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HANNU KALAJA

AN EXAMPLE OF TERRAIN CHIPPING SYSTEM IN FIRST COMMERCIAL THINNING

ESIMERKKI ENSIHARVENNUSPUUN KORJUUSTA PALSTAHAKETUSMENETELMÄLLÄ

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FOLIA FORESTALIA 584

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Hannu Kalaja

AN EXAMPLE OF TERRAIN CHIPPING SYSTEM IN FIRST COMMERCIAL THINNING

Esimerkki ensiharvennuspuun korjuusta palstahaketusmenetelmällä

Approved on 10.2.1984

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The study deals with the methods of terrain chipping in the first commercial thinnings of Scots pine using the Lokomo 919/P1000 forwarder-mounted terrain chipper. A comparison is made between terrain chippings of manually and mechanically felled trees, and landing chipping. The field study has taken place with the same machinery in both Finland and the Estonian Soviet Socialist Republic (Estonia).

In Finland, the output of the Makeri feller-buncher was 11.3 m^3 per effective hour in a stand with an average tree volume of 59 dm^3. In Estonia, the output was 9.8 m^3 for trees of 48 dm^3.

Chipping of manually felled trees including a 300 meter haulage gave an output of 6.5—8.2 m^3 of chips per operating hour depending on the stand conditions. The corresponding figures for the mechanically felled trees were 9.0—9.3 m^3/h. In Estonia, the chipping of mechanically felled trees gave an output of 13.1 m^3/h with a forwarding distance less than one hundred meters. In Finland, the output in landing chipping was 16.4 m^3/h.

Of the damage caused to the stand by Makeri only the damage on stems was measured. The number of remaining trees was 1035/ha, with 1 % of them damaged. In the chipping of manually felled trees the terrain chipper left 1.8—3.1 % of the remaining trees damaged. The chipping of mechanically felled trees left 2.7—3.3 % of the trees damaged. The greatest cause of damage was the grapple loader, which depending on the method used caused 56—71 % of all damage.

Tutkimus selvittää palstahaketusmenetelmiä männikön ensiharvennuksissa Lokomo 919/P1000 palstahakkurilla. Vertailuna on mies- ja konekaadon jälkeinen palstahaketus sekä varastohaketus. Tutkimusta on tehty sekä Suomessa että Eestissä samoilla koneilla.

Makeri kaato-kasauskoneen tehotuntituotos oli 59 dm^3:n runkokoolla 11,3 m^3/h Suomessa tehdyissä kokeissa ja Eestissä vastaavasti 9,8 m^3/h rungon koon ollessa 48 dm^3.

Hakkurin tuotos vaihteli Suomessa palstahaketuksessa mieskaadossa ja leimikko-oloista riippuen 300 metrin ajomatkalla 6,5—8,2 m^3/tehotunti. Kaato-kasauskoneen jäljiltä haketustuotos oli vastaavasti 9,0—9,3 m^3/h. Vajaan sadan metrin siirtymismatkalla Eestissä konekaadon jälkeinen haketustuotos oli 13,1 m^3/h. Suomessa tehdyissä varastohaketuskokeissa tuotos oli 16,4 m^3/h.

Makerin aiheuttamista vaurioista mitattiin vain runkovauriot. Jäljelle jäävä runkoluku oli 1035 kpl/ha ja vaurioitumisprosentti 1,0 %. Palstahakkurin aiheuttamat runkovauriot vaihtelivat siirtelykaatomenetelmässä 1,8—3,1 % jäljelle jäävään runkolukuun nähden ja vastaavasti konekaadon jäljiltä haketettaessa 2,7—3,3 %. Suurin vaurionaiheuttaja oli kuormain menetelmästä riippuen 56 %:sta 71 %:iin.

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PREFACE

The research which is part of the Finnish Forest Research Institute's PERA-project analyses the LOKOMO 919/P1000 forwarder-mounted terrain chipper's operation methods, output, and chip characteristics.

Rauma-Repola's ironworks in Tampere has been responsible for the operations of Lokomo 919's basic machine. The manager of Lokomo's forest machinery division, Olof Thesslund, and project-engineer, Seppo Taatila, have represented the company during the course of the study. Zerne Oy, in Imatra, built the chipper itself, the feeding device and the chip container. Simo Pihlajaviita operated the chipper. On behalf of Makeri Oy, training manager Kauko Papunen assisted in the research and Kai Lahtinen and Pentti Jussila were operators. The field studies were carried out on Enso-Gutzeit Oy's land in Taipalsaari and Ruokolahti. Forestry technician Jukka Huovinen was responsible for the organization of the work sites. Continuation studies were done on Rauma-Repola's land in Multia. Foreman Jouko Nahkola assisted in the organization of the work site.

Foreman Tapio Nevalainen directed the collection of study materials. Kimmo Piirainen, engineer, was responsible for the chipper's ergonomic characteristics concerning vibration and noise measurements. Figures 3 and 4 were done by Pirkko Hakkila, fine arts teacher. Mrs Pirkko Kinanen typed the manuscript. Photographer Pentti Valmunen took the colour page photo. The report was translated into English by Mrs Elva Nurmi. Professor Pentti Hakkila and research station director Pertti Harstela scrutinized the draft copy.

Rauma-Repola handled the chipping studies in Estonia. The following persons participated on the behalf of EKE: as research designer, Jan Kabin, the first vice-chairman; director of housing production Alvar Ild was responsible for study operations; in Pärnu, deputy director of building materials Harri Lusik was responsible for the execution of field studies and Jüri Otsmaa was responsible for forestry practices; Henn Luks, deputy director of the technical development department, and Aarne Röuk, leading specialist, in the areas of language and interpretation.

I wish to extend my thanks and appreciation to EKE and all the people who participated in the study, and especially for the research material I was able to use.

Helsinki, May 1983

Hannu Kalaja

1. INTRODUCTION

Small tree harvesting methods based on whole-tree chipping can be divided according to chipping site in the following way:

- Terrain chipping systems
  - Chipping on the wood lot
  - Chipping on the strip road
- Landing chipping
  - Chipping on the landing
  - Chipping at the centralized processing terminal
  - Chipping at the site of utilization

In clear cutting conditions the terrain chipper can usually move freely about the cutting area, but during thinning it remains on the strip road. When the load is filled, the terrain chipper drives to the landing and empties the load into a truck's changeable pallet.

The terrain chipper can also be used on the landing, where whole- or cut trees are brought from the wood lot. Chips are blown into the chipper's storage bin, straight into a truck, or into a changeable pallet. The disadvantage of chipping on the landing is the need for large space at the site.

