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THINNING CONTROL IN BRITISH WOODLANDS

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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 ACRE (Hoppus feet over bark to 3 ins. top diameter or 2½ ins. QG.) THINNING CYCLE (Number of years before the *next* thinning, *not* since the last)							Yield Class
	3	**4**	**5**	**6**	**8**	**9**	**10**	
20	42	56	70	84	112	**126**	**140**	20
40	84	112	140	168	**224**	**252**	**280**	40
60	126	168	210	**252**	**336**	**378**	**420**	60
80	168	224	**280**	**336**	**448**	**504**	560	80
100	210	280	**350**	**420**	**560**	630	700	100
120	252	**336**	**420**	**504**	672	756	(840)	120
140	294	**392**	**490**	**588**	784		(980)	140
160	336	**448**	**560**	672	896		(1120)	160
180	**378**	**504**	**630**	756			(1260)	180
200	**420**	**560**	700	840			(1400)	200
220	**462**	**616**	770	924			(1540)	220
240	**504**	**672**	840				(1680)	240
260	**546**	728	910				(1820)	260
280	**588**	784	980				(1960)	280
300	**630**	840					(2100)	300

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

Average spacing between rows (feet)	3 rows wide		4 rows wide	6 rows wide	9 rows wide
	Distance in yards along the rows for plot sizes				
	1/100th ac.	1/50th ac.	1/20th ac.	1/10th ac.	1/5th ac.
4	12	24	45½	60½	80½
4½	11	21½	40½	54	71½
5	10	19½	36½	48½	64½
5½	9	17½	33	44	58½
6	8	16	30	40½	54
6½	7½	15	28	37	49½
7	7	14	26	34½	46

NOTE: Doubling the number of rows doubles the plot area, and similarly halving the distances 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 yards for plot sizes				
	1/100th ac.	1/50th ac.	1/20th ac.	1/10th ac.	1/5th ac.
Circular: radius	4	5½	9	12½	17½
Square: sides	7	10	15½	22	31

Conversion table from average spacing to number of trees per acre

Spacing (feet)	No. Trees per acre	Spacing (feet)	No. Trees per acre	Spacing (feet)	No. Trees per acre
3 × 3	4840	7 × 7	889	11 × 11	360
3½ × 3½	3556	7 × 8	778		
		7½ × 7½	774	12 × 12	302
4 × 4	2722	7 × 9	691	12 × 15	242
4 × 5	2178			13 × 13	258
4½ × 4½	2151	8 × 8	681	14 × 14	222
4 × 6	1815	8 × 9	605	15 × 15	194
		8½ × 8½	603	16 × 16	170
5 × 5	1742	8 × 10	544	17 × 17	151
5 × 6	1452			18 × 18	134
5½ × 5½	1440	9 × 9	538	19 × 19	121
5 × 7	1245	9 × 10	483	20 × 20	109
		9½ × 9½	482	22 × 22	90
6 × 6	1210	9 × 12	403	24 × 24	76
6 × 7	1037			26 × 26	64
6½ × 6½	1031	10 × 10	436	28 × 28	56
6 × 8	908	10 × 12	363	30 × 30	48
6 × 9	807	10 × 15	290	35 × 35	36

Quality class/general yield class conversion table

SPECIES	QUALITY CLASS									
	I		II		III		IV		V	
Scots pine	140	(150)	120	(110)	80	(80)	60	(55)	—	—
Corsican pine	180	(185)	140	(150)	120	(115)	80	(85)	—	—
Lodgepole pine	120	(115)	100	(90)	60	(65)	(SP QC Curves)			
Sitka spruce	280	(285)	240	(245)	200	(210)	180	(175)	140	(140)
Norway spruce	200	(200)	160	(160)	120	(125)	100	(90)	—	—
European larch	120	(125)	100	(95)	80	(70)	60	(50)	40	(30)
Japanese and Hybrid larch	160	(170)	140	(140)	100	(110)	80	(80)	60	(55)
Douglas fir	260	(260)	220	(215)	180	(180)	140	(145)	120	(110)
Western hemlock	260	(260)	220	(220)	180	(185)	140	(150)	—	—
Red cedar and Lawson cypress	220	(230)	180	(180)	140	(145)	—	—	—	—
Grand fir	320	(325)	280	(280)	240	(240)	200	(200)	—	—
Noble fir	240	(230)	180	(180)	140	(135)	—	—	—	—
Oak	80	(80)	60	(65)	60	(50)	40	(40)	20	(30)
Beech	100	(100)	80	(80)	60	(65)	60	(50)	40	(40)
Sycamore	100	(110)	60	(70)	40	(40)	—	—	—	—
Ash	140	(145)	100	(100)	60	(65)	40	(40)	—	—

N.B. The yield class numbers in brackets provide a more precise conversion than is afforded by rounding to the nearest class.

Before-thinning basal areas for fully stocked stands

Basal areas in square feet quarter girth per acre

SPECIES	TOP HEIGHT (FEET)														
	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
Scots pine	91	89	89	93	98	104	111	118	125	133	140	148	155	—	—
Corsican pine	119	117	115	113	112	112	113	115	117	120	124	127	131	136	—
Lodgepole pine	—	110	107	105	104	103	104	105	106	107	109	111	114	—	—
Sitka spruce	114	115	116	117	118	119	120	122	124	127	130	133	137	141	144
Norway spruce	—	113	114	116	118	121	125	129	134	139	144	150	156	163	170
European larch	—	77	75	74	75	77	79	82	85	89	93	97	100	—	—
Japanese and Hybrid larch	75	75	76	77	78	79	81	83	86	89	92	95	98	—	—
Douglas fir	—	95	96	97	99	101	103	106	109	113	117	121	126	132	137
Western hemlock	—	113	118	120	121	122	123	124	125	127	129	131	133	135	138
Red cedar and Lawson cypress	—	—	168	170	172	176	181	187	193	200	208	216	224	233	242
Grand fir	—	—	133	133	133	133	133	133	134	136	138	141	145	150	155
Noble fir	—	—	155	156	158	160	162	164	167	170	174	179	184	189	—
Oak	—	82	80	78	77	78	79	81	83	85	87	89	—	—	—
Beech	70	68	70	74	78	83	87	92	97	102	107	112	117	122	127
Sycamore, Ash, Birch	—	53	53	56	61	69	78	88	98	108	128	—	—	—	—

N.B. 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.

ACKNOWLEDGEMENT

The constructive help of all those who commented on the contents and layout of this booklet is gratefully acknowledged, and it is hoped that many will recognise their own contribution to the form and content of the final version.

The development of the techniques has been very much a team effort but particular thanks are due to Messrs. W. T. Waters and G. Haggett.

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.
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 extent of the normal thinning life is indicated by the blue lines on the General Yield Class Curves on pages 10 to 24.

Outline Procedure

10. The normal thinning yield is determined as follows:

(1) **Measure the** *top height* **of the stand** (e.g. 55½ feet).

(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* 120).

(3) **Use the table of thinning yields** (page 1) **to find the** *volume per acre* **to be removed for this yield class for various thinning cycles** (e.g. 3 yrs 252 h.ft, 4 yrs 336, 5 yrs 420, etc.).

Control (but see paras. 52-65 for further details)

11. The next stage is to decide whether the stand is to be thinned or not and, if so, on what cycle. For example: the thinning yield to aim at on the basis of a 5 year cycle would, under normal conditions, be 420 hoppus feet per acre. 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 girths of a sample of the marked trees and determine their average volume, using the top height volume table** (page 32) (e.g. BHQG 6½ inches, top height 55 ft., volume 7.03 h.ft.).

(6) **Estimate the number of thinnings per acre from their average spacing, or by counting the number of marked trees on a plot of known area** (e.g. av. spacing 24 ft., i.e. 76 trees per acre).

(7) **Multiply the number of thinnings per acre by their average volume** (using the alignment chart) (page 31) **to obtain the total volume per acre marked** (e.g. 76 x 7.03 = 530 h.ft/ac.).

(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 530 h.ft/ac. to 420, reduce the number of thinnings to 60 per acre, i.e. 60 x 7 = 420, or to 65 with a reduced girth of 6¼ins., i.e. 65 x 6.44 = 420).

(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. The *Yield Class* system of classifying rate of growth replaces the old Quality Class system but, despite their different bases, it is possible to convert Quality Class into Yield Class and *vice versa* (see the conversion table on page 3).
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 is *top height*, which is defined as the average height of the 40 trees of largest girth per acre. 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 largest tree 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 £8, 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).
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 10 hoppus feet (e.g. SP 50 yrs., 60 ft. yield class 130).
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. Once a yield class has been allocated it should not need to be re-assessed for 10 years.

[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 as current volume increment falls below mean annual increment with increasing age.

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 1/20 acre plots (radius 9 yds.), and when there are three or four main species use 1/10 acre plots (radius 12½ yds.), measuring the largest girthed 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 140, 60 and 100 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 108 which rounds to yield class 110.)

