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Norway Spruce Cuttings Perform Better than Seedlings of the Same Genetic Origin

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Abstract

Growth and survival for seedlings and cuttings of Norway spruce were compared. The two different plant lots originated from the same seed source, and the selection of plants for cutting propagation gave a neglectable reduction of genetic variation. Eight years after planting, both survival and height were superior for cuttings compared to seedlings. The differences in performance for the two plant materials can be explained by differences in morphology and physiology. The results indicate that genetic selection for growth, based on clonal tests, can be improved by using growth in a later stage than from the first eight years when comparing different clones.

Key words: Picea abies, seedlings, cuttings, growth.

Introduction

In Sweden the interest on clonal forestry has been focused on Norway spruce (*Picea abies* (L.) Karst.). An increased growth of about 20% compared to seedlings has been reported (Roulund et al., 1985).

For the tree breeder it has been important to find methods to test selected cuttings at an early age, mainly due to the problem of aging (Kleinschmidt and Schmidt, 1977; Werner and Pettersson, 1981). A clone that is tested for a long time in the field is not usable unless the clone could be maintained in a juvenile status. Early selection is therefore an absolute condition for largescale production of commercial cuttings (Roulund, 1980; Kleinschmit and Schmidt, 1977; Foster et al., 1989).

Another reason for making early selections is that cuttings to a large extent are tested in single tree plots. This implies a risk of making incorrect rankings concerning long term growth rates, since competition occurs at 2 m to 3 m stand height in spacings of 2 m x 2 m (Gemmel, 1988). Clones that start to grow rapidly after planting will thus be favoured ahead of "slow starters".

Cuttings are morphologically different from seedlings depending on the propagation method. Kleinschmidt and Schmidt (1977) found that the root/shoot relation was abouth the same for both cuttings and seedlings, while the young cuttings had larger diameter, higher root and shoot weights than seedlings of the same height. It is suggested that this increases the ability to survive damages, such as attacks by pine weevils. The age of the cuttings and the fact that cuttings are physiologically older than seedlings may also influence establishment and growth. Roulund (1980) points out that plagiotropic growth, caused by taking twigs on old ortets, might be an important factor leading to slow height growth.

Several studies (Lambeth et al., 1983; Huehn et al., 1987; Bentzer et al., 1988) report significant correlation between growth and height 3—6 years after planting and growth after 10 to 20 years. Studying old provenance trials Marklund (1981) found that survival and mean height at age 13 correlated well with total growth at a 70 year age. However, by using only the height information at age 13 the correlation was relatively weak. The plot size in the experiments was 0.04 ha to 0.08 ha, thus avoiding the most severe problem of competition.

In this report, two series of experiments are presented for comparison of seedlings and cuttings from the same seed source. The selection of cuttings was made so that cuttings and seedlings can be regarded as essentially genetically similar.

The objectives of the study were to provide data on establishment and growth of cuttings in a practical situation and to examine nongenetical growth differences between cuttings and seedlings.

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Materials and Methods

Plant material

In autumn 1977, four twigs were taken from three-year-old bare root seedlings, originating from seed orchard 52 in Maglehem, Sweden. This seed orchard consists of plus trees of German origin, selected in stands in southern Sweden. The tallest seedling in clusters of three was selected for cutting propagation, which gave a selection intensity of 1:3. After collection the cuttings were mixed and stored in plastic bags at a temperature of —4 °C until propagation began in spring 1978.

Rooting and the first growing year took place in a gravel bed in an unheated nursery. The rooted cuttings were lifted in autumn 1978 and stored in —4 °C during winter. They were then transplanted as bare root stock outdoors in spring 1979 and were ready for planting two years later.

In the spring of 1978 seeds from the same seed orchard were sown. The seedlings were grown as bare root stock and were ready for planting at the same time as the cuttings. Before planting 20% of the seedlings were sorted out judged as inferior. The seedlings and cuttings were of good quality and of about the same height at the time of planting (M. Werner, pers. comm.).

