OPERATIONAL TESTING OF PLANTING MACHINES IN THE BOREAL FOREST OF ONTARIO

II. Taylor Drum Tree Planter

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FOREWORD

Traditionally, artificial regeneration on both Crown and private lands in Ontario has centred on hand planted bare-root stock. Despite chronic regional labour shortages, ever-increasing labour costs, and often poorly qualified and unmotivated planters, the alternative, machine planting, has never been fully explored or accepted in Ontario.

The Americans and Scandinavians have been using a variety of planting machines for some time. Although these machines are generally commercially available, little information on their use exists except, perhaps, in promotional material released by the manufacturers. Little published data are applicable to areas needing reforestation in Ontario.

In view of the impact made by the almost complete mechanization of harvesting and of the opportunity for adapting mechanization procedure to forest regeneration as well, the Ontario Ministry of Natural Resources (OMNR) and the Great Lakes Forest Research Centre (GLFRC), under the sponsorship of the Canada-Ontario Joint Forestry Research Committee, embarked on a cooperative program to mechanize reforestation operations in Ontario. This program was to entail operational testing of equipment (with field staff involvement) in a number of OMNR districts from 1971 to 1974. The objectives were to obtain an appreciation of the potential for machine planting in the boreal forest, and to provide information on the performance and limitations of conventional planting machines. The latter is essential to the evaluation of the Ontario Planter, a totally new type of planting machine being developed as part of the cooperative mechanization program.

ACKNOWLEDGMENTS

The author wishes to acknowledge the cooperation of the Ontario Ministry of Natural Resources in Cochrane, Dryden and Terrace Bay districts as well as the Ontario Paper Company at Manitouwadge. The valuable assistance of F. F. Foreman, Forestry Technician, in the conduct of the field work is greatly appreciated.

ABSTRACT

Six operational machine-planting trials were carried out on two general soil types to determine the suitability of the Taylor Drum Tree Planter for use in typical boreal forest conditions in Ontario. Site conditions such as stumps, slash, residuals, soil and slope were assessed to determine their effect on planting rate and quality. Changes in operating procedure and machinery modifications resulted from time studies conducted during the trials. The costs of planting with the Taylor and those of the usual alternative of site preparation and hand planting are both included in this report for comparison purposes.

The most critical factor in machine planting is the ability of the prime mover to clear a debris-free path immediately in front of the planting unit. Four different V-blades were used in the trials and are commented on in this report.

We have found the Taylor to be the safest planting machine we have tested to date. It is rugged, yet adaptable to a wide range of planting sites. It is capable of effectively, efficiently and safely regenerating most rock-free sand and clay sites at reasonable cost.

RÉSUMÉ

On a effectué six essais sur le fonctionnement de planteuses mécaniques d'arbres sur deux types généraux de sols pour déterminer le rendement de la planteuse à tambour de marque Taylor en forêt boréale typique dans l'Ontario. On a évalué les diverses situations qu'on peut relever dans une station: souches, déchets d'abattage, arbres restants, sol et pente du terrain pour déterminer leurs effets sur le taux et la qualité de plantation. Des changements dans les méthodes d'opération ainsi que des modifications à l'équipement utilisé ont été le résultat d'études chronométrées menées pendant les essais. Pour fins de comparaison, on a inclus dans le présent rapport les coûts de plantation au moyen de la machine Taylor et ceux de la préparation habituelle du sol et de la plantation manuelle.

Le facteur le plus critique de la plantation mécanique consiste dans la capacité du premier engin à libérer tous les débris de la voie immédiatement devant le mécanisme de plantage. On a employé quatre modèles distincts de lames en V lors des essais et le présent rapport apporte des commentaires sur leur rendement.

La planteuse mécanique Taylor s'est avérée la meilleure, du point de vue sécurité, que l'on ait expérimentée à ce jour. Elle est robuste et s'adapte à une grande variété de stations. Elle peut efficacement et en toute sûreté, régénérer la plupart des stations sableuses libres de cailloux et des stations de terre argileuse, moyennant un coût raisonable.

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INTRODUCTION

Approximately 400,000 acres (161,874 ha) of forested land are harvested annually in Ontario, but only 75% of this area is regenerated either naturally or artificially (Anon. 1971). The remainder, more than 100,000 acres (40,468 ha), is added to a steadily increasing backlog of unregenerated area requiring treatment. Of the 300,000 acres (121,406 ha) treated annually, the majority are hand planted using bare-root stock. Some direct seeding and container planting are carried out as well, but there is every indication that bare-root planting will continue to be the principal technique employed in Ontario's regeneration program for the forseeable future.

In 1972 Ontario announced a considerable expansion of its annual regeneration program and these targets were raised again in 1975 (Reynolds 1975). This, coupled with regional labour shortages, high costs, and all the problems associated with a large seasonal work force, leads to the conclusion that reliance on manual planting methods is not possible. More effective and efficient methods are required.

In planning for the joint OMNR—GLFRC program for the development and testing of mechanical regeneration methods, it was agreed that OMNR would be responsible for the purchase or development of equipment and for the conduct of operational trials, and that GLFRC would be responsible for the site assessments, work studies, planting quality assessment, biological and economic studies and reporting of results.

For the conduct of one series of trials, a Taylor Drum Tree Planter (Model 60D)[1] was purchased from Taylor Machine Works in Louisville, Mississippi in the fall of 1971. Testing of the Taylor began in the spring of 1972 and continued until the spring of 1974. Six trials were conducted, and the results are reported herein.

It is important to note here that the trials were set up to determine the planter's ability to cope with various site conditions, to point out areas for design modification, to improve planting quality and performance, and to determine efficient and effective operating techniques in Ontario's boreal forest conditions. Although we made strenuous efforts to achieve operational efficiency, there is still room for improvement.

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[1] The use of trade names in this report is solely for the information of the reader and does not constitute endorsement by the Canadian Forestry Service of the products named.

Equipment

A complete operational planting unit was considered to be the planting machine, the prime mover, and a site clearing attachment (e.g., a V-blade).

(a) Planting Machine: The planting machine is made up of three independent sections hinged to the hitch assembly (Fig. 1-3).

(i) *The drum coulter* section prepares the ground for the planting and packing actions which follow. The rolling drum crushes loose surface material not removed by the V-blade while the attached coulter cuts through this material producing a continuous planting slit in the soil about 1 ft (30 cm) deep by 1½ in. (4 cm) wide. The drum coulter and the frame that supports it pivot around a horizontal axis at the hitch assembly, independent of the rest of the machine except in the extreme upward position where pivoting is stopped by contact with the other sections. The section is therefore free to follow ground irregularities except when the limit of upward travel is reached.

The coulter section is hydraulically controlled by a pair of cylinders attached to the hitch assembly. The hydraulics exert down-pressure on the drum during planting to provide proper ground penetration by the coulter. Damping control is provided through a built-in accumulator so that the ride is smooth and safe, even in rough conditions. Recommended system operating pressure is 800 psi (56.25 kg/cm^2). The absence of pressure results in the coulter yielding to ground obstructions and jumping erratically, jeopardizing planting quality as well as operator safety.

(ii) *The planting foot* follows the coulter and keeps the slit open while the tree is positioned in the ground. Planting depth is limited by coulter penetration, maximum depth being approximately 1 ft (30 cm).

(iii) *The packing wheels and planter cap* comprise the third section. The planter operator is seated directly over the rigidly mounted packing wheels, with his legs straddling the planting foot. A tree placed in the planting slit is caught up by the soil and packed by the two steel packing wheels immediately to the rear of the planting foot. The cab and packing wheels also follow surface irregularities except in the extreme upward positions of the drum coulter.

The operator is enclosed in a heavy steel cab open only at the rear and at the planting foot. With the addition of a steel mesh door to the rear of the steel cab, the planter operator is well protected. A horn mounted on the planter is used by the planter operator for safety and operational communication with the tractor operator.

