Forestry Commission Booklet No. 32 H M S O: 14s 0d [70p] net

THINNING CONTROL IN BRITISH WOODLANDS (Metric)

By R. T. Bradley, M.A.*
Forestry Commission

Table of normal thinning yields

(Applicable to fully stocked crops of all species for the duration of their normal thinning life—see paras. 30-44 pp. 25-26)

Yield Class	VOLUME PER NET HECTARE (cubic metres over bark to 7 cm top diameter or 7 cm dbh)							Yield Class
	THINNING CYCLES (Number of years before the *next* thinning, *not* since the last)							
	3	**4**	**5**	**6**	**8**	**9**	**10**	
2	4·2	5·6	7·0	8·4	11·2	12·6	**14**	2
4	8·4	11·2	14·0	16·8	**22·4**	**25·2**	**28**	4
6	12·6	16·8	21·0	**25·2**	**33·6**	**37·8**	**42**	6
8	16·8	22·4	**28·0**	**33·6**	**44·8**	**50·4**	56	8
10	21·0	28·0	**35·0**	**42·0**	**56·0**	63·0	70	10
12	25·2	**33·6**	**42·0**	**50·4**	67·2	75·6		12
14	29·4	**39·2**	**49·0**	**58·8**	78·4			14
16	33·6	**44·8**	**56·0**	67·2	89·6			16
18	**37·8**	**50·4**	**63·0**	75·6				18
20	**42·0**	**56·0**	70·0	84·0				20
22	**46·2**	**61·6**	77·0	92·4				22
24	**50·4**	**67·2**	84·0					24
26	**54·6**	72·8	91·0					26
28	**58·8**	78·4						28
30	**63·0**	84·0						30

*Metric revision by G. J. Hamilton and J. M. Christie

Table of rectangular plot sizes
(for use where rows are clearly visible)

Average spacing between rows		3 rows wide		4 rows wide	6 rows wide	9 rows wide
		Distance in metres along the rows for plot sizes				
Feet	Metres	0·005 ha	0·01 ha	0·02 ha	0·05 ha	0·10 ha
4	1·2	13·5	27·5	41	68·5	91
4½	1·4	12	24·5	36·5	61	81
5	1·5	11	22	33	54·5	73
5½	1·7	10	20	30	49·5	66·5
6	1·8	9	18	27·5	45·5	61
6½	2·0	8·5	17	25	42	56
7	2·1	8	15·5	23·5	39	52

NOTE: Doubling the number of rows doubles the plot area, and similarly halving the distance halves the plot area. Other plot areas can be obtained by fractional changes in the plot dimensions.

Table of circular and square plot sizes
(for use where rows are not visible)

Shape of Plot	Length in metres for plot sizes				
	0·005 ha	0·01 ha	0·02 ha	0·05 ha	0·10 ha
Circular: radius	4·0	5·6	8·0	12·6	17·8
Square: sides	7·1	10·0	14·1	22·4	31·6

Conversion table from average spacing to number of trees per hectare

Square spacing in metres	Number of trees per ha.	Square spacing in metres	Number of trees per ha.	Square spacing in metres	Number of trees per ha.
1·0	10000	3·0	1111	5·0	400
1·1	8264	3·1	1041	5·2	370
1·2	6944	3·2	977	5·4	343
1·3	5917	3·3	918	5·5	331
1·4	5102	3·4	865	5·6	319
				5·8	297
1·5	4444	3·5	816	6·0	278
1·6	3906	3·6	772	6·2	260
1·7	3460	3·7	730	6·4	244
1·8	3086	3·8	693	6·5	237
1·9	2770	3·9	657	6·6	230
				6·8	216
2·0	2500	4·0	625	7·0	204
2·1	2268	4·1	595	7·5	178
2·2	2066	4·2	567	8·0	156
2·3	1890	4·3	541	8·5	138
2·4	1736	4·4	517	9·0	123
				9·5	111
2·5	1600	4·5	494	10·0	100
2·6	1479	4·6	473	10·5	91
2·7	1372	4·7	453	11·0	83
2·8	1276	4·8	434	11·5	76
2·9	1189	4·9	416	12·0	69

Annual yields for early thinnings (see para 33)

Volume per hectare (cubic metres over bark to 7 cm top diameter)

NUMBER OF YEARS BEFORE NORMAL TIME OF FIRST THINNING	YIELD CLASS													
	30	28	26	24	22	20	18	16	14	12	10	8	6	4
0	21·0	19·6	18·2	16·8	15·4	14·0	12·6	11·2	9·8	8·4	7·0	5·6	4·2	2·8
1	18·5	17·2	16·0	14·8	13·6	12·3	11·1	9·9	8·6	7·4	6·2	4·9	3·7	2·5
2	15·3	14·3	13·3	12·3	11·2	10·2	9·2	8·2	7·2	6·1	5·1	4·1	3·1	2·0
3	11·1	10·4	9·6	8·9	8·2	7·4	6·7	5·9	5·2	4·5	3·7	3·0	2·2	1·5

NOTE: The figures above are annual yields and must be multiplied by the thinning cycle to give the volume to be removed in a single thinning.

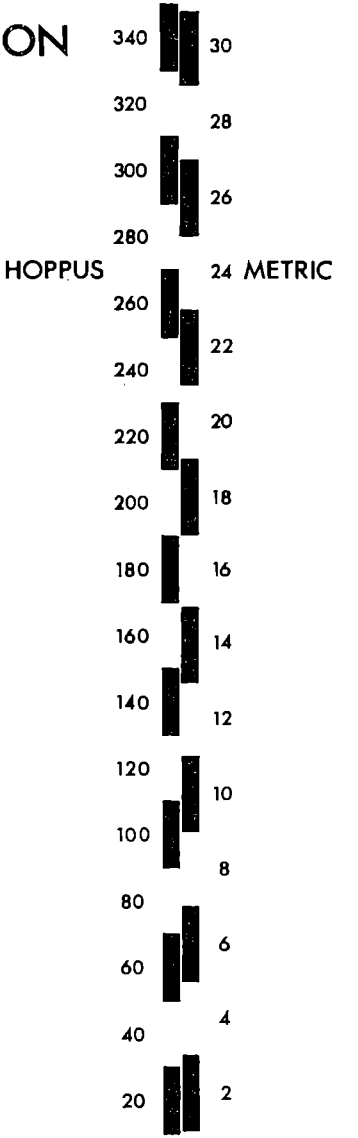
Before-thinning basal areas for fully-stocked stands

Basal areas in square metres per hectare

SPECIES	TOP HEIGHT (METRES)										
	10	12	14	16	18	20	22	24	26	28	30
Scots pine	26	26	27	30	32	35	38	40	43	46	—
Corsican pine	34	34	33	33	33	34	35	36	37	39	—
Lodgepole pine	33	31	31	30	30	31	31	32	33	34	—
Sitka spruce	33	34	34	35	35	36	37	38	39	40	42
Norway spruce	33	33	34	35	36	38	40	42	44	46	49
European larch	23	22	22	22	23	24	25	27	28	30	—
Japanese and Hybrid larch	22	22	23	23	24	24	25	27	28	29	—
Douglas fir	28	28	28	29	30	31	32	34	35	37	40
Western hemlock	32	34	35	36	36	36	37	38	38	39	40
Red cedar	—	49	50	51	53	55	57	60	63	66	70
Grand fir	—	39	39	39	39	39	39	40	41	43	45
Noble fir	—	45	46	46	47	48	49	51	52	54	—
Oak	24	23	23	23	23	24	24	25	26	—	—
Beech	20	20	22	23	25	27	29	31	33	35	37
Sycamore, Ash, Birch	16	15	17	19	22	26	30	34	—	—	—

NOTE: Stands with a yield class which is relatively high for the species, or which are thinned on a long cycle, ought to have basal areas which are up to 10% greater than those quoted in the table.

YIELD CLASS CONVERSION SCALE



QUALITY CLASS TO METRIC G Y C CONVERSION

SPECIES	QUALITY CLASS I	II	III	IV	V
SP	14	10	8	4	
CP	16	14	10	8	
LP	10	8	6		
SS	24	22	18	16	12
NS	18	14	11	8	
EL	12	8	6	4	2
JL / HL	12	10	8	4	
DF	24	20	16	12	10
WH	24	20	16	14	
RC / LC	20	16	12		
GF	28	24	22	18	
NF	20	16	12		
Oak	8	6	4	4	2
Be	8	8	6	4	4
Syc	10	6	4		
Ash	12	10	6	4	

Introduction

Scope

1. This booklet provides a simple guide to the volume to be removed when thinning pure even-aged stands, or with suitable modifications, when thinning woods of mixed species and/or of uneven age. It replaces Booklet 17, giving similar values in Imperial units, which appeared in 1966.
2. The volume prescriptions can be used in conjunction with any type of thinning; the number of trees removed will simply be greater with low thinning and less with the various types of crown thinning, which remove a proportion of the larger trees in the crop.
3. The types of tree removed to make up the specified volume are determined by silvicultural and economic factors in the usual way.[1] The only proviso is that a sufficient number of the dominant trees be retained to maintain the vigour of the stand.

Basis

4. The volume yields specified for various rates of growth and lengths of thinning cycle represent the maximum level of yield which can be sustained without reducing volume increment.
5. This specified thinning intensity will, under most circumstances, be the most profitable intensity in the long term, but type of thinning and length of cycle must be manipulated to achieve maximum profit under different conditions and at different stages in the life of the stand.

Application

6. The specified yields are intended to apply to fully stocked stands during their normal thinning life[2], but they may be removed from understocked or patchily stocked stands provided that a loss of volume increment is acceptable.
7. The thinning yields in this booklet provide no more than a guide. Thinning is only one of many factors involved in woodland management, and efficient thinning practice depends upon intelligent application of the guide under a wide range of conditions.
8. For example, it may pay to thin an understocked stand because of contractual commitments, despite the loss of increment which is likely to result, and despite the fact that recovery of full stocking will be delayed until some later date when thinning can be suspended long enough to effect a recovery.
9. Similarly, the precision of control to be aimed at must inevitably depend upon the skill and resources available, and particularly upon the prevailing conditions. Normally it should be possible to restrict yields to within 15% of the specified figure, but this may become impossibly expensive with mixtures or other less straightforward situations.

[1]See *Forestry Practice*, Forestry Commission Bulletin No. 14. HMSO 5s. 6d.

[2]The start of the normal thinning period is indicated by the black line on the General Yield Class curves on pages 10–24 and the period terminates a few years before the age of maximum mean annual volume increment.

Outline procedure

10. The normal thinning yield is determined as follows:

(1) **Measure the** *top height* **of the stand** (e.g. 16·2 m).

