The Thinning of Sitka spruce – Two Experiments

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INTRODUCTION

Studies on the effects of thinning in even aged plantations have been carried out for almost a hundred years (Braathe 1957). Earliest work in this field was undertaken in Central Europe but to-day, investigations are under way in almost every country where forestry features as a commercial enterprise.

The complexity of analysing data of the many crop characteristics which must be measured has meant that from an early stage thinning research had to be conducted through planned experiments. The earliest and best known are those set up in Bavaria and in Sweden in the last century and have been described by Wiedemann, Ascman, and Carbonnier (Holmsgaard 1958). The experiment of most interest and relevance to conditions in Western Europe was that undertaken by the British Forestry Commission in Norway spruce on a private estate in Bowmont, Scotland. (Hummel 1947). Here for the first time a thinning experiment was established which fulfilled the requirements for statistical analysis. The "Latin Square" design was used and the value of this formal statistical approach has been illustrated in papers interpreting the results since establishment. (McKenzie 1962). In recent years, attention has been focussed by other workers on the difficulty of analysing thinning experiments. The size and uniformity requirements in a stand chosen for experimental purposes often cause difficulties. Various designs, including uni- and multi-factorial type experiments have been formulated to best cope with the considerable volume of data which can be produced. A review of work in the field of thinning experimental design has recently been compiled by the International Union of Forestry Research Orgnaisations (I.U.F.R.O., Unpublished). Here the value of replication was recognised and, though details for an optimum sized experiment were rather inconclusive, it seems that experiments comprising many large sized plots were favoured. Though the advantages of such complex thinning experiments have been recorded by some workers (Schober 1967) greater emphasis is now being given to the statistical properties of experiments to make them more manageable and to facilitate proper interpretation of results (Franz 1967).

Bradley 1967b) describes recent replicated experiments — mainly of the randomised block type — in the United Kingdom. The experiments involve four species and from one to three thinning regime

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components (intensity, cycle, type). These experiments are as yet too recent to yield results, but should provide valuable information on thinning intensities and cycles. Bradley stresses the necessity for objective specifications in experiments to allow quantitative analysis. He emphasises also the value of exercising control through thinning yield rather than on main crop factors.

Two apparently conflicting theories emerge from thinning research to date. The first, most strongly proposed by Möller (1954), is that, over a wide range of stocking conditions from full downwards, there is no reduction in volume increment. On the other hand when referring to conditions in Finland, Voukila (1962) maintained that all thinnings will reduce increment to some extent.

It is against this background of experimental work and theory that the initial effects of thinning on Sitka spruce, a species as yet little investigated, will be discussed.

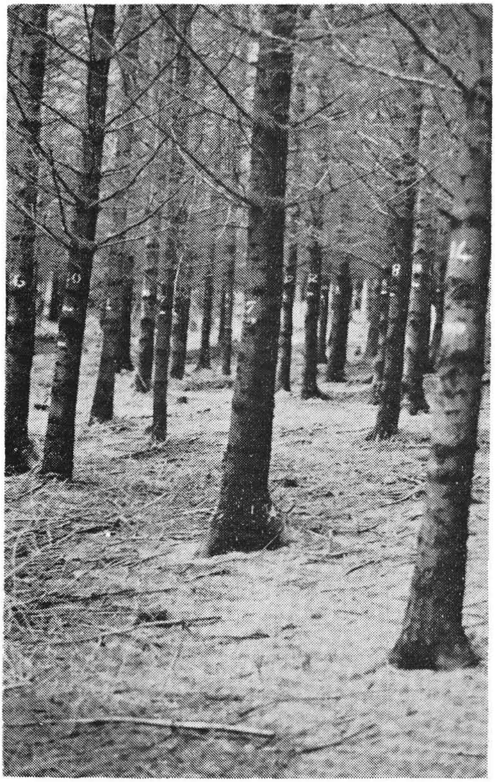
THE EXPERIMENTS

On the establishment of a research branch within the Forestry Division in the Republic of Ireland the value of experimental research into the influence of thinning on even-aged plantations was recognised. The implementation of the afforestation programme in Ireland has meant that most of the crops capable of exploitation are those which are reaching or which have reached thinning stage. This means that the supply of timber in this country will depend largely on thinnings for some time to come. A programme of experimental thinning research was therefore started in 1962. Contorta pine was chosen to be the first species for study. Sitka spruce was included in the following year (Gallagher 1966). A small experiment was established late in 1963 at Coolgreany Forest, Co. Wicklow, to assess the effects of different thinning types on volume production and increment of Sitka spruce, while employing the same intensity of thinning. Early in 1964 another experiment in the same species was set up in Avoca Forest, Co. Wicklow, to assess different thinning intensities. Thinning intensity can be described as the quantity of timber removed per annum, while type of thinning defines the way in which this material is removed in terms of tree categories.