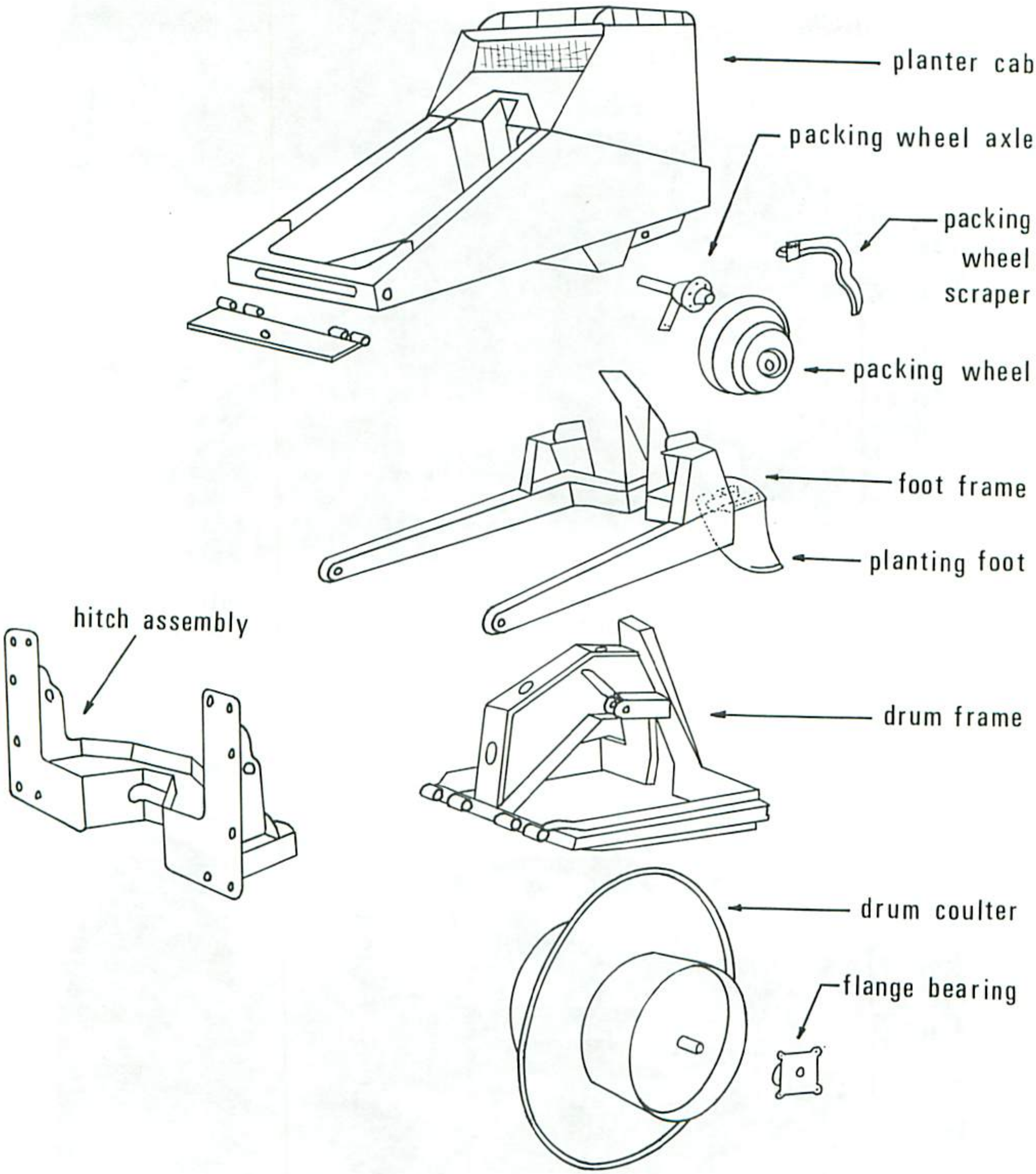

Fig. 1. Schematic of Taylor Drum Tree Planter Model 60-D.

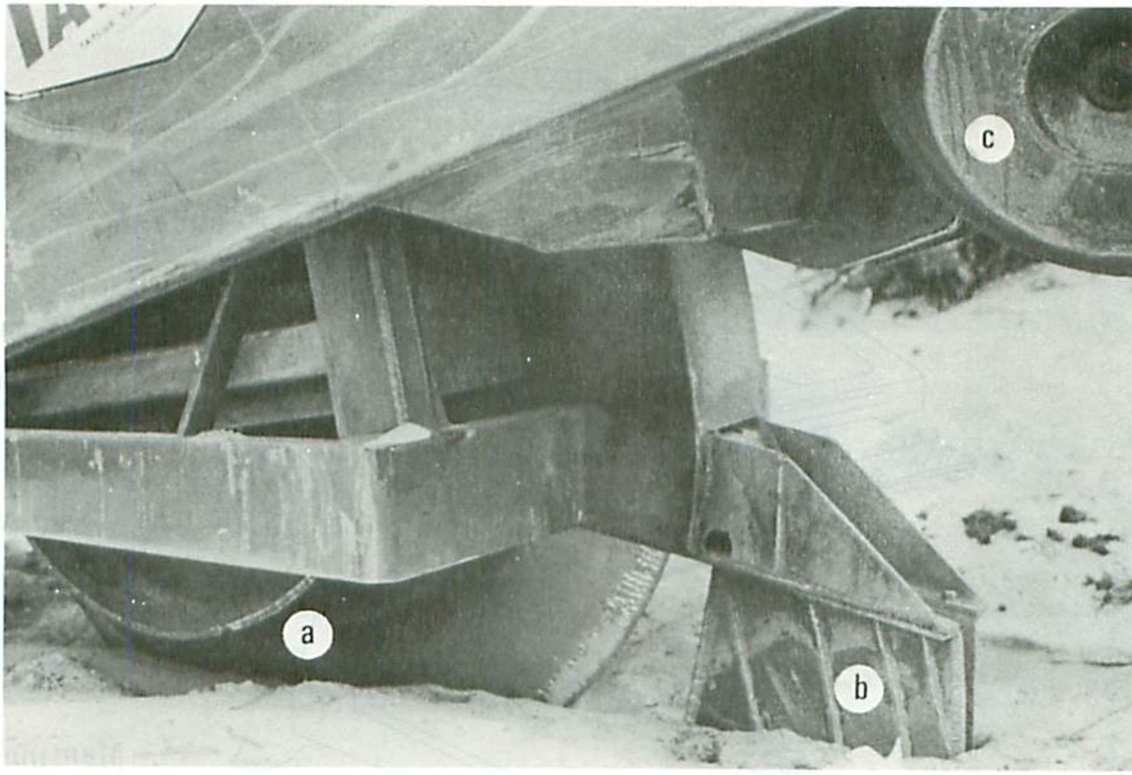

Fig. 2. View of Taylor's working components: a) drum coulter, b) planting foot, and c) packing wheel in raised position.

Fig. 3. Taylor (in raised position) attached to adapter bracket around winch on D6 tractor. Auxiliary pump and motor mounted above bracket.

The Taylor is designed to be bolted directly to the back of a bulldozer, or in the case of a tractor outfitted with a winch, to an adapter bracket which encases the winch. The hydraulic cylinders enable the planter to be lifted clear of the ground for transport or turning. Hydraulic power is most effectively supplied and controlled from the tractor. Lateral movement is severely restricted by planter design.

(b) Tractor: Five different tractors, including both bulldozers and crawler loaders, were used in the trials, all of them in the 100 to 140 net horsepower range. In the first trial, the contractor chose to keep his winch on the bulldozer. This forced us to fabricate an adapter bracket around the winch in order to attach the planter (Fig. 3). As the tractor had no auxiliary hydraulic capabilities, a small gasoline engine and pump unit were rigged to handle the planter hydraulics. Both arrangements were awkward and created unacceptable operational inefficiencies.

We found that by far the easiest and most effective hookup was to remove the winch, and bolt the Taylor directly to the back of the tractor using an adapter plate if necessary. Bulldozers, with auxiliary hydraulic winch pumps, or crawler loaders, can supply the required hydraulic power to operate the planter. A separate lever mounted on the tractor to raise, lower and set hydraulic downpressure on the planter is desirable.

Although the Taylor can be mounted on a crawler loader, there are certain drawbacks to using a loader in cutover conditions. The major one is the loader's fixed beam undercarriage rather than walking beam type used on bulldozers. The walking beam gives additional flexibility and mobility in rough conditions. Generally, loader tracks are also equipped with street or pit grousers which do not provide the required traction.

(c) V-blade: On any mechanical planting operation in cutover conditions, slash and debris must be removed to prepare a suitable planting microsite, and to ensure machine and operator safety. A V-blade with attached scalping foot is one method of achieving this condition. Because the Taylor has no ground clearing capability of its own, the V-blade and scalping foot must clear a path, at least as wide as the planting/packing components, through debris which would otherwise hinder planting and packing performance. The blade is attached to the C-frame of the tractor or, in the case of a crawler loader, to the loader arms to complete the planting unit.

A variety of blades was used on the trials. A D7, full-width, curved-face V-blade with a 4-in. (10-cm) scalping foot proved to be too large for the equipment used on the first trial. It was inefficient and prepared the site inadequately. A Beloit, D6, full-width, curved-face

V-blade with an 8-in. (20-cm) scalping foot did an adequate job in areas of low stumps and light slash (Fig. 4). Increasing the scalping foot depth to 12 in. (30 cm) improved performance. Debris buildup occurred on the curved faces of the V-blades in areas of heavier slash. This tended to reduce productivity as the tractor had to raise the blade frequently to clear it.