Snow and terrain limit the use of the terrain chipper. Nevertheless, terrain chipping has many notable advantages. For example:

- Because tall trees do not necessarily have to be cut in every harvesting system, the felling phase is eased. Landing chipping requires bucking of trees over 7—9 meters in length before forwarding.
- Forest haulage of whole-trees is omitted. This avoids the damage which is easily inflicted on the thinning stand when loading the whole-tree into the forwarder. On the other hand the heavy terrain chipper requires a slightly wider strip road than a medium-weight forwarder.
- Infeed from the side directly into the chipper can be done just as quickly as lifting the trees into the forwarder's load space. The maneuverability of the forwarder-mounted terrain chipper is nearly equal to that of a forwarder hauling whole-trees. Likewise, unloading of the load of chips by dumping occurs in approximately the same amount of time as unloading whole-trees with a grapple loader. For these reasons it is possible to operate the terrain chipping system in certain conditions at lower costs than the harvesting system based on landing chipping. Since the terrain chipper is, however, an expensive mode of transportation, its use is limited to short hauling distances only.
- The terrain chipper is able to move on its own from one work site to another. Many landing chippers are able to do so also, but some require a separate transport vehicle to transfer them from one site to another.
- Storage arrangements are eased because the need for space is smaller than in landing chipping, where whole-tree piles, the chipper and truck all have to be located near each other at the same time.
- Branches, needles, bark and sawdust are always left at the chipping site. The residue is an inconvenience on the landing but in terrain chipping at least some part will be scattered into the forest and will remain as a nutrient source to the soil.
- Terrain chipping will require less handling of wood than landing chipping, so that accordingly the amount of rocks, sand and other impurities which come along with the grapple loader remains smaller. The chipper's knives remain sharp longer and the recovered chips will be cleaner.
- Especially during autumn and spring, when road conditions are poor, the bearing capacity of the landing site can be so low that the movement of the landing chipper and truck will cause problems. The terrain chipper's terrain capabilities as well as the ability to flexibly place the changeable pallet onto a place where the bearing capacity is high enough for the truck are significant advantages in this situation.

For the reasons mentioned above, the terrain chipping system is an economical harvesting system alternative when the terrain and snow conditions, and hauling distance make it feasible. From an economical viewpoint it is presupposed that a sufficient number of stands of this type are available.

2. LOKOMO 919/P1000 FORWARDER-MOUNTED TERRAIN CHIPPER

In Finland, the development of terrain chippers began in 1974, when the first farm tractor-mounted TT-chipper was constructed (Hakkila et al. 1975). The first forwarder-mounted terrain chipper, TT 1000 F, was completed in 1976 (Kalaja 1978).

The Lokomo 919/P1000 terrain chipper, manufactured in 1982, is principally intended for chipping of whole-trees on the strip road. The trees are fed from the right side of the chipper. The chipper's technical information is as follows:

Basic machine: Medium-weight 6- or 8-wheeled Lokomo 919 forwarder

Length	9900 mm
Width	2600 mm
Height	3900 mm
Ground clearance in front and in back	520 mm
Basic machine's weight	10.5 t
Whole unit weight	15 t
Towing capacity	13 t
Bearing capacity	10 t
Motor's power capacity	68 kW 42 r/s

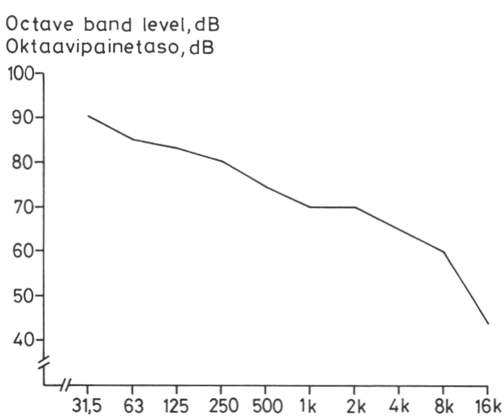

Fig. 1. The dominant noise level in the cab during chipping according to octave analysis.
Kuva 1. Haketuksen aikana ohjaamossa vallitseva äänenpainetaso oktaavianalyysin mukaan.

Sound level in cab: When chipping was in process the sound level was 77 dB (A) (Fig. 1). A sound level of 69 dB was recorded while the chipper was idling and while it was moving 75 dB were measured. In all situations the noise level was lower than that in the SFS 29400 standards, where the highest level permitted in a forwarder is 85 dB (A).

Vibration of the cab: The amount of vibration on the operator was measured in both vertical and perpendicular directions to the course of travel. In both cases agitation measurements were clearly under the safety standards listed in ISO 2631 (Fig. 2).

Chipper: Zerne Oy's cone chipper is mounted between the basic machine and the chip container. The chipper is powered by a 109 kW, air cooled, rotary clutch equipped diesel motor of its own. The chips are blown into the container with the aid of the air current generated by the chipper.

Drum diameter		1060 mm
Rotational velocity	(max.)	21 r/s
Number of knives		2
Infeed speed		1.3 m/s
Adjustable length of chips		20—50 mm

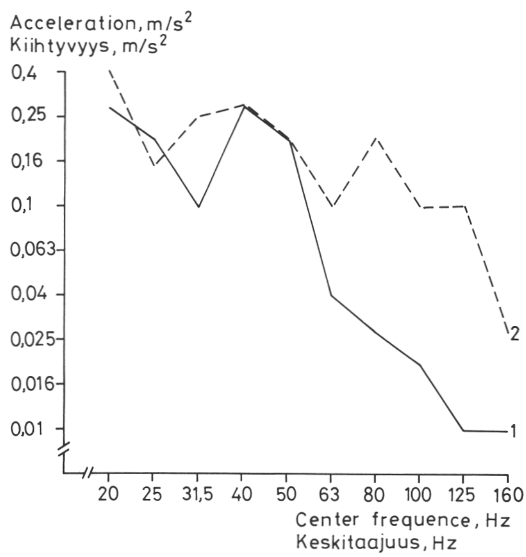

Fig. 2. The agitation of vibration directed against the operator's body during chipping measured according to the tierce analysis. 1) vertical and 2) sideway movement.
Kuva 2. Haketuksen aikana kuljettajan kehoon kohdistuvan tärinän kiihtyvyys terssianalyysin mukaan. 1) pystysuunta 2) sivusuunta.

Chipper's hydraulic feeding device: Above the feeding opening is a vertically moving spiked roller and on the bottom are three smaller hydraulically driven infeed rollers. The feeding device can be raised vertically. The trees are fed perpendicularly from the right side of the machine.

Infeed length	1500 mm
Infeed roller width	400 mm
Infeed opening width	400 mm
Infeed opening height	280 mm

Chip container: The chip container is emptied by dumping. The upper corners in the back section of the container are hinged onto the supportive frame of the load space. The container is equipped with hinged doors made of mesh-like material which open and close automatically during dumping.

