Spacing interaction with genotype and with genetic variation for production and quality traits in a trial of seedlings and grafted clones of Scots pine (Pinus sylvestris L.)

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Abstract

A Scots pine (*Pinus sylvestris* L.) field trial in southern Sweden with two grafted clones and with seedlings originating from seed collected in one stand was measured at the age of 20. The trial had three spacings: 1.7 × 1.7 m, 2.5 × 2.5 m and 4.0 × 4.0 m.

The main purpose was to see if competitive interactions occurred. One possible type of interaction is between spacing and degree of genetic variation within the material, both for assessments of traits and coefficient of variation of traits. The seedlings from the stand represent a genetically heterogeneous population, the grafted clones a genetically homogeneous population. Another possible type is genotype-spacing interaction, investigated by comparing the two clones. Production characters (height, diameter at breast height, tree volume and volume per hectare) and quality characters (height to first living branch, crown diameter, branch diameter and straightness) were analysed with analysis of variance and contrasts.

Diagrams indicated interaction between spacing and degree of genetic variation (genetically heterogeneous seedlings vs genetically homogeneous grafted clones), but analysis of variance failed to show significance for assessments or for coefficient of variation. Genotype-spacing interaction was not found. In contrast tests, seedlings differed significantly from grafted clones in most cases in coefficient of variation and in assessments of height and straightness. These differences were greater for production than quality.

Spacing had greater effect on production and quality characters than did plant material.

Key words: Pinus sylvestris, seedling, graft, clone, genotype-environment interaction, spacing, competition.

Zusammenfassung

Eine Versuchsfläche mit *Pinus sylvestris* L. in Südschweden aus zwei Pfropfklonen und einer Bestandesnachkommenschaft, wurde im Alter von 20 Jahren gemessen. Die Versuchsfläche war in drei verschiedenen Quadratverbänden (1,7 m/2,5 m/4,0 m) angelegt worden.

Als Hauptzweck sollte beobachtet werden, ob konkurrierende Wechselbeziehungen vorkommen. Eine mögliche Interaktion besteht zwischen dem Pflanzverband und dem Grad der genetischen Variation innerhalb des Materials, die sich beide auf die Beurteilung der Merkmale und die Varianzkoeffizienten der Merkmale auswirken.

Die Sämlinge aus dem Bestand stellen eine genetisch heterogene, die gepfropften Klone eine genetisch homogene Population dar. Eine weitere Möglichkeit ist eine Interaktion zwischen Genotyp und Pflanzverband, die durch Vergleichen der zwei Klone untersucht wird. Die Produktionseigenschaften (Höhe, Brusthöhendurchmesser (BDH), Baumvolumen, Ertrag/ha) und Qualitätsmerkmale (Höhe bis zum ersten lebenden Ast, Durchmesser der Krone, Astdurchmesser und Geradschaftigkeit) wurden mittels Varianz- und Kontrast-Analyse errechnet.

Die Diagramme zeigten eine Interaktion zwischen Pflanzverband und Grad der genetischen Variation (genetisch heterogene Sämlinge gegenüber genetisch homogenen gepfropften Klonen), wobei die Varianzanalyse nicht geeignet war, eine Signifikanz der Schätzwerte oder der Variationskoeffizienten aufzuzeigen. Eine Interaktion zwischen Genotyp und Pflanzverband wurde nicht festgestellt.

In den Kontrasttests unterschieden sich die Sämlinge signifikant von den Pfropf-Klonen in den meisten Fällen im Variationskoeffizient und in den Schätzwerten für Höhe und Geradschaftigkeit. Diese Unterschiede waren für die Produktion größer als für die Qualität.

Der Pflanzverband hatte einen größeren Effekt auf die Produktion und die Qualitätsmerkmale als das Pflanzenmaterial selbst.

1. Introduction

Use of single clones or clone mixtures in reforestation has in recent years become an interesting alternative to the traditional choice of plant material. A more precise choice of suitable genotypes to increase yield would then be possible. (In this report the term "material" refers to different genotypes, clones, as well as to populations with different types of genetic structure.)

Reforestation with material possessing smaller genetic variation could require other silvicultural methods. One reason for changed methods could be that competition is stronger because the trees have the same growth and demands. Another reason could be that a genetically uniform stand will be more homogeneous and therefore would have to be managed in other ways. Obtaining knowledge about the effects of competition is therefore one aim of this study of a clonal trial with Scots pine at different spacings. Basic studies concerning the effect of spacing on Scots pine have been done by Andersson (1973), Elfving (1975), Persson (1976 and 1977) and Andersson and Hattemer (1978). Effects of competition have been investigated in other studies where also fertilization was altered (Hattemer *et al.* 1977, Hellström 1982).

Breeding is another area where clones can be useful. Will many individuals with the same genotype give more reliable results than progenies from open pollination in a stand or will variation caused by clonal effects (variation within clones) from propagation methods, etc. dominate? To answer this question the variation within a clone should be compared with the variation within a plant material from a natural stand.

