How Genotype and Silviculture Interact in Forming Timber Properties

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Independent of genotype, increased spacing results in increased branch diameter of Scots pine (*Pinus sylvestris* L.), but on different levels for different genotypes. Frequency of defects like spike knots and crooked stems are under stronger genetic than silvicultural control. Simultaneous improvement of rate of growth and timber properties is feasible. Deteriorating of both factors can happen rapidly at a negative selection. This needs consideration when selecting seed trees for natural regeneration. A defect like stem cracking of Norway spruce (*Picea abies* (L.) Karst.) only manifests itself under drought stress when certain genetic and environmental prerequisites are present, like high fertility and wide spacing. This emphasize the fact that new silvicultural methods may reveal genetic weaknesses.

Keywords *Pinus sylvestris*, *Picea abies*, genotypes, silviculture, wood properties, spacing.
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1 Introduction

The aim of this article is to be a review of the stated subject based on relevant literature and also including some unpublished data from the author.

From the very start of the plus tree selection in Sweden, high quality was kept in high regard. In spite of that, evaluation of progeny trials of Scots pine revealed that although they showed an improved rate of growth through the selection, the quality-related traits had remained rather unimproved (Werner and Ericsson 1980, Wilhelmsson and Palmér 1988). But on the other hand, it has been found a considerable variation in quality traits related to timber properties between progenies (Andersson 1986). This shows that there is a potential for genetic improvement. As the referred studies reveal that quality traits of Scots pine vary rather independently of the volume increment, the prospect of simultaneous breeding for higher quality and improved rate of growth appears feasible.

The inheritance of certain characteristics is clearly shown by Pöykkö (1993). He studied ideotypes and especially the inheritance of certain characteristics from the so called Kanerva pine. This pine is exceptional, as the inheritance may be monogenic, whereas it more commonly is polygenic, as further discussed by Pöykkö and Velling (1993). It was found that the combination of rapid growth and thin branches found in the Kanerva pine was strongly inherited. The matter was, however, complicated by the fact that this special ideotype had one inferior trait as the stems were not straight.

As stated in Wilhelmsson and Palmér (1988), the generally accepted reason for lack of selection results concerning timber properties was that the selected plus trees in the late forties usually were mature trees in naturally regenerated stands. The environmental conditions of the various trees had varied considerably. It is obvious that given favourable conditions from a quality viewpoint, e.g. strong competition at young age, also fairly average genotypes could develop into high quality phenotypes. Also the fact that the progenies were compared under conditions different from those of their parents, viz. planted in approximately 2 m spacing, caused lack of conformity in parent-progeny relationship.

The recognition of the importance of these relationships caused changes in the selection methods, expressed in Werner et al. (1981). The most important of these changes was that the selection of plus trees should be carried out in plantations of age 20–50 years. Through that two things were gained: The selected trees were raised under conditions similar to the expected conditions of the future stands and quality defects, like large branches and spike knots, were still clearly visible on the stem. Through this the importance of environmental factors, out of which silviculture is one, was clearly recognized.

Outside Finland and Sweden, generally little emphasis has been placed on timber properties in breeding programmes. These shortcomings have been stressed several times by prof. Bruce Zobel, an example being Zobel and Kellison (1978).

2 Interaction Genotype – Silviculture

2.1 Examples in Scots Pine: Genotype – Spacing

That silviculture alone has a strong impact on timber properties had been shown by Uusvaara (1974), who showed that plantation-grown pines generally had a lower quality than naturally regenerated ones. Persson (1976, 1977) studied more specifically the impact of spacing on sawn timber and properties related to timber quality. An increased spacing gave lower quality of the sawn timber, and in Persson (1977), it was shown that the effect of spacing was an indirect one and that the growth rate during the early years had an impact on branch diameter which overtook the effect of spacing itself. In Fig. 1, based on Table 8.8 in Persson (1977), the early rate of growth is expressed as the total width of the 5 annual rings outside 20 mm from the pith at breast height. The branch diameter refers to the diameter under bark of largest branch, dead or live, between 1 and 2 m from the ground. How the measure of early rate of growth could be used genetically is shown through the two crosses, representing two trees which both have approximately the same branch diameter, whereas the early rate of growth is considerably different. In this case, the tree represented by the right hand cross must be judged as genetically more narrow-branched than the one represented by the left cross, i.e. has smaller relative branch diameter.

