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THE THINNING OF PLANTATIONS

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OUR outlook on what constitutes a good thinning has changed in recent years. We used to think we could judge whether a thinning was good or not by looking at the result and, as we were mainly influenced by the methods demonstrated by our teachers, we would try to thin so that the remaining trees looked as they had taught us to expect. We had no clear idea of what we were aiming at or how the trees would ultimately turn out.

Our new conceptions are different. Although there are many bad ways of thinning a plantation, there are also many good ways, but each different method will give a different result. You cannot intelligently settle on a method of thinning until you have made up your mind as to the kind of result you want to obtain. You should then direct your thinning towards obtaining that result.

Let me first dispose of the bad ways of thinning. It is clearly wrong to take out the best trees and leave the worst. It may often be wise to remove the biggest trees and keep co-dominants which are straighter or more finely branched, but you must be satisfied that their crowns are sufficiently robust to enable them to become vigorous. In other words, your choice must be qualitatively sound. There are also quantitative limits. You must not, except under conditions which I shall explain later, leave the trees so scattered that they cannot make canopy, or so tight that their crowns become weakened. Particularly with the larches, ash and sycamore, it is necessary to maintain vigorous crowns because, once they become weakened, they have great difficulty in recovering. In some species, particularly Douglas fir, the early thinnings must be reasonably heavy in order to make the individual trees windfirm. On the other hand, in woods which are very dense because thinning has been neglected, special care is required.

It is permissible to adopt methods of " high " thinning, and even " selection " thinning[6] in which the trees removed have a larger mean diameter than those that remain. But I want to-day to speak principally about " low " thinning because it lends itself better to quantitative description. Even with a low thinning it is necessary to remove " wolves " and badly-shaped dominants, but in general the smaller trees are taken and, if the thinning is heavy, only dominants and co-dominants will be left. The choice which remains to us is quantitative. How many trees to the acre should we leave at each thinning ?

What Should Be Our Aim ?

We know that in plantations which are lightly thinned the trees grow slowly in diameter and have narrow annual rings; if they are thinned heavily the trees grow more rapidly in diameter and have broader annual rings. For instance, if Norway spruce, quality class II, is thinned in accordance with the British Yield Table, it takes about eighty years for the final crop trees to reach a breast height quarter girth of 12 inches. With a heavier thinning, which I shall describe later, it takes them fifty-five years to reach this size; and with Wiedemann's " moderate " thinning,[8] which is widely practised in Germany but is very light by our standards, it takes 110 years. So if we want to grow trees of this size the lengths of the rotation will be anything from fifty-five years to 110 years, according to the way we thin. Which of these thinning grades is it reasonable to choose ?

For myself I should generally choose the treatment which is likely to prove most profitable. I say " generally " because we are rightly influenced by other objectives such as amenity and by our love of beautiful stands, and we must be careful not to let down the quality of the soil. But our main job as foresters is to grow the timber that people want at a price they are willing to pay. In time we shall be growing a large part of the conifers we consume and our main objective should be to produce those kinds of sawn softwood timber which will meet out national needs and will compete on the most favourable terms with imported sawn timber. We need to produce the highest reasonable quality at the lowest reasonable cost. Private growers will naturally follow this objective because it will increase their profits; and it is equally desirable for State forests because economic production helps to maintain a high standard of living.

To achieve this objective we need far more knowledge than we have at present. In particular, we need to know how plantations will respond to different thinning grades, how the quality of the timber will be affected, and how variations in treatment will influence the cost of growing the timber and the price we may expect to get for it. And we must not expect quick answers to these questions. It would take many decades to determine in the forest the results of thinning in different ways but, fortunately, forest science has now reached a stage at which it is possible for us to judge with some confidence the probable result of thinning in a new way. Mathematical calculations can help us both in this and in comparing costs.

Many foresters are allergic to calculations and resent the interference of mathematics in their silvicultural practice. And I should hesitate to impose computations on them were it not that the initial results of such work suggest that economies of outstanding importance can be achieved by changes in our methods. I have already referred to three thinning grades in Norway spruce, quality class II, by which the final crop reached a size of 12 inches b.h.q.g. in fifty-five years, eighty years and 110 years, respectively. If we introduce representative costs of land and operations and representative prices for thinnings, the cost per hoppus foot of growing the final crop works out at about 2*s.* 6*d.*, 4*s.* 6*d.* and 19*s.* in the three cases. I hope later in this address to explain how these figures are computed; at present I mention them only as an example. They show how wise we are to escape from the very light thinning practised in Germany. But they also show that by thinning still more heavily than our current practice we can reduce the cost by a further forty per cent. If this can be achieved without seriously impairing quality, it is clearly a matter of the utmost importance.

