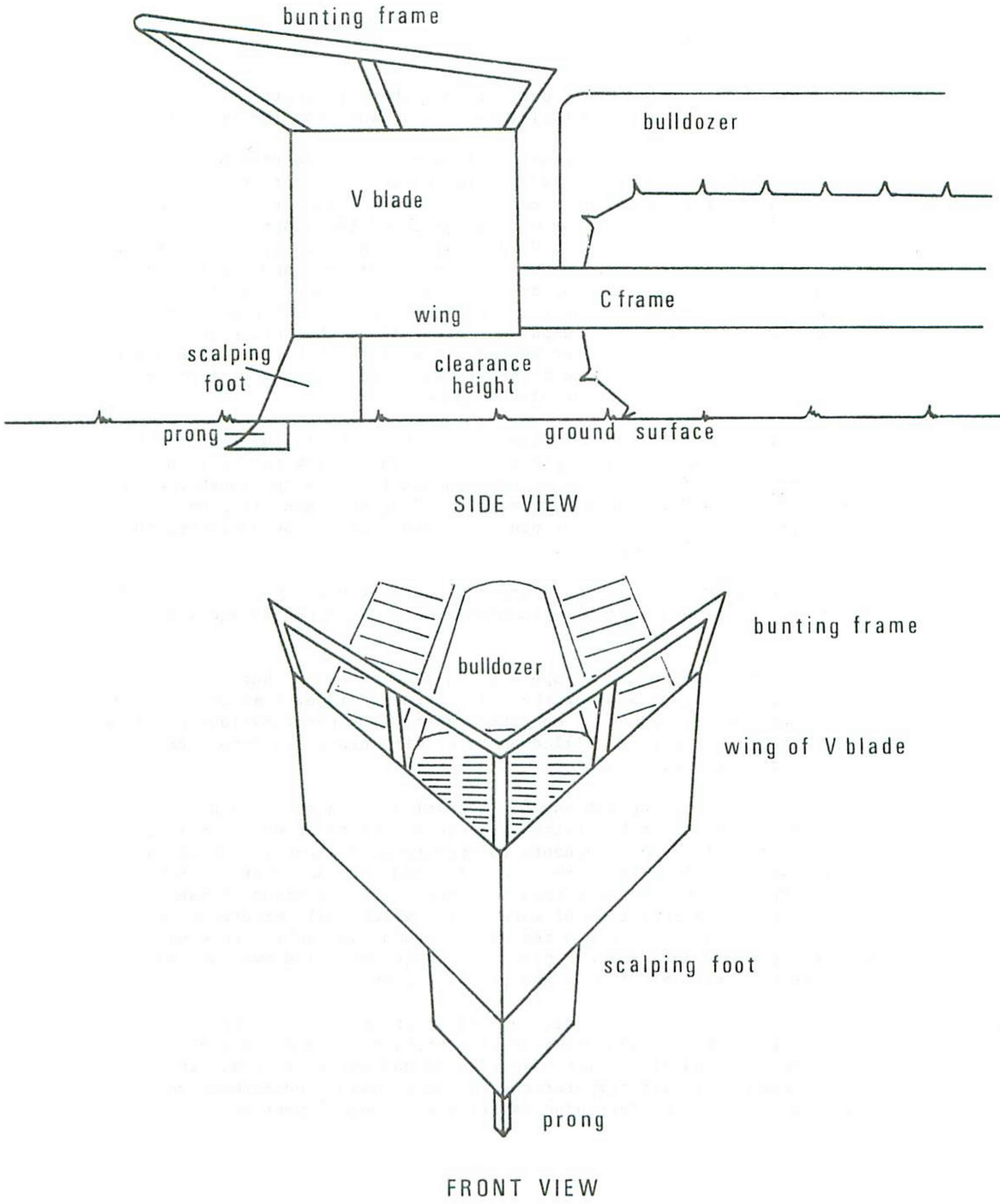

Fig. 1. Simplified drawings show parts of V blade as used with mechanical planters.

the planter's path. It should project from the V blade at its apex and sides so that the standing material is pushed away from the tractor.

The scalping foot is essentially a mini-V blade attached to the bottom of the V blade. It should be wide enough to clear only the path width necessary for the planter components to function properly. In most cases this is equal to the outside width of the planter packing wheels. The scalping foot should be no higher than the ground clearance height of the bulldozer. Depending on site conditions and the tractor used, this can be as high as 45 cm (18 in.). The proper height will allow stumps and slash that need not be removed to pass under the bulldozer without danger of hangup. Stumps and larger slash that are higher than the scalping foot are deflected by the wings of the V blade to the sides of the tractor, or crushed under the tracks. The scalping foot itself will clear the planting row of slash and debris.

This scalping foot may also have a prong on its lower end at the apex. The prong extends 10 to 15 cm (4 to 6 in.) below the scalping foot and is about 5 cm (2 in.) wide, sturdy enough to withstand rough use in front of a bulldozer. The prong travels in the soil and lifts embedded debris onto the face of the scalping foot where it can be deflected to the sides of the planting path.

The majority of V blades are mounted to the tractor C frame with centre pin mounting and either trunnion arms or butt plates and lips (Fig. 2 and 3).

The V blade should be operated in such a manner that the bottom of the scalping foot floats along the soil surface, either removing or leaving the duff layer, depending on site preparation specifications and tree species to be planted. A skilled operator with proper equipment can meet these specifications.

For effective operation of a mechanical planter, a path the width of the tractor need not be cleared. A cleared width of 60-90 cm (2-3 ft) will allow the planting components to operate as designed. Additional clearing serves only to slow the operation and increase costs. In rough cutovers full width clearance entails unnecessary uprooting of many stumps, and the manipulation of much debris which could otherwise be left in situ. Such full width removal of stumps and debris necessarily increases the distance between planted rows because windrowed debris endangers seedlings planted in the previous pass.

In clay soils, wholesale removal of ground cover leaves the soil open to baking, runoff and frost heaving problems. Such treatment can leave both sand and clay soils open to wind and water erosion, high and perhaps lethal soil—air temperatures in the seedling environment on hot days, and little water-retaining capacity in droughty periods.