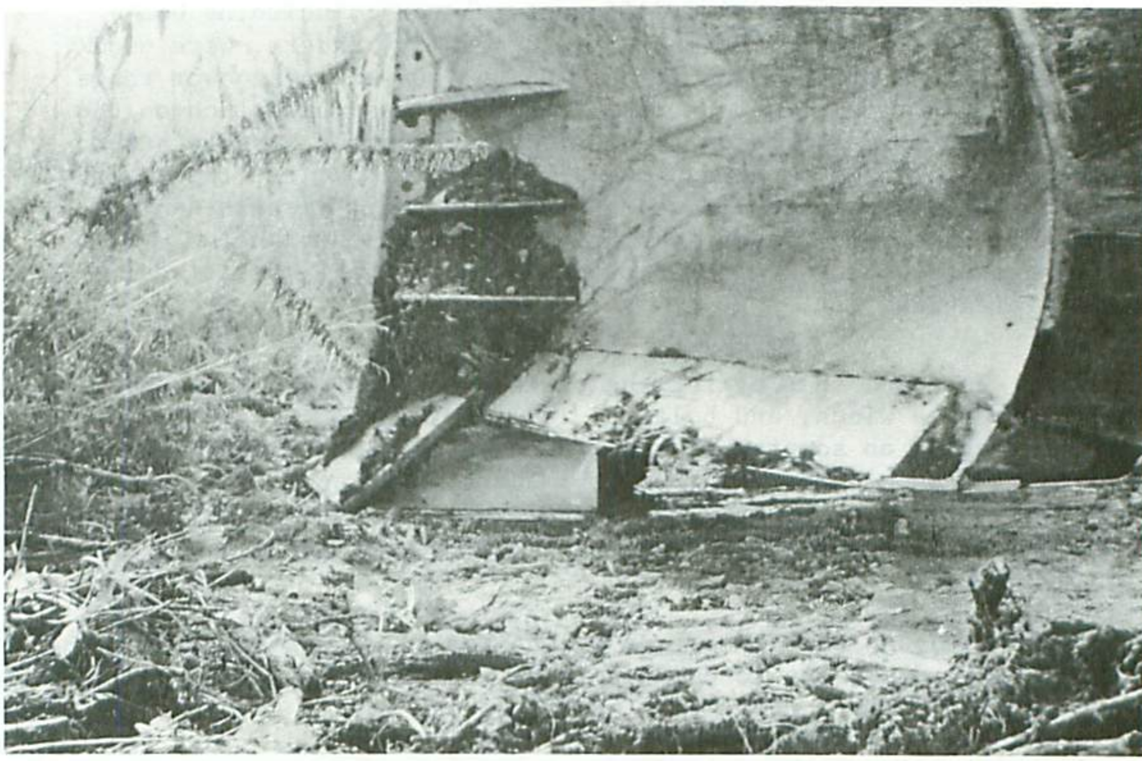

Fig. 4. Side view of 8-in. (20-cm) scalping foot bolted to bottom of curved-face V-blade.

An 8-ft (244-cm)-wide, straight-faced V-blade with a 12-in. (30-cm) scalping foot was found to be too light for the Cochrane 1974 trial conditions in which it was used (Fig. 5). A CFS V-blade was used in the last planter trial and gave promising results (Fig. 6).

Planting Sites

<u>(a) Camp 70</u>: This area, typical of many flat, dry, sandy, jack pine (*Pinus banksiana* Lamb.) sites, had supported a good stand of jack pine with a minor black spruce (*Picea mariana* [Mill.] B.S.P.) component and very few cull trees. It is situated some 16 miles

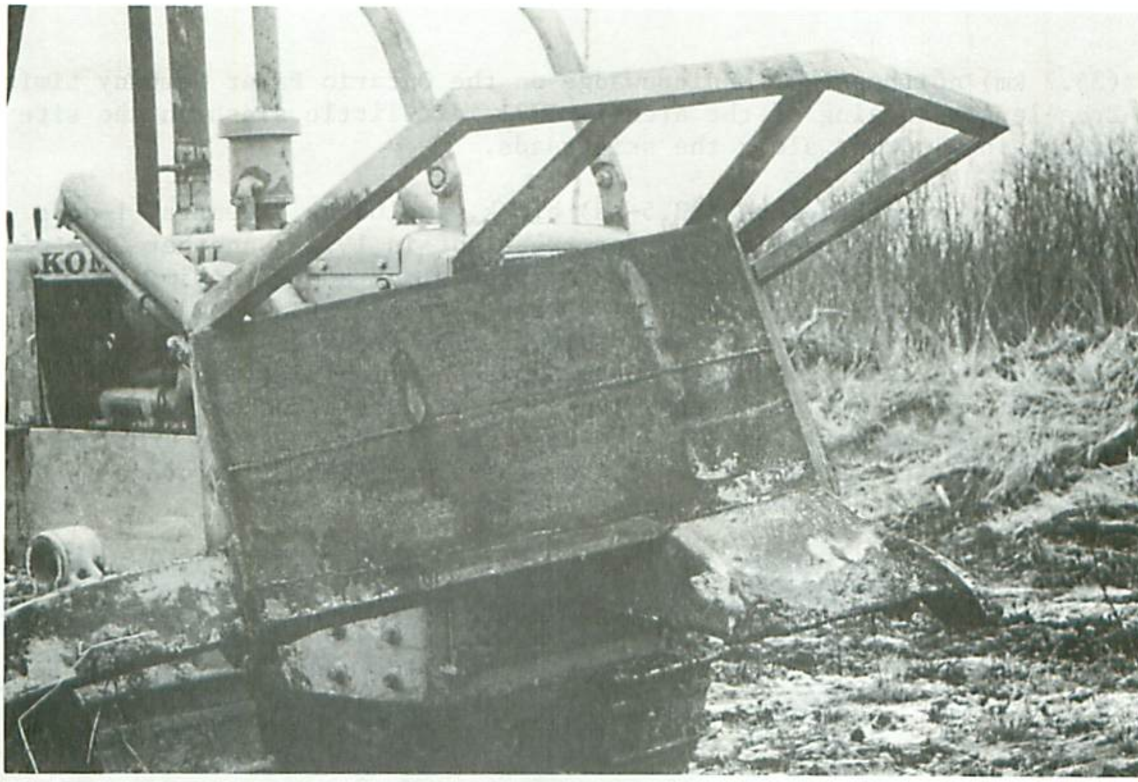

Fig. 5. Straight-faced V-blade with 12-in. (30-cm) scalping foot.

Fig. 6. CFS V-blade mounted on a Komatsu D65A bulldozer. Note central adjustable scalping foot.

(25.7 km) northeast of Manitouwadge on the Ontario Paper Company Limits. Tree-length logging of the area in 1971 left little slash on the site except in windrows along the skid roads.

A single 58-acre (23.5-ha) block, including a central 1-acre (0.4-ha) pond, was delineated for treatment in 1972. Another area of 35 acres (14.2 ha), adjacent to the first block and with similar site conditions, was established in 1973 for a second trial. A ravine and tiny creek ran across the latter block. The creek and ravine, with sides in excess of 25% slope, were avoided during planting because the tractor lacked sufficient traction to clear debris and pull the machine in its planting position. High stumps on the area created problems during the first trial (Fig. 7), but these were generally overcome by the better V-blade used in the second trial.

Fig. 7. The 1972, Camp 70 site. The area is flat and sandy with light jack pine slash and high stumps.

(b) Dryden: Two flat-to-gently-rolling clay sites were chosen in Rugby Township about 16 miles (25.7 km) northwest of Dryden. This was a typical mixedwood area which had supported large trembling aspen (*Populus tremuloides* Michx.) and balsam poplar (*P. balsamifera* L.) and a mixture of jack pine and spruce. Large stumps and heavy poplar slash remained scattered over the area after winter logging in 1971-1972. Subsequently the fertile, moist site developed an abundant population of poplar suckers and alder (*Alnus rugosa* [Du Roi] Spreng.) (Fig. 8).

Fig. 8. The Dryden site supported abundant alder and poplar suckers and scattered poplar residuals at the time of planting.

One 35-acre (14.2-ha) block and an adjacent 47-acre (19.0-ha) block were chosen for the trials. The study was broken into two trials. Of the 35-acre block, 28 acres (11.4 ha) were designated the 'before modifications' trial. The remaining 7 acres (2.8 ha) plus 20 acres (8.1 ha) of the larger block were designated the 'after modifications' trial. The remaining area was machine planted by OMNR at the end of the trials.

(c) Cochrane: Two flat-to-gently-rolling upland sites were chosen in Challies Township about 35 miles (56.3 km) east of Cochrane on the Abitibi Paper Company Limits. A 23-acre (9.3-ha) block and an adjacent 30-acre (12.1-ha) block were located on this typical, fresh-to-moist Clay Belt site. Pockets of wet muck were present in both areas. Logging took place in 1958-1959 and, as a result, existing stumps and slash were well rotted. Prior to cutting, the area supported a stand of white spruce (*Picea glauca* [Moench] Voss) and black spruce, balsam fir (*Abies balsamea* [L.] Mill.), trembling aspen, balsam poplar and white birch (*Betula papyrifera* Marsh.). At the time of planting, the ground was covered with a heavy growth of alder and young poplar. Large old poplar residuals were also present (Fig. 9).

Fig. 9. The Cochrane site. The alder has been knocked down during the passage of the tractor/planting unit. Large poplar residuals remain standing after completion of the planting.

