COMPARATIVE EVALUATION OF SEVEN SITE PREPARATION TOOLS IN A RESIDUAL POPLAR MIXEDWOOD STAND IN SASKATCHEWAN

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ABSTRACT

Seven tools including the TTS-35 disc trencher (model 2.4 m), the Bräcke cultivator (two-row), the Leno-77 patch scarifier (modified), the Cazes and Heppner (C & H) front V-plow, the Angled dozer blade (model 8A), the Modified V-blade and the Fesco front V-plow (VP540), were comparatively tested in a residual poplar mixedwood stand in Saskatchewan. The three light skidder-drawn tools (TTS-35, Bräcke and Leno-77) achieved the highest numbers of plantable microsites in relation to prescribed spacing. However, the Leno-77 produced a higher density of microsites consisting of duff over a mineral soil base (plantable and marginally plantable). Scarification by the C & H and Fesco V-plows differed considerably from that by the wider Angled blade and Modified V-blade in terms of severity of the disturbance and final distribution of microsites . It is recommended that in residual poplar stands where high stand density precludes the use of light skidder-drawn equipment, front tractor mounted V-blades or plows capable of producing two rows of microsites be used to improve the efficiency and spacing of corridoring.

RÉSUMÉ

Sept appareils incluant le scarificateur à disques TTS-35 (modèle 2.4 m), le Bräcke cultivateur (deux-rang), le scarificateur à poquet Leno-77 (modifié), la charrue avant en "V" Cazes and Heppner (C & H), la lame de bouteur à angle (modèle 8A), la lame en "V" modifiée, et la charrue avant Fesco (VP540), furent comparées dans un peuplement résiduel de peuplier d'origine mélange en Saskatchewan. Les trois appareils légers (TTS-35, Bräcke et Leno-77) tirés par les débusqueuses produirent la plus grande quantité de microsites plantables en relation avec l'espacement prescrit. Cependant, le Leno-77 produisit une plus grande densité de microsites avec la présence de litière demeurant sur la base de sol minéral (plantable et marginalement plantable). La scarification effectuée par les charrues en "V" C & H et Fesco différèrent considérablement de celles des lames, plus larges, à angle et en "V" modifiée, de par la sévérité de la perturbation et de par la distribution finale des microsites. Il est recommendé que dans les peuplements résiduels de peuplier où la densité empêche l'usage de l'équipement léger tiré par des débusqueuses, des charrues et lames en "V" montées à l'avant de bouteur mais pouvant produire deux rangs de microsites soient utilisées pour améliorer l'efficacité et l'espacement des corridors.

ACKNOWLEDGMENTS

The authors wish to acknowledge the initiative, support and cooperation of D. Hanline, H.S. Price (now with the Canadian Forestry Service in Edmonton), C.D. Fulton, J.B. Smith and other support staff of the Forestry Division at the Department of Parks and Renewable Resources of Saskatchewan, who provided the resources for conducting this study. We would also like to thank F. Foreman, D. Kennington, M. von der Gonna and G. Davis of Great Lakes Forestry Centre (GLFC) for technical assistance.

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INTRODUCTION

The selection of the best site preparation tool to treat a particular area is critical in achieving overall management objectives. Ideally, tools are selected on the basis of their ability to produce the largest number of microsites of the highest quality as defined by the forest manager. Although biological considerations should never be seriously compromised, other factors such as regional availability of tools and/or prime movers, operating and capital costs, and specific operational considerations such as tree planter access play an important role in tool selection.

Many site preparation tools on the market today produce similar results or are claimed to produce certain results. Such an array of equipment can pose a problem for the forest manager wishing to prescribe the tool that will best meet his/her objectives.

What is required is the ability to assess equipment performance quantitatively under known site conditions. Knowledge of the relationship between scarification results, site variables and operational techniques will result in better equipment selection and prescription.

In boreal mixedwood stands, the artificial establishment of conifers on sites that would normally revert to poplar *(Populus* spp.) is a difficult task. Intensive site preparation and planting are essential for success (Heikurinen 1981). Often site preparation on such areas may be further complicated by the presence of a residual stand of hardwoods. In such cases the hardwoods are not fully utilized because of insufficient or incomplete markets. When the density of residual hardwoods is high, access to the site by mechanical site preparation equipment may be impeded (Puttock and Smith 1986)[1].

In July 1983 a comparative evaluation of seven site preparation tools was undertaken in Saskatchewan by the Saskatchewan Department of Parks and Renewable Resources (DPRR) in cooperation with the Mechanization of Silviculture Unit, Great Lakes Forestry Centre (GLFC). The evaluation included three light tools: a TTS-35 disc trencher (model 2.4 m), a Bräcke cultivator (two-row) and a Leno-77 patch scarifier (modified). These tools were in common use in the province but only the TTS-35 had been used in residual stands. Three blades or front plows were evaluated: the Cazes and Heppner (C & H) front V-plow, the Angled dozer blade and the Modified V-blade. These had also been used previously in the province and are commonly employed in residuals stands. One other tool, a FESCO front V-plow (model VP 540), was used for the first time on a trial basis (see Appendix A).

The purpose of the evaluation was to determine the comparative ability of each tool to prepare planting sites in residual poplar stands through the assessment of the quality and distribution of the microsites produced.

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[1] Puttock, G.D and Smith, C. Rodney. 1987. Evaluation of site preparation with Young's Teeth on sites with dense residual poplars. Gov't. of Can., Can. For. Serv., Sault Ste. Marie, Ont. (in prep.).

LOCATION AND SITE DESCRIPTION

The study area is located near Smoothstone Lake, 215 km north of Prince Albert, Saskatchewan (Fig. 1) in Mixedwood Section 18A of the Boreal Forest Region (Rowe 1972). The geological history in this area is characterized by glacial till overlain by fluvial-lacustrine material, in this case a silty sand. The site was moderately well drained and had gently rolling terrain with slopes up to 10%.

Prior to harvesting, the stands were predominantly mixedwood types of white spruce (*Picea glauca* [Moench] Voss) and trembling aspen (*Populus tremuloides* Michx.), aspen being the major component. Stand age was approximately 90 years, with crown closure ranging from 30 to 50% in three of the test blocks and 55 to 80% in the remaining four (stand information provided by DPRR). Harvesting was conducted under an area allocation permit during the winter of 1981/1982 as a conventional tree-length cut-and-skid operation to remove white spruce with chainsaws and cable skidders. The remaining stand of residual poplar ranged in density from 120 to 300 stems/ha, with average diameters of 28 to 37 cm. The post-cut site was identified as representative of conditions in which site preparation is routinely conducted under provincial contract. The area is classified as 2.1.1 under the CPPA Terrain Classification for Canadian Forestry system (Mellgren 1980).

SCARIFIERS AND PRIME MOVERS[2]

TTS-35 Disc Trencher (Model 2.4 m)

The TTS is a mechanical disc trencher designed to create two continuous furrows. Two passive discs are mounted beneath a triangular box frame (Fig. 2 and 3). As the machine advances, the discs rotate, throwing debris and soil outward. The angle of the discs and the weight of the scarifier determine both the ability of the discs to penetrate the soil and the width and depth of the furrow. The setting can be changed by five 6° increments or by 30° increments if the minor adjustment is insufficient to obtain satisfactory results. The weight can be increased by loading the box of the triangular frame. For this study the major setting was at 30° and the minor at 18° (angle settings do not necessarily represent the disc's angle with respect to the direction of travel) and no extra weight was added.

The TTS was pulled by a 90-kW (flywheel) Timberjack 380 cable skidder that could lift the TTS for travelling by means of a main line cable and fairlead. The towbar was connected to the skidder's butt plate by means of a universal joint and mounting plate.

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[2] For detailed specifications see Appendix A.

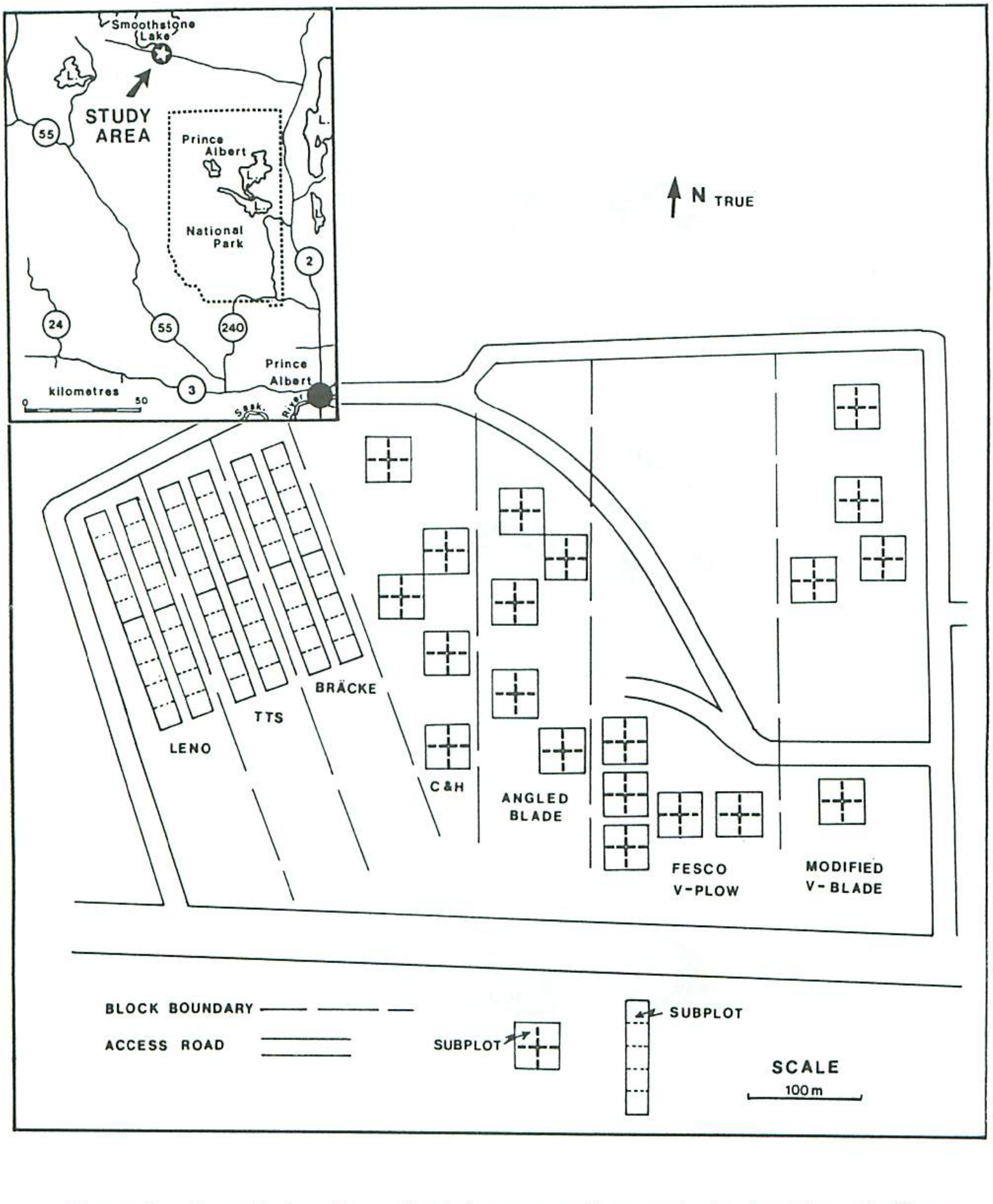

Figure 1. General location of study area and approximate location of 20-m x 20-m subplots within treatment blocks in the Smoothstone Lake area.

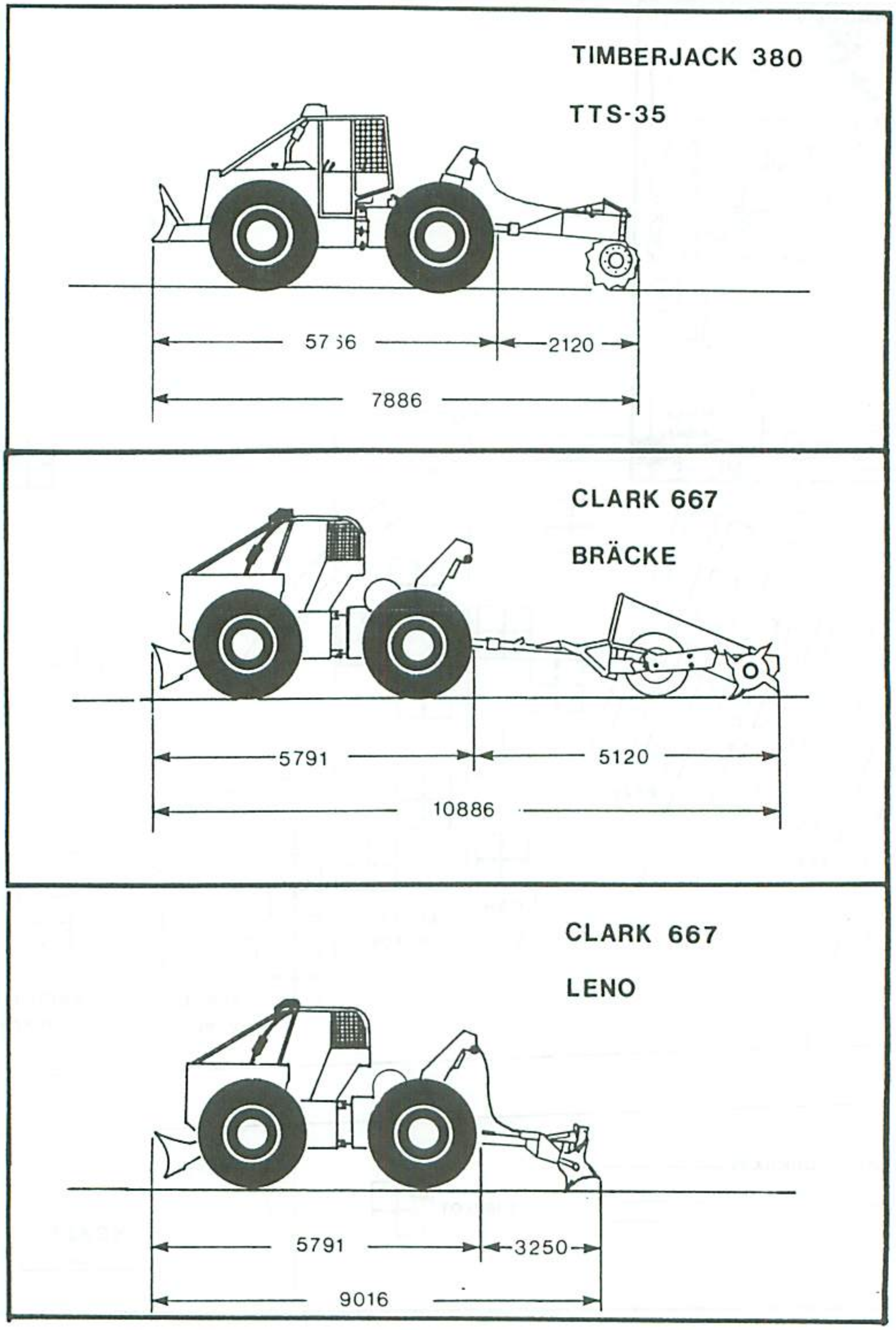

Figure 2. Overall dimensions (mm) and working position of the TTS-35, Bräcke and Leno-77.

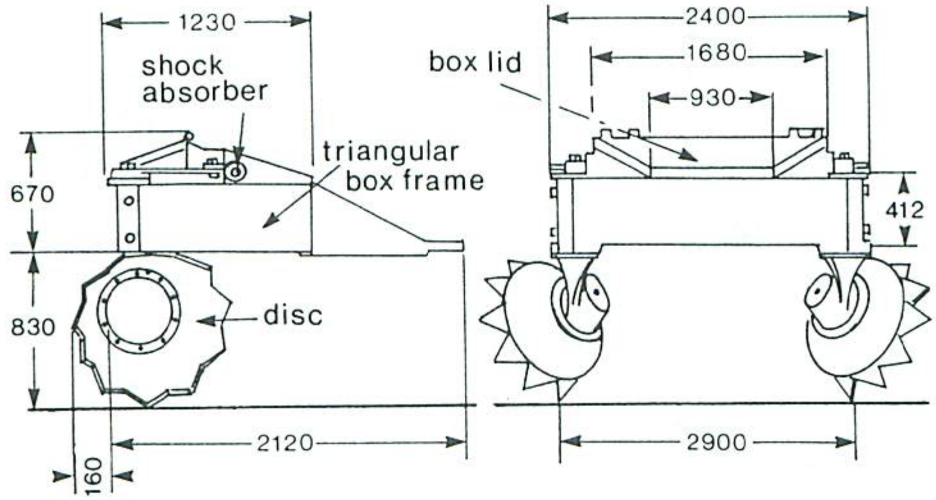

Figure 3. Major components and dimensions (mm) of the TTS-35 (model 2.4 m) disc trencher. (Adapted from Friberg 1975 in Smith et al. 1985).

Bräcke Cultivator (Two-row)

The Bräcke produces two rows of scarified patches or scalps spaced approximately 2 m apart. It consists of two machine box frames and a towbar mounted on a triangular drawbar frame (Fig. 2 and 4). Mounted within each machine frame is a rubber tire and a mattock wheel. A chain drive with an intermediate gearbox from the rubber tire rotates each mattock wheel in the same direction as the tires, but more slowly. Therefore, each pair of tines drags through the ground until the rotation lifts them clear.

This creates a series of scarified patches separated by undisturbed soil. Patch length and the number per hectare can be varied by changing the gear ratio in the chain drive or the number of teeth from four to five per mattock wheel. The unit in the study had the 17- to 19-tooth sprocket combination and four tines per mattock wheel. The 19-tooth setting only was used. The major components of the Bräcke are connected by means of pivot joints. This allows each part to move independently, both horizontally and vertically. The pivot system also allows the mattock wheels to be lifted from the ground for transport while the Bräcke rides on its rubber tires.

The Bräcke was pulled by a 90-kW (flywheel) Clark Ranger 667 grapple skidder. The towbar was connected to a Bräcke 'quick release' hitch mounted on the skidder's butt plate with the skidder's mainline attached to the towbar through the hitch. The prime mover was specially modified for site preparation with a lower range transmission and increased cooling capacity by means of a larger radiator and a 65-cm fan.

