A Thinning Experiment in Avoca Forest: Results Over 23 Years

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Background

During the spring of 1964, a thinning experiment was established in Avoca Forest, Co. Wicklow. The object of the experiment as stated in the Working Plan was "to determine the effects of thinning to different levels of standing basal area after treatment, on basal area and volume increment, diameter and height of the 40 largest stems per acre and diameter assortments of the crop". At that time, management tables had not yet been constructed and there was no recognised thinning prescription consistent with crop productivity. British forest management tables first appeared in 1966 (Bradley et al., 1966). These were in imperial units and were followed in 1971 (Hamilton and Christie) by tables in metric units and, more recently, by a wider range of yield models (Edwards, 1981)). Thinning grades, defined by the Forestry Commission of Great Britain varied from "A" or no thinning to "D" or heavy thinning.

The Experiment

The experiment is located in a crop of Sitka spruce at Avoca Forest, compartment 81032G. The site is 160 metres above sea level and slopes gently southwards. Soil type is a brown earth, previously cultivated for agricultural purposes. Provenance is uncertain, it is probably Washington coast.

The crop was planted in the spring of 1943 at an average spacing of 1·5 metres or 4,000 plants per hectare. No site cultivation was carried out.

Local yield class is in the range 20-24m^3, maximum mean annual increment.

Three thinning treatments described as light, moderate and heavy are compared. Experimental design is a randomised block with each treatment replicated twice. Plot size is 0·04 hectares.

History of Thinning

The crop was 21 years of age when the experiment was established and first thinnings felled. Subsequent thinnings followed at 25, 29, 34, 39 and 44 years. All six thinnings were low and selective in type. The experiment has survived intact, no windblow or other

Avoca Forest, Sitka spruce age 26 moderate thinning.

damage has occurred. A full assessment was taken at each thinning with an additional assessment at 37 years.

Outline of Experimental Treatments

The present paper sets out details of all full assessments in the familiar "yield table" format (Tables 1, 2 & 3). Effects on growth of the three thinning treatments are outlined with special emphasis on heavy thinning: a breakdown into the important sawlog categories are presented.

All data refer to live stems whose diameter is 7m or greater at breast height.

The following observations are relevant to the three tables:

1. In Table 1, which itemises the light thinning treatment, a small thinning was removed at 44 years which has been ignored in the table so that the details presented are for the total crop before thinning.

2. In the present context, the light thinning treatment may be regarded as a control. It is safe to assume that the thinnings removed represent the trees which would have died in a real, no-thin situation.

Table 1 Avoca 1/64, Details (per ha.) of Light Thinning.

		MAIN CROP AFTER THINNING							THINNINGS					TOTAL CROP		
Year Ended	Age	Stems	Top Ht (m)	Mean Ht (m)	Diam (cm)	Basal Area (m^2)	Vol. 7 (m^3)	Mean Vol (m^3)	Stems	Diam (cm)	Basal Area (m^2)	Vol. 7 (m^3)	Mean Vol (m^3)	Basal Area (m^2)	Vol. 7 (m^3)	M.A.I. (m^3)
1963	21	2,856	12.4	10.5	13.9	43.6	220.5	.077	1,126	9.1	7.3	23.2	.020	50.9	243.7	11.6
1967	25	2,522	15.0	13.2	16.0	51.0	327.4	.130	334	11.0	3.2	13.8	.041	61.5	364.4	14.6
1971	29	2,274	17.0	15.5	18.0	57.8	467.4	.206	247	12.0	2.8	17.0	.069	71.1	521.4	18.0
1976	34	2,136	20.1	18.2	19.3	62.3	584.5	.274	62	13.6	0.9	6.4	.103	76.5	644.9	19.0
1979	37	2,136	21.8	19.3	19.9	66.6	647.4	.303						80.8	707.8	19.1
1981	39	2,000	23.2	19.6	20.7	67.6	698.2	.349	No	Live	Trees			81.8	758.6	19.4
1986	44	1,828	25.6	20.9	22.6	73.2	797.3	.436						87.4	857.7	19.5

Table 2 Avoca 1/64, Details (per ha.) of Moderate Thinning.