Operating Procedures

We carried out the first trial to familiarize ourselves with the operation and capability of the test unit. Because the determination of limiting site conditions was one of the aims of the trials, the approach was to move gradually from "easy" to "difficult" sites as the trials progressed.

Cut-over jack pine sand flats are considered the easiest planting sites commonly encountered in Ontario's boreal forest. Increasing amounts of stumps, slash, rock, and adverse slopes can be expected to increase the difficulty of machine planting. Clay sites are generally more difficult planting chances than sandy sites because clay soils are more difficult to penetrate and more effort is required to pack the soil once the tree has been placed in the planting slit.

Availability of shop facilities for repairs and modifications was considered in the choice of locations for these trials. Another factor was the desire to familiarize a cross-section of OMNR field staff with mechanized planting operations.

Project planning for the trials rested with GLFRC staff. After reconnaissance of the planting chance, a planting pattern was chosen and assessment plots established. From this point, Ministry staff assumed responsibility for all operational details--stock requirements, planting prescription, supervision, planting organization and servicing.[2]

Assessments

Prior to planting, the sites were assessed for those physical factors which we thought might affect the passage of the tractor or the planter, the mechanics of planting and packing, and subsequent survival.[3] The results of the site assessment are outlined in Tables 1 to 5.

Table 1. Stump assessment

Location	Frequency (per acre)[a]	Avg ht (in.)[b]	Ht range (in.)	Avg diam (in.)	Diam range (in.)
Camp 70, 1972	246	12.4	3-26	9.4	2-18
Camp 70, 1973	215	10.9	3-20	9.6	2-22
Dryden 1972 before modification	69	13.6	6-48	13.7	6-18
Dryden 1972 after modification	98	11.3	4-36	12.7	4-18
Cochrane 1973	344	15.8	6-24	11.2	5-20
Cochrane 1974	107	18.8	6-55	8.1	2-15

[a] 1 acre = 0.40 ha

[b] 1 in. = 2.54 cm

2 For further information on organizing a machine planting operation refer to Cameron (1975b).

3 For further information on the method of site assessment refer to Riley (1975) Appendices A and B.

Table 2. Slash assessment

Location	Pieces (per 66 ft[a] of tally) <3 in.[b]	3 in.+	Avg diam (in.)	Diam range (in.)	Avg length (ft)	Length range (ft)	Volume (cu. ft/acre)[c]
Camp 70, 1972	16	8	5.1	1-14	13.2	1-63	1130
Camp 70, 1973	7	6	5.8	1-15	17.7	2-73	1115
Dryden 1972 before modification	26	4	5.1	1-13	18.7	3-44	650
Dryden 1972 after modification	32	5	5.3	1-13	13.2	1-38	760
Cochrane 1973	2	6	8.0	1-18	23.4	6-56	455
Cochrane 1974	1	2	7.9	1-18	20.0	5-70	444

[a] 1 ft = 30.48 cm

[b] 1 in. = 2.54 cm

[c] 1 cu. ft/acre = 0.07 m^3/ha

Table 3. Residual tree assessment

Location	Alder[a] density per acre[b]	Frequency (per acre) <4 in.[c] DBH	4 in.+	Avg DBH (in.)	Diam range (in.)	Avg ht (ft)[d]	Ht range (ft)
Camp 70, 1972		0	0	0	0	0	0
Camp 70, 1973		9	1	2.9	2-6	14.4	5-30
Dryden 1972 before modification		710	30	2.6	2-13	30.1	10-60
Dryden 1972 after modification		1280	18	2.2	2-13	28.2	10-50
Cochrane 1973	15,500	302	62	4.5	2-24	25.4	10-80
Cochrane 1974	15,500	92	29	5.3	2-21	51.2	10-80

[a] Alder was measured separately in Cochrane. It ranged from 1 to 2 in. DBH and from 8 to 15 ft high.

[b] 1 acre = 0.40 ha

[c] 1 in. = 2.54 cm

[d] 1 ft = 30.48 cm

Table 4. Slope assessment

Location	Level (± 2%) (% of lineal tally)	Avg slope (%)	Max up-slope (%)	Length of max upslope (chains)[a]	Max down-slope (%)	Length of max down-slope (chains)
Camp 70, 1972	90.1	0.3	12	.3	-8	.5
Camp 70, 1973	69.2	2.0[b]	31	.5	b	b
Dryden 1972 before modification	42.5	1.1[b]	14	.5	b	b
Dryden 1972 after modification	67.9	1.1[b]	12	1.0	b	b
Cochrane 1973	56.0	1.6[b]	5	1.0	b	b
Cochrane 1974	90.0	0.3[b]	3	1.0	b	b

[a] 1 chain = 20.12 m

[b] Planting unit travelled in both directions so that maximum downslope was the same as maximum upslope.

Table 5. Soil and vegetation assessment

Location	Minor veg.	Depth to mineral soil (in.)[a]	Texture	Soil depth (ft)[b]	Soil moisture
Camp 70, 1972	light	1-5	sand	>3	dry
Camp 70, 1973	light	1-6	sand	>3	dry
Dryden 1972 before modification	medium	1-2	clay	>3	dry-fresh
Dryden 1972 after modification	heavy	1-2	clay	>3	fresh
Cochrane 1973	medium	1-13	clay	>3	dry-fresh
Cochrane 1974	medium	1-18	clay	>3	dry-fresh

[a] 1 in. = 2.54 cm

[b] 1 ft = 30.48 cm

Time studies were carried out to pinpoint reasons for delay and inadequate performance be they site related, mechanical or organizational. Time study also aided in the correction of these problems. Post-treatment assessment of the planting provided further feedback on how well the objectives of the exercise were being met. The assessment criteria were based on the number of trees per acre, planting depth, and packing quality. These are controllable factors that affect adequate stocking and survival.

Results

(a) Time Studies: Table 6 provides a complete summary of all times recorded in the time studies for six trials. The times are broken down as to category, such as 'stop planter', and reason, such as 'supplying stock'. 'Forward' is considered productive time, with actual planting being carried out. The other categories represent nonproductive time. The 'stop' and 'reverse' categories allocate delay time to either the tractor or the planter and further delineate the specific cause of delay. 'Manoeuvring' identifies those periods when the unit was travelling but not actually planting trees. 'Personal' time includes work stoppages due to coffee breaks, lunches, etc. The Appendix gives definitions and groupings.

The important features to note in Table 6 are the 'stop planter', 'manoeuvring' and 'personal' categories. These establish the principal causes and effect of delay. The other categories are less important and can be eliminated from detailed consideration.

'Stop planter' times are delays caused directly by the planting machine itself through mechanical or operational shortcomings. The 'raise and lower' delay times were recorded as such only during the first trial. Invariably they occurred in connection with the quarter turn made by the unit as it proceeded around the block in the concentric pattern used. These delays occurred because of the awkward and inefficient independent hydraulic setup used in the trial, and represent time required to prepare for the turn itself (Fig. 10). Actual turning time for all trials is recorded under 'manoeuvring'. In the rest of the trials, tractor hydraulics operated the Taylor. The tractor did not have to prepare for the turn but simply raised the planter in anticipation of the turn, while continuing forward motion. A parallel or back and forth planting pattern was used after the first trial. 'Motor stall' and 'refuelling' are also directly related to the setup used in the first trial. A comparison of delay times related to the use of the auxiliary unit versus the tractor hydraulics shows, for similar sites at Camp 70, a net saving in delay time for tractor hydraulics of (4.9 + 5.5 + 1.3 + 2.6) - 3.0 = 11.3%. The other trials fluctuated depending on location of the hydraulic valve and conditions on the clay sites. On the heavier soils, some clearing was often required while turning in preparation for lowering the planter onto 'clean' ground.

Table 6. Work study time summary for Taylor Drum Planter trials in terms of basic motions and functions on six sites of varying difficulty (concluded)

	Sand sites				Clay sites							
	Camp 70				Dryden 1972				Cochrane			
	1972 sampled time		1973 sampled time		Before mod. sampled time		After mod. sampled time		1973 sampled time		1974 sampled time	
Function	minutes	%	minutes	%	minutes	%	minutes	%	minutes	%	minutes	%
Reverse planter												
clearing debris	3.40	.1	112.23	3.2	.73	-						
other	.85	-										
Total	4.25	.1	112.23	3.2	.73	-						
Reverse tractor												
clearing debris	7.79	.2	5.28	.1	7.71	.3	4.05	.2				
Manoeuvring												
clearing debris	232.60	6.2			127.06	5.8	36.35	1.6	79.88	3.9	17.66	.7
turn	98.46	2.6	105.00	3.0	157.57	7.1	82.15	3.7	123.84	6.0	100.19	4.0
wet	11.73	.3			34.10	1.5						
stuck					22.47	1.0					11.85	.5
servicing					3.08	.1					5.25	.2
instructions-CFS	36.88	1.0	.98	-					2.73	.1		
-OMNR									10.93	.5	1.43	.1
other			62.01	1.8	33.72	1.5	29.63	1.3	28.83	1.4	112.51	4.5
Total	379.67	10.1	167.99	4.8	378.00	17.1	148.13	6.6	246.21	11.9	248.89	10.0
Personal												
lunch	441.60	11.7	471.70	13.4	138.55	6.3	148.61	6.6	240.37	11.7	356.15	14.2
rest	120.91	3.2	15.56	.4	40.05	1.8	26.18	1.2	61.68	3.0	54.06	2.2
other	12.24	.3	2.77	.1			10.47	.5				
CFS tour							73.34	3.3				
instruction-CFS	3.73	.1	5.39	.1								
-OMNR			6.09	.2								
Total	578.48	15.4	501.51	14.2	178.75	8.1	258.60	11.5	302.05	14.7	410.21	16.4
TOTAL[a]	3767.65	100.0	3524.79	100.0	2212.41	100.0	2242.41	100.0	2061.18	100.0	2501.74	100.0