Fig. 2. Crank Axle planter drawn by Cat D6C bulldozer. Note trunnion arms on curved face of V blade.

Fig. 3. V blade showing "butt plate and lips" method of attachment to tractor C frame.

With the scalping foot, the intention is to remove only those stumps directly in the path of the planter components. Often stumps are encountered by the angled faces of the scalping foot rather than directly at the apex. This will usually swing the tractor slightly off its line of travel. Although the resultant planting row is not straight, it has not been necessary to remove these stumps. This can be advantageous to the general planting operation since a stump rolled out of the ground often presents an obstacle in the form of a heavy root mat which may foul the operation. A rolling stump can get caught under the tractor belly pan and hang it up. It can get jammed in the planter components or drag along behind the planter, uprooting planted seedlings. More effort is required to remove a stump than to avoid it.

V blades are designed to be self-clearing and should be allowed to function in this way. The operator should not raise the V blade to clear it of debris, as raising it will allow high stumps and slash to pass under the tractor, increasing the risk of tractor hangup or planter fouling.

If possible, standing material should be left standing, as a single piece of downed material may be encountered on several planting passes. Pushing down trees also slows forward progress considerably.

The majority of V blades are designed for a specific make and model of tractor. Often the manufacturer has a line of blades to fit several makes and models, or he may be able to supply, upon request, parts that fit a different make and model of tractor. Generally, smaller blades which do not wrap around the outside width of the tractor C frame are easier to fit, but do not stand up to use on heavier tractors. Larger V blades, when modified to fit smaller tractors, become unwieldy.

A number of V blades of different shapes and sizes but of basically similar design have been used in the trials. Their use has revealed limitations in both design and construction and has suggested a number of ways in which improvements could be made.

In the spring of 1974 the Great Lakes Forest Research Centre developed a prototype, called the CFS V blade, which was a first attempt to develop a unit that would fit all different tractor makes and models, and combine those features which suit it to site preparation for mechanical planters (Fig. 4 and 5). The goal has been to design a blade that would float on its own rather than through operator manipulation. The incorporation of a rolling drum coulter into the scalping foot is intended to give the blade the advantage of self float. Self-floating V blades can reduce operator fatigue by freeing the operator to attend to other functions inherent in traversing the site while pulling a planter. Self float also minimizes the tendency to skip and scalp, a common problem with operator-controlled float. Maximum planting efficiency can be obtained only when the site is properly prepared and a regular planting rhythm, uninterrupted by misses and gouges, can be maintained.

Fig. 4. CFS V blade showing method of attachment.

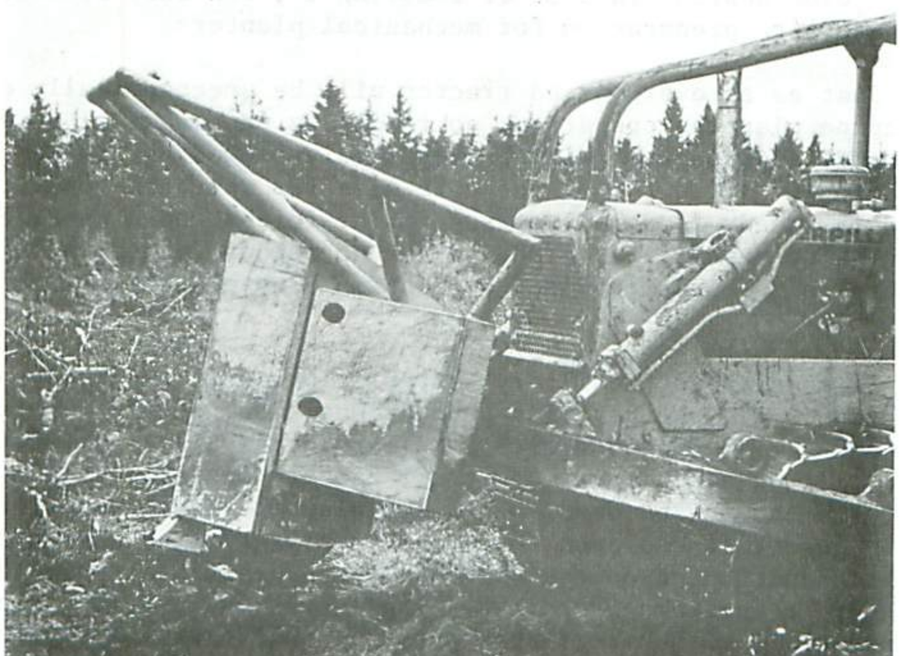

Fig. 5. CFS V blade mounted on Cat D6C C frame.

ii) Tractor

Boreal cutovers of northern Ontario can present conditions that are very rugged and trying to mechanical planting machines. Stumps, slash and debris, and terrain often pose formidable barriers to an operation which much incorporate site preparation and planting in a single pass. The steady yet slow forward speed required by manned mechanical planters and the need to remove debris from the path of the planter have prompted the use of crawler tractors in conjunction with planting machines to the exclusion of all other means of propulsion. Only bulldozers have the gearing required for continuous working speeds of 1.6-2.0 km/hr (1 to 1 1/4 mph). Tracklaying machinery has excellent traction and, as opposed to rubber-tired equipment, provides a smooth pull, uninterrupted by wheel bounce or wheel distortion, upon encountering obstacles. Jerky forward advancement of the planting machine is hazardous and uncomfortable for the planter operator and hinders proper operation of the planting components.

The effect of slash passing under the tractor's tracks owing to the use of a V blade and scalping foot has occasioned considerable discussion. Bulldozers have little difficulty moving forward over slash, and tractor speed can be adjusted to suit terrain conditions and planting machine requirements. Because heavy machinery such as a bulldozer crushes much of this debris, savings in time and energy gained by "walking" over debris, instead of removing it, can only reinforce this approach to site preparation for mechanical planters.

Just as an overpowered tractor will be uneconomically employed on a machine planting operation, so too it is uneconomical to employ an underpowered tractor that will be repeatedly slowed by stumps or slash accumulations. A tractor of adequate size for the site conditions is required if steady forward progress for efficient and effective machine planting is to result. The 100-140 net horsepower range represents the general size class required on most machine-plantable sites in Ontario.