		MAIN CROP AFTER THINNING							THINNINGS					TOTAL CROP		
Year Ended	Age	Stems	Top Ht (m)	Mean Ht (m)	Diam (cm)	Basal Area (m^2)	Vol. 7 (m^3)	Mean Vol (m^3)	Stems	Diam (cm)	Basal Area (m^2)	Vol. 7 (m^3)	Mean Vol (m^3)	Basal Area (m^2)	Vol. 7 (m^3)	M.A.I. (m^3)
1963	21	1,817	12.8	11.4	16.0	36.8	196.8	.108	1,880	11.2	18.4	79.5	.042	55.2	276.3	13.2
1967	25	1,496	15.0	13.6	18.9	42.1	297.3	.199	322	14.3	5.2	33.0	.102	65.7	409.8	16.4
1971	29	1,236	16.8	16.7	21.8	46.2	401.2	.324	260	16.8	5.8	48.4	.186	75.6	562.1	19.4
1976	34	1,074	19.8	19.5	24.2	49.6	506.2	.471	160	19.1	4.6	40.9	.256	83.6	708.0	20.8
1979	37	1,074	22.0	20.8	25.4	54.4	558.4	.520						88.4	760.2	20.5
1981	39	952	22.8	21.4	26.7	53.3	583.9	.613	123	21.3	4.4	42.4	.345	91.7	828.1	21.2
1986	44	814	26.0	24.7	30.2	58.4	725.6	.891	136	22.9	5.6	62.0	.456	102.4	1031.8	23.4

Table 3 Avoca 1/64, Details (per ha.) of Heavy Thinning.

		MAIN CROP AFTER THINNING							THINNINGS					TOTAL CROP		
Year Ended	Age	Stems	Top Ht (m)	Mean Ht (m)	Diam (cm)	Basal Area (m^2)	Vol. 7 (m^3)	Mean Vol (m^3)	Stems	Diam (cm)	Basal Area (m^2)	Vol. 7 (m^3)	Mean Vol (m^3)	Basal Area (m^2)	Vol. 7 (m^3)	M.A.I. (m^3)
1963	21	1,162	13.0	12.0	18.1	30.0	165.6	.142	1,916	13.4	27.1	136.9	.071	57.1	302.5	14.4
1967	25	890	15.4	14.6	21.7	32.8	230.0	.258	272	17.6	6.6	43.4	.160	66.5	410.3	16.4
1971	29	655	17.3	16.8	26.1	35.0	305.8	.467	235	21.8	8.8	75.8	.323	77.5	561.9	19.4
1976	34	543	19.9	19.6	29.4	36.8	365.0	.672	111	25.3	5.6	52.0	.468	84.9	673.1	19.8
1979	37	543	22.4	21.1	31.3	41.8	421.0	.775						89.9	729.1	19.7
1981	39	432	23.1	22.5	33.6	38.2	417.0	.965	111	28.1	6.9	71.5	.644	93.2	796.6	20.4
1986	44	333	26.0	25.2	39.7	41.2	471.8	1.417	98	33.0	8.4	95.8	.978	104.6	947.2	21.5

3. Neither treatment has a pronounced effect on top height. Mean height is increased by heavy thinning due to the successive removal of small stems. The differential between top and mean height narrows significantly with heavy thinning.

4. Total volume removed in six thinnings amounted to 306·2m^3 with moderate thinning and 475·4m^3 with heavy thinning, or 29·7% and 50·2% of total production, respectively.

5. Cumulative production expressed as volume to 7cm top diameter is greatest after moderate thinning.

6. There is no indication that mean annual increment figures have yet maximised.

Effect of Thinning on Diameter

Since all thinnings at Avoca were selective, mean diameter growth is a reflection of two concepts:

1. Removal of small-diameter trees in thinning.

2. Enhanced growth rate resulting from thinning to various intensities.

No attempt has been made to separate the two elements.

Table 4 demonstrates the classification of stems after thinning at 44 years into a range of diameter classes.

