III) of filled seed from six low elevation trees, following various short stratification periods (six months or less) and germination canditions, was 55 percent with family means ranging from 45 to 61 percent. Equivalent means based on data from high elevation trees were 29 percent and 13 to 42 percent. Only continuous cold stratification for as long as 18 months substantially promoted germination of these high elevation seed. Of the several other observed relationships, the positive effects of light and late fall collection warrant consideration in seed testing and handling.

Seed from many high elevation treas apparently have a complex and/or long chilling requirement which has not been fully elucidated in this study. Part of the observed variation may be due to environmental preconditioning effects associated with parent tree locations. Furthermore, the clarification of this chilling requirement is complicated by the fact that many seed which were subjected to long stratification-germination cycles decayed during these treatments. Results of CLARK and BOYCE (1964) also suggest some loss to decay in such cycles though this was not directly observed. Familial variation in susceptibility to such decay is probable.

It is clear, however, that populations of yellow-poplar have seed germination strategies which contribute to fitness mainly by extending the germination period over the course of several years, as has been noted by previous investigators. Data from this study further suggest that both intra- and interfamily variation in dormancy relations contribute to this attribute. This variation should be recognized in breeding and planting programs where the possibility exists of eliminating large portions of a population through unintentional selection ob early germinators. While this selection may not always be undesirable, it should be dane eonsciously and based upon a knowledge of the material's germination characteristics. Until further information is available on the genetics of germination characteristics, a long stratification period which, will result in a more complete germination is recommended, particularly for progenies from high elevation provenances in the southern Appalachians.

Literature Cited

ADAMS, R. E.: Are alternating temperatures more beneficial than constant temperatures during stratification of yellow-poplar seeds? Tree Planters Notes 19 (3), 16–17 (1968). — BONNER, F. T., and T. E. RUSSELL: Liriodendron *tulipifera* L. Yellow-poplar. In Seeds of Woody Plants in the United States. USDA Forest Service Agri. Handbook No. 450, pp. 508–511 (1974). — BONNER, F. T., and G. L. SWITZEH: Upgrading yellow-poplar seed. USDA Forest Service Res. Note SO-129 (1971). — BONNER, F. T.: Maturation and collection of yellow-poplar seeds in the midsouth. USDA Forest Service, Research Paper SO-121, 8 pp. (1976). — BOYCE, S. G., and J. F. HOSNER: Alternating storage temperatures increase the germination of yellow-poplar seed. J. For. 61: 731–733 (1963). — CLARK, F. B. ,and S. G. BOYCE: Yellow-poplar seed remains viable in the forest litter. Journal Forestry 62: 564—567 (1964). — TVA: Yellow-poplar seed collection, storage, and seeding practices. Tennessee Valley Authority, Div. of Forestry Relations. Tech. Note No. 1, 6 pp. (1940). — WILLIAMS, R. D., and C. C. MONY: Yellow-poplar seedling yield increased by seed stratification. J. For. 60: 878 (1962).

A comparison of seedlings and clonal cuttings of sitka spruce (Picea sitchensis (Bong.) Carr.)

By H. ROULUND

The Royal Veterinary and Agricultural University,
Arboretum, Hørsholm, Denmark.

(Received January / July 1978)

Abstract

Eight clones of Sitka spruce *(Picea sitchensis* (BONG.) CARR.) and a comparable set of seedlings were investigated in a period of six years concerning the traits: height, stem form, and time of flushing.

At the end of this period the cuttings were 44% higher than the seedlings. The variation in height is smaller within clones than between seedlings. In stem form the variation is smaller during the first years and equal at the last assessment. The variation in flushing is considerably smaller within clones than among seedlings.

This may indicate that this character is highly heritable.

Key words: Cuttings, Picea sitchensis (BONG.) CARR.

Zusammenfassung

Acht Stecklings-Klone von ***Picea sitchensis*** (BONG.) CARR. sowie vergleichbare aus Samen hervorgegangene Sitkafichten wurden sechs Jahre lang auf die Merkmale Höhe, Stammform und Triebentwicklung hin untersucht. Nach sechs Jahren waren die Stecklingspflanzen 44% höher als die Sämlingspflanzen, wobei die Variation innerhalb der Stecklings-Klone geringer war als zwischen den Stecklingspflanzen. Die Stammform variierte in den ersten Jahren weniger und war bei der letzten Schätzung gleich. Die Variation der Triebentwicklung war innerhalb der Klone erheblich geringer als bei den Sämlingen. Das könnte bedeuten, daß die Pflanzen in diesem Merkmal einen hohen Heritabilitätsgrad aufweisen.