Container volume	16.4 m^3
Maximum height when dumping	2.7 m

Basic engine Deutz BF 6 L 913 motor:

Displacement		6.128 dm^3
Maximum capacity	109 kW	42 r/s
Maximum torque	468 Nm	27.5 r/s
Fuel tank volume		200 dm^3

Grapple loader: Fiskars 60L + AJ	3200 boom
Gross lifting capacity	70 kNm
Reach	9.1 m

3. MAKERI 33 T FELLER-BUNCHER

Felling, and especially bunching, of small whole-trees to the strip road involve heavy manual labour. The Makeri 33 T, a small-sized tractor set on tracks is used as the basic machine for the feller-buncher in first commercial thinning of young forests. In this research study the work done by the Makeri feller-buncher is compared to felling manually.

Basic machine:

Motor:	Deutz F2L 511, 2-cylinder, water cooled diesel, 25.7 kW/50 r, (35 hp/3000 rpm).
Transmission:	Hydrostatic. Each track has its own variable displacement pump and a closed hydraulic system including a hydraulic motor
Steering:	Rod-controlled by driving the two tracks at different speeds and in different directions

Length with feller-buncher device attached	3660 mm
Width	1620 mm
Height	2750 mm
Ground clearance	410 mm
Weight	3620 kg
Hoisting arms and felling-bunching device	Tilting forward and back 120° Side swing −23°...27° Hoisting the arms −6°...24°
Grapples	Two pairs of grapples, the lower pair hinged, which enables it to store and carry 1—6 trees simultaneously
Shearing knives	Hydraulic shear with maximum shearing capacity of 250 mm

4. RESEARCH MATERIAL

41. Studied harvesting systems

The terrain chipping system was studied in the first commercial thinnings of pine stands on two different work sites. Landing chipping was carried out on only one site in Ruokolahti. The following harvesting systems were studied:
Terrain chipping system based on manual felling with chain saw:

The trees are felled with a felling-frame equipped chain saw and the felled trees are manually stockpiled at a distance of 1—9 m from the strip road. If necessary, longer trees are bucked before bunching. The distance between strip roads is 25 m. The trees are chipped on the strip road directly from the piles the logger has made. The chips are transported in the chipper's container to the changeable pallet on the landing. 241 m^3 of chips were produced (Fig. 3 and 4).

Fig. 3. Multilift changeable pallet system. (Photo by Kauko Papunen).
Kuva 3. Multilift vaihtolavajärjestelmä. (Kuva Kauko Papunen).

Terrain chipping system based on mechanical felling:

Felling and bunching to the strip road are done with Makeri 33 T tractor. The distance between strip roads is 30 meters. Chipping is done from rather large piles placed alongside the strip road. The chips are transported as in the above system. 482 m^3 of chips were produced (Fig. 5).

Landing chipping system based on manual felling with chain saw:

Manual felling and bunching are done as in the first system. Tall trees must be bucked with a chain saw before forwarding. The trees are forwarded to the landing, where chipping is done from large stockpiles. The chips are first blown out into the chipper's container and then dumped into a changeable chip pallet. 151 m^3 of chips were produced, 70 % of which was Scots pine and 30 % Norway spruce.

42. Stand data

The chipping studies were carried out on the strip road of a first commercial thinning pine stand in summer. Difficulty of maneuverability in the stands was rated as terrain class 1 (Specifications: terrain is mostly flat with maximum grades of: Down-grade $<$15 %, up-grade $<$10 % and side-grade $<$5 %. The exsisting large rocks and stumps can be avoided. Ruts do not hinder forwarding).

Continuation studies were done in Multia, when the chipper operator had more experience in chipping. The terrain of the study area in Multia was also in terrain class 1, although the terrain was softer in places and the slope was steeper.

Stand data is given in Table 1.

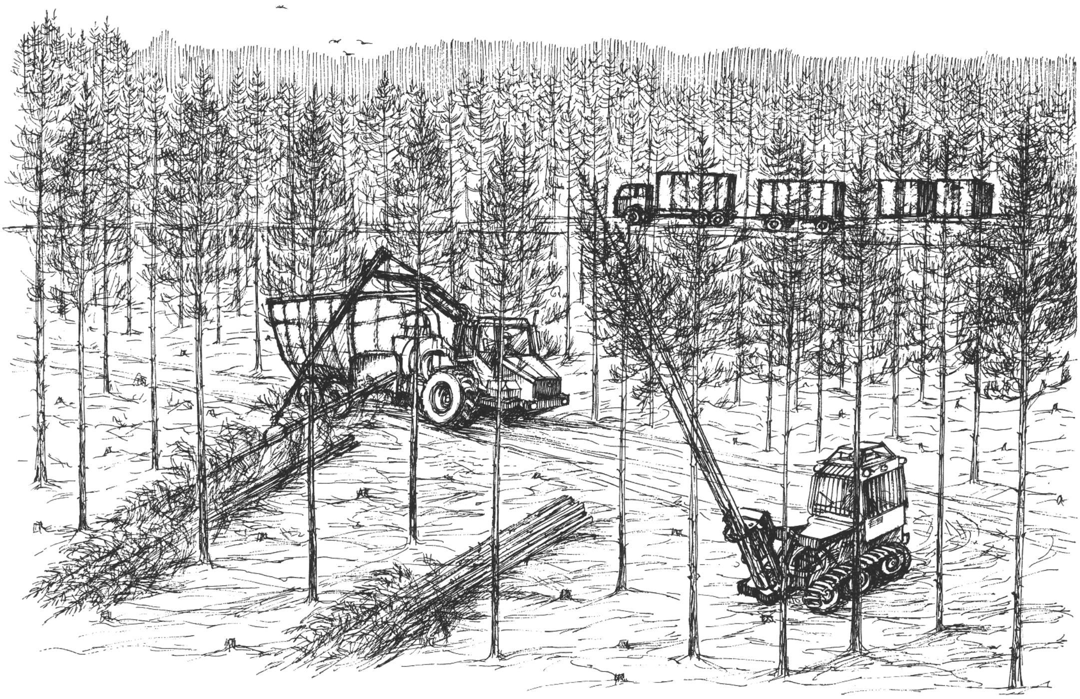

Fig. 4. Harvest system 1. Felling and bunching is carried out manually utilizing directed felling and felling frame. Chipping is done on the strip road straight from the small piles made by the logger. The strip road spacing was 25 m.

Kuva 4. Korjuuketju 1. Kaato ja kasaus suoritetaan siirtelykaatomenetelmällä, haketus ajourilta suoraan hakkuumiehen tekemistä pienistä kasoista. Ajouraväli 25 m.

