STAND DEVELOPMENT AND STEM FORM OF THE DOUGLAS FIR (*PSEUDOTSUGA TAXIFOLIA BRITT.*) IN THE NETHERLANDS [1)]

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SUMMARY

1 On the basis of increment data from 65 trial plantations, a summary is given of the development of strongly thinned Douglas stands up to the age of thirty years.
2 The yield from these stands corresponds satisfactorily with that shown in KANZOW's yield tables, but lies considerably below the figures given in the tables of GRANDJEAN–VAN SOEST.
3 A taper table has been compiled from data supplied by 801 trunks, measured after felling.
4 At heights lower than 20 metres, the stem forms of the Douglas fir and the Japanese larch correspond closely. Above this height the Douglas tapers more pronouncedly owing to the difference in the average H/D quotient and the greater influence of root swelling.

INTRODUCTION

In 1923 the former State Forestry Research Station began to import from North America Douglas fir seed of varying provenance, with the object of ascertaining the most desirable source area for seed to be sown in the Netherlands. Investigation of the youthful development of the stands grown from this seed was provisionally completed in 1951 (B. VEEN), while yield research is now being continued by the Forest Mensuration Department of the Institute of Forest Research of the Agricultural University, Wageningen. The object of this yield research is to determine the wood production of Douglas fir stands of varying provenance, laid down in different ways, on sites of differing degrees of fertility. Since 1947 the trial plantations have been measured every two or three years, so that we now have at our disposal increment data from 50 stands, each of which has been measured several times. Besides carrying out yield research the Institute is also occupied in investigating the question of thinning as regards the Douglas fir, to which end thinning series have been planted out for purposes of comparison, in various stands of differing site class and age, and are measured from time to time.

By combining these data we have now obtained an adequate idea of the development of 65 stands in all, up to the age of 30 years. Since Douglas fir stands more than 30 years old are still comparatively rare in the Netherlands, it is considered desirable, even at this early stage of investigations, to compile the results obtained in concise form. The material for our stem form investigations consists of 801 trunks, a considerable number of which were kindly made available to us by the Forestry Research Station of the T.N.O. (Council for Applied Scientific Research).

THE STAND DEVELOPMENT OF THE DOUGLAS FIR — METHOD OF INVESTIGATION

In compiling yield tables, site classes are formed, representing the growth process on soils of varying fertility. Since thinnings are regularly carried out in a stand, neither the content, nor the average diameter of the remaining stand is a suitable basis for forming site classes, as both these factors depend on the degree and nature of the thinnings. Accordingly, the basis generally

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chosen is the average height of the stand, i.e., the regression height of the stem of the mean basal area. The dependence of the degree of thinning on the average height is implicit in the definition thus chosen. Accordingly, in order to eliminate this drawback, we have chosen as point of departure the dominant height, i.e., the arithmetical mean of the highest trees in each are in a stand. For each trial plantation the dominant height has been plotted graphically against the age at the time of observation, after which the corresponding points have been connected by development lines in the case of each plantation. In this way a group of development lines are obtained which are narrow to begin with, but become steadily broader as the trees grow older. When forming site classes a number of curves are constructed in this line series, corresponding to the number of site classes required. In doing so, one is comparatively independent as regards choice of the level of the curves, but their direction must be in conformity with the direction of the development lines of the material under observation. In compiling an increment summary for the Douglas fir, we have grouped our material in four site classes – on the basis of the average – in which connection, however, it must be noted that stands belonging to the first and fourth site classes occur only rarely.

For further treatment of the material, various methods may be applied. It is possible to plot wood production from remaining stand and thinnings, separately from each other, against age, and fit the curve, whereby the total wood production is found indirectly, viz., by summating remaining stand and thinnings. This method has been applied by KANZOW, inter alia, in compiling a yield table for the Douglas fir (KANZOW, 1937). We have elected to base our calculations on the total wood production, as this has the advantage of being less dependent on the degree of thinning. This is probably owing to the fact that the assimilating crown canopy area is of approximately equal size in both slightly and strongly thinned stands. In the case of trial plantations which, according to the dominant height graph, belong to the second and third site classes, the total stem production has been plotted graphically against age for each separate site class, after which the mean development lines have been found by fitting.

