The Influence of Tree Spacing on Sitka Spruce Growth

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INTRODUCTION

In spite of a long history of forestry practice there is surprisingly little known about many of the fundamental relationships between tree growth and the growing space per tree. In Northern Ireland Sitka spruce is the most important single species, but it is often planted on sites where ground conditions make thinning extraction, without causing damage, a very costly operation. There is accordingly very considerable interest in growth development without thinning for this species with particular regard for the effects on individual tree size and gross increment.

As experiments starting from date of planting and attempting to determine these relationships would take a long time to produce results, it was felt that the process could be speeded up by starting with an existing plantation. The experiment was, therefore, started in 1960 on a stand of Sitka spruce planted in 1949. At 12 years of age the crop was approximately 4 m mean height and the side branches of the lower whorls were almost but not generally touching. The ground was virtually 100% covered with Polytrichum moss. It was hoped that the plants were sufficiently widely spaced (approximately 1.83 m or 6 ft.) that there had been no competition between individual trees at the commencement of the experiment. It was decided to use this area which was reasonably fast growing and appeared to be fairly uniform to get quick results and to follow up with a series of trials planted on deep peat at various spacings. The latter is in progress.

An area of approximately 4 ha was divided into 25 plots each 0.148 ha in a 5 x 5 arrangement. Five different spacing treatments were then allocated in a Latin Square design. As the area was already planted the spacings could not be arranged in a neat experimental sequence and it was necessary to use 3,000, 1,500, 750, 500 and 330 stems per hectare approximately as the treatments. The closest was the existing planting taken in its entirety, the next was obtained by cutting out every alternate tree in each row and leaving approximately square distribution of about 2.6 m, the next

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took out alternate rows and then alternate trees in the remaining rows to give approximately 3.66 m x 3.66 m distribution, etc, etc. It will be noted that the removals were completely mechanical and great care was taken with this aspect to make sure that the wider spacing did not contain a higher proportion of genetically better trees as would have been the case with a thining.

The stand is on an area of thin peaty humus over heavy blue clay and is the second rotation of Sitka spruce on this site, the first one having been planted about 1921.

At the centre of each plot a sub plot of 49 trees was selected for individual tree measurement. All these trees were measured every 3 years and the following records taken:—

a. Height to nearest foot (approx. 0.3 m).

b. Height to 10 inches girth over bark (approx. 8 cm diameter o.b.) to nearest foot—timber height.

c. Girth over bark at breast height (1.3 m) to nearest 0.1 inch (approx. 1 mm diameter).

d. Girth over bark at half the timber height with precision as at c. above.

From these records all subsequent measures were derived, tree volumes for the purpose of this report being taken to be the volume of a cylinder with height as at b. above and diameter as at d.

In addition to the 3 yearly measurements, records were taken every year on the two treatments where it appeared diameter at breast height differences may have been starting. In December 1969 special measurements were taken on 5 trees in each plot, randomly selected by strata of breast height diameters, to indicate the number of branches in whorls 2 m above ground and at stem diameters of 24 cm and also the size of the two largest in cm diameter.

Although the records were in Imperial units they have been transformed into metric for this report and all future measurements will be in metric units. If possible future tree volume records will be taken from a greater number of points than up to 1969.

TREE HEIGHT

The height of the dominant 4% of the trees in each spacing varied at December 1969 from 12.2m in the closest spacing down to 11.45m in the widest spacing. There is just a suggestion that the wider spacing has depressed this domin-
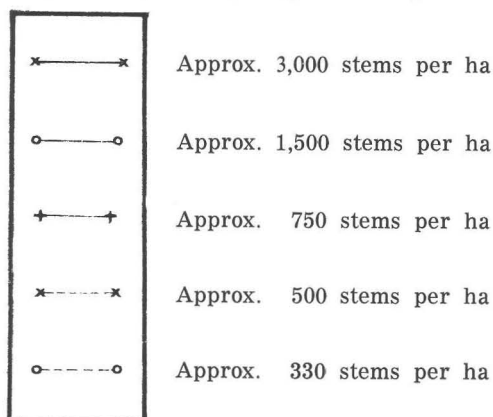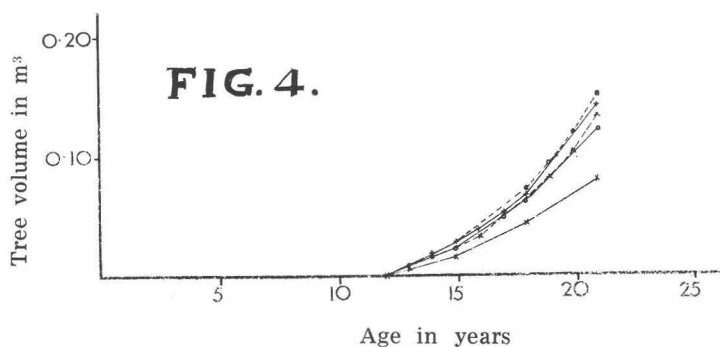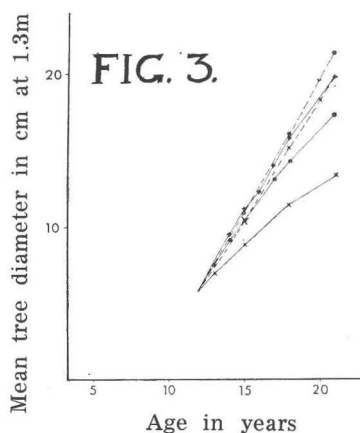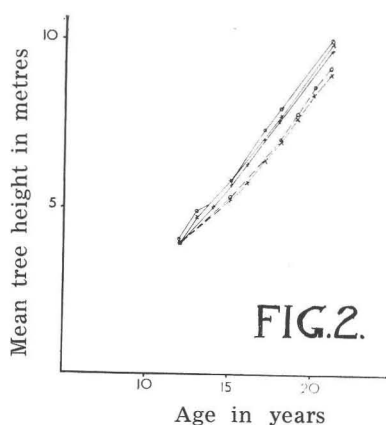
×———————×	Approx. 3,000 stems per ha
○———————○	Approx. 1,500 stems per ha
+———————+	Approx. 750 stems per ha
×– – – – –×	Approx. 500 stems per ha
○– – – – –○	Approx. 330 stems per ha

Fig. 1 Legend for all figures where relationships for different spacings are shown separately.