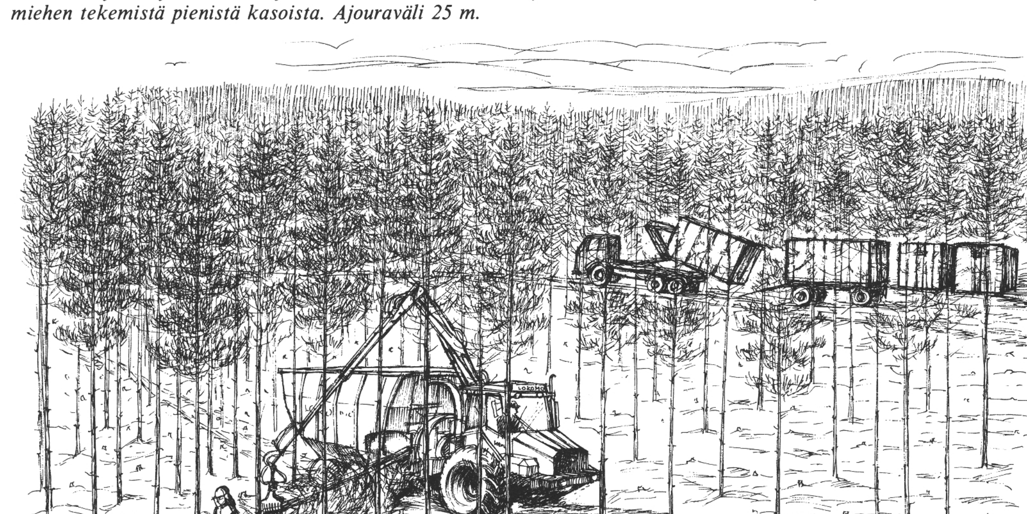

Fig. 5. Harvest system 2. Felling and bunching is carried out with the Makeri small-sized tractor. Chipping is done from large piles placed alongside the strip road. The strip road spacing was 30 m.

Kuva 5. Korjuuketju 2. Kaato ja kasaus Makeri pientraktorilla. Haketus uran varteen kasatuista suurista kasoista. Ajouraväli 30 m.

5. RESULTS OF THE STUDIES DONE WITH THE FELLER-BUNCHER

The field research of the Makeri feller-buncher was done only in Taipalsaari, in three different stands. The stem volume varied slightly. The results are given in Table 2.

The output was nearly twice that of studies previously carried out in Poland (comparison: Hakkila and Wòjcik 1980). In Poland the stem volume was only 36 dm^3. In Finland the transfer distances were nearly half as long as those in Poland.

The output per effective hour of previously carried out studies in Finland was 11.1 m^3 with a stem volume of 70 dm^3 (Rumpunen 1982) i.e., almost the same as in this study.

Half of the operator's time was spent felling the trees and moving from one stem to the next. Movement from the strip road to the first tree while empty and also moving to the pile while loaded accounted for, in both cases, one-fifth of work time. Dumping the bunch took up one-tenth of work time (Table 3).

Table 1. Stand data.
Taulukko 1. Leimikkotietoja.

	Terrain chipping — *Palstahaketus*			
	Mannually felled *Kaato käsin*		Mechanically felled *Kaato koneistettu*	
	Taipalsaari	Multia	Taipalsaari	Multia
Tree volume, dm^3 *Puun koko, dm^3*	43	53	60	48
Pile size, dm^3 *Kasan koko, dm^3*	198	130	318	240
Grapple size, dm^3 *Haketustaakan koko, dm^3*	91	100	144	129
Number of trees in bunch *Puita taakassa, kpl*	2.1	1.9	2.4	2.6
Drain, m^3/ha *Poistuma, m^3/ha*	27	53	74	42
Number of remaining trees in stand/ha *Jäävä puusto, kpl/ha*	922	1003	1035	985
Terrain classification *Maastoluokka*	1	1	1	1

Table 2. Results of studies done with the Makeri feller-buncher.
Taulukko 2. Tuloksia Makeri kaato-kasauskoneella tehdyistä kokeista.

Variable — *Muuttuja*	Test — *Koe* 1	2	3	Average *Keskim.*
Tree volume (to the branches), dm^3 *Puun tilavuus oksineen, dm^3*	55	72	51	59
Number of trees in bunch *Taakassa puita, kpl*	2.6	1.9	2.1	2.2
Bunch volume, dm^3 *Taakan tilavuus, dm^3*	143	136	108	129
Transfer from the strip road when empty, m *Siirtyminen ajouralta tyhjänä, m*	5.8	5.6	5.5	5.6
Transfer to the strip road when loaded, m *Siirtyminen ajouralle kuormattuna, m*	5.8	5.1	4.9	5.3
Output per effective hour: trees, No/h *Tehotuntituotos: puita, kpl/h*	202	158	201	187
m^3/h	11.1	12.5	10.3	11.3

Table 3. Distribution of time consumption for the operator of Makeri 33 T feller-buncher.
Taulukko 3. Makeri 33 T kaato-kasauskoneen kuljettajan ajankäytön jakauma.

	%
Moving while empty *Siirtyminen tyhjänä*	20.5
Shearing and moving from stem to stem *Katkaisu ja siirtyminen rungolta toiselle*	49.5
Moving while loaded *Siirtyminen kuormattuna*	19.7
Dumping of bunch *Taakan pudotus*	9.8
Oraganizing the pile *Kasan järjestely*	0.5
Total *Yhteensä*	100.0


MAKERI

6. RESULTS OF CHIPPING STUDIES

61. Time consumption of chipping

The chipper's time consumption was studied in both terrain chipping and landing chipping. In table 4 the same average moving and unloading times have been used for each system, because they are independent of the method. The hauling distance in terrain chipping is 300 m and correspondingly 100 m in landing chipping.

In Taipalsaari, nearly 40 % more time per cubic meter was spent during chipping after manual felling than after using the feller-buncher. An average of 60 % of effective work time was spent on just chipping manually felled trees while the chipping of trees left by mechanical felling took only 51 % of effective work time. On the Taipalsaari work site, where the terrain was even, the chipper's speed when moving without a load was 80 m/min and with a load 67 m/min.

Moving to the chipping site while empty and loaded consumed, on an average, thirty per cent more time in the Multia experiment than in Taipalsaari. Actual chipping after manual felling was 21 % faster in Multia. The volume of removed trees per hectare in Multia was almost twice that of Taipalsaari.

Table 4. The time consumption for chipping on the strip road and the landing (centiminute = cmin).
Taulukko 4. Palstahakkurin ajanmenekki ajouralla ja varastolla haketettaessa.