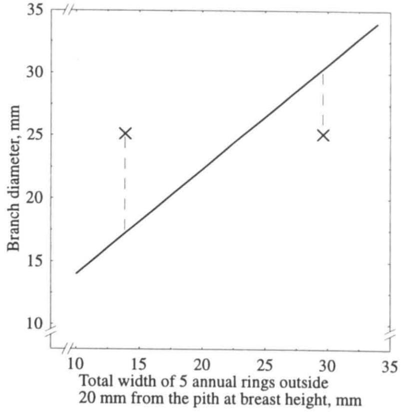

Fig. 1. Average relationship between early diameter growth and diameter under bark of largest branch 1–2 m above ground. From Persson (1977).

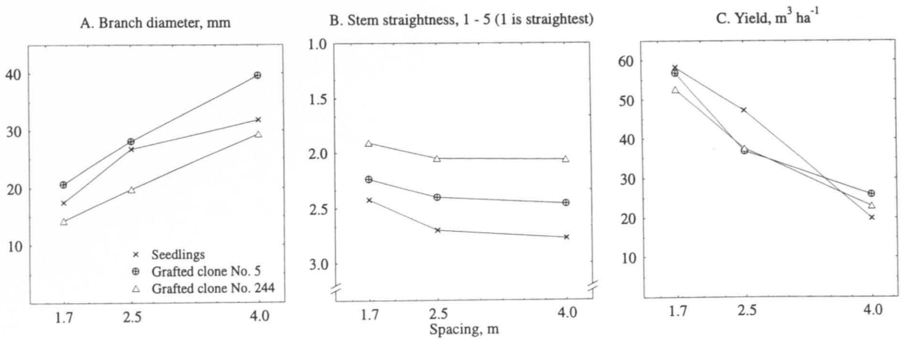

Fig. 2. Variation with spacing of three traits for different genotypes. From Fries (1984).

The general increase in stem diameter at breast height and branch diameter in the first whorl above 1.3 m from the ground with increasing spacing is shown by Dippel (1982). Increased spacing also increases the percentage of stems with bad form and of trees with double leaders.

An interesting illustration to the possibilities of simultaneous breeding for yield and quality of Scots pine was given by Fries (1984). At a locality in south Sweden, Skillingaryd, lat. 57°27'N, long. 14°06'E, altitude 190 m, grafted ramets from one plus tree (No. 244, from lat. 61°30'N, long. 12°30'E, altitude 370 m) and one tree selected as average (No. 5, from lat. 59°30'N, long 18°E and close to sea level) were compared with seedlings (No. 0) from open-pollinated trees in a neighbouring stand. The age was 20 years.

Some results from Fries' study are shown i Fig. 2. The plus tree ramets had both the smallest branches and the straightest trees, while the volume per hectare was similar for all materials at each spacing, except that the seedlings had higher volume at 2.5 m spacing. The differences in volume between spacings was of the magnitude that the author concluded that "the effect of spacing seems to be greater than the effect of material". Although the inheritance is not clarified, the study gives powerful indications that a high yield per unit area can be combined with favourable timber properties, in this case straight stem and fine branches. But even for the best material, increased spacing gave increased branch diameter. There is also a tendency of decreasing straightness with increasing spacing, although the change is not as pronounced as for branch diameter. These findings are in line with what was found in spacing experiments by Persson (1977).