FIG. 2.

FIG. 3.

FIG. 4.

FIG. 5.

Mean tree periodic annual height increment in metres

0·7

0·6

0·5

1967- 69 INC.

1964 -66 INC.

1961-63 INC.

3·344   6·688   13·38   20·07·   30·1

Space per tree in m²

FIG. 6.

Mean tree periodic annual diam. inc. in cm

2·0

1·5

1·0

0·5

1964 - 66 INC
1967 - 69 INC
1961 - 63 INC

3·344   6·688   13·38   20·07   30·1

Space per tree in m²
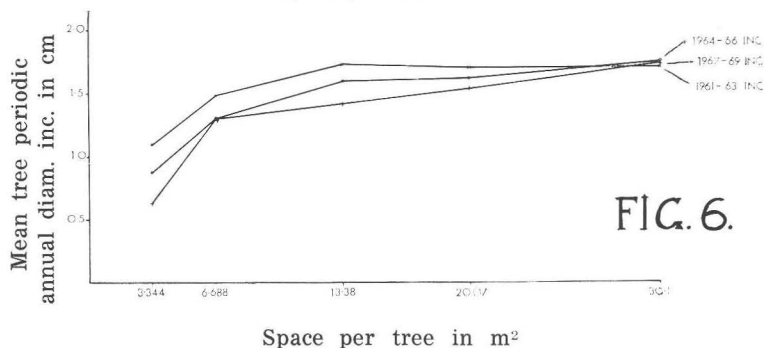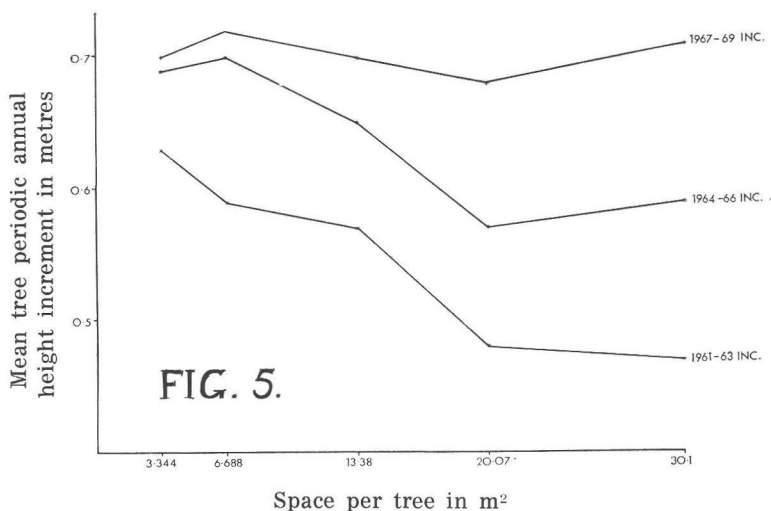
ant tree height. If dominant tree height is expressed as the
mean height of the 100 largest per hectare as in the FC
Management Tables then quite considerable differences are
found from 12.4 m in closest spacing to 10.6 m in the widest.
These are based on approximately 3% of the crop for the
closest spacing and 30% for the widest spacing.

Based on the closest spacing the crop would appear to be
approximately Forestry Commission Metric Yield Class 20
and Production Class A.

The mean tree height has progressed at a very even rate
throughout the 9 years of measurement and has generally
increased from 4 m to 10 m for the 3 closest spacings, but
is only approximately 9 m for the two widest spacings.
(Fig. 2) This differentation took place very soon after the
cutting out at 12 years of age and continued until 18 years

of age. During the past three years all treatments have put on height growth at a similar rate. Taking the mean annual height growth by three-yearly periods one finds that in 1961-63 inclusive there was a fairly steady drop in annual height growth of some 0.075 m for every 10 m^2 extra space per tree until 20 m^2 is reached when there is no further effect. The trees at the start of this period were approximately 4 m high. From 1964-66 inclusive the drop in height growth relative to an extra 10 m^2 space had fallen to 0.065 m over much the same range with no effect over 20 m^2 per tree. Between 1967 and 1969 inclusive the mean leader growth was the same for all spacings. (Fig. 5).

MEAN TREE DIAMETER, BREAST HEIGHT

The following analysis is based on the mean diameters and not on the diameter of the tree of mean basal area.

At 12 years of age when the cutting out was done the trees were on average 4 m high and had a mean diameter of just under 6 cm. Right from the first year the closest spacing of 3.34 m^2 approximately per tree showed that competition was reducing diameter growth relative to 6.69 m^2 and wider spacings. By age 16 when the mean height was about 6.5 m there appeared to be the beginning of competition influence in the 6.69 m^2 spacing relative to wider spacings and a similar pattern developed by age 19 when the mean height was 8 m for the 13 m^2 spacing. The large effect of this can be noted from the differences at December 1969 between almost 20 cm mean diameter for the three wider spacings relative to just over 17 cm for the 6.69 m^2/tree and just over 13 cm for the 3.34 m^2/tree spacing. (Fig. 3).

It may therefore be inferred that if one wishes to avoid competition influencing mean tree diameters it will be necessary to reduce stocking to give more than 3.5 m^2 per tree at average height of 4 m, 7 m^2 at 6.5 m average height and 13 m^2 at 8 average height. It will be noted that the latter is equivalent to a stocking of under 750 stems per hectare before a normal first thinning would be attempted.