Variable *Muuttuja*	System 1 *Ketju 1* Taipal-saari	Multia	System 2 *Ketju 2* Taipal-saari	Multia	System 3 *Ketju 3* Ruoko-lahti
			cmin/m^3		
Moving to the chipping site *Siirtyminen haketuspaikalle*	69	95	69	95	24
Chipping *Haketus*	554	436	336	299	365
Moving in the chipping process *Siirtyminen haketuksessa*	81	57	81	57	—
Moving to the pallet *Siirtyminen vaihtolavalle*	83	121	83	121	28
Unloading *Purkaminen*	59	39	59	39	59
Total effective time *Tehoaika yhteensä*	846	748	628	611	476
Interruptions 20 % *Keskeytykset 20 %*	169	150	126	122	95
Total *Yhteensä*	1015	898	754	733	571

62. Distribution of the operator's time consumption

Table 5 presents the distribution of the operator's time consumption in actual chipping. In both terrain chipping systems 75 % of work time was spent handling the grapple loader. Nearly all of the work time was spent handling the grapple loader during landing chipping.

The distribution of the operator's working time during chipping alone was measured only for system two in Multia. Approximately nine per cent of the operator's time was spent raising the feeding device after chipping. Before the new bunch could be chipped, the feeding device had to be lowered, which took up about six per cent of the operator's time. Raising and lowering of the feeding device together, therefore, accounted for roughly 15 % of the operator's work time.

63. Output of chipping

The output of the chipper in terrain chipping was 30 % greater after mechanical felling and bunching than after manual felling. The trees were gathered into larger stockpiles in mechanical felling. The pile size after manual felling was 200 dm^3 and after

Table 5. Distribution of the operator's time consumption during actual chipping.

Taulukko 5. Kuljettajan ajankäytön jakauma varsinaisen haketusvaiheen aikana.

Work phase *Työvaihe*	System 1 *Ketju 1* %	System 2 *Ketju 2* %	System 3 *Ketju 3* %
Preparation for chipping *Valmistautuminen haketukseen*	1.7	1.4	—
Moving empty grapple *Kouran siirto tyhjänä*	24.2	28.2	24.8
Grappling *Kouraisu*	9.7	9.2	16.3
Moving loaded grapple *Kouran siirto kuormattuna*	20.8	16.7	30.1
Setting the trees into the feeding device *Puiden asettelu syöttölaitteeseen*	18.1	17.6	15.7
Infeed assistance *Syötön auttaminen*	2.1	1.8	11.1
Waiting while infeed takes place *Odotus syötössä*	8.3	7.1	2.0
Moving from pile to pile *Siirtyminen haketuksessa*	15.1	18.0	—
Total *Yhteensä*	100.0	100.0	100.0

mechanical felling was 320 dm^3. The stem volume in mechanical felling was nearly 30 % larger as well and trees were tall and uncut, whereas in manual felling tall trees had to be bucked before bunching. In addition, the amount of trees per hectare removed in mechanical felling was 30 % greater. For example, on a 300 meter hauling distance on the Taipalsaari work site the chipping output in manual felling was 6.5 m^3/h and in mechanical felling 9.0 m^3/h. The corresponding figures in Multia were 8.2 m^3/h and 9.3 m^3/h (Table 6).

In the Taipalsaari study, the difference in output of chipping after manual or mechanical bunching is largely owing to the necessity for the chipper to move 1.3 times after manual felling, whereas the chipper must

Table 6. Chipper's output in terrain chipping of pine whole-trees depending on hauling distance.

Taulukko 6. Hakkurin tuotos mäntykokopuun palstahaketuksessa kuljetusmatkasta riippuen.

Hauling distance, m *Kuljetusmatka, m*	System 1 — *Ketju 1*		System 2 — *Ketju 2*	
	Output m^3/effective hour *Tuotos m^3/tehotunnissa*			
	Taipalsaari	Multia	Taipalsaari	Multia
100	7.3	10.1	10.5	12.3
300	6.5	8.2	9.0	9.3
500	5.8	7.0	7.8	7.5

move only 0.8 times per cubic meter of chips after mechanical bunching. In connection with each move, it is necessary to wait for: the last bunch to go through the chipper; the feeding device to be raised; the grapple loader to be raised; the move to the next bunch; the feeding device to be lowered; and the grapple to be moved to the next bunch. The chipper's idling time in system 1 was 53 % of the effective chipping time. The idling time after mechanical bunching was a good ten per cent shorter.

The difference in output between chipping after manual and mechanical bunching in the Multia study, is a result of the feller-buncher's ability to make considerably larger piles. The stem volume was the same for both bunching systems. The chipper had to move 1.5 times per cubic meter of chips after manual felling and 1.3 times after mechanical felling. This also affects the results to some extent. The chipper's idling time after manual felling was 54 % of chipping time, while only 42 % after mechanical felling.

The average tree volume was only 30 dm^3 in landing chipping, because the tall trees had been bucked. The size of the chipping bunch was 84 dm^3, which was smaller than in terrain chipping.

The output of the terrain chipper in landing chipping is shown in the following table. The TT 1000 F terrain chipper is presented as a comparison (Kalaja 1978).

	Lokomo 919/P1000 m^3/h	TT 1000 F m^3/h
Output, m^3/h	16.4	13.2
The chipper's idling time: percentage per chipping time	39.8	14.0


LOKOMO
919


LOKOMO

7. RESULTS OF COMPARABLE STUDIES CARRIED OUT IN ESTONIA

In October, 1982, Rauma-Repola's Lokomo ironworks arranged a joint study in cooperation with the Estonian collective farm development organization EKE on the Surju working site in Pärnu, Western Estonia. The same men who were operators in the studies carried out in Finland were operators in the Estonian study. EKE carried out the research. The chips were brought to EKE's Viisnurkka particle board factory with a full-trailer truck equipped with Partek's Multilift changeable pallet system.

Studies in the first commercial thinning pine stand:

The first commercial thinning pine stand was growing on flat, well-drained, sandy terrain. The species composition consisted of 80 % pine, 15 % spruce and 5 % birch. The stand density before thinning was about 2500 trees/ha and after thinning about 1300 trees/ha. The dominant height of the stand was 8—10 meters. Altogether, 27 solid m^3 of the whole-trees were chipped, producing 68 m^3 of chips.

The selection of trees with the Makeri feller-buncher was according to previous marking. The distance between strip roads was 30 meters. Chipping was done on the strip road in the usual way. The hauling distance to the landing varied from 60—100 meters.

The stem volume was 0.048 m^3 and the dbh was 9 cm. The feller-buncher's output per effective hour was 9.8 m^3/h. The conditions were the same as in the Taipalsaari study. The stem volum in Taipalsaari, however, was 20 % larger. In the studies done in Finland, the output per effective hour was 11.3 m^3/h.

The average volume of trees was the same in Finland and in Estonia. Chipping output in Estonia was 13.1 m^3/h. In the Multia study the output was 12.3 m^3/h including a 100 meter hauling distance. The portion of chipping time in Estonia was nearly 70 % while, in Finland it was ten per cent shorter.