Stands of uneven age

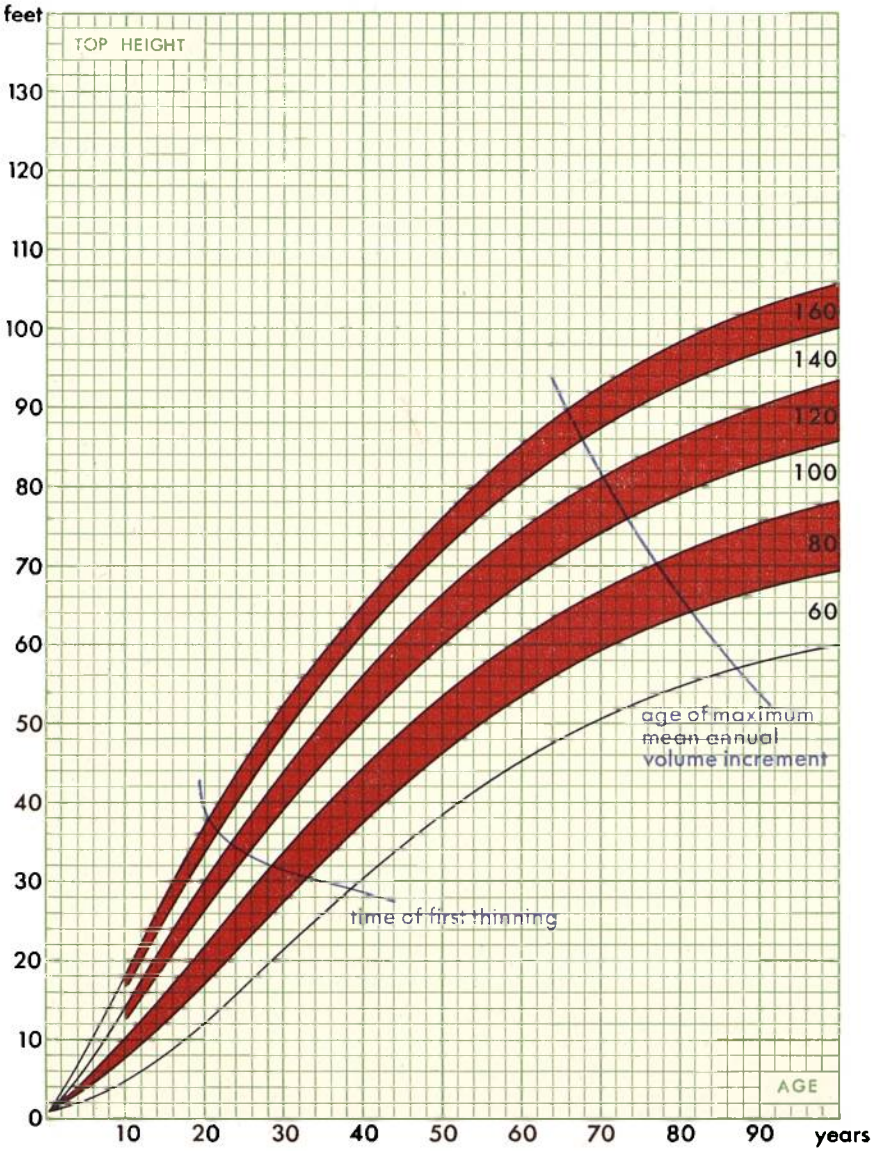
28. Two-storied or all-aged stands can be allocated a yield class by treating each age category separately, then averaging the yield classes or, in situations where the range of ages is not too great, by using an average age. In determining the average age and yield class the various age categories should 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 3 feet (these facts can usually be estimated from whorl counts) and the present age and height are 40 yrs. and 35 ft., the values to use in determining yield class are 30 years and 32 feet).