[a] Percentages may not total 100 because of rounding

Table 6. Work study time summary for Taylor Drum Planter trials in terms of basic motions and functions on six sites of varying difficulty

	Sand sites				Clay sites							
	Camp 70				Dryden 1972				Cochrane			
	1972 sampled time		1973 sampled time		Before mod. sampled time		After mod. sampled time		1973 sampled time		1974 sampled time	
Function	minutes	%	minutes	%	minutes	%	minutes	%	minutes	%	minutes	%
Forward	1622.35	43.1	1395.34	39.6	1055.83	47.7	1244.31	55.5	748.75	36.3	604.10	24.1
Stop planter												
raise and lower	184.77	4.9										
clearing debris	113.63	3.0	144.41	4.1	82.91	3.7	114.15	5.1	154.23	7.5	25.17	1.0
breakdown	45.27	1.2	151.74	4.3	3.88	.2			3.16	.2	406.84	16.3
motor stall	208.98	5.5										
refueling	49.17	1.3									2.84	.1
planter cab, blade servicing	131.57	3.5	116.36	3.3	26.77	1.2	251.25	11.2	101.68	4.9	204.37	8.2
supplying stock	150.97	4.0	188.99	5.4	49.43	2.2	56.49	2.5	103.68	5.0	64.73	2.6
changing planters	2.81	.1	13.13	.4	3.64	.2	4.51	.2	26.77	1.3	4.24	.2
instruction-OMNR	12.05	.3	8.83	.2	16.00	.7			.43	–	.26	–
-CFS	3.25	.1	8.79	.2	49.07	2.2			10.10	.5		
other	1.23	–			2.87	.1	1.68	.1	17.14	.8		
CFS experiment	117.92	3.1										
Total	1021.62	27.1	632.25	17.9	234.57	10.6	428.08	19.1	417.19	20.3	708.45	28.3
Stop tractor												
clearing debris	47.46	1.3	103.25	2.9	13.21	.6	23.87	1.1	112.03	5.4	29.93	1.2
breakdown	9.11	.2	576.42	16.4	3.25	.1	9.96	.4	62.18	3.0	187.30	7.5
servicing	28.82	.8	8.51	.2	12.75	.6	50.68	2.3	16.91	.8	6.35	.3
refueling	21.50	.6	10.57	.3	8.55	.4			8.54	.4	15.46	.6
instruction-OMNR	5.02	.1	4.43	.1	31.70	1.4	7.23	.3	.52	–	13.86	.5
-CFS	4.95	.1	4.92	.1	4.90	.2	1.07	–	5.56	.3	4.95	.2
other	4.58	.1	2.09	.1	.70	–	2.15	.1	.48	–	2.61	.1
stuck	32.05	.9			281.91	12.7	64.28	2.9	140.76	6.8	269.63	10.8
Total	153.49	4.1	710.19	20.1	356.97	16.1	159.24	7.1	346.98	16.8	530.09	21.2

(continued)

Fig. 10. Taylor raised to make turn. Note the wide inter-row spacing due to the inefficient V-blade and heavy stump concentrations. Camp 70, 1972.

'Clearing debris' refers to the removal of surface material that would interfere with the forward progress or operation of either the tractor or the planter. Delays due to 'clearing debris' were high, ranging between 8.0% (Dryden, after modification) and 16.8% (Cochrane 1973). The CFS V-blade made its debut in the 1974 Cochrane trial and although one observation cannot be considered conclusive, the decrease in time spent clearing debris to 2.9% is propitious.

The 1974 'stop planter' 'breakdown' delay of 24.6% requires some explanation. Approximately 16% of this delay occurred as the result of initial fitting problems with the CFS V-blade. The rest of the delay time occurred when it was discovered that the packing wheels had been put on backwards. During the trials, 'breakdown' causes have generally been bearings or flange failures and packing wheel axle breakages. These problems were alleviated with the addition of machined steel flanges and redesigned axles, plus a daily maintenance program.

'Supplying stock' and 'changing planters' represent from 2.4% to 6.3% delay and this range is an indication of the efficiency of the planting crew.

In some cases, the tractor had to 'clear debris' in order that it could continue moving forward. The delay times represent partly the V-blade used and partly the site difficulty encountered. 'Stuck' delay time was sometimes the result of not 'clearing debris'. In the Dryden 'before modification' trial there was one instance in which the crawler loader rode up onto a stump and stayed, causing a delay of 12.7% total time. The bulldozers also got hung up over stumps but their walking beam undercarriage and the bush grousers on the tracks ensured that the delay was not long. In the Cochrane trials a delay of approximately 6% in each case resulted from the tractor becoming stuck in areas where peat thickness over clay was in excess of 3 ft (1 m). For the sake of assessment regularity over the entire site, planting was attempted in suspected areas, often with adverse results.

When reversing either tractor or planter, the Taylor's planting foot would plug unless raised out of the ground.

The time taken for lunch was recorded under 'personal' time as long as it was within the set lunch time for the job. Additional lunch time spreading beyond the set limits of 30 minutes or 1 hour was recorded under 'rest' along with coffee and smoke breaks. Tours and instruction to the operators by CFS staff would not occur on a normal operation.

Some 'nonproductive' elements in no way reflect on the efficiency of the machine on a specific site condition, e.g., tours, tractor problems and research-related delays (Table 7). This category falls outside available time.

Lunch time, however, is not paid for in tractor rental and does not appear at all in the regrouping of the data.

By definition, planting machine availability, designated as operating time in Table 7, falls within the industrially accepted 80% availability, except for the 1974 Cochrane trial in which it was 74.4%. Considerable attention should be directed towards reducing the work-oriented nonproductive and nonoperating categories.

(b) Planting Quality: Inter-row spacing varied with site conditions, particularly with respect to the volume of slash, and the closest spacing achieved was 7.6 ft (2.3 m). Because of tractor size, blade width and the possibility of damage to trees in the previously planted row, inter-row spacing of less than 6½ ft (2 m) probably is not attainable. Therefore, to increase the planting density achieved in these trials, intertree spacing within the rows must be tightened considerably. Average spacings in the trials were considered too wide and the numbers of trees planted per unit area were generally too low (Table 8).

Table 7. Time breakdown in terms of productive and nonproductive effort[a]

	Sand sites				Clay sites							
	Camp 70				Dryden 1972				Cochrane			
	1972		1973		Before mod.		After mod.		1973		1974	
	min.	%	min.	%	min.	%	min.	%	min.	%	min.	%
Productive (1)	1622.35	53.0	1395.34	58.7	1055.83	62.5	1244.31	65.8	748.75	47.6	604.10	46.9
Nonproductive												
personal (2)	133.15	4.3	24.42	1.0	40.05	2.4	36.65	1.9	61.68	3.9	54.06	4.2
work-oriented (2)	718.99	23.5	488.02	20.5	507.58	30.0	299.11	15.8	527.83	33.5	301.01	23.3
nonoperating (3)	588.77	19.2	470.22	19.8	86.80	5.1	312.25	16.5	235.29	15.0	330.27	25.6
Nonavailable (tractor)(4)	537.66	17.6	1126.71	47.4	468.18	27.7	275.68	14.6	469.24	29.8	849.35	65.9
Nonavailable (CFS)(4)	166.73	5.4	20.08	0.8	53.97	3.2	74.41	3.9	18.39	1.2	362.95	28.1
Total time (1+2+3+4)	3767.65	123.0	3524.79	148.2	2212.41	130.9	2242.41	118.5	2061.18	131.0	2501.94	194.0
Available time (1+2+3)	3063.26	100.0	2378.00	100.0	1690.26	100.0	1892.32	100.0	1573.55	100.0	1289.44	100.0
Operating time (1+2)	2474.49	80.8	1907.78	80.2	1603.46	94.9	1580.07	83.5	1338.26	85.0	959.17	74.4

[a] See Appendix for definitions.