Studies in clear cutting conditions:

The terrain of the clear cut area resembled a Finnish spruce swamp, the thickness of the organic pad was about 40 cm and a silt base was underneath. The terrain difficulty in Estonian conditions was average. Softwoods accounted for 60 % of the stand and hardwoods for 40 %. The total cubic volume was 370 m^3/ha with a dominant height of 25—30 m. The study contained a total of 101 m^3, i.e., 253 m^3 of chips.

Softwood trees with a maximum diameter of 20 cm and all hardwoods with allowable diameters were felled and bunched. A distance of 15 meters between strip roads was used. All oversized trees along the strip roads were felled with a chain saw. The stems were cut into logs and the tops under 20 cm were left to be chipped separately. The hauling distance to the landing was from 100 to 200 meters.

The Makeri's output per effective hour in clear cutting studies, where the average stem volume of stems was 0.123 m^3 and the dbh 13 cm, was 14.2 m^3/h. Maneuverability was slow, owing to a soft soil base and obstacles such as big roots and old stumps. In addition, the trees were tall and oversized. About one-third of the operator's work time was spent moving while loaded and unloaded and shearing the trees.

In clear cutting conditions the chipper's output on an average hauling distance of 150 meters from the stand to the landing was 10.3 m^3/h.

The following table presents the screening results of chips received from the Estonian studies. The share of needles was 4 % and the share of bark 12.8 %.

	Length distribution, mm				
	0—5	5—10	10—30	30—50	over 50
Share, %	8.3	8.4	67.1	10.0	6.2

According to Soviet Union standards 90 % of chips used in particle board production should be between 10—30 mm large.

8. HARVESTING COSTS

The comparison of costs for alternative harvesting systems is presented in Table 7. The following principles have been used in the calculations.

Manual felling and bunching: Felling of small diameter whole-trees was done by piece-rate. The pay rate for manual felling in terrain chipping is 15.62 FIM/m^3 and in landing chipping 18.63 FIM/m^3, including social benefits, when the stem volume is 0.048 m^3.

Feller-buncher: The Makeri tractor equipped with a feller-buncher had an output per operating hour of 8.2 m^3/h with whole-trees, and the machine's costs per hour were 170 FIM. The calculations were derived using a stem volume of 0.051 m^3 and the share of interruptions being 20 %.

Short distance haulage: The forwarder's output of 6 m^3/h was used. The costs per hour for the medium-weight machine have been determined at 202.60 FIM.

Chipping: An hourly cost of 263.00 FIM was used for the Lokomo 919/P1000 terrain chipper. The calculations were based on a 300 meter haulage distance, a stem volume of 0.048 m^3, and the share of interruptions being 20 %. The output figures were those acquired earlier in the study.

Long distance haulage is based on hauling over a distance of 65—70 km.

Landing cost: Costs at the landing have been calculated to be 0.30 FIM/m^3 for terrain chipping and 1.00 FIM/m^3 for landing chipping.

Overhead costs: Movement between work sites, supervision and management, scaling and other general costs have been calculated at 15.00 FIM/m^3.

Table 7. Costs of harvesting pine whole-trees with the Lokomo 919/P1000 terrain chipper.
Taulukko 7. Kustannukset korjattaessa mäntykokopuuta Lokomo 919/P1000 palstahakkurilla.

	Terrain chipping *Palstahaketus* 1	2	Landing chipping *Varasto-haketus*
		FIM/m^3	
Manual felling *Siirtely-kaato*	15.62	—	18.63
Mechanical felling *Koneellinen kaato*	—	20.73	—
Short distance haulage *Lähikuljetus*	—	—	33.77
Chipping *Haketus*	44.58	36.03	20.08
Long distance haulage *Kaukokuljetus*	35.93	35.93	35.93
Storage costs *Varastokustannus*	0.30	0.30	1.00
Overhead costs *Yleiskulut*	15.00	15.00	15.00
Total FIM/m^3 *Yhteensä mk/m^3*	111.43	107.99	124.41

9. STEM DAMAGE INFLICTED ON THE STAND BY THE CHIPPER

The number of remaining trees on the Taipalsaari study site was 922/ha on the stand marked for manual felling and 1035/ha on the stand marked for the Makeri feller-buncher. The amount of damage caused by the terrain chipper with reference to the areal unit is listed in the following table.

Felling system	Damaged trees No/ha	%
Manual		
Taipalsaari	17	1.8
Multia	48	3.1
Mechanical		
Taipalsaari	34	3.3
Multia	41	2.7

Table 8. Percentage of stem damage caused by the terrain chipper within each harvesting system.
Taulukko 8. Palstahakkurin runkovaurioiden aiheuttajat korjuumenetelmittäin.

Source of damage *Vaurion aiheuttaja*	Manual felling *Kaato käsin*	Mechanical felling *Kaato koneistettu*
	%	
Grapple loader *Kuormain*	66.3	57.2
Trees in the grapple *Kourassa olevat puut*	22.0	8.0
Chip bin *Hakesäiliö*	4.8	19.9
Basic machine *Peruskone*	0.7	10.8
Feeding device *Syöttölaite*	5.5	2.7
Others *Muut*	0.7	1.4
Total *Yhteensä*	100.0	100.0

The number of trees damaged by the chipper was greater in the manual felling harvesting system carried out in Multia. In Multia, the number of remaining trees on stems was slightly larger, the terrain had more slope in places, and the strip road was narrower.

Table 8 contains the sources of the damage. Depending on the harvesting system the grapple loader caused from 56 to 71 per cent of all damage. The trees in the grapple and the grapple itself did not cause as much damage when chipping after mechanical felling as when chipping after manual felling. The feller-buncher can leave the bunch alongside the strip road, where it can more easily be picked up with the chipper's grapple without damaging the remaining trees.

The basic machine was the source of ten per cent of the damage. The strip roads were slightly winding and junctions were too steep in places.

The amount of stem damage caused by Makeri was measured in Taipalsaari, where the number of trees remaining on stems was 1035/ha and the percentage of damage was 1.0. The extent of root damage was not determined in this study. Nevertheless, while moving between strip roads on unfrozen ground the feller-buncher caused more damage than manual felling and bunching.

10. CHIP CHARACTERISTICS

The length distribution of chips was determined with a hole screen and thickness distribution using a slot screen according to fresh weight. The screening results are presented in figures 6 and 7. The chipper's knives were set at 20 mm and 30 mm chip length.