The first problem was treated by comparing the assessments of different traits for each material at different spacings.

Should the rank of the materials change, there would be interaction between spacing and degree of genetic varia-

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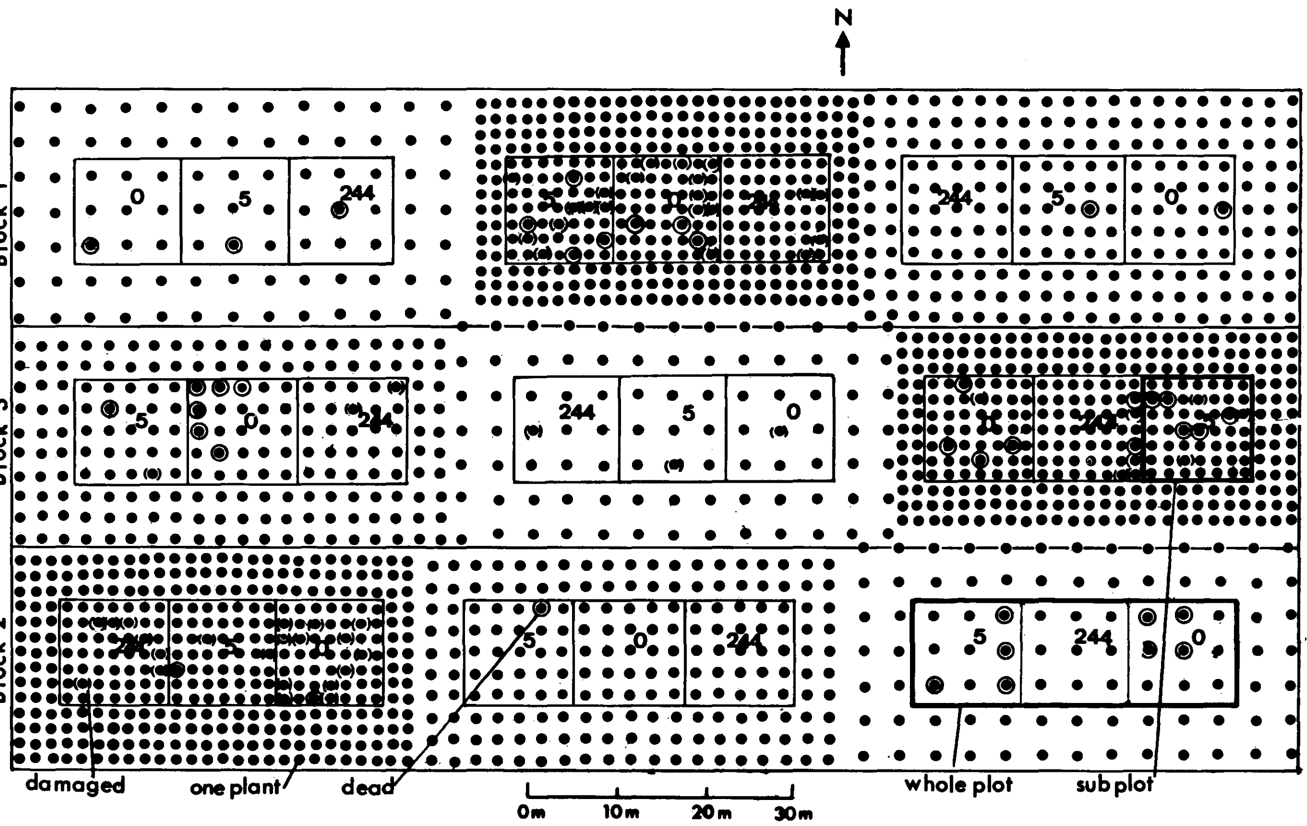

Figure 1. — The design of the trial. A modified split plot plan with three different square spacings (4.0 m : 9 plants each, 2.5 m : 25 plants and 1.7 m : 49 plants) and three materials (0 : seedlings, 5 and 244 : two grafted clones). All replicated in three blocks.

tion. Special spacing and thinning programs should therefore be chosen depending on the type of material used.

In response to the second problem, coefficients of variation were calculated and compared. This made it possible to compare the variation in material with different mean values. The squared coefficient of variation has been used earlier in evaluations of clone trials (Roulund 1980).

The bases for the results discussed here are the graphs in *Figures 2* and *3*, analyses of variance, components of variance and contrast tests *(Tables 2—4)*.

This trial indicated that the use of genetically homogeneous grafted clones in forestry may require modified silvicultural methods as regards spacing. The question arises whether the different requirements found here are caused by the fact that the genetically homogeneous material in the trial consists of clones or of grafts. It seemed possible to improve breeding work by using grafted clones due to reduced variation for most characters, but spacing was at least as important for variation.