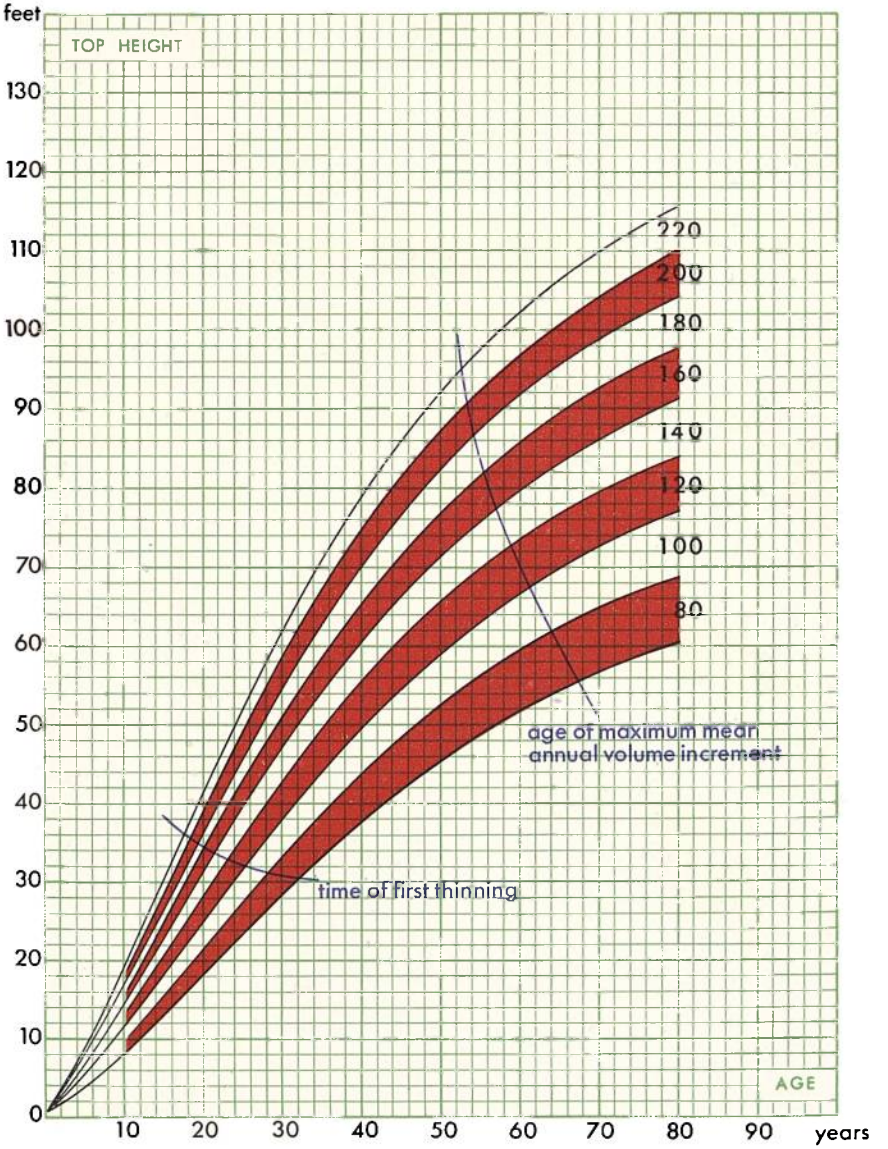
SCOTS PINE

GENERAL YIELD CLASS CURVES



CORSICAN PINE

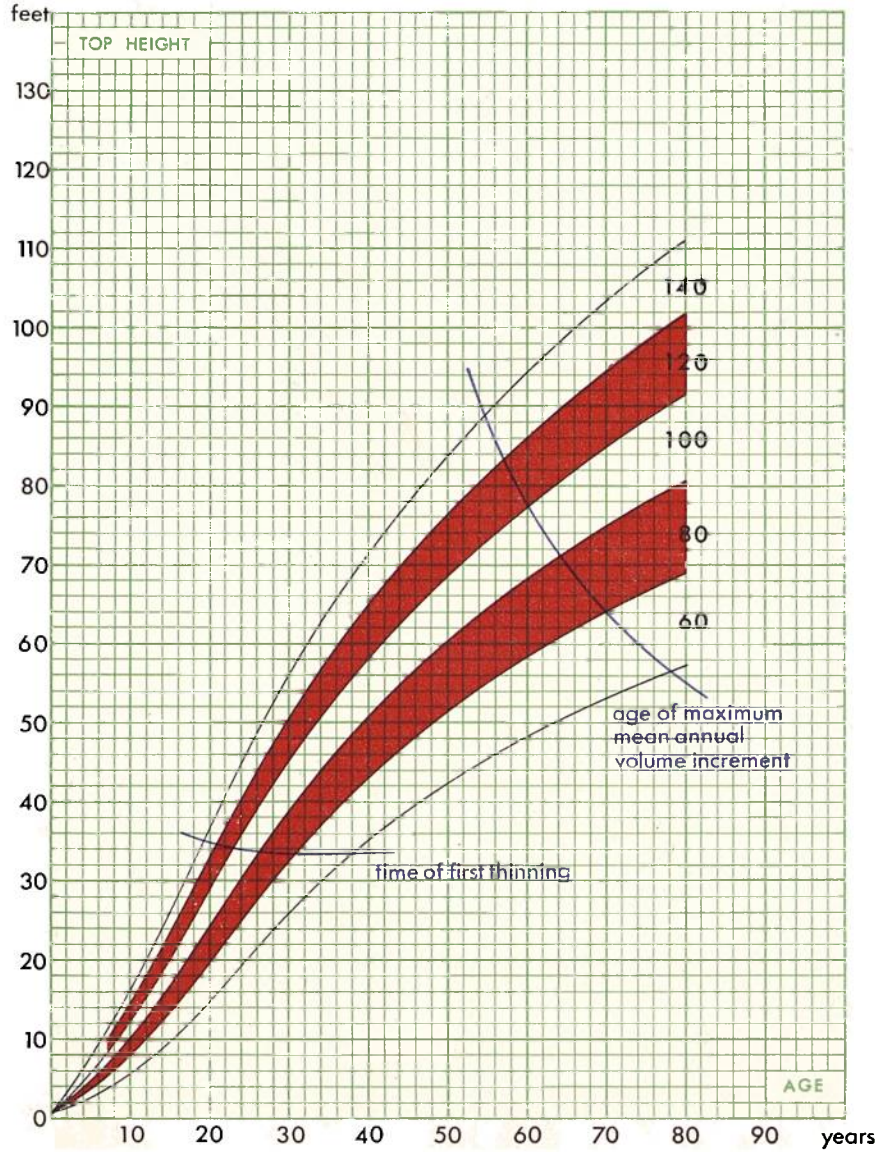
GENERAL YIELD CLASS CURVES



LP LP

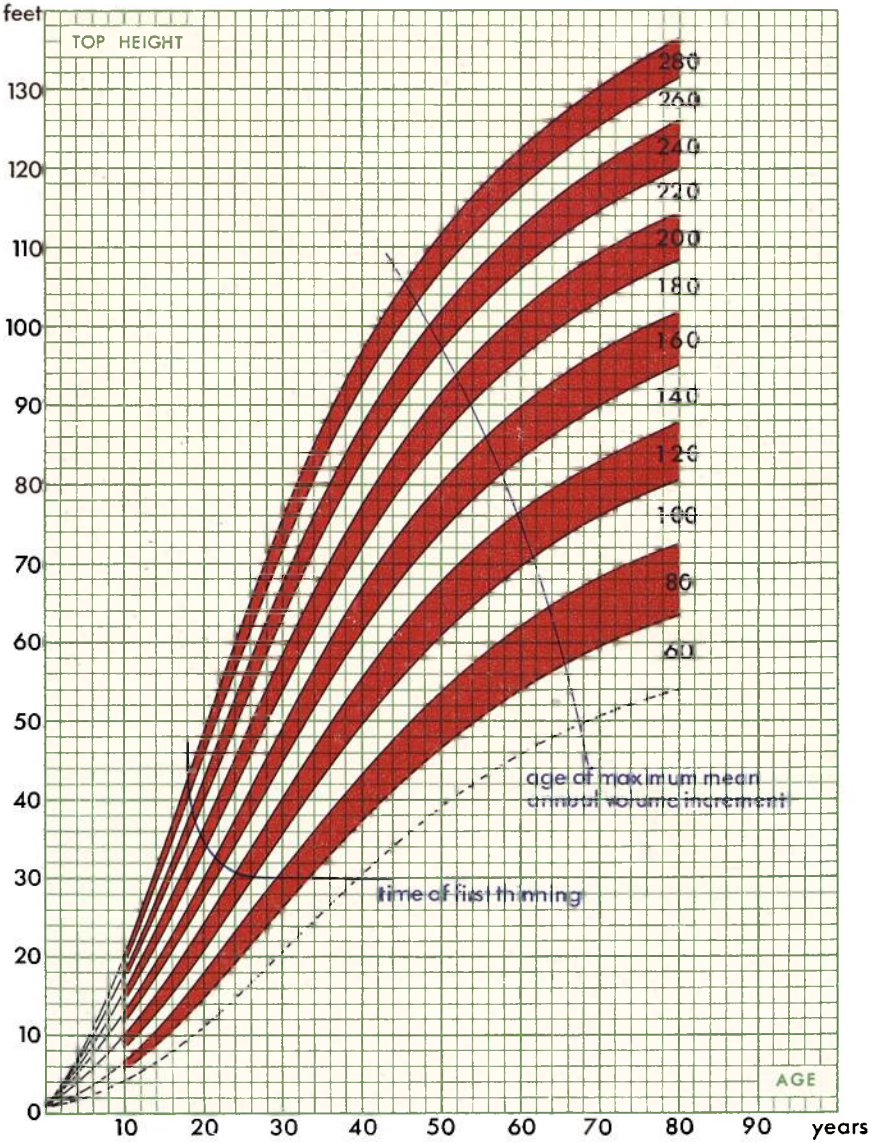
LODGEPOLE PINE

GENERAL YIELD CLASS CURVES



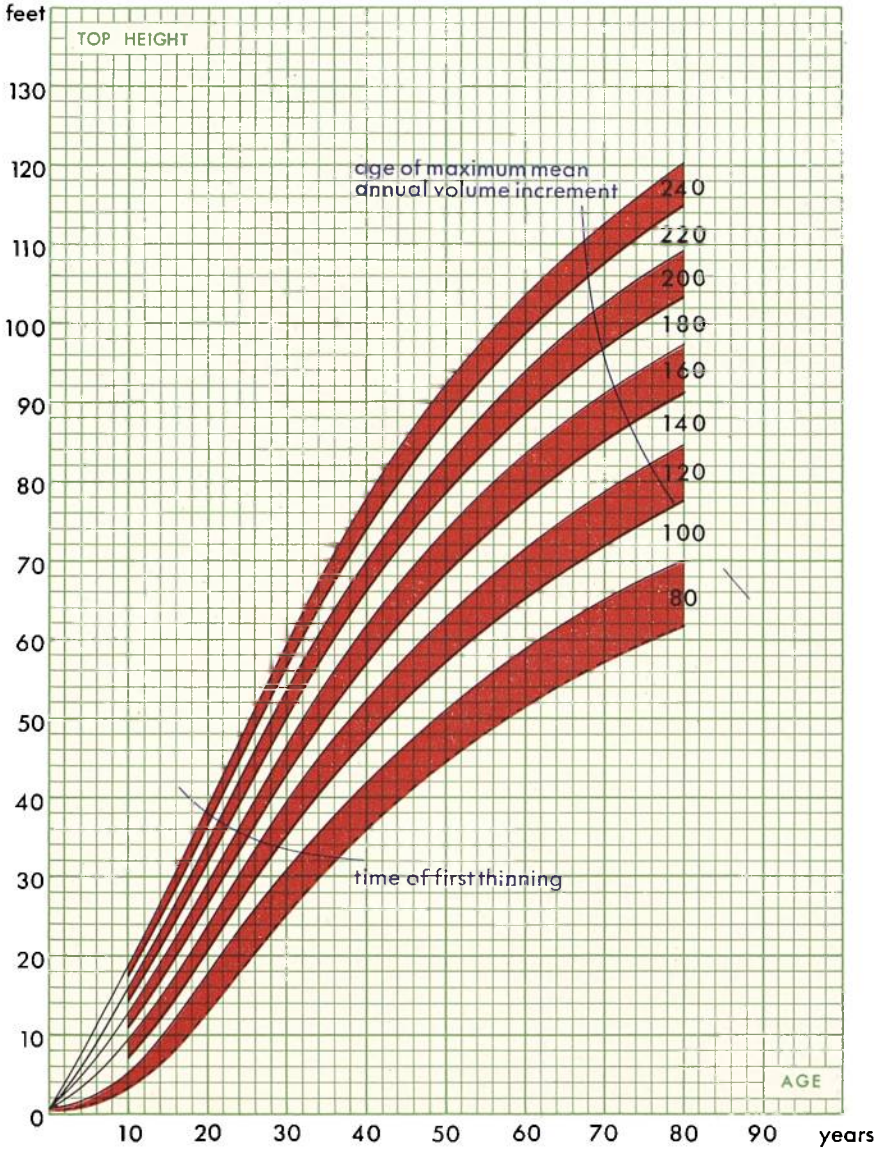
SITKA SPRUCE

GENERAL YIELD CLASS CURVES



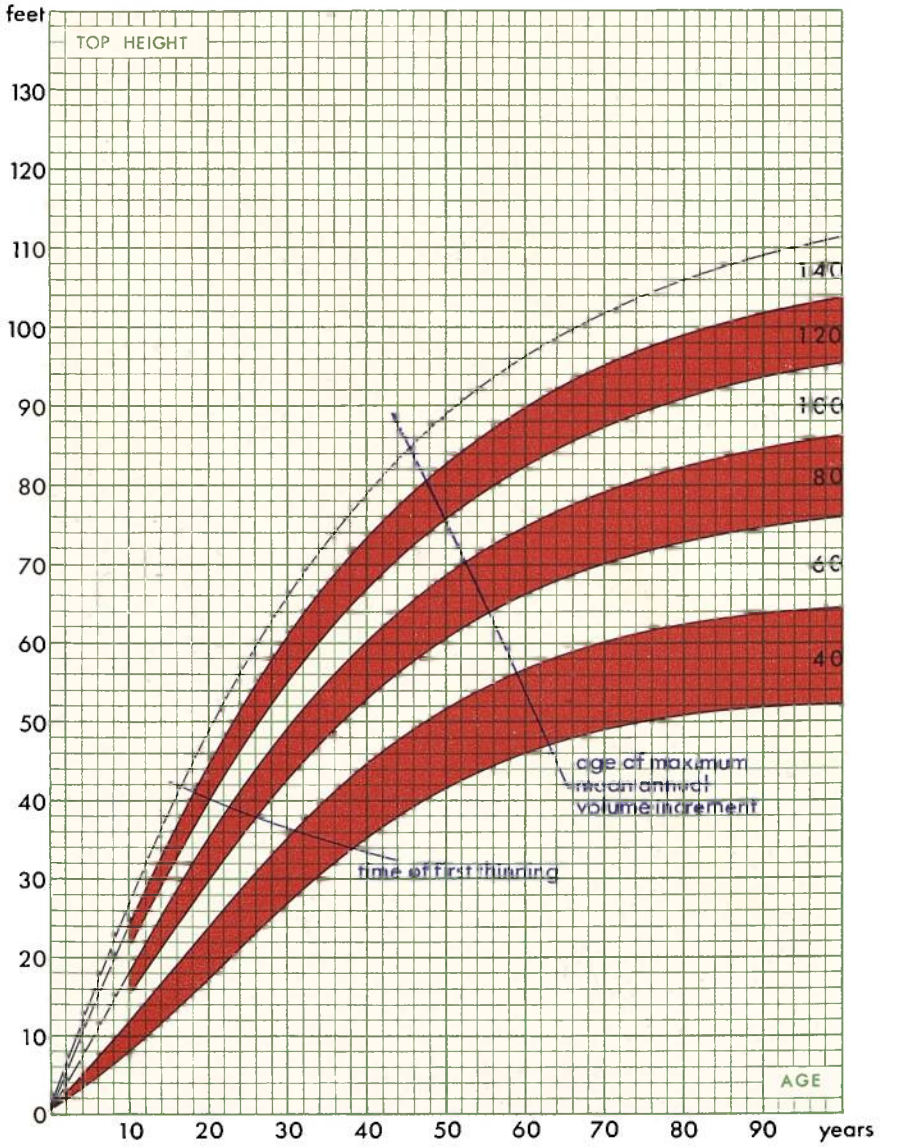
NORWAY SPRUCE

GENERAL YIELD CLASS CURVES



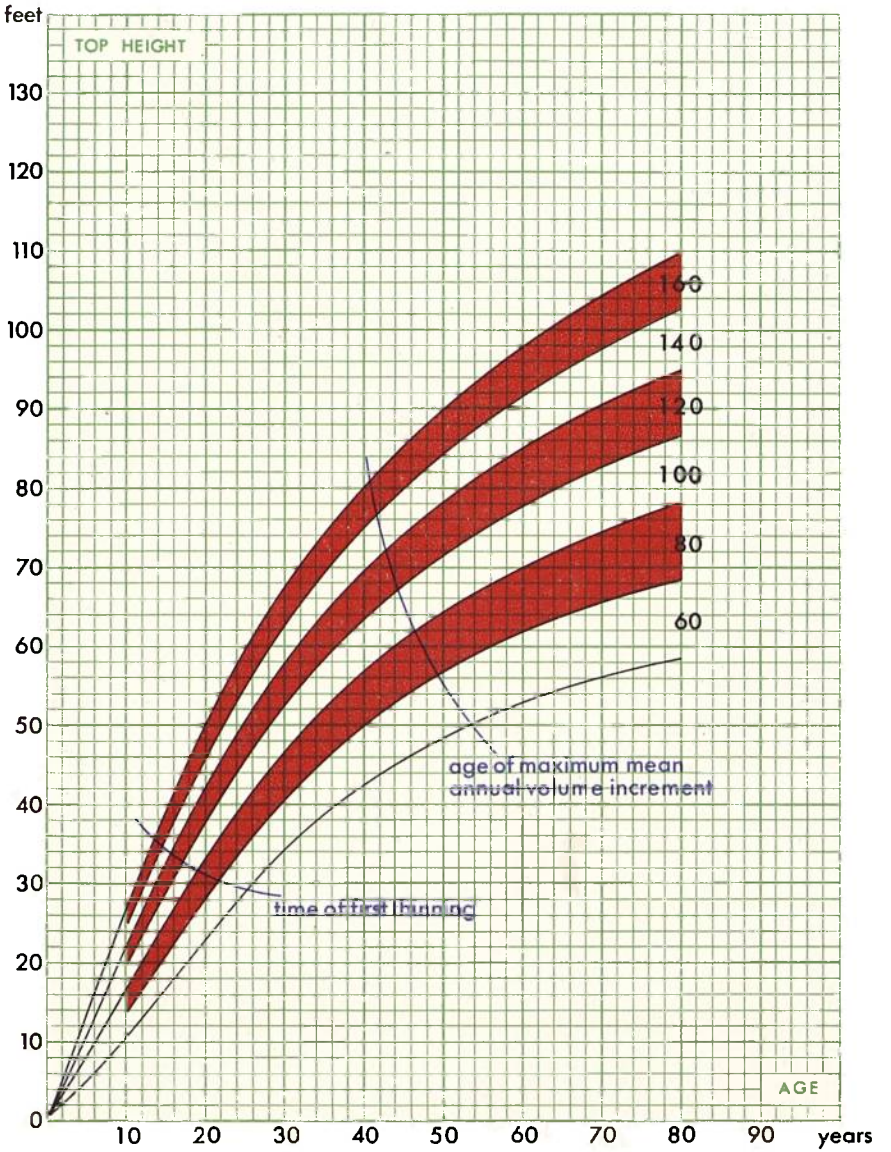
EUROPEAN LARCH

GENERAL YIELD CLASS CURVES



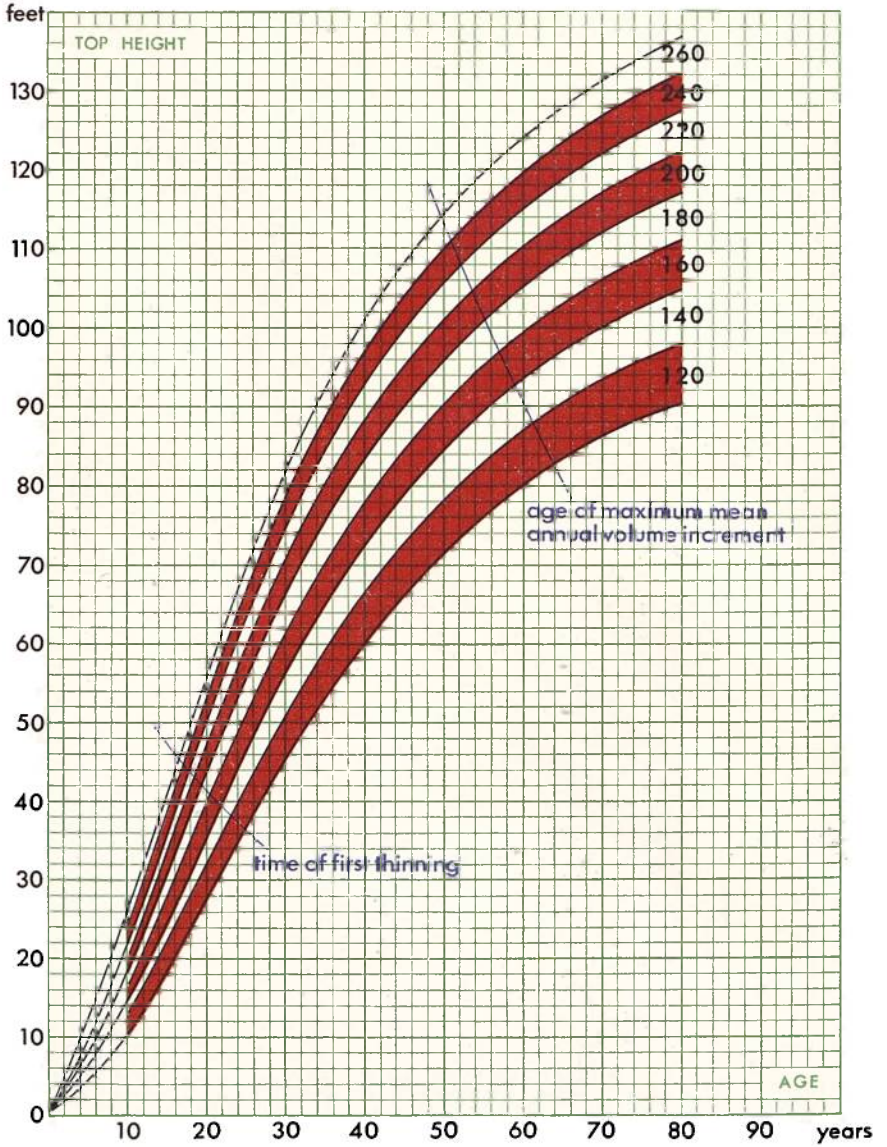
JAPANESE LARCH

GENERAL YIELD CLASS CURVES



DOUGLAS FIR

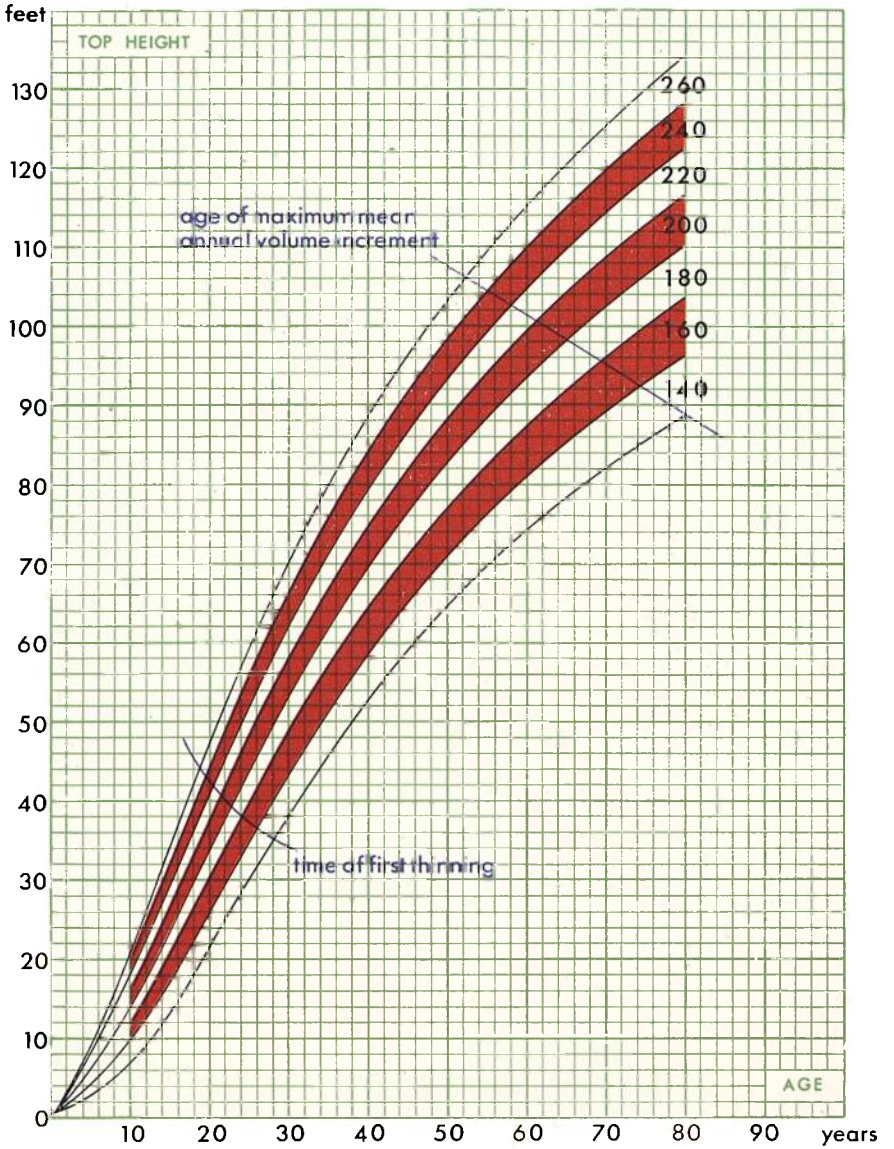
GENERAL YIELD CLASS CURVES



WH

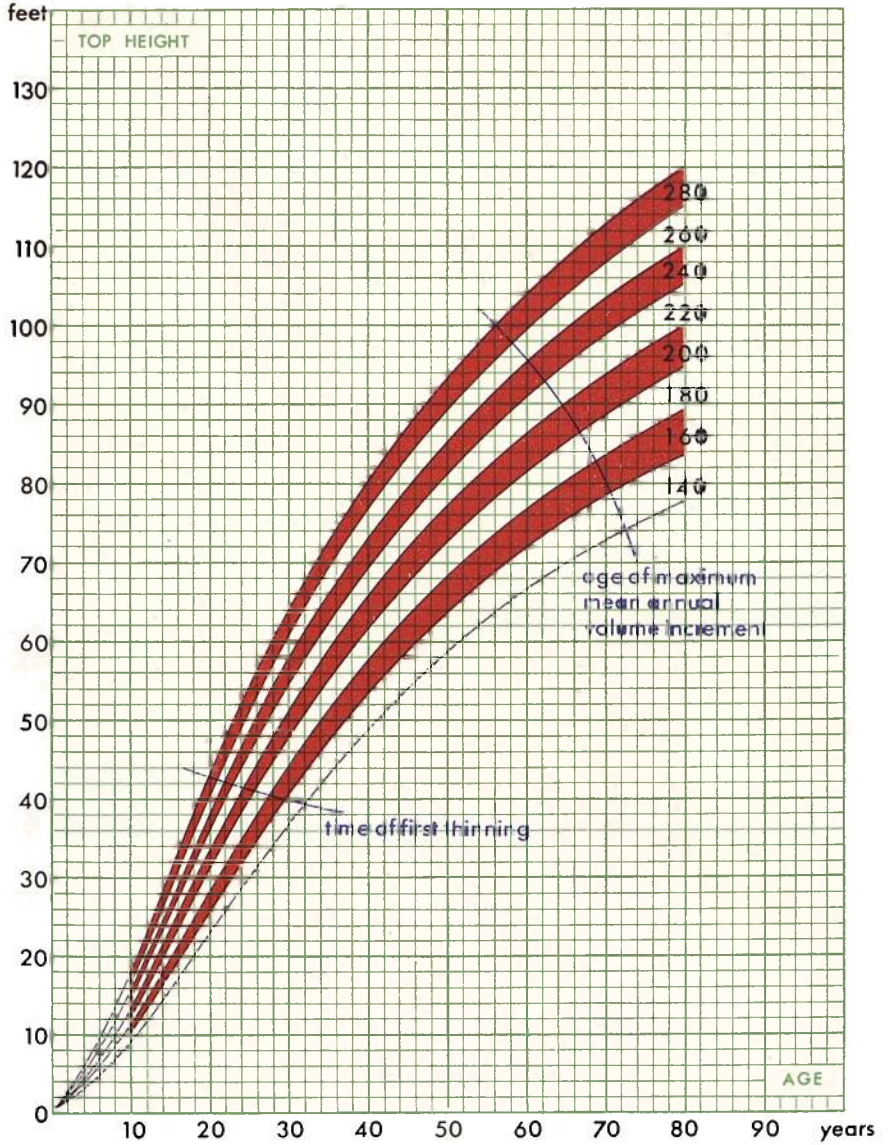
WESTERN HEMLOCK

GENERAL YIELD CLASS CURVES



RED CEDAR

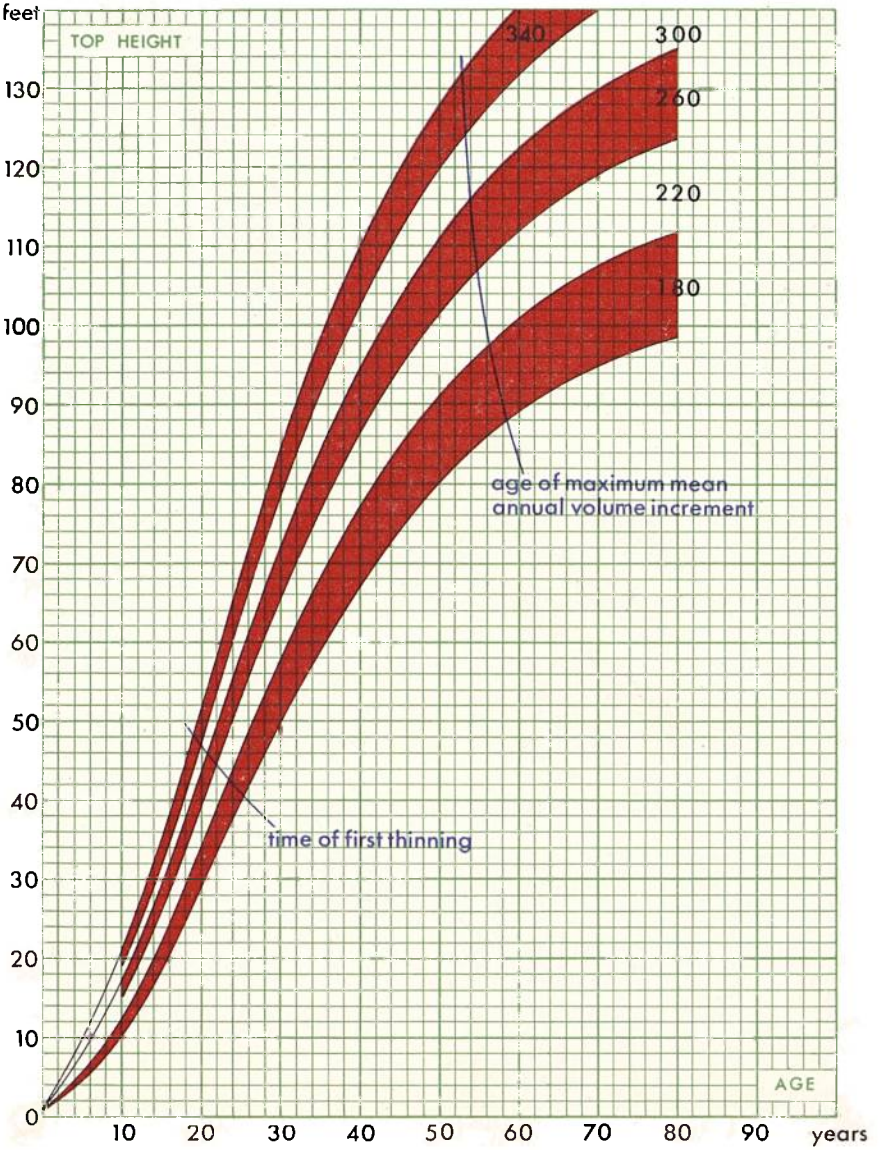
GENERAL YIELD CLASS CURVES



GF

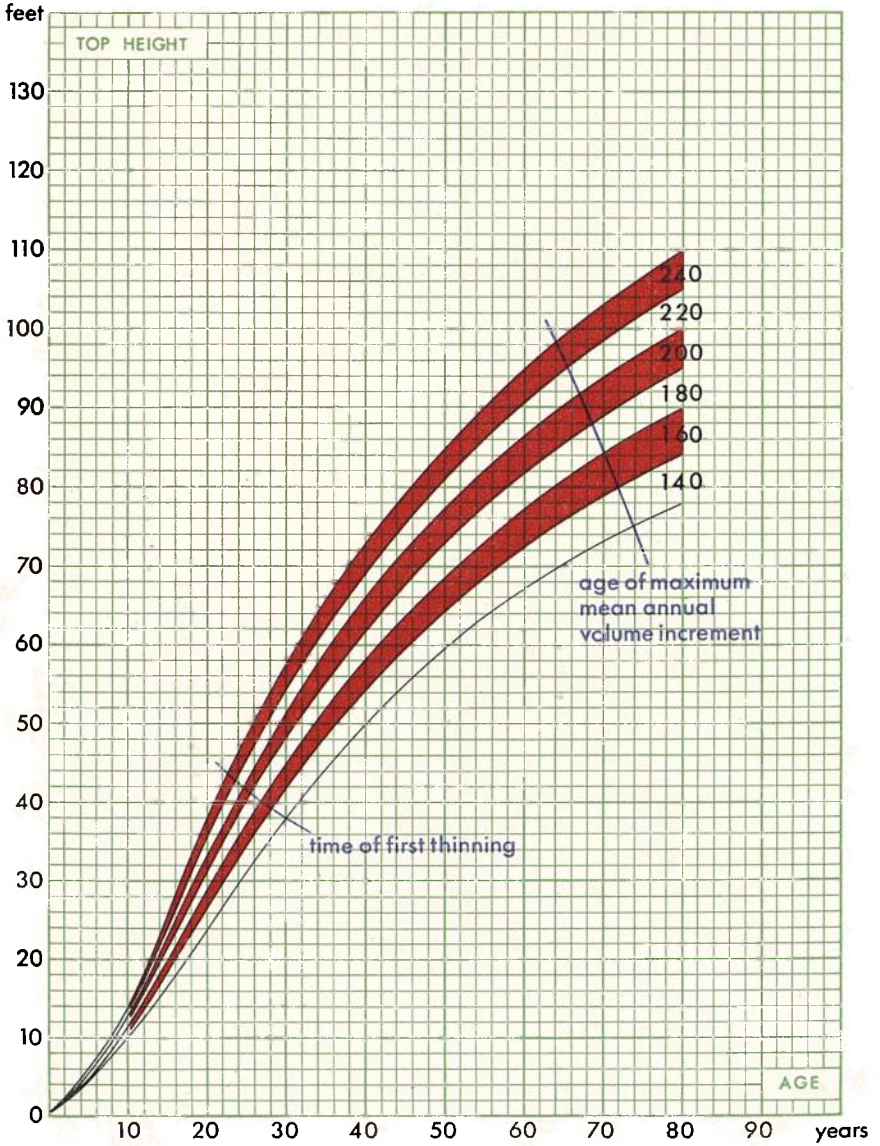
GRAND FIR

GENERAL YIELD CLASS CURVES



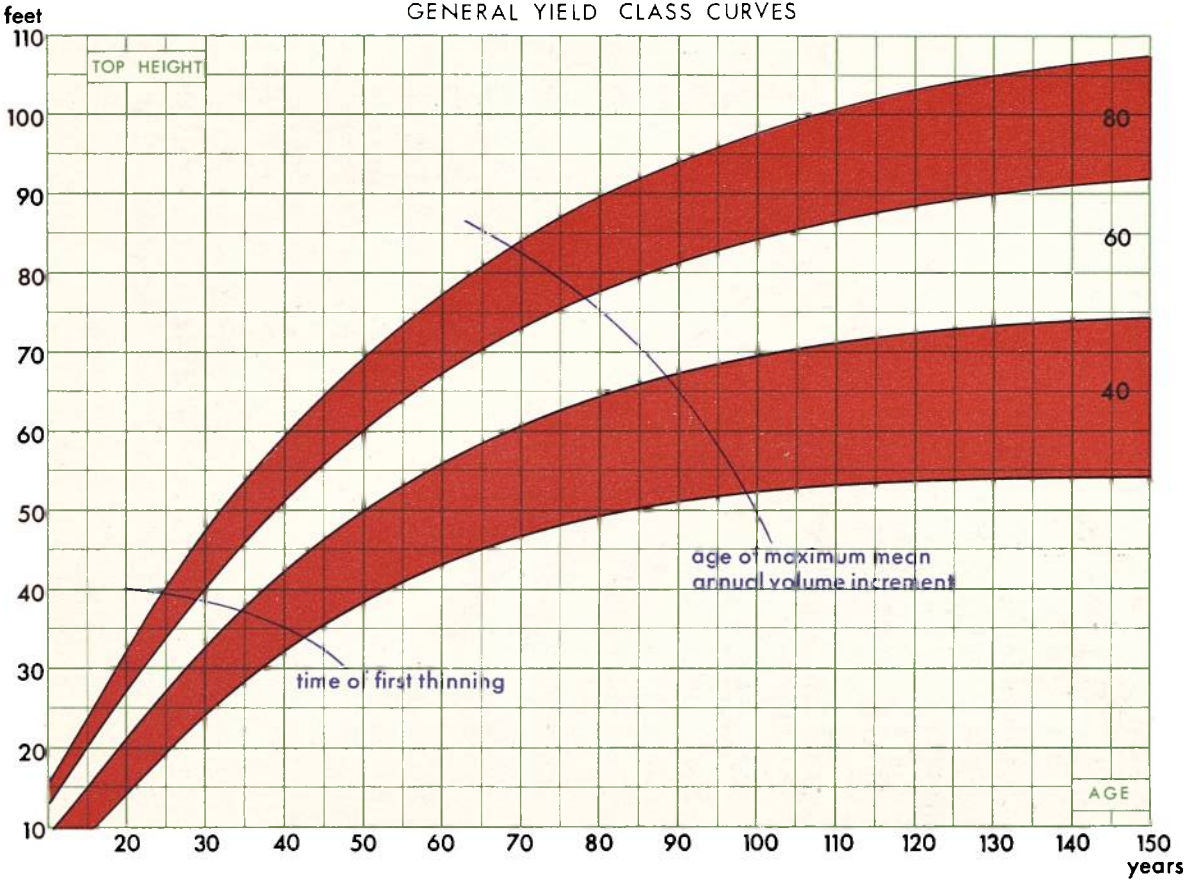
NOBLE FIR

GENERAL YIELD CLASS CURVES



OAK

GENERAL YIELD CLASS CURVES

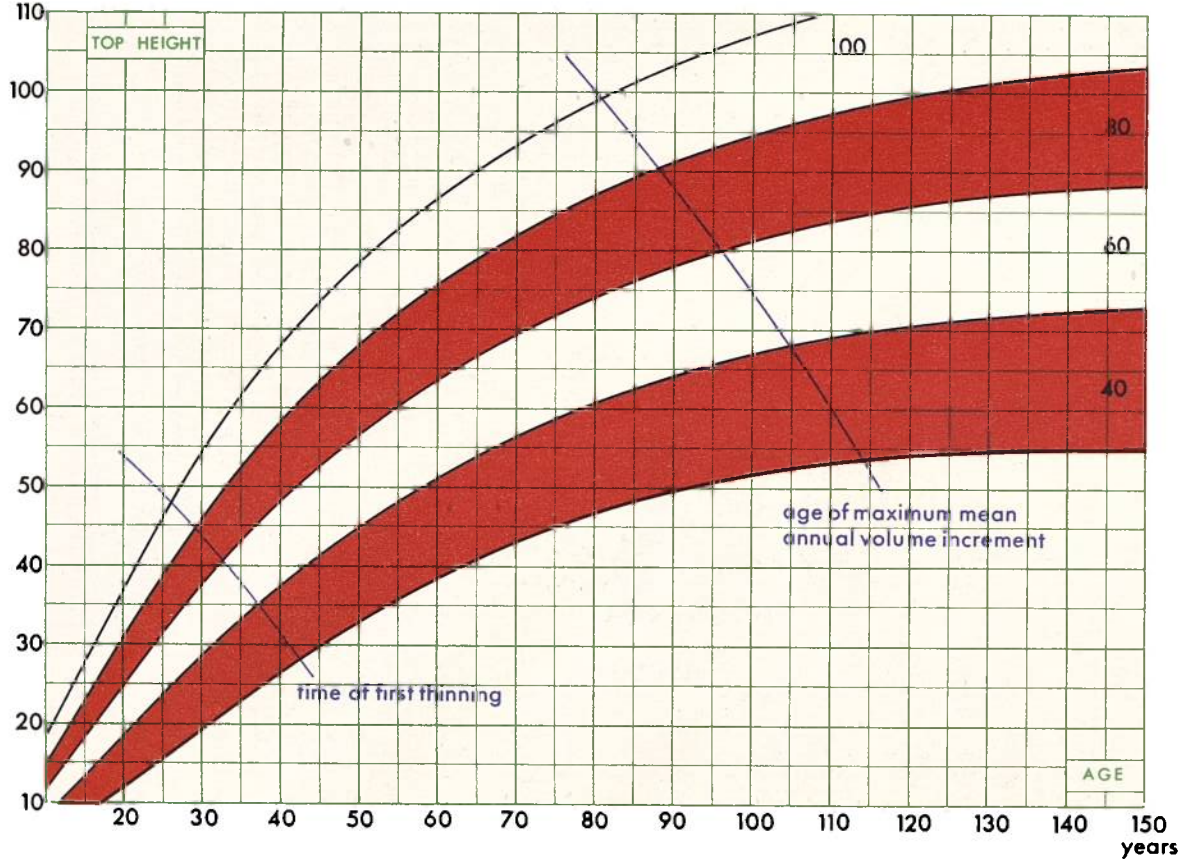


OAK

OAK

BEECH

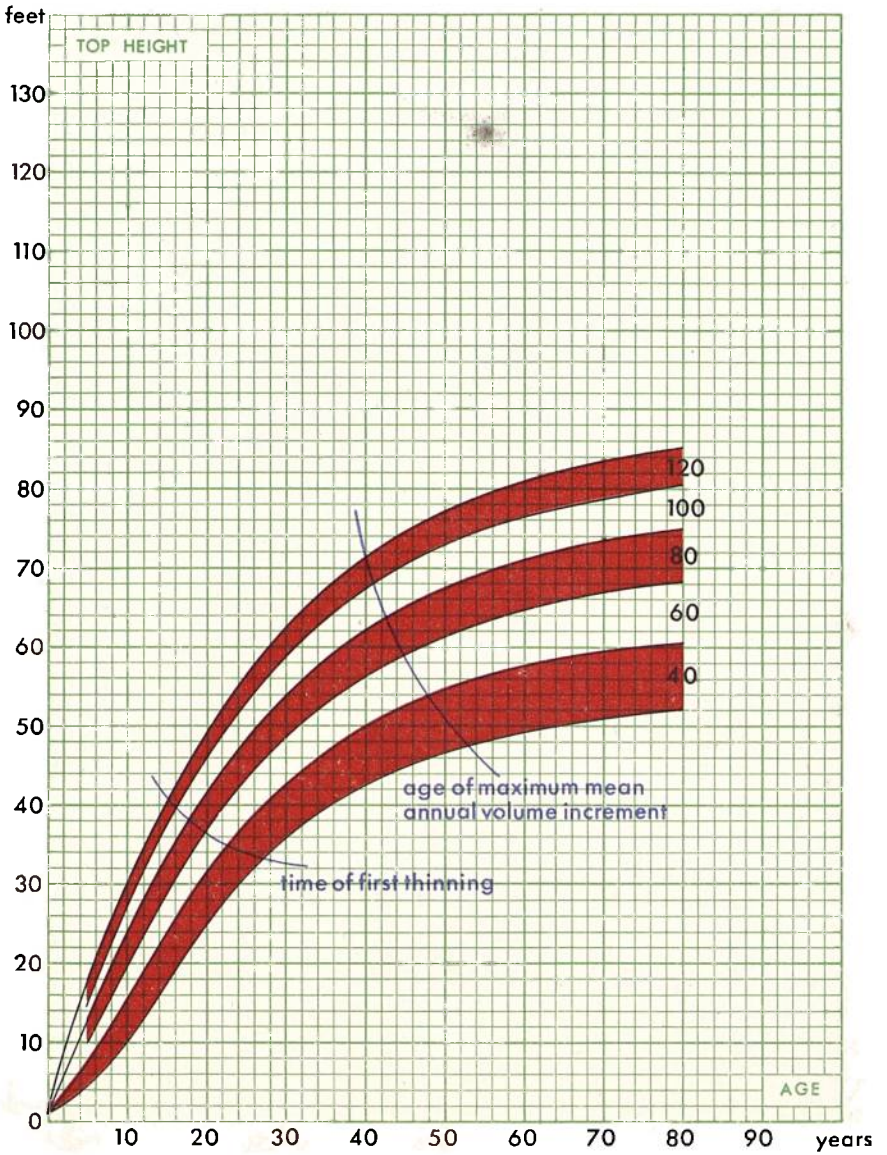
GENERAL YIELD CLASS CURVES



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, which is defined by the blue lines on the GENERAL YIELD CLASS CURVES. During the normal thinning life, the annual thinning yield for fully stocked stands is equal to 70% of the yield class value. (This annual yield is obtained by dividing the yields for a 10-year cycle in the table of normal thinning yields by 10, e.g. YC 100, 700/10=70 h.ft./acre, or 70% of 100.)