The length and thickness distributions of whole-tree and tree length chips were equal for both 20 mm and 30 mm knife settings. In the whole-tree chips the share of chips over 32 mm was twice as high for the knife setting of 30 mm than for the setting of 20 mm. The difference was slightly smaller for stemwood chips. The share of desired chip sizes of 6—32 mm was around 80 % for whole-trees. The share of particles less than 6 mm in length was greater for the 20 mm setting. With the 30 mm setting the share of chips over 10 mm in thickness was considerably higher for whole-trees than stemwood. 75 % of the chips filled the quality standards. The only exceptions were whole-tree chips made with a 30 mm knife setting (66 %).

The chipper's feeding device removes small branches, needles and bark which fall underneath the feeding device and are left on the strip road in heaps. Data show that these particles account for only 0.2 % of the final chip volume. The volume of branches removed by the feeding device on the TT 1000 F terrain chipper was much bigger: 6 % of the recovered chip volume (Kalaja 1978). Only those branches removed by the feeding device were taken into consideration in measurements. In addition, the amount of branches, needles and bark which was removed during other work phases and which was left on the strip road was not measured.

Some of the chip loads were weighed on a truck scale. The moisture content of pine

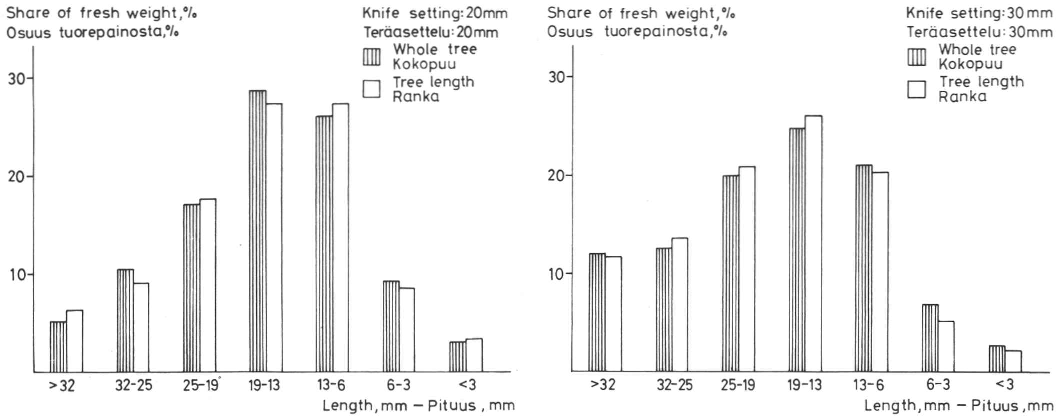

Fig. 6. Length distribution of whole-tree and stemwood chips produced with the Lokomo 919/P1000 forwarder-mounted terrain chipper.
Kuva 6. Lokomo 919/P1000 palstahakkurilla valmistetun kokopuu- ja rankahakkeen pituusjakauma.

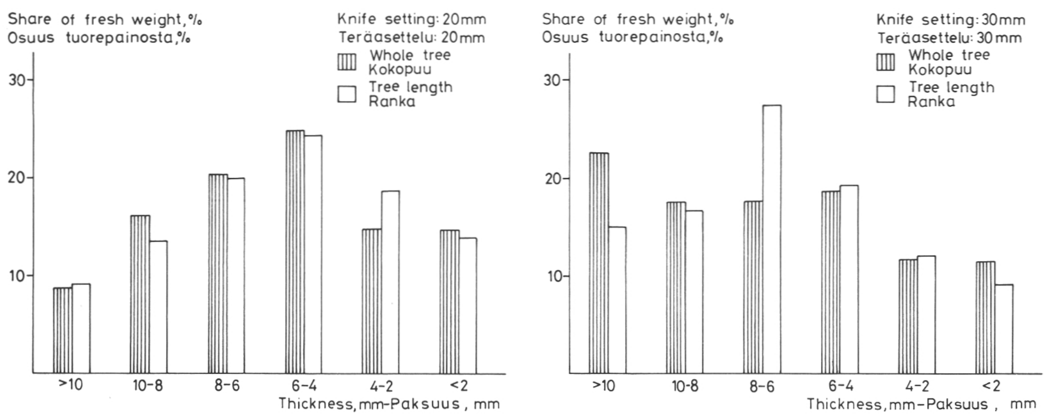

Fig. 7. Thickness distribution of whole-tree and stemwood chips.
Kuva 7. Kokopuu- ja rankahakkeen paksuusjakauma.

whole-tree chips in terrain chipping was 53.3 %. During landing chipping of whole-trees (70 % pine and 30 % spruce) the moisture content was 46.6 %. The chips' average fresh and dry weights and range are presented in the following table. The weights were taken in the forest after dumping the load into a changeable pallet.

	Fresh weight	Dry weight	Fresh weight	Dry weight
Chipping location	Average kg/m^3		Range kg/m^3	
Terrain chipping	317	146	300—325	136—161
Landing chipping	286	133	281—291	127—139

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SELOSTE

Tutkimuksessa selvitetään Lokomo 919/P1000 palstahakkuriin perustuvia palstahaketuksen korjuuketjuja kahdelta eri työmaalta Suomesta sekä yhdeltä työmaalta varastohaketuksessa ja sen lisäksi eestiläisten suorittamat kokeet Rauma-Repolan kanssa Virossa.

Tutkitut korjuuketjut olivat seuraavat:

1. Moottorisahakaatoon perustuva palstahaketusketju. Puut kaadetaan kahvakehikolla varustetulla moottorisahalla ja kasataan miesvoimin siirtelykaatomenetelmällä 1—9 m:n etäisyydelle ajourasta kaadon yhteydessä. Uraväli on 25 m. Puut haketetaan ajouralla suoraan kaatomiehen tekemistä kasoista. Hake kuljetetaan hakkurin säiliössä varastolla olevalle vaihtolavalle (Kuvat 3 ja 4).
2. Koneellistettuun kaatoon perustuva palstahaketusketju. Kaato ja kasaus uran varteen tehdään teloilla varustetulla Makeri 33 T pientraktorilla. Ajouraväli on 30 metriä. Haketus tapahtuu ajouran varteen kasatuista suurehkoista kasoista. Hake kuljetetaan samalla tavalla kuin edellisessä menetelmässä (Kuva 5).
3. Moottorisahakaatoon perustuva varastohaketusketju. Siirtelykaato ja kasaus tehdään kuten kohdassa yksi. Pitkät puut on katkaistava moottorisahalla ennen kuljetusta. Puut kuljetetaan kuormatraktorilla välivarastolle, missä haketus tapahtuu suurista varastokasoista. Hake puhalletaan ensin hakkurin konttiin ja kipataan siitä edelleen hakelavalle.

Kokeet suoritettiin kesällä ensiharvennusmänniköissä ajouralla kahdella eri työmaalla. Varastohaketuksessa haketettiin pääasiassa ensiharvennuskokopuuta, mutta joukossa oli noin kolmannes kuusikokopuuta. Leimikoitten kulkuvaikeus edusti ensimmäistä maastoluokkaa.