Calculated Thinning Grades

The Revised British Yield Tables[4] are constructed to conform with a grade of thinning which is generally described as C/D[7]. It is heavier than a C thinning but is lighter than a D thinning. Compared with most German thinnings it is heavy, but in its later stages it is lighter than the Danish model[6] and, for our purposes, we may describe it as a moderate grade. The yield tables include figures of the mean quarter girth of the 100 largest trees at each thinning, and these figures enable us to visualize the pattern of annual ring widths which we may expect to find at breast height in the dominant trees. The number of rings per inch put on in each ten-year period has been calculated and examples from each of the seven species are shewn in Table 1.[3]

It will be seen that in nearly every instance the annual rings near the centre of the tree are fairly broad but that they become narrower and narrower towards the outside. The most striking example of this is European larch in which the latest rings are only about one-thirtieth of an inch wide. The trees have almost stopped growing although at seventy years the second quality has only reached a mean b.h.q.g. of 10 inches. Both the larches call for a very different method of cultivation. Personally, I advocate considerably heavier thinning in early years followed by a reduction to about fifty trees to the acre half-way through the rotation; these widely-spaced trees can then be underplanted to produce a two-storied high forest.

With most other species I would aim at more rapid growth than is depicted in the table. On fertile soils we cannot ordinarily avoid very broad annual rings in the extreme centre of a tree, but

TABLE 1. NUMBER OF RINGS PER INCH IN THE 100 LARGEST TREES

(Figures calculated from *Revised Yield Tables for Conifers in Great Britain* after smoothing quarter girths)

Species	Scots pine			Corsican pine			European larch			Japanese larch			Norway spruce			Sitka spruce			Douglas fir		
quality class	I	II	IV	I	II	IV	I	III	V	I	III	V	I	II	IV	I	III	V	I	III	V
Age (years) 20-30	8·5	9·4	—	9·2	9·3	—	10·6	11·7	—	9·0	10·3	15·5	8·2	10·0	—	5·4	7·1	8·8	6·0	6· 4	7·3
30-40	8·5	9·4	17·0	9·2	12·0	15·2	13·6	16·2	21·2	11·4	12·2	18·0	8·2	10·0	16·5	7·9	7·9	8·8	8·5	8·3	8·1
40-50	9·4	10·6	17·0	11·7	14·0	16·6	16·2	22·7	28·3	14·9	16·3	21·4	9·4	10·3	16·5	13·8	11·1	10·3	11·0	11·0	11·8
50-60	12·1	12·6	17·0				20·0	30·9	30·1												
60-70	15·4	16·2	17·9				26·1	37·8	35·0												

I would like them to settle down to six to seven rings to the inch (which corresponds with a growth in quarter girth of $\frac{1}{4}$ inch each year) or a few more. This is a narrow enough ring width for strength, but if the rings become much narrower the trees do not pay for keeping. Unfortunately, this will require the adoption of thinning grades which have never been tried out on a sufficient scale to give statistical results. Must we wait for long-term experiments, or can we *calculate* what is likely to happen if we thin more heavily ?

Calculated thinning grades are not new to forestry. The most famous case is Craib's[1] calculated grades for *Pinus radiata* and *Pinus patula* in South Africa, which have been followed with extraordinary precision for fifteen years. We have more evidence to work on than he had, and an important principle, which is now widely recognized, comes to our assistance.

This principle, which S. O. Heiberg calls " Möller's theory ",[6] is that, within certain limits, the volume increment of a plantation is not influenced by the density of stocking. It means in practice that an equal volume production can be obtained on a much lower growing stock than is generally considered necessary.