The pronounced effects of spacing on branch diameter causes problems in discerning the genetic effect. Even small differences in survival and subsequent differences in spacing result in the genetic effect being overshadowed as shown by Mathieu (1968) and Remröd (1976).

Other effects of spacing on quality were shown by Prescher and Ståhl (1986), who studied the so called Eiche provenance series, where the provenances are planted in two different spacings. They identified clear provenance differences, which were, however, much smaller than differences between localities. They identified three factors why a closer spacing has a pronounced positive effect on the quality:

1. A competitive effect, causing slower growth in early age and thus a higher quality
2. A thinning effect, causing an early reduction in the number of low quality trees
3. With the same proportion of high quality trees, there will be a higher total number per unit area

In modern progeny trials it is impossible to evaluate and compare the differences caused by dif-

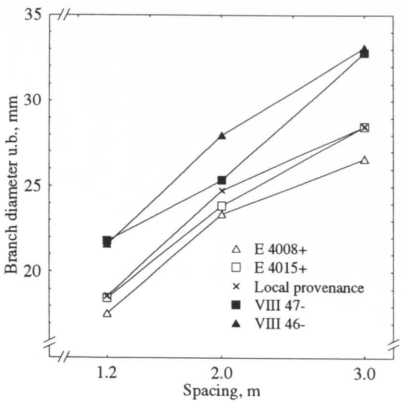

Fig. 3. Variation with spacing of diameter of largest branch between 1 and 2 m from the ground of different genetic entries in the experiment near Vetlanda, described in Persson et al. (1995).

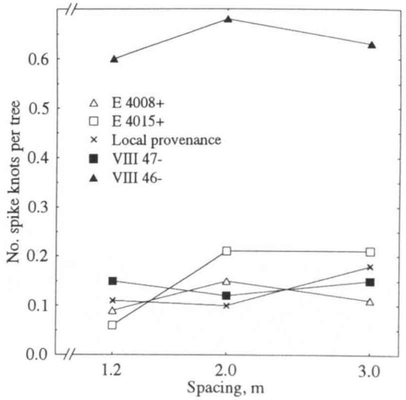

Fig. 4. Variation with spacing of number of spike knots per tree of different genetic entries in the experiment near Vetlanda, described in Persson et al. (1995).

ferent spacing as the trials usually are established as single-tree plots with uniform spacing. An interesting experiment which combined five different genetic entries of Scots pine with three different spacings (1.2 × 1.2, 2.0 × 2.0 and 3.0 × 3.0 m) was established 1961 by Carin Ehrenberg near Vetlanda in southern Sweden (lat. 57°25'N, long. 15°08'E, altitude 195 m). The site index is T 26 (Hägglund and Lundmark 1981), which means a rather fertile site. The meaning of the index is that the dominant height of Scots pine at the age of 100 years (H_{100}) at this site is 26 m. The genetic entries are progenies from the plus trees E 4015 and E 4008 and from the minus trees VIII 46- and VIII 47-. The trees were described by Ehrenberg (1963). All are selected within the same stand nearby Boxholm, Östergötland county, lat. 58°07'N, altitude 180 m. The selection of the plus trees had been carried out in the normal way for Swedish tree breeding at that time, while the phenotypically inferior minus trees were selected for studies of inheritance. The fifth entry is the control, a local provenance, intended to represent the experimental site. The experiment is further described in Persson et al. (1995).

In 1975, 15 years after planting, an assessment of various traits of importance for timber properties was carried out (unpublished study by the author). Branch diameter, which is calculated as average for the 1500 main stems per hectare, is shown in Fig. 3. The same pronounced increase with increasing spacing as in other referred studies is manifested also here. The plus tree progenies have at all spacings thinner branches than the local provenance and especially the minus tree progenies. It may be expressed in that way that the plus tree progenies have about the same branch diameter at 3 m spacing as have the minus tree progenies at 2 m spacing.