In some cases, auxiliary hydraulic power is required to operate the planter (e.g., the Reynolds-Lowther Dual Coulter and the Taylor Drum) (Fig. 6 and 7). Bulldozers with auxiliary hydraulic capabilities such as blade tilt or additional, optional, factory-installed valve banks, are adequate and may be used. When the planter requires auxiliary hydraulic power, it has been found that small gasoline engine/hydraulic pump units constructed on the site have been unsatisfactory, as they are subject to possible breakdown. The most trouble-free and efficient method has utilized a direct hookup to the bulldozer. A separate lever to control only the planter hydraulics is desirable in the tractor cab.

Although crawler loaders have been used in some of our trials, and do have the hydraulic capabilities required, there are certain draw-

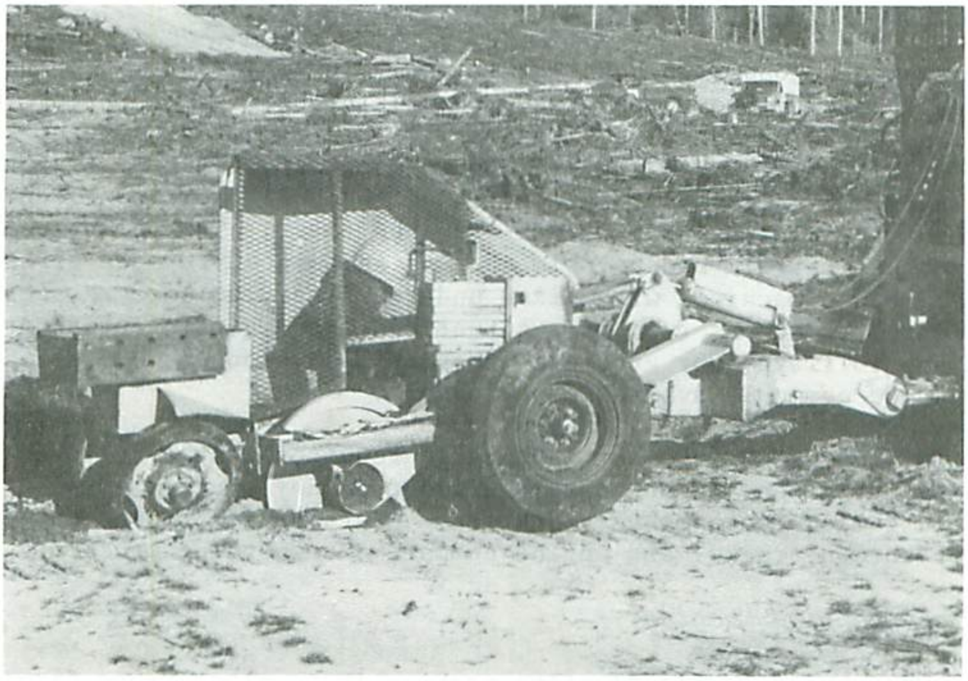

Fig. 6. Reynolds-Lowther Dual Coulter planter.

Fig. 7. Taylor Drum planter mounted on Cat D6B bulldozer. Note debris passing under wings of V blade while scalping foot clears necessary path.

backs to using a loader in bush conditions. The major drawback concerns the fixed undercarriage rather than the walking beam undercarriage used in most bush crawler tractors. Cutover terrain is not smooth and flat, and the walking beam gives the bulldozer added articulation, improving the riding and handling characteristics of the bulldozer and the performance of the planter and V blade attached to it. The bulldozer can handle rougher terrain and is able to push and manoeuvre more effectively. In comparison to machines with fixed undercarriage, bulldozers are able to extricate themselves from more situations where getting stuck or hung up is a possibility. For greatest traction bush grousers are essential. These are not commonly available on loaders.

The Loggers Safety Act in Ontario requires that a rollover protection safety canopy be standard equipment on any tractor working in the woods, and common sense makes track frame guarding (to reduce the possibility of thrown tracks) and engine compartment guarding mandatory.

iii) Tree-planting Machine

The task of a tree-planting machine is to plant trees firmly at root-collar depth at a specified spacing in the planting chance. As is the case for most regeneration operations, both mechanical and manual, complete coverage of the area is required for satisfactory stocking results.

To date, we have tested several continuous furrowing machines such as the YLO Finn Forester, Reynolds-Lowther Crank Axle (Fig. 2), Reynolds-Lowther Dual Coulter (Cover and Fig. 6) and the Taylor Drum (Fig. 7). This category of planting machine usually has a rolling disc or coulter preceding a planting head which is dragged in the ground, creating a continuous slit in which trees are placed one after another at the desired lineal spacing. The advantages of this type of machine are the simplicity of its construction and operation, its few moving parts, and the ease with which it plants (Fig. 8 and 9). A disadvantage is its limited applicability in some soil types such as clays, or in excessively stony soils. A scalped furrow is unsuitable in the former, whereas use in stony conditions may cause a continuous furrower to jump repeatedly upon contact with underground obstructions, thus reducing its planting effectiveness.

We have also tested continuously advancing, intermittent furrowing, dibble-type planters such as the Timber Cat Dibble and the Mark II and Mark III prototypes of the Ontario Planter (Fig. 10). These machines have a planting head which is in the soil only part of the time. The rest of the time it is carried clear of the ground, an advantage when it encounters immovable objects. This machine always advances while planting. Its advantages lie in its ability to control the choice of planting spots on difficult sites, and in moving the planterman further from contact with the ground or furrow created, thereby increas-