Table 8. Planting production summary

	Sand sites				Clay sites							
	Camp 70				Dryden 1972				Cochrane			
	1972		1973		Before mod.		After mod.		1973		1974	
Soil type	sand		sand		clay		clay		clay		clay	
Total trees planted	21,060		16,200		19,800		15,700		10,200		6,300	
Acreage[a] planted--gross	58		35		28		27		23		30	
--net	54		35		26		26		22		22	
Trees planted/gross acre[a]	363		463		707		581		443		210	
Trees planted/net acre[a]	390		463		762		604		464		286	
Duration of trial total elapsed time (hr)[b]	62.8		58.7		36.8		37.4		34.4		35.7	
Available time (hr)	51.1		39.6		28.2		31.5		26.2		21.5	
(%)		100.0		100.0		100.0		100.0		100.0		100.0
Operating time (hr)	41.2		31.8		26.7		26.3		22.3		16.0	
(%)		80.8		80.2		94.9		83.5		85.0		74.4
Productive time (hr)	27.0		23.3		17.6		20.7		12.5		10.1	
(%)		53.0		58.7		62.5		65.8		47.6		46.9
Trees planted/available hr	412		409		702		498		389		293	
Trees planted/operating hr	511		509		742		597		457		394	
Trees planted/productive hr	780		695		1,125		758		816		624	
Net area planted/available hr (acre)[a]	1.1		0.9		0.9		0.8		0.8		1.0	
Net area planted/operating hr (acre)[a]	1.3		1.1		1.0		1.0		1.0		1.4	
Net area planted/productive hr (acre)[a]	2.0		1.5		1.5		1.3		1.8		2.2	
Avg forward speed (mph)[c]	1.15		1.25		1.07		1.15		1.38		1.32	
Avg intertree spacing (ft)[d]	9.3		9.3		6.5		9.1		11.4		13.5	
Avg inter-row spacing (ft)[d]	11.9		10.1		8.8		7.9		8.2		11.4	
Avg spacing (ft)[d]	10.6		9.7		7.6		8.5		9.8		12.5	

[a] 1 acre = 0.40 ha

[b] Any time differences (%) between this table and Table 7 are the result of conversion from centiminutes (1/100 of a minute) to hours and are not greater than ±0.1%

[c] 1 mile = 1.61 km

[d] 1 ft = 30.48 cm

Tractor speed bears directly on intertree spacing and therefore on trees per unit area. The physical limitations of both machine and operator dictate the maximum number of trees that can be planted during a given time. The slowest speed of 1.07 mph (1.72 km) had the highest number of trees planted per unit area. The higher speeds of 1.32 and 1.38 mph (2.12 and 2.22 km, respectively) had the lowest number of trees planted per unit area. Slower speeds also provided a smoother ride and increased comfort and safety.

In Dryden, density per net acre (0.40 ha) was substantially greater than at Camp 70 and can be attributed to stricter adherence to the planting prescription and an improved V-blade/scalping foot combination. The second improvement 'after modifications' was the addition of packing wheel weights which did improve packing on the heavy clays at Dryden by almost 50%. On the softer areas the extra weight caused problems by increasing spacing between trees and thus lowering the number of trees planted per acre. Cochrane's figures of 464 and 286 trees per net acre (1,147 and 707 trees per net ha) for 1973 and 1974, respectively, are due to poor clearing as a result of the V-blade used in the heavy alder conditions in 1973, and in 1974 almost entirely to improper operation of the Taylor planter.

The percentage of trees planted to a satisfactory depth was, for the most part, over 80%, which was considered acceptable (Table 9). In the 1974 Cochrane trial, the planter's hydraulic system was not maintained at operating pressure, and this resulted in the high percentage of "shallow" trees.

A minimum acceptable limit of 80% for packing firmness was arbitrarily set. The assessment showed that the firmly packed trees are almost always the ones planted to the proper depth. It was the low (50%) firmness figure in the Dryden 'before modifications' trial that led to the addition of weights. Packing firmness increased to 72% as a result of this modification. The 1974 Cochrane trial dramatically illustrates this point. The 74% "loose" shown in that trial is directly attributable to the removal of the packing wheel weights by field staff who feared that the extra weight would damage the packing wheel axles. However, their concern was unwarranted as the axles had been redesigned especially to take the greater weight. In heavy soils these weights are essential for adequate packing.

In the 'other' columns, 'trees covered by debris from planting the adjacent row' bears some explanation. At Camp 70, inter-row spacing was 11.9 ft (3.6 m) and debris coverage was 3% in the first trial. This width resulted from using an overly large V-blade with a vestigial scalping foot which cleared a path about 8 ft (2.4 m) wide. Debris was windrowed to the sides of this path. In the second trial at Camp 70, a better V-blade/scalping foot combination permitted a

Table 9. Planting quality in terms of the number and percentage of trees affected

	Sand sites				Clay sites							
	Camp 70				Dryden 1972				Cochrane			
	1972		1973		before mod.		after mod.		1973		1974	
Quality class	No. trees[a]	% of total	No. trees	% of total	No. trees	% of total	No. trees	% of total	No. trees	% of total	No. trees	% of total
Depth												
deep	16	1	5	-	19	1	141	6	40	4	15	2
satisfactory	1534	79	1438	85	1382	81	1794	83	587	60	417	66
shallow	388	20	256	15	304	18	234	11	354	36	203	32
	1938	100	1699	100	1705	100	2169	100	981	100	635	100
Packing												
firm	1554	80	1485	87	854	50	1558	72	648	66	164	26
loose	384	20	214	13	851	50	611	28	333	34	471	74
	1938	100	1699	100	1705	100	2169	100	981	100	635	100
Other												
injury during planting	1	-	3	-	3	-	3	-	1	-	-	-
trees covered by debris[a] during planting	5	-	21	1	150	9	275	13	302	31	30	5
trees with exposed roots	201	10	217	13	319	19	212	10	290	29	191	30
trees covered by debris[b] from planting adjacent row	61	3	59	4	104	6	289	13	-	-	-	-

[a] Trees were tallied immediately upon being planted and their condition was recorded (i.e., debris-covered or not).

[b] Immediately upon passage of the tractor in the adjacent row, the above trees were again tallied and any additional debris was recorded as resulting from the planting of the adjacent row.

reduction of inter-row spacing to 10.1 ft (3.1 m) with debris coverage of only 4% in the adjacent row. At Dryden, inter-row spacing was 8.8 ft (2.7 m) and 7.9 ft (2.4 m) with 6% and 13% debris coverage, respectively. In the Cochrane 1973 trial there was an 8.2-ft (2.5-m) inter-row spacing but debris from the heavy alder stand covered 31% of the planted trees. In this case the wide V-blade and scalping foot could not adequately cope with the site, especially at that inter-row spacing. A narrower V-blade and scalping foot would allow debris to be windrowed closer to the planting path and allow close inter-row spacing. The 1974 Cochrane trial employed the narrower CFS V-blade. A vast improvement was made in reducing debris coverage to 5% but relaxed supervision and poor guarding around the tractor engine compartment allowed inter-row spacing to increase to 11.4 ft (3.5 m). In general, only a small percentage of trees were covered and most of these are expected to survive and grow unhindered.

The percentages of exposed roots were as high as 30% in the Cochrane plantings. This is related to the shallow planting and loose packing noted previously.

After our first experience with stumps (where 9.5% of the plantable distance was lost because of them) the loss was gradually reduced to an acceptable 3% by scalping foot modification (Table 10). Debris continued to give problems, accounting for losses in plantable distance ranging from 12% to almost 40%. The high percentage in the 1973 Cochrane trial was a factor in the decision to develop a new V-blade. Dense alder made this site the most difficult of those included in the trials. With the new blade, losses were 27.3% and might have been lower but for the inadequate operation of the Taylor. As a result, debris that might have been cut and planted through was not. Likewise the increase from 2.6% to 12.6% in the 'other causes' category in Cochrane is attributable to the adverse working conditions for the man inside the planter (resulting from improper operation).

(c) Costs: Detailed planting cost data are not included because the frequency of modifications resulted in costs that are not typical of normal full-scale operation. The calculated district cost (Table 11) is based on the total costs of the operation (including standby time for the tractor while modifications were made), some modification costs, planting crew wages for such nonproductive effort, and other incidental items. The total costs are given in the table under calculated district cost and were supplied by the district. Many of the stoppages and extra costs which would not occur in a regular planting operation were removed for purposes of calculating "revised costs". All costs have been discounted at 8% to the 1972 base year and rounded to the nearest dollar.