The results from this trial can not give definite answers to the questions, since only two clones and seedlings from one single stand were represented. However, combined with results from similar analyses (von Euler 1982, Hellström 1982) and with investigations which are now in progress, useful conclusions can be drawn.

A preliminary report on this investigation has been published locally (Fries 1982).

Table 1. — Estimates of degrees of freedom, mean squares, F-values for significance tests used in the analyses of variance and estimate of expected mean squares for components of variance.

Source	df	MS	F	Expected MS for components of variance
Material (M)	$n_M - 1 = 2$	$\frac{SS_M}{df_M}$	$\frac{MS_M}{MS_{MxS+Error}} = {}^1F_{(2,22)}$	$9\sigma^2_M + 3\sigma^2_{MxS} + \sigma^2_{Error}$
Spacing (S)	$n_S - 1 = 2$	$\frac{SS_S}{df_S}$	$\frac{MS_S}{MS_{MxS+Error}} = {}^1F_{(2,22)}$	$9\sigma^2_S + 3\sigma^2_{MxS} + \sigma^2_{Error}$
Interaction (MxS)	$(n_M-1)(n_S-1) = 4$	$\frac{SS_{MxS}}{df_{MxS}}$	$\frac{MS_{MxS}}{MS_{Error}} = F_{(4,18)}$	$3\sigma^2_{MxS} + \sigma^2_{Error}$
Error	$n_{Tot} - 2(n_M-1)(n_F-1) - 1 = 18$	$\frac{SS_{Error}}{df_{Error}}$		σ^2_{Error}
Total	$n_{Block} \cdot n_M \cdot n_F - 1 = n_{Tot} = 26$			

[1] The reason for using pooled MS $_{M\,x\,S\,+\,Error}$ in the significance tests was that statistical significance for interaction was not found in any of these analyses.