Experimental sites

Field experiments were established on forest land in southern Sweden (*Figure 1*). The experimental design was:

— a randomized block experiment, in the following named the "block experiment" (*Table 1*);

— pairs of comparisons of seedlings and cuttings. They were established in commercial plantations on 27 different sites, and will be referred to as the "commercial plantations" (*Table 2*).

In the block experiment each treatment was replicated 10 times, distributed on 3 different sites (*Table 1*).

In the commercial plantations, each clearcutting was divided into two parts; (i) one half of the area was planted with cuttings and (ii) the other half with seedlings. The landowner was responsible for planting and was instructed to use 1.8 m x 1.8 m spacing. Sites chosen for the practical plantations were not homogeneous, and site conditions were quite variable (*Table 2*).

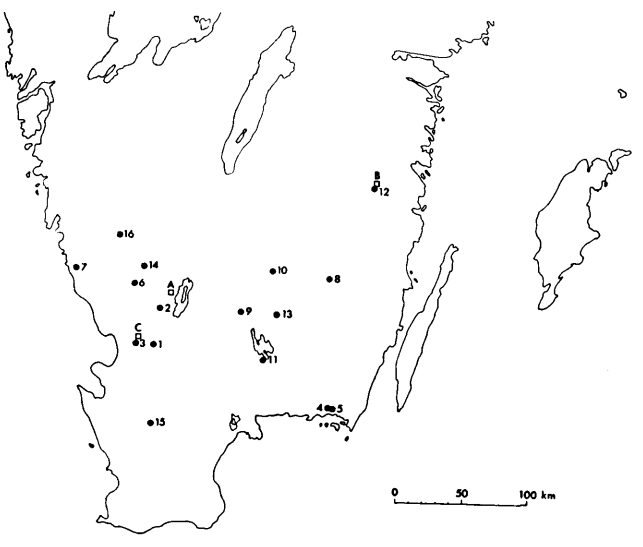

Figure 1. — Map of experimental sites. A to C = "block experiments", 1—16 = "commercial plantations". (cf. *Tables 1* and *2*).

Table 1. — Description of the experimental sites, "block experiments".

	Sites		
	Tiraholm A	Lidhem B	Tönnersjöheden C
Site index	G 28	G 34	G 32
Soil moisture	mesic	mesic	mesic
Soil texture	sand-fine	sand-fine	sand-fine
Field layer	grass	low herbs	grass
Number of blocks	4	4	2
Plants/plot	64 (8*8)	48 (6*8)	324 (18*18)
Spacing (m)	1.8*1.8	1.8*1.8	1.5*2.0
Total number of plants	512	384	1296

Table 2. — Description of the experimental sites, "commercial plantations". Vm=Vaccinium vitis-idea type, My=Vaccinium myrtillus type, Gr=grass type, Th=tall herb type, Lh=low herb type.

Nr	Site	Site index	Soil moisture	Soil texture	Field layer
1	Egernahult	G32	Mesic	Sand-fine	Vm
2	Öjaböke krp	G30	Moist	Sand	Lh
3	Tönnersjöheden	G28	Mesic	Sand-fine	Gr
4	Johannishus	G28	Moist	Sand-fine	Th
5	Johannishus	G28	Mesic	Sand-fine	Th
6	Drängsered	G24	Mesic	Sand-fine	Gr
7	Grimeton	G28	Mesic	Sand-fine	Lh
8	Kärseskruv	G26	Mesic	Sand-fine	Gr
9	Oby	G28	Moist	Sand-fine	My
10	Asa	G28	Mesic	Sand-fine	Gr
11	Hackekvarn krp	G34	Moist	Silt	Th
12	Lidhem	G34	Mesic	Sand-fine	Lh
13	Fyllerud	G32	Mesic	Sand-fine	Lh
14	Tönnerbohult	G28	Mesic	Sand-fine	Gr
15	Klingstorps krp	G34	Mesic	Sand-fine	Gr
16	Mjöbäck	G24	Mesic	Gravel	Gr

Site index and site properties are described using a system developed by Hägglund and Lundmark (1977) (*Tables 1, 2*).

