THINNING RESEARCH IN FORESTRY [1])

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Some years ago the Institute of Forestry of the Agricultural University at Wageningen, Holland, started a research into the influence of thinning on the productivity of even-aged forest plantations.

Thinning has generally the aim to benefit the development of the selected remaining trees of a stand. This measure can influence the productivity of the stand in different ways:

a an increase of the volume production is possible in consequence of a more optimal spacing;

b an increase of the value production is possible by the concentration of the increment on fewer selected stems, causing larger stem diameters with a higher unit value;

c finally a further improvement of the profit of the production is possible by reduction of the capital investment.

The aim of this research is to establish experimentally the influence of different thinning degrees on these three points.

For the investigation sample plots of about 40 × 40 meters are laid out in regular even-aged unthinned young stands, mutually separated by an isolation strip of 20 meters. Every sample plot is subdivided into 16 squares of 10 × 10 meters. In each of these squares the highest tree is measured. The average of these heights gives the top height of the sample plot. With the aid of the standard deviation of the top height the comparableness of the sample plots of a thinning series can be judged.

In order to be able to undertake such an investigation the application of an objective standard for the thinning gradation is necessary. This is the more urgent as the thinning must be repeated periodically during several years in the same degree and probably by different persons. The usual thinning gradation after three classes (dominants, co-dominants etc.) is less suitable to our investigation, because this gradation is not sharp enough as to exclude subjective influences. Therefore we have applied for our thinning gradation the spacing percentages (S %) of HART which value indicates the mutual distance of the trees as a percentage of their height. Expressed in a formula: $d = S \cdot \frac{H}{100}$. On the assumption of a regular triangular spacing the number of the remaining trees per hectare can be calculated with the formula: $N_{ha} = \frac{10.000}{\frac{1}{2} d^2 \sqrt{3}}$. In this way the number of the remaining trees of a chosen thinning degree can be calculated quite objectively. Only the selection of the remaining trees is still subjective. Experience showed, however, that when the number of the remaining trees is fixed, their choice offers little difference of opinion. A further advantage of this method is that with every periodical thinning the original degree can be accurately restored.

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For the height of the stand the top height (= the average height of the 100 highest trees per ha) is chosen instead of the average height, because the top measure is more independent of the thinning degree of the stand and, moreover, it can be determined before undertaking the thinning.

We fitted the scale of the thinning gradations for our investigation as close as possible to the usual forestry practice. In the forestry of the Netherlands a very conservative thinning degree is general. For the Douglas fir this thinning degree corresponds to a spacing percentage of about 16. Therefore we kept this spacing percentage for a weak thinning (A) and added more progressive thinning degrees with intervals of 3 percent, viz for a moderate thinning (B) S = 19%, for a heavy thinning (C) S = 22% and for a very heavy thinning (D) S = 25%.

After such a thinning the thinning degree of a stand will fall by the height growth of the trees. In general, a repetition of the thinning to restore the original thinning degree will be desirable as soon as the thinning degree has dropped about 3 percent.

A difficulty of this thinning design is the very sudden reduction of the number of stems in the heavily thinned sample plots at the beginning of the experiment by which a certain shock reaction will be inevitable. Fortunately many tree species, especially the Douglas fir, bear this shock reaction rather well in youth.

We shall now consider the first results of such a thinning series laid out in a 17 years' old Douglas fir plantation in 1949 in which the thinning was repeated in 1951. This thinning series embraces only three sample plots, thinned resp. on S = 16, 19 and 22%. It is a pity that the stand was not large enough to include also a very heavily thinned sample plot. The measuring data of the 3 sample plots are tabulated in appendix I.

a The influence of the thinning degree on volume production

The volume of a stand can be calculated by the product of basal area, height and form factor. The volume increment is the effect of the changes in these volume factors. The change in form will be very small in a short period and we neglected this in our investigation by using the same volume table for all sample plots.

Of the two other volume factors the basal area is the most important one and the one most accurately assessed by callipering all the trees. The basal area of the 3 sample plots after the first thinning differs considerably, being 21.3, 19.4 and 15.5 m^2/ha resp. Nevertheless, the basal area increment for all 3 sample is nearly the same, viz 3.2, 3.1 and 3.1 m^2 p. ha resp. There was no indication as to any shock reaction in the plot that underwent the heaviest thinning. The increment of the removed trees has been taken over immediately and completely by the remaining trees. Perhaps this remarkable result is due to the fact that often the roots of Douglas fir trees are grown together.