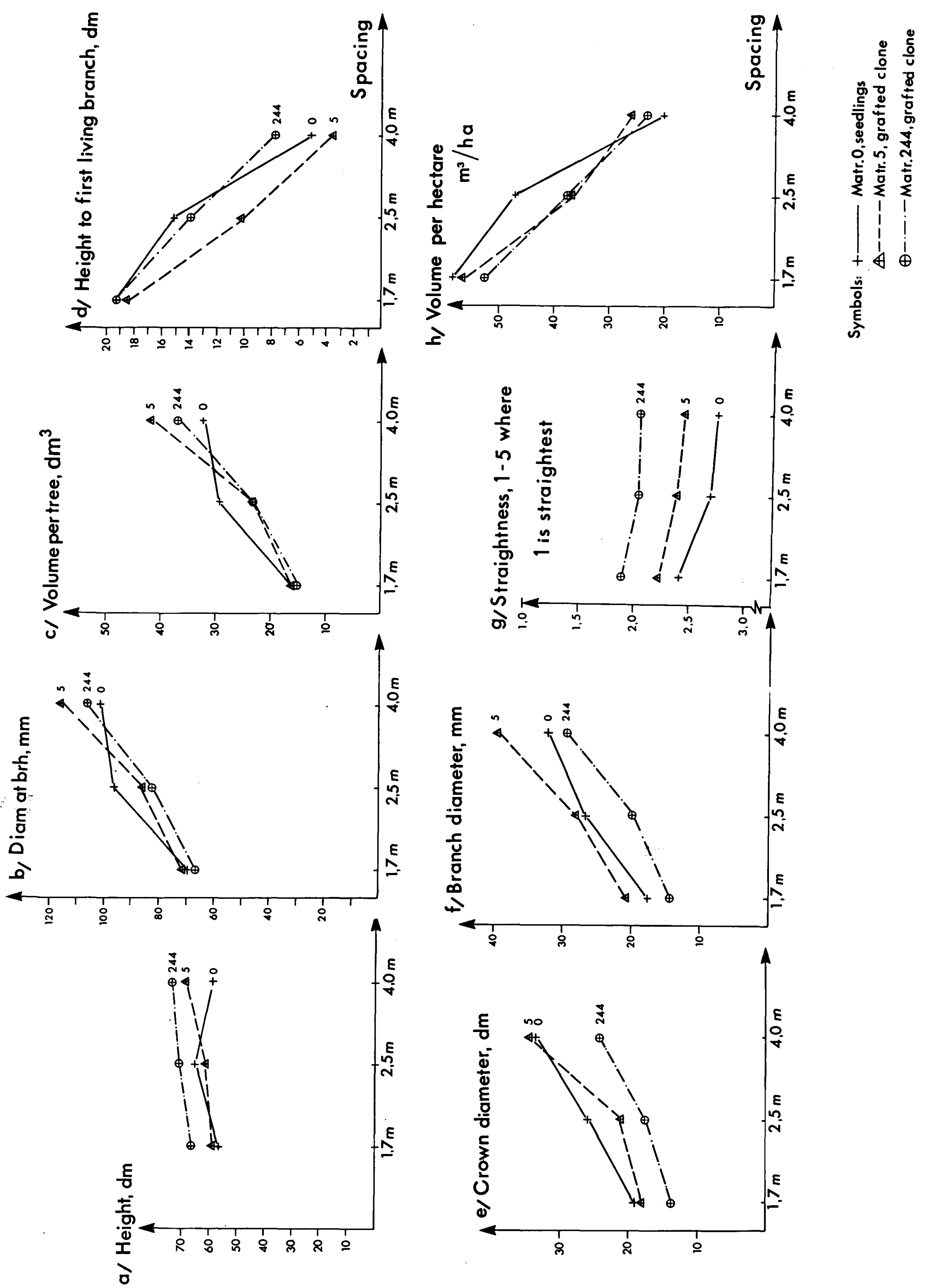

Figure 2. — Mean values for the characters analysed at the three different spacings a/ height, b/ diameter at breast height, c/volume per tree, d/ height to first living branch, e/ crown diameter, f/ branch diameter, g/ straightness, h/volume per hectare.

2. Materials and Methods

2.1 *Trial and plant material*

This trial with Scots pine *(Pinus sylvestris* L.) in Skillingaryd (south Sweden, lat. 57⁰ 27' 00", long. 14⁰ 06' 20", alt. 187 m) was measured at a plant age of 20 years. Grafting was done in 1959—1960 with one plus clone (no. 244) from lat. 61⁰, long. 12.5⁰, alt. 370 m, and one average clone (no. 5), from lat. 59.5⁰, long. 18⁰ and close to sea level. The seedlings (no. 0) were obtained from open-pollinated seeds in a neighbouring stand and were 3 years old when planted in 1963. The trial was laid out on dry flat forest land. The type of soil is fine sand and the site quality class is about 4—4.5 forest cubic meters per hectare. The surrounding stand is also Scots pine, which is the most suitable species for the site. In fact, the only environmental factor causing variation seems to be spacing. Total plant number was 747, of which 707 were measured.

2.2 *Experimental design and statistical analysis*

The design of the trial is shown in *Figure 1.*

The experimental design is a factorial experiment with 2 factors — material and spacing — and 3 levels of each factor: material no. 0, no. 5 and no. 244 and square spacing 1.7 m, 2.5 m and 4.0 m. This makes 9 treatments and the trial has 3 replicates: blocks 1, 2 and 3. The block effect was considered negligible after statistical test.

The model of analysis of variance for the evaluation of treatment effects was as follows:

$$Y_{ij} = \mu + m_i + s_j + (ms)_{ij} + e_{ij}$$

where μ is the overall mean, m is the effect of material, s is the effect of spacing, (ms) is the interaction between material and spacing, and e is the experimental error. Analyses were made on mean values of subplots with the three blocks as replicates. The mean values of subplots were calculated on surviving trees. Estimates of degrees of freedom, mean squares, F-values for significant tests, and mean squares for components of variance are shown in *Table 1.*

Contrasts were performed both for assessments and coefficients of variation (NETER and WASSERMAN 1974). In the tests, each of the three materials and each of the three spacings were compared with the sum of the two others. After examination of the graphs some additional contrasts were tested. They were performed only for spacing, and with seedlings (no. 0) and clones (no. 5 and no. 244) kept separate.

2.3 *Assessments*

Measured characters were height, diameter at breast height, height to first living branch, crown diameter, branch diameter, and straightness. Volume per tree was calculated from height and diameter at breast height with Näslunds small volume function no. 4 for southern Sweden (NÄSLUND 1948). In addition, volume per hectare was calculated. This was done by multiplying volume per tree with number of trees per hectare at the actual spacing. No reduction for dead plants was done, the reason being that all treatments except one had the same survival rate. The mean values of the subplots were used in the analyses of variance, contrast-tests and when calculating the components of variation.

2.4 *Variation within materials*

From the measurements on individual trees, the standard deviation (s_x) and the mean value ($\bar{x}$), were calculated for every subplot (see *Figure 1).* The coefficient of variation ($\frac{s_x}{\bar{x}}$) for each treatment was then used when comparing variation within them. This was not possible for volume production per hectare, however.

3. Results

3.1 *Assessments*

The results of the assessments are expressed graphically in *Figure 2,* and results from analyses of variance and the components of variance are shown in *Table 2.*

Figures 2 a—c indicate that to obtain a high wood production per tree, grafted clones should be planted at wider spacing than seedlings. Seedlings tend to have a maximum height at 2.5 m spacing. The clones, on the other hand, increase in height when spacing is increased *(Figure 2 a).* (About this interaction, see part 3.3.) The relation between materials is the same for diameter and volume per tree, but here the increasing effect of spacing dominates, giving higher assessments at 4.0 m spacing *(Figures 2 b—c).* Volume per hectare, on the other hand, decreases with increasing spacing due to the lower number of plants per hectare *(Figure 2 h).* Thus the effect of spacing seems to be greater than the effect of material.