(2) **Use age and top height to determine** *General Yield Class* **from the curves provided** (pages 10–24) *(e.g. Scots pine, age 41, GYC 10).*

(3) **Use the table of thinning yields** (page 1) **to find the** *volume per hectare* **to be removed for this yield class for various thinning cycles** (e.g. 3 years 21 cubic metres, 4 years 28, 5 years 35, etc).

Control (See paras. 52-63 for further details)

11. The next stage is to decide whether the stand is to be thinned or not, by visual inspection and by reference to the table of threshold basal areas on page 3. This table gives the minimum basal area levels normally required before thinning is carried out. The thinning cycle must then be decided and the appropriate thinning yield deduced. The thinning yield to aim at in the above example on the basis of a 5 year cycle would be 35 cubic metres per hectare. This volume is marked as follows;

(4) **Marking is started in the most representative corner of the stand and the usual types of tree are marked.**

(5) **Measure the breast height diameters (dbh) of a sample of the marked trees and determine their average volume, using the top height volume table** (page 30) (e.g. dbh 20 cm, top height of the stand 16·2 m, (round to nearest 1 m) volume 0·222 m^3).

(6) **Estimate the number of thinnings per hectare from their average spacing or by counting the number of marked trees on a plot of known area** (e.g. av. spacing 7·5 m, i.e. 178 trees per hectare).

(7) **Multiply the number of thinnings per hectare by their average volume** (using the alignment chart page 31) **to obtain the total volume per hectare marked** (e.g. $178 \times 0{\cdot}222 = 39{\cdot}5$ m^3/ha).

(8) **Repeat this procedure several times and if the volume marked is found to be consistently greater or less than the specified volume, adjust the size and/or number of trees marked accordingly** (e.g. to reduce 39·5 m^3/ha to 35·0 m^3/ha reduce the number of thinnings to 158 per hectare i.e. $0{\cdot}222 \times 158 = 35{\cdot}1$ or with a reduced dbh of 19 cm i.e. $178 \times 0{\cdot}198 = 35{\cdot}2$ m^3/ha).

(9) **Continue marking to this revised standard, making only occasional checks.**

12. The ultimate objective is for the marker to be able to mark the specified volume without recourse to the above procedure except when a new type of crop is encountered. When thinnings are measured for purposes of standing sale or after conversion in the wood, it may be possible to use this volume as a retrospective check on the marking, provided that the wooded area of the stand is known (which is not always the case since area figures often include rides and other unproductive areas).

13. If checking is carried out subsequent to marking, but before felling, it will not usually be worth the expense of re-marking to correct the yield, since corrections can always be made at the next thinning. It will usually be more useful to ensure that the next stand is marked correctly.

Yield Class

14. Where yield class has previously been assessed in terms of Hoppus feet, this may be converted to metric yield class using the conversion scale on page 4.
15. The yield class number for a stand refers to the maximum mean annual volume increment[1] which the stand is *capable* of producing (even though it may not be achieved because the stand is felled before it has reached the maximum, or because it is understocked).
16. Since records of previous thinning yields are not usually available from which to calculate the actual mean annual increment, yield class is normally estimated from the height growth of the dominant trees in the crop, the average height of this category being least affected by thinning treatment.

Top height

17. The particular measure of height used is *top height*, which is defined as the average height of the 100 trees of largest dbh per hectare. These trees will usually be dominants but may not be the tallest trees in the crop.
18. To obtain a reliable estimate of top height for the crop as a whole, 5 (but preferably more) positions should be located objectively throughout the stand, and the tree of largest diameter within 6 paces of each position measured for total height (to the tip of the tree).
19. There should be no attempt to select top height sample trees other than by this method, which is designed to ensure that an adequate cross-section of variation in the height of the dominant canopy is obtained (including that in the weakest parts of the crop).
20. Efficient hypsometers can be purchased from about £10, but an acceptable standard of accuracy can usually be achieved with simpler devices by measuring a larger number of top-height sample trees.

General yield class

21. A yield class which is estimated through the medium of height growth is termed a *general* yield class, to distinguish it from one based on the actual mean annual volume increment of the stand (termed a *local* yield class[2]).
22. Coloured height/age curves are provided on pages 10 to 24 for purposes of determining the general yield class. The bands define the extent of each yield class, and intersections of top height and age which fall on the boundaries may sometimes be more conveniently recorded to the nearest 1 cubic metre (e.g. SP 40 years, 16·5 m, yield class 11).

[1]Mean annual volume increment is the cumulative volume production (including dead trees and all previous thinnings) divided by the age of the stand. MAI continues to increase during the early years of vigorous growth, reaches a maximum, and then declines with increasing age.

[2]Where local yield class is known this should be used in preference to General Yield Class for thinning control.

23. The yield class determined at some earlier date can be used at subsequent thinnings provided that the pattern of height growth appears to follow the trend of the curves. Re-assessment of yield class need only be carried out in normal circumstances at about 10 year intervals.

Other species

24. The yield class for species other than those for which specific curves are provided can be estimated by making use of the curves for other species. Limited experience suggests the following possibilities:

For these species:	*use the curves for:*	
Maritime pine (*P. pinaster*):	Lodgepole pine	
Weymouth pine (*P. strobus*):	Scots pine	(But increase by one yield class)
Monterey pine (*P. radiata*):	Corsican pine	
Serbian spruce (*P. omorika*):	Norway spruce	(„ „ „ „ „ „)
Silver fir (*A. alba*):	Noble fir	
Redwood and Wellingtonia:	Grand fir	(„ „ „ „ „ „)
Alders and Norway maple:	Sycamore, Ash and Birch	
Elm, Sweet chestnut, Red oak, Nothofagus and Hornbeam:	Beech	

Species mixtures

25. The technique for determining yield class has to be modified slightly when there is more than one species in the crop. The procedure is to determine a separate top height for each of the more important species, to calculate separate yield classes and then to average these, weighting each species according to its importance.

26. When measuring heights in mixtures of two main species, use 0·02 hectare plots (radius 8 m), and when there are three or four main species use 0·05 hectare plots (radius 12·6 m), measuring the largest dbh tree of each of the main species in each plot (of which there should be at least three per stand).

27. The yield class for each species is probably best weighted by the proportion of the canopy which it occupies, (e.g. three species might have yield classes of 14, 10 and 8 and occupy respectively 50, 30 and 20 per cent of the canopy. Multiplying each yield class by its canopy per cent, adding the products and dividing by 100 gives a yield class for the mixed crop of 11·6 which rounds to 12.)

Stands of uneven age

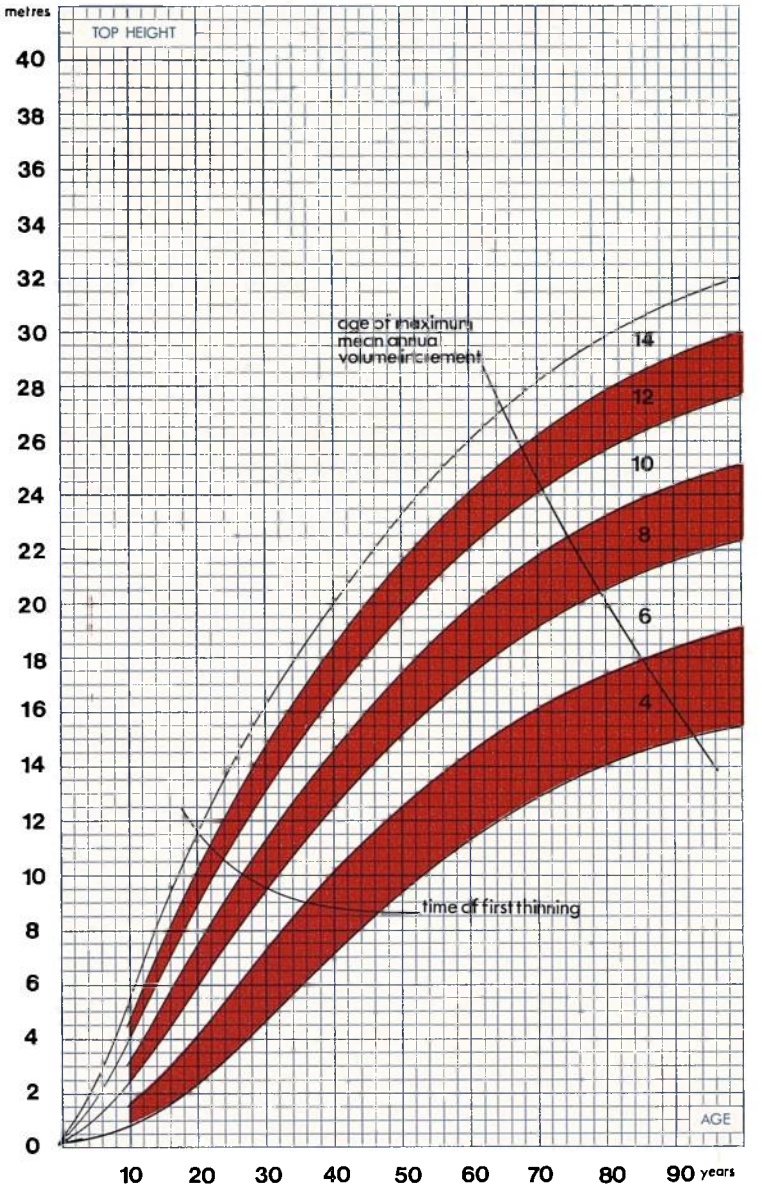
28. Two-storied or all-aged stands can be allocated a yield class by treating each age category separately, then averaging the yield classes or, in situations where the range of ages is not too great, by using an average age. In determining the average age and yield class the various age categories should be weighted as for species mixtures, para. 27.

Stands which have at some time been in check

29. The yield class of crops now growing vigorously after a long period of checked growth will usually be greater than the yield class given by their present top height and age. The correct yield class can be estimated by deducting the number of years and height growth for the duration of the period of check from the present age and height of the stand (e.g. if the crop was in check for 10 years, during which time it grew only 1 m (these facts can usually be estimated from whorl counts) and the present age and height are 40 years and 11 m, the values to use in determining yield class are 30 years and 10 m).