Except for the 30 m^2 spacing there has been a general slowing down of diameter increment in consecutive 3-yearly periods since 1960, but this has been more marked with the closest spacings. (Fig. 6). In the last 3 years 1967-69 the closest spacing put on only just over 0.6 cm diameter per year while the widest spacing grew at nearly three times this rate. Throughout the measurement period all spacings except the 3.34 m^2/tree and the 6.9 m^2/tree for 1964-69 inclusive put on more than 1.3 cm per annum, and this is equivalent to very approximately 4 rings per inch which is

one of the limits used in timber grading. It must be assumed that if one wishes to grow to this timber quality and wishes to get it in the centre 15 cm of the average tree at 1.3 m above ground level then the stocking must not be less than 5 m^2/tree (2,000 stems per hectare) when the crop mean height is below 6 m, and not less than 1,500 stems per hectare when the crop mean height is 10 m.

MEAN VOLUME PER TREE

When the cutting out was done the average tree had a volume to 8 cm top diameter ob of only 0.004 m^3, but right from this date the closest spacing (3,000 stems per ha) appeared to be effecting volume growth, i.e., when mean height was only 4 m. (Fig. 4)). The results suggest that competition effects were influencing volume growth of the next closest spacing of 6.69 m^2 per tree relative to wider spacings at 20 years of age or just over a mean height of 9 m. There is, therefore, a much longer time required for competition to influence tree volume than to influence breast height diameter growth. Nevertheless the magnitude of the effect can be judged by comparing mean tree volume at age 21 and mean height approximately 10 m of 0.08 m^3 for 3,000 stems per hectare and 0.14 m^3 for wider spacings. Similarly the periodic annual increment of the mean tree between 18 and 21 years of age was 0.012 m^3 for the 3,000 stems per ha, 0.020 m^3 for 1,500 stems per ha and approximately 0.024 m^3 for the wider spacings. (Fig. 7).

BASAL AREA PER SUB PLOT (49 trees)

Before the spacing cleaning was carried out the basal area sub-plot varied from 0.15 to 0.165 m^2. Six years later the closest spacing of approximately 3,000 stems per hectare was significantly less at 0.565 m^2 than the next three spacings which varied from 0.85 m^2 to 0.98 m^2. A similar difference had been noted 3 years earlier at 15 years of age. However, by 18 years of age the widest spacing of 330 stems per hectare had significantly greater basal area than any other and the basal area of the 1,500 stems per hectare was visibly less than wider spacings. By 21 years of age the widest spacing at 1.88 m^2 was significantly greater than all others and the next two were significantly greater than the 1,500 stems per hectare at 1.26 m^2 which in turn was significantly greater than the closest at 0.77 m^2. As the total number of trees per plot was very similar the above indicates the type of effect on the tree of mean basal area and is similar to the findings for mean diameter given above as would be expected.

Basal area increment per plot showed a similar pattern to that described for total basal area above.

FIG. 7.

FIG. 8.

FIG. 9.
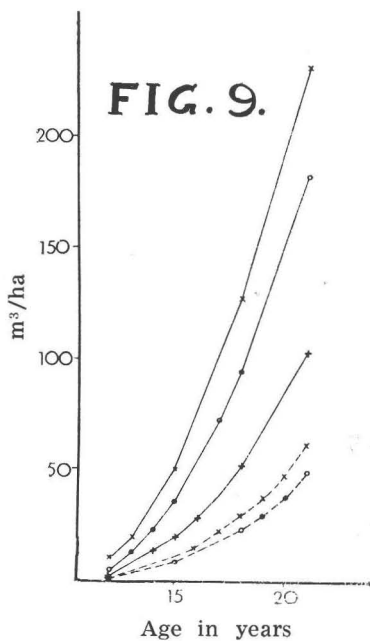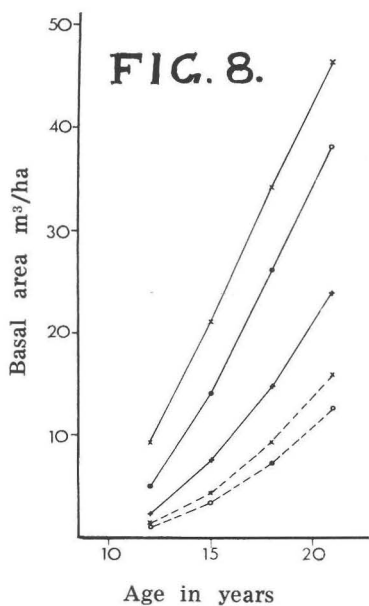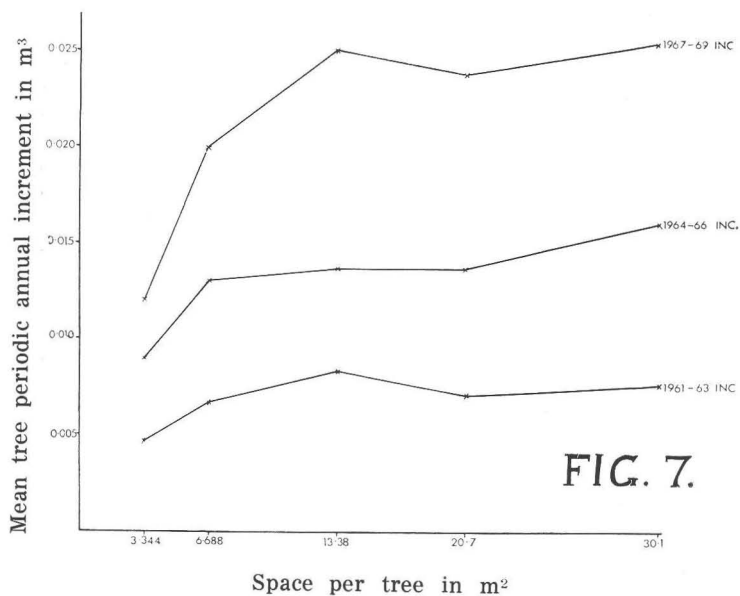
BASAL AREA PER HECTARE

Rather more interest centres on the effect of spacing on basal area per unit area and here there is a very clear cut effect due to spacing. Thus the total basal area per hectare of the 330 stems per hectare is at 21 years of age (12.7 m²/ ha) similar to the basal area of the 3,000 stems per hectare at 13 years of age, and is only about 28% of the present 3,000 stems per hectare basal area (46.8 m²/ha). (Fig. 8).