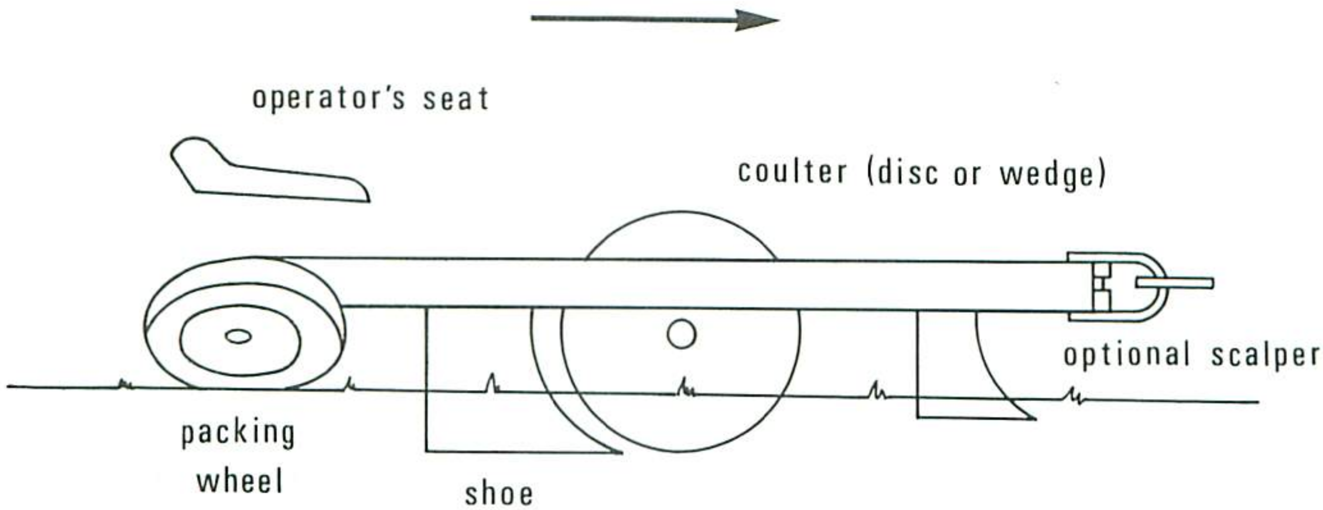

Fig. 8. Diagram of a continuous furrowing tree planter representative of machines such as the Forester, Wildland, Crank Axle, Taylor Drum, Finn Forester (rear-facing seat) and Forestland (rear-facing seat) tree planters.

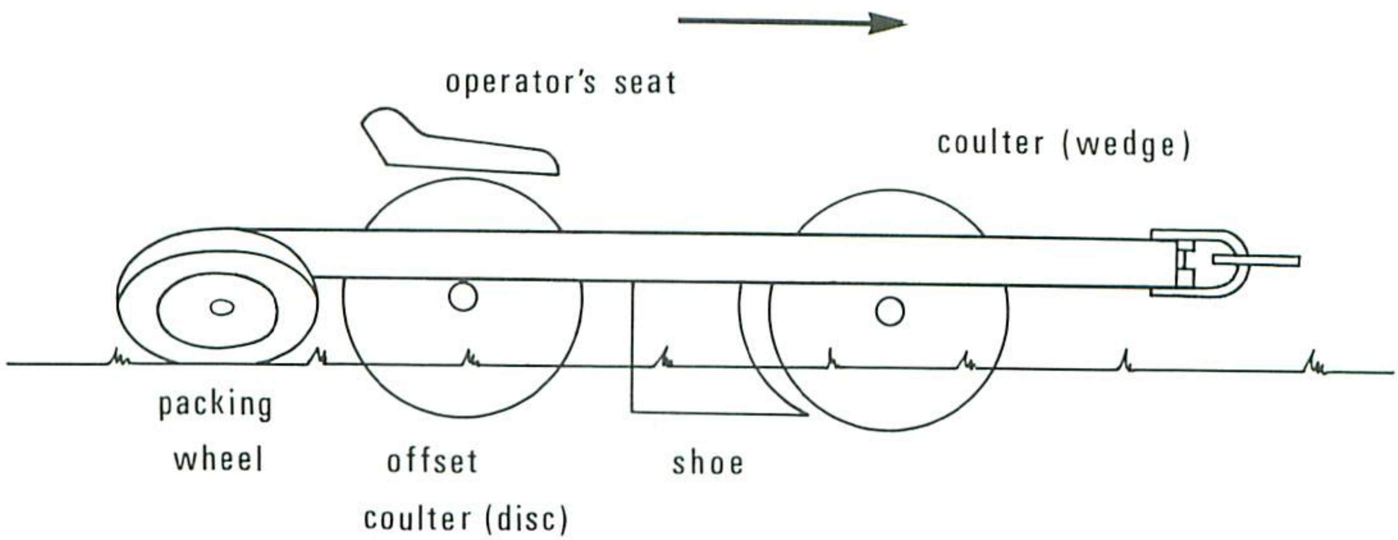

Fig. 9. Diagram of a continuous furrowing tree planter representative of machines such as the Dual Coulter.

ing his safety. Disadvantages arise from the increased machine complexity brought about by the addition of more moving parts.