Table 4 Avoca 1/64: Diameter Distributions — standing crop at 44 years (Stems/ha).

Diameter (cm)	Light Thinning	Moderate Thinning	Heavy Thinning
0-19.9	827	12	—
20-29.9	815	457	12
30-39.9	160	346	210
40-49.9	25	12	74
50 and over	—	—	37

It is obvious that both thinning treatments lead to an enhanced growth rate as evidenced by the numbers of stems in the larger diameter classes. Only heavy thinning yields stems in excess of 50cm diameter at breast height.

Determination of Yield Class

The yield class system outlined by Hamilton and Christie (1971) is used in Ireland to determine crop productivity. General Yield Class (GYC) is derived from top height and age and forms the basis of production forecasting.

Estimates of GYC at Avoca vary from 20 (at 21 & 25 years) to 18 (at 29, 34, 37 and 39 years) to 20 (at 44 years) based on top heights averaged over all 6 plots.

Yield Class is expressed in terms of maximum average volume production per hectare per annum, or maximum mean annual increment (MMAI). Reference to Table 2 indicates an MMAI figure for the crop at Avoca of at least 23. This would indicate that the Production Class for the crop (Hamilton and Christie, 1971) is rated "A" or greater. A local yield class of 24 is possible and should be verifiable at the next assessment.

Effect of Thinning on Production

A differential in standing volume between the three treatments already existed when the experiment was established at 21 years. When allowance is made for these initial differences by use of the covariance analysis technique, adjusted increment values for the 23-year thinning period are derived. These are itemised in Table 5.

Table 5 Volume Increment at Avoca (m^3ha).

Treatment	Initial Volume	Adjusted Increment in the Period:						Adj. Total
		21-25	21-29	21-34	21-37	21-39	21-44	
Light	243.7	106.7	257.2	377.3	437.8	468.7	555.4	799.1
Moderate	276.3	134.4	287.1	433.3	485.7	555.0	759.6	1035.9
Heavy	302.5	120.8	278.5	392.8	451.1	537.1	699.2	1001.7

The moderate treatment consistently accounts for the greatest growth rate. Heavy thinning has reduced increment by 60m^3/ha adjusted, but the effect on total production is minimal. The most significant effect is evident in the control treatment where more than 200m^3/ha production has been lost compared to moderate thinning – increment has fallen off dramatically from about 37 years.

THE EFFECTS ON VOLUME ASSORTMENTS

Three categories of volume assortments are normally recognised. These are defined as "large sawlog" (volume from base to 20cm top diameter), "small sawlog" or "boxwood" or "palletwood" (volume from base to 14cm top diameter and/or the portion from 20cm to 14cm top diameter) and pulpwood (volume from 14cm to 7cm top diameter). A minimum length of 3 metres applies to base lengths to 14cm or 20cm, it does not apply to mid-portions of small sawlog. No minimum length applies in the case of pulpwood. Timber prices vary for each category, large sawlog being the most lucrative.

Taking each treatment at Avoca separately:

Light Thinning: as previously stated, it has been decided to ignore the thinnings removed by this treatment so that only the total crop at 44 years is relevant.

Table 6 Volume Categories from Light Thinning (m^3ha).

Status	Volume	Diam. (cm)	Large Sawlog	Small Sawlog	Pulpwood
Total Crop	797.3	22.6	308.4	315.0	173.9

Moderate Thinning: Both first and second thinnings comprised only pulpwood. Table 7 itemises the situation pertaining to all thinnings, the present standing crop and the total crop.

Table 7 Volume Categories from Moderate Thinning (m^3ha).

Age in Yrs.	Status	Volume	Diam (cm)	Large Sawlog	Small Sawlog	Pulp-wood
21	First Thin.	79.5	11.2	—	—	79.5
25	Second Thin.	33.0	14.3	—	—	33.0
29	Third Thin.	48.4	16.8	—	29.2	19.2
34	Fourth Thin.	40.9	19.1	4.0	26.5	10.4
39	Fifth Thin.	42.4	21.3	8.4	23.9	10.1
44	Sixth Thin.	62.0	22.9	26.4	27.5	8.1
44	Main Crop	725.6	30.2	595.2	99.9	30.5
44	Total Crop	1031.8	—	634.0	207.0	190.8

A total thinning output of 306·2m³/ha comprised 38·8m³ large sawlog, 107·1m³ small sawlog and 160·3m³ pulpwood.