31. The annual yield is converted into a thinning yield by multiplying by the number of years before the stand is to be thinned again, i.e. by the thinning cycle (e.g. for YC 100 the annual yield is 70 h.ft. and the thinning yield on a 5-year cycle is 350 h.ft./acre).

Time of first thinning

32. The times of first thinning indicated by the blue line on the height/age 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, but the annual thinning yield will usually have to be reduced. Reduced early yields are provided in the more detailed thinning control tables published as part of the Forest Management Tables[1], but a convenient rule of thumb is to reduce the yield by 15% for every year by which the normal time of first thinning is anticipated.

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 acre 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 heavier 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.

[1]Forestry Commission Booklet No. 16, HMSO 1966, 30s.

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 them again. (See table on page 3 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 acreages which include roads, rides and other non-productive areas must be reduced to a net acreage which excludes such areas, before a volume per acre can be calculated for purposes of thinning control.

48. It would have been possible, as has been done in the Forecasting Tables, to base the system on gross acreages which include an average allowance for unproductive area. 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 acreages 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* acre, 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* acre.

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.

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 acre 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 acre.

Methods of sampling

53. Both the number of thinnings per acre 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 acre 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 acre

54. The tables on page 2 can be used to convert the average spacing between thinnings into the number per acre 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 acre to be able to use small plots, circular plots will usually be best; but where the size is 1/10 acre 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 of 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 times the denominator of the plot size, will give the number per acre (e.g. 7 trees in a plot of 1/20 acre would represent 140 per acre).

Average spacing of thinning

59. If the number of thinnings per acre 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 volume