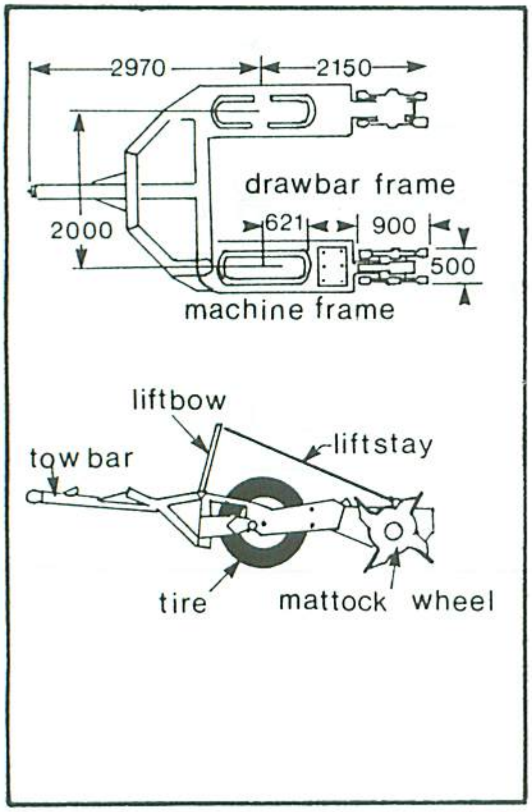

Figure 4. Major components and dimensions (mm) of the Bräcke cultivator. (Adapted from Friberg 1975 in Smith et al. 1985)

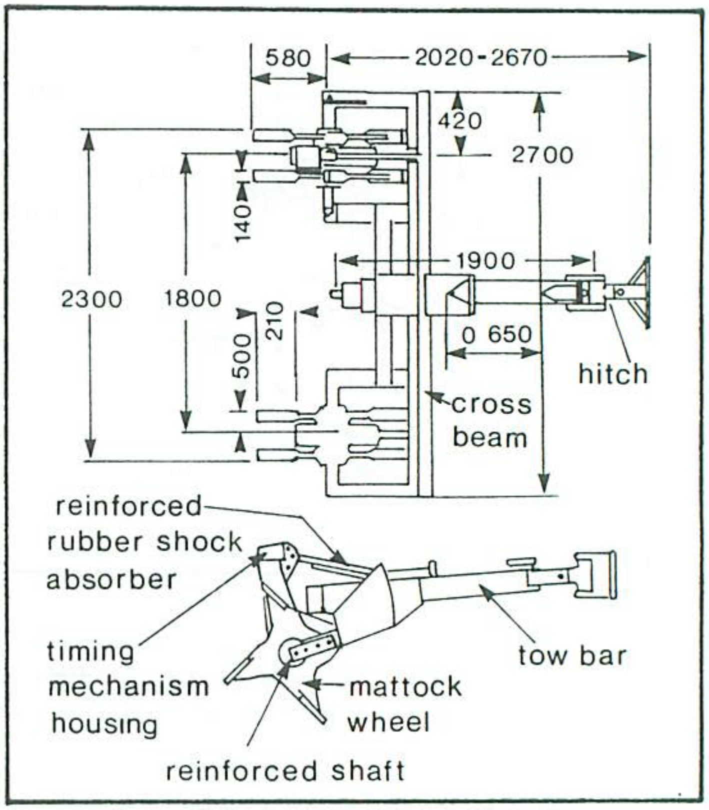

Figure 5. Major components and dimensions (mm) of the Leno-77. (Adapted from Friberg 1975 in Smith et al. 1985)

Leno-77 Patch Scarifier (Modified)

The Leno produces two rows of scarified patches or scalps approximately 1.8 m apart. It consists of two mattock wheels mounted on a crossbeam that slides up and down a tubular towbar (Fig. 2 and 5). The towbar is connected to the skidder's butt plate by means of a universal joint and mounting plate. Each mattock wheel has four pairs of scarifying tines. The tines are locked hydraulically into the scarifying position and create a scalp or patch as they are dragged through the soil by the prime mover. After a preset time has elapsed, the mattock wheel turns one quarter revolution until the next set of tines is locked into position. The timing, which is controlled by an enclosed hydraulic system, can be adjusted to obtain the desired patch length. An automatic overload releases the tines when an obstacle such as a boulder or stump is encountered. The unit used in this trial had reinforced shafts on the mattock wheels and a stronger rubber suspension, both of which are similar to those of the Leno-81. For this study, mattock timing produced many scalps close together.

The Leno can be lifted off the ground by the prime mover's winch for maneuvering or travel. In the raised position, the crossbeam slides toward the universal joint end of the towbar.

The Leno was pulled by the same 90-kW (flywheel) Clark Ranger 667 grapple skidder as the Bräcke.

Cazes and Heppner (C & H) Front V-plow

Designed to clear a continuous slash-free strip approximately 2.5 m wide, the V-shaped plow will fit the C-frame of a crawler tractor in the 130 to 175 kW size class (Fig. 6 and 7). The implement has a dual plow design. A leading plow (nose) and side arm assembly lift and direct logging residue outside the C-frame. An inner plow scalps the duff layer to obtain mineral soil exposure. Some scalping and mixing are achieved at the edges of the scarified strip by the side arms. The inner plow is vertically adjustable, independent of the prime mover's hydraulics, to allow some control over the amount of scarification. During this study the inner plow was positioned so that only the leading plow (nose) was scarifying.

The C & H plow comes equipped with a rolling drum colter located under the leading plow and designed to provide flotation, but the plow used in this trial had been operated for some time with the drum colter removed. The benefit of reduced weight more than offset the limited floatability provided by the rolling drum. Depth was controlled by the operator.

The C & H plow was mounted on a 134-kW (flywheel) Caterpillar D7F tractor.

Angled Dozer Blade (Model 8A)

Designed for various bulldozing tasks, the blade can be angled up to 25° to the side and is used for corridoring in residual poplar stands (Fig. 6). Blade width is 4.85 m when positioned straight and 4.39 m when set at the maximum angle of 25°. During this study the maximum 25° angle was used.

The Angled dozer blade was mounted on a 201-kW (flywheel) Caterpillar D8H tractor.

Modified V-blade

This blade was created through extensive modifications of a Beales blade to produce a large V-shape suitable for corridoring in residual poplar stands (Fig. 6 and 8). The blade is 3.6 m wide at the base and the protection boom at the top is 3.7 m wide. The height is 2.08 m and the length from the nose to the back of the 'V' is 1.52 m.

The blade was mounted on a 201-kW (flywheel) Caterpillar D8H tractor equiped with a bulldozer C-frame.

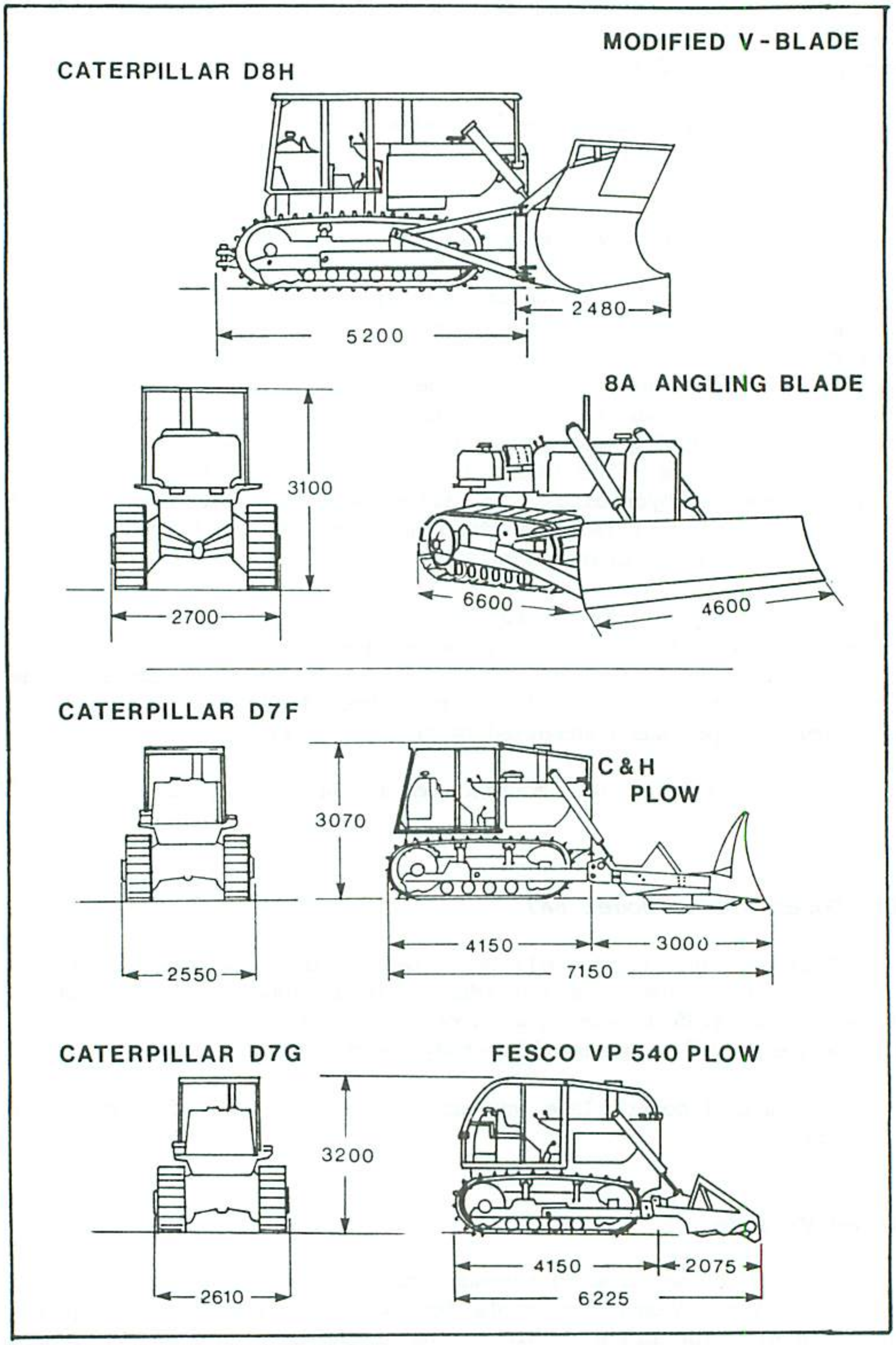

Figure 6. Overall dimensions (mm) and working position of the Modified V-blade, Angled blade, C & H plow and Fesco V-plow.

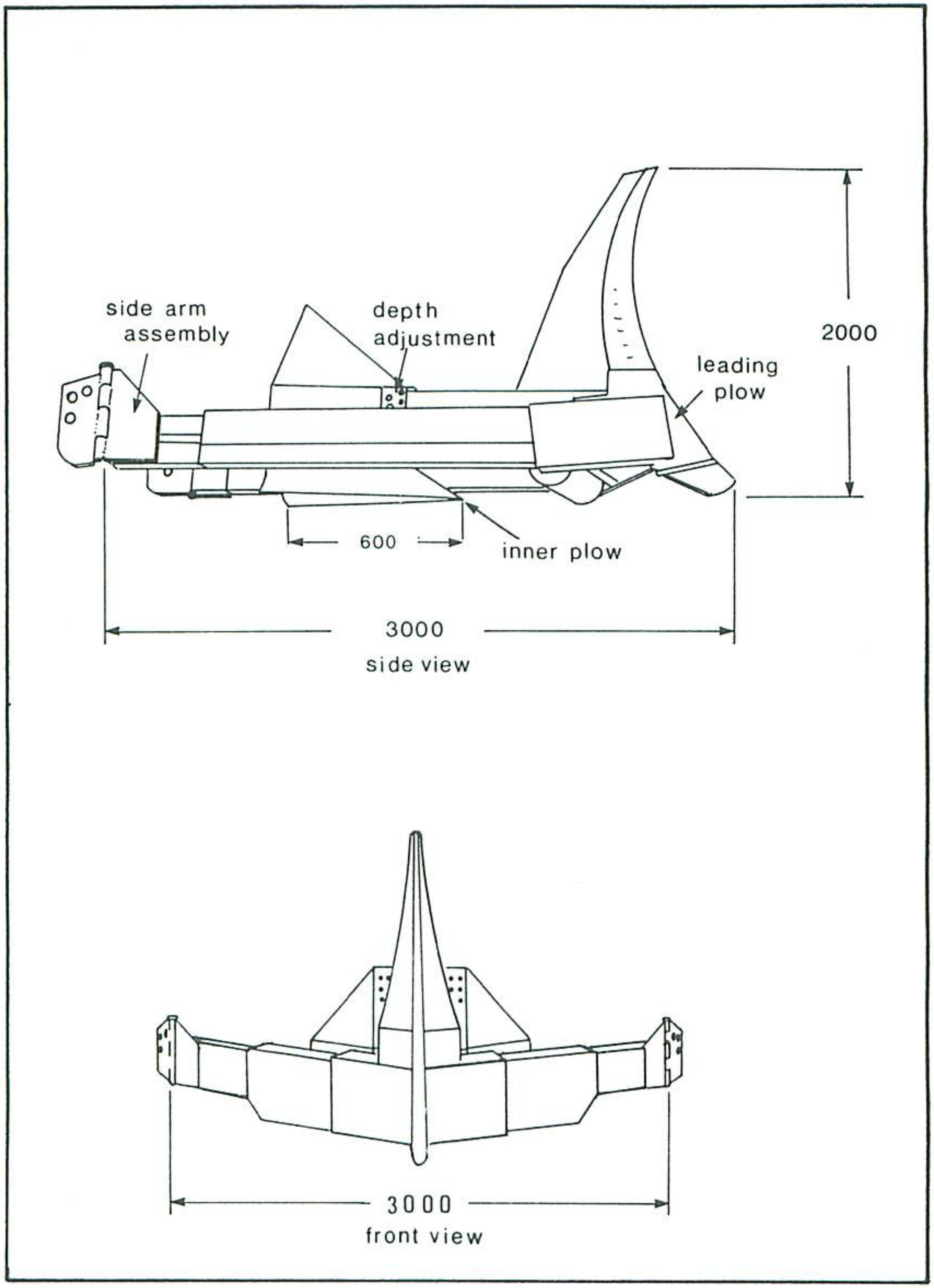

Figure 7. Major components and dimensions (mm) of the Cazes and Heppner (C & H) plow.

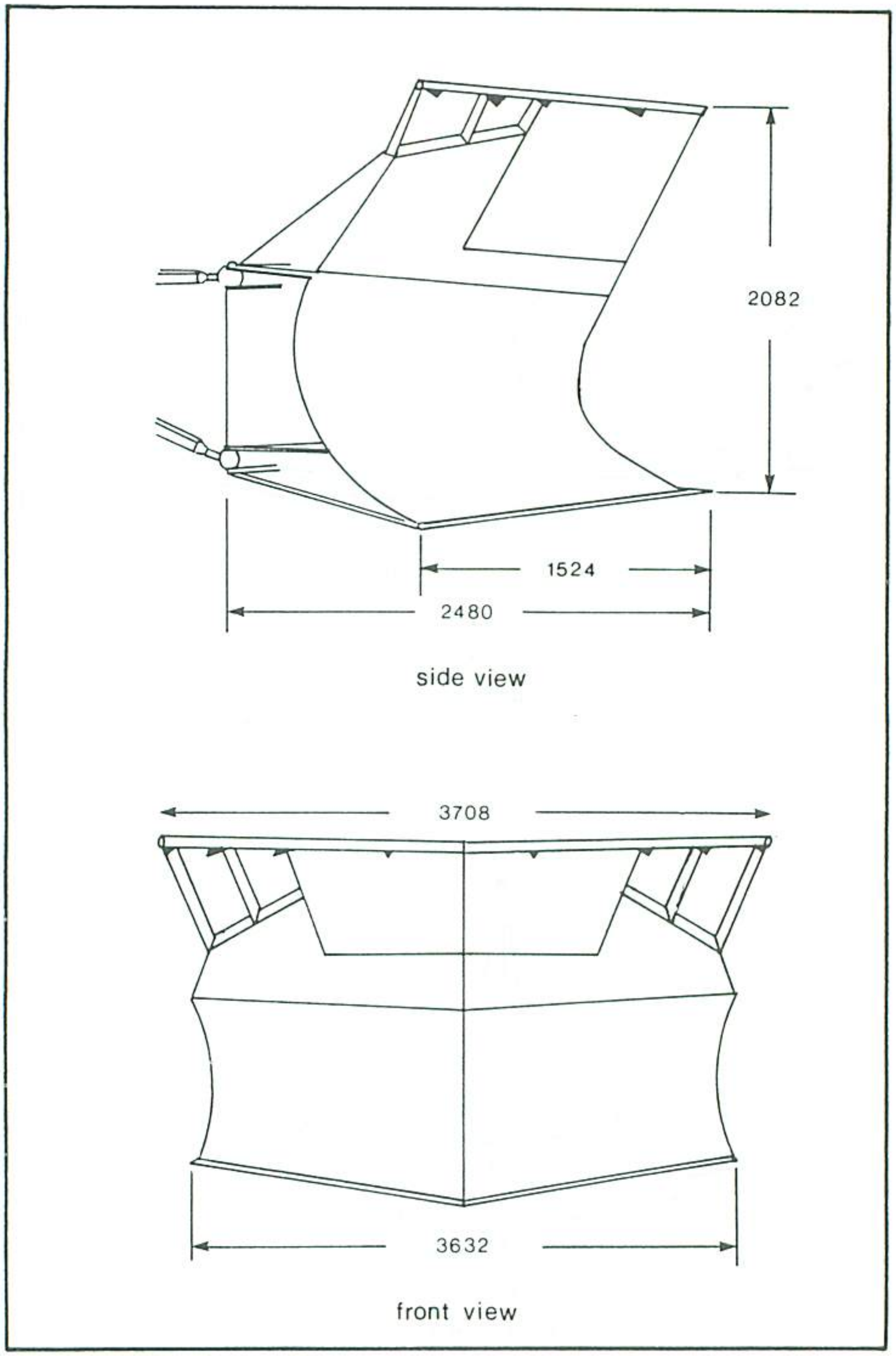

Figure 8. Major components and dimensions (mm) of the Modified V-blade.

Fesco Front V-plow (Model VP540)

The front-mounted Fesco is designed to clear a continuous slash-free swath approximately 1.37 m wide. It consists of a double moldboard plow with depth control provided by two vertically adjustable skid plates or shoes located at the nose (Fig. 6 and 9). For this trial the shoes were set at 5 cm above the bottom cutting edge of the plow. The Fesco plow is 2.1 m long from the nose to the rear of the cutting edge.

The unit was mounted on the C-frame of a 149-kW (flywheel) Caterpillar D7G tractor.

ASSESSMENT PROCEDURE

The evaluation consisted of a pretreatment assessment of site conditions, a limited time study and a post-treatment assessment of the quantity and quality of site preparation as measured against a predetermined prescription.

Prior to scarification, 20 subplots, each 0.04 ha, were established in each block for both the pretreatment and post-treatment assessments (Fig. 1 and B1, Appendix B). In the pretreatment assessment, site factors likely to affect the passage of the implements and the scarification produced were assessed according to the standard GLFC methodology developed for equipment evaluation (Riley 1975, Smith et al. 1985) (see Appendix B).

During equipment operation, time studies were carried out in each subplot to determine the time needed for each machine to treat the subplots only and the delays caused by obstacles and average travel speed (see Appendix C). Each pass through the 20-m subplots was timed and delays were recorded. The average travel speed was determined in the passes in which no delay occurred. Normally, a continuous time study is conducted over a larger area and a longer period of time. Therefore, while the information is useful in examining operating characteristics of the tools, it is not possible to provide productivity data that would be representative of regular operations.

For the post-treatment assessment the site preparation prescription was to produce microsites, sufficient in both quantity and quality, for operational planting of white spruce bare-root stock with a planting shovel. The method of assessment was from Smith et al. (1985), modified for the purposes of this trial (see Appendix D). The definition of a plantable spot and the description of microsite categories were provided by DPRR in consultation with GLFC. Microsite categories used in the assessment of overall quantity and quality of ground disturbance and of plantability are listed in Appendix D. Clusters of 10 quadrats, each 2 m x 2 m, were used to assess disturbance and were layed out as 2-m x 20-m transects perpendicular to the direction of machine travel. Plantability was assessed within 0.9 m of either side of the transect center line within the planting rows. The prescription called for 1.8-m within-row spacing. This method accurately measures inter-row spacing but overestimates plantability within the row. However, for the purposes of the trial, plantability results among machine blocks are comparable.