Another point is the distribution of this total wood production over remaining stand and thinnings. In thinning research in the Netherlands, the basis of investigations is the height number of trees per hectare density index of Hart, which expresses the degree of thinning of the stand as the quotient of $\frac{\text{distance between the trees}}{\text{dominant height}}$. This distance between each tree and the next is calculated – on the assumption of regular triangular planting – from the formula $N = \frac{10\,000}{\frac{1}{2}a^2\sqrt{3}}$, while the dominant height is equal by definition to the average height of the highest trees in each are of the stand. Thinning research has proved that, under Netherlands conditions, it is economically justifiable to apply drastic thinning, fluctuating round about 22%, in stands of Douglas fir. Since it may be assumed that no substantial changes will take place in this optimum thinning figure at greater age, we have based our calculations, in compiling the increment summary, on a constant degree of thinning of 22% for the remaining stand. Since it is desirable to avoid sudden alterations in the density of the stand, it will be necessary to make an early start with the first thinning, i.e., at an age when the thinning degree of the stand has fallen to 19%. This age is therefore dependent on the site class and the mode of planting (triangular, square, etc.); with an initial number of trees of 4.000 per hectare the age will be 15 years for the second site class, and 19 years for the third. By this first thinning the thinning degree of the remaining stand becomes 22%. The second thinning is carried out as soon as height increment has caused the degree of thinning to decrease to 19%, after which the stand is again thinned to 22%. Since the dominant height increment declines as the trees grow older, the interval between two succussive thinnings becomes steadily greater. The result of arranging the successive thinnings in this way is that the crown is gradually liberated, whereby the process of assimilation takes its course more uniformly. Moreover, this lessons the risk of damage by storms, as the root system gradually adapts itself to the freer position.

In the case of those trial plantations which have been treated according to the method described here, the total stem content of the remaining stand has been plotted graphically against age, and the curve fitted, for each of the two site classes separately. The wood volume of the successive thinnings can be deduced from the difference in relation to the development of the total production. The average height of all stands has then been graphically plotted against the dominant height, so that the average height can be deduced from the dominant height. The development of the stem form factor has been determined separately for each of the two site classes, by fitting according to age. The basal area of the remaining stand has finally been found as the quotient of $\frac{V}{F \times H}$, and the average diameter from the quotient of $\frac{G}{N}$.

Results

The basis taken for the site classification is the development of the dominant height of the trial plantations with age. Since, however, it is customary to take the average height of the stand as the standard in site classification, we have converted the dominant height into terms of average height, after treatment of the statistical material.

In compiling the increment summary, it was found that only two trial plantations (on old agricultural land) fell in the first site class, and only a few trial plantations, containing trees of inferior origin, fell in the fourth

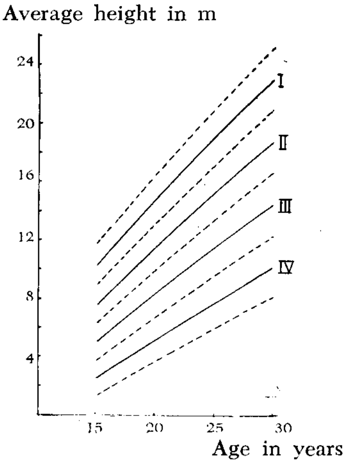

FIG. 1. SITE CLASSIFICATION GRAPH FOR THE DOUGLAS FIR. AVERAGE HEIGHT OF REMAINING STAND-AGE.

Table 1. Summary of the increment of strongly thinned Douglas fir stands up to the age of 30 years.