60. The average volume of the thinnings can be estimated by averaging the volume of a number of thinnings (a) of all sizes or (b) all of which are of about average girth. The average girth, however, must allow for the fact that the larger trees have a volume which is more than proportional to their girth. The average girth when weighted by volume is termed the *mean* girth.

Estimating mean girth

61. The mean girth can be estimated by girthing a number of thinnings and taking the girth of the tree which falls 40% from the large end of the distribution (e.g. 8 7¼ 6¾ 6½ 6½ 6¼ 6 5¾ 5½ 5 gives a mean of 6½) or, less reliably, by measuring only the smallest and largest thinnings and multiplying the girth of the former by 6 and of the latter by 4, adding the products and dividing by 10 (e.g. $5\times6)+(8\times4)=30+32=62$ which when divided by 10 is 6·2, or 6¼ to the nearest quarter-inch).

Calculating tree volume

62. The volume of a tree can be calculated (a) by using hoppus tables to convert the girth at mid length into cross sectional area, and then to multiply this by the timber length (e.g. the table on page 30 for a *mid girth* of 4¾ and a length of 45 feet gives a volume of 6·27 for 40 feet, +0·78 for 5 feet, or a total of 7·05 h.ft.) or (b) by using the TOP HEIGHT VOLUME TABLE on the back cover which for a *breast height* girth of 6½ inches gives a volume of 7·03 h.ft. for a stand with a top height of 55 feet (this will be known either because it has been measured to determine yield class or can be found if yield class and age are known, by reading off the coloured height/age curves in reverse).