Introduction

Sitka spruce ***(Picea sitchensis*** (BONG.) CARR.) is an important tree species in Denmark, and has been cultivated in the last hundred years. Compared to Norway spruce *(Picea abies* L. KARST) the preferences are tolerance against salt, which makes cultivation possible in coastal areas, especially in the dunes, and rapid growth which is evident on poorer soils.

In 1970 a breeding programme was set up (BRANDT, 1970). This programme included a traditional seed orchard system with backwards selection i.e. selection among the clones according to their breeding value based on progeny testing, and a system of selection and mass propagation by cuttings.

This study was carried out basically with three aims:

To study the performance in several traits of rooted cuttings compared with seedlings of Sitka spruce *(Picea sitchensis)*.

To study the variation within clones compared with the variation among seedlings.

To find the response to selection in height growth, when the propagation technique was rooted cuttings.

The investigation is a part of a series of experiments made to obtain information about the possibility and value of cutting propagation as a method for mass propagation of improved material.

Characteristics Investigated

The characteristics investigated were:

1. Height
2. Stem form
3. Time of flushing

The height was measured in units of 1 cm. It was defined as the length of the plant and not the vertical height of the apical bud.

This was chosen to give a better impression of the growth energy, and since also the stem form of the plant was investigated.

The stem form was scored according to a scale from 1—9, where 1 is straight and vertical and 9 is bent and horizontal. The values between show different degrees of plagiotropism. This scale has previously been used in Norway spruce (Roulund, 1975 and 1977).

Frequency of forks was assessed by counting the numbers of forks. In normal seedlings one would hardly investigate the frequency of forks since forks would be sorted out during the transplanting. If forking occurs, one of the shoots often becomes leader, but this does not affect the later use of the wood. Nevertheless, with cuttings from ortets of this age, where a pronounced branch habit occurs in the first years, it is important to investigate this development.

The time of flushing was assessed according to a scale from 0—5, where 0 is the dormant stage and 5 is the completed elongated shoot. This scale has earlier been used for Norway spruce and Omorika spruce *(Picea omórika* (Pančić) Purkyne), (Roulund, 1971 b, 1977).

Plant Material

The plant material consisted of the following clones: V. 3803, V. 3804, V. 3805, V. 3806, V. 3807, V. 3808, V. 3809, V. 3810.

The ortets were selected as the tallest and best formed trees in an eight years old stand of Sitka spruce in the forest "Rude skov" compt. 578. The provenance of this stand is "Wedellsborg F.253", and the origin presumably Washington.

The cuttings were made at the Hørsholm Arboretum in the autumn of 1969 (Roulund, 1971 a). The twigs, 6—12 cm long, were taken all over the tree as shoots of second and third order. Before insertion they were mixed carefully.

As standard in the experiment, 2/0 seedlings from the selected stand "Rye Nørskov F.229" were used. This seed lot seems to be better than "Wedellsborg F.253" according to a 17 years old progeny test (Kjersgaard, pers comm.[1])).

In order to calculate the selection intensity, the selected tree and, if possible, the nearest 12 trees were measured. The ortets were selected as the tallest compared to the surrounding trees, so selection was made both on good and less good soil conditions within the compartment (Wellendorf 1970). The selection differential and selection intensity are shown in *table 1*.

Experimental Methods and Designs

The cuttings were inserted in August 1969 and rooted during the autumn.

The rooting experiment was laid out as two parallel experiments, one in a greenhouse containing an automatic mist unit, the other in electrically heated frames. The layout consisted of a splitplot design with two replications. The main plots consisted of the rooting media perlite, fresh sphagnum/sand (1 : 1), and sand with a grain size of 0—5 mm. Within the randomised main plots the sub-plots consisting of the individual clones were also randomised. Each plot consisted of 40 cuttings giving a total of 240 cuttings per clone in each of the experiments. There was a significant difference between clones, but no significance for blocks, media nor interactions. The average rooting percentages in the greenhouse and the frames were 80.9 and 83.7 respectively. The performance of the cuttings was reasonably uniform irrespective of rooting media and location. Nevertheless, the cuttings were carefully mixed before samples were taken to the nursery experiment.