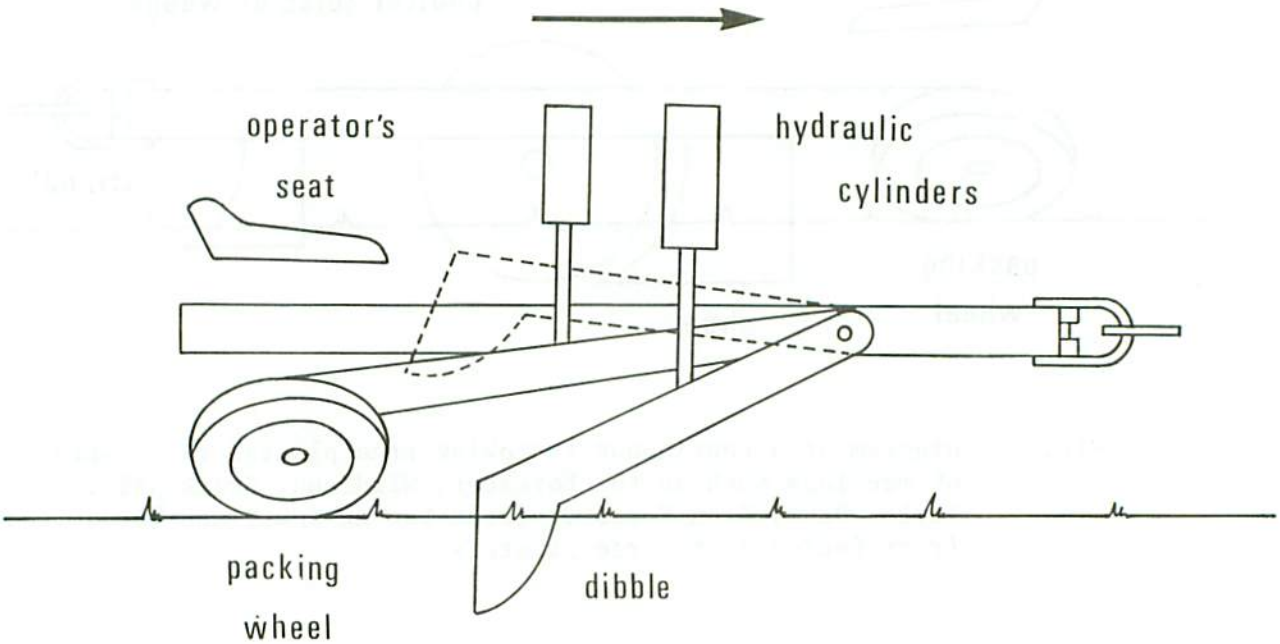

Fig. 10. Diagram of an intermittent furrowing or dibble type planter, the Ontario Planter.

Other types of planting machines that are intermittently advancing dibble-type planters are on the market.

a) <u>Machine characteristics</u>: Planting components must work at the proper depth in the ground to achieve good results. As a matter of good practice, the operating manual supplied with the planter should be thoroughly studied. The Taylor, for example, must be operated at 56.25 kg/cm^3 (800 psi) hydraulic system downpressure when planting. The Taylor is the only machine tested that must be bolted to the back of the tractor. By far the easiest and most effective hookup has been achieved by removing the winch and bolting the Taylor to the tractor, using the winch mounting holes and adapter plates where necessary.[1] There are drawbacks to this method. Removing and remounting the winch is a heavy job, and many tractor operators are uneasy about working in the bush without their winches. An adapter plate must be fabricated and bolted to the tractor through the winch mounting holes. The Taylor is then bolted to the plate.

Most planting machines have a simple sandwich hitch or clevis hitch which requires only a pin to hook up to the tractor drawbar hitch. The Finn Forester requires a three-point hitch and power takeoff from the tractor.

The Dual Coulter and Crank Axle require hydraulic pressure to raise and lower the transport wheels only and do not require any down-pressure other than their own weight to penetrate the soil. Where soil conditions warrant, additional weights can be added to improve penetration. All of the machines we have encountered so far use angled wheels to pack the soil around the trees. Further addition or removal of stacked weights to the packing wheels or frame, as warranted by soil type or condition, will improve packing effectiveness.

The planting machines employ either rubber tires or shaped steel wheels for packing. We have been unable to detect any significant differences in effectiveness but tend to prefer steel wheels that can be modified (if need be) to suit conditions in the field.

Planting machines such as the Taylor and Dual Coulter that do not scalp the soil may require extra consideration with respect to frontal clearing. Small debris that is not removed by the V blade can jam the moving parts of the planter or otherwise hinder planting. The Crank Axle employs a scalper (Fig. 8) that provides for the removal of such debris. Riley (1975), having found that debris was still wedging between coulter and shoe in some cases, suggests that the Crank Axle be modified so that the coulter wheel will ride in a small groove in the toe of the shoe, thereby minimizing chances of fouling by debris.

b) <u>Safety</u>: The safety of the planter operator is of paramount importance. All of the machines tested were unsafe to some degree in boreal forest conditions. Improvements in safety and comfort on some planters were achieved through minor modifications such as the addition of padding, steel plate, mesh doors and slash guards. I consider the Taylor, as modified, to be a safe machine. Openings through which slash can pass into the planter operator's compartment must be

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[1] In our first trial with the Taylor (Cameron 1975) an adapter bracket was fabricated around the winch. It was a heavy, awkward setup which failed twice during a 20-ha (50-acre) trial. Taylor Machine Works Inc. in Louisville, Mississippi does have a winch bracket setup available, by make, for tractor hookup. I am unable to comment on its use or problems, or on contractor acceptance.

minimized. Slash deflectors should be installed where openings cannot be avoided. When it is necessary to back up for any reason, the planting machine should be raised from the ground. Failure to do so will clog the planting foot. It could also result in damage to the machine or in planterman injury due to unseen hazards.

A horn should be standard safety equipment on any planting machine. An electric car horn wired to the bulldozer or to a dry cell battery and operated from inside the planter compartment by an easily accessible button or other activating device must bring instant action from the tractor operator should anything go wrong with the planting machine. The tractor operator should be aware of the hazards involved and be prepared to act immediately upon hearing the signal. A single blast means "stop!" Two blasts mean "raise" or "reverse" depending on the machine. Three blasts mean "go ahead".

OPERATING PROCEDURES

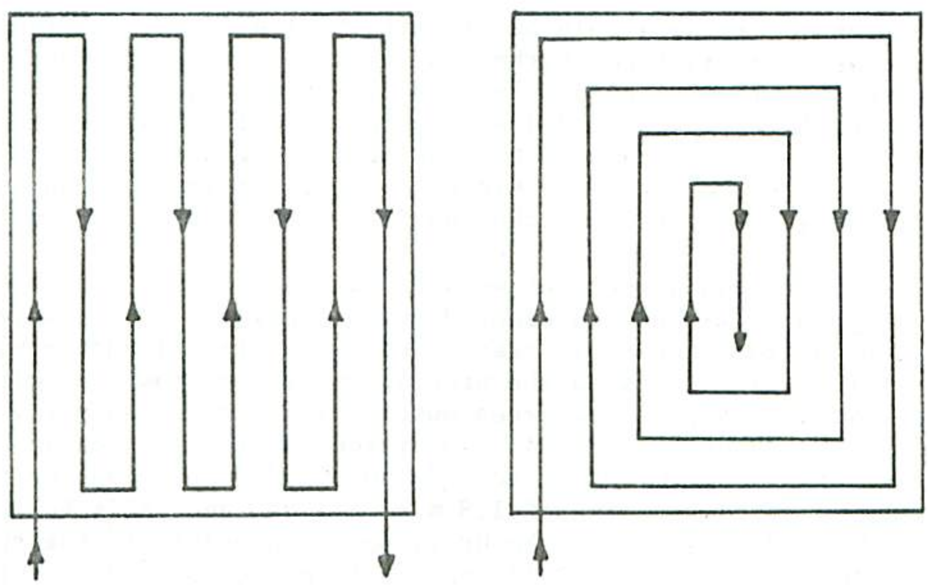
i) Project Planning

Areas requiring regeneration will usually occur as a result of final felling. The size, volume and distribution of the resultant logging waste will vary according to stand characteristics and harvesting methods. The site conditions of slope, humus depth and soil depth must be favourable in order to consider machine planting feasible. An economical machine planting operation is not likely to be carried out on sites of less than 20 ha (50 acres) in size. Site will influence the relative economy of various machines. It will influence the choice of equipment, area layout and mode of operation. Heavy slash, for example, will require a larger tractor than might ordinarily be used.