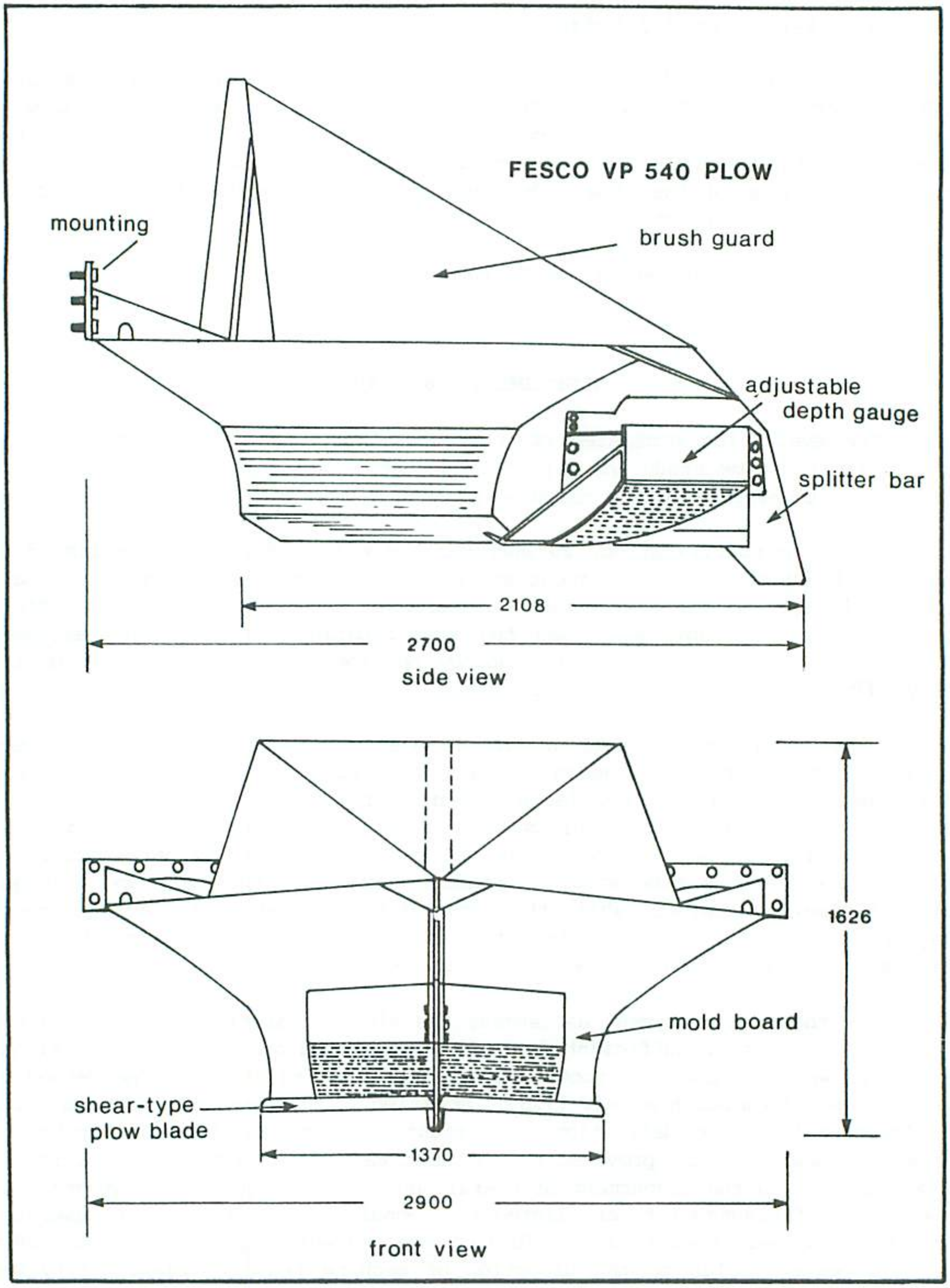

Figure 9. Major components and dimensions (mm) of the Fesco V-plow (VP540).

RESULTS AND DISCUSSION

TTS-35 Disc Trencher (Model 2.4 m), Bräcke Cultivator (Two-row), Leno-77 Patch Scarifier (Modified)

Pretreatment data were compared[3] to identify differences between blocks for the following variables: ground condition, vegetation cover, debris and residuals. Differences among blocks were assessed to determine whether differences in site conditions rather than inherent characteristics of the tools were responsible for differences in tool performance.

Site Conditions

In Table 1, the site conditions for the three light tool blocks are presented. Stump frequency and diameter, and all ground characteristics (duff depth, stoniness, soil texture, ground moisture, ground condition and roughness and slope) were not significantly different among the three blocks. Only the height of stumps, mineral soil depth and slope along the direction of travel were significantly different among the Bräcke and the Leno-77 blocks. However, these differences should not be considered relevant for the following reasons: the average stump heights were 38, 38, and 32 cm, small differences that should not alter the performance among tools; the average soil depths recorded exceeded the penetration capabilities of the equipment; and the differences in slopes were mainly in the negative or downhill direction of travel and on relatively low-grade slopes.

As mentioned earlier, ground cover characteristics such as slash and brush may affect tool penetration. The large-diameter slash (5 cm), consisted mostly of windfallen poplar evenly distributed across the three blocks. Their average diameter varied significantly but the difference was small (2 cm) and not considered important in its effect on equipment operation among blocks (Fig. 10-13).

The small-diameter slash (1 to 5 cm) was found to be significantly different, in terms of number of pieces and volume, the TTS-35 block having lower values (see Fig. 14 and 15). This difference coincides with a lower number of conifer species found in the TTS-35 block than in both the Bräcke and the Leno-77 blocks. In a previous study, a quantity of small slash similar to that on the Bräcke and Leno-77 blocks, but fresh and still foliated, has been found to limit site preparation effectiveness severely for the same three scarifiers (Smith et al. 1985). However, because the conifer slash was 1 1/2 years old, not foliated and brittle, the limiting effect on equipment is considered to be much reduced and therefore the difference in numbers of pieces and volume among blocks would have a minimal effect on the comparison of the three tools.

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[3] Means and frequency distribution were compared statistically (Chi-square or t-test at $p= 0.5$).

Table 1. Pretreatment site conditions in the TTS-35 disc trencher, Bräcke cultivator and Leno-77 patch scarifier blocks.

				TTS-35			Bracke			Leno-77		
Slash: no. of pieces per 20 m of lineal tally	diam 1-5 cm	(no.)	t[a]	32	3.3[b]	pq	52	*9.1*	p	51	*8.8*	q
	diam 5 cm	(no.)	t	5.0	*.59*		6.0	*.97*		5.8	*.86*	
volume	diam 1-5 cm	(m^3/ha)	t	6.5	*.67*	pq	10.4	*1.85*	p	10.3	*1.76*	q
	diam 5 cm	(m^3/ha)	t	86.9	*14.33*		127.3	*22.32*	p	97.0	*21.22*	
	total	(m^3/ha)		93.4			137.7			107.3		
diameter (quadratic mean)	diam 5 cm	(cm)	t	16.4	*.90*	p	18.4	*.79*	pr	16.1	*.88*	r
length	diam 5 cm	(m)	t	3.6	*.50*		3.5	*.50*		3.2	*.33*	
depth		(cm)	t	11.7	*1.12*		14.4	*2.29*		13.7	*2.03*	
species composition	conifer/hardwood	(%)	t	48/52	a		53/47			64/36	a	
Stump: frequency		(no./ha)	t	320	*90*		370	*79*		380	*86*	
diameter		(cm)	t	27	*3.1*	p	33	*3.3*	p	29	*3.4*	
height		(cm)	t	38	*4.3*		38	*2.9*	r	33	*2.1*	r
species distribution white spruce/balsam fir/aspen/other or unknown		(%)		75/10/7/8			96/1/3/-			83/4/12/1		
Depth of mineral soil[c]		(cm)	t	28	*.7*	p	27	*.7*	pr	28	*.5*	r
Depth to mineral soil (duff[LFH])		(cm)	t	7.8	*.72*		8.5	*.76*		8.3	*.48*	
Stoniness[d]		(%)	t	30	*5.7)*		37	*5.7*		30	*4.0*	
Soil texture[e]				loamy sand			loamy sand			loamy sand		
Ground moisture				dry			dry			dry		
Ground condition[f]				1			1			1		
Ground roughness[f]			t	1 [2]			1 [2]			1 [2]		
Slope distribution[g]	-15 to -11	(%)	t	-			-		r	9		r
	-10 to -6	(%)		25			15		r	30		r
	-5 to -1	(%)		25			31			10		
	0 to +5	(%)		27			19			16		
	+6 to +10	(%)		18			26			31		
	+11 to +15	(%)		5			9			4		
Brush: density		(stems/ha)	t	5140	*1345*	p	1840	*466*	pr	3500	*1070*	r
stocking[h] aspen/balsam fir and spruce/other hardwood/=Total		(%)		33/19/9/=61			11/19/5/=35			25/21/3/=49		
Residual: density		(stems/ha)	t	140	*67*		150	*76*		120	*48*	
stocking[h]		(%)	t	6.0	*2.8*		5.8	*2.8*		4.5	*1.9*	
diameter (quadratic mean)		(cm)		38			36			34		

[a] Test of significant difference (Chi-square or t-test) at p = 0.5: p(TTS-35/Bräcke), q(TTS-35/Leno-77), r(Bräcke/Leno-77).
[b] Values in italics are confidence intervals at 10% significance level (sampling = 20 subplots).
[c] Soil depth > 35 cm was recorded as 35 cm. Average is for a zone from 0 to 35 cm.
[d] A steel rod was shoved into the soil every 2 m along transects. The presence of stones was recorded if a stone or boulder was encountered within the first 35 cm of mineral soil.
[e] According to Belisle's (1980) field manual for describing soils.
[f] Assessed according to Swedish terrain classification system (Anon. 1969). Square brackets refer to a % occurrence > 10% of the sample area. Ground roughness includes stumps as well as surface rocks, boulders, overturned stumps and depressions.
[g] Percentage of 20-m-long passes of implements within 6 classes of slope. Slopes refer to forward direction of travel.
[h] The presence or absence of at least one stem in a 2-m x 2-m quadrat.

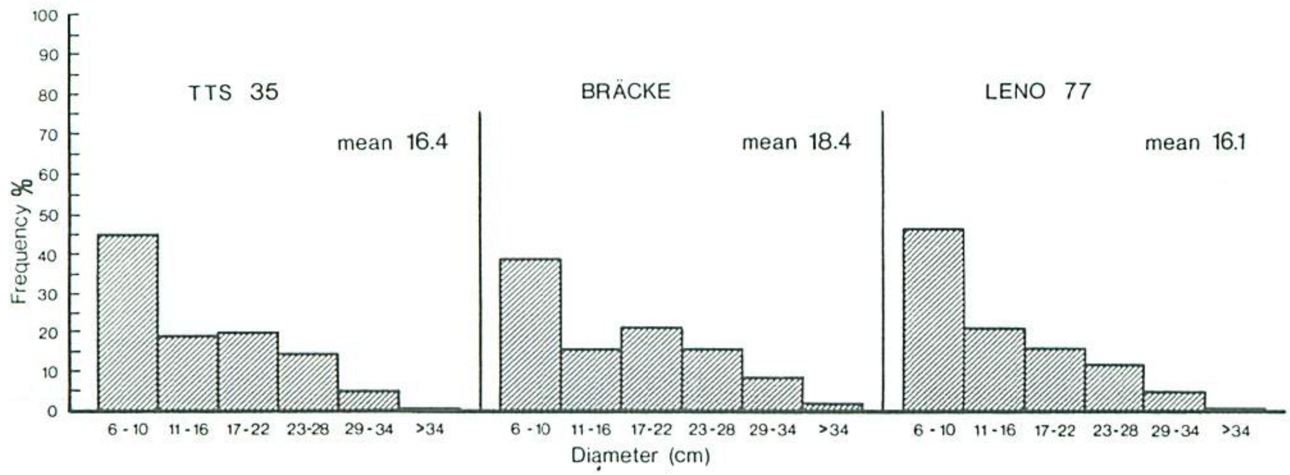


Figure 10. Slash--frequency distribution of diameter (for pieces > 5 cm in diameter)

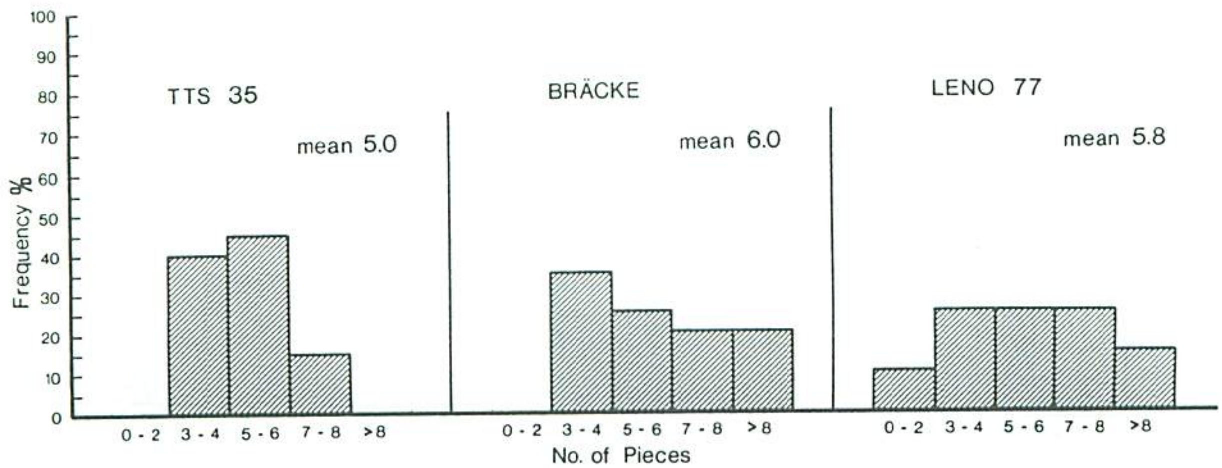


Figure 11. Slash--frequency distribution of number of pieces per 20 m of lineal tally (for pieces > 5 cm in diameter)

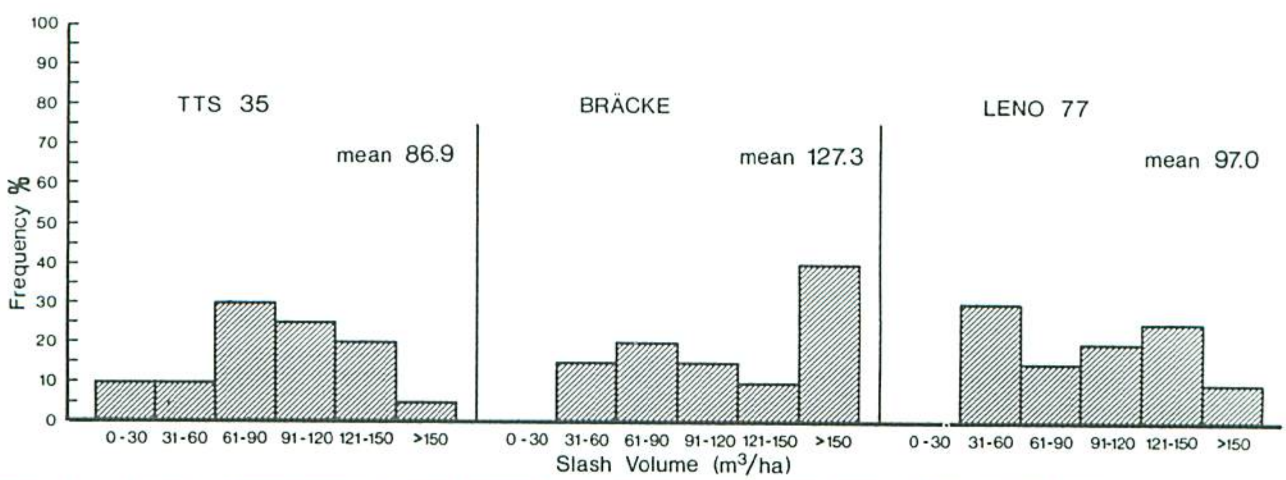


Figure 12. Slash--frequency distribution of volume per quadrat (for pieces > 5 cm in diameter)

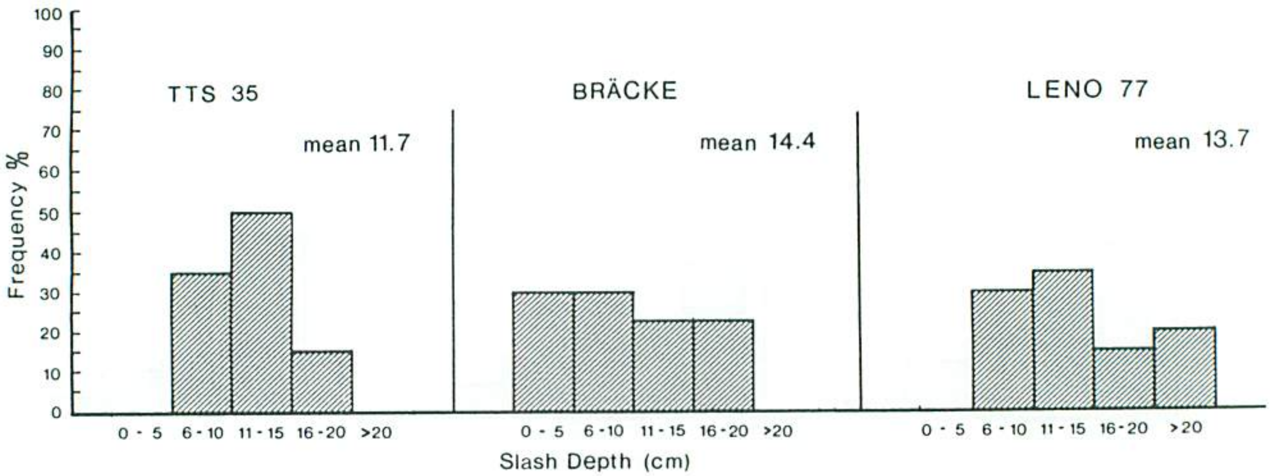


Figure 13. Slash--frequency distribution of depth

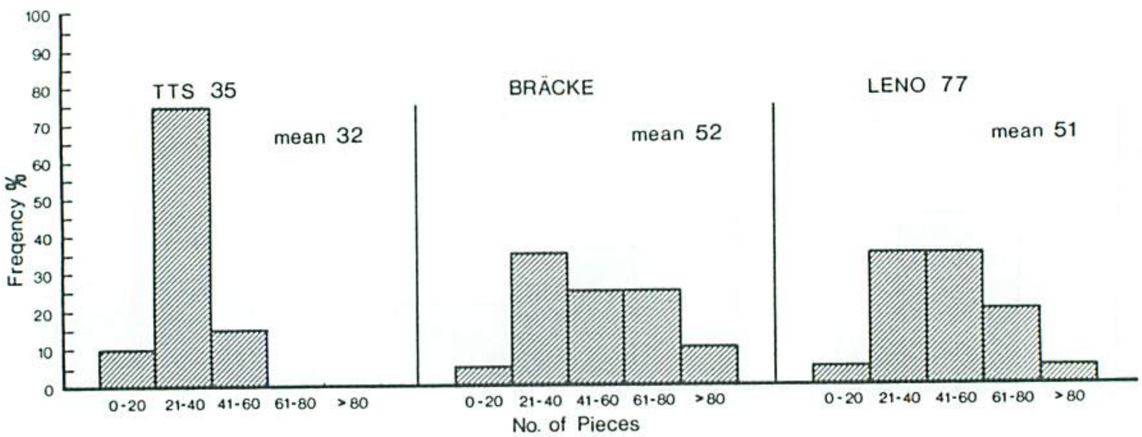


Figure 14. Slash--frequency distribution of number of pieces per 20 m of lineal tally (for pieces 1-5 cm in diameter)

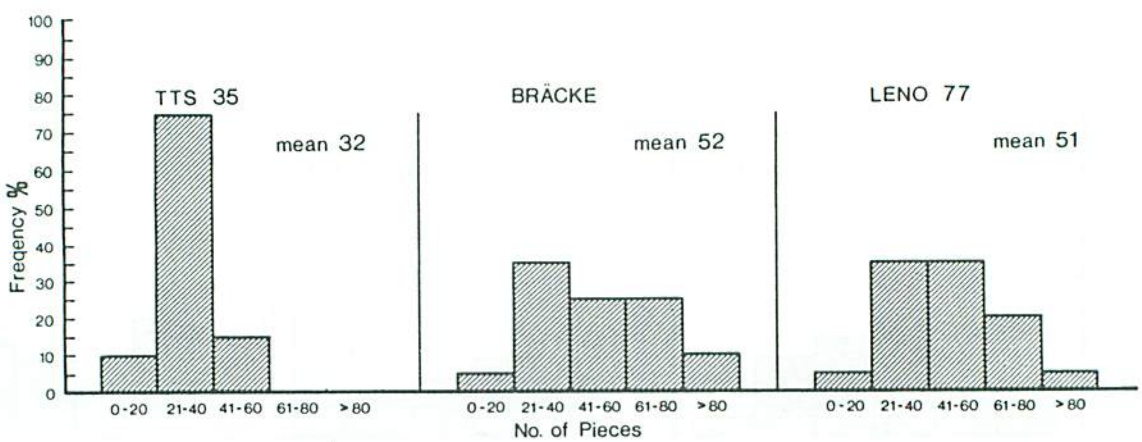


Figure 15. Slash--frequency distribution of volume per quadrat (for pieces 1-5 cm in diameter)

Brush in high densities can create a penetration problem for some tools because of its sinewy nature and matted root systems. Brush consisted primarily of poplar and balsam fir *(Abies balsamea* [L.] Mill.) on all blocks. The average density of brush was found to be significantly lower on the Bräcke block, i.e., 1,840 stems/ha versus 5,140 and 3,500 stems/ha for the TTS-35 and Leno-77, respectively. The Bräcke block had the lowest stocking of brush (2 m x 2 m), i.e., 35% versus 61% and 49% for the TTS-35 and the Leno-77 blocks, respectively (Fig. 16). Conifer brush was scattered with little difference in stocking (19, 19 and 21% for the TTS-35, Bräcke and Leno-77, respectively) and density among the blocks. The stocking in hardwood was very different for the three tools, 42, 16 and 28% for the TTS-35, Bräcke and Leno-77, respectively, but the difference shows only 2% more quadrats stocked with 12,500 stems/ha or more for the Leno-77 over the Bräcke and 9% for the TTS-35 over the Leno-77 (Fig. 16 and 17).