Table 1. — Selection differential and selection intensity of the eight ortets. A Bartlett's test did not show significant differences between the variances of the different groups. Therefore a pooled estimate of the standard deviation is used when calculating the selection intensity.

Clone	Height of ortet	Neighbour trees		Pooled estimate of standard deviation	Selection diff.		Selection intensity
		number	mean height				x)
	cm		cm	cm	cm	%	i ± 2 s
V.3803	250	11	122.7		127.3	104	4.01 ± 1.89
V.3804	270	11	148.2		121.8	82	3.83 ± 1.82
V.3805	240	11	130.0		110.0	85	3.46 ± 1.66
V.3806	250	12	137.5		112.5	82	3.54 ± 1.62
V.3807	290	13	151.5	31.77	138.5	91	4.36 ± 1.86
V.3808	240	13	153.1		86.9	57	2.74 ± 1.25
V.3809	220	11	130.9		89.1	68	2.80 ± 1.39
V.3810	240	14	102.1		137.9	135	4.34 ± 1.78
Average						88	3.64 ± 0.30

*) The standard deviation of the selection intensity is calculated as $\frac{1}{n} + \frac{i^2}{2(n-i)}$

where n is the number of trees and i is the selection intensity.

[1]) Kjersgaard, O., sci. ass., The Danish Forest Experiment Station Springforbivej 4, 2930 Klampenborg.

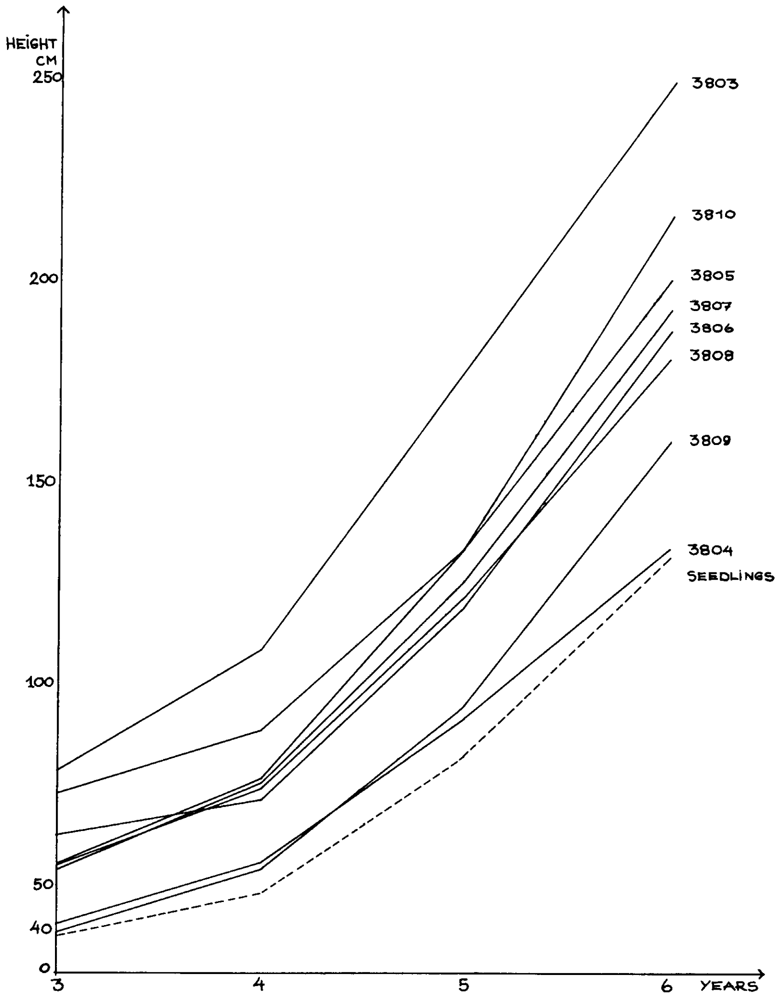

Figure 1. — Height growth from 1972—75 for the eight Sitka spruce clones and the seedlings.

——— = clones - - - - - = seedlings

In the spring of 1970 they were planted in the nursery. The nursery experiment was a randomised block design with four blocks and 24 plants per clone. The spacing was 50 × 50 cm.

In the spring of 1973 the experiment was outplanted in the forest at one location.

It is therefore impossible to study genotype/site interaction on this material.

The field experiment is situated in the forest "Folehaven" at Hørsholm State Forest District at Sjælland. The area slopes gently toward NE and there is approximately 30 cm layer of humus upon the moraine gravel.