Those areas to be avoided in planting, such as heavy concentrations of residuals and soft areas, should be marked out. Soil conditions that might require two different packing pressures should be noted for separate planting. Then the planting pattern should be chosen. The choice will depend on the machine to be used and the site conditions. Most existing tree-planting machines must cover the entire area with planted rows (Bäckström 1970). The choice becomes one of either parallel or outline driving (Fig. 11).

Parallel driving is a pattern suitable for use under all planting conditions although it may not always be the most efficient. Turning times at the end of each planting row can diminish the productive planting times. For example, it usually takes a fixed time for a tractor to turn at the end of a row. This time will not vary whether the length of the row be 50 metres or 5,000. Therefore, long runs would be advantageous in a parallel driving situation.

Figure 11



With parallel driving, the operation is easily planned and carried out. When the parallel method is used, the planted area is always easily delineated. The operation can be shut down at any time and the planting done up to that point will be in a single, cohesive unit.

Outline driving girdles the planting chance in an ever-decreasing planted spiral until the centre is reached. A halt in the operation before completion leaves an island of unplanted area within a sea of planted seedlings. When planting with the outline driving technique is finished, the planting machine is in the centre of the planted area. This is often inconvenient, and destructive of the planted rows when the machine is walked out. Generally, outline driving should be avoided when undulating areas, where the planting machine may have to operate on dangerous side slopes, are being planted. Such areas can be traversed with parallel driving when the pattern is reoriented for down- or up-grades.

Rigidly mounted machines with limited lateral motion will dictate the pattern chosen. The Taylor is rigidly mounted on the back of the tractor so that any turning or swinging by the tractor is accentuated in the planter. When the coulter is in the ground making a continuous slit for planting trees, it will be forced to plow the soil with its side as it swings through a turn. Trees that are inserted are often uprooted or damaged by the packing wheels during turns. For these reasons, this machine must be lifted clear of the soil to make a turn. Trailing machines like the Crank Axle, the Dual Coulter or the Ontario Planter are able to follow a tractor through a curve because they can pivot where the hitch is attached to the tractor. A general recommendation for the Taylor, since it must be lifted to turn, is to use a parallel driving system. A trailing planter is suited to either parallel or outline driving.

ii) Stock Requirements

Tree seedlings should be of uniform size. Varying sizes within bundles upset the planting rhythm and generally reduce productivity. Trees with overall lengths of 30-45 cm (12-18 in.) are most acceptable for machine planting. The desired tree density is obtained by varying the width between planted rows and the mean plant spacing in the advancing direction of the machine. Closer spacing within rows can compensate for wider rows. This reduces the cost per planted tree (Brown 1966).

With the equipment that we are using at present, the minimum width we can achieve between planted rows is 2.1 m (7 ft). Below this width, debris from successive passes becomes a significant problem in damaging or burying trees in the previously planted row. As width between rows increases, more trees must be inserted in each row to maintain the same density level. Intertree spacing is greatly affected by tractor speed. If other factors do not hinder the planting process, an average intertree spacing of 1.8 m (6 ft) can generally be achieved if forward speed is about 1.6 km/hr (1 mph). However, if the speed is increased beyond 2.0 km/hr (1 1/4 mph), it becomes difficult for the operator to maintain a 1.8-m (6-ft) spacing because he cannot plant the trees quickly enough. To attain a spacing of less than 1.8 m (6 ft), tractor speed must be reduced correspondingly. This will vary somewhat according to the planter operator's ability and agility. The following examples illustrate the above points:

planting rate 900 trees/hr = 15 trees/min = 1 tree/4 sec

tractor speed 1.6 km/hr (1 mph) = 26.8 m/min (88 ft/min) = 1.79 m/4 sec (5.87 ft/4 sec)

spacing at 900 trees/hr and 1.6 km/hr (1 mph) = 1.79 m (5.87 ft)

tractor speed 2.0 km/hr (1 1/4 mph) = 33.5 m/min (110 ft/min) = 2.23 m/4 sec (7.33 ft/4 sec)

spacing at 900 trees/hr and 2.0 km/hr (1 1/4 mph) = 2.23 m (7.33 ft)

On the basis of our experience, we estimate that a reliable planting machine, operating at a speed that can be maintained all day by one man, should plant at least 800 trees per hour on reasonable site conditions. The machines tested all have trays for holding at least 500 to 1,000 spruce (*Picea* spp.) or jack pine (*Pinus banksiana* Lamb.) seedlings depending on size and age. We have worked mainly with 2-0 and 3-0 nursery run stock. Restocking is therefore required at least once an hour. To avoid running out of stock at a location remote from the supply, restocking of trays should take place well before they are empty.

iii) Organization

Given an average planting day of 8 to 10 working hours, two planter operators will be required for a machine. It is tedious and demanding work requiring high production in terms of numbers of trees planted per hour. In order to keep the planterman continuously engaged in planting trees, a second man is required to prepare stock for loading into the holding trays of the planter. Supplies and stock should be located in an accessible shady place convenient to the planting chance, and water should be available for caring for the stock. This is part of the second man's duties. Other duties would include assessing planting quality, spacing and distribution and providing feedback to the planterman and tractor operator as well. At regular, specified intervals, such as the end of a planting row or some other mutually acceptable arrangement, the plantermen should alternate jobs. One uninterrupted hour on the machine would be the maximum time permitted.