Table 10. Failure of machine to plant, by cause, in terms of fail length along the planting row

	Sand sites				Clay sites							
	Camp 70				Dryden 1972				Cochrane			
	1972		1973		before mod.		after mod.		1973		1974	
	Fail length/plot (ft[a]/ chain[b])	% Fail	Fail length/plot (ft/ chain)	% Fail	Fail length/plot (ft/ chain)	% Fail	Fail length/plot (ft/ chain)	% Fail	Fail length/plot (ft/ chain)	% Fail	Fail length/plot (ft/ chain)	% Fail
Stumps	6.3	9.5	3.9	5.9	2.8	4.2	4.6	7.0	1.4	2.2	2.1	3.2
Debris	8.0	12.1	15.4	23.4	6.9	10.5	9.8	14.8	26.3	39.8	18.0	27.3
Other causes	5.0	7.6	6.4	9.7	4.2	6.4	7.7	11.7	1.7	2.6	8.3	12.6
Total fail length	19.3	29.2	25.7	39.0	13.9	21.1	22.1	33.5	29.4	44.6	28.4	43.1

[a] 1 ft = 30.48 cm

[b] 1 chain = 20.12 m

Table 11. Costs for machine planting (1972 dollars)

	District avg[a]		Calc. district cost[c]		Revised cost[d]	
	per acre[b]	per M	per acre	per M	per acre	per M
Camp 70						
1972	55.00	69.00[e]	124.00	317.00	46.00	118.00
1973	55.00	69.00[e]	55.00	118.00	48.00	104.00
Dryden 1972						
before mod.	45.00	56.00[e]	47.00	70.00	42.00	62.00
after mod.	45.00	56.00[e]	47.00	70.00	42.00	62.00
Cochrane						
1973	54.00	70.00	155.00	370.00	62.00	133.00
1974	54.00	70.00	125.00	305.00	57.00	199.00

[a] Cost established by the district for site preparation and hand planting based on experience from previous years.

[b] 1 acre = 0.40 ha

[c] Total cost for the trial, as reported by the district, exclusive of permanent salaries.

[d] Total cost, exclusive of expenses, incurred because of the experimental nature of the trials and other costs not directly related to the conduct of the trials.

[e] 800 trees/acre used in calculating cost per thousand.

The 'revised cost' in each case is very competitive with the alternative on a per unit area basis. The cost per thousand reflects the need for increasing the number of trees per unit area planted by machine.

DISCUSSION

Experience from these and similar trials shows that, regardless of the type of planting machine, planting quality and production efficiency are strongly related to the preparation of a suitable planting microsite. This condition has been most effectively achieved through the use of a front-mounted V-blade with scalping foot on bulldozers pulling the mechanical tree planter. A number of V-blades of different shapes and sizes but of basically similar design have been used in these trials. Their use revealed limitations in both design and construction and suggested a number of ways in which improvements could be made.

When using mechanical planters, it is not necessary that a path the width of the tractor V-blade (as occurred in 1972 Camp 70 trial) be cleared in order to plant a single row of trees. In rough cutovers this entails unnecessary moving of many stumps and much debris which could otherwise be left in situ. Full-width removal of stumps and debris increases the necessary width between adjacent planted rows because of the need to windrow the debris beside each planted row. Such treatment also requires more horsepower.

(a) Stumps: In the initial trial, stumps reduced the plantable area by 9.5%. A full-width V-blade plowed roads rather than planting strips. Misses occurred when stumps, which were not routinely removed in passing, were encountered on the outside wings of the V-blade, forcing the blade to skip over them while at the same time missing stumps directly in the planter path. This was not the major effect of stumps. Varying frequencies and sizes of stumps account for little loss (<5%) of plantable distance. The real losses were in terms of production efficiency. Stumps were the main cause of machine breakdowns and tractor downtime. It was stumps in most cases that caused packing wheel axle breakages, planter shoe breakages and, in one trial, thrown tracks. Stump frequency had less effect than did stump height, stumps over 14 in. (35.6 cm) being particularly hazardous. Stumps of this height could be caught by the wings of the V-blade or the scalping foot and rolled out of the ground. As the tractor continued moving forward, the stumps would roll and cause trouble under the tractor or upon encountering the planter.

Stumps should be avoided whenever possible and removed only when contacted by the apex of the scalping foot or when they are high enough that they would impede forward progress if the blade was lifted over them.

(b) Slash: Two categories are considered in this discussion of the effect of slash on machine planting. The first is the large-diameter, long slash, such as downed chicots and residuals, and tree lengths missed in the skidding operation. Such slash poses an obstacle to the forward motion of the tractor and requires power to move it. A V-blade will swing this material until it passes out of the planter path. Such material can rip out planted trees in adjacent rows and it can be encountered by the unit on several passes. Nevertheless, except at narrow inter-row spacings (less than 7 ft, or 2.1 m), the number of planted trees affected by slash in volumes up to 1,130 cu. ft per acre (79 m^3/ha) was minimal.

The second category of slash is the small material which, if missed by the blade, can foul the operation of the planter and create a safety hazard for the operator when he is positioning a tree in the planting foot. Even if a tree is properly placed in the slit, the surrounding debris may dissipate the force of the packing wheels and result in poor packing.

(c) Residuals: Scattered residuals pose no real problem to the planting operation. If possible, they should be left standing by diverting the tractor to avoid them. Fallen residuals become large slash. When a tree is rooted out, it is sometimes difficult to make it slide off the V-blade, and manoeuvring of the tractor may be required. Areas where large numbers of residuals occur, such as the site of the 1973 trial at Cochrane, are best left untreated. The Taylor was able to plant in the initial passes, but delays and weaving made the effort unprofitable.

Alder ingrowth up to 2 in. (5 cm) DBH which occurred in frequencies of as high as 17,000 per acre (42,000/ha) in Cochrane was a major problem. It fouled the planter, hindered forward motion, and was responsible for the high loss of plantable area to debris in 1973 and 1974 (39.8% and 27.3%, respectively).

(d) Soil: The Taylor was tested on both sandy and clay soils. Clay sites, because they are more fertile, offer increased vegetative competition for planting stock. Scalped sites which expose the clay are subject to baking, runoff, and frost heaving problems. For this reason, the prescription at Dryden required that the trees be planted without removing the duff layer, which was expected to protect the soil, hold moisture and provide some nourishment for the seedlings. The scalping foot was modified for this purpose, and thereafter it was quite successful in removing the debris while leaving the duff layer intact.

Heavy soils are also as difficult to pack as they are to penetrate. The fact that the Taylor was not able to close the soil firmly around the tree accounted for the major portion of the 50% loosely packed trees on the machine's first trial in clay soils.

Where operating instructions of 800 psi (56.25 kg/cm^2) of downpressure were followed in using the Taylor, soil penetration was not a problem in either the sand or the clay. Obstacles in the coulter path are usually cut or crushed. If not, the coulter will ride over them.

In both the Dryden and Cochrane trials, mucky areas were encountered. In these, the extra weight on the packing wheels caused soil to be pushed up in front of the wheels thereby increasing the nonplanted distance along the rows considerably. Since this was not a problem before the addition of the weights, the solution was to plant these areas separately using different weightings on the packing wheels. Sand soils, in contrast, pose little problem.

No stones or boulders were encountered on any of the sites. Bedrock outcropped on the edge of the 1973 Camp 70 site. This isolated encounter showed that the Taylor requires about a foot (30 cm) of soil on which to operate.

(e) Modifications: To improve packing in clay soils, approximately 1100 pounds (500 kg) of steel rail were stacked on the sides of the planter cab frame. Two steel uprights were welded on either side of the planter cab allowing 4-ft (120-cm) lengths of steel rail to be added as required. This forced us to redesign the packing wheel axles to take the increased weight. The original axles had scraper arms welded to them and it was the area around the weld where the metal crystallized and broke on several occasions. To eliminate breakage at this point, a scraper arm with a sleeve was manufactured for each packing wheel and the sleeve was fitted over a new axle and held with a large cotter pin. Easily fabricated axle replacements can be kept on hand, and the scraper arms need only the replacement of a cotter pin.

The cast iron flanges holding the bearings for the rolling drum coulter continually failed at the bolt holes. After they were replaced with machined steel flanges, no further trouble occurred.

The foot wells in the Taylor were battered and pushed up during the 1972 trials, decreasing the room inside for the planterman. The wells were reinforced with ¼-in. (0.64-cm) steel plate.

A steel box was bolted to the top railing of the planter to carry up to three bales of trees. This arrangement aids efficiency in supplying stock to the planter, especially in areas some distance from the tree cache.

To improve safety in the Taylor, a ¼-in. (0.64-cm) steel mesh door was added to the rear of the planter. When the planter is raised and the tractor manoeuvres or backs up, the operator cannot always see the hazards from behind. Before the door was added, one large pole did pass through the back of the Taylor, narrowly missing the planterman. The door also protects the planterman from smaller bushes and branches that can be encountered when turning at the end of a planting row.

The opening in the floor of the Taylor through which the tree seedlings are planted is not very big and, although the drum coulter crushes any debris in front of this hole, there is always a chance that a small stick may come up through and injure the planterman who is seated straddling the opening. A steel shield was fashioned around the trailing edge of the opening and extended up in front of the planter seat protecting the groin. The shield was constructed in such a way that it will deflect any object coming through the opening without hindering planting performance.

Foam padding 2 in. (5 cm) thick was added to the inside corners of the packing wheel wells where the planterman's legs were subjected to rubbing and bumping. Similar padding is standard in the rest of the cab.

Safety cables were added to the planter cab frame so that the cab could be raised and secured to the hitch assembly for inspection or for working under the planter. These cables are used when transporting the planter between areas and sometimes aid in clearing jammed debris from the moving parts on the planter.