In Fig. 4 the average number of spike knots is shown for the same main stems. Here no systematic differences between spacings can be found. What is striking is that the progenies from minus tree VIII 46- has considerably higher number of spike knots at all spacings. It indicates that this trait is strongly genetically based, and not affected by a silvicultural difference like spacing.

In 1982, a first silvicultural low thinning was carried out in the two closer spacings. In 1990, 30 years after planting, the second thinning was carried out, systematic in two replications and a silvicultural low thinning in three replications. The results at this age are available in Persson et al. (1995). The total yield for each genetic entry and spacing is shown in Fig. 5. The lowest yield was found for the minus tree progenies, whereas the local provenance competed well with the best plus tree. The differences between spacings were, as could be expected, decreased yield with increased spacing. Worth noting is that the range in yield between 1.2 and 3.0 m spacing is of the same magnitude as between the best and the worst progenies.

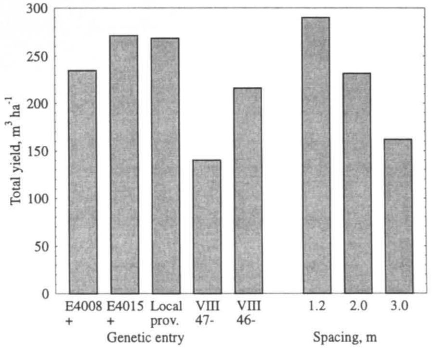

Fig. 5. Total yield 30 years after planting for different genetic entries and spacing in the experiment near Vetlanda, described in Persson et al. (1995).

Test sawing was carried out of the logs from thinned trees, although the size did not permit sawing of all. Both the logs and the central yields were graded according to the export grading rules (Föreningen Svenska Sågverksmän 1965). The central yields were also stress-graded according to the principles described by Brundin (1981). The machine used was a Cook-Bolinder At-Gs. The results from the gradings are shown in Fig. 6.

Based on this figure and other data, the following conclusions can be drawn:

1. At this fertile site, even as close a spacing as 1.2 × 1.2 is insufficient for obtaining good timber properties
2. The timber properties further deteriorate with increased spacing.
3. The deterioration with increased spacing follows the same pattern for all genetic entries.
4. The plus tree progenies are not considerably better than the local bulk seed source.
5. The minus tree progenies, especially VIII 46, have very poor quality in all respects.

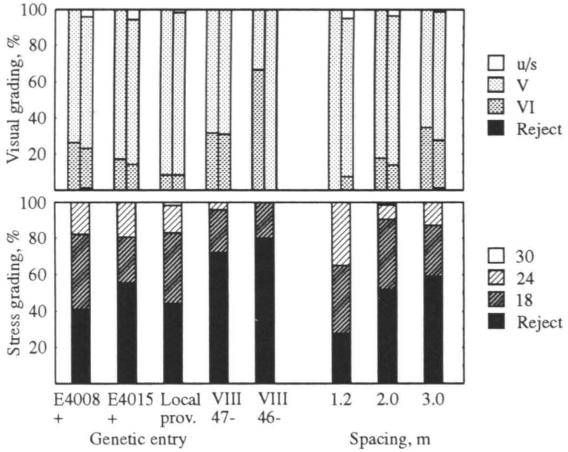

Fig. 6. Results from grading of logs and sawn timber from the experiment near Vetlanda. In the upper diagram, the left columns indicate log quality judged before sawing, the right columns quality of the sawn central yields, which are also stress-graded and results shown in the lower diagram. From Persson et al. (1995).

2.2 Examples in Norway Spruce: Stem Cracking

Studies of the stem cracks in Norway spruce illustrate well the combined effect of environments and genotype. A study of the findings from a project investigating this subject is recently published (Persson 1994), why only a brief summary is given here.

Stem cracking of Norway spruce occuring in 1911 was reported in Germany by Flander (1913). A thorough analysis of stem cracking in conifers, including Norway spruce, during the latter part of 1947 was carried out by Day (1954). He concluded that cracking was caused by an abnormal drought.