Initial instructions by the supervisor and follow-up help when problems occur can often nip poor operating practices in the bud and will reduce opposition to the use of planting machines. The supervisor and the plantermen should recognize the proper tractor speed, site clearing, coulter penetration, packing, planting depth and intertree and interrow spacing that are required to suit the site conditions and the planting prescription. Should anything be amiss, either the supervisor or the planter operator should make the necessary adjustments or provide feedback and instructions to the tractor operator to correct the unit's performance. The earlier the changes are made, the better for all concerned. Communication is a very necessary part of a mechanical planting operation just as it is in a hand planting operation.

iv) Servicing and Maintenance

Planting machinery used in the rough conditions associated with bush work in northern Ontario requires regular maintenance. A proper maintenance program will save a great deal of possible downtime due to inopportune breakdowns, and it will serve to familiarize the crew with the machine's operation. The operator should read the operating manual supplied with the machine. Understanding the machine's operation is important for safety reasons as well as for maximum productivity. Also, the tractor operator who understands the planter's functioning will be able to tailor his tractor operation to that of the machine.

Planting machine maintenance should be on a regular daily basis. The start of the shift is the best time to do maintenance for three reasons: 1) it is nearly impossible to spot oil leaks under the unit at the end of a shift; 2) inspection time allows a warm-up period for those planters equipped with engines or hydraulic systems; (Greasing can also be done at this time.) 3) this is the best time to spot vandalism, before machine damage or operator injury (Anon. 1975). The operator should make a habit of removing excess dirt and branches from the machine on a daily basis. Nuts and bolts, on the planting foot, on packing wheels, and especially on flanges holding coulters, should be checked and tightened daily. Daily cleaning and greasing of all moving parts is necessary, as is checking of the hydraulic hoses for leaks and wear. A daily onceover check will result in savings in downtime due to preventable and inopportune breakdowns.

Daily servicing also applies to the auxiliary motors and pumps on such machines as the Crank Axle and the Ontario Planter. Refueling, depending on tank capacity, should be done regularly at convenient stoppages in conjunction with reloading stock.

Ideally, the planter operator should have on hand enough tools to carry out proper routine servicing of the planting machine. Supplies would include electrical tape, a grease gun and spare grease nipples, an assortment of nuts and bolts and other spare parts that are normally replaced on a regular basis. In addition, there should be on hand the standard tools of any bush operation: shovel, axe, chainsaw, crowbar, sledgehammer, length of chain, pry bar, bucket and fire extinguisher.

SITE DIFFICULTY

There has been a tendency to relegate machine planting to the most difficult sites rather than to the most operable. Areas that are steep-sloped, shallow-soiled, excessively wet, or covered with heavy residuals should be avoided when planning a machine planting operation.

As mentioned earlier, areas to be regenerated by machine planting are usually the result of clear-cut mechanical harvesting. From an economic point of view, the minimum size of treatment in both cases is about 20 ha (50 acres). The so-called clearcuts may still support patches of large residuals of undesirable species. The amount and distribution of slash remaining on the site will vary depending on wood utilization and method of harvest. Such areas differ in stumps, slash, residuals and soils.

Machine performance will be discussed with respect to these factors.

i) Stumps

If the V blade and scalping foot unit is being operated properly, stump frequency, diameter and height should not markedly reduce plantable distance available. However, a poorly designed or operated blade can produce real losses in terms of production efficiency. Stumps have been the major agent of tractor hangup and planter damage. To minimize this problem, the tractor operator should be instructed to move around stumps wherever possible; only unavoidable stumps and/or those higher than the clearance of his tractor should be removed.

ii) Slash

Slash can be considered in two categories: the large-diameter, long material such as downed chicots, residuals and mixed tree lengths from the skidding operation; and small material, generally small stems and branches. Long slash poses an obstacle to forward motion of the tractor and requires power to move it. A V blade encountering such material will swing it until it passes out of the planter path. This slash can rip out planted trees in adjacent rows and can be encountered by the unit on several passes. Given a 2.4-m (8-ft) interrow spacing prescription and 1.8-m (6-ft) intertree spacing, the number of planted trees affected by large slash in volumes of up to and exceeding 70 m^3/ha (1,000 cu. ft per acre) is minimal.

The smaller material, if not removed from the planting path, can foul a planting machine, become a safety hazard to the planter operator, and foul the packing operation. For instance, if it remains in the planting path it can prevent the planter from preparing a slit; it can fill the slit so that a tree can't be inserted; or if the tree is planted, the debris can dissipate the packing force of the packing wheels away from the tree, leaving loose trees.

A properly operating V blade scalping foot will minimize these problems without causing increases in interrow width.

iii) Residuals

Residuals are best left standing, for if knocked down they behave as large slash. Areas where many large residuals occur should be avoided in a mechanical planting operation. Pockets of large balsam poplar (*Populus balsamifera* L.) and trembling aspen (*P. tremuloides* Michx.) or white birch (*Betula papyrifera* Marsh.) residuals, for example, which are left from a clearcut, should be avoided when planting. Other clearcuts where residuals number about 10 to 60 per ha (5 to 25 per acre) can be planted while those trees are left standing.

Areas supporting smaller residuals such as aspen suckers and speckled alder (*Alnus rugosa* [Du Roi] Spreng.), occurring at frequencies as high as 42,000 stems/ha (17,000/acre), have been planted. They behave more like small slash when knocked down. A suitable V blade will do an acceptable job in these conditions.

iv) Soil

It is important that soil problems be discussed. We have tested planting machines on both main soil types, sand and clay. Clay sites, because they are more fertile than sand sites, have increased vegetative competition for planted stock. Black spruce (*Picea mariana* [Mill.] B.S.P.) and white spruce (*P. glauca* [Moench] Voss), the usual choices for these sites, are less tolerant than jack pine of planting stresses. Clay sites which are scalped, exposing the clay, are subject to baking, runoff and frost heaving problems. This is a good reason for prescribing that trees be planted without completely removing the duff layer. The duff layer protects the soil by holding moisture and providing the seedlings with some nourishment. Heavy soils are also difficult to pack. Additional weights on the planter will improve penetration and packing in this type of soil.