Hardwood brush does appear to be different among blocks but does not seem to affect equipment performance (at the stocking and density levels encountered). Conifer brush does not appear to be different. Regression shows that the TTS is affected at higher densities of conifer brush ($R = -.43$ between mineral soil exposure and conifer brush density). However, there were only a few scattered pockets of conifer brush dense enough to affect performance. Therefore, brush had only a minor effect on the overall comparison of equipment.

No statistically significant differences in mean and frequency distribution of residual density and stocking were found among the three blocks. However, as indicated in Figures 18 and 19, density and stocking varied considerably among subplots, and this is indicative of the scattered and/or bunched nature of the residual stand. Spatial distribution of large residuals can subjectively affect the decision of an operator selecting a route for the passage of light prime movers such as skidders.

Scarification Results

Site conditions were considered similar among blocks, and therefore tools could be compared on the basis of their operating and design characteristics (Fig. 20). The exception was residuals, which had a scattered and/or bunched distribution that varied among and within the blocks and may have affected interpass spacing.

Scarification results were assessed by classifying the ground disturbance into various disturbance categories that are divided into plantable, marginally plantable and nonplantable. Each category was summarized by surface coverage and distribution of overall disturbance on each tool block (Table 2).

Patches and furrows were characterized (i.e., as to length, width and area) in terms of both gross (including berms) and subsurface (acceptable disturbance only) dimensions. This included the number of rows and passes and, for the patch scarifiers, the number of attempts within a row (Table 3).

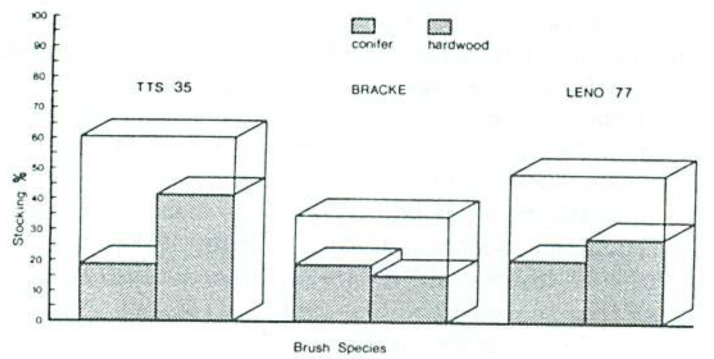


Figure 16. Stocking (2-m x 2-m) of brush by species

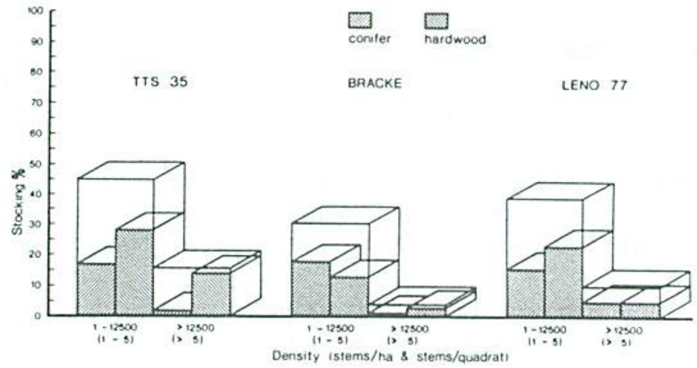


Figure 17. Stocking (2-m x 2-m) of brush by density and species

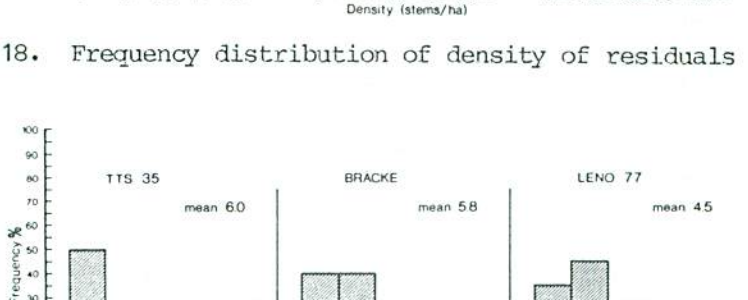


Figure 18. Frequency distribution of density of residuals (subplot basis)

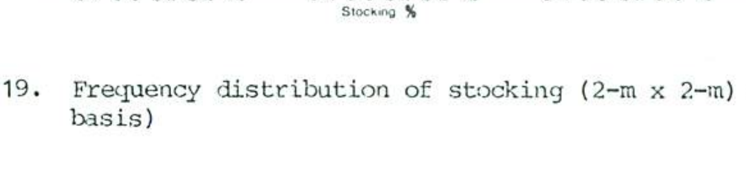


Figure 19. Frequency distribution of stocking (2-m x 2-m) of residuals (subplot basis)

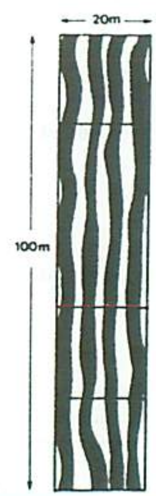
Table 2. Overall soil disturbance in the TTS-35 disc trencher, Bräcke cultivator and Leno-77 patch scarifier blocks.

Disturbance categories		Surface coverage (%) TTS-35	Surface coverage (%) Bräcke	Surface coverage (%) Leno-77		Distribution (stocking) (%) TTS-35	Distribution (stocking) (%) Bräcke	Distribution (stocking) (%) Leno-77
Plantable disturbance								
Exposed mineral soil or loose mineral soil < 10 cm on firm mineral soil base	t[a]	**4.3** *0.9*[b] pq	**2.2** *0.5* pr	**0.9** *0.3* qr	t	**60** *6.6* q	**62** *7.9* r	**36** *8.6* qr
Duff/mineral soil compactable mixed on firm mineral soil base	t	**1.0** *0.3* pq	**0.4** *0.2* p	**0.5** *0.2* q		**27**	**24**	**26**
Duff < 4 cm on firm mineral soil base	t	**2.4** *0.3* p	**1.0** *0.2* pr	**2.3** *0.5* r		**63**	**53**	**59**
Total of plantable disturbance	t	**7.7** *1.0* pq	**3.6** *0.5* p	**3.7** *0.5* q		**72**	**83**	**70**
Marginally plantable disturbance								
Duff > 4 cm but < 8 cm on firm mineral soil base	t	**0.5** *0.2*	**0.3** *0.2* r	**0.6** *0.2* r		**24**	**23**	**29**
Total of plantable and marginal disturbance	t	**8.2** *1.0* pq	**3.9** *0.5* p	**4.3** *0.7* q		**73**	**84**	**76**
Non-plantable disturbance								
Duff > 8 cm, mounded mineral soil on duff, hollow, water, bedrock		**27.0**	**20.3**	**14.1**				
Total disturbance		**35.2**	**24.2**	**18.4**				

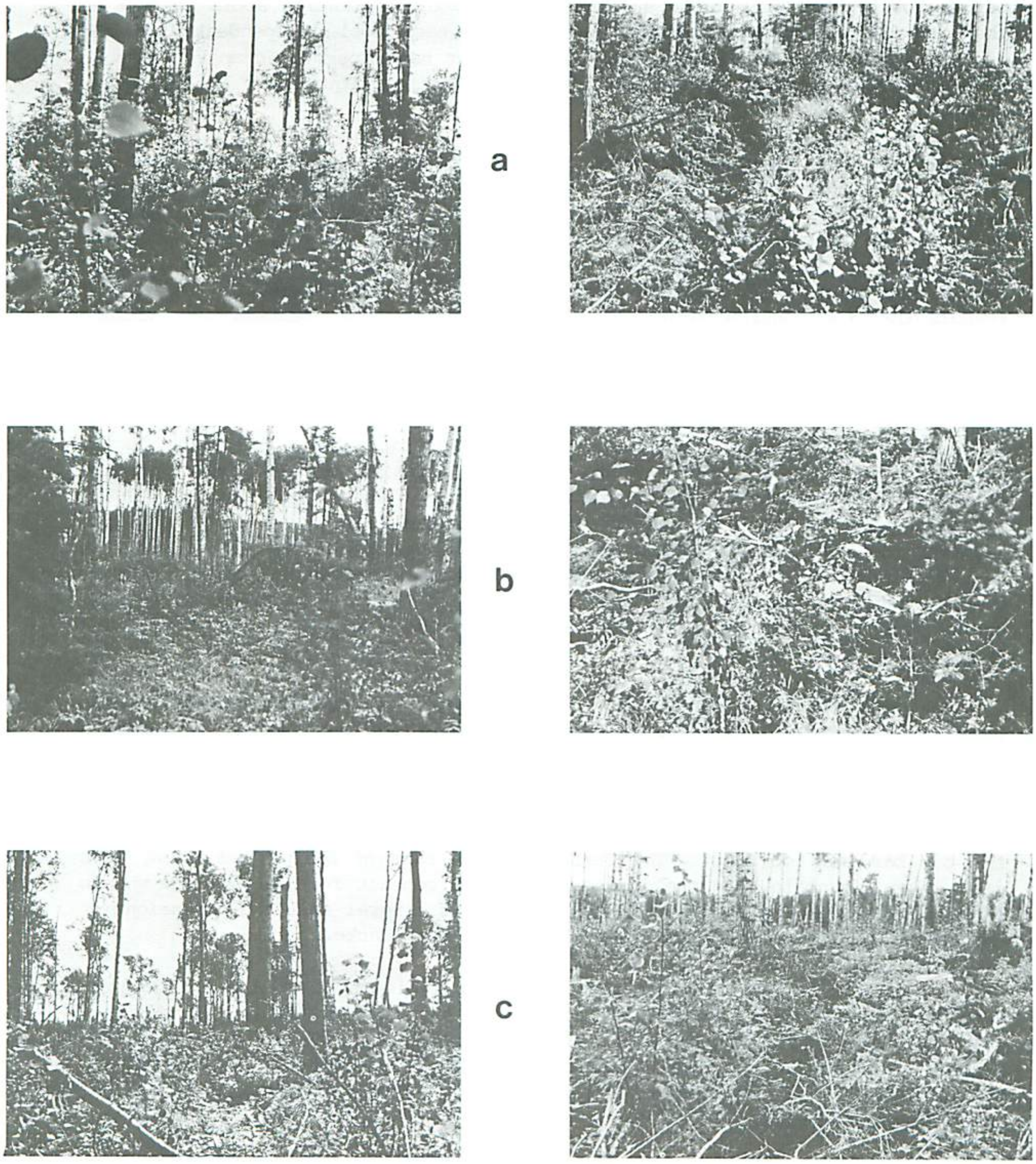
[a] Test of significant difference (Chi-square or t-test) at p = 0.5: p(TTS-35/Bräcke), q(TTS-35/Leno-77), r(Bräcke/Leno-77).

[b] Values in italics are confidence intervals at 10% significance level (sampling = 20 subplots).

Table 3. Characteristics of patches and furrows for the TTS-35 disc trencher, Bräcke cultivator and Leno-77 patch scarifier.

				TTS-35		Bräcke		Leno-77	
Furrow/patch									
Gross[a]	length[b]	(cm)		200		147		151	
	width	(cm)		140		74		48	
	area	(cm^2)		28000		10878		7248	
Subsurface[c]	length	(cm)		180		42		35	
	width	(cm)		50		42		31	
	area	(cm^2)		9000		1764		1085	
No. of rows per 20 m perpendicular to the direction of travel		(no.)	t[d]	7.25	*.26*[e] pq	8.80	*.36* p	8.90	*.29* q
No. of passes per 20 m perpendicular to the direction of travel		(no.)		3.62		4.40		4.45	
Avg spacing between adjacent plantable or marginal spots		(m)	t[d]	2.28	*.07* pq	2.08	*.05* p	1.99	*.07* q
No. of patches within row									
	attempts	(no./100 m)		(continuous)		56		93	
	avg spacing	(m)				1.78		1.08	
	plantable or marginal	(no./100 m)				48		69	
	avg spacing	(m)				2.08		1.45	
Example of scarification coverage									

[a] Includes berms (See Appendix D).
[b] Maximum of 200 cm.
[c] Acceptable disturbance only (See Appendix D).
[d] Test of significant difference (Chi-square or t-test) at p = 0.5: p(TTS-35/Bräcke), q(TTS-35/Leno-77), r(Bräcke/Leno-77).
[e] Values in italics are confidence intervals at 10% significance level (sampling = 20 subplots).



Prescarification Post-Scarification

Figure 20. Prescarification and post-scarification in the a) TTS-35, b) Bräcke and c) Leno-77 blocks

In addition, the proportion and density of planting spots are presented per microsite category (Table 4). The proportion of planting spots quantifies the range of microsite qualities produced by each tool independently of the others. Density of planting spots, on the other hand, permits comparison among tools for both the quality and quantity of microsites required by the prescription.

Overall disturbance per microsite category: As shown in Table 2 and Figure 21, the TTS-35 produced approximately twice the surface coverage of plantable and marginally plantable overall disturbance as the Bräcke and the Leno-77 (8.2 versus 3.9 and 4.3%), even though the TTS-35 produced fewer passes per 20-m width, 3.6 versus 4.4 and 4.5 for the Bräcke and the Leno-77, respectively (Table 3). Further inspection of Table 3 reveals that the continuous-furrowing TTS-35 achieved the greatest mean subsurface area (9000 cm^2 versus 1764 cm^2 and 1085 cm^2 for the Bräcke and the Leno-77, respectively). Note that the Bräcke subsurface area was 63% greater than that of the Leno-77.

The Leno-77 produced the lowest distribution (36%) of the category "exposed mineral soil" (Table 2 and Fig. 22). The Leno-77 produced approximately the same amount of the disturbance category "duff 1-4 cm" as the TTS-35, and twice that of the Bräcke, 2.3% and 2.4% for the Leno-77 and the TTS-35 and 1.0% for the Bräcke (Table 2 and Fig. 21). Note that 20% of the quadrats on the Leno-77 block were stocked exclusively (i.e., there were no other materials in the plantable or marginal disturbance categories) with the disturbance categories "duff 1 to 4 cm" and "duff 4 to 8 cm", versus 5 and 8% for the TTS-35 and Bräcke (Fig. 23).

Differences in results between the Leno-77 and Bräcke are attributable to the fact that the Leno-77 is lighter than the Bräcke and has less aggressively designed and wider mattock teeth (Smith et al. 1985). These characteristics can result in reduced penetration by the Leno-77 in comparison with the Bräcke. In this trial the Leno-77 was set to produce many scalps close together and at the same time was positioned improperly with respect to the prime mover (i.e., the tow bar was too low). The resulting high rate of scalp production, less dwell time per scalp, and the improper angle of contact for the mattock wheels can explain in part the lower surface coverage of mineral soil and dimensions of the scalps in comparison with those produced by the Bräcke.

In summary, the disturbance assessment indicates that the TTS-35 produced considerably more plantable disturbance than the Bräcke and Leno-77 and that the distribution of microsite categories is similar for the TTS-35 and the Bräcke. A comparatively lower distribution of exposed mineral soil was achieved by the Leno-77 and resulted in a higher distribution of thin and moderately thick duff categories.

Table 4. Proportion and density of planting spots per microsite category and percentage of prescribed number of planting spots per ha in the TTS-35 disc trencher, Bräcke cultivator and Leno-77 patch scarifier blocks.

Microsite categories	Proportion (%) TTS-35	Proportion (%) Bräcke	Proportion (%) Leno-77		Density (no./ha) TTS-35	Density (no./ha) Bräcke	Density (no./ha) Leno-77
<u>Plantable spots</u>							
Exposed mineral soil or loose mineral soil < 10 cm on firm mineral soil base	48 [-1][a]	49 [-2]	23 [-1]	t[b]	972 *116*[c] q [-7]	1180 *158* q [-62]	563 *131* qr [-7]
Duff/mineral soil compactable mixed on firm mineral soil base	13	17 [-1]	12	t	264 *86*	410 *143* [-16]	299 *110* [-7]
Duff < 4 cm on firm mineral soil base	33	23	43 [-3]	t	660 *104* q	556 *91* r [-7]	1035 *102* qr [-42]
Total of plantable spots	94 [-1]	89 [-3]	78 [-4]	t	1896 *93* [-7]	2145 *167* [-86]	1897 *155* [-56]
<u>Marginal</u>							
Duff >4 cm but < 8 cm on firm mineral soil base	2	6 [-1]	12 [-1]	t	35 *29* q	139 *86* r [-31]	278 *79* qr
Total of plantable and marginal spots	96 [-1]	95 [-4]	90 [-5]	t	1931 *88* pq [-7]	2283 *120* p [-116]	2175 *131* q [-56]
Percentage of prescribed spots					88% (2222)	100% (2222)	98% (2222)
<u>Non-plantable spots</u>							
Duff > 8 cm, mounded mineral soil on duff, hollow, water, bedrock	4	5	10		90	126	250
Total of plantable, marginal and non-plantable attempts	100	100	100		2021	2409	2425

a Values in square brackets represent the portions that should be subtracted to obtain the number and density after the loss of microsites as a result of penetration problems (mainly rocks).

b Test of significant difference (Chi-square or t-test) at p = 0.5: p(TTS-35/Bräcke), q(TTS-35/Leno-77), r(Bräcke/Leno-77).

c Values in italics are confidence intervals at 10% significance level (sampling = 20 subplots).

