Forest Research

The Research Agency of the Forestry Commission

TECHNICAL DEVELOPMENT

INTERNAL PROJECT INFORMATION NOTE 11/98

Project: East Anglia Whole Tree Thinning by Chipping

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Ref: 1000A/22/98 Title: EAST ANGLIA WHOLE TREE THINNING BY CHIPPING

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Summary

1. Base data on whole tree chipping operations were required by East Anglia F D to support marketing. Studies were untdertaken of Hafo thinning and whole tree chipping in various crops of Corsican pine (with some limited Scots pine), average tree sizes varying from 0.1 m³ to 0.14 m³. Thinning across rows and with rows was studied.

2. The Hafo can be used to thin and chip whole trees. Selective thinning of the crop matrix is possible.

3. Whole tree tonne to volume (7 cm ob) ratios of 1.39:1 to 1.55:1 were recorded at 57% moisture content. A tariff number of 14 was used to assess broadleaf volumes.

4. If the relevant conifer tariff numbers are used, ratios would be 1.35:1 to 1.50:1.

5. The highest output of 6.19 tonnes/shr/100 m was achieved when in a thinned tree size 0.13 m³ ob working with the row in a 1 in 7 row removed with selective matrix thinning.

6. The lowest output of 3.93 tonnes/shr/100 m was recorded when in a thinned tree size 0.103 m³ ob working across the rows in a crop with significant broadleaf intrusion.

7. Thinning, chipping and extraction costs to ride/roadside public road transport bins can vary from £5/tonne to £10/tonne per 100 m extracted depending on crop size, thinning method and machine cost assumptions.

Introduction

8. The main market for whole tree chips in East England would be the bird litter and wood chip burning power station at Thetford. Other known markets include use as a peat substitute. Base data on whole tree chipping operations is required by senior management when negotiating with chipping contractors.

9. Forest Enterprise, North and East England Region commissioned Technical Development Branch to collect data on:

   - Whole tree tonnage related to tree volume (7 cm top diameter).
   - Thinned quantities per hectare.
   - Thinning data from selected crop types and methods.
   - Moisture content of whole tree chips.
   - Safety constraints.
   - Cost and output.

Machine Description

10. A Hafo GMR21 four wheel drive rear steer drum chipper was used in the thinning trials at Thetford. The machine is powered by an Iveco 6 cylinder turbo diesel engine producing 115 kW (154 hp). The transmission is hydro-mechanical.

11. The Hafo was 6.5 m long by 2.1 m wide with a maximum height of 3.3 m. It was fitted with relatively narrow tyres. Front tyres were Dunlop TG32 14.5-20 (368 mm wide) and rear tyres Nokia Tractor FS 13.6-28 (345 mm wide). Wheel ruts were generally 10 to 15 cm deep after multiple passes.

12. The Mowi 2255 loader (5.5 m reach) was fitted with a Hultdin chainsaw felling head with a cutting capacity of 30 cm. The head did not have a delimbing ability and was not fitted with a rotator. The loader was mounted in an offset position (close to nearside) and had an effective reach of 3 m to the off side of the machine and a reach of 5.2 m to the near side.

Table 2

Crop Details

Study No	Compartment Number	Working Direction	Species	Average* Tree Size (m^3 ob)	Average dbh (cm)	Comments
1771 1776 1777	3019 b	Across rows	CP	0.103	14.1	Significant Broadleaf intrusion with areas of failed conifer crop
1772	3026 a	Across rows	CP	0.139	15.5	Crop at limit of machines ability. Cross row selected to avoid larger stems
1773 1774	3026 a	With rows	CP	0.130	15.1	1 in 7 row thinning possible
1775	3026 a	Across rows	SP/CP	0.097	13.3	SP intruded stems selected in preference to CP. BL intrusion present

* The average tree size relates to the size of thinned trees removed and not the size of the standing crop before thinning.

Working Method

16. A rack centre was marked for guidance and it was agreed with the operator that he could deviate 2 m either side of this guide. Trees to be selectively thinned from the matrix were selected by the operator.

17. One study rack was orientated with the rows, resulting in a 1 in 7 rows removed with 3 matrix rows thinned to each side of the rack. All other studies had racks aligned across the rows to reduce machine access rack widths. Drift dimensions are given in Table 3.