The design of the field experiment is a randomised block design with four replications and 16 plants per plot. The spacing is 2 × 2 m.

Results and Discussion

Height

The development in height is seen in *figure 1*. After the first growing season the seedlings were substantially smaller than the cuttings, 15 cm below the mean height of the cuttings. Nevertheless, the height growth is nearly as good for the seedlings as for the cuttings during the nursery period. After that the growth for all the clones is larger than for the seedlings, and one clone "V. 3803" grows remarkably fast. After six growing seasons, three in the nursery and three in the field experiment, the average of the clones is 58.9 cm or 44% higher than the seedlings. The average of the six best clones is 73.5 cm or 55% higher than the seedlings and the best clone is 117.2 cm or 88% higher.

The differences in height may have two reasons, 1) a genetic superiority in height growth, 2) a genetic resistance to frost

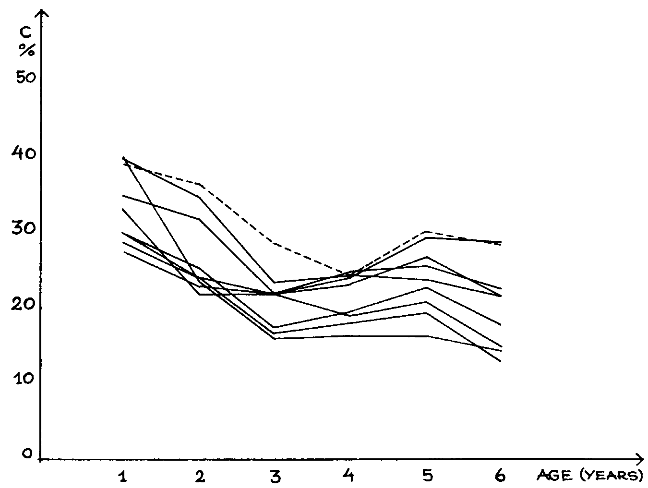

Figure 2. — The variation in height from 1970—75 of the eight Sitka spruce clones and seedlings expressed by the coefficient of variation (C%).

——— = clones - - - - - = seedlings

During the six years the experiment has run, some damage has been observed caused by frost in the autumn. Most has been on the seedlings.

The method used in this experiment does not distinguish between these two factors. One might conclude that the selection of the highest individuals in an eight years old stand has also caused a selection of frosthardy genotypes.

The variation in height growth is seen in *figure 2.* A considerable tendency in the pattern of variation is that a large variation the first year in the nursery is followed by a decrease in the following two years.

The variation among the seedlings *(figure 2)* is in general larger than the variation within the clones. That is what one would normally expect, but in this experiment a part of the variation among seedlings is due to frost damage. Although the within clonal variation in height growth is smaller than that among seedlings, one should not conclude that the "clonal effect" which is variation associated with cloning does not exist (Libby and Jund, 1962; Shelbourne, 1974; Burdon and Shelbourne, 1974). This is most clearly seen in the investigation of stem form.

Stem form

The scoring of stem form has been done according to the scale earlier described. The results are seen in *table 2.* In *figure 3* the straightest of the clones are seen.

It is seen that the stem form improves for the cuttings as well as for the seedlings. There is a statistically significant difference between the clones. After four years of growth, the stem form of the seedlings is about the same as the average of the clones.

Table 2. — Scoring values and standard deviations of stem form of the eight clones and the seedlings. 1 = vertical, 9 = horizontal.

Clone	Stem form after			Standard deviation after		
	2 yrs	3 yrs	4 yrs	2 yrs	3 yrs	4 yrs
V.3803	3.0	2.0	1.7	1.14	0.63	0.65
V.3804	2.9	2.4	2.2	1.41	1.95	0.85
V.3805	3.1	2.5	2.1	1.26	1.00	0.75
V.3806	5.2	4.3	3.7	1.55	1.45	1.20
V.3807	4.6	2.9	2.5	1.58	1.44	0.78
V.3808	3.5	2.6	2.3	1.48	1.05	0.88
V.3809	4.9	3.6	2.9	1.79	1.22	1.03
V.3810	4.2	3.3	3.1	1.55	1.26	1.05
Seedlings	3.5	3.0	2.3	1.76	1.97	0.85

Table 3. — The mean values and standard deviations of flushing according to a scale 0—5, where o is the dormant stage and 5 is the full elongated shoot.