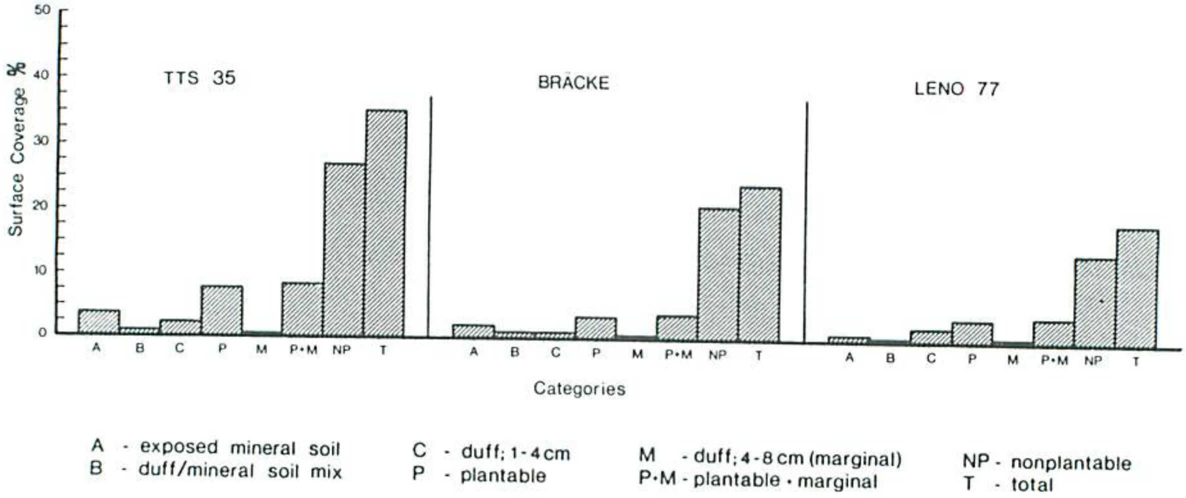


Figure 21. Surface coverge of overall disturbance per microsite category

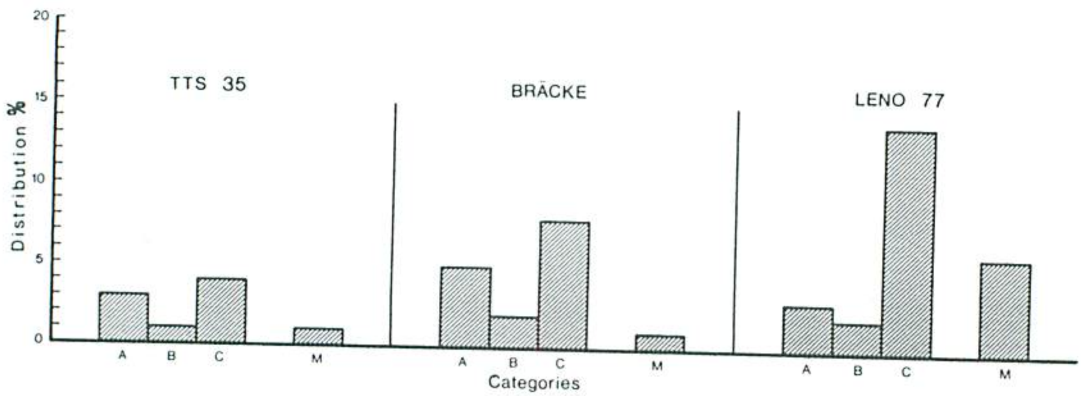


Figure 22. Distribution (stocking) of overall disturbance per microsite category

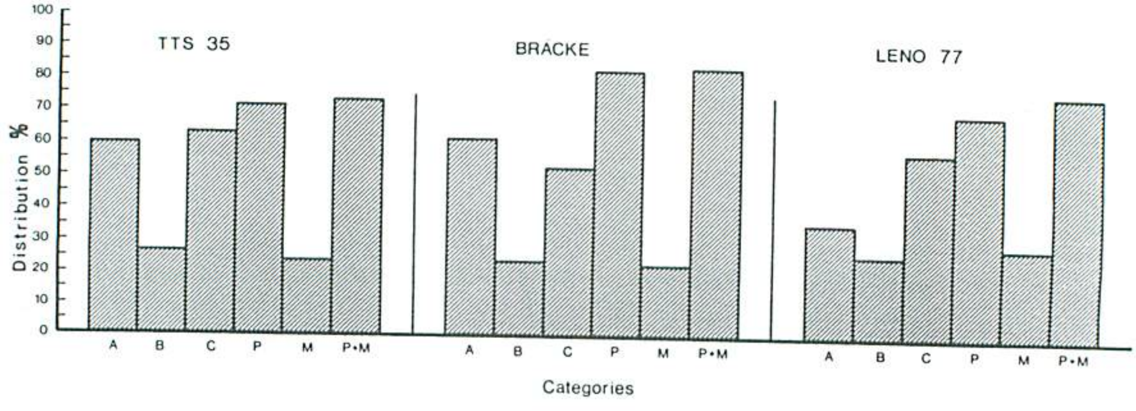


Figure 23. Exclusive distribution (exclusive stocking) of overall disturbance per microsite category

Proportion of planting spots per microsite category: In Table 4, values in square brackets represent microsites in which stoniness prevented adequate penetration of the planting tool. The degree of stoniness was found to be significantly different among blade tractor blocks. Exclusion of the microsites in which stoniness prevented penetration permits comparison among all seven equipment blocks.

Lower production of exposed mineral soil by the Leno-77 resulted in a lower proportion of planting spots under the category "exposed mineral soil" than was the case with the TTS-35 and the Bräcke, respectively (23 versus 48 and 49%) (Table 4 and Fig. 24). While the total proportion of plantable and marginal microsites appears high for the Leno-77 (90%), distribution favors the 1- to 4-cm and 4- to 8-cm duff depth categories as discussed previously under the quadrats stocked exclusively with one plantable or marginal disturbance category.

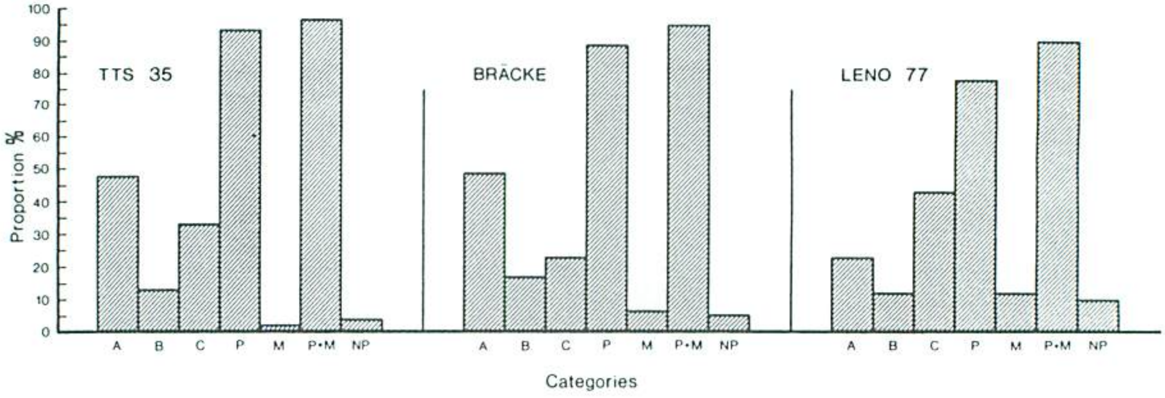
Density of planting spots per microsite category: To assess density of planting attempts, planting spots were inspected at the prescribed spacing of 1.8 m along the furrow for the TTS-35, Bräcke and Leno-77. The number of rows prescribed was eight per 20-m width for the three tools. (This represents 2222 spots/ha.) All tools achieved a high percentage of the prescribed number of plantable or marginally plantable spots/ha, 88%, 100% and 98% for the TTS-35, Bräcke and Leno-77, respectively (Table 4)

The Bräcke produced the greatest density of plantable and marginal spots (2283/ha), although this figure was not significantly different from those achieved by the Leno-77. The Bräcke did, however, have more spots in the exposed mineral soil category (1180 spots/ha vs 972 and 563 spots/ha for the TTS-35 and the Leno-77, respectively) (Table 4 and Fig. 25). The Bräcke surpassed the prescribed eight rows per 20-m width and produced an attempt every 1.78 m along the direction of travel (Table 3).

The Leno-77 produced the second highest density of plantable and marginal spots (2175/ha) (within 2% of the 2222 spots/ha prescription). The high value for the Leno-77 was achieved because the tool exceeded both the prescribed number of furrows per 20-m width and the number of attempts per 100-m length (Table 3).

The density of planting spots per microsite category reveals that the category "exposed mineral soil" was lowest for the Leno-77 while the categories "duff 1-4 cm" and "duff 4-8 cm" over mineral soil were the highest. A planting assessment of the Leno-77 block conducted by DPRR subsequent to this trial revealed that plantable spots were more difficult for the planters to locate because of the lower frequency of mineral soil microsites.

The TTS-35 did not perform as well as the Bräcke or the Leno-77; there was a significant difference in terms of density of plantable and marginal spots. This was due to the fact that the TTS-35 achieved only 7.25 rows per 20-m width, i.e., below the minimum requirement of eight rows. The lower number of rows is in part a function of the 2.4-m fixed distance between discs on this model of TTS but, as mentioned previously, inter-row spacing can also be affected by operator decisions, especially when the operator is working among large residuals with light prime movers.



A - exposed mineral soil
B - duff/mineral soil mix
C - duff; 1-4 cm
P - plantable
M - duff; 4-8 cm (marginal)
P+M - plantable + marginal
NP - nonplantable
TA - total attempts

Figure 24. Proportion of planting spots per microsite category

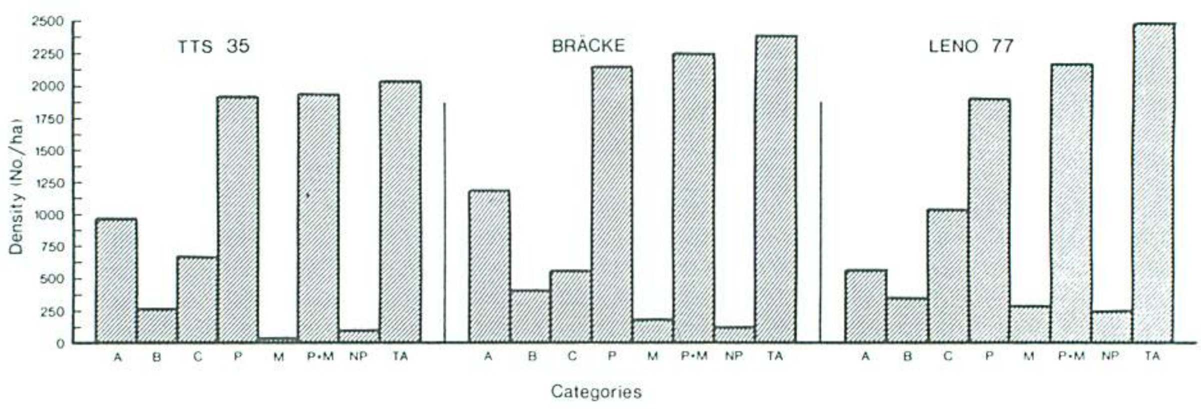


Figure 25. Density of planting spots per microsite category

Work Study

For the three tools, the recorded travel speed was between 3.5 and 4 km/hr (1st or 2nd gear) (Table 5). It is widely accepted that travel speeds not exceeding 3 km/hr for all such implements result in better ground contact by the implement, and this improves the quality of microsites produced (Ryans 1986).

Examination of the percentage of time spent travelling forward and scarifying and the percentage lost in delays (Table 5) reveals no apparent differences among the three tools. As a result the number of subplots treated per hour is a function of travel speed and the number of passes. The number of rows or passes per 20-m width was similar for both the Leno-77 and the Bräcke (Table 3); however, the lower travel speed resulted in fewer subplots per hour (46) treated by the Leno-77 (Table 5). The TTS-35 achieved the slowest travel speed of all three tools but also the fewest number of passes. The latter factor resulted in wider interpass spacing and consequently the highest number of subplots treated per hour (56).

For the three tools, the major source of delay within the subplots was maneuvering because of residuals, but this amounted to only 5% of the time spent inside the subplots. As stated earlier, the degree of maneuvering (overlapping of passes) depends partly on the required number of passes to achieve the desired inter-row spacing and partly on the operator's decision in selecting the route.

Cazes and Heppner (C & H) Front Plow, Angled Blade (Model 8A), Modified V-blade and Fesco Front V-plow (Model VP540)

The same procedure used for the light tool blocks was followed for the analysis of the blade and front plow blocks.

Site Conditions

Site conditions for the four tractor-mounted tools are presented in Table 6. There were no significant or meaningful differences among blocks for the ground characteristics: soil and duff depth, soil texture, ground moisture, ground roughness and slope.

There was a significant difference in stump height among the angled blade and the modified V-blade blocks (36 and 28 cm, respectively), but neither the number of stumps nor the diameter were significantly different. As scarification with both tools removed the stumps (mainly conifer), the differences in stump height should not be a factor affecting one tool more than another.

Stoniness was significantly different among the Fesco and the modified V-blade and among the angled blade and the modified V-blade, but as mentioned in the section on light skidder tools, stoniness affected penetration during followup planting and was not included in the calculation of proportion and density of planting spots per microsite so as to permit comparison among tools (see Tables 4 and 9).

Table 5. Average speed, number of subplots treated per hour and distribution of time elements in the TTS-35 disc trencher, Bräcke cultivator and Leno-77 patch scarifier blocks.

			TTS-35	Bräcke	Leno-77
No. of timed 20-m segments sampled		(no.)	80	109	89
Avg speed (without delays)		(km/hr)	3.48	4.54	4.05
No. of subplots treated per hr[a]		(no. of subplots/hr)	56.0	50.5	46.0
Distribution of time elements:	travelling forward and scarifying time	(%)	94.7	95.2	94.6
	delays caused by obstacles				
	stump	(%)	0.4	-	0.8
	residual	(%)	4.8	4.8	4.3
	slash	(%)	.1	-	0.3

[a] Used for the purpose of comparison only. Values do not represented absolute productivity in long-term trials.

Table 6. Pretreatment site conditions in the Cazes and Heppner plow, Angled blade, Modified V-blade and Fesco V-plow blocks.

				Cazes and Heppner	Angled blade	Modified V-blade	Fesco V-plow
Slash: no. of pieces per 20 m of lineal tally	diam 1-5 cm	(no.)	t[a]	47 *7.2*[b] pq	68 *7.8* p	64 8.5	80 8.3 r
	diam 5 cm	(no.)	t	6.1 *.72*	6.8 *.66*	7.0 1.26	6.7 .74
volume	diam 1-5 cm	(m^3/ha)	t	9.6 *1.45* pr	13.8 *1.57* p	12.8 1.74	16.1 1.66 r
	diam 5 cm	(m^3/ha)	t	92.7 *14.81*	83.9 *8.56*	89.6 18.15	97.5 19.92
	total	(m^3/ha)		102.3	97.7	102.2	113.6
diameter (quadratic mean)	diam 5 cm	(cm)	t	15.6 *.81*	14.2 *.62*	14.3 *.84*	15.0 *.97*
length	diam 5 cm	(m)	t	3.8 *.41*	4.4 *.33* x	4.6 *.38* y	3.3 *.38* xy
depth		(cm)	t	14.0 *1.59*	16.9 *1.86*	16.4 *2.85*	14.9 *1.67*
species composition conifer/hardwood		(%)	t	53/47 pqr	67/33 p	65/35 q	65/35 r
Stump: frequency		(no./ha)	t	460 *95*	406 *72*	480 *95*	438 *81*
diameter		(cm)	t	28 *1.2*	28 *2.9*	26 *2.2*	30 *2.1*
height		(cm)	t	31 *2.6*	36 *3.5* s	28 *3.1* sy	33 *1.7* y
species distribution white spruce/balsam fir/aspen/other or unknown		(%)		95/4/1/-	91/3/4/2	89/6/2/3	72/9/11/-
Depth of mineral soil[c]		(cm)	t	28 *.7*	27 *.5*	28 *.5*	28 *.5*
Depth to mineral soil (duff [LFH])		(cm)	t	7.0 *.60* q	7.9 *.52*	8.4 *.62* q	8.1 *.55*
Stoniness[d]		(%)	t	30 *6.4* r	20 *3.8* s	33 *5.7* sy	18 *4.5* ry
Soil texture[e]				loamy sand	loamy sand	loamy sand	loamy sand
Ground moisture				dry	dry	dry	dry
Ground condition[f]				1	1	1	1
Ground roughness[f]			t	1 [2]	1 [2]	1 [2]	1 [2]
Slope distribution[g]	-15 to -11	(%)	t	-	-	-	-
	-10 to -6	(%)		13	25 sx	6 s	9 x
	-5 to -1	(%)		36	22	46	40
	0 to +5	(%)		38	25	38	43
	+6 to +10	(%)		13	28	10	8
	+11 to +15	(%)		-	-	-	-
Brush: density		(stems/ha)	t	2800 *811* q	2140 *518* s	5020 *1260* qsy	1720 *526* y
stocking[h] aspen/balsam fir-spruce/other hardwood/=Total		(%)		18/21/5/=44	18/18/3/=39	20/27/14/=61	13/31/1/=35
Residual: density		(stems/ha)	t	270 *85* r	250 *72* x	300 *86* y	170 *50* rxy
stocking[h]		(%)	t	10.3 *3.1* r	10.0 *2.9* x	11.8 *3.5* y	6.8 *2.1* rxy
diameter (quadratic mean)		(cm)		29	36	26	31

a Test of significant difference (Chi-square or t-test) at p = 0.5: p(C & H/Angled), q(C & H/Modified V-blade), r(C & H/Fesco), s(Angled/Modified V-blade), x(Angled/Fesco), y(Modified V-blade/Fesco).

b Values in italics are confidence intervals at 10% significance level (sampling = 20 subplots).

c Soil depth > 35 cm was recorded as 35 cm. Average is for a zone from 0 to 35 cm.

d A steel rod was shoved into the soil every 2 m along transects. The presence of stones was recorded if a stone or boulder was encountered within the first 35 cm of mineral soil.

e According to Belisle's (1980) field manual for describing soils.

f Assessed according to Swedish terrain classification system (Anon. 1969). Square brackets refer to a % occurrence > 10% of the sample area. Ground roughness includes stumps as well as surface rocks, boulders, overturned stumps and depressions.

g Percentage of 20-m-long passes of implements within six classes of slope. Slopes refer to forward direction of travel.

h The presence or absence of at least one stem in a 2-m x 2-m quadrat.

There were also significant differences among the slopes recorded in the angled blade, modified V-blade and Fesco blocks but all slopes ranged from -10 to +10%, and this would not be considered a limiting factor for the tracked prime movers. Similarily, there was a significant difference between the duff depths in the C & H plow and the modified V-blade blocks but all depths were less than 10 cm and would not be considered a factor in light of the operating characteristics and weight of the tools.