Table 3

Rack, Row & Drift Measurements

Study	Working Direction	Row Spacing (m)	In Row Spacing (m)	Rack Width (m)	Thinned Drift Width (m)
1771 1776 1777	Across rows	2.60	1.19	3.10	12.33
1772	Across rows	2.84	1.40	3.54	14.32
1773 1774	With rows	2.83	1.49	5.10	18.70
1775	Across rows	2.67	1.44	3.95	13.02

18. Dominant and sub dominant trees of poor form (usually forked) were normally selected for thinning to enable trees of better form to improve. Trees of poor form were left in some cases to prevent large gaps in the canopy from being created. Small diameter conifers and all broadleaved (BL) stems were thinned where possible, although no large gaps were to be left in the canopy.

19. The operator felled rack trees and matrix trees on each side of the rack in his first pass. The Hafo was driven into natural or created crop spaces to extend the drift width (Plate 1). A second matrix thinning pass with the machine travelling in the opposite direction was necessary because the off centre mounting of the loader restricted offside reach (Plate 2). This second reverse pass also allowed the operator to fell and access matrix stems on both sides of the rack from another direction (restricted head manoeuvrability & reach). This improved the thinning in the matrix and possibly reduced damage to standing trees (Plate 3).

Plate 1

Machine Driven in Crop

Plate 2

Restricted Offside Reach

Plate 3

Processing Matrix Tree

20. One pass shortwood 1st thinning with a tracked excavator harvester (Atlas/Pika) was found to give a 7% increase in output compared to a 2 pass thinning in 0.05 m³ OB Scot Pine crop. One pass thinning can result in significant output gains and should be studied in relation to other constraints.

21. The Hafo usually reversed out of the rack (using video camera) or turned in natural spaces when travelling out of the crop to empty the bin. Reversing can:

    - Increase travelling times.
    - Increase crop damage.
    - Increase operator fatigue.
    - Reduce operator field of vision.

    In Compartment 3019 unplanted strips with BL intrusion (50 m to 70 m spacing) were used for access. Where these strips are not present in longer racks and where turning spaces cannot be found cut access racks would need to be cut at c 100 m intervals to reduce machine travel in reverse.

22. The Hafo tipped chips into 30 m^3 capacity bins (Plate 4) placed on rides and roads. Chips are shown in Plate 5. These larger bins were handled by self unloading/loading trailers equipped with hydraulic lifting and pulling/pushing arms. JCB Fastrac tractors were used to move the trailers. Bin payloads were measured in tonnes on a weighbridge and related to study volumes.

Plate 4

Tipping into 30 m^3 Road Transport Bins

Plate 5

Hafo Whole Tree Chips

23. To aid felling and reach, the fitting of the following would be beneficial:

- a rotator on the felling head,
- a roof window for crop inspection and
- a longer reach loader.

Recovery

24. Thinned tree volume (7 cm top diameter ob) was related to net hectare area measurement. Tariff numbers from top height samples were used to calculate CP and SP volumes. To obtain a BL volume a tariff number of 14 was used in Table 4 and for comparison the study conifer tariff was used to obtain BL volume in paragraph 26.

25. Recovery rates are shown in Table 4.

Table 4

Recovery Rates

Study No's	Tree Size (m^3 ob/ha)	Average dbh	Conifer vol (m^3 ob/ha) > 7 cm dbh	Conifer vol (m^3 ob/ha) < 7 cm dbh	BL vol (m^3 ob/ha)	Total vol (m^3 ob/ha)	Total (tonnes/ha)	Ratio of tonnes to m^3 (ob/ha)
1771 1776 1777	0.103	14.1	72.45	0.08	6.52	79.05	122.62	1.55:1
1772	0.139	15.5	74.88	0.08	3.05	78.01	108.13	1.39:1
1773 1774	0.130	15.1	80.65	0.08	5.37	86.10	123.04	1.43:1
1775	0.097	13.3	71.75	0.23	4.08	76.06	116.98	1.54:1

26. The following conifer tariff numbers were used:

- 23 for studies 1771,1776 & 1777.
- 24 for studies 1773 & 1774.
- 25 for studies 1772 & 1775.

27. When the conifer Tariff number is used for broadleaved volume assessment instead of Tariff 14, the following tonne to volume ratios are derived:

Studies	1771, 1776, 1777	=	1.50:1
Study	1772	=	1.35:1
Studies	1773, 1774	=	1.37:1
Study	1775	=	1.49:1

28. The moisture content (wet basis) of freshly felled and processed chips was calculated at 57% which equates to c 570 kg water per tonne. Moisture content is calculated by:

    Wet weight - dry weight/wet weight x 100

29. The recorded thinning intensity (conifer above 7 cm dbh) for each study related to recommended management Table volume is shown in Table 5. General Yield Class values have been used.