In Sweden, cracking was studied in a combined clonal and seedling seed orchard by Eriksson et al. (1975). About 4 % of the stems showed cracks, but no differences in cracking frequency between provenances could be found. From 1980 stem cracks in Norway spruce was recognized as a problem in southern Sweden. Stands 15–20 years of age that had been planted at a wide spacing on fertile sites were most affected. Because of the severity of the problem funds were provided for a thorough study. Also in Norway stem cracking had been studied and reported by Dietrichson et al. (1985), who found drought to be the triggering factor. Later on, Caspari and Sachsse (1990), in a more technical approach, revealed that the cause of cracking is that during hot and dry periods the normal sucking tension between the crown and the root increases to such an extent that cell collapse occurs. This develops into xylem cracks and when wood strength proves to be insufficient, fully developed stem cracks are formed.

Through author's own data and data provided from Denmark and Norway, it was found that increased spacing increased the frequency of cracked trees and that some provenances were more prone to cracking than others (Persson 1994). Provenances from Slovakia and Romania had a higher than average frequency of cracked trees, whereas provenances from Finland, northern Poland and an area comprising the Baltic states, Belorussia and western Russia had a lower than average frequency, all other factors being constant. The genetic impact became very obvious when studying the frequency in a seed orchard in southern Sweden (Scania). Conditions in seed orchards are conducive to the formation of cracks since the spacing is wide and the soil is well fertilized. Out of the 45 clones in the seed orchard, each represented by about 150 grafts (ramets), only 5 had more than two cracked ramets. For those clones, the cracking frequency varied between 4 and 71 %. The highest frequency was found for a clone from Poland. Other clones from the same area showed no cracking at all.

In the seed orchard studied by Eriksson et al. (1975), further observations were carried out in 1985 by Persson et al. (1987). By that time the frequency of cracked stems had increased to 12 %. Test-sawing of cracked and equally large uncracked trees revealed that both kinds produced very weak central yields. From the cracked trees, 21 % of the yields qualified for the lowest grade of structural timber (T 18), whereas the corresponding value for yields from uncracked trees was 24 %.

In Persson et al. (1987) as well as in other similar studies, e.g Monchaux and Nepveu (1986) and Boulet-Gercourt and Nepveu (1988, refers to *Abies grandis*), the basic density of cracked trees was 5–6 % lower than that of uncracked trees of the same diameter. However, also the uncracked trees had unsatisfactory low basic density and strength (Persson et al. 1987). The conclusion was that low basic density, and thus low strength, rather than cracking itself is the major cause of economic losses in cracking-susceptible stands. The cracking is consequently, rather than being the problem itself, merely a symptom of an unfavourable combination of silviculture and genotype.

To summarize, formation of stem cracks in Norway spruce is affected by the following factors:

Genotype	(clone, progeny, provenance)
Site quality	(only fertile sites affected)
Silviculture	(wide initial spacing, heavy early thinnings)
Precipitation	(triggered by drought, if other preconditions present)
Soil	(hampered root growth downwards increases the risk)

3 Conclusions

From findings in referred studies can be concluded:

1. It is easier to impair timber properties of Scots pine through a negative selection than improving them through a positive one. This stresses the importance of a proper choice of seed trees when planning natural regeneration.
2. It is possible in Scots pine to combine thin branches, straight stems and a high yield per unit area.
3. *But*, for both species studied, there is always a deterioration in quality when competition is reduced, e.g. through wider spacing or early and heavy pre-commercial thinning.
4. Hidden weaknesses may be revealed through new silvicultural methods. As an example, large scale planting in wide spacing on abandoned agricultural land revealed that Norway spruce may crack, which in turn is a symptom of badly matching silviculture and genotype.
5. In any breeding programme, the silvicultural regimes to be used have to be considered.

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