No significant differences were found among the average diameter, the number of pieces or the volume of slash > 5 cm in diameter in all four blade tractor blocks. The large slash was made up primarily of windfallen hardwoods. Although they were not considered factors, differences were found in the quantity and volume of small slash 1 to 5 cm. (Figures for the angled blade, the modified V-blade and the Fesco V-plow were higher than those for the C & H plow). The small-diameter slash was predominantly conifer, 1½ years old.

There were significant differences in brush density among blocks. However, the size and weight of the tools and the prime movers involved far exceeded any effect that this brush could have on equipment operation.

Among the modified V-blade, the C & H plow and the angled blade sites the stocking and density of residuals were not significantly different and the values were higher than on the light skidder tool blocks. However, the Fesco V-plow block had significantly lower stocking and density than the other blade and front plow blocks and tended to have values closer to those found in the light skidder tool blocks (Fig. 26).

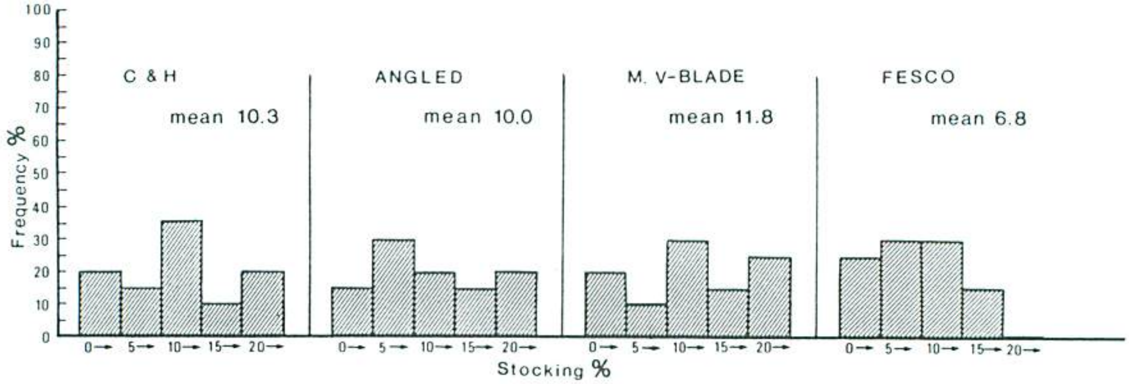


Figure 26. Frequency distribution of stocking (2 m x 2 m) of residuals (subplot basis)

Scarification Results

As with the light tool blocks, site conditions were considered similar among the blade and plow blocks, and this permitted comparison of tools on the basis of their operating characteristics (Fig. 27). Scarification results were assessed according to the same procedure as the light skidder tool blocks.

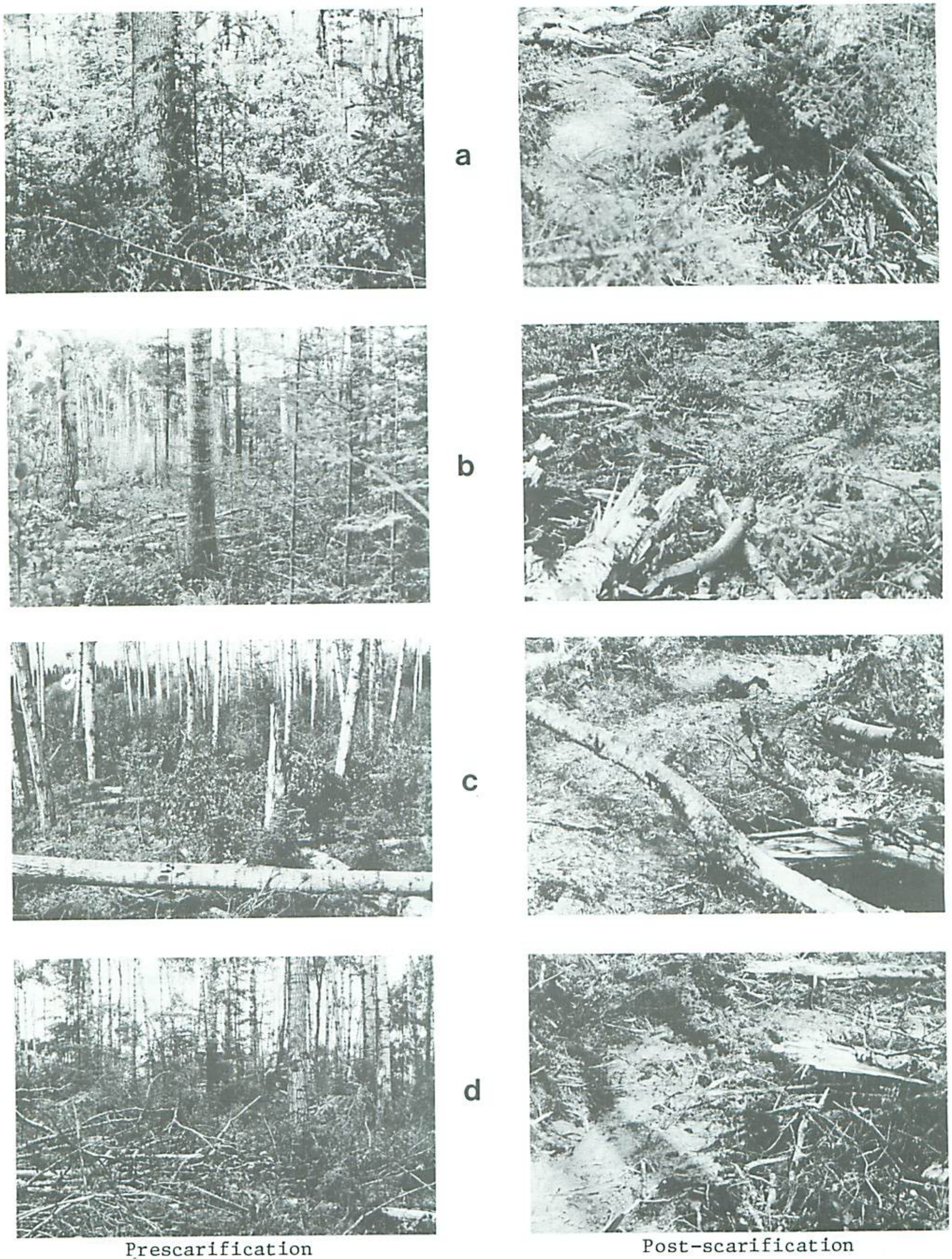


Figure 27. Prescarification and post-scarification in the a) C & H plow, b) Angled blade, c) Modified V-blade and d) Fesco V-plow blocks

Overall disturbance per microsite category: Under the "exposed mineral soil" category, the Cazes and Heppner and the Fesco V-plow did not differ significantly, nor did the modified V-blade and angled blade (Table 7). However, the wide blades as a group were significantly higher than the two front plows. The surface coverage of nonplantable overall disturbance was higher for the plows than for the blades, and this suggests that more quadrats were disturbed by the front plows (Fig. 28-30). Both the blades and the plows produced considerably more surface disturbance than the light skidder tools, as well as a higher degree of disturbance in the "exposed mineral soil" category.

The surface coverage of the "duff/mineral soil mix" category was higher for the angled blade (5.5%) than for the modified V-blade (2.2%) (Fig. 28). In Table 8, it can be seen that the net and subsurface widths of the angled blade were wider than those of the modified V-blade because the operating pattern of the angled blade requires more side pushing of debris than does the modified V-blade. This could explain the larger amount of mixed disturbance.

A comparison of the distribution (stocking) of overall disturbance yielded results that are similar for all four tools (Table 7).

Proportion of planting spots per microsite category: The modified V-blade achieved the highest proportion of planting spots under the category "exposed mineral soil", and conversely the lowest proportion of duff/mineral soil mix (Table 9 and Fig. 31) because of the high concentration of mineral soil exposure and low concentration of mixed duff/mineral soil on the subsurface of the corridor. The planting spots of all tools studied, with the exception of the Leno-77 and the modified V-blade which have been discussed, are similar with respect to the proportions of each microsite category (Tables 4 and 9).

Density of planting spots per microsite category: To assess density of planting attempts for the four tools, a spacing of 1.8 m along the corridor was prescribed with three rows in each corridor, 2.5 corridors per 20-m width (7.5 rows) or 2083 spots/ha for the modified V-blade and the angled blade, and one row per corridor, seven corridors per 20-m width (7.0 rows) or 1944 spots/ha for the C & H and Fesco plows. As the number of corridors completed by the angled blade was lower than normal, the density figures in Table 9 and the overall surface coverage figures in Table 7 have been adjusted upward from the actual 1.545 corridors achieved to 2.0 per 20-m width.

The modified V-blade produced a significantly higher number of plantable microsites per ha than the other three tools (Table 9 and Fig. 32). This is explained by the fact that the modified V-blade produced the highest number of rows, 7.4 per 20-m width (Table 8). This in turn resulted in the closest average spacing between adjacent planting spots, 1.53 m. A higher average spacing between rows of planting spots for the angled blade, 1.82 m, was the result of the greater net width of corridor for the angled blade (4.55 m) than for the modified V-blade (3.78 m).

Table 7. Overall soil disturbance in the Cazes and Heppner plow, Angled blade, Modified V-blade and Fesco V-plow blocks.

Disturbance categories		Surface coverage (%) Cazes and Heppner	Surface coverage (%) Angled blade[a]	Surface coverage (%) Modified V-blade	Surface coverage (%) Fesco V-plow	Distribution (stocking) (%) Cazes and Heppner	Distribution (stocking) (%) Angled blade[a]	Distribution (stocking) (%) Modified V-blade	Distribution (stocking) (%) Fesco V-plow
Plantable disturbance									
Exposed mineral soil or loose mineral soil < 10 cm on firm mineral soil base	t[b]	9.7 *2.1*[c] pq	20.1 *3.1* px	19.0 *3.1* qy	13.2 *1.6* xy	58	52	54	67
Duff/mineral soil compactable mixed on firm mineral soil base	t	2.2 *0.7* p	5.5 *1.6* psy	2.2 *0.9* s	1.9 *0.5* y	39	41	25	38
Duff < 4 cm on firm mineral soil base	t	3.1 *1.0* pq	9.1 *2.6* px	8.1 *2.1* qy	2.2 *0.7* xy	55	48	44	44
Total plantable disturbance	t	15.0 *2.4* pq	34.7 *4.7* px	29.3 *2.4* qy	17.1 *1.9* xy	76	66	65	79
Marginally plantable disturbance									
Duff > 4 cm but < 8 cm on firm mineral soil base	t	1.0 *0.3*	1.8 *0.9*	1.5 *0.5*	0.7 *0.5*	26	21	18	22
Total plantable and marginal disturbance	t	16.0 *2.6* pq	36.4 *5.0* px	30.8 *2.4* qy	17.8 *2.1* xy	77	68	66	83
Nonplantable disturbance									
Duff > 8 cm, mounded mineral soil on duff, hollow, water, bedrock		64.0	33.0	39.8	63.8				
Total disturbance		83.1	69.5	70.6	81.6				

a Adjusted values from 1.545 corridors to 2.

b Test of significant difference (Chi-square or t-test) at p = 0.5: p(C & H/Angled), q(C & H/Modified V-blade), r(C & H/Fesco), s(Angled/Modified V-blade), x(Angled/Fesco), y(Modified V-blade/Fesco).

c Values in italics are confidence intervals at 10% significance level (sampling = 20 subplots).

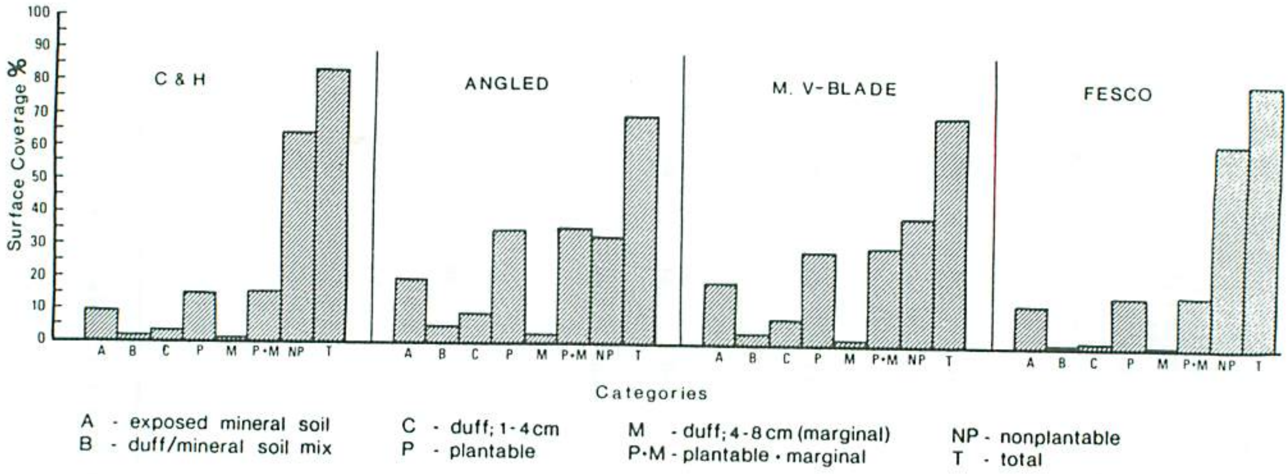


Figure 28. Surface coverage of overall disturbance per microsite category

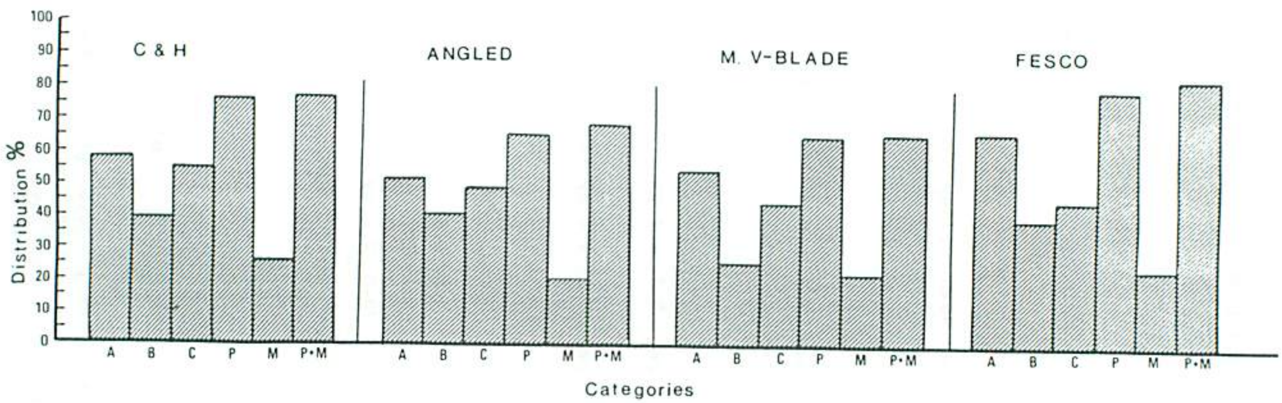


Figure 29. Distribution (stocking) of overall disturbance per microsite category

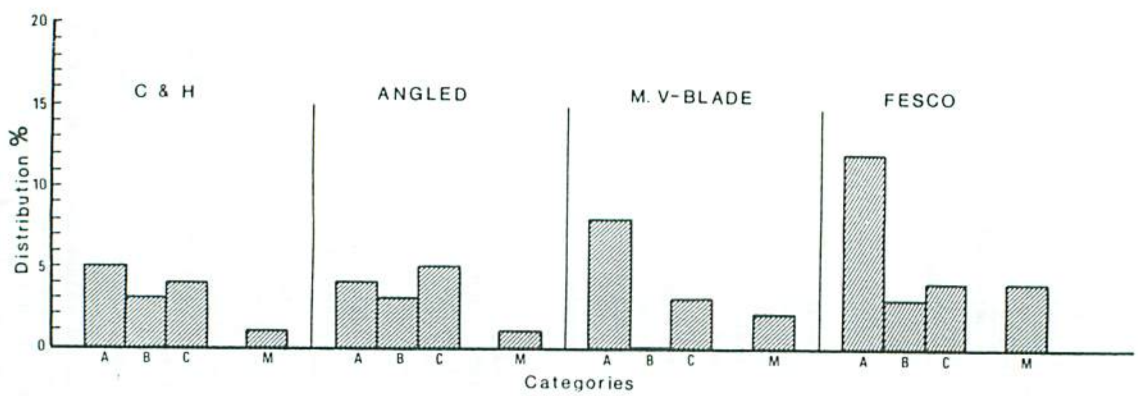
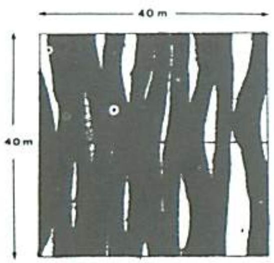
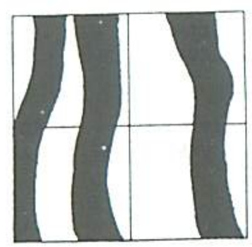
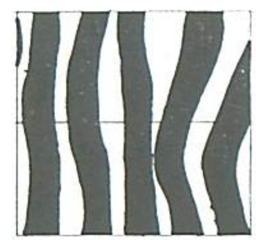
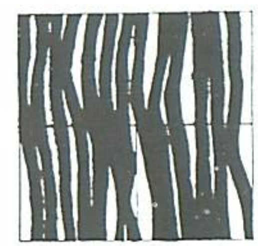


Figure 30. Exclusive distribution (exclusive stocking) of overall disturbance per microsite category

Table 8. Characteristics of corridors and furrows for the Cazes and Heppner plow, Angled blade, Modified V-blade and Fesco V-plow.

				Cazes and Heppner	Angled blade	Modified V-blade	Fesco V-plow
Corridor/furrow							
Gross[a]	length[b]	(cm)		200	188	200	200
	width	(cm)		398	697	600	300
Net[c]	length	(cm)		200	188	200	200
	width	(cm)		194	455	378	124
Subsurface[d]	length	(cm)		169	184	184	188
	width	(cm)		104	359	292	94
No. of rows per 20 m perpendicular to the direction of travel		(no.)	t[e]	5.5 *0.2* bc	6.1 *0.7* d	7.4 *0.3* bd	6.8 *0.2* c
No. of corridors per 20 m perpendicular to the direction of travel		(no.)		5.3	2.0	2.3	6.7
Avg spacing between adjacent plantable or marginal spots		(m)	t	2.46 *.26* ab	1.82 *.09* ae	1.53 *.07* bf	2.50 *.10* ef
Example of scarification coverage							

[a] Includes berms (See Appendix D).
[b] Maximum of 200 cm.
[c] Excludes berms (See Appendix D).
[d] Acceptable disturbance only (See Appendix D).
[e] Test of significant difference (Chi-square or t-test) at p = 0.5: a(C & H/Angled), b(C & H/Modified V-blade), c(C & H/Fesco), d(Angled/Modified V-blade), e(Angled/Fesco), f(Modified V-blade/Fesco).
[f] Values in italics are confidence intervals at 10% significance level (sampling = 20 subplots).
[g] Adjusted values from 1.545 corridors to 2.

Table 9. Proportion and density of planting spots per microsite category and percentage of prescribed number of planting spots per ha in the Cazes and Heppner plow, Angled blade, Modified V-blade and Fesco V-plow blocks.

