Experiences with Picea abies Cuttings Propagation in Germany and Problems connected with large Scale Application

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Introduction

First rooting of Norway spruce cuttings has been done by Pfifferling in 1830. It was about 100 years later that a more intensive work with cutting propagation started at different places of the world with the beginning of forest tree breeding.

After the second world war in Germany before all Schmucker, Fröhlich, Herrmann and Richard Kleinschmit initiated more intensive research in cutting propagation as a tool for forest tree breeding. Starting from 1948 Norway spruce cutting propagation has been continuously developed in Escherode. During the first years methods of optimal rooting conditions have been studied, later on the interest focused more and more on questions of aging, topophysis and the use of cuttings within a breeding program.

Similar work has been done before all in the Hessische Institut of Forest Tree Breeding under Fröhlich.

In 1967 most of the basic problems had been solved for Norway spruce.

Present Propagation

To develop cutting propagation as a means for practical use it was necessary to test cheap, at least partly mechanized and economic methods. This has been done by application of finplasthouses, the use of gravel as a propagation medium and the quite rough immediate transplanting of rooted cuttings to the nursery.

The development of methods has been discussed in Silvae Genetica 1973 (Kleinschmit *et al.* 1973). One central point however of this propagation methods has been the use of juvenile material for propagation. Since it is necessary to test selected trees for their genetic constitution in progeny tests, young plant material is available anyhow. The decision about the further use of the selected tree in a breeding program is done according to the performance of the progeny. So it seems logical to use this progeny for propagation, too. I think that it is necessary to stress this point because most of the early forest tree breeders had the idea to propagate the old selected trees and they got into trouble.

Economical Situation

For large scale application of cuttings under practical conditions in Germany cutting plants have to compete with Norway spruce transplants 2-2 years. Today the prices for 1.000 transplants 2-2 years old Norway spruce amount 225,00 to 380,00 DM. From the total costs about 10% (30,00 to 35,00 DM/1.000) are costs of the 2-0 seedlings before transplanting. The development of costs for cutting plants under the situation in our breeding program and alternatively under practical situation is demonstrated in fig. 1. This figure shows, that under practical conditions the costs of a cutting are three times the costs of a 2 year old seedling plant.

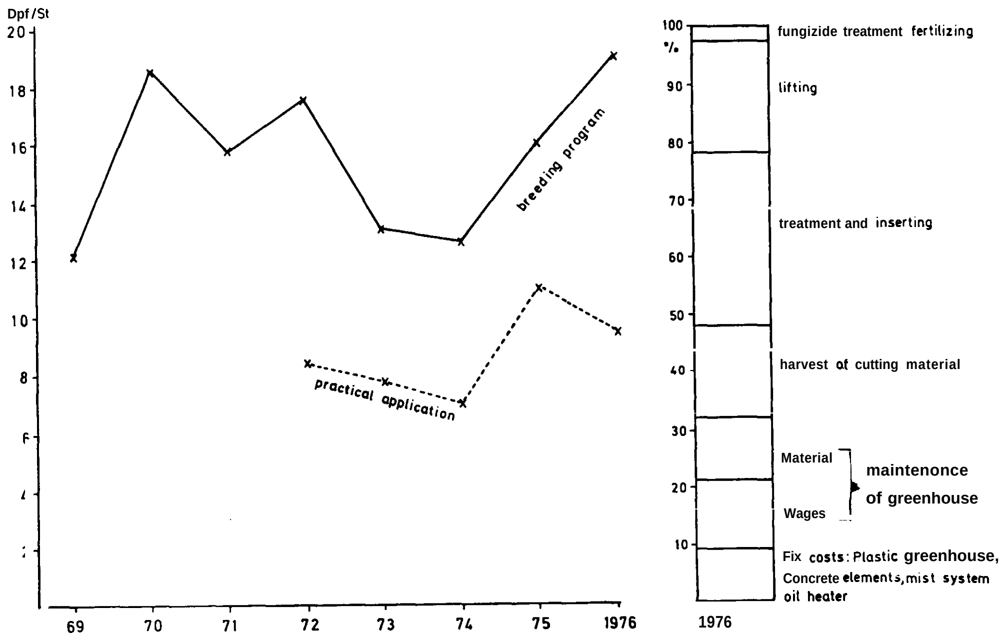

Fig. 1. — Development of costs per piece rooted Norway spruce cutting 1969—1976.
Entwicklung der Kosten je bewurzelter Fichten-Steckling 1969—1976.