Coolgreany

This experiment was originally intended as a field demonstration of different thinning methods, but it was decided that more valuable information could be obtained by replicating the treatments twice in randomised blocks. Each measurement plot was 0.2 acre.

Since the establishment of the experiment the site has been assessed as General Yield Class (Bradley, Christie and Johnston 1966) 240-260 in the early stages and 220-240 in the most recent



measurements. Blocks have been allocated according to site productivity. First thinning was carried out at 17 yrs. (Top height 34 feet). Two types of thinning were compared :— (a) the Scottish eclectic thinning method (Macdonald 1961) and (b) a moderately heavy low thinning — C/D grade. (Hummel et al. 1959). The former aims at a predetermined number of dominant trees selected for the final crop by removing competing dominants and favouring selected dominants and non-competing co-dominants. It is argued that the system provides a fairly heavy thinning regime resulting in large sized material early in the rotation and ensuring a final crop grown in conditions of little competition. The low thinning used in the experiment is that generally employed in current management practice in which smaller and poor quality competing stems are removed. There is no particular emphasis on final crop dominants.

In order to assume a similar weight of thinning all, plots were adjusted to the same standing basal area after thinning. This adjustment was carried out after thinning to avoid bias in the method of thinning. First thinning involved a reduction to 86 square feet

Plate 1. *(Far left). Avoca. Light low thinning.*

Plate 2. *(Left). Avoca. Heavy low thinning.*

Plate 3. *(Below). Coolgreany. Scottish eclectic thinning.*

basal area[1] main crop or 28% basal area and 27% volume removal for all plots. The plots were re-thinned in 1968 (top height 39 feet) at which stage 80% of the periodic basal area increment since first thinning was removed. The quantitative adjustment was again carried out after marking.

Avoca

This stand has been assessed as General Yield Class 220-240. First thinning was undertaken at a later stage than at Coolgreany, when the crop was 21 years old (top height 41.5 feet).

Here the basis of the experiment was the consideration that, of all thinning components, the intensity, or annual thinning yield has the greatest effect on production.

Level of stocking was defined by basal area after thinning. Three intensities of low thinning were imposed. These resulted in

HEAVY ... Thinning to 100 square feet basal area main crop

MODERATE Thinning to 125 square feet basal area main crop

LIGHT ... Thinning to 150 square feet basal area main crop

The treatments were replicated in two randomised blocks using measurement plots of 0.1 acre. Initial total standing basal area was 155-170 square feet so the thinnings represented a removal of approximately 48%, 34% and 16% basal area or 42%, 28% and 10% volume. A desire to keep the treatments evenly spaced for analysis purposes influenced their selection.

First thinning was carried out in Spring 1964. The stand was re-thinned in 1968 (top height 49.5 feet) at which stage predetermined percentages of basal area increments were removed.

Heavy: 75% B.A. increment removed.

Moderate: 50% B.A. increment removed.

Light: 25% B.A. increment removed.

This was based on the mean basal area increments of both plots of each treatment. This maintained thinning intensities relative to one another while allowing some compensation for possible increment loss in heavily thinned plots. Second thinnings were equivalent to the removal of from 40% to 13% of the volume increment between first and second thinnings.

1. All basal area and volume data are in Hoppus measure (=.785 true measure).

VARIABLES

Stems per acre: All stems 1.3 ins. diam. and over.

Top Height: Mean height of the 40 largest girthed trees per acre (feet).

Dominant Diameter: Mean diameter at 4 ft. 3 ins. of the 40 largest trees per acre (ins.).

Mean Diameter: Arithmetic mean diameter at 4 ft. 3 ins. of trees 1.3 ins. diameter and over, weighted by basal area (ins.).

Basal Area: Basal area per acre of trees 2.7 ins. diameter and over (square feet).

Volume to 3 ins.: Volume to 3 inches top diameter per acre of trees 2.7 ins. diam. and over (cubic feet).

Total Stemwood: Total stem volume per acre of trees 1.3 ins. diam. and over (cubic feet).

Periodic Annual Volume Increment to 3 ins.: Annual volume production from 1st to 2nd thinning (cubic feet).

Periodic Annual Basal Area Increment: From 1st to 2nd thinning (Square feet).