Between 12 and 15 years of age the basal area increment per hectare in the 4 widest spacings was similar to what one would expect in a condition of no competition effects but the curtailment of diameter in the close spacing of 3,000 stems was having a very noticeable effect. (Fig. 10) This pattern was repeated in the following 3 years, but with some evidence of the 1,500 stems per hectare falling behind as well. By 18-21 years of age the basal area per hectare increment was less for 3,000 stems per hectare than for the 1,500 stems per hectare. Over the latter 6 years there was also less difference in basal area per hectare growth between the two widest spacings than one would get from number of trees only.

It can, therefore, be taken that spacing has had a very marked effect on total basal area growth although there are indications that 1,500 stems per hectare may now be growing reasonably similarly to 3,000 stems per hectare. Wider spacings have considerable way to go to even approach current growth per hectare in the closest spaced crop.

VOLUME PER HECTARE

Spacing has a very important bearing on total volume production at least up to 21 years of age and the range is

FIG.10.

1967- 69 INC.

1964-66 INC.

1961-63 INC.
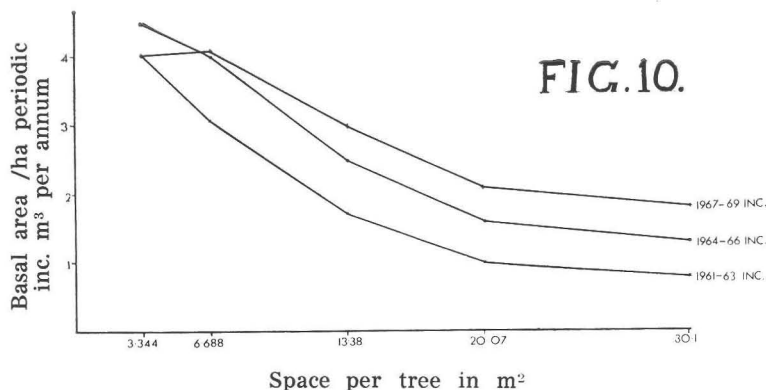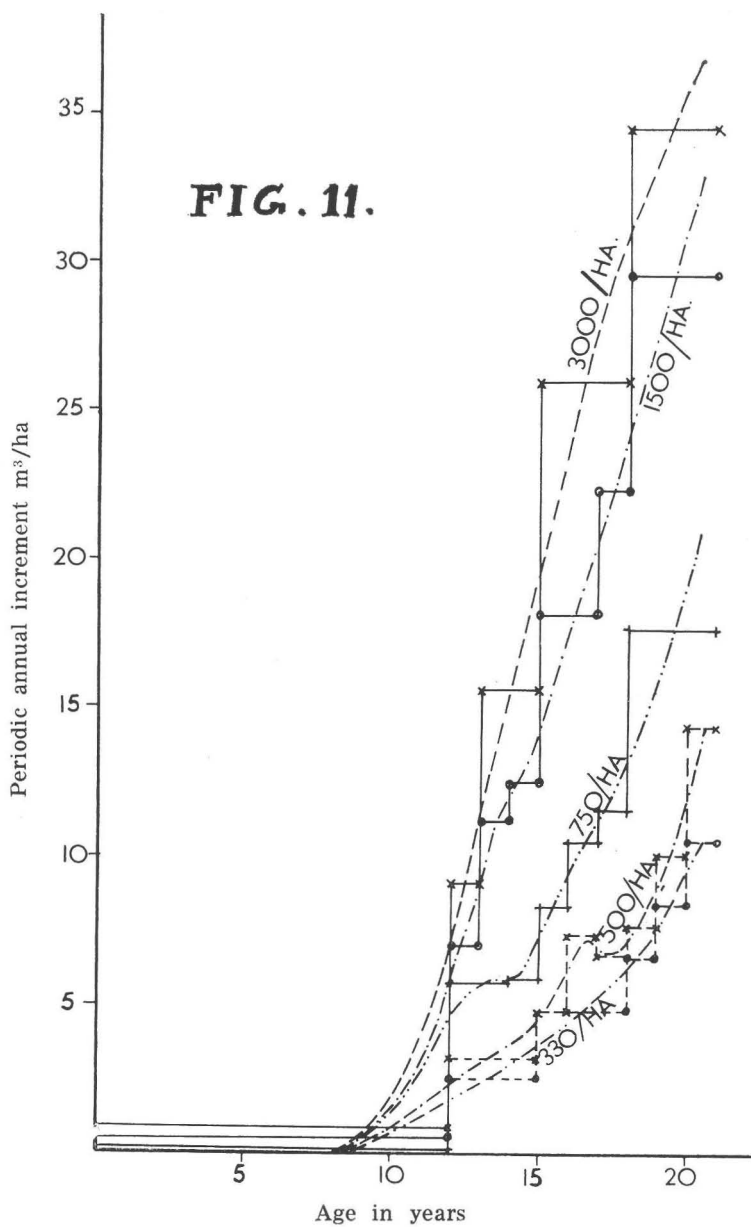
Space per tree in m²

FIG. 11.

from 233m³/ha for 3,000 stems per hectare down to 49m³/ha for 330 stems per hectare at that age. (Fig. 9)

It would, however, appear, (Fig. 11), that the volume increments per hectare for the 6.69 m² space per tree was in recent years fairly close to that for the 3.34m² per tree spacing and may have been increasing faster annually than the closer spacing which has tended to have a falling rate of increase over the past few years. Similarly the results suggest that the 13m² per tree spacing and 20m² per tree spacing may be starting to put on volume increment similar to what the 3.34m² spacing was doing some 4 and 7 years earlier respectively. The widest spacing of roughly 30m² per tree is still in recent years increasing its CAI at a slower rate than the closest spacing ever did.