63. The use of the top height volume table avoids the need to estimate either mid girth or timber length, and it can also be used to avoid the possibility of error in estimating mean girth. The technique is to look up the volume for each girth which is measured, then to average these volumes directly (e.g. for the girths in para. 61 assuming a top height of 55 feet, 11·1, 8·95, 7·65, 7·03, 7·03, 6·44, 5·87, 5·33, 4·81, 3·83, giving a total of 68·04 and an average volume of 6·8 h.ft. which is, incidentally, equivalent to a mean girth of just under 6½).

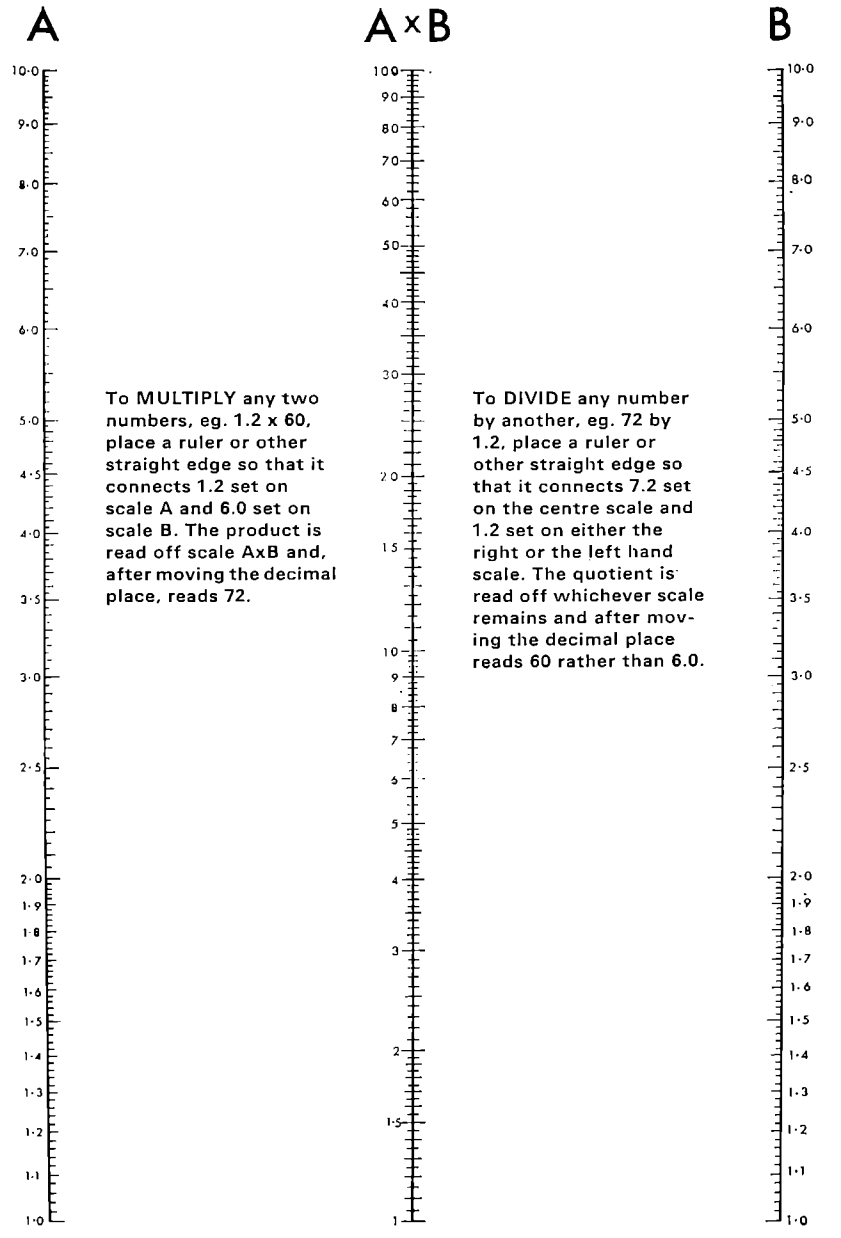
64. The method can be further improved if the volumes for a given top height are occasionally checked against the felled volume of thinnings from such crops to obtain a correction factor for local conditions. Those familiar with the tariff method will recognise that the volume table is based on the tariff tables (e.g. the volumes for a top height of 75 ft. are the same* as those for a tariff number of 33). The tariff number assumed is given by the volume for a BHQG of 12 inches, so that if the tariff number is known from experience with similar crops the volume table can be used as a tariff table. (*the minor rounding errors can be ignored)

Average volume yield

65. 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.