SCOTS PINE

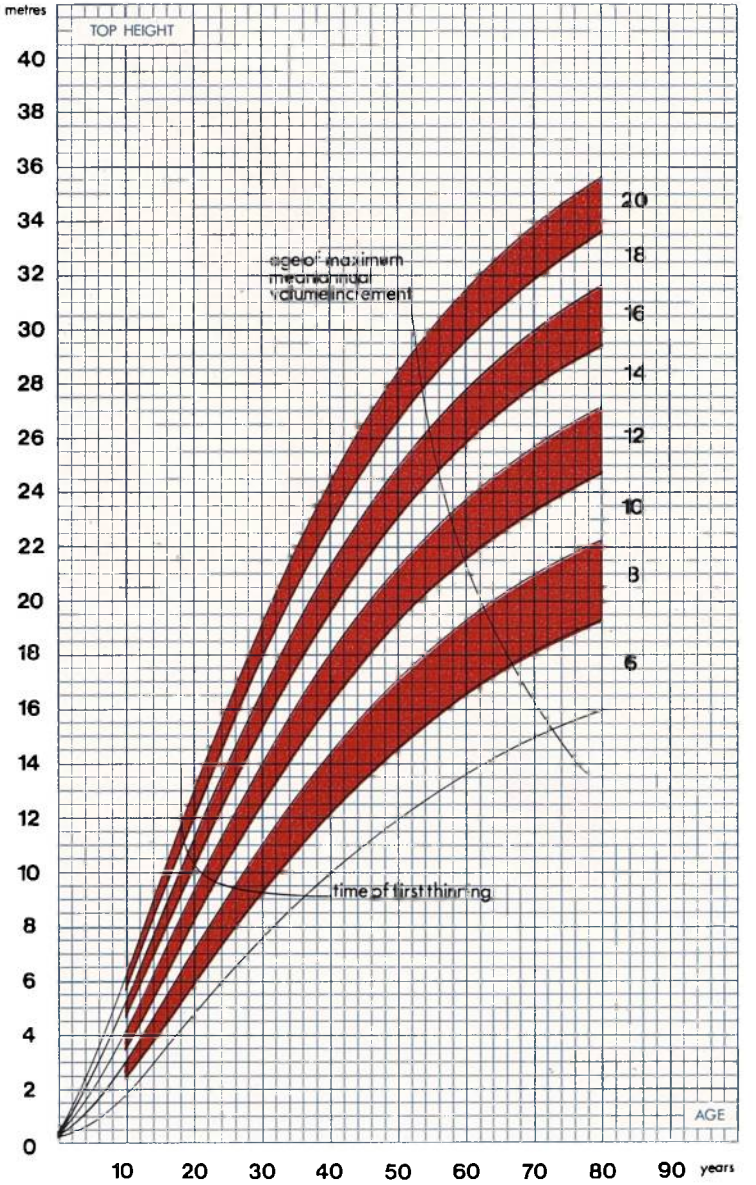
GENERAL YIELD CLASS CURVES



CP

CORSICAN PINE

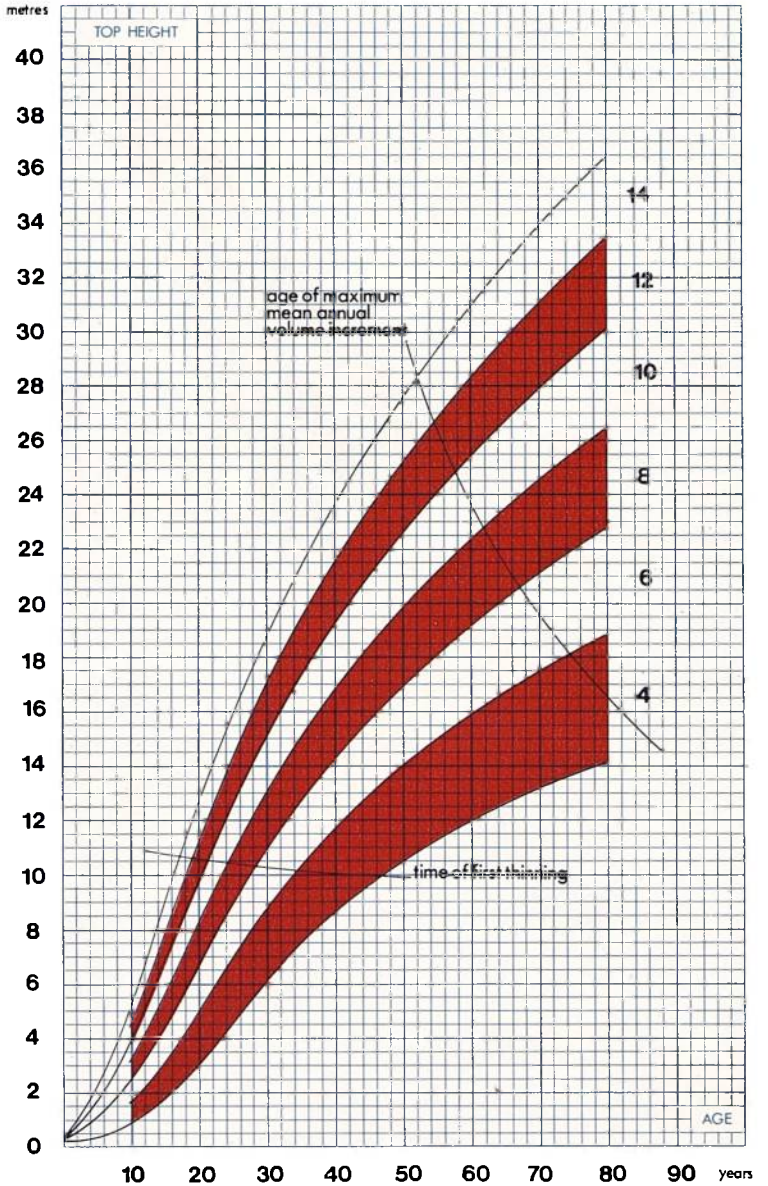
GENERAL YIELD CLASS CURVES



LP

LODGEPOLE PINE

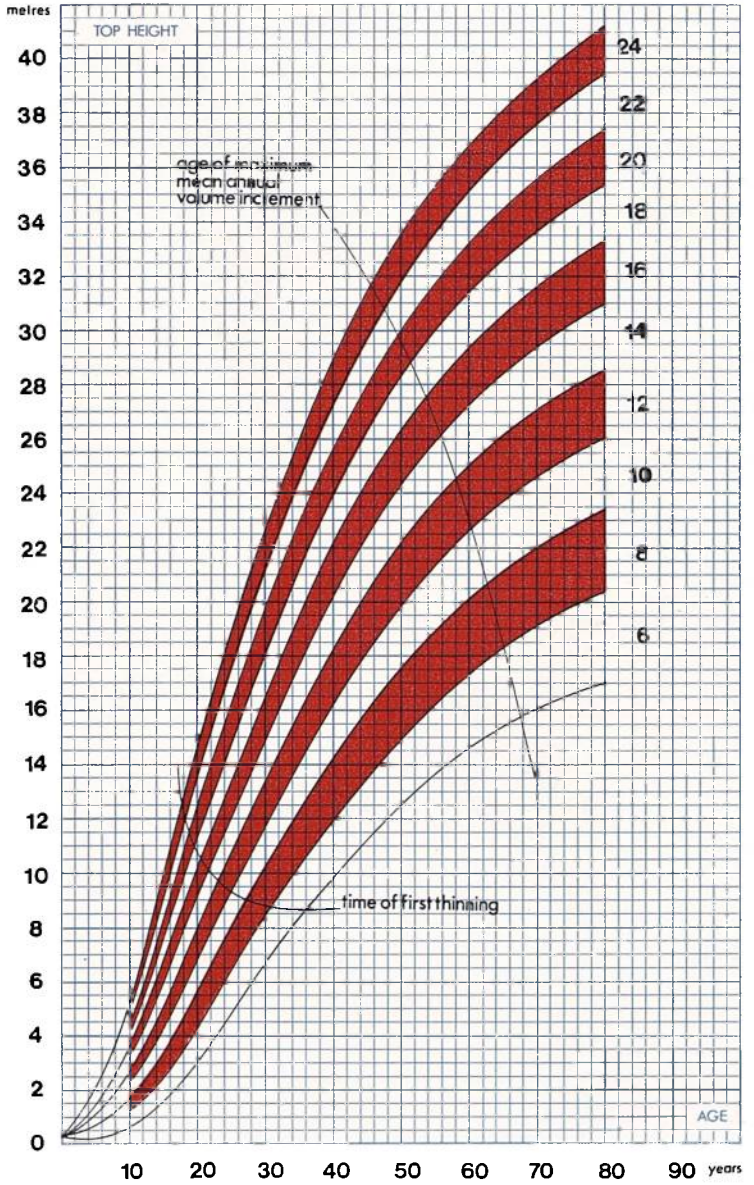
GENERAL YIELD CLASS CURVES



SS

SITKA SPRUCE

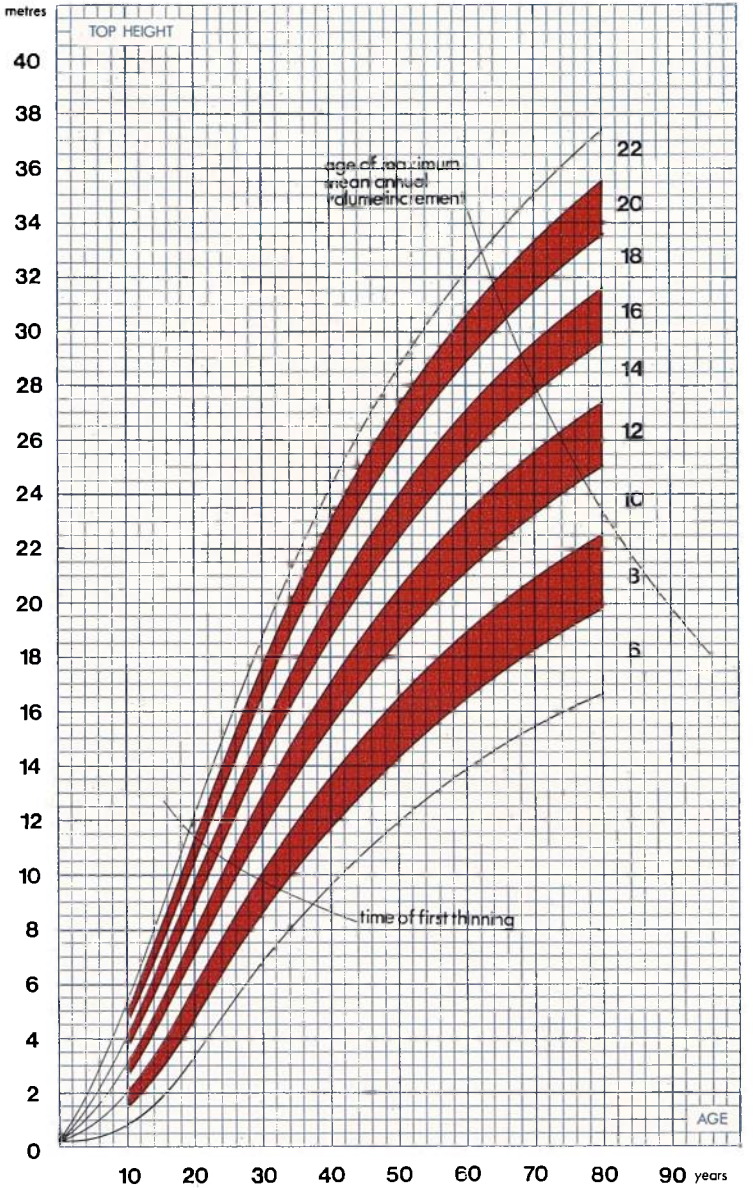
GENERAL YIELD CLASS CURVES



NS

NORWAY SPRUCE

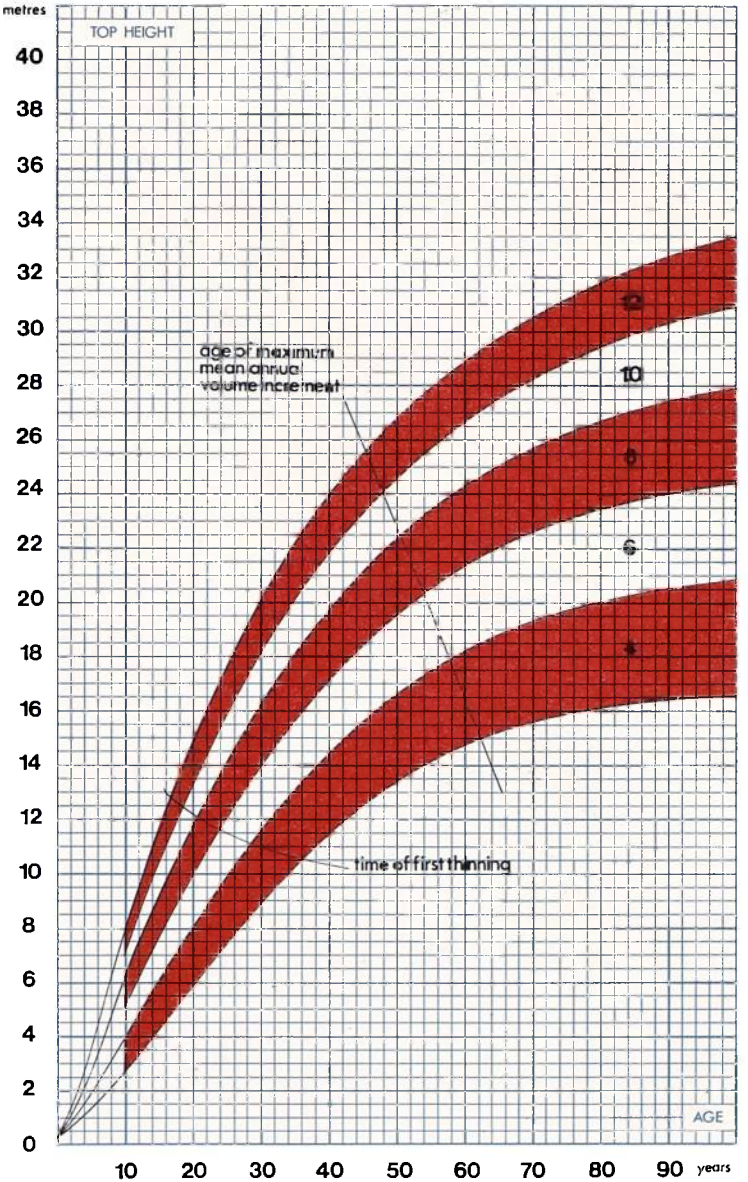
GENERAL YIELD CLASS CURVES



EL

EUROPEAN LARCH

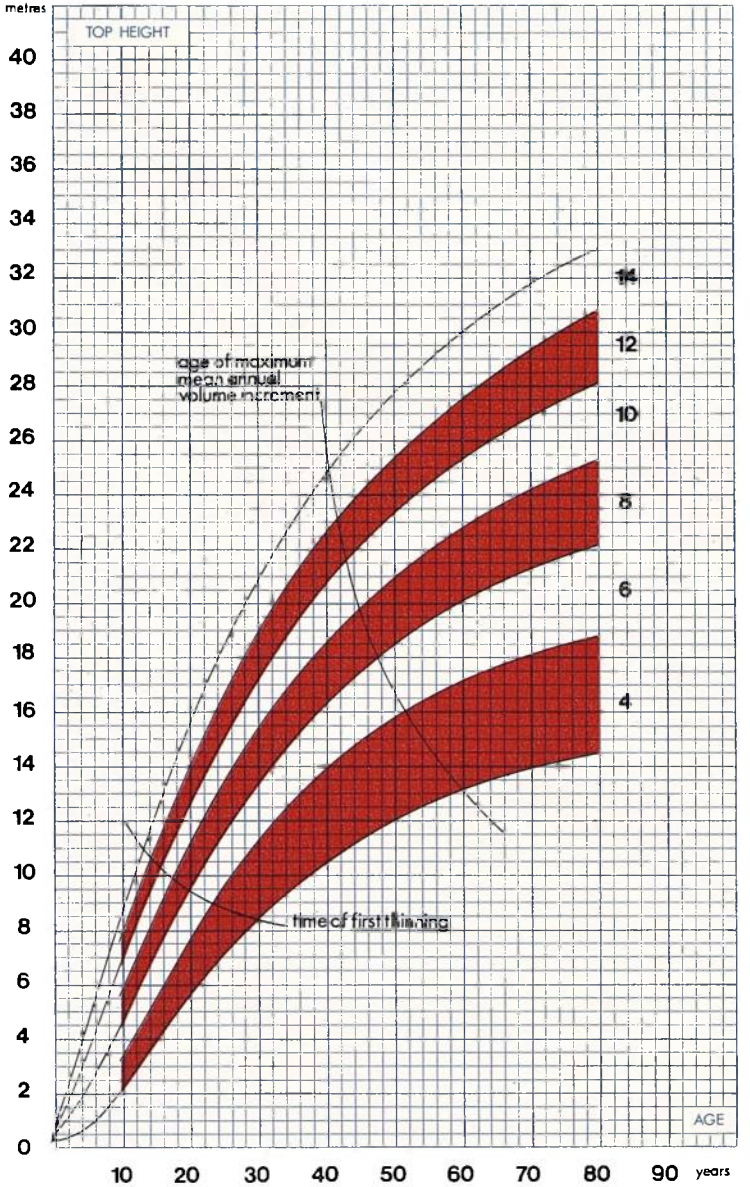
GENERAL YIELD CLASS CURVES



JL

JAPANESE LARCH

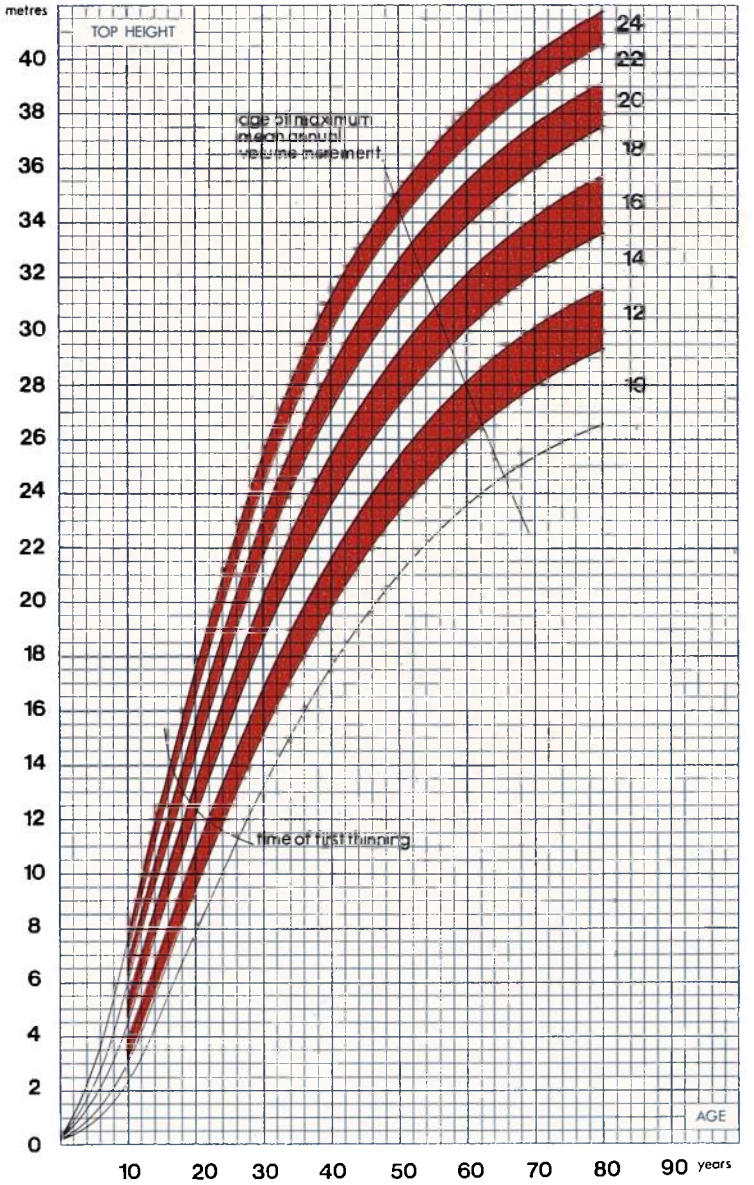
GENERAL YIELD CLASS CURVES



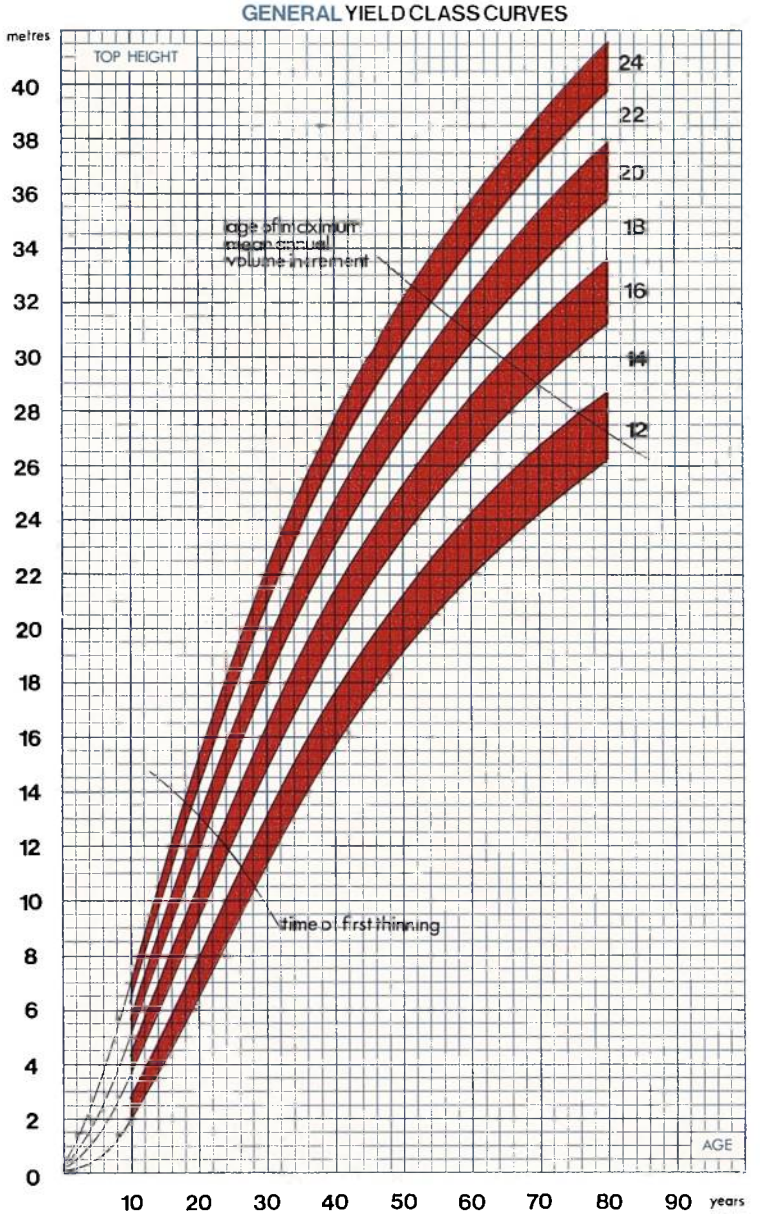
DF

DOUGLAS FIR

GENERAL YIELD CLASS CURVES

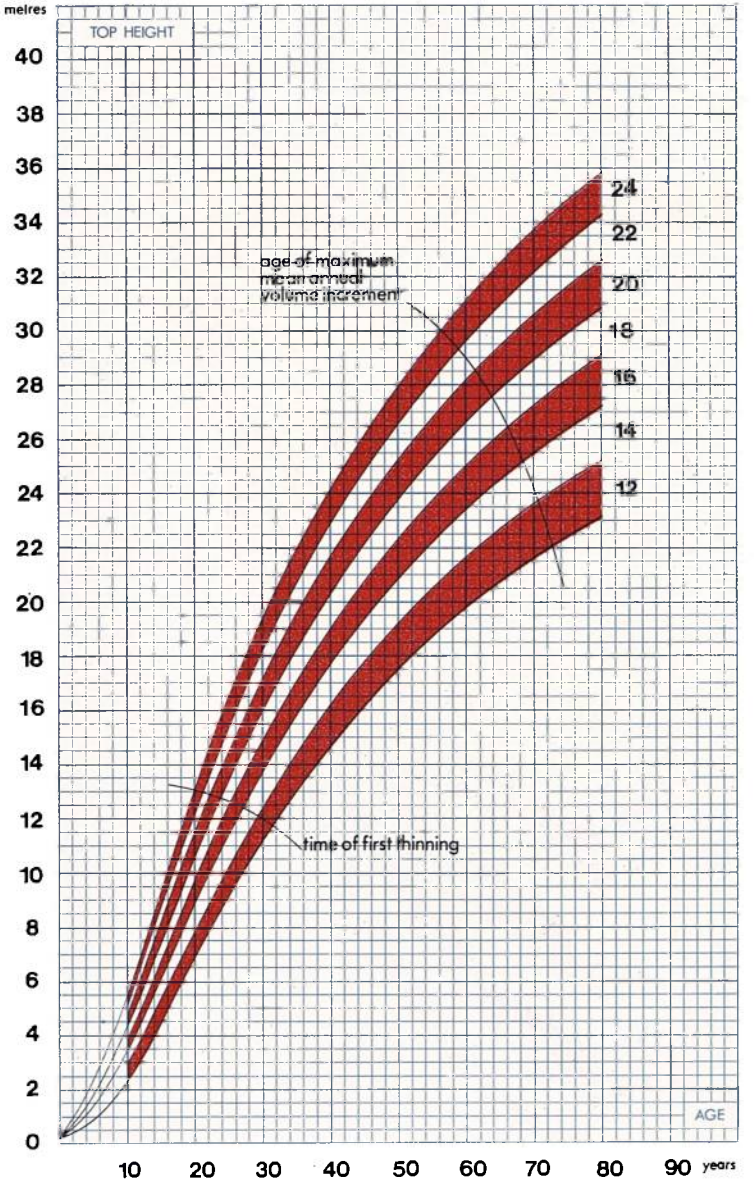


WESTERN HEMLOCK



RED CEDAR