A very crude approximation based on the above (and which may not stand the test of time) is that for every extra 10m² spacing given to the trees initially over and above 3.34m² (3,000 per hectare) total volume production is put back by 4 years. If this suggestion is valid and the pattern continues it means that a crop planted at 13.34m² spacing (750 stems per hectare) would at age 30 have only the same volume as the same species planted on the same site at 3.34m² spacing would have given at age 26.

BRANCHINESS AT 24 CM DIAMETER

Only 4% of the trees in the 3,000 stems/ha spacing, 28% of the 1,500, 48% of the 750, 56% of the 500 and 52% of the 330 stems/ha spacing sampled for branchiness had diameters over 24 cm. Where the trees had grown to this dimension it appeared that the 500 and fewer stems per ha had approximately 8 branches per whorl as distinct from approximately 7 branches in the closer spacing at the whorl nearest 24 cm diameter . The greater light had apparently encouraged the growth of more branches. There was no significant effect due to the tree diameter at breast height.

The diameter of the two largest branches in the whorl nearest to 24 cm diameter also appeared to be in general 0.5 cm greater with the two widest spacings than with the 750 or 1,500 stems per hectare where the trees had reached this diameter limit at any point on the stem. Again there were no significant regression differences with diameter at breast height although some spacings suggested an increase of 1 cm diameter for each 0.1 cm diameter breast height increase.

BRANCHINESS AT 2 M ABOVE GROUND

The number of branches in the whorl and diameter of the two largest branches in this whorl at 2 m above ground

level - ie, the first whorl just above where normal brashing would stop were also measured in December 1969.

The mean number of branches per whorl appears to be just over 5 for 3,000 stems/ha spacing and just under 6 for 1,500 spacing with 750 and fewer stems per ha having somewhat more than 7 branches per whorl. There is a hint of increasing numbers of branches as the tree diameter at breast height increases but the trend is not significant. This suggests that the opening up (when the mean tree height was about 4 m) has permitted more small branches at 2 m to develop in the wider spacings than would otherwise have persisted.

The diameter of the two largest branches in the whorl at 2m exhibit statistically significant differences due to tree diameter at breast height and although the slopes are similar there are significant differences in the constants for the different tree spacings. Thus although there is a general increase of 0.7 cm diameter for every 10 cm diameter breast height increase, (Fig. 16) there is a general difference of 0.3 cm between all of the spacings in the experiment except for the two widest.

Although the wider tree spacings appear visually to have much bigger branches than the closer spacings it is noted that this can be partly accounted for by the bigger tree diameters. Care must, therefore, be taken when interpreting visual effects. The differences are, however, of considerable practical importance and indicate a substantial deterioration in quality with wider spacing. This, combined with the greater number of branches per whorl, may be sufficient to influence pulp yields.

FREQUENCY DISTRIBUTION OF TREE VOLUMES AT DECEMBER 1969

For many purposes the size of the mean tree is not particularly useful by itself and a knowledge of the distribution by size class is more valuable. Such frequency diagrams are difficult to interpret when prepared from the actual data where there are few observations and they were, therefore, fitted to an incomplete Beta distribution function of the form - $f(x) = x^{\alpha}(1-x)^{\gamma}$
for each of the five spacings. The resulting relative frequency distributions are shown in Fig. 12 and all represented a satisfactory fit of the observations using a Chi-squared test.

It is evident that spacing has had a considerable effect on the skew of these distributions and it can be inferred that competition has not only reduced the size of the mean tree, but has also reduced the frequency with which large
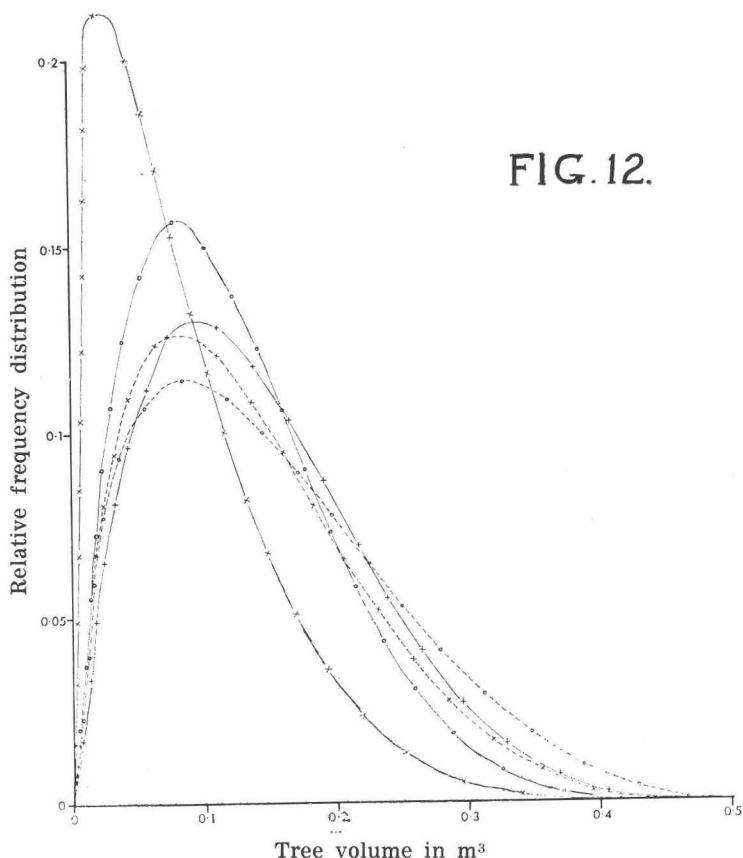
FIG. 12.

Relative frequency distribution

Tree volume in m³

trees are found. This rather contradicts the evidence of thinning experiments in older Sitka spruce where large dominant trees tended to keep large and dominant and growing at a fairly uniform rate irrespective of the weight of the thinning. It suggests that the growth of all trees can be influenced by spacing and this result may be of very considerable importance when included with the relationship between felling costs and tree size.

The Alpha and Gamma coefficients of the Beta distribution were plotted against space per tree and for the four widest spacings gave fairly good linear fits dropping by approximately 0.25 and 1.2 respectively for each increase of 10m² in tree space. The coefficients for the closest spacing of 3.34m² per tree (3,000 stems per hectare) did not fit this linear trend.