Microsite categories	Number (%)					Density (no./ha)			
	Cazes and Heppner	Angled blade[a]	Modified V-blade	Fesco V-plow		Cazes and Heppner	Angled blade[a]	Modified V-blade	Fesco V-plow
<u>Plantable spots</u>									
Exposed mineral soil or loose mineral soil < 10 cm on firm mineral soil base	38 [-2][b]	49 [-1]	58 [-5]	49 [-1]	t[c]	576 *133*[d] qr [-28]	826 *129* s [-7]	1181 *138* qsy [-83]	889 *110* ry [-28]
Duff/mineral soil compactable mixed on firm mineral soil base	16	20	8	17 [-1]	t	243 *74*	347 *102* s	167 *72* s	306 *79* [-14]
Duff < 4 cm on firm mineral soil base	38 [-1]	27	31	27 [-2]	t	583 *107* [-14]	450 *97*	639 *95*	479 *117* [-7]
Total of plantable spots	92 [-3]	96 [-1]	97 [-5]	93 [-3]	t	1402 *71* qr [-42]	1623 *174* s [-7]	1987 *81* qsy [-83]	1674 *86* ry [-49]
<u>Marginal spots</u> Duff > 4 cm but < 8 cm on firm mineral soil base	2	4	3	3	t	35 *29*	71 *41*	69 *28*	49 *26*
Total of plantable and marginal spots	94 [-3]	100 [-1]	100 [-5]	96 [-3]	t	1437 *78* [-42]	1694 *188* [-7]	2056 *90* [-83]	1723 *78* [-49]
Percentage of prescribed plantable spots						74% (1944)	81% (2083)	99% (2083)	89% (1944)
<u>Nonplantable spots</u> Duff >8 cm, mounded mineral soil on duff, hollow, water, bedrock	6	-	-	4		90	-	-	76
Total of plantable, marginal and nonplantable attempts	100	100	100	100		1527	1694	2056	1799

a Adjusted values from 1.545 corridors to 2.

b Values in square brackets represent the portions that should be subtracted to obtain the number and density after the loss of microsites as a result of penetration problems (mainly rocks).

c Test of significant difference (Chi-square or t-test) at p = 0.5: p(C & H/Angled), q(C & H/Modified V-blade), r(C & H/Fesco), s(Angled/Modified V-blade), x(Angled/Fesco), y(Modified V-blade/Fesco).

d Values in italics are confidence intervals at 10% significance level (sampling = 20 subplots).

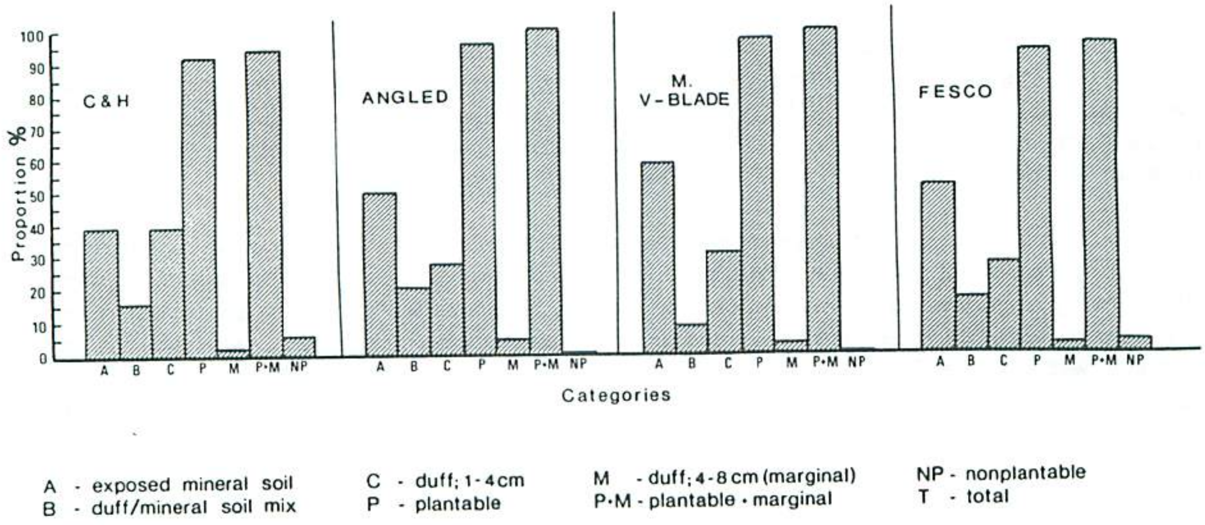


Figure 31. Proportion of planting spots per microsite category

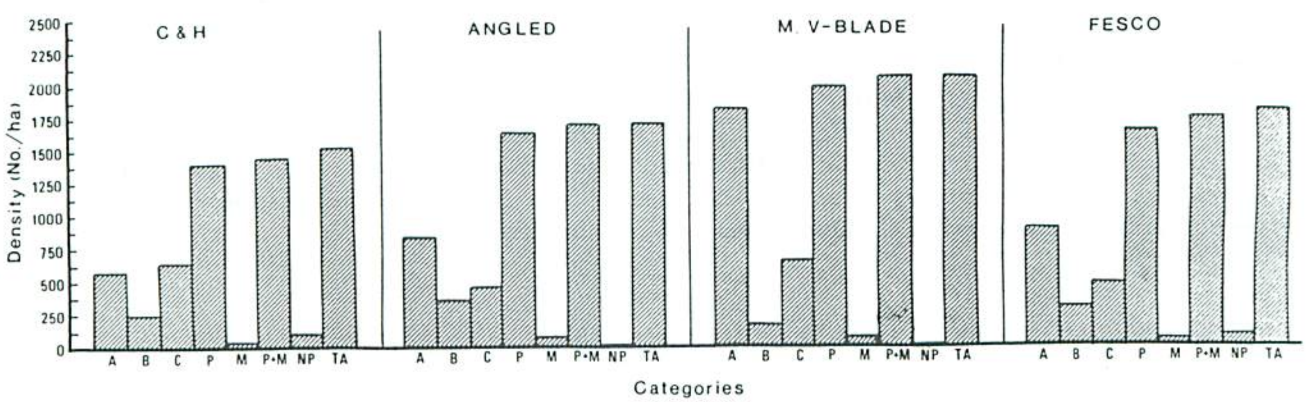


Figure 32. Density of planting spots per microsite category

The gross corridor widths achieved by both the modified V-blade and the angled blade, 6.0 and 6.9 m, respectively, indicate that a higher number of corridors than the 2.3 and 2.0 per 20-m width is possible with both tools. The wide blades displaced considerable debris and tended to maneuver around dense pockets of residuals, and this resulted in excessively wide leave strips. However, the closer spacing of corridors would result in more residuals being felled across leave strips and possibly into adjacent corridors. This could pose an obstacle to planters as well as to equipment passage.

The narrower and more maneuverable Fesco and C & H plow were able to weave between most residual clumps, and consequently, interpass spacing with these two plows was narrower. For the Fesco, the number of rows achieved (6.8) was very close to the number expected (7) as opposed to the C & H where the figures were 5.5 and 7, respectively. However the greater number of rows produced by the Fesco should have resulted in a higher density, but, because of an overlapping of passes, the potential number of spots was reduced (Table 9).

A lower density of plantable microsites in the C & H block than in the Fesco, 1402 vs 1674, can be explained as follows. The lower number of passes achieved by the C & H plow resulted from the greater gross width of the pass (3.98 m vs 3.0 m for the Fesco), even though only one row of trees could be planted (Table 8), because a comparatively narrow subsurface or usable width, 1.04 m vs 0.94 m, was achieved by the C & H and Fesco, respectively.

As with the wide blades, it may be possible to achieve a closer spacing of corridors for the Fesco and the C & H plows. However, it is doubtful that more passes per 20-m width would be possible with either tool without knocking down a high percentage of residuals across the adjacent corridors.

The modified V-blade achieved the highest density of plantable and marginal spots/ha, coming to within 1% of the 2056/ha objective (Table 9). When compared with the light skidder tools, the modified V-blade came to within 8% of the 2222 spots/ha prescription. The Fesco was the next highest, coming to within 11% of its 1944 spots/ha prescription. The angled blade was third, as it was adversely affected by excessive undisturbed area between passes. The C & H produced the poorest results, primarily because of the low degree of usable area in comparison with the overall area disturbed in the pass.

Work Study

For the tractor-mounted tools, with the exception of the angled blade, the recorded travel speed was between 2.4 and 3.2 km/hr (Table 10). Of the four tools, the modified V-blade achieved the highest number of subplots treated per hr. However, the range of values, from 16.8 to 27.8 subplots per hr, is only half that for the light skidder tools (45-56 subplots/hr). Of interest is the fact that the modified V-blade achieved a density of plantable and marginal spots similar to that achieved in the light skidder tool blocks but required twice the time to do so.

Table 10. Average speed, number of subplots treated per hour and distribution of time elements in the Cazes and Heppner plow, Angled blade, Modified V-blade and Fesco V-plow blocks.

			Cazes and Heppner	Angled blade	Modified V-blade	Fesco V-plow
No. of timed 20-m segments sampled		(no.)	114	27	44	139
Avg speed (without delays)		(km/hr)	2.35	n.a	3.22	2.52
No. of subplots treated per hr[a]		(no. of subplots/hr)	0.70	1.04	1.11	0.67
Distribution of time elements:	travelling forward and scarifying time	(%)	88.4	56.5	67.8	85.2
	delays caused by obstacles					
	stump	(%)	0.9	5.7	1.2	0.7
	residual	(%)	4.1	19.3	6.6	12.0
	slash	(%)	1.9	18.5	20.2	1.0
	windfall (downed from previous passes)	(%)	4.7	-	4.2	1.1

[a] Used for the purpose of comparison only. Values do not represented absolute productivity in long-term trials.

The time lost as a result of delays was greatest with the angled blade and the modified V-blade and considerably greater than in the light skidder tool blocks. This difference is even more striking when one considers the fewer number of passes created by the two tractor-mounted blades in comparison with any of the light skidder tools. The high proportion of delay time, 44% for the angled blade, was the result of maneuvering to clear residuals and slash ahead of the blade path. During this process the blade was lifted repeatedly, and as a result there were few usable microsites. The high proportion of delay time for the modified V-blade, 24%, arises from the need to reverse travel momentarily in order to part and clear debris built up during forward travel.

For the C & H and Fesco plows the number of passes per 20-m width, 5.3 and 6.7, respectively, is higher than for the light skidder tools (3.6 to 4.5). This resulted in fewer subplots treated per hr by the plows than by the light skidder tools, a fact that is further explained by a 10% lower proportion of time spent scarifying and a lower travel speed, 2.4 to 2.5 km/hr.

The distribution of delays in Table 10 indicates that downed residuals were less of a problem for the Fesco than for the wider C & H plow because fewer were knocked down; however, the density of residuals was lower in the Fesco block. On the other hand, the Fesco spent a larger proportion of time maneuvering around residuals than clearing them. The additional planting space created by pushing down more residuals rather than maneuvering around them is questionable in view of the fact that downed residuals present a considerable obstacle to equipment passage, as stated previously, and eliminate all shelter for the ground.

The lower productivity of tractor-mounted blades in comparison with the light skidder tools is a price that must be paid in high-density residual stands where the close spacing of large trees either standing or on the ground precludes the use of skidders as prime movers. However, proper matching of the design and size of site preparation equipment on the basis of residual conditions will help optimize scarifier efficiency.

SUMMARY AND RECOMMENDATIONS

The light skidder tools were evaluated in residual stands with 120 to 150 stems/ha while the four blade and plow tools were used in higher density stands of 170 to 300 stems/ha. The Fesco V-plow block had significantly lower density and stocking than the blocks on which other tractor-mounted tools were used. There was minimal variation in other site factors; consequently, a reasonable comparison of tools was possible.

For the Bräcke and the Leno-77 it was felt that each tool produced as many passes as was possible in view of the residual density and stocking. The TTS-35 model 2.4 m produced fewer passes in comparison. This may have been because of differences in operator decision with respect to the route chosen and/or differences in the distribution of residual stems, i.e., scattered vs clumped residuals.

The continuous furrows created by the TTS-35 clearly offered more opportunity for microsite selection than the intermittent patches created by the patch scarifiers on these site conditions. The choice of patch or continuous furrow scarifiers will depend on the thickness of duff and the amount and type (i.e., stumps, stones or slash) of ground obstacles present. Disc trenchers, for example, generally provide more continuous ground contact but, on sites with a very high density of surface obstructions such as boulders and/or stumps, the mattock-type scarifiers may be more effective because of the dragging of the teeth as opposed to the rolling disc action of trenchers. Interaction of the tools with the site conditions is a variable to consider. However, the number of passes achieved by the TTS during this trial will have to be increased so that the resulting density of plantable and marginal spots can come closer to the 2222 spots/ha prescription. Use of a narrower disc trencher than the 2.4-m model may allow a more even and perhaps higher row density by decreasing the fixed distance between discs and the overall width of the implement.

The Bräcke did achieve the prescribed 2222 spots/ha. As the gear setting was already at the 19-tooth sprocket, the number of attempts per lineal distance could be increased only by using a five-tine mattock wheel, and this would result in smaller scalps. In this trial the use of the five-tine mattock wheel was not necessary because the spacing of the furrows was sufficient to provide the density of plantable or marginal spots required by the prescription. The Leno-77 is lighter with less aggressively designed and wider mattock teeth than the Bräcke. In addition, in this trial the tool was improperly mounted and set. Collectively, these factors reduced the ability of the Leno-77 to penetrate duff to mineral soil and consequently a high proportion of light and medium duff microsite categories was chosen in the plantability assessment. Modifications such as adding weight to increase penetration would, however, have improved the quality of scalps produced by the Leno-77 in this trial. Future trials are recommended for the three light skidder tools in higher-density residual stands to determine limits of operation.

It appears that the "V" shape of the modified V-blade, the C & H and Fesco V-plows is a more efficient design than the angled straight blade, as debris is parted and aligned continuously with the former rather than being pushed to the side with considerable maneuvering. Both the angled and the modified V-blade create a spacing problem, as plantable microsites are concentrated in the corridors that are separated by excessively wide leave strips.

Both the Fesco and the C & H plows suffered from excessive unusable disturbance within each pass. The result was that only one row of plantable or marginal spots was created per pass in this type of soil. In soils that are soft or less compacted, the C & H will likely produce wider effective scarification (i.e., two rows) as the leading plow (nose) will sink deeper. This will result in more effective scarification or screefing by the outer deflection arms (Clarke 1977).

A scaled-down version of the modified V-blade or wider screefing by the C & H so that two rows of microsites are created per pass by the deflection arms would increase the efficiency of both tools. In the case of the modified V-blade excessive leave strips would be reduced and fewer obstacles would be encountered, so that the delay time associated with debris and residuals would be reduced. If the C & H were operated as a two-row rather than a single-row scarifier as was the case in this trial, fewer passes would be required to achieve the prescribed planting density. This would also increase productivity.

Site preparation in cutovers with mature and overmature poplar residuals is a common silvicultural problem not only in Saskatchewan but also in most boreal forest regions across Canada. Greater species utilization in the future may eliminate the need to contend with residual stands as an obstacle to scarification.

At present, large and costly tractors are used to clear corridors in such stands for planting. From an **operations point of view,** smaller and more maneuverable skidder-drawn implements offer a cheaper alternative and should be preferred until the stocking and density of residuals is so high that heavy blade-type tools are required to permit access to the site. Further refinements in the design and use of blades for corridoring could result in more effective clearing, better distribution of corridors and less severe disturbance of the site.

From a **biological point of view,** the scarification produced by the light tools and the Fesco and C & H plows appears to be preferable in terms of better spatial distribution of microsites, reduced severity of microsite exposure and closer proximity of soil nutrients to planted tree seedlings, but it raises the problem of proximity and growth of vegetative competition associated with mixedwood stands and the relatively narrow furrows and patches. The Saskatchewan government has established a followup tree planting trial on the study site. It is hoped that the results from this trial will indicate which types of microsite preparation are best under these conditions. It is recommended that further biological studies be undertaken.

LITERATURE CITED

Anon. 1969. Terrain classification for Swedish forestry. Skogsarbeten, Stockholm, Sweden. Report No. 9. 10 p. + appendices.

Belisle, J. 1980. Field manual for describing soils. Ont. Inst. Pedol., Univ. Guelph, Guelph, Ont.

Clarke, F.R. 1977. Evaluation of the C and H plough. Ont. Min. Nat. Resour., Intern. Rep. 38 p.

Heikurinen, J.K.K. 1981. Current management practices in the boreal mixedwood forest: Northeastern Region. p. 184-192 *in* R.D. Whitney and K.M. McClain, Cochairmen. Boreal Mixedwood Symposium. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont., Symp. Proc. O-P-9.

Mellgren, P.G. 1980. Terrain classification for Canadian forestry. For. Eng. Res. Inst. Can., 14 p.

Riley, L.F. 1975. Operational testing of planting machines in the boreal forest of Ontario. Reynolds-Lowther heavy duty crank axle planter. Dep. Environ., Can. For. Serv., Sault Ste. Marie, Ont. Report O-X-219. 37 p. + appendices, illus.

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

Ryans, M. 1986. Powered site preparation equipment: Potential application under Canadian conditions. p. 161-168 *in* Proc. 67th Annu. Meet., Woodlands Sect., Can. Pulp Pap. Assoc.

Smith, Rodney C., Ryans, M., and Leblanc, J.-D. 1985. Evaluation of the effect of tree-length and full-tree harvesting on the performance of three scarifiers. Can. For. Serv./For. Eng. Res. Inst. Can., Sault Ste. Marie, Ont. Joint Rep. No.6 and FERIC Rep. No. SR-26. 38 p. + appendices.