Clone	Stem form after				Standard deviation after			
	2 yrs	3 yrs	4 yrs	6 yrs	2 yrs	3 yrs	4 yrs	6 yrs
V.3803	2.72	2.51	2.25	2.00	0.53	0.05	0.00	0.00
V.3804	2.95	3.02	3.25	2.23	0.22	0.07	0.00	0.53
V.3805	2.99	3.02	3.24	2.97	0.32	0.07	0.07	0.18
V.3806	2.91	3.23	3.00	2.92	0.42	0.11	0.00	0.27
V.3807	2.97	2.96	2.28	2.28	0.17	0.12	0.09	0.45
V.3808	2.85	3.00	3.19	3.00	0.48	0.00	0.16	0.00
V.3809	2.66	1.99	1.88	1.97	0.48	0.51	0.22	0.18
V.3810	2.94	3.00	2.75	3.00	0.22	0.00	0.00	0.00
Seedlings	1.35	2.25	1.52	1.97	0.87	0.71	0.65	0.69

Three clones still show pronounced plagiotropic growth, namely V. 3806, V. 3809 and V. 3810.

It is seen that the standard deviation within the seedlings at the 2nd and 3rd year is larger than it is within the clones. At the 4th year it drops down to the same level.

One reason for the smaller variation in the last year may be that most of the plants at that time had converted to orthotropic growth of the scale.

Nevertheless, the phenomenon that the within clonal variation no longer is smaller than the variation among seedlings may be interpreted as a remaining "clonal effect" in the clones.

Flushing.

The flushing was scored in the 3rd week of May in the 2nd, 3rd, 4th and 6th years according to a scale from 0—5 as earlier mentioned. The results are shown in *table 3.*

Since the clones were not selected for early or late flushing, the mean values are of less interest in this connection, but the variation of this trait is interesting. The standard deviations are shown in *table 3.*

It is seen that there is a substantially larger variation between the seedlings than within the clones. The increase of the standard deviations at age 6 is difficult to explain, but may be due to some unknown environmental changes. In spite of this increase there is a remarkable difference between the standard deviations of the seedlings and of the

Figure 3. — Clone V.3803 after three growing seasons. Mean height: 79,8 cm. Stem form value: 2.0.

clones. The standard deviation of the clones is on an average 0.20 and that of the seedlings is 0.69, which is 3.5 times more. This indicates a high heritability and a low "clonal-effect" in this trait.

Repeatabilty

A repeatability of height is calculated as described by BECKER (1967).

At first a two way analysis of variances for the 8 clones is made. The analysis is carried out on plot means.

A pooled estimate of the within plot variance is calculated seperately.

Source of variation	d.f.	SS	MS	F	Variance components
clones	7	342.2301	48.8900	16.32***	$\sigma^2_e + b\sigma^2_c$
blocks	3	20.0209	6.6736	2.23NS	$\sigma^2_e + c\sigma^2_b$
residual	21	62.9211	2.9962		σ^2_e
total	31	425.1721			

where σ^2_e = residual
σ^2_b = variance due to blocks
σ^2_c = variance due to clones
c = number of clones
b = number of blocks

Variance within plots:

ss = 6924 d.f. = 471 ms = 14.7006 $\sim \sigma^2_w$

$$R = \frac{\sigma^2_c}{\sigma^2_c + \sigma^2_w} = \frac{11.4735}{11.4735 + 14.7006} = 0.44$$

$$R_{\bar{c}} = \frac{\sigma^2_c}{\sigma^2_c + \frac{\sigma^2_e}{b}} = \frac{11.4735}{11.4735 + 0.7491} = 0.94$$

R is repeatability on single tree level and $R_{\bar{c}}$ is repeatability based on clone means.

Although the within clonal variance is encumbered with "clonal effect", which in other situations may be smaller or larger, the repeatability is of a size which indicates that a reasonable gain may be obtained by mass propagation of cuttings from individual selection in an eight years old Sitka spruce stand, and further gain might be obtained by selection in a clonal experiment.