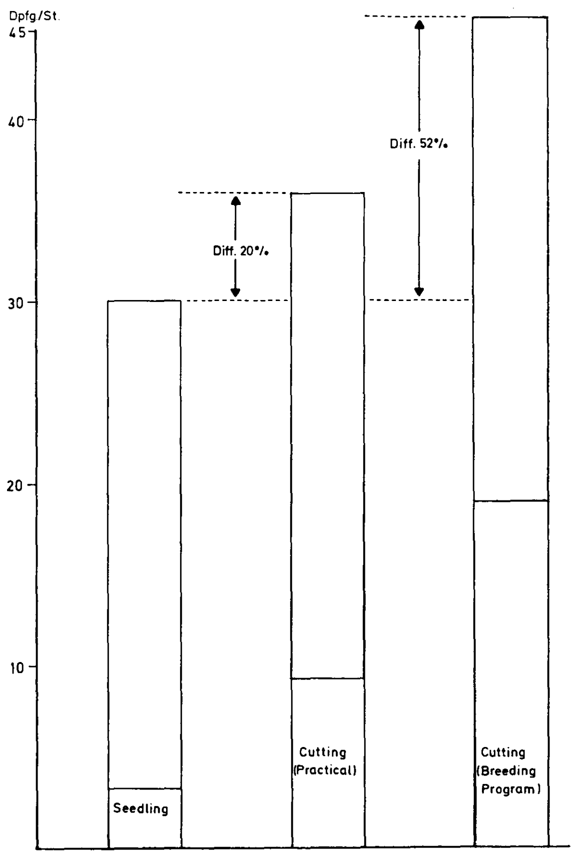

Fig. 2. — Mean costs of a seedling transplant as compared to a cutting transplant 1976.
Mittlere Kosten einer verschulten Sämlingspflanze im Vergleich zu einer verschulten Stecklingspflanze 1976.

Starting from transplantation all costs of seedlings and cuttings are comparable. From this it is clear, that the total costs for cutting plants surpass the costs of a 2—2 year seedling transplant by 20 to 52 percent *(Fig. 2)*, depending on the sophistication of the propagation. This may be very different under conditions of other countries if they use as regular planting stock younger material.

Under practical propagation conditions the single clones are not separated. A clonal mixture comprising more than 1.000 clones is easier to handle than a lot of separated small clonal units. This explains the differences in costs between the both alternative situations (breeding program or practical propagation).

Higher costs than seedling plants are only justifiable, if there is a gain in production by using cuttings. From our clonal tests we know, that a minimum gain of 10% as compared to seed orchards is obtainable anyhow and that the gain may be much bigger. This depends not only on the breeding concept but also on the silvicultural situation in the respective countries. Maintenance of high genetic variation diminishes the possible gain as well as high site heterogeneity. Breeding for specific site requirements and reduction of variation increase the genetic gain until a point where it is balanced by the increase of risk. From our experiments a gain of at least 20% seems to be realistic.

All economic calculations depend on the economic situation of the respective silviculture.

If we compare different situations within a breeding program *(Fig. 3)* it becomes clear, that the years between initiation of a breeding program and the return, which is different for alternative strategies, as well as the plant costs have impact on net profit. The basic data used for this figure are given in *table 1.*

Under our situation in Germany the application of cuttings has a sound economical base. A large scale cutting