Now, the volume increment per acre in a plantation in one year is the total volume of the annual rings which are put on in that year by the cambium on all the trees. Let us now think in terms of the total area of the cambium on the main stems of all the trees on an acre, what is called the " bole area " per acre. If half of an evenly growing plantation is left unthinned, while the other half is thinned in such a way that the bole area is reduced to a half, it follows from Möller's principle that, on the average, the trees in the thinned portion must put on rings which are twice the thickness of those put on in the unthinned portion. Perhaps this is too much to expect in the first year, but the volume of wood put on in the five years following the thinning will probably be the same in each case. What this means is that, when the effects of different grades of thinning are compared, the average ring widths will be inversely proportional to the bole areas. This provides a mathematical basis for calculating the effect of a different numerical thinning from that adopted in the yield table.[3]

There is another method of calculation, also based on Möller's principle but without using the bole area,[2] and it is found that with appropriate precautions, these two methods give approximately the same results. It would exhaust your patience if I were to attempt to explain these mathematical methods in greater detail and I will confine myself to describing the result of computations based on the Norway spruce table to which I have already referred.

It was first necessary to extrapolate the British Yield Table to eighty years. There are so many continental yield tables for spruce, some of which are continued to 120 years, that this was fairly easy, and it was possible to continue the same general thinning trend as is followed in the British Yield Table. In this table 181 trees to the acre are left after thinning at eighty years, and the number of rings per inch at breast height in the 100 largest trees has increased from 10·0 at twenty to thirty years to 17·2 at seventy to eighty years.

We then calculated a new thinning grade designed to give 6·6 rings at twenty to twenty-five years, increasing evenly to 8·2 rings at sixty to sixty-five years. Only 100 trees would then be left after thinning at sixty years. Comparing the two tables shewed that the first gave a final crop of 7,310 h. ft. at eighty years with a mean b.h.q.g. of 11·7 inches, whereas the second gave a final crop of 5,555 h. ft. at fifty-five years with a mean b.h.q.g. of 11·8 inches. In each case the thinnings that would be taken with the final crop are included. So these two rotations, eighty years in the first case and fifty-five in the second, produce trees of about 12 inches b.h.q.g.

You will see that in this calculated table we have not contemplated a thinning grade which is so heavy that the trees produce shockingly broad annual rings. And we need not fear that if the number of trees is reduced to 100 per acre at sixty years they will fail to make canopy. Möller's table reduced them to 100 at sixty-seven years and this is normal Danish practice; but his table allows of very light thinnings in early years, so that the trees have narrow rings in the centre and broader rings further out. The Danes do not like having to prune their trees.

The Cost of Growing Trees

The simplest index of the financial attractiveness of a method of cultivation is the financial yield, or rate of compound interest which is earned on the capital invested in the plantation. Using certain data for costs of operations and a price-size gradient for thinnings and final yield, the financial yield for the moderate thinning with a rotation of eighty years is 3·53 % and is lower with longer rotations. With the heavy thinning, and a rotation of fifty-five years, the financial yield is £4·11 % and it becomes higher with a somewhat longer rotation.

Using the same data, but regarding the price per hoppus foot of the final crop as the unknown in place of the rate of interest, we can work out a figure for the "cost of production." In order to earn compound interest at 4 % a price of 4·52*s.* per hoppus foot is required with moderate thinning, but 2·54*s.* is sufficient with the heavy thinning. If larger trees were required the differences in the cost of production by the two methods would be greater.

The saving which is achieved through heavier thinning is due partly to the higher intermediate receipts which the more extensive thinnings provide, and partly to the shortening of the rotation which prevents compound interest from piling up for so long. Long rotations are very expensive. But, with the thinning grades recommended by the Forestry Commission, very long rotations will be required to produce trees of timber size on poor soil. Norway spruce quality class II, represents fairly rapid growth and, if we can save 40 % in cost in plantations of this quality, we can save much more in plantations which grow more slowly. So, taking all plantations into account, it is likely that a saving of more than 50 % can be achieved by adopting heavier thinning grades.

Quality of Trees

Apart from obvious defects such as crookedness, scars and rot, high quality consists mainly in three features. The first is size, because nearly always a large tree fetches more per cubic foot than a small tree. Timber merchants who use heavy band-saws like very large trees, even 20 inch q.g. and up, and at present the market in the southern half of Britain is keenest for such trees. But Gordon Jacob[5] tells us that, when mills have been built to deal with the large quantities of conifers which will be available in future decades, trees of 12 inch b.h.q.g. will be far more economical to saw. We may find in time that trees which are too large for the saws which are then employed become difficult to sell.