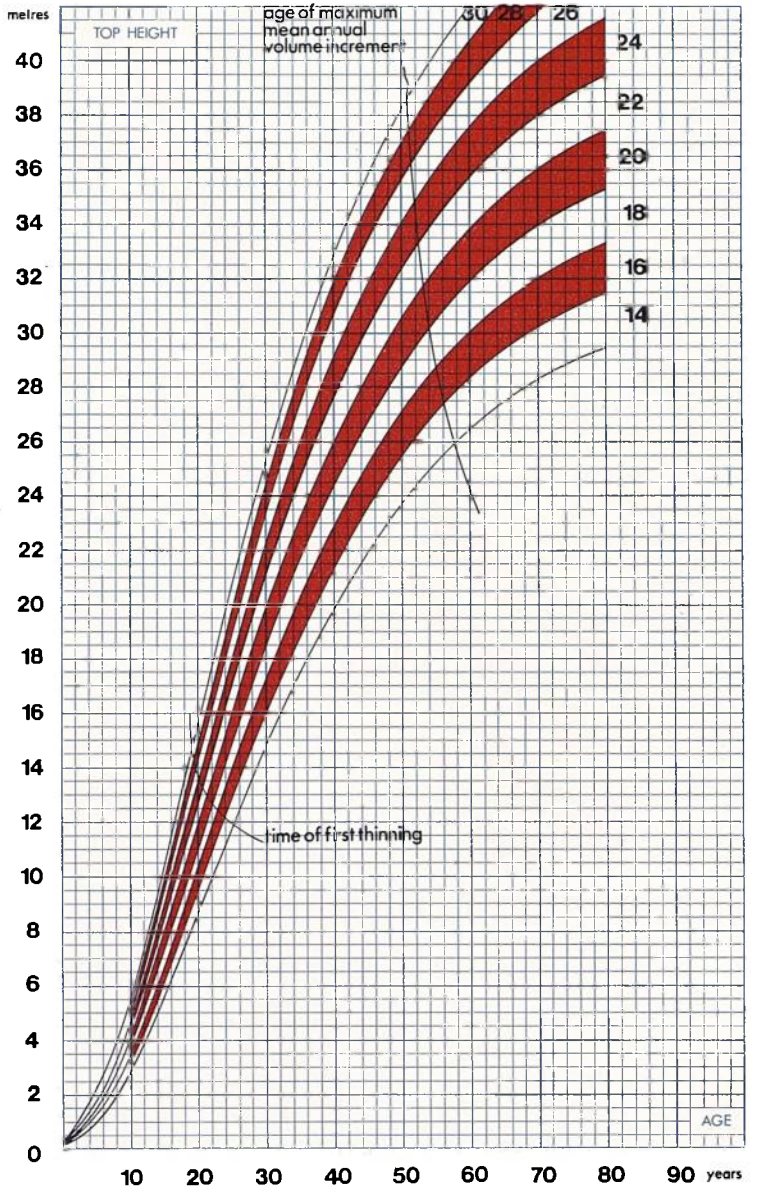
GENERAL YIELD CLASS CURVES



GF

GRAND FIR

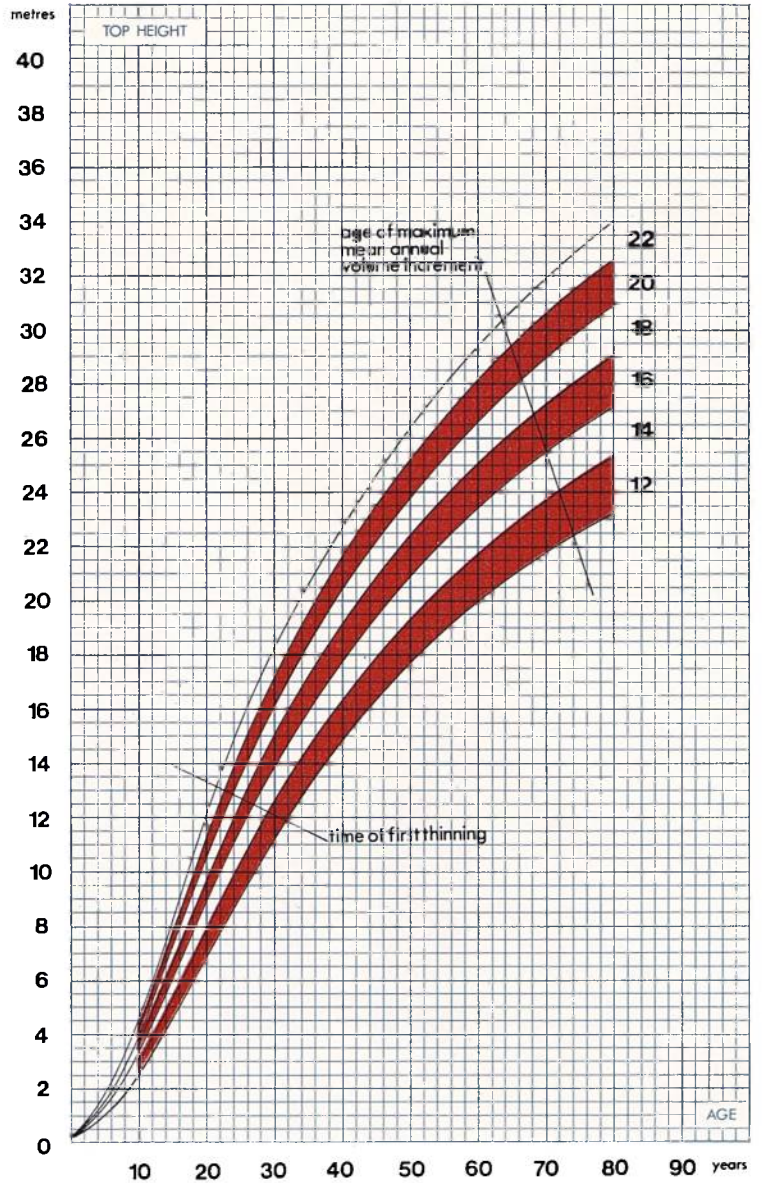
GENERAL YIELD CLASS CURVES



NF

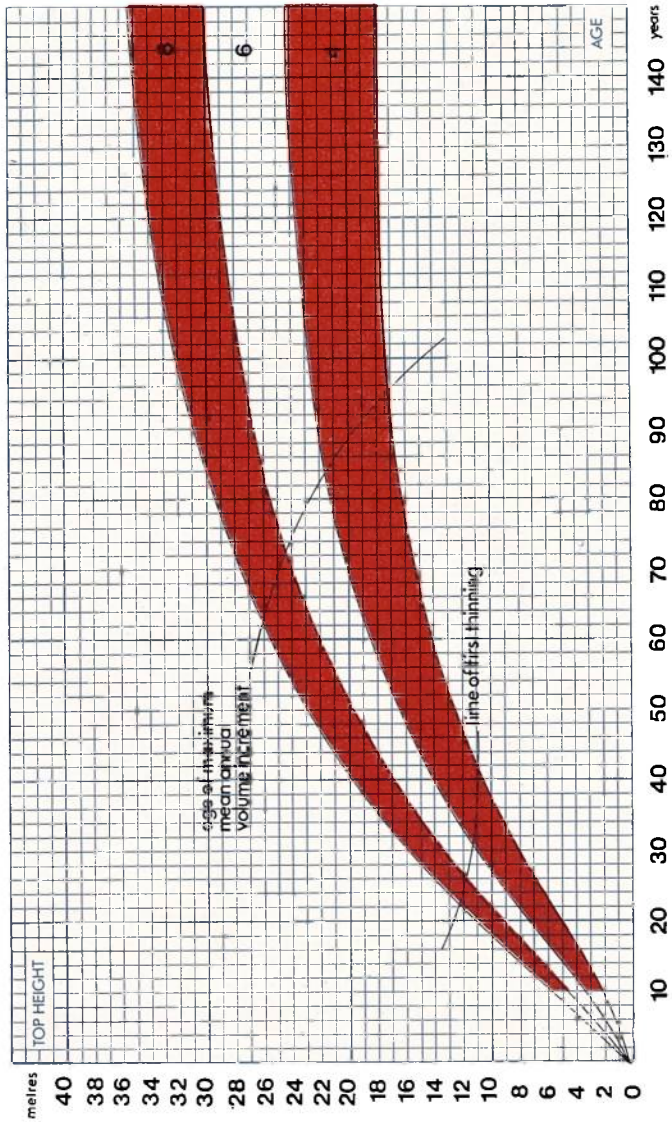
NOBLE FIR

GENERAL YIELD CLASS CURVES



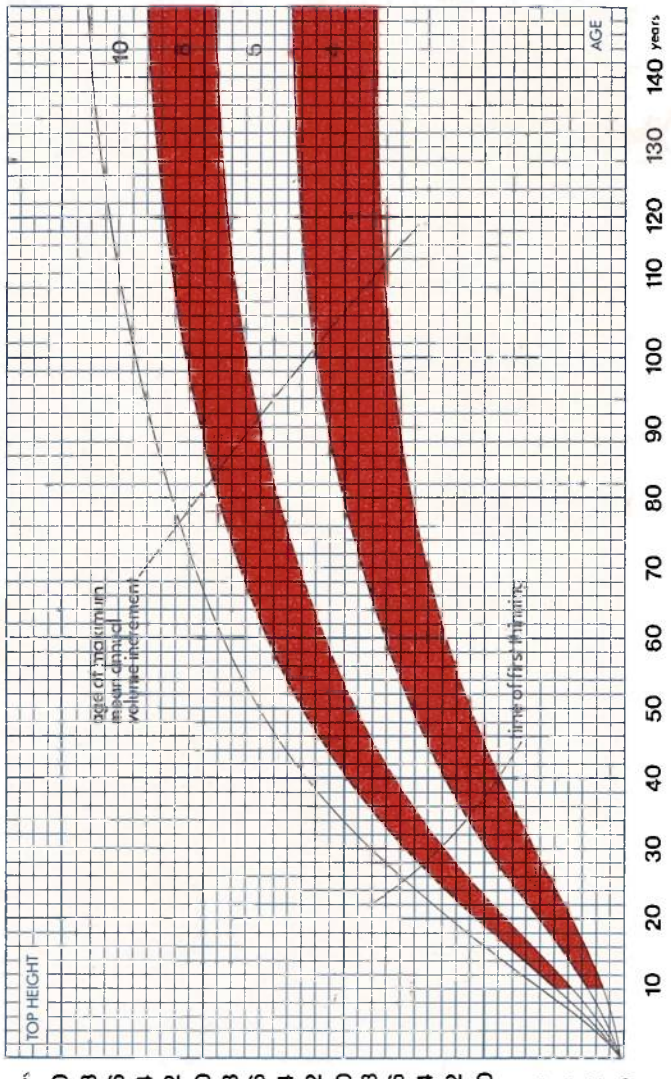
OAK

OAK


GENERAL YIELD CLASS CURVES
metres
TOP HEIGHT
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
years
AGE
8
6
4
age of maximum mean annual volume increment
time of first thinning

BE

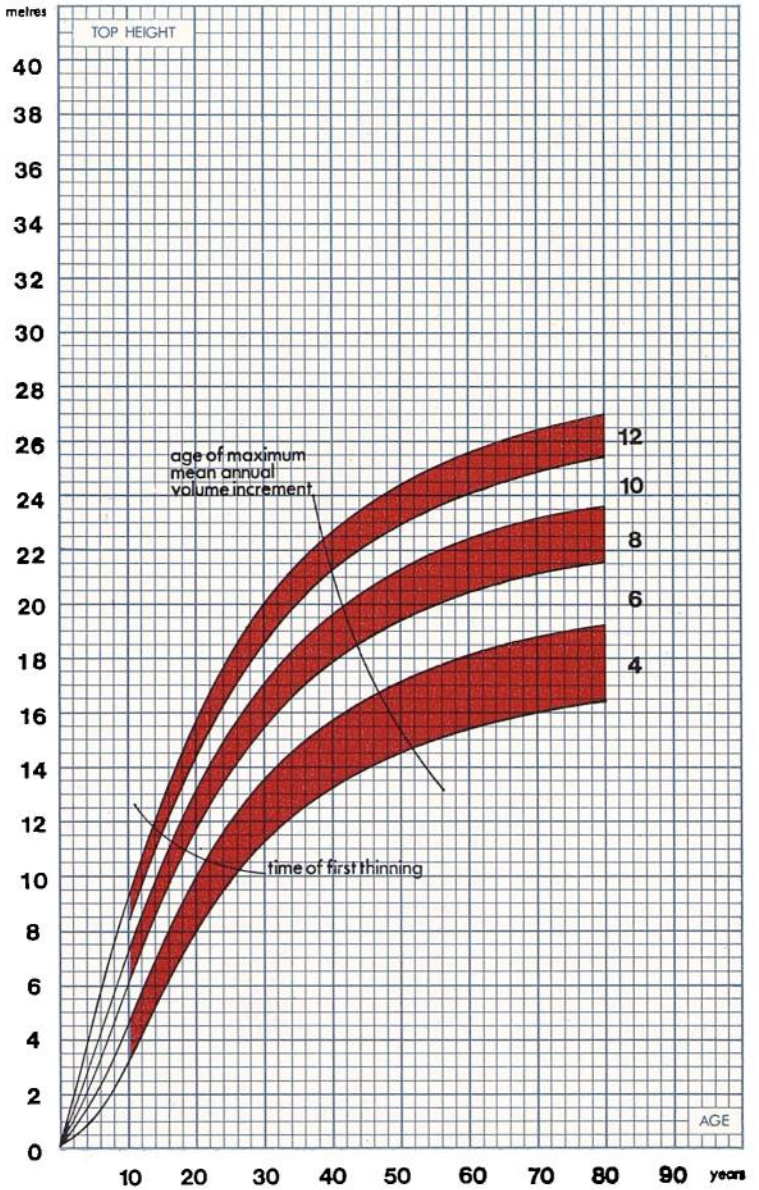
BEECH


GENERAL YIELD CLASS CURVES
TOP HEIGHT
metres
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
age of maximum mean annual volume increment
time of first thinning
10
8
5
4
10
20
30
40
50
60
70
80
90
100
110
120
130
140 years
AGE

SAB

SYCAMORE, ASH AND BIRCH