Mean Annual Volume Increment: Total volume production to 3 ins. top to date divided by age (cubic feet).

Crown %: (Length of live crown/h) x 100. Mean of 10 trees per plot.

In each plot every stem was measured with a diameter tape to determine diameter and basal area. Volume was obtained through the least squares calculation of the volume/basal area regression $Y=a+bX$ for 10 fully measured sample trees in each plot (X is plot mean basal area and Y is plot mean volume). Total stemwood volume includes tops which are assumed to be conical and therefore 0.386 L (L=length of top) is added to the volume of each sample tree.

ANALYSIS

Analysis of variance was employed to assess variation due to blocks, treatment and error. In the Avoca experiment variation due to treatments was subdivided into linear and quadratic components. Tables 1 and 6 show the significance of differences in basal area and diameter increments between treatments. In a number of cases the levels of significance are very low but in view of the limited size of the experiments they are worth recording to suggest, if not prove, growth trends.

RESULTS AND DISCUSSION

Avoca

Analysis of growth after first thinning showed some significant difference with regard to basal area and mean diameter development. Through differences for other factors were much lower, volumes and increments are shown, as the trends are related to basal area growth and might have shown up more clearly in a more sensitive experiment. Crop characteristics such as the reduction in stems per acre and thinning data are shown in tables 4 and 5.

Basal area

Table 1 shows basal area increment per acre for five years since first thinning. Though levels of significance are low, certain trends are visible. Increased intensity of thinning tended to depress basal area increment until the fourth year after thinning, at which stage there was a significant recovery in the heavily thinned plots. After second thinning there was no depression of increment and in fact the heavily thinned plots may be still recovering relative to lightly thinned plots. Overall it is possible that moderately heavily thinned plots did best.

Mean diameter

The effect on mean diameter is more definite. Increasingly severe depression of mean diameter growth occurs in lightly thinned plots each year after thinning. This effect is maintained after second thinning also, at which stage diameter growth in heavily thinned plots is twice that in lightly thinned plots. This effect is to be expected as different thinning intensities give rise to differently sized mean trees (Table 1).

Volume

Though levels of difference are not significant there is a suggestion that volume may follow a similar trend to that of basal area (Table 2). Increment on heavily thinned plots is least and on moderately thinned plots greatest. Increments on moderately and lightly thinned plots are closer than heavily and moderately thinned plots. Table 2 shows volume production and annual increment patterns.

Crowns

There was a greater reduction in crown % in lightly thinned plots, the average rate of decrease being twice that of trees in heavily thinned plots (Table 3). All crowns are now approximately 40% of total height.

Dominant Diameter

It is interesting to note that there was no increment differential on dominants for different treatments, individual plots varying only between 1.4 and 1.5 inches. This is relevant to the contention that thinning does not radically influence the final crop.

TABLE 1

Avoca. Effects of thinning intensity on basal area (square feet Hoppus/acre) and mean diameter (inches).

	Heavy	Moderate	Light	Significance of linear component
Basal area:				
After 1st thinning	102.3	125.7	149.0	—
Increment Year 1	6.07	6.70	8.47	10%
,, 2	6.11	8.79	8.89	25%
,, 3	9.09	10.97	11.16	25%
,, 4	11.21	9.89	7.06	5%
Increment Years 1-4	32.48	36.35	35.58	25%
After 2nd thinning	122.53	152.74	184.69	—
Increment Year 5	12.20	12.36	11.23	25%
Diameter:				
After 1st thinning				
Increment Year 1	0.25	0.15	0.20	25%
,, 2	0.20	0.25	0.20	25%
,, 3	0.35	0.20	0.15	5%
,, 4	0.35	0.25	0.15	1%
Increment Years 1-4	1.15	0.85	0.70	1%
After 2nd thinning	8.30	7.45	6.30	—
Increment Year 5	0.45	0.30	0.20	5%

TABLE 2

Avoca. Effects of thinning intensity on volume to 3 inches top diameter, and total stemwood (cubic feet Hoppus/acre).

	Light	Moderate	Heavy
Periodic annual volume increment	329	341	306
Mean annual volume increment	162	179	171
Increase in mean annual volume increment since first thinning	31	31	25
Periodic annual stemwood increment	329	341	304
Mean annual stemwood increment	180	195	195
Increase in mean annual stemwood increment since first thinning	28	28	20

TABLE 3

Avoca. Effects of thinning intensity on crown development.