Measurements

In the autumn 1983 (Tönnersjöheden) and 1984 (Tiraholm and Lidhem), height and survival were recorded in the block experiments. In the autumn 1988 height was measured on all living plants within the experiments and survival recorded. On every fourth tree the diameter 0.2 m above ground and distances between branch whorls were measured.

In 1988 data from 16 of the original 27 commercial plantations were taken. No data from the other plantations were taken because of severe damage and/or difficulties to separate originally planted plants from beeted plants and natural regeneration. On each site, 35 to 45 circular plots of 10 m² per treatment were systematically laid out. On each sample plot, the number of planted plants were registered and the tree closest to the centre of the plot was chosen as sample tree. Height, diameter 0.2 m above ground and distance between branch whorls were measured on the sample tree.

Table 3. — Height, diameter 0.2 m above the ground, length of leading shoot and survival 1988 for cuttings and seedlings in the block experiments. Values from 1983/1984 years measurement within brackets.

Site	Plant type	Height cm	Diameter mm	Shoot cm	Survival %
Tiraholm	cutting	211 (60)	42	56 (17)	71 (73)
	seedling	168 (47)	38	48 (10)	40 (41)
Lidhem	cutting	310 (92)	51	71 (26)	88 (91)
	seedling	271 (73)	47	68 (22)	58 (60)
Tönner-sjöheden	cutting	276 (52)	56	67 (17)	73 (73)
	seedling	249 (42)	53	63 (13)	49 (49)

Table 4. — Statistical differences between cuttings and seedlings in survival, height, diameter 0.2 m above ground and height growth. NS = P>0.05, * = P < 0.05, ** = P<0.05, *** — P<0.001.

	Block experiment	Commercial plantations
Survival 1988	***	-
Height 1988	***	*
Height 1985	**	*
Height growth 1985-88	*	*
Diameter 1988	*	NS
Length of leading shoot 1988	NS	NS

Calculations

The distances between whorls were used to calculate the height development for every single sample tree.

Differences in height, height development and diameter 0.2 m above ground were compared for seedlings and cuttings. When analysing the data from the commercial plantations, each site was considered as a block. Analysis of variance was used according to the method for randomized blocks.

Results

Block experiments

The survival and height growth were superior for cuttings compared to seedlings on all experimental sites (*Table 3*). The survival 8 years after planting was, as a mean for all plots, 78% for cuttings and 49% for seedlings. The difference was significant (*Table 4*).

The cuttings were significantly higher than the seedlings. On an average the height of the seedlings 8 years after planting was 85% of the cuttings (225 cm and 264 cm, respectively). The difference increased from 1985 to 1988 (*Figure 2*). The height growth of the seedlings between 1985 and 1988 was 88% of the height growth of the cuttings. The difference was significant. However, the difference in length of leading shoot 1988 was not significant, but was 11% higher for cuttings than for seedlings (*Table 4*).

On all experimental sites and every studied year the length of the leading shoot was higher for cuttings than for seedlings. However, also the mean height was higher for cuttings in the beginning of each vegetation period (*Figure 3*).

The diameter 0.2 m above ground of the seedlings was 92% of the cuttings. The difference was significant (*Table 4*).

Commercial plantations

In the commercial plantations, differences between seedlings and cuttings 8 years after planting were similar

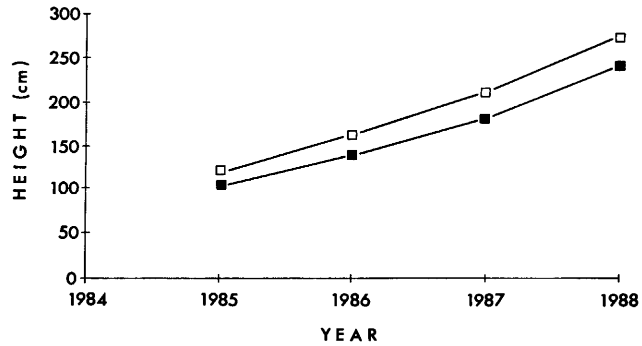

Figure 2. — Height development of cuttings (□) and seedlings (■) of Norway spruce planted in spring 1981 in southern Sweden. "Block experiments".