GENERAL YIELD CLASS CURVES



Normal Thinning Yield (see table on front cover)

30. The volumes in the *TABLE OF NORMAL THINNING YIELDS* can be applied during the normal thinning life of the crop. The start of this period is indicated on the General Yield Class curves and thinning will normally cease a few years before the age of maximum mean annual volume increment, which is also indicated on these curves. The *annual* thinning yield during this period is equal to 70 per cent of the yield class value (e.g. Yield Class 14, annual thinning yield 9·8 m^3/ha).
31. The volume to be removed in a single thinning is obtained by multiplying the annual thinning yield by the proposed thinning cycle (e.g. yield class 14, annual yield 9·8 m^3/ha, cycle 5 years, thinning volume to be removed 49·0 m^3/ha).

Time of first thinning

32. The times of first thinning shown on the General Yield Class curves are fixed partly on the basis of experience and partly by the need to have a large enough standing volume to be able to remove the recommended yields on a reasonable thinning cycle of from three years in more rapidly growing crops, to eight years in slower growing crops.
33. Thinning can be started at ages earlier than those indicated if necessary, provided the annual thinning yield is reduced. A table of reduced early yields is given for this purpose at the top of page 3.
34. Slow initial establishment or wide spacing may mean that first thinning has to be delayed beyond the normal age. The extent of the delay can only be judged subjectively.