Conclusion

Recently vegetative propagation of spruce has met with an increasing interest. Several large scale programmes have been developed, mainly in Norway spruce (KLEINSCHMIT *et al.*, 1973; LEPISTÖ, 1974; WERNER[2]), pers. comm.; BENTZER[3]), pers. comm.), but also in other spruce species. White spruce *Picea glauca* (MOENCH) Voss) (RAUTER, 1974) and Sitka spruce (BRANDT, 1970) the use of rooted cuttings has been incorporated in breeding programmes. One of the most problematic questions in these programmes is that of ageing (SCHAFFALITZKY, 1959; LIBBY, 1974; SHELBOURNE, 1974). Ageing influences the rooting ability and the stem form as well. This has been pointed out for Norway spruce among others by RUDEN (1966), KLEINSCHMIT *et al.* (1973) and ROULUND (1973 and 1975). Due to this most breeding programmes for spruce have started with selection in four years old plants. This experiment indicates at the same time that this starting point is necessary if plagiotropic growth shall be avoided, but also that even if some ageing of clones will take place through a number of repeated propagations, a positive responces to selection for height and stem form can be maintained.

The variation in height is smaller within clones than between seedlings. In stem form it is smaller during the first years and equal at the assessment. In flushing it is outstandingly smaller within clones than among seedlings.

The fact that variation in height is smaller within clones than among seedlings should not lead to the conclusion that a "clonal effect" does not exist, but only that it is not serious as random component, but it might still exist as a systematic source of variation between clones.

The large difference in variation in flushhing may indicate that this character is highly heritable.

Literature

BECKER, A. W.: Manual of Procedures in Quantitative Genetics. Washington State University, Washington. 170 pp. (1967). — BRANDT, K.: Statusopgørelse for sitkagran. Dansk Skovf. Tidsskr. 55: 300—329 (1970). — BURDON, R. D., and SHELBOURNE, C. J. A.: The use of vegetative propagules for obtaining genetic information. N.Z.J. For. Sci. 4: 418—425 (1974). — KLEINSCHMIT, J., MÜLLER, W., SCHMIDT, J., and RACZ, J.: Entwicklung der Stecklingsvermehrung von Fichte (*Picea abies* KARST.) zur Praxisreife. Silvae Genetica 22: 4—14 (1973). — LEPISTÖ, M.: Succesful propagation by cuttings of *Picea abies* in Finland. N.Z.J. For. Sci. 4: 367—370 (1974). — LIBBY, W. J.: A Summary Statement on the 1973 Vegetative Propagation Meeting in Rotorua, New Zealand. N.Z.J. For. Sci. 4: 454—458 (1974). — LIBBY, W. J., and JUND, E.: Variance associated with cloning. Heredity 17: 533—540 (1962). — RAUTER, M. R.: A Short Term Tree Improvement Programme Through Vegetative Propagation. N.Z.J. For. Sci. 4: 373—373 (1974). — ROULUND, H.: Experiments with Cuttings of *Picea abies, Picea sitchensis* and the Hybrid *Picea omorika* × *Picea sitchensis*. Forest Tree Improvement. 3: 25—57 (1971 a). — ROULUND, H.: Observation on Spontaneous Hybridization in *Picea omorika* (PANČIĆ PURKYYNE. Forest Tree Improvement. 2: 3—17 (1971 b). — ROULUND, H.: The Effect of Cyclophysis and Topophysis on the Rooting Ability of Norway Spruce Cuttings. Forest Tree Improvement 5: 21—41 (1973). — ROULUND, H.: The Effect of the Cyclophysis and Topophysis on the Rooting and Behaviour of Norway Spruce Cuttings. Acta Horticulturae 54: 39—50 (1975). — ROULUND, H.: A Comparison of Seedlings and Clonal cuttings of Norway Spruce (*Picea abies* L. KARST.). Forest Tree Improvement 10: 1—26 (1977). — RUDEN, T.: Forelesninger i skogbrukets planteforeding. Norsk inst. for Skogsforskning: 149 pp. (1966). — SCHAFFALITZKY DE MUCKADELL, M.: Investigations on Ageing of Apical Meristems in Woody Plants and its Importance in Silviculture. Forstl. Forsøgsv. Danm. 25: 308—445 (1959). — SHELBOURNE, C. J. A.: Clonal Test with *Picea abies* (L.) KARST. in Norway. 10 to 17 Years Results. Norsk inst for Skogsforskning: 37 pp. (1974). — WELLENDORF, H.: Resemblance in Height Growth Between Original Trees and Clones of Scots Pine (*Pinus sylvestris* L.). Forest Tree Improvement 1: 25—45 (1970).

[2]) WERNER, M., Director, Institute for Forest Improvement, Ekebo S-26800, Svalöv, Sweden.

[3]) BENTZER, B., Geneticist, Hilleshög Seed Company Ltd., Box 302, S-26123, Landskrona, Sweden.