Moisture in the soil creates further problems, as too much coulter or packing weight in soft, mucky ground squeezes the soil up around the planting foot and packing wheels, making it very difficult to plant a tree. The solution is to plant these areas separately, adjusting the penetration and packing weights to the prevailing condition in each case.

Planters incorporating scalpers, such as the Crank Axle, would not perform so well from the biological standpoint, especially when it comes to exposing clay soils (Riley 1975). The slit or dibble would be better employed in minimizing mineral-soil exposure in this type of soil.

By comparison, sand soils pose little problem. Most of the planting machines we have tested will plant trees satisfactorily in boreal forest sand cut-over conditions.

Areas where appreciable amounts of subsurface boulders, bedrock or frozen ground occur are generally not suited to mechanical planting with the equipment available at present.

COST

Generally, in a single-pass site preparation and planting operation, costs are comparable to those of site preparation and hand planting for similar areas. In the boreal forest conditions of northern Ontario, up-to-date site preparation costs have been in the area of $37 to $62 per ha ($15 to $25/acre) and hand planting costs from $74 to $111 per ha ($30 to $45/acre) on OMNR operations. Normal costs[2] for machine planting based on our trials have been between $99 and $173 per ha ($40 and $70/acre) over the past 5 years.

SUMMARY

As the introduction to this paper points out, mechanized tree planting has not been employed to any extent in Ontario. In fact, in any

[2] These costs result from removing those outside influences on planting costs that are due to the testing and modification nature of the trials and are a fairer representation of what the costs would be under operational conditions.

of Canada's provinces, work with mechanical tree planters has been minimal. The time is fast approaching, however, when this will not be the case. Because of regional labour shortages and for economic reasons we will be using new and different planting units which must be given every opportunity to work successfully. Everyone concerned, from supervisor to planterman, must have the right attitude where planting machinery is tried for the first time. Silversides (1972) observes that "Operators, mechanics, supervisors must all be conditioned to receive new and different units, and be determined to make them work. The importance of the manner in which new equipment is introduced on operations cannot be over-emphasized and a considerable amount of the poor experience with new machines can be traced to this cause".

Planting machine operation in boreal forest cutovers of northern Ontario has certain prerequisites for success. Besides employing a bush-equipped bulldozer of adequate horsepower with or without auxiliary hydraulic capabilities as required, experience has shown that regardless of the type of planting machine, planting quality and production efficiency are very positively related to preparation of a suitable planting microsite. A tractor V blade and scalping foot unit is designed to do that job. Feedback, early corrective action and instruction will give benefit far outweighing the input required. Strict adherence to the machine operating instructions and a definite schedule of regular servicing and maintenance are major factors in a successful operation. Machine availability will increase and operators will become more skilled as technical information becomes available to the users and to the equipment manufacturers.

RÉSUMÉ

En Ontario, la plantation mécanique des arbres n'est pas populaire. De fait, cet état de choses existe partout au Canada. Cependant, dans un avenir rapproche, il n'en sera plus ainsi. En raison de pénuries régionales de main d'oeuvre et pour des raisons économiques, nous utiliserons des planteuses nouvelles et différentes qui doivent pouvoir donner un bon rendement. Tous ceux qui sont concernes, du surveillant à celui qui opère la planteuse, doivent avoir une bonne attitude lorsque la planteuse est essayée pour la première fois. Silversides (1972) observe que "Les opérateurs, les mécaniciens, les surveillants doivent devenir receptifs au machines nouvelles et différentes: et qu'ils soient déterminés à les faire fonctionner. On doit insister beaucoup sur l'importance de la manière dont les nouveaux engins sont présentés au personnel et un grand nombre de mauvaises expériences avec ceux-ci proviennent de cette cause".

Afin que les plantations mécanisées en forêt déboisée dans la forêt boréale soient couronnées de succès, on doit observer certaines normes. Outre l'utilisation d'un bulldozer bien équipe pour les travaux forestiers et suffisamment puissant, avec accessoires hydrauliques requis, on a démontré que quel que soit le type de planteuse, la qualité de la plantation et l'efficacité de production dépendent très nettement de la préparation d'une microstation convenable de plantation. Une lame de tracteur en V et un accessoire servant à "scalper" doivent faire ce travail. Une réaction et une action corrective et des instructions rapides contribueront à l'emporter sur la consommation requise. Deux facteurs importants de succès sont l'observance stricte des instructions pour opérer la planteuse et un programme défini de réparations et d'entretien. Le choix de planteuse augmentera et les opérateurs deviendront plus habiles à mesure que plus d'informations techniques deviendront connues des utilisateurs et des industriels.

REFERENCES

Anon. 1966. Annual Report. Ont. Dep. Lands For., Toronto, Ont. 358 p.

Anon. 1971. Statistics 1971. Ont. Dep. Lands For., Toronto, Ont. 325 p.

Anon. 1974. Statistics 1974. Ont. Min. Nat. Res., Toronto, Ont. 116 p.

Anon. 1975. Is your unit's hydraulic system a profit or loss centre? Can. Pulp Pap. Ind., April, p. 103, 106.

Brown, G. 1966. The use of modified wildland tree planters. Silvic. Notes No. 10, Ont. Dep. Lands For.

Backstrom, Per-Ove. 1970. Performance and cost of mechanized tree planting. R. Coll. For., Stockholm, No. 19.

Cameron, D. A. 1975. Testing and evaluation of mechanical tree planters. p. 59-69 *in* Mechanization of silviculture in northern Ontario. Can. For. Serv., Sault Ste. Marie, Ont. Symp. Proc. O-P-3.

Riley, L. F. 1975. Operational testing of planting machines in the boreal forest of Ontario. I. Reynolds-Lowther Heavy Duty Crank Axle Planter. Can. For. Serv., Sault Ste. Marie, Ont. Report O-X-219. 37 p.

Rowe, J. S. 1972. Forest regions of Canada. Can. For. Serv., Ottawa, Ont. 172 p.

Silversides, C. R. 1964. Developments in logging mechanization in eastern Canada. Univ. B.C., H. R. MacMillan Lect. For. 29 p.

Silversides, C. R. 1972. Achievements and failures in logging mechanization - Why? Pul Pap. Mag., Feb.