Thinning cycle

35. The thinning cycle to use for purposes of determining the thinning yield relates to the *future*, not to the past, because the number of years since the last thinning has little relevance to future growth provided that the stand is now fully stocked and ready for thinning.
36. The length of the thinning cycle will usually be chosen to suit the average rate of growth over the whole forest or estate, and to ensure that on average a large enough thinning yield per hectare is achieved to make use of scale economies in marking, measuring, felling and extracting the timber. It should not be so long, however, that the resulting yield involves a drastic opening of the canopy with the attendant risk of windthrow, a rise in the water table or invasion of the site by woody vegetation.
37. The combinations of yield class and thinning cycle, which are printed in bold type in the table of normal thinning yields, are suggested as being the most likely combinations for practical use. The heavier yields are included mainly for interest, since it will rarely be practicable to use cycles of this length for stands growing at these rates.

Modified Thinning Yield

Understocked stands

38. Since the normal thinning yields are intended for use with fully stocked stands, some reduction in yield is called for when thinning crops in which the trees already have more growing space than they can effectively use. The other, and often more practical alternative, is to leave such stands until they have recovered full stocking before thinning again. (See table, page 3, Before-Thinning Basal Areas, and text below.)

39. While removal of the normal thinning yield is only likely to result in serious loss of increment in severe cases of understocking, recovery of full stocking will be delayed much less if the thinning yield is reduced by the equivalent of at least one year's cut (e.g. if the stand is due for thinning in 4 years time, remove the cut for a 3-year cycle instead of 4).

Overstocked stands

40. The normal thinning yield will often appear inadequate in stands in which the individual trees are so crowded that crown development is severely restricted. Remember, however, that too-sudden an opening of the canopy can often be dangerous in these circumstances, and that, since more trees than usual will have to be removed to make up the normal thinning yield, the degree of overstocking will automatically be reduced.

41. If more rapid reduction in stocking appears to be both desirable and silviculturally practicable, a convenient rule of thumb is to increase the yield by one extra year's cut (e.g. take a 4 year's cut on a 3-year cycle). If the stand is still overstocked at the next thinning the procedure can be repeated, so achieving a controlled reduction in density of stocking. Where there is a choice, short rather than long thinning cycles should be used in dealing with overstocked stands.

Species mixtures

42. If one component of a species mixture is removed in thinning in preference to the others, the average yield class (see paras 25–27) is best weighted in favour of the species which remain, since the future growth of the stand depends more on these than on the species removed.

Uneven-aged stands

43. If the crop approximates to an even-aged condition, use the normal thinning yield as determined by the average yield class (see para 28), but in stands approaching a truly all-aged condition, the annual thinning yield should be increased until, for a stand giving sustained yield, the annual yield is equal to the yield class rather than to 70% of the yield class. At this stage the yield will consist of trees of all ages and all sizes, and the largest trees will be of rotation age.

Diseased stands

44. It is not possible to give general guidance on the treatment of diseased stands except to note that it may be necessary to reduce the normal thinning yield or to suspend thinning altogether; the correct treatment will depend upon the particular circumstances.

The Basis of Thinning Control

Basis

45. The system of control recommended in this booklet is control *via* the volume **removed** as thinnings. Another commonly used basis is control of the volume (or basal area) *remaining* after thinning, the main advantage of which is that it discourages the indiscriminate removal of thinning yield from stands whose growing stock is already depleted.

46. Control by the volume removed, however, has three important advantages:

(a) it provides a reasonably consistent level of yield which is vital for efficient management and for effective planning,

(b) it considerably reduces the effect which errors in yield class assessment may have on the level of the growing stock, and

(c) it discourages drastic reduction of the level of the growing stock of overstocked stands which often results in windthrow or other catastrophes stemming from too-sudden an opening of the canopy.

Net and gross areas

47. The thinning yields in this publication refer to conditions of full stocking so that areas which include roads, rides and other non-productive land must be reduced to a net area, which excludes such land, before a volume per hectare can be calculated for purposes of thinning control.

48. It would have been possible to base the system on gross areas which include an average allowance for unproductive land[1]. The disadvantages of such a system would be that the allowance necessary for one stand would differ appreciably from that required by another, and that direct control of thinning during the process of marking would not be practicable, since this entails the use of net or productive areas unless the correct proportion of rides and gaps is included in each plot.

49. Although, when the stand is being measured for purposes of sale or for payment of men, it would often be convenient to use the volume per *gross* hectare, the ideal form of control is to ensure that the correct volume is marked in the first place. While it may ultimately be possible for experienced markers to instinctively mark a specified volume yield, the training and supervision of markers is most easily carried out through the medium of small sample plot estimates of the volume per *net* hectare.

Extraction racks

50. Extraction racks provide an example of the principle of control *via* net area. Once the racks have been removed, the thinning yield will be controlled in the productive area *between* the racks, and the area of the racks will reduce the net (productive) area of the stand until such time as the canopy closes over again. At the time when the racks are marked it will be simplest to control in the normal way between the racks, and to accept that the total volume removed will be increased by the extra volume removed in the rackways.

[1]Such an allowance is incorporated in the Production Forecast Tables of F.C. Booklet 34 *Forest Management Tables (Metric). (In preparation).*

Partially-checked crops

51. When parts of a crop are ready for thinning but others are not, thinning will usually be started when the thinnable area is large enough for economic working, and the yield should be controlled in the normal way in the areas which are fully stocked. The total yield for the stand will be reduced by the area which is not thinnable or from which only a reduced yield is available, but may be partially compensated for by increased yield from the more densely stocked parts of the crop.

Controlling the Volume Marked

52. To estimate the volume per hectare which is being marked it is necessary to take sample measurements to determine (a) the average volume of the thinnings and (b) the number of thinnings per hectare.

Methods of sampling

53. Both the number of thinnings per hectare and their average volume can be estimated by measuring the thinnings which fall within sample plots of known area. Alternatively, the number of thinnings per hectare can be estimated by measuring the average distance between a number of marked trees which are also measured for volume. The advantage of the second method is that the sample trees can be spread more effectively throughout the crop whereas plots concentrate the sample in smaller areas which may not be representative of the stand as a whole.

Number of thinnings per hectare

54. The tables on page 2 can be used to convert the average spacing between thinnings into the number per hectare or to lay out plots of known area. At least 15 trees should be sampled before calculating the average thinning yield, whether these trees are in plots or not.

Size, shape and number of plots

55. A minimum of 3 plots should be measured before calculating the average thinning yield, which means that the plot size should be chosen so that there are at least 5 thinnings per plot to provide the minimum of 15 trees noted in para 54.

56. Plots can be square, rectangular or circular but different situations call for different shapes of plot. When the rows are still clearly visible it pays to use a rectangular plot, while in stands where the rows are not distinct but where there are enough thinnings per hectare to be able to use small plots, circular plots will usually be best; but where the size is 0·05 ha or larger, square plots will probably take less time to lay out.

Rectangular (row) plots

57. If the rows are clearly visible and regularly spaced a rectangular plot can be very easily established by taking, say, 3 rows and pacing out a distance along the rows which, for the average spacing *between* the rows, gives a plot of the required size. The first table on page 2 gives distances for various spacings, numbers or rows and sizes of plot.

58 The technique for laying out such plots is to stop marking, scuff the ground without reference to the spacing of the trees in the rows, turn round, pace back the required distance along the rows, and to return counting and measuring the thinnings marked within the number of rows specified until the original scuff mark is reached. The number of trees counted divided by the plot size, will give the number per hectare (e.g. 7 trees in a plot of 0·02 ha would represent 350 per hectare).

Average spacing of thinnings

59. If the number of thinnings per hectare is to be estimated from their average spacing rather than by use of plots, the spacing can be estimated by pacing the average distance between a marked tree and the nearest thinnings, repeating this at least three times as for plots.

Estimating average tree volume

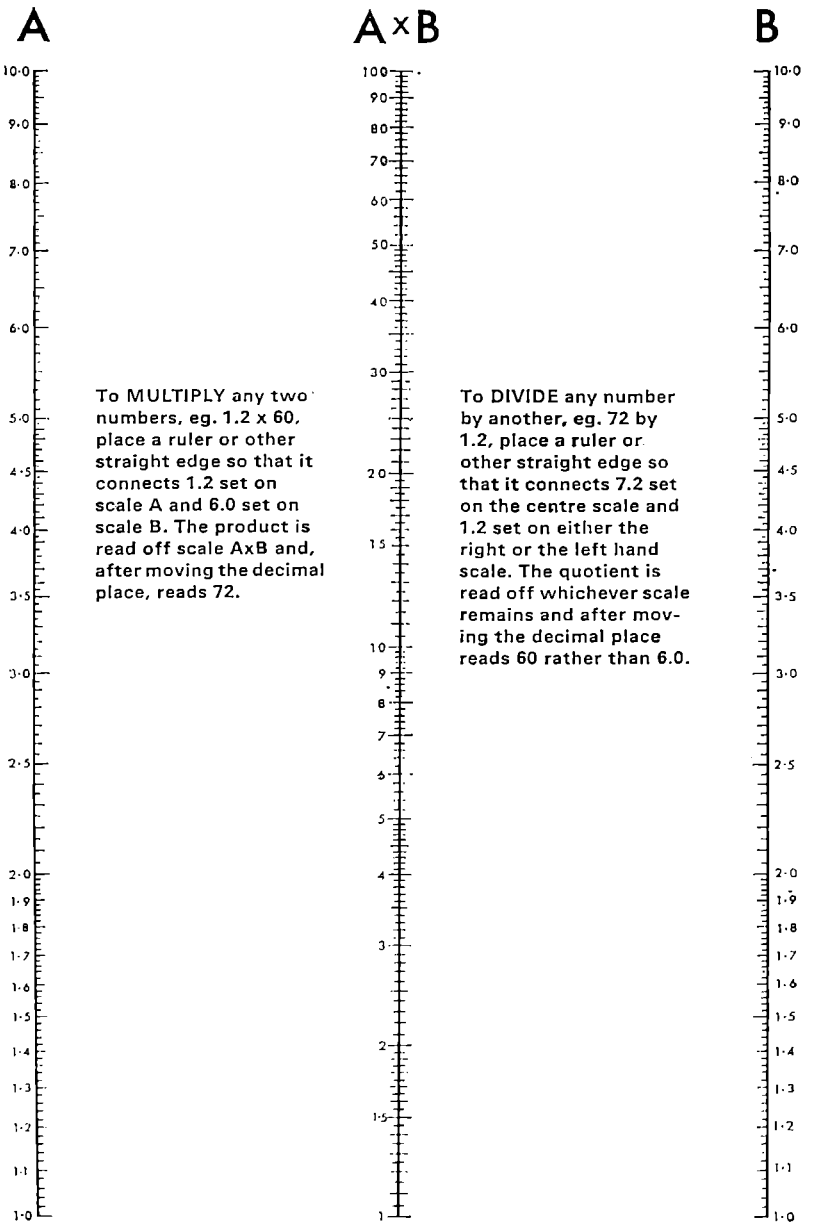
60. The average volume of the thinnings is best estimated simply by averaging the volume of a number of thinnings.
61. The volume of a tree can be estimated by using the TOP HEIGHT VOLUME TABLE on page 30. The top height of the stand will have been measured for yield class assessment, or alternatively if the yield class and age is known, top height can be deduced from the General Yield Class curves. Given that, for example, the top height of a stand is 18 m, a tree of 20 cm dbh will have a nominal volume of 0·242 m^3.
62. The method can be further improved if the volumes for a given top height are occasionally checked against the felled volume of thinnings from such crops to obtain a correction factor for local conditions. If the tariff number of a stand is known from experience in similar crops, then the appropriate tariff table may be used. The top height volume table is in fact based on the tariff tables, and the nearest equivalent tariff number is shown at the bottom of the table.