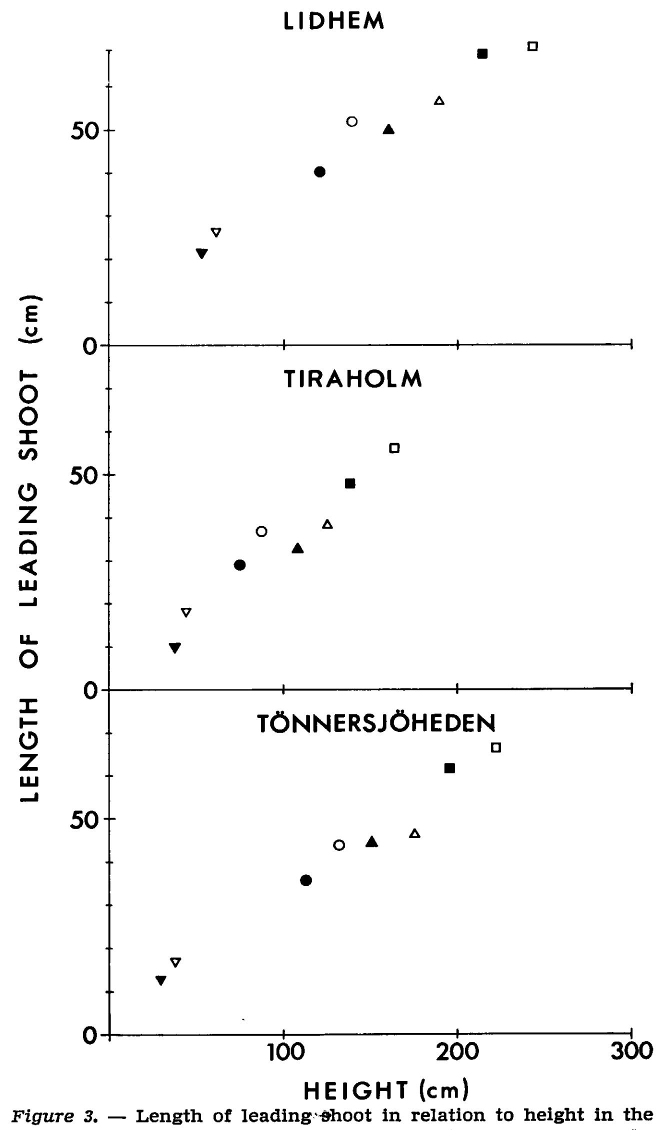

Figure 3. — Length of leading shoot in relation to height in the beginning of the vegetation period for cuttings (open symbols) and seedlings (filled symbols). "Block experiments". The symbols represent the following years:
▽, ▼ = 1983, 1984 ○, ● = 1986 △, ▲ = 1987 □, ■ = 1988.

to the differences in the block experiment. Cuttings were higher and had a larger diameter compared to seedlings on 12 of the 16 sites (*Figure 4*). The mean height of the seedlings were 89% of that of the cuttings. Corresponding value for diameter was 94%. The difference in height was significant whereas difference in diameter was not (*Table 4*).

The difference in height between seedlings and cuttings increased from 1985 to 1988 (*Figure 5*). During that period height growth of the seedlings was 92% of height growth of the cuttings. The difference was significant. The average number of plants per hectar was nearly the same for seedlings (1866 pl/ha)and cuttings (1885 pl/ha).

There was a positive correlation between superiority in survival and height, i. e. on sites where cuttings were higher than seedlings also survival of cuttings was higher than for seedlings (*Figure 6*).