FIG.13.

Form factor

Space per tree in m²

FIG.14.

Crop form height

Ht. of largest 100 stems per ha m
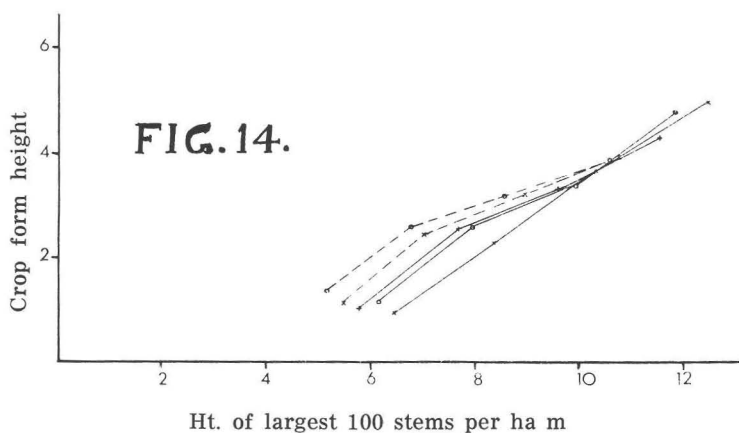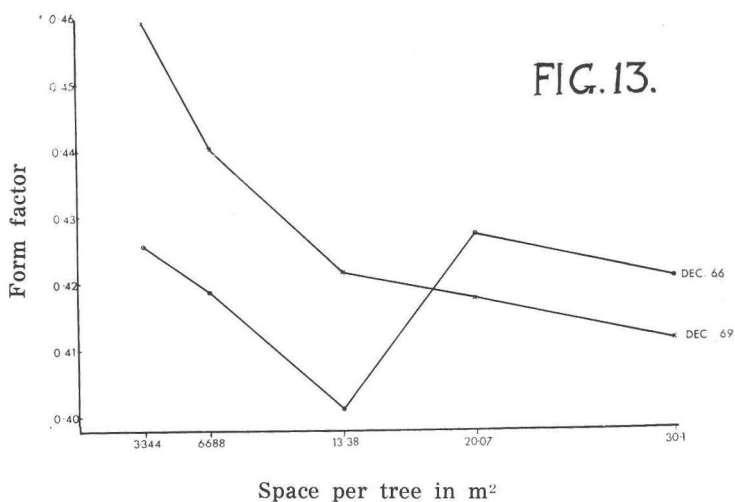
The Alpha coefficients for the relative volume frequency distributions at December 1966 were at a similar level to December 1969, but showed a rather different pattern with a peak at approximately 13m² per tree. The Gamma coefficients at that time were not quite so clearly on a straight line, but did fall at approximately 1.4 for each increase of 10m² in tree space. They started however from Gamma = 15 for 3,000 stems/ha in December 1966 whereas the December 1969 equivalent was Gamma = 6.5. Unfortunately these results are too varied to suggest a prediction which would be used to describe the likely frequency distribution in the future.

FORM FACTOR

The form factor of individual trees which were over 8 cm diameter at 1.3m above ground were calculated for December 66 and December 69. At December 66 or approximately 8m height there were no significant differences due to spacing, and the mean was very nearly 0.42. By December 69 there were highly significant differences betweet the 3,000 stems/ha at 0.44 and 750 stems at 0.42 with the wider spacings just slightly under this, (Fig 13). Differences of this magniude would have important implications for the use of volume tables in different spacing regimes and one can expect the differences to increase in future.
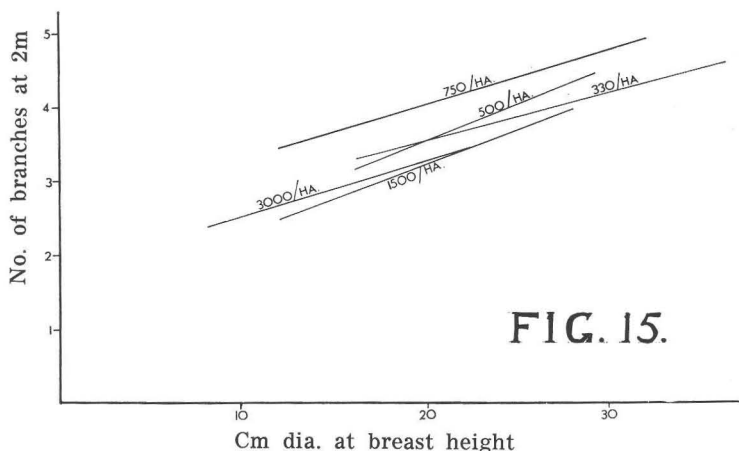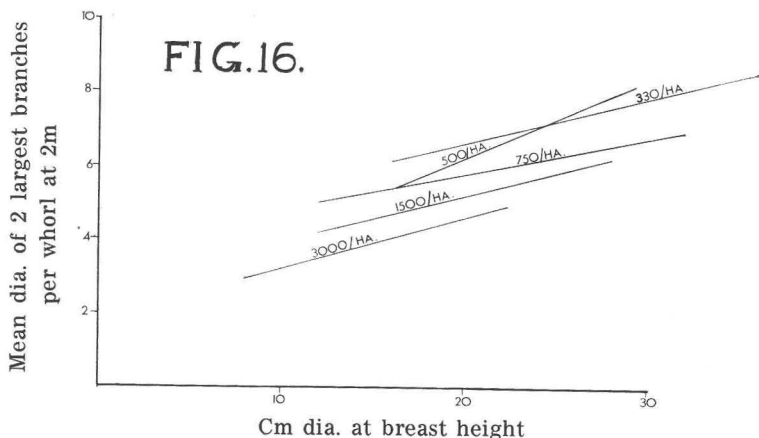

FIG. 15.

FIG. 16.