In traits connected with quality the differences were generally larger, both between types of materials and between the two clones *(Figures 2 d—g).*

However, except for straightness, the effect of spacing was even larger than the effect of material among quality

Table 2. — Assessments and coefficients of variation with material and spacing. Results from analyses of variance and the components of variance in percent on subplot mean-values. Model for calculations: see Materials and Methods.

Character	Assessments							Coefficient of variation						
	Analysis of variance			Components of variance				Analysis of variance			Components of variance			
	Material (M)	Spacing (S)	Inter-action (MxS)	M	S	MxS	Error	Material (M)	Spacing (S)	Inter-action (MxS)	M	S	MxS	Error
HEIGHT	P≤0.025	P≤0.1	NS	28.4	13.5	0	58.1	P≤0.1	P≤0.0025	NS	19.5	30.2	26.8	23.5
DIAMETER AT BRH	NS	P≤0.0005	NS	0	71.4	0	28.6	P≤0.05	P≤0.01	NS	16.3	30.2	4.3	49.2
MEAN VOLUME PER TREE	NS	P≤0.0005	NS	0	61.0	0	39.0	P≤0.1	P≤0.01	NS	15.0	29.1	0	55.9
VOLUME PER HECTARE	NS	P≤0.0005	NS	0	62.4	0	37.6	-	-	-	-	-	-	-
HEIGHT TO 1ST LIVING BRANCH	NS	P≤0.0005	NS	1.7	78.4	0	19.9	NS	P≤0.0005	NS	8.1	49.1	0	42.8
CROWN DIAMETER	P≤0.0005	P≤0.0005	NS	23.8	62.7	0.7	12.8	P≤0.05	P≤0.05	NS	26.7	10.6	16.3	46.4
BRANCH DIAMETER	P≤0.005	P≤0.0005	NS	16.2	64.0	0	19.8	P≤0.01	NS	NS	32.9	0	4.6	62.5
STRAIGHTNESS	P≤0.005	NS	NS	37.7	8.1	0	54.2	P≤0.01	NS	NS	33.2	10.4	0	56.3

Table 3. — Results from contrast-tests with assessments on material and spacing in different groups.

Character	Assessments: Material 0 vs 5+244	5 vs 0+244	244 vs 0+5	Square spacing 1.7 vs 2.5+4.0	2.5 vs 1.7+4.0	4.0 vs 1.7+2.5
HEIGHT	$P \leq 0.05$	NS	$P \leq 0.01$	$P \leq 0.1$	NS	NS
DIAMETER AT BRH	NS	NS	NS	$P \leq 0.0005$	NS	$P \leq 0.0005$
MEAN VOLUME PER TREE	NS	NS	NS	$P \leq 0.0005$	NS	$P \leq 0.005$
VOLUME PER HECTARE	NS	NS	NS	NS	NS	NS
HEIGHT TO 1ST LIVING BRANCH	NS	NS	NS	$P \leq 0.0005$	NS	$P \leq 0.0005$
CROWN DIAMETER	NS	NS	$P \leq 0.05$	$P \leq 0.0005$	NS	$P \leq 0.0005$
BRANCH DIAMETER	NS	$P \leq 0.1$	$P \leq 0.1$	$P \leq 0.0005$	NS	$P \leq 0.001$
STRAIGHTNESS	$P \leq 0.02$	NS	$P \leq 0.005$	NS	NS	NS

traits. The importance of the competition effect is demonstrated with the components of variance. Spacing has a larger component than material for all traits except for height and straightness. The interaction term is negligible, but the experimental error variance is rather large (*Table 2*). Analyses of variance and contrast tests also show higher significance for spacing than for material for all traits except height and straightness (*Tables 2* and *3*).

3.2 *Variation within materials*

Coefficients of variation for many characters changed in the opposite direction compared to the absolute measurements. Mean height was greater for seedlings at 2.5 m, but the coefficient of variation was then smallest. It was also smallest at 2.5 m spacing for diameter, volume per tree, crown diameter and for branch diameter (*Figures 3 a—f).* This can be interpreted in two ways:

i) standard deviation has the same absolute value although the stand is growing better and the relative variation in a rather small stand decreases during growth.

ii) there really are special growing conditions for seedlings of this height at 2.5 m spacing.