The next important feature is freedom from knots. One of the benefits of light thinning, especially during early years, is that side branches are killed off while they are still small, and small dead branches fall off more quickly than large dead branches. Nevertheless, artificial pruning is much more effective than natural pruning in securing clean timber. And with heavy thinning artificial pruning is far more economic than with light thinning. We have seen that with Norway spruce, quality class II, trees of 12 inch b.h.q.g. may be produced in fifty-five years rotation with heavy thinning, eighty years with moderate thinning and 110 years with light thinning. If we prune at twenty years at a cost of say, 6*d.* a tree, we receive our return thirty-five years later with heavy thinning, sixty years later with moderate thinning and ninety years later with light thinning. But, at 5 % compound interest, 6*d.* grows to 2*s.* 9*d.* in thirty-five years, to 9*s.* 4*d.* in sixty years and 40*s.* 4*d.* in ninety years. So we are much more likely to see a good return on the cost of pruning with heavy thinning than with moderate or light thinning.

In South Africa and Kenya, where rotations are very short, pruning has become the accepted practice and pays handsomely. Even with our far higher wages it will pay if rotations are reasonably short. So pruning becomes associated with heavy thinning and with this treatment we may expect to produce a large proportion of clear timber in the butt lengths.

Heavy thinning influences knottiness in another way. It encourages the crowns to be bigger and deeper, so that a larger part of each tree becomes almost useless. I doubt whether this seriously detracts from the value of a tree, because even in a tree with a shallower crown, the part below the live branches is extremely knotty.

The third important feature which influences timber quality is the ring width, and in conifers, though not generally in hardwoods, high quality is usually associated with narrow annual rings. This is a very complicated subject, about which the authorities differ, but I can see little merit in the ring width patterns shewn by most species in Table 1. When such trees are sawn up the boards they produce will have broad rings in the middle and narrow rings at the edges whereas boards with even ring widths throughout would be better.

So, comparing the qualities of 12 inch q.g. trees produced by the two thinning regimes we may expect the following differences. The slower grown trees will be taller (because they are older) and will have shorter crowns. If the more heavily thinned trees have been pruned, the bottom one or two logs will have a higher proportion of clear timber, but will have somewhat broader annual rings. The price per hoppus foot may slightly favour the more lightly thinned trees, but the difference in price is likely to be small.

Conclusions

I am sometimes asked why we at Dartington have not made a real working plan. We have a Plan of Operations, but this is little more than a prescription for five or ten years. What we mean by a working plan is a picture of the kind of normal forest we are aiming at when we have something approaching a complete series of age gradations.

The reason why we cannot yet make a working plan is that we do not know what kind of trees we are trying to grow. When the country is producing large quantities of conifers we shall need a new type of mill which is designed for handling them in bulk; and the type of mill will depend on size of tree we decide to grow. It should be possible to work out a size which, when costs of growing and costs of saw-milling have been combined, will produce sawn timber at a price which will compare most favourably with the price of similar imported sawn timber. Next, the cost of growing trees of a given quarter girth will depend on the annual ring widths we are prepared to accept.

So, before we can make working plans we need a considerable volume of research on three matters: first, on the cost of growing trees of various sizes in various ways; second, on the cost of sawing trees of various sizes; and third, on the quality of the sawn timber and the proportion of waste which results from various treatments. Such research has already been undertaken in South Africa where their general forest policy is more advanced than ours. In Britain, where all the important decisions lie ahead of us, the need for such research is urgent.

In the meantime we all have to thin our woods and we should try to do it in such a way as to produce trees of a kind that is wanted as cheaply as possible. I am convinced that most of the thinning grades recommended by the Forestry Commission are too light, especially in their later stages, but it will take some time to work out fresh ones. The grade we have calculated for Norway spruce, qu. cl. II, maybe expressed numerically in the manner shewn in Table 2, in which the Forestry Commission figures are included for

TABLE 2. *Norway spruce qu. cl. II. Number of trees per acre after thinning*

Age	years	20	30	40	50	60
Top height	feet	32½	46½	59	70	79½
No. of trees F.C. Yield Table		1,200	730	470	325	246
No. of trees calculated Yield Table		690	426	264	163	100

comparison. The same numbers of trees *at the same heights* might be applied to other quality classes of Norway spruce, but they would not give the same ring widths. To achieve this it would be necessary to have more trees, for any given top height, in a higher quality class, and fewer trees in a lower quality class.

Alternative thinning grades for other trees can be worked out and some have already been worked out,[3] but this takes time and we may hope that State resources will become available for the furthering of what I regard as our most promising branch of forest research.

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