The height growth in the 3 sample plots, however, is different. The increment of the top height was 0.87, 1.16 and 1.45 meters resp. showing a gradual increase of the height growth in the heavily thinned plots. The development of the average height – determined after diameter-height curves – is less regular 0.9, 0.5 and 1.3 meters resp. The sample plot S 19 falls out of line. Altogether we may still conclude that the height increment is better in the most heavily thinned plot. The widely held opinion that a dense spacing will stimulate the height growth seems to be incorrect.

The resulting effect of both volume factors is a volume increment of 11.5, 10.9 and 12.5 m^3/ha/year resp. i.e. a ratio of 100, 95 and 109. Neglecting the irregularity of S 19 an increase of the volume production by heavier thinning of young Douglas fir plantations is possible till 9 %. It is a pity that this Douglas fir plantation was not large enough to add a thinning degree $S = 25\%$ to define the optimal spacing more clearly.

b the influence of the thinning degree on the gross value production

The fact that the basal area increment in all 3 sample plots is equal, will give a larger increment of the average diameter in the more heavily thinned plots 0.6, 0.8 and 0.9 cm resp.

For the calculation of the value production the stands of the sample plots are split up in diameter classes of 1–5, 6–10, 11–15 and 16–20 cm. The stumpage value of these diameter classes is estimated according to the present price level which amounts to fl 30, 35, 40 and 45 per m^3 resp. The calculation of the stock value of the sample plots is carried out in appendix II, thereby taking into account a yield loss of 10 %.

The value increment of the stock in the 3 sample plots during these 2 years amounts to fl 846, 860 and 988 per ha resp. To these figures should be added the rent at a rate of 4 % of the first thinning yields ad fl 11, 50 and 78 resp. The total gross value production is consequently fl 857, 910 and 1066 resp., that is a ratio of 100 : 106 : 124. These figures illustrate the combined effect of the better volume and quality production by heavier thinning degrees. A comparison with the figures for the effect of the volume production only (sub *a*) shows that the influence on the quality production is more pronounced. For the most heavily thinned plot it amounts to : 124 – 109 = 15 %.

c the influence of the thinning degree on the profit of the production

This last point must be considered as the crucial matter. For a judgment of the economy of production besides the profits (= gross value increment), the production costs must be taken in account also. By heavy thinning the cost value of the stock is considerably reduced and this will raise the profit of the production.

The cost value of the stock can be calculated from the formula:
$V_{ct} = (G + B)\ 1.\ op^t + c\ 1.\ op^t - T_a\ 1.\ op^{t-a}$, in which V_{ct} = cost value at the age of t years p. ha, (G) = soil value p. ha, B = maintenance costs capital p. ha, c = cultivation costs per ha, T_a = thinning yield at the age of a years and p = rate of interest. In this experiment G = fl 500 per ha, B = fl 400 per ha, c = fl 1750 per ha and $p = 4\%$. For the unthinned 17 years' old stand the cost value amounts to: V_{c17} = fl 4332. After the first thinning the cost values of the remaining stands of the 3 sample plots are fl 4167, 3576 and 3166 per ha resp. The production costs during the two following years can be calculated through multiplication of these values by $(1.04^2–1)$ which results in fl 340, 292 and 258 per ha resp. The net value production is value increment minus the production costs amounting to fl 506, 568, and 730 per ha resp. i.e. a ratio of 100, 112 and 144. These figures illustrate the combined effect of the better

volume and quality production and the reduction of the capital investment. By comparison with the figures (sub *b*) the influence of the reduction of the capital investment can be deduced. For the most heavily thinned plot it amounts to 144 – 124 = 20 %.

This investigation shows clearly the economical superiority of the thinning degree $S = 22\%$ for young Douglas fir plantations.

In order to get a general survey of the subject the results are summarized in table 1.

Table 1. Influence of the thinning degree on the productivity of a 17 years' old Douglas fir plantation.