Kaato-kasauskoneen tehotuntituotos oli 59 dm^3:n runkokoolla 11,3 m^3 (taulukko 2). Kuljettajan ajankäytöstä puolet kului rungon katkaisuun ja puolet siirtymiseen rungolta toiselle.

Haketustyön ajanmenekki ja tuotos

Pelkkään haketukseen kului keskimäärin 60 % tehollisesta työajasta mieskaadon jälkeen haketettaessa. Konekaadon jälkeen siihen kului 51 %. Varsinaisessa haketuksessa molemmissa palstahaketusketjuissa kuljettajan ajankäytöstä kului kuormaimen käsittelyyn 75 % työajasta (taulukko 5). Varastohaketuksessa lähes koko työaika kului kuormaimen käsittelyyn. Taipalsaaren työmaalla, missä maasto oli helppoa, hakkurin siirtymisnopeus tyhjänä oli 80 m/min ja kuormattuna 67 m/min.

Työmaasta riippuen palstahaketusketjuissa hakkurin tuotos oli konekaadon ja kasauksen jälkeen 12—28 % suurempi verrattuna mieskaatoon. Konekaadossa näet puut tulevat kerätyiksi suurempiin kasoihin kuin mieskaadossa. Mieskaadossa kasan koko vaihteli 130—200 dm^3:iin ja konekaadossa 240—320 dm^3:iin. Rungon kokokin oli suurempi konekaadon jälkeen ja poistuvan puuston määrä hehtaaria kohden. Siirtymismatkan ollessa 300 m haketustuotos oli mieskaadon jälkeen 6,5—8,2 m^3 ja konekaadon jälkeen 9,0—9,3 m^3 tehotunnissa (taulukko 6). Hakkurin tyhjänäpyörimisajat vaihtelivat mieskaadossa 53—54 % haketusajasta ja konekaadossa 34—42 %.

Varastolla haketettaessa tuotos oli 16,4 m^3 tehotuntia kohden. Hakkurin tyhjänäpyörimisaika oli 40 % haketusajasta.

Tuloksia Eestissä suoritetuista vertailevista kokeista

Rauma-Repolan Lokomon tehtaat järjesti lokakuussa 1982 yhteistyössä Eestin kolhoosiehityksen (EKE:n) kanssa haketuskokeen Länsi-Eestissä Pärnussa. Varsinaisesta tutkimuksesta vastasi EKE. Kokeissa käytettiin samoja koneita ja kuljettajia kuin Suomessa suoritetuissa kokeissa.

Ensiharvennusmännikkö oli maastoltaan tasainen hiekkakumpare, maastoluokitukseltaan ensimmäistä luokkaa. Puuston tiheys ennen harvennusta oli n. 2500 kpl/ha ja harvennuksen jälkeen n. 1300 kpl/ha. Puuston valtapituus oli 8—10 metriä. Makeri kaato-kasauskoneella suoritettiin ennalta tehdyn leimauksen mukainen harvennus. Uravälinä käytettiin 30 metriä. Haketus suoritettiin normaaliin tapaan ajouralla.

Rungon koko oli 0,048 m^3. Kaato-kasauskoneen tuntituotos oli 9,8 m^3/h. Olosuhteet olivat samaa luokkaa kuin Suomessa Taipalsaaren kokeissa. Suomessa rungon koko oli lähes 20 % suurempi. Suomessa tehdyissä kokeissa useamman koepalstan tehotuntituotoksen keskiarvo oli 11,3 m^3/h. Sekä Eestissä että Suomessa kuljettajan työajan jakaumasta noin puolet kului rungon katkaisemiseen ja siirtymiseen rungolta toiselle.

Haketettujen puiden keskimääräinen koko oli Eestissä ja Suomessa sama 0,048 m^3. Haketustuotos Eestissä oli 13,1 m^3 tehotyötunnissa, kun kuljetusmatka vaihteli 60—100 metriin. Multian kokeissa tuotos oli 12,3 m^3/h 100 m:n kuljetusmatkalla. Eestissä pelkän haketuksen osuus oli lähes 70 % ja Suomessa 60 %.

Puuston vaurioituminen

Taipalsaaren työmaalla siirtelykaatoleimikossa jäljelle jäävän puuston runkoluku oli 922 kpl/ha ja Makeri kaato-kasauskoneen leimikossa 1035 kpl/ha. Palstahakkurin aiheuttamien runkovaurioiden määrät olivat seuraavat:

Korjuumenetelmä	Vauriot kpl/ha	%
Siirtelykaato:		
Taipalsaaren työmaa	17	1,8
Multian työmaa	48	3,1
Koneellinen kaato:		
Taipalsaaren työmaa	35	3,3
Multian työmaa	41	2,7

Multian kokeissa siirtelykaatomenetelmässä hakkurin aiheuttamien vaurioiden määrä oli suurempi, mutta siellä jäljelle jäävä runkolukukin oli hieman suurempi. Myös maasto oli Multialla hieman vaikeampaa ja ajoura kapeampi.

Suurin vaurionaiheuttaja oli kuormain, menetelmästä riippuen 56 %:sta 71 %:iin.

Makerin aiheuttamia runkovaurioita mitattiin vain Taipalsaaren työmaalla, siellä vaurioitumisprosentti oli 1,0 %. Tässä tutkimuksessa ei ole selvitetty juurivaurioita.

Hakkeen laatu

Kokopuu- ja rankahakkeen palakokojakaumat olivat melkein yhtä suuret eri teräasetuksilla (kuvat 6 ja 7). Pituusjakaumassa laatuvaatimusten mukaista 6—32 mm:n haketta oli noin 80 %. 20 mm:n teräasetuksella yli 32 mm:n tikkujakeen osuus oli vain noin puolet 30 mm:n teräasetukseen verrattuna. 20 mm:n teräasetuksella alle 6 mm:n purujakeen osuus oli taas reilusti suurempi (kuva 6).

Hakkeen paksuusjakaumassa 30 mm:n teräasetuksella oli kokopuuhakkeessa yli 10 mm:n tikkujakeen osuus huomattavasti suurempi rankahakkeeseen nähden. Laatuvaatimusten mukaista haketta 2—10 mm oli noin 75 % kaikissa muissa paitsi kokopuuhakkeella 30 mm:n teräasetuksella, missä sitä oli vain 66 %. Purujakeen osuus vaihteli 9—15 %:iin (kuva 7).

Eestissä suoritettujen mittausten mukaan sallittuja fraktioita 10—30 mm oli 77 %. Pienen purujakeen osuus oli liian suuri Neuvostoliiton Kost.-normin mukaan.

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