Age in years	Remaining stand							Thinning stand					Total volume production in m^3	Current increment in m^3 per year	Average increment in m^3 per year
	Number of trees per ha	Basal area in m^2/ha	Average diameter in cm	Average height in m	Stem volume form factor	Total stem volume in m^3	Dominant height in m	Number of trees per ha	Average diameter in cm	Average height in m	Total stem volume in m^3	Total thinnings			
							Second site class								
15	2946	15.8	8.3	7.5	0.591	70	9.0	1054	6	7	17	17	87	15.0	5.8
17	2145	17.2	10.1	9.0	0.549	85	10.6	801	8	8	15	32	117	16.0	6.9
19	1632	18.6	12.0	10.6	0.517	102	12.1	513	9	9	15	47	149	19.0	7.8
22	1156	20.6	15.0	13.0	0.489	131	14.4	476	11	10	28	75	206	20.0	9.4
25	876	22.5	18.1	15.3	0.471	162	16.5	280	14	12	29	104	266	20.2	10.6
30	591	25.6	23.5	18.8	0.457	220	20.1	285	17	15	43	147	367	—	12.2
							Third site class								
15	4000	16.6	7.3	5.0	0.680	56	6.5	—	—	—	—	—	62	5.8	4.1
19	2916	17.0	8.6	7.5	0.604	77	9.0	1084	5	6	8	8	85	8.5	4.5
21	2241	17.3	9.9	8.8	0.571	87	10.3	675	6	7	9	17	104	11.7	5.0
24	1608	18.0	11.9	10.7	0.530	102	12.2	633	9	8	20	37	139	15.0	5.8
27	1209	18.9	14.1	12.5	0.504	119	14.0	399	11	10	28	65	184	15.7	6.8
30	948	19.7	16.3	14.4	0.494	140	15.9	261	12	12	26	91	231	—	7.7

class. Since it is impossible to obtain reliable results by treatment of such a small number of data, we have confined our attention, in compiling the summary, to the second and third site classes.

COMPARISON WITH OTHER YIELD TABLES

Comparison with increment data published previously in the Netherlands and Germany shows that the tables of GEHRHARDT (1930) and ZIMMERLE (1952) give results for the Netherlands which are far too high. The tables of GRANDJEAN-VAN SOEST (1953) and KANZOW (1937), however, provide more suitable material for comparison. As regards height development, our second site class corresponds satisfactorily with GRANDJEAN-VAN SOEST's site class I and KANZOW's site class I. Since KANZOW's table presupposes slightly thinned stands, it is necessary to apply a small correction to the average height, owing to the arithmetical shift of the average diameter.

After this correction has been applied, the average height for the thinning degree of 22% in the table for KANZOW I, when the trees are thirty years old, is 18.2 m; in the table for GRANDJEAN-VAN SOEST I it is 18.5 m; and in our table, 18.8 m. In this connection, the difference in average height of the trees at the age of thirty years must be taken into account when making a comparison of the total wood production. Furthermore, in KANZOW's table the thick wood volume must be converted into terms of the total stem volume. Whereas our table for the situation when the trees are thirty years old gives a total production of 367 cubic metres, total production, after the necessary corrections, according to GRANDJEAN-VAN SOEST's table I is 462 cubic metres, and according to KANZOW, 382 cubic metres. As regards the third site class, total production at the age of thirty years is 231 cubic metres according to our table, and, after the same corrections, 292 cubic metres according to GRANDJEAN-VAN SOEST, and 251 cubic metres according to KANZOW.

From these figures it will be seen that the development of the stands, which formed the basis for our table, corresponds satisfactorily with the picture given by KANZOW's tables; total production is 4% higher in KANZOW I and 9% higher in KANZOW II. GRANDJEAN-VAN SOEST's tables, however, give a total wood production at 30 years of age which is 26% higher for both site classes.