Average volume yield

63. Since the density of stocking, and thus the intensity of marking, varies appreciably from one part of the stand to another, it is essential to take several sets of sample measurements before an average is calculated. It will save some time if the sample measurements are recorded cumulatively and an average worked out directly from the individual trees, without troubling to work up the figures for the separate plots or groups of sample tree measurements.

Top height volume table for thinnings

BH DIAM cm	VOLUMES IN CUBIC METRES TO 7 CENTIMETRES TOP DIAMETER — TOP HEIGHT IN METRES																BH DIAM cm
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
10	0·028	0·029	0·031	0·032	0·034	0·035	0·037	0·038	0·040	0·041	0·042	0·044	0·045	0·047	0·048	0·050	10
11	0·037	0·039	0·042	0·044	0·046	0·048	0·050	0·052	0·054	0·056	0·058	0·060	0·062	0·064	0·066	0·068	11
12	0·048	0·050	0·053	0·056	0·059	0·061	0·064	0·067	0·069	0·072	0·075	0·077	0·080	0·083	0·085	0·088	12
13	0·059	0·062	0·066	0·069	0·073	0·076	0·079	0·083	0·086	0·090	0·093	0·096	0·100	0·103	0·107	0·110	13
14	0·071	0·075	0·079	0·084	0·088	0·092	0·096	0·100	0·104	0·109	0·113	0·117	0·121	0·125	0·129	0·133	14
15	0·084	0·089	0·094	0·099	0·104	0·109	0·114	0·119	0·124	0·129	0·134	0·139	0·144	0·149	0·154	0·159	15
16	0·098	0·104	0·110	0·116	0·122	0·127	0·133	0·139	0·145	0·151	0·157	0·163	0·168	0·174	0·180	0·186	16
17	0·113	0·120	0·127	0·133	0·140	0·147	0·154	0·160	0·167	0·174	0·181	0·188	0·194	0·201	0·208	0·215	17
18	0·129	0·137	0·144	0·152	0·160	0·168	0·175	0·183	0·191	0·199	0·206	0·214	0·222	0·230	0·238	0·245	18
19	0·145	0·154	0·163	0·172	0·181	0·189	0·198	0·207	0·216	0·225	0·234	0·242	0·251	0·260	0·269	0·278	19
20	0·163	0·173	0·183	0·193	0·203	0·213	0·222	0·232	0·242	0·252	0·262	0·272	0·282	0·292	0·302	0·312	20
21	0·18	0·19	0·20	0·21	0·23	0·24	0·25	0·26	0·27	0·28	0·29	0·30	0·31	0·33	0·34	0·35	21
22	0·20	0·21	0·23	0·24	0·25	0·26	0·27	0·29	0·30	0·31	0·32	0·34	0·35	0·36	0·37	0·39	22
23	0·22	0·23	0·25	0·26	0·28	0·29	0·30	0·32	0·33	0·34	0·36	0·37	0·38	0·40	0·41	0·42	23
24	0·24	0·26	0·27	0·29	0·30	0·32	0·33	0·35	0·36	0·38	0·39	0·41	0·42	0·44	0·45	0·47	24
25	0·26	0·28	0·30	0·31	0·33	0·35	0·36	0·38	0·39	0·41	0·43	0·44	0·46	0·48	0·49	0·51	25
26	0·29	0·30	0·32	0·34	0·36	0·38	0·39	0·41	0·43	0·45	0·46	0·48	0·50	0·52	0·54	0·55	26
27	0·31	0·33	0·35	0·37	0·39	0·41	0·43	0·45	0·46	0·48	0·50	0·52	0·54	0·56	0·58	0·60	27
28	0·34	0·36	0·38	0·40	0·42	0·44	0·46	0·48	0·50	0·52	0·54	0·56	0·58	0·61	0·63	0·65	28
29	0·36	0·38	0·41	0·43	0·45	0·47	0·50	0·52	0·54	0·56	0·59	0·61	0·63	0·65	0·67	0·70	29
30	0·39	0·41	0·44	0·46	0·48	0·51	0·53	0·56	0·58	0·60	0·63	0·65	0·68	0·70	0·72	0·75	30
31	0·42	0·44	0·47	0·49	0·52	0·54	0·57	0·60	0·62	0·65	0·67	0·70	0·72	0·75	0·78	0·80	31
32	0·44	0·47	0·50	0·53	0·55	0·58	0·61	0·64	0·66	0·69	0·72	0·75	0·77	0·80	0·83	0·86	32
33	0·47	0·50	0·53	0·56	0·59	0·62	0·65	0·68	0·71	0·74	0·77	0·80	0·83	0·85	0·88	0·91	33
34	0·50	0·53	0·57	0·60	0·63	0·66	0·69	0·72	0·75	0·78	0·82	0·85	0·88	0·91	0·94	0·97	34
35	0·53	0·57	0·60	0·63	0·67	0·70	0·73	0·77	0·80	0·83	0·87	0·90	0·93	0·97	1·00	1·03	35
36	0·57	0·60	0·64	0·67	0·71	0·74	0·78	0·81	0·85	0·88	0·92	0·95	0·99	1·02	1·06	1·09	36
37	0·60	0·64	0·67	0·71	0·75	0·79	0·82	0·86	0·90	0·93	0·97	1·01	1·05	1·08	1·12	1·16	37
38	0·63	0·67	0·71	0·75	0·79	0·83	0·87	0·91	0·95	0·99	1·03	1·07	1·11	1·15	1·18	1·22	38
39	0·67	0·71	0·75	0·79	0·83	0·88	0·92	0·96	1·00	1·04	1·08	1·12	1·17	1·21	1·25	1·29	39
40	0·70	0·75	0·79	0·83	0·88	0·92	0·97	1·01	1·05	1·10	1·14	1·18	1·23	1·27	1·32	1·36	40
Approx Tariff No.	18	19	20	22	23	24	25	26	27	28	30	31	32	33	34	35	Approx Tariff No.



ALIGNMENT CHART

Abbreviated volume ready reckoner

DIAM	VOLUMES IN CUBIC METRES										DIAM
	LENGTHS IN METRES										
cm	1	2	3	4	5	6	7	8	9	10	cm
10	0·008	0·016	0·024	0·031	0·039	0·047	0·055	0·063	0·071	0·079	10
11	0·010	0·019	0·029	0·038	0·048	0·057	0·067	0·076	0·086	0·095	11
12	0·011	0·023	0·034	0·045	0·057	0·068	0·079	0·090	0·102	0·113	12
13	0·013	0·027	0·040	0·053	0·066	0·080	0·093	0·106	0·119	0·133	13
14	0·015	0·031	0·046	0·062	0·077	0·092	0·108	0·123	0·139	0·154	14
15	0·018	0·035	0·053	0·071	0·088	0·106	0·124	0·141	0·159	0·177	15
16	0·020	0·040	0·060	0·080	0·101	0·121	0·141	0·161	0·181	0·201	16
17	0·023	0·045	0·068	0·091	0·113	0·136	0·159	0·182	0·204	0·227	17
18	0·025	0·051	0·076	0·102	0·127	0·153	0·178	0·204	0·229	0·254	18
19	0·028	0·057	0·085	0·113	0·142	0·170	0·198	0·227	0·255	0·284	19
20	0·031	0·063	0·094	0·126	0·157	0·188	0·220	0·251	0·283	0·314	20
21	0·035	0·069	0·104	0·139	0·173	0·208	0·242	0·277	0·312	0·346	21
22	0·038	0·076	0·114	0·152	0·190	0·228	0·266	0·304	0·342	0·380	22
23	0·042	0·083	0·125	0·166	0·208	0·249	0·291	0·332	0·374	0·415	23
24	0·045	0·090	0·136	0·181	0·226	0·271	0·317	0·362	0·407	0·452	24
25	0·049	0·098	0·147	0·196	0·245	0·295	0·344	0·393	0·442	0·491	25
26	0·053	0·106	0·159	0·212	0·265	0·319	0·372	0·425	0·478	0·531	26
27	0·057	0·115	0·172	0·229	0·286	0·344	0·401	0·458	0·515	0·573	27
28	0·062	0·123	0·185	0·246	0·308	0·369	0·431	0·493	0·554	0·616	28
29	0·066	0·132	0·198	0·264	0·330	0·396	0·462	0·528	0·594	0·661	29
30	0·071	0·141	0·212	0·283	0·353	0·424	0·495	0·565	0·636	0·707	30
31	0·075	0·151	0·226	0·302	0·377	0·453	0·528	0·604	0·679	0·755	31
32	0·080	0·161	0·241	0·322	0·402	0·483	0·563	0·643	0·724	0·804	32
33	0·086	0·171	0·257	0·342	0·428	0·513	0·599	0·684	0·770	0·855	33
34	0·091	0·182	0·272	0·363	0·454	0·545	0·636	0·726	0·817	0·908	34
35	0·096	0·192	0·289	0·385	0·481	0·577	0·673	0·770	0·866	0·962	35
36	0·102	0·204	0·305	0·407	0·509	0·611	0·713	0·814	0·916	1·018	36
37	0·108	0·215	0·323	0·430	0·538	0·645	0·753	0·860	0·968	1·075	37
38	0·113	0·227	0·340	0·454	0·567	0·680	0·794	0·907	1·021	1·134	38
39	0·119	0·239	0·358	0·478	0·597	0·717	0·836	0·956	1·075	1·195	39
40	0·126	0·251	0·377	0·503	0·628	0·754	0·880	1·005	1·131	1·257	40

NOTE: This table may also be used to calculate basal areas by using breast height diameters and substituting number of trees for lengths in metres.

Printed in England by The Artisan Press Ltd, Anstey, Leicester,
and published by Her Majesty's Stationery Office

Dd.501970 K.50

SBN 11 710011 0.