Description of the data	Thinning degree		
	16	19	22
Volume production			
Basal area increment m^2/ha	3.2	3.1	3.1
Top height increment in m	0.87	1.16	1.45
Average height increment in m	0.9	0.5	1.3
Volume increment in m^3/ha pro year	11.5	10.9	12.5
Figures indicating the ratio	100	95	109
Gross value production (Volume + quality production)			
Average diameter increment in cm	0.6	0.8	0.9
Value increment of the stock in glds/ha	846	860	988
Rent of the first thinning yield	11	50	78
Gross value production	857	910	1066
Figures indicating the ratio	100	106	124
Net value increment (Volume + quality production + lowering investment capital)			
Cost value of the stock before thinning glds/ha	4332	4332	4332
Thinning yield glds/ha	165	756	1166
Cost value of the remaining stock glds/ha	4167	3576	3166
Production costs during 17–19 years	340	292	258
Value increment of the stock in glds/ha	846	860	988
Net value increment in glds/ha	506	568	730
Figures indicating the ratio	100	112	144

These figures lead to the supposition that the weakly thinned plot is overstocked. An analysis of the diameter growth in the various diameter classes in this sample plot justifies such a supposition. This analysis has been carried out by comparing the diameter distribution at the beginning of the period to that at the end. Starting with the largest diameter classes the number of stems is calculated with a diameter increment of 0, 1 or 2 cm. The results are listed in table 2.

Table 2. Analysis of the diameter growth in the sample plot S = 16 from 1949 till 1951.

Diameter classes cm	Distribution of the diameter classes		Diameter growth classes in cm			Average diameter growth in mm
	1949	1951	0	1	2	
4	2	2	2	—	—	0.—
5	39	32	32	—	—	0.—
6	73	61	54	7	—	1.—
7	95	76	57	19	—	2.5
8	113	102	64	38	—	3.7
9	101	95	46	49	—	5.2
10	70	80	25	55	—	6.9
11	50	51	6	45	—	8.8
12	34	45	1	44	—	9.8
13	13	28	—	28	—	10.0
14	12	16	—	11	5	13.1
15	3	9	—	7	2	12.2
16	—	6	—	1	5	18.3
17	—	2	—	—	2	20.0
Total	605	605	287	304	14	5.5

Table 2 shows that the diameter increment of the small diameter classes is very poor and that these diameter classes must be considered as unproductive capital.

Summarizing we may conclude that a heavy thinning S = 22 % will raise the productivity of young Douglas fir plantations to a high degree. The thinning should be repeated as soon as the thinning degree has fallen to 19 %.

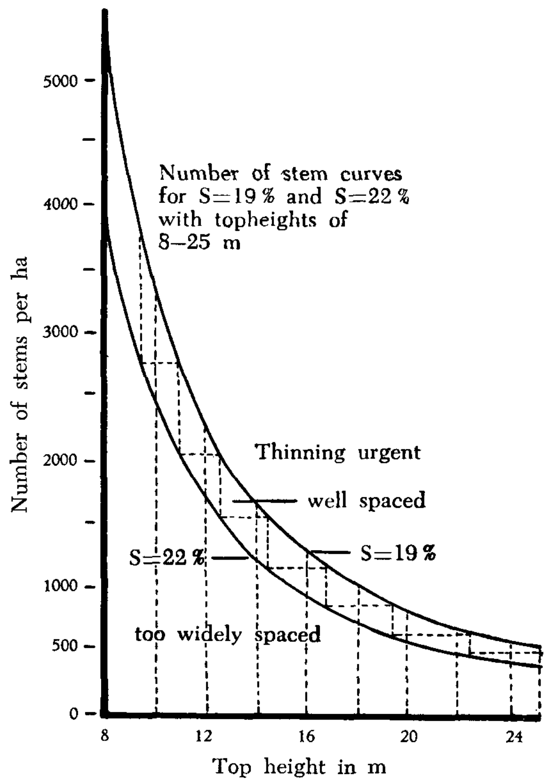
In order to facilitate the application of this heavy thinning in practice the number of stems per ha are given for S = 19 % and S = 22 % with different topheights in table 3.

Table 3. Number of stems per ha for S = 19 % and S = 22 % with different topheights.

Topheight in m	Number of stems per ha	
	S = 19 %	S = 22 %
8	5000	3730
9	3950	2950
10	3200	2390
11	2640	1970
12	2220	1660
13	1890	1410
14	1630	1220
15	1420	1060
16	1250	930
17	1110	830
18	990	740
19	890	660
20	800	600
21	730	540
22	660	490
23	610	450
24	560	410
25	510	380

From these figures the thinning graph is designed. The strip between the two curves indicates the allowed variation in the number of stems when care is taken of a good thinning with different top heights. A plantation of 5000 stems per ha must be thinned as soon as the topheight reaches 8 m. At this moment the number of stems should be reduced to 3730 per ha. A second thinning will be necessary when the top height reaches 9.30 m and accordingly the number of stems should be reduced to 2790 and so on. The course of the number of stems of this plantation is indicated in the graph by a broken line. The interval between the thinnings will be in the beginning 2 years, later gradually 3, 4 or 5 years.