CROP FORM HEIGHT

This was calculated on the basis of the volume of all trees over 8 cm diameter breast height as a ratio of the height of the 100 largest stems per hectare times the basal area at breast height for each plot and details are given in Fig. 14. Apart from quite considerable differences in the early years of the experiment which can be attributed to the use of the 100 largest per hectare for height determination which, therefore, requires the acceptance of a much higher % of the available stems for the wider spacings, it is remarkable how similar has been the relationship of crop form height to 100 largest height once the crop was over 10m high and how uniform has been the convergence. It will be interesting to watch the future development of this relationship relative to the changes in individual tree form pattern noted above.

MORTALITY

A number of trees were windthrown in the very severe gales of September 1961 when the crop was just 12 years of age. This storm largely affected the 500 stems per hectare spacing where almost 8% of the trees were blown over. In all other spacings of 1,500 and fewer stems per acre mortality including theft, etc., has been under 4% to date. With the closest spacing of 3,000 stems per hectare there are now some deaths occuring and at 12m top height there has been a $6\frac{1}{2}$% mortality to date.

VOLUME/BASAL AREA RELATIONSHIPS

The relationship of volume to 8 cm top diameter ob per hectare to basal area at breast height indicates that for a given basal area volume production is greater with the wider spacings. It must be remembered that the closer spacings reached these basal areas at an earlier age and, therefore, height was much less and also that the wider spacings have still very small basal areas relative to the close spacings. (Fig. 8).

The periodic annual increment (calculated from consecutive 3-year periods) relative to the basal area of the crop at the beginning of the period is now showing a very similar relationship for both the 3,000 and 1,500 stems per hectare treatments. (Fig. 17). The wider tree spacings have a smaller volume increment but again the basal areas are still quite small at this stage of the experiment and it will be some time before a pattern can be traced from the data.

FIG.17.

Total basal area m²/ha at begining of 3 year period
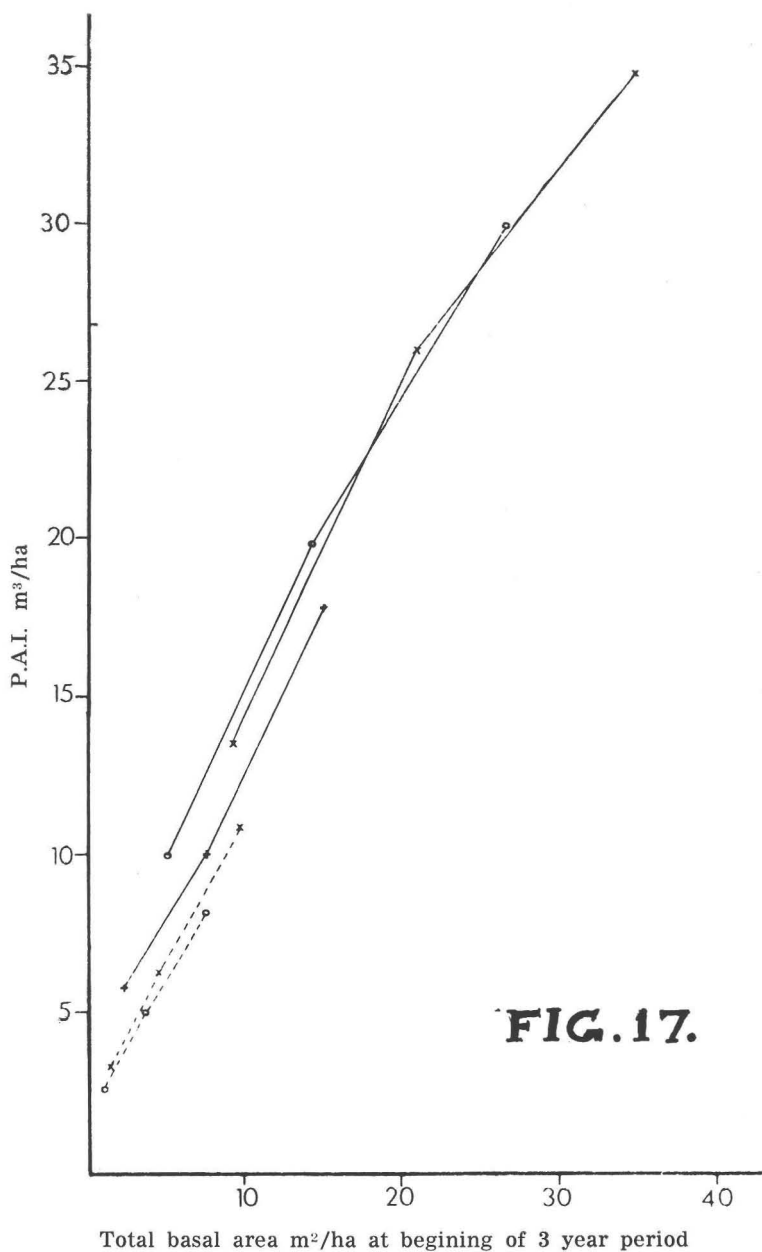
DISCUSSION

Although the spacings were made when the crop averaged 4 m high and it is true that the results suggest that there could well have been some diameter competition effects before this time it is unlikely that these or any influence on other crop characteristics were of great magnitude. The results of this experiment may therefore be used to draw inferences on the likely effects of differing initial planting distances without much probability of error. Comments in the results discussed above can be assumed to apply to crops planted at equivalent initial spacings.

It would appear from an inspection of smooth lines taken from the figures that the results given in table 1 could be expected from spacings of approximately 2,200 per hectare (7' x 7') and 1,685 per hectare (8' x 8').

Table 1

Factor	2,200 per hectare	1,685 per hectare
Mean tree height	10.0 m	10.0 m
Height of 100 largest per hectare	12.1 m	11.9 m
Mean tree diameter	16.0 cm	17.5 cm
Mean tree volume	0.101 m^3	0.114 m^3
Volume per hectare	218 m^3	188 m^3
Basal area per hectare	43.4 m^2	40.1 m^2

Notes

The mean tree height would be the same as that obtained with the crop planted initially at 3,000 stems per hectare on a similar site. The height of the 100 largest per hectare as above would have been 12.4 metre when initial planting distance was 3,000 per hectare. Although all replicates of the experiment were on a similar site it could be taken as fairly certain that the above results could be obtained when crops planted at these spacings had reached top heights as shown.