Table 5

Thinning Intensity

Study Numbers	General Yield Class	Study Thinning Intensity (m^3/ha)	Recommend Intensity (Management Tables) (m^3/ha)
1771, 1776, 1777	16	72.45	67
1772	18	74.88	88
1773, 1774	16	80.65	67
1775	18	71.75	88

30. There is some doubt about the application of Management Table data to the crops at East Anglia FD If the tables are used as a guide it can be seen that:

    - Studies 1771,1776 & 1777 were thinned near recommended intensity.
    - Studies 1772 & 1775 were significantly under thinned.
    - Studies 1773 & 1774 were significantly over thinned.

31. Studies 1771, 1776 and 1777 took place in a crop with broadleaf intrusion. The actual thinning intensity would be higher because there were areas of conifer failure.

32. The thinning intensity in studies 1772 and 1775 looked acceptable although the Management Tables suggest underthinning by 15% to 18%.

33. The 'with the row' thinning in studies 1773 and 1774 was overthinned by 20% and may be explained to some extent by removal of complete rows as racks.

Outputs and Costs

34. Standard outputs are shown in Table 6 and include a Rest allowance of 18% and an Other Work allowance of 17%. Output assumes a 100 m extraction of chips out of the wood.

Table 6

Outputs

Study	Working Direction	Crop Description	Average tree size (m^3 ob)	Output tonnes (shr/100 m)
1771,1776, 1777	Across rows	Failed areas with BL intrusion	0.103	3.93
1772	Across rows	Limit of Hafo ability	0.139	5.26
1773, 1774	With rows	1 in 7 row thinning, wide drift	0.130	6.19
1775	Across rows	SP &BL Intrusion	0.097	4.42

35. Estimated running costs for a Hafo chipper (1 000 or 1 600 hrs/year) are given in Table 7. It is understood that Hafo chippers are not manufactured at present.

Table 7

Hafo Running Costs

Formula Explanation	Hafo GMR 21 1 000 hrs/year	Hafo GMR 21 1 600 hrs/year
C is capital cost (£)	85 000	85 000
RV is residual value (£)	8 500	8 500
PH is productive hour/year	1 000	1 600
L is life hours	5 000	8 000
n is life in years	5	5
R is interest rate % (r=R/100)	6	6
Dn is discount factor Dn=1/(1+r)n	0.7473	0.7473
An is equivalent annual cost An+r/1-Dn	0.2374	0.2374
Capital cost (£/hr) $\frac{[C-(RV \times Dn)]}{PH} \times An$	18.67	11.67
Labour cost (£/hr)	10.00	10.00
Fuel & oil costs (£/hr)	2.50	2.50
Repair & maintenance costs (£/hr)	8.00	8.00
Total Running Cost (£/hr)	**39.17**	**32.17**

36. The forest roadside/rideside costs per 'fresh' tonne at 57% moisture content are shown in Table 8 when chips are loaded for subsequent road transport. These costs do not include:

    - Transport costs to market.
    - Machine placement.
    - Operator subsistence.
    - Profit margins.

Table 8

Production Costs

Study Numbers	Output (tonnes/shr/100 m)	Production Cost (1 000 hrs/year) (£/tonne)	Production Cost (1 600 hrs/year) (£/tonne)
1771, 1776,1777	3.93	9.97	8.19
1772	5.26	7.45	6.12
1773, 1774	6.19	6.33	5.20
1775	4.42	8.86	7.28

37. Study data indicates that chip working costs to roadside can vary from £5/tonne to £10/tonne depending upon working method, crop type and machine utilisation.

38. The highest output was obtained when working with the row (1773,1774) and thinning 3 rows on each side of the felled rack. This method simplified rack tree selection and the wide rack gave sufficient space for the machine to manoeuvre to select trees in the matrix. This is the optimum system for maximising machine output. The crop size was approaching the working maximum for the machine and, according to Management Tables, was over thinned by 20%.

39. The lowest Output was recorded when working across the rows (1771,1776, 1777) in the smallest crop which had failed areas. There was significant broadleaf intrusion in the failed areas.