In contrast to oak and Japanese larch the Douglas fir needs no rise of the optimal spacing percentage until they have reached an age of about 50 years.



Appendix I. Measuring data of the 3 Douglas fir sample plots.

Description of the measuring data	$S = 16\%$		$S = 19\%$		$S = 22\%$	
Year of measuring	1949	1951	1949	1951	1949	1951
Size sample plot in ha	0.1710	0.1710	0.1704	0.1704	0.1704	0.1704
Age in years	17	19	17	19	17	19
Top height in m	11.19	12.06	11.48	12.64	11.33	12.78
Remaining stand						
Number of stems per ha	3538	3105	2418	2019	1837	1461
Basal area m^2/ha	21.3	23.1	19.4	20.5	15.5	16.3
Average diameter cm	8.8	9.7	10.1	11.4	10.4	11.9
Average height m	8.5	9.6	9.6	10.4	9.4	11.1
Stem volume m^3/ha	101.9	119.1	100.0	112.4	78.3	92.0
Thinning degree	16.2	16.0	19.1	18.9	22.2	22.0
Thinning						
Number of stems per ha	795	433	1502	399	2242	376
Basal area m^2/ha	1.4	1.3	5.2	2.0	8.5	2.3
Average diameter cm	4.7	6.3	6.7	8.0	7.0	8.8
Average height m	5.5	7.4	7.2	8.3	7.2	8.9
Stem volume m^3/ha	5.5	5.8	23.4	9.4	36.8	11.3
Total stand						
Number of stems per ha	4333	3538	3920	2418	4079	1837
Basal area m^2/ha	22.7	24.5	24.7	22.5	24.1	18.6
Average diameter cm	8.2	9.4	9.0	10.9	8.7	11.3
Average height m	8.1	9.4	8.9	10.1	8.4	10.7
Stem volume m^3/ha	107.4	125.0	123.3	121.8	115.0	103.3
Thinning degree	14.6	15.0	15.0	17.3	14.8	19.6
Current annual stem volume increment m^3/ha	—	11.5	—	10.9	—	12.5
Current stem volume increment percent	—	10.2	—	9.8	—	13.8

Appendix II. Calculation of the stock value of the Douglas fir sample plots.

Description of the data	17 years old			19 years old			Stumpage value per m^3 in glds
	Total stand	Thinning stand	Remaining stand	Total stand	Thinning stand	Remaining stand	
S 16 Volume diameterclasses 1– 5 cm	4.42	2.77	1.65	1.36	0.87	0.49	30
m^3/ha „ 6–10 cm	62.49	1.98	60.81	60.12	4.90	55.21	35
„ 11–15 cm	40.23	0.78	39.45	57.10	–	57.10	40
„ 16–20 cm	–	–	–	5.92	–	5.92	45
Total volume	107.44	5.53	101.91	124.50	5.77	118.73	
Stock value – 10 % yield loss	3545	165	3380	4226	178	4048	
S 19 Volume diameterclasses 1– 5 cm	3.38	3.11	0.27	0.18	0.18	–	30
m^3/ha „ 6–10 cm	51.29	13.50	37.79	33.76	7.96	25.80	35
„ 11–15 cm	60.33	5.94	54.39	69.79	1.36	68.43	40
„ 16–20 cm	8.32	0.81	7.51	18.25	–	18.25	45
Total volume	123.32	23.36	99.96	121.98	9.50	112.48	
Stock value – 10 % yield loss	4216	756	3460	4320	305	4015	
S 22 Volume diameterclasses 1– 5 cm	3.64	3.58	0.06	0.04	0.04	–	30
m^3/ha „ 6–10 cm	58.76	27.87	30.89	25.42	8.04	17.38	35
„ 11–15 cm	48.45	5.33	43.12	61.39	3.23	58.16	40
„ 16–20 cm	4.17	–	4.17	16.60	–	16.60	45
Total volume	115.02	36.78	78.24	103.45	11.31	92.14	
Stock value – 10 % yield loss	3862	1166	2696	3684	371	3313	