THE STEM FORM OF THE DOUGLAS FIR

A characteristic which is taken into account in judging the stem form is "tapering", by which is understood the decrease in diameter with increasing distance from the bottom of the trunk to the top of the tree. In this connection, the diameter at various heights can be expressed as a percentage of the diameter at a height of 1.30 m (breast height), when one speaks of "normal diameter-quotient series". If the basic diameter chosen is the diameter at a certain specified percentage of the height of the tree, one speaks of "true diameter-quotient series". In the present case we have compiled a table for normal diameter-quotient series, on the basis of 801 trunks measured after felling.

To do this, the following procedure was applied. The trees were divided into height classes, each differing from the next by one metre, and ranging from 7 to 30 metres, inclusive. The diameter of each tree at 1, 3, 5, etc., metres was expressed as a percentage of the diameter at a height of 1.30 metres, after which the arithmetical mean of this diameter ratio was determined for

Table 2. Taper table for Douglas fir.

Height class	Diameter at a height of ...... metres as a percentage of diameter at breast height														
	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29
7	104.8	76.5	46.0												
8	104.5	80.7	55.3	19.7											
9	104.2	83.7	61.4	35.0											
10	104.0	85.5	66.4	44.0	13.0										
11	103.7	86.8	70.9	50.8	28.2										
12	103.5	88.0	74.7	57.5	37.9	12.0									
13	103.3	88.9	77.6	63.4	46.5	26.2									
14	103.2	89.7	80.0	68.4	54.2	38.7	13.8								
15	103.0	90.4	81.9	72.1	61.5	48.1	28.0								
16	103.0	90.9	83.2	74.7	66.5	54.7	39.0	16.8							
17	103.0	91.2	83.9	76.4	69.1	59.4	46.0	27.0							
18	103.0	91.2	84.3	78.0	71.2	62.6	50.6	34.7	13.0						
19	103.1	91.1	84.6	78.9	72.5	64.7	54.2	40.2	21.8						
20	103.1	91.0	84.7	79.4	73.2	65.9	56.9	44.7	29.2	9.8					
21	103.2	90.9	84.8	79.4	73.6	66.9	58.9	48.1	35.4	18.0					
22	103.3	90.8	84.8	79.4	73.8	67.6	60.4	50.8	40.1	25.8	8.8				
23	103.4	90.7	84.6	79.3	74.0	68.1	61.4	53.0	43.9	31.8	16.5				
24	103.6	90.6	84.5	79.2	74.0	68.4	62.1	54.6	46.4	33.6	22.5	8.0			
25	103.9	90.5	84.4	79.0	74.1	68.7	62.7	55.8	48.1	38.7	27.4	13.7			
26	104.2	90.4	84.2	78.8	74.1	68.9	63.3	56.8	49.7	41.4	31.2	18.9	6.6		
27	104.6	90.3	84.0	78.6	74.1	69.1	63.8	57.8	51.1	43.5	34.5	23.1	11.2		
28	105.0	90.2	83.8	78.5	74.1	69.3	64.2	58.7	52.4	45.5	37.4	27.1	16.4	7.1	
29	105.6	90.0	83.6	78.3	74.2	69.4	64.5	59.5	53.6	47.3	40.0	30.7	20.8	10.9	
30	106.2	89.9	83.4	78.1	74.2	69.5	64.8	60.2	54.7	48.8	42.4	33.6	24.4	14.2	6.0

each height class per measuring point (i.e. 1, 3, 5 metres, etc.). This diameter ratio was then plotted graphically against the height class in the case of every measuring point, and fitted by a smooth curve. In this way, we arrived at a taper table, in which the diameter of the tree at various points on its stem is expressed as a percentage of the diameter of the tree at breast height, for height classes differing from each other by one metre.

In Germany, SCHOBER compiled such a taper table for the Japanese larch (1953). A comparison of the two tables shows that the stem form of Douglas fir and Japanese larch corresponds well up to tree heights of 20 metres. Thus, we find the following comparative figures for the 19 metres height class:

Table 3. Comparison of the diameter-quotient series of Douglas fir and Japanese larch in the 19 metres height class.