40. In study 1772 the Hafo worked across the rows in a crop size at the limit of the machines ability. The second widest thinned drift width was recorded in this study as the operator drove the machine into the crop matrix.

Health and Safety

41. The Risk Zone displayed on the Hafo is 50 m. This can be compared to the 50 m Risk Zone displayed on a Bruks 800 (UK) or 60 m displayed on a Scandinavian Bruks unit. A Scandinavian IF 300 Bruks chipper has a 60 m Risk Zone displayed on the machine.

42. Risk areas to note are:

    - In front of chipper infeed.
    - In line with saw bar/chain.
    - The zone associated with felling (2 tree lengths + boom length or specified risk zone (50 m with Hafo) whichever is the greater, FSC 24 Mechanical Harvesting).
    - Behind the machine, especially when moving.

- Chip transfer & storage/transport.

43. No woody material was seen to be ejected more than 15 m from the machine. During studies with a Bruks 800 chipper a wood chip was ejected about 30 m from the chipper infeed. Metal pieces could be ejected from the chipper during catastrophic chipper failure.

44. FSC Guide 24 can be referred to for guidance on risk zones.

45. The operator relies on a camera and opening the cab door (occasional) to view the area behind the machine when reversing. Opening the cab door when reversing (especially in crop) could lead to operator injury. Operator vision when reversing will be limited compared to vision with forward travel.

Other Chipper

46. **Bruks IF 300**: During the Hafo studies a Bruks IF300 was seem (Plate 6). The chipper unit is one of 2 discontinued prototypes in the world. It was designed to produce white chips with minimal bark and needle content. The machine has a shear felling head, 2 pairs of delimbing knives and was fitted with a debarking unit which has been removed. The unit is mounted on a Brunnett forwarder base.

Plate 6

Bruks IF 300 Delimber Debarker Chipper

47. The unit is 2.80 m wide (600 mm tyres), and 3.95 m high with a 9 m reach. This 8 wheeled unit would be more suitable for softer sites than the 4 wheel Hafo.

48. Trees are felled with the shear head and fed into the front loading disc chipper. Chips are directed into the rear bin irrespective of machine slew angle.

49. The machine was not able to delimb a 20 cm dbh Corsican pine, which was subsequently chipped by the Hafo. It was able to delimb and chip a smaller 14 cm dbh tree. Mr M Edwards planned to remove the delimbing facility and use the machine as a conventional whole tree chipper.

Conclusions

50. Whole tree tonne to volume (7 cm ob) (for the combined crop of conifer and broadleaves) ratios from 1.39:1 to 1.55:1 were recorded at 57% moisture content when a Tariff number of 14 was used to assess broadleaf volumes.

51. Whole tree tonne to volume (7 cm ob) (for the combined crop of conifer and broadleaves) ratios from 1.35:1 to 1.50:1 were recorded at 57% moisture content when using conifer Tariff numbers for broadleaf volume assessment.

52. The Hafo can thin and chip whole trees. Selective thinning of the crop matrix is possible. To aid felling and reach the machine should be equipped with:

    - a rotator,
    - a roof window for crop inspection and
    - a longer reach loader.

53. Average thinned drift widths when working across the rows ranged from 12.33 m to 14.32 m. When working with the rows, 1 in 7 rows were removed as racks and an average drift width of 18.70 m was obtained. The relatively poor reach of the Hafo was offset to some extent by its in crop manoeuvrability.

54. The highest output of 6.19 tonnes/shr/100 m was achieved with a thinned volume of 0.13 m^3 when working with the row in a 1 in 7 row removal with selective matrix thinning.

55. The lowest output of 3.93 tonnes/shr/100 m was recorded with a thinned tree volume 0.103 m^3 when working across the rows in a crop with significant broadleaf intrusion. With a mean tree of 0.139 m^3 the output was 5.26 tonnes/shr.

56. Thinning, chipping and extraction costs to ride/roadside public road transport bins can vary from £5/tonne to £10/tonne depending on crop size, thinning method and machine costing assumptions.

57. Reversing to significant distances has considerable disadvantages and should be minimised.

58. The current specification of the Hafo could be improves by fitting

    - A rotator

58. The crop with an average thinned tree size of 0.139 m^3 ob was the largest crop that could be thinned by the Hafo.

Recommendations

57. It is recommended that:

    - Improved machine specifications are considered to give possible output gains
    - One pass thinning (may be possible with improved m/c specification) should be studied.

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