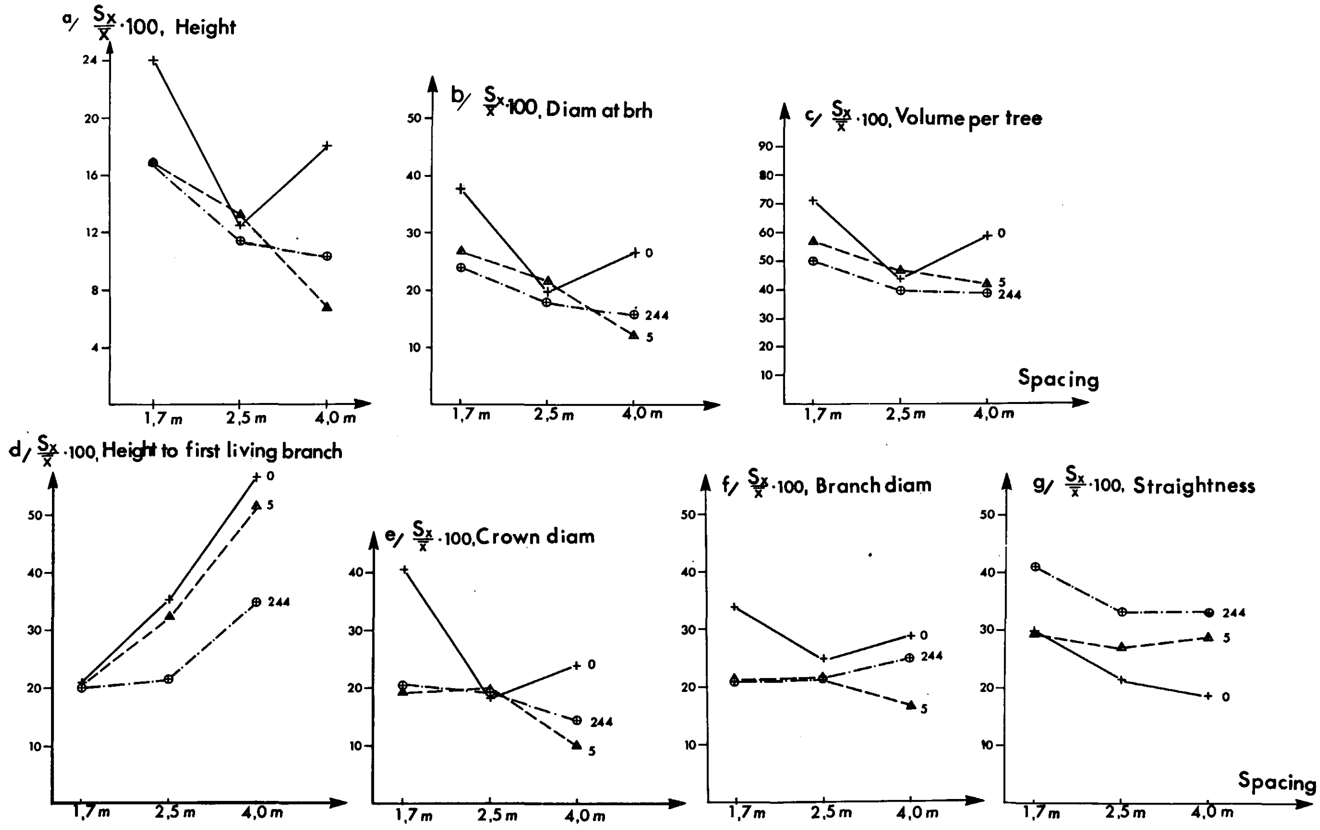

Figure 3. — Coefficients of variation ($\frac{s_x}{\bar{x}} \cdot 100$) for the characters analysed at the three spacings (not volume per hectare). Symbols and indices: see *Figure 2.*

Table 4. — Results from contrast-tests with coefficient of variation for material and for spacing in different groups.

Character	Coefficient of variation					
	Material			Square spacing (m)		
	0 vs 5+244	5 vs 0+244	244 vs 0+5	1.7 vs 2.5+4.0	2.5 vs 1.7+4.0	4.0 vs 1.7+2.5
HEIGHT	P≤0.1	NS	NS	P≤0.05	NS	NS
DIAMETER AT BRH	P≤0.1	NS	NS	P≤0.05	NS	P≤0.1
MEAN VOLUME PER TREE	P≤0.05	NS	NS	P≤0.005	NS	NS
HEIGHT TO FIRST LIVING BRANCH	NS	NS	P≤0.1	P≤0.05	NS	P≤0.02
CROWN DIAMETER	P≤0.05	NS	NS	P≤0.1	NS	NS
BRANCH DIAMETER	P≤0.05	P≤0.1	NS	NS	NS	NS
STRAIGHTNESS	P≤0.05	NS	P≤0.05	P≤0.1	NS	NS

Equation and statistical model:

$$\text{Coefficient of variation} = \frac{s_x}{\bar{x}} \cdot 100\ (\%)$$

Contrast-test with the contrast: $L = \sum_{j=1}^{r} c_j u_j$ where $\sum_{j=1}^{r} c_j = 0$ and an unbiased estimator of $\sigma^2(L)$ is: $s^2(\hat{L}) =$

$= MS_{Error}(\text{or } MS_{MxS+Error}) \cdot \sum_{j=1}^{r} \frac{c_j^2}{n_j}$. L = 2 (number of groups), $c = \{^{-1}_{+1}\}$ and n = 3 and 6 resp. (no. of repl.)