Discussion

Cuttings were found to have superior height growth compared to seedlings. The difference was of the same order as reported for selected cuttings in comparison with seedlings from selected seed stands by ROULUND et al. (1985).

The selection intensity in the programmes for Norway spruce cuttings in Sweden is about 1:3000 (e.g. BENTZER et al., 1988). The selection intensity in the present study was only 1:3, suggesting that the genetic selection effect should be of little significance.

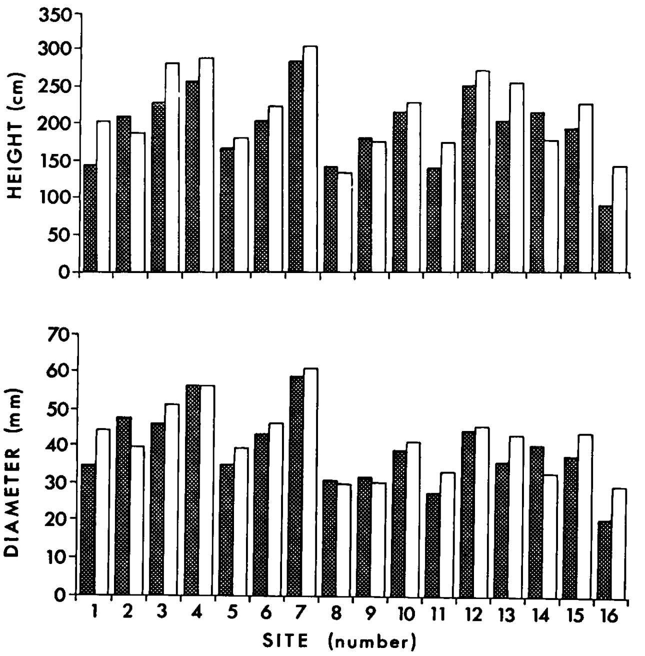

Figure 4. — Height and diameter of cuttings (open) and seedlings (shaded) 8 years after planting. "Commercial plantations". For data on the sites see *table 2*.

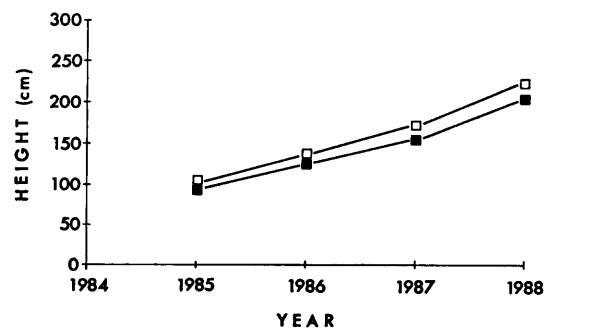

Figure 5. — Height development for cuttings (□) and seedlings (■) planted in 1981. "Commercial plantations". (cf *Figure 4*).

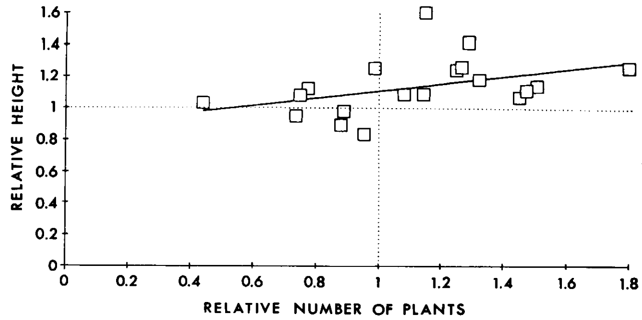

Figure 6. — Correlation between relative number of plants (cuttings per ha/seedlings per ha) and relative height (cutting height/seedling height). Data from "block experiments" and "commercial plantations" (cf *Tables 2* and *3*).

Growth differences between cuttings and seedlings in this experiment is thus mainly nongenetical and might be explained by differences in morphology and physiology for seedlings and cuttings. Size of the growth difference is remarkable since seedlings and cuttings were regarded as equal concerning height and quality when leaving the nursery.