Height	Species	Average diameter in cm	1	3	5	7	9	11	13	15	17
19	Douglas fir	18.7	103.1	91.1	84.6	78.9	72.5	64.7	54.2	40.2	21.8
	Japanese larch	19.1	102.5	93.5	85.5	79.5	72.5	63.5	53.5	39.0	–

Comparison of the diameter-quotient series in lower height classes does not clearly confirm the indication given by this table – i.e., that, up to halfway up the height of the tree the Douglas fir tapers more emphatically than the Japanese larch, and less emphatically above the halfway mark. In height classes above a height of 20 metres considerable differences in stem form occur between the two species. Thus, for the 28 metres height class, we find the following comparative diameter-quotient series.

Table 4. Comparison of the diameter-quotient series of Douglas fir and Japanese larch in the 28 metres height class.

Height	Species	Average diameter in cm	1	3	5	7	9	11	13	15	17	19	21	23
28	Douglas fir	37.5	104.8	90.1	83.8	78.9	74.5	69.8	65.4	59.9	53.8	46.9	38.4	28.7
	Japanese larch	28.9	103.5	94.0	88.5	85.0	80.5	76.0	71.0	65.5	59.0	51.5	42.5	32.0

In the case of this height class we have represented the difference in stem form by converting the diameter percentage ratio into terms of the actual measurements.

It will therefore be seen that the Douglas fir tapers a great deal more abruptly than the Japanese larch in the higher height classes – a tapering which is very largely caused by the difference in H/D quotient. In order to get an idea of whether the trend of the stem form of the Douglas fir is different from that of the larch, when the diameter at breast height and the height of the tree are the same in both cases, we selected 18 trees in the

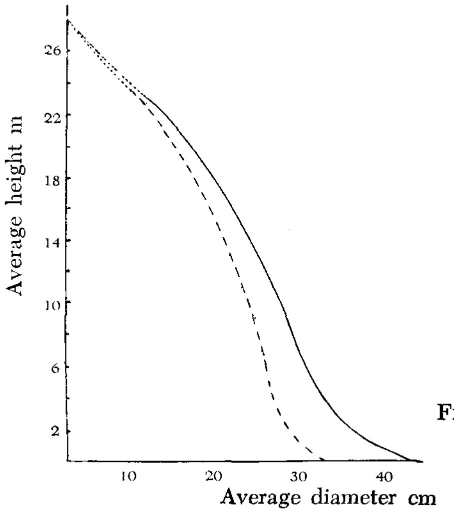

FIG. 2. COMPARISON OF THE STEM FORM OF THE DOUGLAS FIR (———) AND JAPANESE LARCH (- - - - -) FOR THE 28 METRES HEIGHT CLASS.

28 metres height class, with an average diameter at breast height equal to the average diameter of SCHOBER's initial material. From these the following table was compiled.

Table 5. Diameter in cm at a height of .... m, with an average diameter of 29 cm and a height of 28 m.

Species	1	3	5	7	9	11	13	15	17	19	21	23
Douglas fir	30.5	26.2	24.4	23.0	21.6	20.3	18.9	17.4	15.7	13.8	11.4	9.0
Japanese larch	30.0	27.3	25.7	24.7	23.3	22.0	20.6	19.0	17.1	14.9	12.3	9.3

This table shows that the more pronounced tapering of the Douglas fir is caused by the greater influence of the root swelling. Calculating from a height of 1 metre, the diameter of the Douglas fir declined by 0.98 cm/m, up to a height of 23 m, and the larch by 0.94 cm/m. If, however, the point of departure chosen is a height of 4 m, the Douglas fir shows a decline in stem diameter, up to 23 metres, of 0.86 cm/m, the larch of 0.90 cm/m.

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