Heavy Thinning: First thinning was comprised only of pulpwood. Table 8 contains relevant details.

Table 8 Volume Categories from Heavy Thinning (m³ha).

Age in Yrs.	Status	Volume	Diam (cm)	Large Sawlog	Small Sawlog	Pulp-wood
21	First Thin.	136.9	13.4	—	—	136.9
25	Second Thin.	43.4	17.6	—	22.4	21.0
29	Third Thin.	75.8	21.8	32.1	29.0	14.7
34	Fourth Thin.	52.0	25.3	31.6	16.1	4.3
39	Fifth Thin.	71.5	28.1	54.4	13.2	3.9
44	Sixth Thin.	95.8	33.0	81.2	11.2	3.4
44	Main Crop	471.8	39.7	441.5	21.8	8.5
44	Total Crop	947.2	—	640.8	113.7	192.7

Six heavy thinnings yielded 475·4m³/ha of which 199·3m³ was large sawlog, 91·9m³ was small sawlog and 184·m³ was pulbwood.

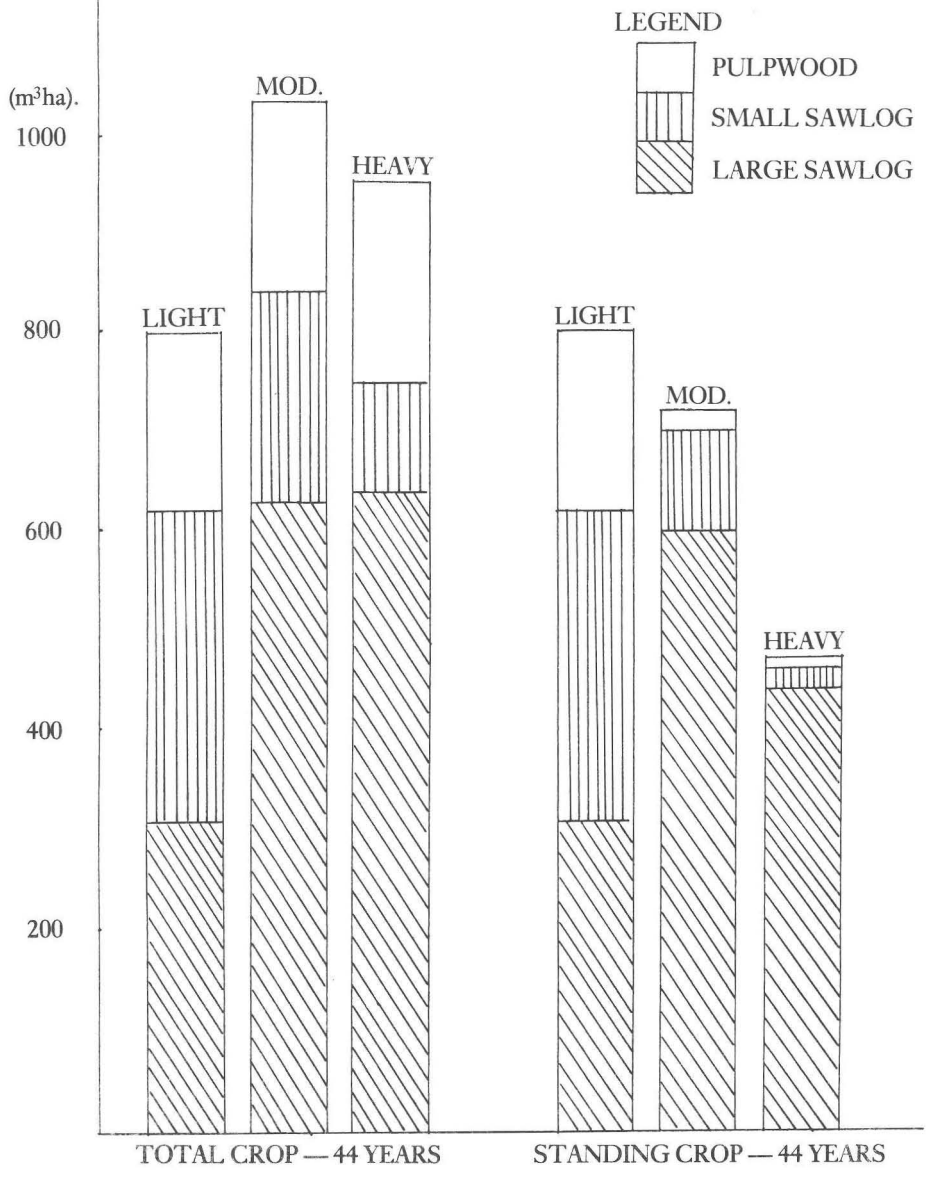
Figure 1 outlines the situation in histogram form for the total crop and the main crop after sixth thinning. the heavily thinned standing crop is composed almost entirely of large sawlog.