There are several reasons why cuttings could perform better than seedlings. The larger diameter and the higher shoot and root weights for cuttings compared to seedlings of the same height (KLEINSCHMIT and SCHMIDT, 1977) could be important factors when regarding vegetation competition and attacks by pine weevils. ÖRLANDER et al. (1990a) reported that height growth was negatively correlated with damage from pine weevils. If the assumption of the impact of morphological differences is correct, this relation might have contributed to the observed growth differences in this study.

Although the experiment was replicated on several locations, the same plant material was used. This, together with the fact that planting was conducted the same year, limits the possibilities to generalize the result.

Differences in height increased during the whole study period (8 years after planting). However, eight years after planting, the difference in length of leading shoot was not significant when comparing seedlings and cuttings. This indicated that the effects on growth of establishment become weaker over time.

When analysing remaining effects of establishment on growth between 1985 and 1988 a direct comparison of growth is not fully correct. In 1985 the seedlings were shorter than the cuttings. Since the length of leading shoots increases every year up to about 5 meters height (HÄGGLUND, 1976) it is more adequate to compare the length of leading shoot in relation to height in the beginning of the growth period (*Figure 3*). However, the length of the leading shoot is correlated with weather conditions which complicates the comparison.

Studies of the development of planted seedlings show that a difference in establishment can have a significant influence of growth several years after planting (e. g. MELLBERG and NÄSLUND, 1987; ÖRLÄNDER et al., 1990b). Growth differences that occur directly after planting might thus be detected even in young stands.

If the superior establishment of cuttings compared to seedlings found in this study is considered, it implies problems in the clonal testing programmes, especially when using small plots. However, referring to present rules in Sweden, the acceptance of cutting propagated clones for commercial use is determined by the total gain compared to recommended seedling material without separating the genetic gain from other components. This means that the total gain when using mixtures of accepted clones includes effects of the cutting propagation method as well as genetic selection effects. There is reason to believe that the propagation effect is variable, which makes it difficult to generalize single quantifications of this effect.

Practical implications

A considerable part of the superiority of cuttings compared to seedlings might be caused by physiological and morphological differences for the two plant materials; i.e. the effect of the cutting propagation method has not been quantified. A suggested method for determining the genetic gain by using selected cuttings would be to compare with randomly selected bulk propagated cuttings.

Height growth comparisons in clonal tests might be improved by measuring the length of a fixed number of internodes (distance between branch whorls) from about 2.5 m height. The method has been developed to estimate site index (Hägglund, 1976) and makes it possible to get good estimations of future growth.

As the establishment success plays an important role in the economy of a forest stand, it is necessary to include this effect in a selection procedure. Development of a selection index where establishment and growth capacity are combined, but considered as separate properties, might be a good solution.

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Serial Propagation in Norway Spruce (Picea abies (L.) Karst.): Results from Later Propagation Cycles

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Abstract

Maturation state can adversely affect the success of vegetative propagation, insofar as more mature material is difficult to root and tends to grow plagiotropically. One method used to retard maturation of trees in clonal tree improvement programs is serial vegetative propagation, which has the advantage of being practical for large-scale operations. Norway spruce ramets first rooted in 1968 have been re-rooted seven times, while new clones have been added regularly. Growth traits such as height, root collar diameter and fresh and dry weight, as well as form traits such as habit, tropism, root development and number of branches are compared on four trees of each three-year-old clone to evaluate the success of serial propagation in retarding maturation. There are distinct differences in the performance of seedlings and cuttings. Cuttings are generally superior in total dry matter production, even in higher propagation phases where a decrease in height can be observed. While clones that have been rooted from one to four times show fast growth and good form, some clones within later propagation phases show decreases in both traits, indicating a higher maturation state. It may be possible to select against these fast-maturing clones, thus prolonging the possible period for vegetative propagation, but a restriction of repropagation to seven or eight phases seems to be necessary.