Confidence limits of L: $\hat{L} - t(1-\frac{\alpha}{2}; 4) \cdot s(\hat{L}) \leq L \leq \hat{L} + t(1-\frac{\alpha}{2}; 4) \cdot s(\hat{L})$

Variation among grafted clones decreased in most cases when spacing was increased, and clones had significantly smaller variation than seedlings, except for height to first living branch and straightness ($P \leqq 0.1$, *Table 4* and *Figure 3).*

Where competition had started at the densest spacing, production traits had higher variation for all materials than at the two wider spacings *(Figures 3 a—c).* This difference was significant when pooling all types of material ($P \leqq 0.05$, *Table 4).* For quality traits the differences are not so clear and the characters do not all follow the same pattern *(Figures 3 d—g).* The additional contrast-tests, in which seedlings were analysed separately and the 2.5 m spacing was tested against the sum of the two others, did not show significance. When the grafted clones were kept separate and the 4.0 m spacing was tested against the denser ones, no significance was found either.

3.3 *Interaction*

The graphs indicate that interaction exists between type of genetic material and spacing in the assessments and also in their coefficient of variation *(Figures 2* and *3).* This seems to be true especially for the coefficient of variation in height, diameter at breast height, mean volume per tree and also crown diameter. However, in the analysis of

Table 5. — Effects of *decreasing* spacing on assessments of different traits. Comparison of the present results with those from other studies.

Trait	Reference							Present study
	Sakai & Mukaide (1967)		Elfving (1975)	Persson (1977)	Hattemer et al. (1977)		Hellström (1982)	
					Clones			
	Clones	Seedlings	Seedlings	Seedlings	Unfertilized	Fertilized	Clones	Clones
CONDITION			Poorer	Poorer			Poorer (NS)	Poorer (NS)
HEIGHT	Lower	Lower	Lower	Higher	Lower	No difference	Lower	Lower (P≤0.1)
DIAM AT BRH	Smaller	Smaller	Smaller	Smaller	Smaller	No difference	Smaller	Smaller (P≤0.0005)
STRAIGHTNESS				Straighter			More crooked	Straighter (NS)
VOLUME PER TREE			Lower	Lower (trials in southern Sweden)			Lower	Lower (P≤0.0005)
VOLUME PER HA (all stems)							Higher	Higher (NS)
HEIGHT TO FIRST LIVING BRANCH				Higher			Higher	Higher (P≤0.0005)
BRANCH DIAM			Smaller	Smaller	Smaller (larger differences among unfertilized plots)	Smaller	Smaller	Smaller (P≤0.0005)

variance on this material, no significance was found (*Table 2*). On the whole, interaction between spacing and degree of genetic variation is less pronounced in graphs describing quality traits, and the interaction component of variance is negligible in all cases except for coefficient of variation in height and crown diameter.

Interaction between genotype and spacing does not seem to exist in this trial. The two clones have almost parallel lines for all the traits, indicating no interaction either in assessments or coefficient of variation (*Figures 2* and *3*).

4. Discussion

4.1 *Shortcomings*

This trial has only two grafted clones and one seedling material. This could be why the indications on interaction between seedlings and grafted clones in *Figures 2* and *3* are not significant and the error components of variance are often high (*Table 2*). With a greater number of clones it might be possible to find interaction between some genotypes and spacing. The number of plants, especially in the 4.0 × 4.0 m spacing, is also small and this makes the estimates of mean values and of variation uncertain as well as volume production per hectare. One could also discuss whether it is correct here to use coefficients of variation when mean values are too different. Can standard deviation change with the same amplitude as the mean value used in the denominator when calculating the coefficient of variation? When the coefficient of variation decreases in contrast to the assessment, this negative correlation could simple represent an effect of the increased mean value.

Another shortcoming is that it is not possible to know whether differences between seedlings and grafted clones depend on the clones being grafts or on being genetically homogeneous.

4.2 *Interaction with spacing*

In the 1.7 m spacing, natural thinning has started and the results for this spacing could be explained by competition. It can be expected that some trees are suppressed, causing lower assessed mean values and larger variations. This is in accordance with the results for most traits among both grafts and seedlings.

The seedlings are highest at 2.5 m spacing, and at this intermediate spacing the trees seem to have been growing without suppressing neighbouring ones. This is also the situation for other traits. Competition has not yet started and variation is lower.

In the widest spacing one could assume that the seedlings have not grown dense enough to give each other the shelter they need when small, thus causing high variation.

Material (seedlings or grafted clones) seems, however, to interact with spacing in this trial. The grafted clones grow better at 4.0 meter spacing and seem thus to need wider spacing. One possible explanation could be that their genetic identity causes higher competition. The individuals have exactly the same demands, which is not the case in the more genetically varied seedling material.

Another explanation is that they are adapted to grow like tops of trees, with lots of space. This would be the case if the performance of the grafted clones is much influenced by their being regenerated by grafting.