The large sawlog element of cumulative production is very similar for both thinning treatments but is significantly in excess of that in control. At 39 years, the differential between the thinning treatments was wider – 401·9m³/ha large sawlog with moderate thinning compared to 493·8m³/ha after heavy thinning. The fact that equalisation is now evident is explained by the increased increment in the moderate treatment during the 39-44 year interval being composed entirely of large sawlog.

Thinning Intensities at Avoca

Hamilton and Christie (1971) discuss the concept of "marginal thinning intensity". They recommend it as the optimum intensity to which forest crops should be thinned. Marginal intensity is reasonably close to an intensity which in terms of annual rate of volume removal is 70% of the yield class. Production forecasts for this country assume the application of marginal thinning intensity unless special constraints apply.

Figure 1 Avoca 1/64: Volume Assortments



In order to express total thinnings felled under the moderate and heavy thinning regimes at Avoca, the following assumptions are made:

1. Both crops will be clear-felled at 49 years.
2. Yield class is 24.
3. A thinning range of 23 years applies.

Based on these assumptions, moderate thinning (306·2m³/ha removed) is equivalent to 55% of yield class while heavy thinning (475·4m³/ha removed) equates to 86% of yield class, lighter and heavier, respectively than that normally assumed.

To Sum Up

The experiment at Avoca has proved extremely valuable in providing a comprehensive quantity of data over a full thinning period. Crops of Sitka spruce similar to those at Avoca would normally be clear-felled at about 46 years (indicated age of maximum mean annual increment). However, it is intended to retain the plots at Avoca indefinitely so that growth trends can be monitored into the future. Felling of thinnings in the heavy treatment will be suspended, although in the remaining plots it will be continued.

It is of interest in passing to note that the project was almost abandoned at the outset because of persistent invasions by starlings which ended only when first thinnings were felled.

The heavy thinning treatment is of particular interest. It describes a thinning intensity far in excess of that recommended or practiced in this country. On free-draining, stable sites it offers a series of lucrative thinnings with very little deleterious effect on production. Thinning to this intensity can significantly shorten the economic rotation of a Sitka spruce crop due to the early attainment of tree sizes of maximum value.

A further reflection of the effects of thinning systems such as those applied at Avoca, is seen in the sale price for the standing crop alone after thinning at 44 years. Using current prices for standing timber, the lightly thinned crop (1,828 stems) is worth approximately IR£11,000 per hectare. Equivalent prices for the moderately (814 stems) and heavily (333 stems) thinned crops are IR£17,000 and IR£13,000 per ha respectively. The price for the heavily thinned crop is a reflection of the significant amount of large sawlog present for which a premium price is obtainable.

The experiment at Avoca is unique in that it is the only stand of timber in Ireland which has been carefully monitored throughout

its full thinning cycle. The present paper has highlighted only a portion of the data available form the experiment, emphasis has been placed on those areas considered to be most relevant to the Irish forestry situation.

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