The experimental results can also be used to make projections of future growth although these must be subject to some uncertainty. Details of individual tree volume increment by 3-year periods plotted against age appeared to offer the most reliable forecasting curves and these multiplied by numbers of stems but with some allowance for mortality suggest that the total crop yield in the next few years would be as in table 2.

Table 2

Date	3,000 per hectare	1,500 per hectare	750 per hectare
December 1972	360 (356)	300 (288)	200
December 1975	500 (486)	440 (415)	310

It was considered too problematical to project the curves any further. Because of the peakiness which was appearing in the curves of the basal area increment and the uncertainty of whether crop form height would in future show a single relationship to top height, irrespective of spacing, projections of volume per hectare using these characters appeared to be too uncertain. Estimates using the periodic volume per hectare increment over age curves were difficult to make but did suggest that the above table would be overestimating the increment of the 2 closest spacings by about 10 per cent to give the figure shown in brackets in table 2. The height of the 100 largest per hectare is likely to be about 16.2 metres by December 1975 on the closest spacing and by this time there will be a loss of 60 - 70 m^3 per hectare by planting at 1,500 rather than 3,000 stems per hectare.

Projections for the next 3 years for likely volume growth of the 2,220 per hectare and 1,685 per hectare spacings considered above can be made with a fair degree of certainty from basal area increment curves and the relationship of periodic annual increment to basal area at the start of the 3-year period (Fig. 17) and these suggest that the volumes per hectare at December 1972 will be 335 m^3 and 300 m^3 respectively. Thus planting at about 2,000 stems per hectare will result in some 30 to 35 m^3 per hectare loss of production

at 12 m top height (about 40 feet) but this could be accept-
able where first thinning was normally uneconomic and the
increased branchiness was not likely to seriously influence
final crop prices.

The characteristic of distribution of tree stems by volume
classes together with the initial effect of different spacings
can have a major influence on costs and some calculations
are given below to indicate how an economic appraisal of the
complete system from planting through to produce loaded on
customer's lorry can alter decisions from these suggested
by looking only at the tree growth statistics. Unfortunately
the calculated parameters of the Beta distribution did not
exhibit sufficient stability to enable forecasts to be made of
the likely distribution in the future and so the calculations
are based on clear felling a crop of 12.4m dominant tree
height at 3,000 stems per hectare planting spacing because
this is the oldest stand for which information is available
from the experiment. They should not be taken as an indic-
ation that clear felling at this height is suggested as a good
management practice for such stands as the determination of
rotation lengths etc. must be based on the owner's overall
objectives and decision making criteria.

There is a strong suggestion from Table 2 above that
much better financial returns would be obtained by having
much longer rotations under the usual conditions which
apply. Site factors would alter the ranking, etc, for poorer or
better sites than used in the calculations.

Calculations of net discounted revenue were made for
clear felling at 21 years of age of 3,000, 2,200 and 1,500 stems
per hectare using the data inferred above where necessary,
and are summarised in Table 4. It will be noted that under
the assumed conditions the best financial return would be
made by an initial spacing of 2,200 plants per hectare. This
is partially made up, relative to the 3,000 stems per hectare,
of a saving in gross felling costs of some 10% while volume
production only fell by 7% and a saving of some 10% on
expenditure in the year of formation of the plantation. Wider
spacings would have given greater losses.

It is hoped that this paper will stimulate interest in the
factors influenced by initial plant spacing whether they are
of a silvicultural or an operational nature.

Irish Forestry

Table 3

Costs, etc. assumed

Type	Operation	Unit Costs	Remarks
Fixed Costs	Clearing lop and top, draining, etc, pre-planting.	£25 per ha	Constant
	Weeding.	£75 per ha	"
	Maintenance, including roads, drains, etc.	£2.5 per ha per year.	"
Variable Costs	Young trees.	£10 per 1,000 trees.	Costs proportional to numbers.
	Planting.	£10 per 1,000 trees.	do.
	Extraction and conversion and loading.	£2.44 per m³	Total costs proportional to volume removed.
	Felling and snedding	£0.076 per tree of 0.036 m³	Total costs depend on gross volume to be felled and the distribution of this by tree size. Unit costs are based on a regression line of standard time against tree volume in h ft.
	do.	£0.127 per tree of 0.108 m³	
	do.	£0.167 per tree of 0.180 m³	
	do.	£0.208 per tree of 0.252 m³	
	do.	£0.250 per tree of 0.324 m³	
	do.	£0.292 per tree of 0.397 m³	
Revenue		£5.55 per m³ loaded	Clear felling at age 21. Total revenue proportional to volume to be felled. No bonus for larger logs.
Interest Rate		5%	

Table 3 (continued)

NOTES   a. Costs are taken to include all labour, machinery, supervision general overheads, etc.

b. It will be obvious the above data are oversimplified.

c. A further simplification which affects the magnitude of differences but not their ranking was to treat ground preparation and weeding as being done in the year of planting.

d. No provision is included for risk or for conversion loss.

Table 4

Summary of calculations on a hectare basis

Type	Date	Operation	3,000 stems /ha	2,200 stems /ha	1,500 stems /ha
Actual Expdt	Year 0	Draining and weeding.	100	100	100
	" "	Planting and young trees	60	44	30
	Year 0-20	Maintenance	52	52	52
	Year 21	Felling, etc.	263	229	178
	" "	Extractions, etc	565	530	450
Discounted Expdt to Year 0	Year 0	Draining and planting	160	144	130
	Year 0-20	Maintenance	32	32	32
	Year 21	Felling, extraction, etc.	297	272	225
			489	448	387
Actual Revenue	Year 21	Sale of produce traded at forest gate.	1,290	1,210	1,020
Discounted Revenue	" "	do.	463	435	366
Net discounted revenue to Year 0			- 26	- 13	- 21

ACKNOWLEDGMENTS