A V-blade with scalping foot is a necessity for planting with the Taylor. If the V-blade is to be used for work other than planting, the scalping foot can be bolted to the bottom of the V-blade. The height of the scalping foot should be such that it raises the V-blade wings up off the ground by about 1 ft (30 cm) and is still within the clearance of the tractor used. The width of the scalping foot should be such that it will clear a path for the planting and packing components of the planter. The minimum working width would probably be 2 ft (60 cm). A prong extending below the scalping foot aids in lifting embedded debris in the planter path and starting it rolling. With a prong, the scalping foot can ride along the ground surface without gouging and without fear of missing or passing over debris.

We have found that auxiliary hydraulics in the form of a separate motor and pump are a nuisance. Direct hookup to the tractor without its winch causes fewer problems[4], and tractor hydraulics have performed best in our trials. A separate lever to control the raising and lowering of the Taylor and to set the downpressure is a must. An adapter plate bolted to the back of the tractor allows the Taylor to be bolted to the plate in the field in an hour.

<u>(f) Safety</u>: Some of the modifications previously mentioned were made specifically for safety purposes. With proper field operation, this machine is by far the safest we have tested. It must be operated at 800 psi (56.25 kg/cm^2) system downpressure, especially in clay soils to provide penetration, to absorb shocks in changing ground conditions, to crush and split debris, and to smooth the planter foot travel. A horn is standard equipment and is a necessity on any machine planting operation.

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[4] Taylor does have a winch bracket setup available by make for tractor hookup. We are unable to comment on its use, problems, or contractor acceptance.

(g) Cost: The costs for machine planting as revised for a normal operation are well within District costs for hand planting and site preparation. Although cost per thousand is high, it can be reduced by adherence to a planting prescription.

SUMMARY AND CONCLUSIONS

The Taylor Drum Tree Planter was cooperatively tested by OMNR—GLFRC as one possible machine of a number which might be of use in Ontario's boreal forest cutovers. The Taylor is a rigidly mounted machine, requiring a man in its cockpit to place tree seedlings in a planting slit prepared by a rolling drum coulter. Packing wheels close the slit. The drum coulter is hydraulically raised and lowered and operated from an external power source. It has no site-clearing ability of its own and therefore requires a bulldozer in the 100-140 hp class equipped with a V-blade and scalping foot to prepare the site.

This report on the Taylor covers results obtained in six trials, two soil types and three Districts with five tractors and four V-blades. Site conditions such as stumps, slash, residuals, soil, and slope were assessed to determine their effect on planting rate and quality so as to gain an understanding of the Taylor's capability, reliability, and safety. Changes were made in operating procedures and machinery was modified as the work progressed so as to obtain the best possible performance from this machine. For comparison purposes, the costs of planting with the Taylor versus those of the usual alternative of site preparation and hand planting are included in this report.

Certain site conditions affect efficiency and hence cost. High stumps and long slash are major factors. With the class of tractor used, upslopes greater than 20% preclude planting and site preparation at the same time. Residuals are a factor when they occur in dense patches and should be avoided in such cases.

Wet soil conditions, heavy soils, and debris affect planting quality by reducing packing effectiveness. Debris can be removed, wet areas can be avoided, and packing pressure can be adjusted to obtain effective packing. Production efficiency has been increased by redesigning the site preparation tool to handle the conditions encountered and by avoiding known problem areas in the planting chance. Optimum planting density can be achieved through improved operating procedures. Planting quality is improved through a proper consideration for site preparation, packing pressure, and safety and comfort within the planter cab.

The field crew must be familiar with the operation of the Taylor and the operating instructions must be followed. It must be serviced regularly. For maximum efficiency the planting should be planned to capitalize on long runs, regular restocking should be provided for and a two-man planter crew should be used, the one relieving the other in the planter at regular intervals. Provided that the planting microsite is properly prepared, the actual planting is a fairly simple matter. The problems related to the planting machine itself have largely been solved and the performance of the CFS V-blade suggests that the problem of site preparation for planting in the boreal forest can be solved also.

The Taylor has been the safest planting machine we have tested. It is rugged, yet adaptable to a wide range of planting sites. We have found that the Taylor is capable of effectively, efficiently, and safely regenerating most rock-free sand and clay sites at reasonable cost.

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APPENDIX

APPENDIX

WORK STUDIES

To obtain a complete event record for the entire planting operation and to relate site factors to productivity, work efficiency studies are conducted on each trial. As nearly as possible a 100% time study is conducted and all time elements as indicated below are recorded and coded.

Equipment required includes a clipboard with three stopwatches set up in sequence for the timing of each element plus a 30-minute stopwatch for recording total elapsed time.

When plots are being traversed by the planter, the time spent in each subplot on each pass is recorded. In assessing the planted subplots, an equal number of equidistant passes for each plot is taken so that the same travelled distance is recorded for each plot within a block. Coverage intensity is worked out from inter-row and intertree spacing.

Times are tallied in minutes and centiminutes (1/100 of a minute) in seven primary categories:

Forward

Stop (planter-caused)

Stop (tractor-caused)

Reverse (planter-caused)

Reverse (tractor-caused)

Manoeuvring

Personal

Categories 2-7 are further broken down and coded as shown later in this Appendix.

In the case of breakdown, delays are recorded as to time of day and duration, including (if necessary) removal time to the shop and return and the mechanic's time to the field from the shop. Breakdowns of the tractor or other tractor-caused delays are not included in the assessment of the capabilities of the planter. Account is taken of this factor when assessing the planting operation as a whole.

DEFINITIONS

Total elapsed time:

The entire time period for the trial.

Available Time:

The total time available for operating during the day is dictated by tractor availability, i.e., the time over which the tractor and its operator are available for operation within the accepted working day. Time lost due to tractor breakdown, operator absenteeism or CFS timing of the operation is considered *Nonavailable Time.*

Operating Time:

The total time for which the planting unit is functionally available[a] (operable) during the working period or *Available Time* minus delays due to breakdown, servicing, etc., of the *planter (Non-operating Time).*

Productive Time:

The total *Operating Time* minus all delays other than those occasioned by *inoperability* of the planter or *Available Time* minus all delays encountered during the working period.

Nonproductive Time:

This is divided into three categories:

(a) *Personal nonproductive:*

Nonworking time (of the planter) due to the on-the-job personal requirements of the workers directly involved in the planting operation excluding the tractor operator and those involved in time studies.

(b) *Work-oriented nonproductive:*

All nonworking time (of the functionally available planter) occurring during the normal working day other than (a) above.

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[a] The condition existing when the planter is capable of performing in the intended manner, i.e., is capable of planting trees, has trees available to plant and is in good mechanical repair. This is exclusive of the planter operator and other external influences such as site factors, weather or supervision.

(c) *Nonoperating:*

The time during which the planter is not functionally available.

Nonavailable Time:

Time during which the tractor is not available for operation or during which the operation is halted for a reason not related to the planting machine, operational organization, etc.

The categorization of each time element into productive, nonproductive or nonavailable units for the purposes of the tables in the body of this report is set out on the next page. The diagram illustrates the relationships among these units.

<table>
<tr><td rowspan="2">PRODUCTIVE TIME
for planting machine</td><td colspan="3">NONPRODUCTIVE TIME</td><td rowspan="3">NONAVAILABLE
(Tractor)</td><td rowspan="4">NONAVAILABLE
(CFS and other)</td></tr>
<tr><td>(a)
PERSONAL</td><td>(b)
WORK-ORIENTED
-clearing debris
-reverse
-lift planter
-etc.</td><td rowspan="2">(c)
NONOPERATING
-servicing
-breakdown
-loading
-etc.</td></tr>
<tr><td colspan="3">OPERATING TIME
for planting machine</td></tr>
<tr><td colspan="4">AVAILABLE TIME
for tractor (100% base)</td><td>-servicing
-personal</td></tr>
<tr><td colspan="6">TOTAL TIME (>100%)</td></tr>
</table>

P = productive time
Pe = personal (nonproductive)
WO = work-oriented nonproductive

NO = nonoperating
NA = nonavailable (tractor)
NA (b) = nonavailable (CFS)

P = FORWARD

STOP PLANTER

WO	raise and lower
WO	clearing debris
NO	breakdown
NO	motor stall
NO	horn wires
NO	refueling
NO	planting cab, blade
NO	servicing
NO	supplying stock
NO	changing planters
WO	instruction - OMNR
NA (b)	- CFS
WO	other
NA (b)	CFS experiment

REVERSE PLANTER

WO	clearing debris
WO	other

PERSONAL

NA	lunch
Pe	rest
Pe	other

STOP TRACTOR

WO	clearing debris
NA	breakdown
NO	scalper
NA	servicing
NA	inspect problem
NA	refueling
WO	instruction - OMNR
NA (b)	- CFS
NA	other
NA	stuck

REVERSE TRACTOR

WO	clearing debris
NA	stuck

MANOEUVRING

WO	clearing debris
WO	turn
WO	wet
NA/NA (b)	stuck
NA/NO	servicing
WO	instruction - OMNR
NA (b)	- CFS
WO	other