	Average Crown %		
	Light	Moderate	Heavy
After first thinning	64.0	51.0	49.0
After second thinning	48.0	39.5	41.0
Decrease	15.5	11.5	8.0

Stems per acre

The difference in stocking which now exists is clearly illustrated in Table 4 by the variation in number of stems per acre from over 1,000 in lightly thinned plots to 350 in heavily thinned plots. The volume and basal area differences are not so dramatic, indicating the unreliability of stems per acre as a criterion for stocking.

Thinnings

Table 5 shows a very heavy initial yield from heavy thinning, which includes relatively large-sized material. Yield from moderate thinnings at first treatment are still considerable but both size and quantity of material from light thinnings are negligible.

At a second thinning there was less variation in thinning produce as the treatments tended to move a little closer. The yield in size and quantity was still consistent however with the pattern shown at first thinning.

TABLE 4

Avoca. Stems per acre after thinning.

	Light	Moderate	Heavy
First thinning	1155	735	470
Second thinning	1020	615	360

TABLE 5.

Avoca. Details of thinnings removed.

Thinning	Intensity	Mean Diam. (inches)	Stems/ acre	Volume to 3 ins. top diameter acre
	Light	3.2	645	264
First	Moderate	4.0	930	897
	Heavy	5.0	875	1,313
	Light	4.2	135	153
Second	Moderate	5.8	130	369
	Heavy	7.0	110	487

The money equivalent yields per acre have been estimated as follows:

	1st	2nd	Total
Heavy	£100	£36	£136
Moderate	£68	£28	£96
Light	£19	£11	£30

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Here two types of thinnings were compared. Intensity of thinning was kept constant for both types. The results are much more tentative as the experiment was small, two treatments and two replications only. Levels of statistical significance were therefore very low.

However, taking experimental size into account, some of the recorded increments are of interest.

Basal area

Effects are given in Table 6. Though the "F" values were very low there was a slight suggestion that low thinning resulted in greater increment per acre for the four years after thinning. By second thinning, there was an apparent increase in basal area increment of about 10% in low thinned plots over eclectically thinned plots. The total effect of two thinnings may also suggest better growth on low thinned plots.

Mean diameter

Here it is suggested that, if any effect is apparent, it is that mean trees in low thinned plots increased more. After first thinning mean trees in low thinned plots were larger than in eclectically thinned plots (Table 6).

Volume

Again there is a suggestion of greater volume increment both for volume to 3 ins. top diameter and total stemwood for low thinnings (Table 7).

Crowns

Crown % was roughly the same for both treatments at first thinning. At second thinning crown % in low thinned plots decreased at twice the rate of that in eclectically thinned plots (Table 8).

Dominant diameter

Dominant diameters were initially greater in low thinned plots and increased .2 inches more than those in eclectically thinned plots.

Stems per acre

After first and second thinnings, remaining stems per acre were more numerous in eclectically thinned plots as a large number of

TABLE 6

Coolgreany. Effect of thinning type on basal area (square feet Hoppus/acre) and mean diamter (inches)

	Eclectic		Significance
Basal area :			
After 1st thinning	111.05	110.17	—
Increment Year 1	12.47	13.38	>25%
,, 2	11.78	11.74	>25%
,, 3	9.89	12.53	>25%
,, 4	13.48	14.39	>25%
Increment Qears 1-4	47.62	51.75	10%
After 2nd thinning	121.28	120.35	—
Increment Year 5	11.87	12.24	>25%
Increment Years 1-5	58.49	63.99	20%
Diameter :			
After 1st thinning	4.65	5.00	>25%
Increment Year 1	.25	.30	25%
,, 2	.25	.20	25%
,, 3	.20	.25	25%
,, 4	.25	.30	25%
Increment Qears 1-4	.95	1.05	25%
Increment Year 5	.25	.30	5%
Increment Years 1-5	1.20	1.35	10%

small stems were ignored at thinning. The distribution in low thinned plots is more normal (Table 9).

Thinnings

Table 10 shows thinning data from both types of thinning. In eclectically thinned plots a smaller number of larger trees resulted in about 100 cubic feet extra removed at first thinning. In the second thinning volumes were much the same, though the average size of trees removed in eclectically thinned plots was still larger. The size of these trees may be more attractive to timber merchants resulting possibly in a slight price difference.

Conclusions

The results to date indicate that thinning intensity does effect increment to some extent and also the size of trees within the stand. Type of thinning also seems, though less conclusively, to influence increment and stand structure somewhat.