Abbreviated hoppus table

Quarter Girth (inches)	Volumes or basal areas for lengths in feet or numbers of trees										Quarter Girth (inches)
	1	2	3	4	5	6	7	8	9	10	
2	0·043	0·087	0·130	0·174	0·217	0·260	0·304	0·347	0·391	0·434	2
2 1/4	0·053	0·105	0·158	0·210	0·263	0·315	0·368	0·420	0·473	0·525	2 1/4
3	0·063	0·125	0·188	0·250	0·313	0·375	0·438	0·500	0·563	0·625	3
1/4	0·073	0·147	0·220	0·293	0·367	0·440	0·513	0·587	0·660	0·734	1/4
1/2	0·085	0·170	0·255	0·340	0·425	0·510	0·595	0·681	0·766	0·851	1/2
3/4	0·098	0·195	0·293	0·391	0·488	0·586	0·684	0·781	0·879	0·977	3/4
4	0·111	0·222	0·333	0·444	0·556	0·667	0·778	0·889	1·000	1·111	4
1/4	0·125	0·251	0·376	0·502	0·627	0·753	0·878	1·003	1·129	1·254	1/4
1/2	0·141	0·281	0·422	0·563	0·703	0·844	0·984	1·125	1·266	1·406	1/2
3/4	0·157	0·313	0·470	0·627	0·783	0·940	1·097	1·253	1·410	1·567	3/4
5	0·174	0·347	0·521	0·694	0·868	1·042	1·215	1·389	1·563	1·736	5
1/4	0·191	0·383	0·574	0·766	0·957	1·148	1·340	1·531	1·723	1·914	1/4
1/2	0·210	0·420	0·630	0·840	1·050	1·260	1·470	1·681	1·891	2·101	1/2
3/4	0·230	0·459	0·689	0·918	1·148	1·378	1·607	1·837	2·066	2·296	3/4
6	0·250	0·500	0·750	1·000	1·250	1·500	1·750	2·000	2·250	2·500	6
1/4	0·271	0·543	0·814	1·085	1·356	1·628	1·899	2·170	2·441	2·713	1/4
1/2	0·293	0·587	0·880	1·174	1·467	1·760	2·054	2·347	2·641	2·934	1/2
3/4	0·316	0·633	0·949	1·266	1·582	1·898	2·215	2·531	2·848	3·164	3/4
7	0·340	0·681	1·021	1·361	1·701	2·042	2·382	2·722	3·063	3·403	7
1/4	0·365	0·730	1·095	1·460	1·825	2·190	2·555	2·920	3·285	3·650	1/4
1/2	0·391	0·781	1·172	1·563	1·953	2·344	2·734	3·125	3·516	3·906	1/2
3/4	0·417	0·834	1·251	1·668	2·086	2·503	2·920	3·337	3·754	4·171	3/4
8	0·444	0·889	1·333	1·778	2·222	2·667	3·111	3·556	4·000	4·444	8
1/4	0·473	0·945	1·418	1·891	2·363	2·836	3·309	3·781	4·254	4·727	1/4
1/2	0·502	1·003	1·505	2·007	2·509	3·010	3·512	4·014	4·516	5·017	1/2
3/4	0·532	1·063	1·595	2·127	2·658	3·190	3·722	4·253	4·785	5·317	3/4
9	0·563	1·125	1·688	2·250	2·813	3·375	3·938	4·500	5·063	5·625	9
1/4	0·594	1·188	1·783	2·377	2·971	3·565	4·159	4·753	5·348	5·942	1/4
1/2	0·627	1·253	1·880	2·507	3·134	3·760	4·387	5·014	5·641	6·267	1/2
3/4	0·660	1·320	1·980	2·641	3·301	3·961	4·621	5·281	5·941	6·602	3/4
10	0·694	1·389	2·083	2·778	3·472	4·167	4·861	5·556	6·250	6·944	10
1/4	0·730	1·459	2·189	2·918	3·648	4·378	5·107	5·837	6·566	7·296	1/4
1/2	0·766	1·531	2·297	3·063	3·828	4·594	5·359	6·125	6·891	7·656	1/2
3/4	0·803	1·605	2·408	3·210	4·013	4·815	5·618	6·420	7·223	8·025	3/4
11	0·840	1·681	2·521	3·361	4·201	5·042	5·882	6·722	7·563	8·403	11
1/4	0·879	1·758	2·637	3·516	4·395	5·273	6·152	7·031	7·910	8·789	1/4
1/2	0·918	1·837	2·755	3·674	4·592	5·510	6·429	7·347	8·266	9·184	1/2
3/4	0·959	1·918	2·876	3·835	4·794	5·753	6·711	7·670	8·629	9·588	3/4
12	1·00	2·00	3·00	4·00	5·00	6·00	7·00	8·00	9·00	10·00	12



ALIGNMENT CHART

Top Height Volume Table for Thinnings

B.H.Q.G. (Inches)	Volumes in Hoppus Feet Over Bark (to 3 ins. top diam. o.b.)													B.H.Q.G. (Inches)
	Top Height in Feet (av. ht. 40 largest girthed trees/ac.)													
	30	35	40	45	50	55	60	65	70	75	80	85	90	
2½	0·24	0·27	0·29	0·31	0·33	0·36	0·38							2½
2¾	0·41	0·45	0·48	0·52	0·56	0·60	0·64	0·68						2¾
3	0·59	0·64	0·70	0·75	0·81	0·87	0·92	0·98						3
3¼	0·79	0·86	0·93	1·01	1·08	1·16	1·23	1·31	1·39					3¼
3½	1·00	1·09	1·18	1·28	1·37	1·47	1·57	1·67	1·77					3½
3¾	1·23	1·34	1·45	1·57	1·69	1·81	1·93	2·05	2·18	2·30				3¾
4	1·47	1·61	1·74	1·88	2·02	2·17	2·31	2·46	2·61	2·76				4
4¼	1·73	1·89	2·05	2·21	2·38	2·55	2·72	2·89	3·07	3·25				4¼
4½	2·01	2·19	2·37	2·57	2·76	2·95	3·15	3·35	3·56	3·76	3·97			4½
4¾	2·30	2·51	2·72	2·94	3·16	3·38	3·60	3·84	4·07	4·31	4·54			4¾
5	2·61	2·84	3·08	3·33	3·58	3·83	4·09	4·35	4·62	4·89	5·15			5
5¼	2·93	3·19	3·46	3·74	4·03	4·31	4·59	4·89	5·19	5·49	5·79	6·09		5¼
5½	3·27	3·56	3·86	4·18	4·49	4·81	5·12	5·46	5·79	6·13	6·46	6·79		5½
5¾	3·62	3·95	4·28	4·63	4·98	5·33	5·68	6·05	6·42	6·79	7·16	7·53		5¾
6	3·99	4·35	4·72	5·10	5·49	5·87	6·26	6·67	7·08	7·48	7·89	8·30	8·71	6
6¼	4·38	4·78	5·17	5·60	6·02	6·44	6·86	7·31	7·76	8·21	8·66	9·10	9·55	6¼
6½	4·78	5·21	5·65	6·11	6·57	7·03	7·49	7·98	8·47	8·96	9·45	9·94	10·4	6½
6¾	5·20	5·67	6·14	6·64	7·15	7·65	8·15	8·68	9·21	9·74	10·3	10·8	11·3	6¾
7		6·14	6·65	7·20	7·74	8·28	8·83	9·40	9·98	10·6	11·1	11·7	12·3	7
7¼		6·63	7·18	7·77	8·36	8·95	9·53	10·2	10·8	11·4	12·0	12·6	13·3	7¼
7½		7·14	7·73	8·37	9·00	9·63	10·3	10·9	11·6	12·3	12·9	13·6	14·3	7½
7¾		7·66	8·30	8·98	9·66	10·3	11·0	11·7	12·5	13·2	13·9	14·6	15·3	7¾
8			8·89	9·61	10·3	11·1	11·8	12·6	13·3	14·1	14·9	15·6	16·4	8
8¼			9·49	10·3	11·0	11·8	12·6	13·4	14·2	15·1	15·9	16·7	17·5	8¼
8½			10·1	10·9	11·8	12·6	13·4	14·3	15·2	16·0	16·9	17·8	18·7	8½
8¾			10·8	11·6	12·5	13·4	14·3	15·2	16·1	17·1	18·0	18·9	19·9	8¾
9				12·4	13·3	14·2	15·2	16·1	17·1	18·1	19·1	20·1	21·1	9
9¼				13·1	14·1	15·1	16·1	17·1	18·1	19·2	20·2	21·3	22·3	9¼
9½				13·8	14·9	15·9	17·0	18·1	19·2	20·3	21·4	22·5	23·6	9½
9¾				14·6	15·7	16·8	17·9	19·1	20·3	21·4	22·6	23·8	24·9	9¾
10					16·6	17·7	18·9	20·1	21·4	22·6	23·8	25·1	26·3	10
10¼					17·5	18·7	19·9	21·2	22·5	23·8	25·1	26·4	27·7	10¼
10½					18·4	19·6	20·9	22·3	23·7	25·0	26·4	27·8	29·1	10½
10¾					19·3	20·6	22·0	23·4	24·8	26·3	27·7	29·1	30·6	10¾
11						21·6	23·1	24·6	26·1	27·6	29·1	30·6	32·1	11
11¼						22·7	24·2	25·7	27·3	28·9	30·5	32·0	33·6	11¼
11½						23·7	25·3	26·9	28·6	30·2	31·9	33·5	35·2	11½
11¾						24·8	26·4	28·2	29·9	31·6	33·3	35·0	36·8	11¾
12	17·6	19·2	20·8	22·5	24·2	25·9	27·6	29·4	31·2	33·0	34·8	36·6	38·4	12

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