APPENDIX A

TECHNICAL DATA ON THE SCARIFIERS AND PRIME MOVERS

Scarifiers

TTS-35 DISC TRENCHER (MODEL 2.4 m)

disc type	Canadian
disc diameter	120 cm
number of teeth/disc.	9 (square-end)
length of teeth	28 cm
recommended power of prime mover. . .	97 kW +
weight.	2050 kg
- maximum loaded weight	3600 kg
angle adjustment: minor.	5 x 6° per major setting
major.	30° setting
maintenance	6 greasing points
hitch options	pin and draw 3-way swivel (universal joint) modified Bräcke hitch
price	$27,000 with 'O' ring hitch, 1986 F.O.B Dorion, Quebec

Manufacturers	Distributors
Tyotehoseura Ry Metsakoesema SF 05200 Rajamaki FINLAND	KBM Forestry Consultants Inc. 360 Mooney St. Thunder Bay, Ontario P7B 5R4
Tyovaline Oy (Finnish Agent) Karapellontie 10 P.O. Box 7 02611 Espoo 61 FINLAND	Hakmet Ltée. P.O. Box 248 Dorion, Quebec J7V 7J5

LENO MODEL 77 PATCH SCARIFIER (MODIFIED)

mattock wheels.	2 mattock wheels with 4 pairs of tines per wheel
tine width (manufacturer)	14 cm
length (manufacturer).	21 cm
distance between center of mattocks .	180 cm
weight.	1800 kg
recommended power of prime mover. . .	60 kW +
patch length	time of scalping is continuously adjustable with control knob
options	seeder attachment
overload protection	hydraulic control will release mattock wheels at a load of approximately 1700 kP on the teeth

hitch type.	universal joint, bolted to butt-plate
modifications	reinforced shafts on the mattock wheels - stronger rubber suspension
price	$44,000 to $49,000, 1986

Manufacturer	Distributors
System Svedlund AB P.O. Box 445 S-701 06 Orebro SWEDEN	Canadian Forestry Equipment Ltd., Western Office 17217-106 Avenue Edmonton, Alberta T5S 1H9
	Canadian Forestry Equipment Ltd., Ontario Office 7355 Torbram Road, Unit 15 Mississauga, Ontario L4T 3W3
	Canadian Forestry Equipment Ltd., Quebec Office 90E Brunswick Boulevard DDO Montreal, Quebec H9B 2C5
	Canadian Forestry Equipment Ltd., Maritime Office 65 Thornhill Drive, Burnside Industrial Park Dartmouth, Nova Scotia B3B 1R9

BRÄCKE CULTIVATOR (TWO-ROW)

mattock wheels.	2 mattock wheels with 4 pair of tines per wheel
tine(tooth) width.	11 cm(15 cm)
length	24 cm(67 cm)
weight.	3000 kg
tires	30.0 x 60.0 cm, 16-ply
recommended power of prime mover. . .	97 kW +
drive sprocket.	17 teeth/sprocket
options	one-, two- and four-row model seeders
. . . .	travel trailer
. . . .	15- and 19-toothed sprockets for changing patch length
. . . .	mattock wheel with 5 pairs of tines
hitch	Bräcke type
price	$37,350 including hitch, 1986

Manufacturer	Distributors	
Robur Maskin AB Gransgatan 42 S-840 60 Brac SWEDEN	KBM Forestry Consult. Inc. 360 Mooney St. Thunder Bay, Ontario P7B 5R4	Woodlands Services Inc. Box 257 Moose Lake, Minnesota 55167 USA
	KBM Forestry Consult. Inc. Box 5462 Rome, Georgia 30162 USA	FORABI Inc. 221 rue Bolduc Amos, Quebec J9T 3M4

CAZES AND HEPPNER PLOW

configuration	"V" type
width	3 m
length	3 m
height	2 m
weight	2650 kg
options	5-cm-high center colter on rolling drum to help break down slash
mounting	C-frame
price	$16,900, 1986

Manufacturer and Distributor

Cazes and Heppner Forest
Services Ltd.
81 Hamm Road,
R.R. # 1,
Abbostford, B.C.
V2S 1M3

ANGLE BLADE (MODEL 8A)

configuration	angle
width	4.85 m
angle from tractor	25°
effective width	4.39 m
height	1.29 m
weight(shipping)	5451 kg
mounting	C-frame
price	n/a

Manufacturer	Distributors
Crothers Caterpillar One Crothers Drive P.O. Box 5511 Concord, Ontario L4K 1E2	All Crothers Caterpillar dealers (Head office) One Crothers Drive P.O. Box 5511 Concord, Ontario L4K 1E2

MODIFIED V-BLADE

configuration	"V" type
length	1.52 m
width	3.7 m
height	2.08 m
weight	4536-5443 kg
mounting	C-frame
price	n/a

Manufacturer	Distributor
(locally modified Beale shearing blade and KG blade) E & L Construction Ltd. P.O. Box 146 Big River, Saskatchewan S0J 0E0	(not applicable)

FESCO V-PLOW (MODEL VP540)

configuration . . . . "V" type
length (front to rear of
cutting edge) . . . . 2.1 m
width (cutting) . . . . 1.37 m
height. . . . . 1.6 m
weight. . . . . 1910 kg
hitch . . . . C-frame
price $17,000, 1986

Manufacturer	Distributors
Fesco Forestry Equipment Specialists P.O. Box 1277 Starksville Mississippi 39759 USA	KBM Consultants Inc. 360 Mooney Street Thunder Bay, Ontario P7A 4M3 Canadian Forestry Equipment Ltd., Western Office 17217-106 Avenue Edmonton, Alberta T5S 1H9 Canadian Forestry Equipment Ltd., Ontario Office 7355 Torbram Road, Unit 15 Mississauga, Ontario L4T 3W3 Canadian Forestry Equipment Ltd., Quebec Office 90E Brunswick Boulevard DDO Montreal, Quebec H9B 2C5 Canadian Forestry Equipment Ltd., Maritime Office 65 Thornhill Drive, Burnside Industrial Park Dartmouth, Nova Scotia B3B 1R9

Prime Movers

CLARK RANGER 667 GRAPLE SKIDDER

engine. . . . . 453 Detroit Diesel
power rating 90-kW SAE flywheel (124 HP)

power train . . . . torque converter - single-stage transmission - powershift, 3-speed forward and reverse-low reduction

maximum travel speeds	1st gear	2nd	3rd
	4.8 km/hr	12.8 km/hr	24.1 km/hr

tires . . . . 24.5 x 33 -- chains on front and rear during trial

TIMBERJACK 380 CABLE SKIDDER

engine. . . . . 453 Detroit Diesel
power rating 90-kW SAE flywheel (124 HP)

power train . . . . torque converter -- single-stage transmission -- powershift, 3-speed forward and reverse

maximum travel speeds	1st gear	2nd	3rd
	4.8 km/hr	12.8 km/hr	24.1 km/hr

tires . . . . 23.1 x 26 - no chains

CATERPILLAR D8H (model 46A) TRACK-TYPE TRACTOR

engine. . . . . Turbo-charged Cat diesel model
power rating 201 kW SAE flywheel (270 HP)

power train . . . . torque converter -- single-stage transmission -- power shift 3-speed forward and reverse

maximum travel speeds	1st gear	2nd	3rd
	3.9 km/hr	6.8 km/hr	10.5 km/hr

tracks. . . . . width 6096 mm (24 in)
length (on ground) 3150 mm (124 in)

APPENDIX B

ASSESSMENT PLOTS

A plot system modified from that described by Smith et al. (1985) for the testing of light scarification machines was used for the TTS-35, the Bräcke (two rows) and the Leno-77 (modified) in this trial. For the Cazes and Heppner plow, the angled blade, the modified V-blade and the Fesco V-plow, a plot system modified from that employed in the previous plots was used.

In the first case, each plot was 100 m long by 20 m wide (0.2 ha) with five 20-m x 20-m (0.04-ha) subplots. In the second case, each plot was 40 m x 40 m (0.16 ha) with five 20-m x 20-m (0.04-ha) subplots as indicated in Figure B1.

The subplots facilitate data analysis and the timing of equipment operations in the plots. Four plots (20 subplots) were established in each of the TTS-35, Bräcke and Leno-77 blocks and five plots (20 subplots) in each of the C & H plow, angled blade, modified V-blade and Fesco V-plow blocks.

Corners on one side were marked by semipermanent corner posts and all subplot boundaries were marked by flagged chaining pins to facilitate relocation after equipment operation.

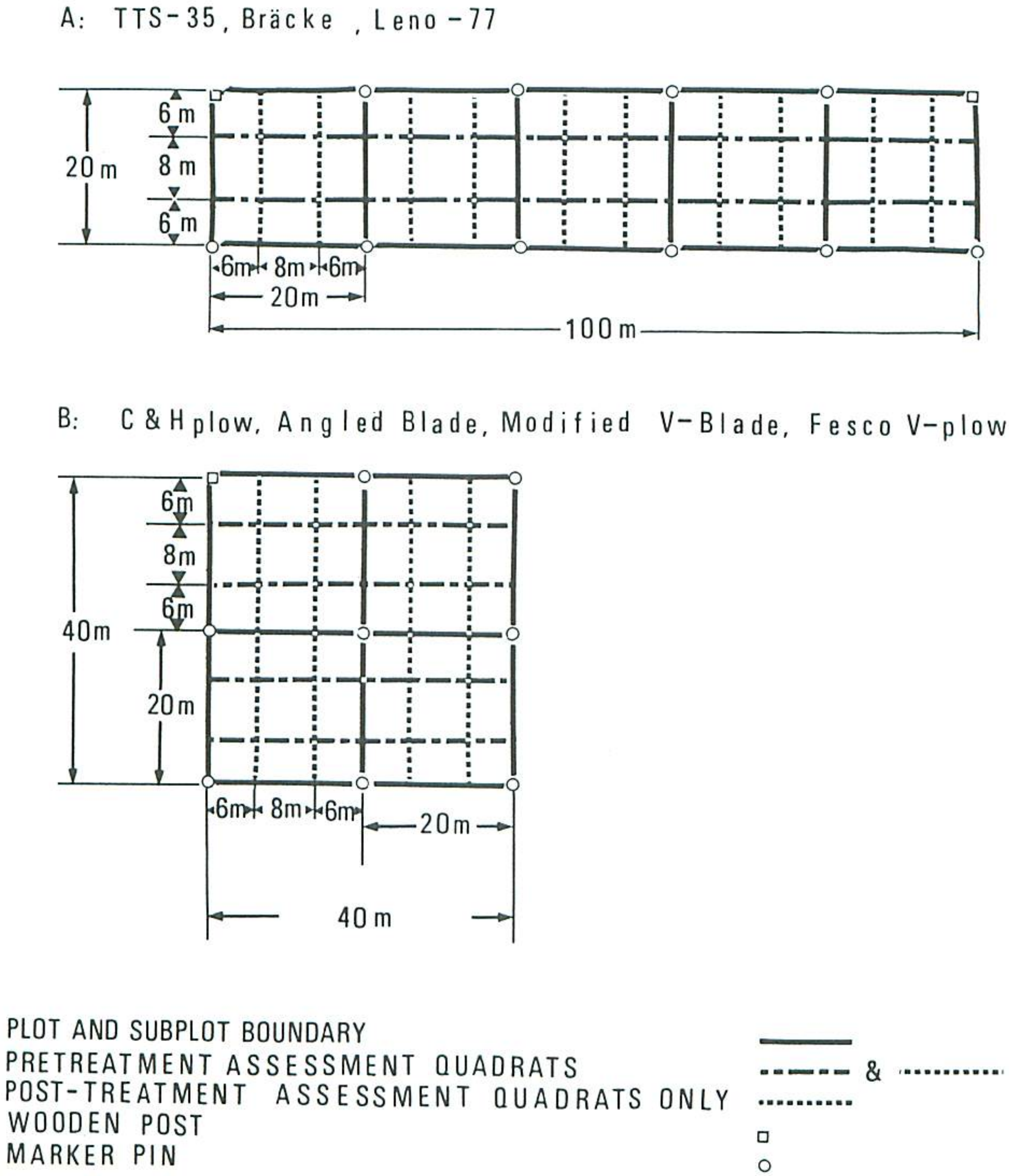


Figure B1. Plot layout for pre- and post-treatment assessments.

APPENDIX C

DEFINITION OF SHORT-TERM STUDY TIME ELEMENTS

The time study was recorded in the subplots only.

FORWARD AND SCARIFYING: Begins when the implement is in the soil and the prime mover begins forward travel. The scarifying time can include **winching** if the implement is equipped with a quick disconnect hitch and there is effective scarification during winching.

OBSTACLE: Is the time between stopping, because of an obstacle, and resumption of scarification. It includes various elements, depending upon the scarifier. Depending upon the cause, the obstacle time is charged against the implement or the prime mover.

APPENDIX D

POST-TREATMENT ASSESSMENT

The amount and quality of site preparation were assessed in terms of the production of plantable spots and disturbance. The basic sample unit was a 2-m x 2-m quadrat for disturbance. Two transects, each 1.8 x 20 m, were aligned perpendicular to the direction of scarification for plantability across each subplot.

Plantability

Within each furrow of the TTS-35, Bräcke and Leno-77, or within each row within the corridors of the C & H plow, angled blade, modified V-blade and Fesco V-plow, the best microsite was selected, tested for plantability and described. A plantable microsite was defined as a spot approximately 30 cm^2 meeting the best conditions for each of the following four categories.

Note: 'P' denotes a plantable condition, 'M' marginal and 'NP' nonplantable.

Debris (needles, bark, twigs, stems, roots, etc.)

P None. No debris or debris insignificant with respect to hand planting or survival.

M Light. Partially covered with debris, so that the planter is required to displace a slight amount of material prior to planting.

NP Heavy. Mostly or completely covered with debris, so that the planter is required to alter the microsite prior to planting.

Vegetative Competition

P None.

M Competing herbaceous vegetation only.

NP Competing woody vegetation.

Soil/Duff Modification Categories

P 1. Exposed mineral soil with a firm base, or
2. Thin (⩽10 cm) duff/mineral soil mix which would readily settle to a firm base, or

3. Thin ($\leqslant$4 cm) duff on firm mineral soil.

M 1. Moderately thick (>4 cm but < 8 cm) duff on firm mineral soil.

NP 1. Excessively deeply exposed mineral soil; i.e., 'C' horizon, or
2. Mounded mineral soil on thick duff or debris, or
3. Thick (>10 cm) duff/mineral soil mix, or
4. Thick (>8 cm) duff, or
5. Inverted sod layer, or
6. Other, including mounded duff, exposed rock, water, etc.

If a microsite meeting all of the above criteria for plantability were not available, a microsite with marginal or, if necessary, unplantable conditions would be designated the best choice. A planting shovel was used to test whether the selected spot was penetrable. If it was not, another spot was selected.

The final spot selected was described according to the P, M or NP classes listed for the conditions above. In addition, the following were recorded:

Penetration

P Full penetration

NP Rock
Root mat
Debris
Water

Origin of Planting Spot

Created by implement
Created by prime mover (logging or scarification)
Natural disturbance
No disturbance

Microrelief of Planting Spot

Level
Raised
Side
Hollow

Spots created by the implement were given first priority for selection as plantable spots. If only marginally acceptable conditions were created by the implement, plantable conditions created by other means would be selected if available. Similarly, marginal conditions created by the implement were given higher priority over marginal conditions originating from other sources. In terms of microrelief, the preferred location was in plantable quality soil disturbance on the side of the scalp or furrow close to the mineral soil-humus interface.

Disturbance

Quantity

The total percentage (to the nearest 5%) of soil and/or duff disturbed by the implement in each quadrat was recorded. The combined disturbance from logging, implement prime mover and natural causes was also recorded. Disturbance was defined as:

1. exposed or dislocated mineral soil
2. reduced, compressed (less than half undisturbed depth) or dislocated duff
3. exposed rock previously covered by duff and/or mineral soil.

Quality

The total percentage of area to the nearest 1% in each of the P and M soil disturbance categories listed under 'Soil/Duff Modification Categories' was recorded on every second quadrat. A distinction was made between disturbance created by the implement and disturbance from other sources.

Dimensions of Scalps/Furrows/Corridors

In each subplot, two scalps/furrows/corridors were measured to determine the average length and width of the hollowed-out useful (subsurface) and mounded (gross) sections. For the furrows/corridors the gross length was to a maximum of 2 m, the net (without berms but not necessarily usable) and the subsurface surfaces were also recorded (Fig. D1, D2 and D3).

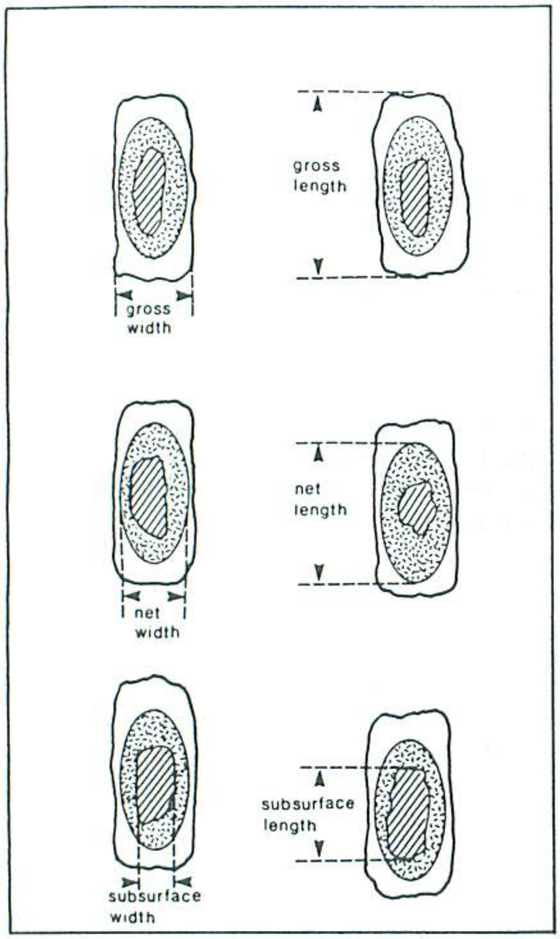


Figure D1 (above). Gross, net and subsurface parameters for Bräcke and Leno-77 scarification.

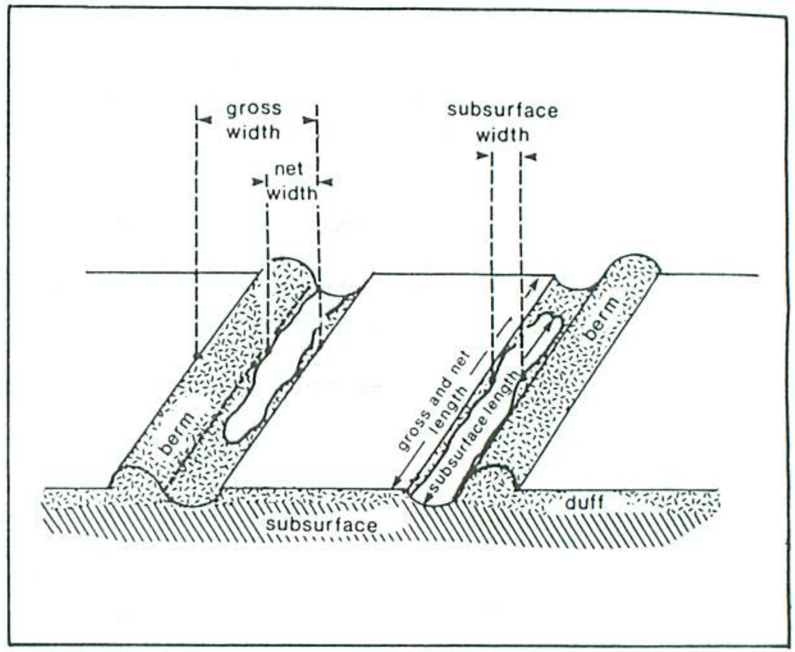


Figure D2. Gross, net and subsurface parameters for TTS-35 disc trencher scarification.

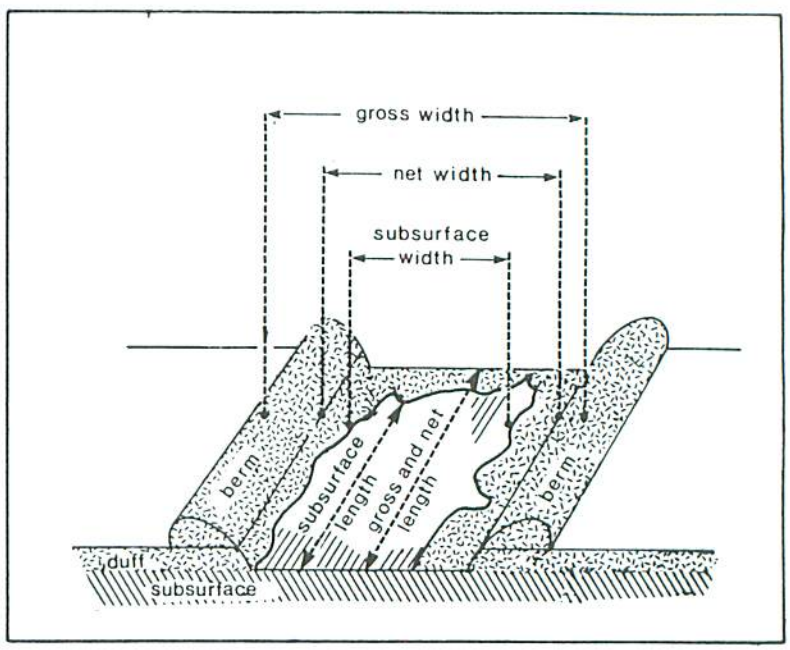


Figure D3 (right). Gross, net and subsurface parameters for Blades and Plows scarification.