It is obvious that Sitka spruce is a very flexible and tolerant crop as regards thinning intensity and that first thinnings can be quite heavy without adverse repercussions, though at greater than 40% volume removal, increment loss is likely to occur. Recovery appears to be quite rapid—within four years. The removal of 30% by volume or basal area is quite safe.

This is encouraging in the light of recent developments in systematic thinning trends and at present experiments are being set

TABLE 7

Coolgreany. Effect of thinning type on volume to 3 inches top diameter, and total stemwood (cubic feet Hoppus/acre).

	Eclectic	Low
Periodic annual volume increment	349	403
Mean annual volume increment	162	168
Increase in mean annual volume increment since first thinning	44	55
Periodic annual stemwood increment	348	404
Mean annual stemwood increment	176	187
Increase in mean annual stemwood increment since first thinning	44	55

up incorporating 33% reduction of stock at first thinning together with various systematic stem reductions at the same intensity. The maintenance of increment after a heavy second thinning is also encouraging and confirms the characteristic recovery power of spruces, suggested for Norway Spruce by Vuokila (1962) and McKenzie (1962).

Though the heavy thinnings in the Avoca intensity experiment varied somewhat from the "marginal intensity" defined by Bradley, Christie and Johnston (1966) and Bradley (1967a) — somewhat heavier at first thinning and a little lighter at second thinning in terms of volume removal they are close enough for comparison.

TABLE 8

Coolgreany. Effects of thinning type on crown development.

	Average Crown %	
	Eclectic	Low
After 1st Thinning	48.5	55.5
After 2nd Thinning	40.5	41.5
Decrease	8.0	14.5

The hypothesis that 50% removal of current annual volume increment will be near optimum for increment production seems to be supported in view of the continued high increment in heavily thinned plots after second thinning. A point of note is the changing relationship between volume and basal area with crop development. At first thinning basal area percentage removal was roughly equivalent to volume removal but at second thinning the removal of 75% basal area increment was equivalent to 40% volume increment removal—less than expected.

The lack of any real difference in diameter growth on the 40 largest trees per acre between thinning intensities is of interest indicating the possibility that any intensity of thinning which does not definitely select dominants will have little effect on the final rotation crop.

The overall suggestion from the thinning type experiment is that, if anything, low thinning is best for production and that it is doubtful if the work involved in selection for eclectic thinning is warranted by the increase in thinning size — though this is a point to be considered. In third and later thinnings differences in thinning production should weigh in favour of low thinnings as many of the larger trees will have been removed earlier in eclectic thinnings. That a thinning method with so definite a bias in favour of early selection shows relatively little difference from a less selective procedure is again encouraging in the light of probable future developments in more objective and systematic methods.

TABLE 9

Coolgreany. Stems per acre after thinning.

	Eclectic	Low
First thinning	1205	1038
Second thinning	929	676

Considerable differences in thinning yield are apparent for different intensities. The substantial first and second thinning yields from the heavier intensities translated into money terms do much to offset accumulating establishment costs at an early stage. The values per unit volume of these yields would also be increased by the numbers of larger trees included. Better monetary yields should also be obtained from early eclectic thinnings but the difference between those and low thinnings would be much less than between intensities. Tree sizes in eclectic thinnings also tend to drop in time as compared with low thinnings as the pool of large size trees decreases. On the basis that optimum first thinning for Sitka spruce lies between 50%-33%

TABLE 10

Coolgreany. Details of thinnings removed.

Thinning	Type	Mean diam (ins.)	Stems/acre	Vol. to 3 ins. top diameter/acre (cubic feet Hoppus)
1st	Low	4.0	632	485
	Eclectic	4.8	452	584
2nd	Low	5.2	362	696
	Eclectic	5.8	275	719

basal area removal (43%-30%) volume and second thinnings at 80%-60% basal area increment removal (50%-40% volume) these studies are being developed to include a more refined intensity experiment for Sitka spruce with a greater number of treatments and replicates, and an experiment into various means of systematic thinning with a standard first reduction of one third on stocking. Other species, notably contorta pine, Norway spruce and Scots pine are also at present under investigation.

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SUMMARY

The paper reviews the initial effects on Sitka spruce crop growth of three intensities and two types of thinning. Main crop basal areas and probably volumes are depressed by very heavy intensities in the early years after first thinning but recovery is recorded in the fourth year. Main crop diameter increment is significantly greater with heavy thinnings which also yield higher thinning volumes. Little difference is recorded between low and eclectic thinning though there is a suggestion that main crop growth is greater with the former. First thinning produce from the eclectic method is greater in tree size and volume yield though indications are that this difference will disappear in time.

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