If grafted clones do require changed silvicultural methods, the suggestion is that the clones be grown at a wider spacing to yield more, give higher quality and produce a more even stand. Whether this is an effect of grafting or of genetic homogenity within the clone is not possible to show here, but for spruce the propagation method seems to be rather important. Roulund (1980) found very big differences in the coefficient of variation within clones of Norway spruce. Within some clones it was even larger than within open-pollinated material. For most clones it was of the same magnitude as within the clones in this trial.

4.3 *Effects of spacing*

4.3.1 Effects on assessments, comparisons with other trials.

Table 5 shows a comparison of the present results with those from other spacing trials comprising genetically variable (open-pollinated seedlings) and genetically homogenous (clones) of Scots pine plants.

4.3.2 Effects on variation, this trial

The small micro-environmental differences in this trial largely enhanced variation in plots with narrow spacing.

This could be seen from the fact that for all characters except height to first living branch not only the seedlings but also the grafted clones increased their coefficients of variation when spacing was denser (*Figure 3*). For height this increase was drastic ($P \leq 0.05$) and, except for branch diameter, all these characters had higher variation at 1.7 m spacing than at wider spacing. The differences, however, were of low significance in crown diameter and straightness ($P \leq 0.1$, *Table 4*).

4.4 *Components of variance*

A small number of materials was included in this trial. However, one can conclude that it is more important to choose a suitable spacing than to choose the best material. The spacing components of variance from assessments are nearly always higher than those from materials. For production traits the effect on coefficient of variation from spacing is also larger than the effect from material (*Table 2*).

This is in agreement with other results. Persson (1976) says that in southern Sweden an initial spacing of 1.0 m is needed to get good quality root stock unless pruning is done. Avoiding bad branching by choosing plant material with superior quality is not possible. Persson claims that a wide spacing has too strong a negative effect on branching.

However, another trial with 20 clones of grafted Scots pine in one single spacing indicated that the material effect and also heritability were large enough to justify selection of clones at an age of 12 years (Wellendorf 1970). The problem with differences caused by grafting is also pointed out here.

4.5 *Special differences in some traits*

Some special growth differences between seedlings and grafted clones can also be seen. The variation in straightness was reversed: the grafted clones varied much more in straightness than the seedlings ($P \leq 0.05$, *Table 4* and *Figure 3 g*). The probable reason was that the grafting procedure gave variable success. However, looking at the assessments of straightness, the seedlings were more crooked ($P \leq 0.02$ and *Figure 2 g*).

The seedlings seemed to produce longer but thinner branches than the grafted clones. Crown diameter was greater among the seedlings, indicating longer branches. In spite of these longer branches on the seedlings, the branch diameter was the same as for the grafts. One can mention here that the quality of branches of Scots pine is known to be better on forest land, as in this trial, than on agricultural land (Blomqvist 1976).

5. Conclusions

Somewhat changed silvicultural methods may be needed when using grafted clones in forestry. Choice of proper spacing is then important and research on the effect of competition and on the method at plant propagation is needed. On the whole the variation between plants within the seedling material was larger than between grafts within the clones except for straightness *(Figure 3 a—g)*. The reason could be that genetic differences within the seedling material caused more variation than the genetic differences in the root part and the physiological differences resulting from the grafting procedure.

It seems to be possible to decrease variation, especially for volume production, by conducting trials with grafted clones, but then competition must be low. Clones could thus be a great help in breeding work. A greater number of clones must be tested to give information of interaction between genotype and spacing.

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The somatic chromosomes of Cryptomeria japonica with special reference to the marker chromosomes[1])

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Summary

The diploid chromosome number of *Cryptomeria japonica* was found to be $2n = 2x = 22$, which concurs with previous reports. The majority of chromosomes were found to have median kinetochores. One submetacentric chromosome pair has an unusually long primary constriction which consists of chromomeres connected by the kinetonema. The possibility that this unusual region is of a compound nature, containing the nucleolar organizer and microtubule attachment sites, is discussed. Observations of the present study were compared with results of previous studies in order to provide a better understanding of the chromosome morphology in *Cryptomeria*.

Key words: Cryptomeria, Taxodiaceae, marker chromosomes, kinetochore, kinetonema.

Zusammenfassung

Die diploide Chromosomenzahl von *Cryptomeria japonica* hat sich als $2n = 2x = 22$ herausgestellt, was mit früheren Berichten übereinstimmt. Die Mehrzahl der Chromosomen zeigten mittelgroße Kinetochoren. Ein submetazentrisches Chromosomenpaar hat eine ungewöhnlich lange primäre Constriktion, die aus Chromomeren besteht, welche durch Kinetonemen verbunden sind. Die Möglichkeit, daß diese ungewöhnliche Region zusammengesetzter Natur ist und einen nukleolaren Organisator und mikrotubulare Anknüpfungsstellen enthält, wird diskutiert. Beobachtungen der gegenwärtigen Untersuchung wurden mit den Ergeb-

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