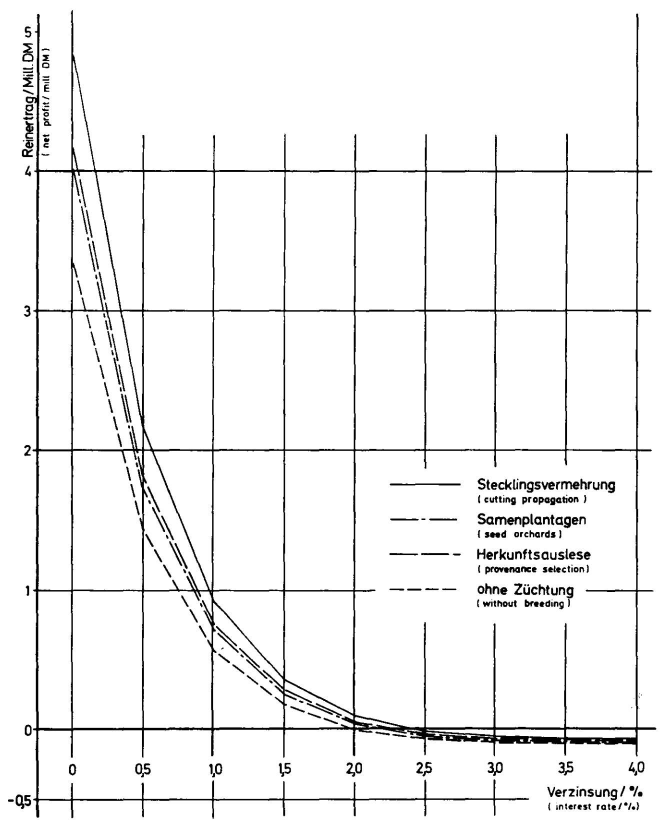

Fig. 3. — 50 years breeding with alternative breeding methods.
50 Jahre Züchtung nach alternativen Verfahren.

Tab. 1. — Comparison of different levels and propagation systems in a Norway spruce breeding program

level	breeding method	application	time until application	propagation costs/ plant	quantity of production	genetic gain	versatility
1. provenance	selection	seed stand	2 years (= 4 years between seed years; assumed that stands are still available)	100%	limited	20%	limited
2. half-sib family	selection + cross breed.	seed orchard	20 years	110%	limited	30%	strongly limited
3. individual	selection, cross breed. mutational breed.	cutting propag.	7 years (4—10 = 1—3 propagation cycles)	130%	unlimited	40%	great

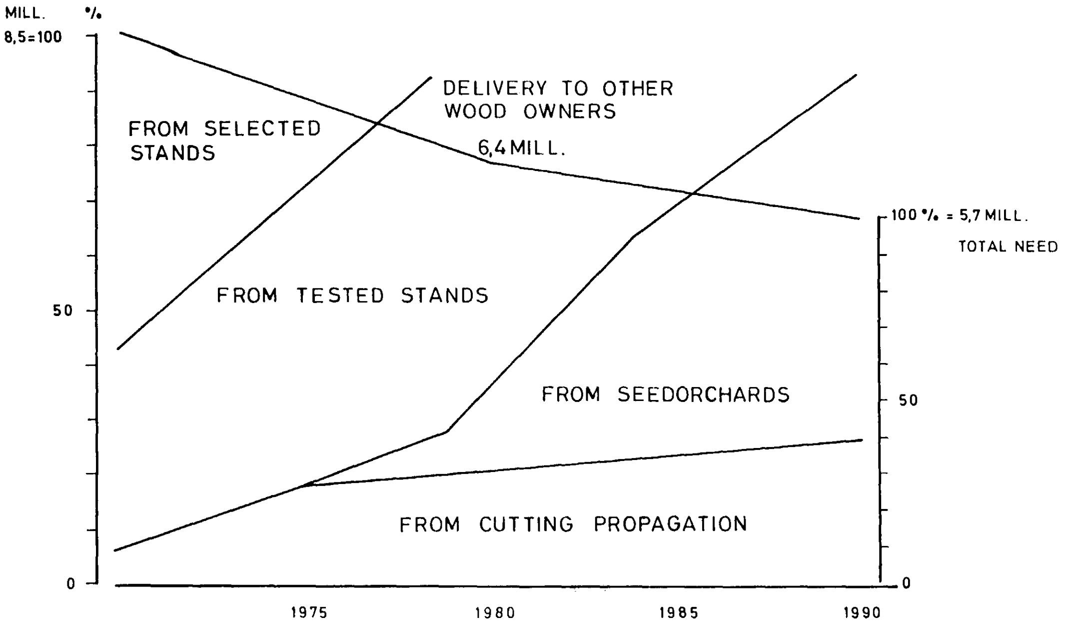

Fig. 4. — **Seed procurement of the Lower Saxony Forest Service, Norway Spruce. Saatgutbeschaffung der Niedersächsischen Landesforstverwaltung, Fichte.**

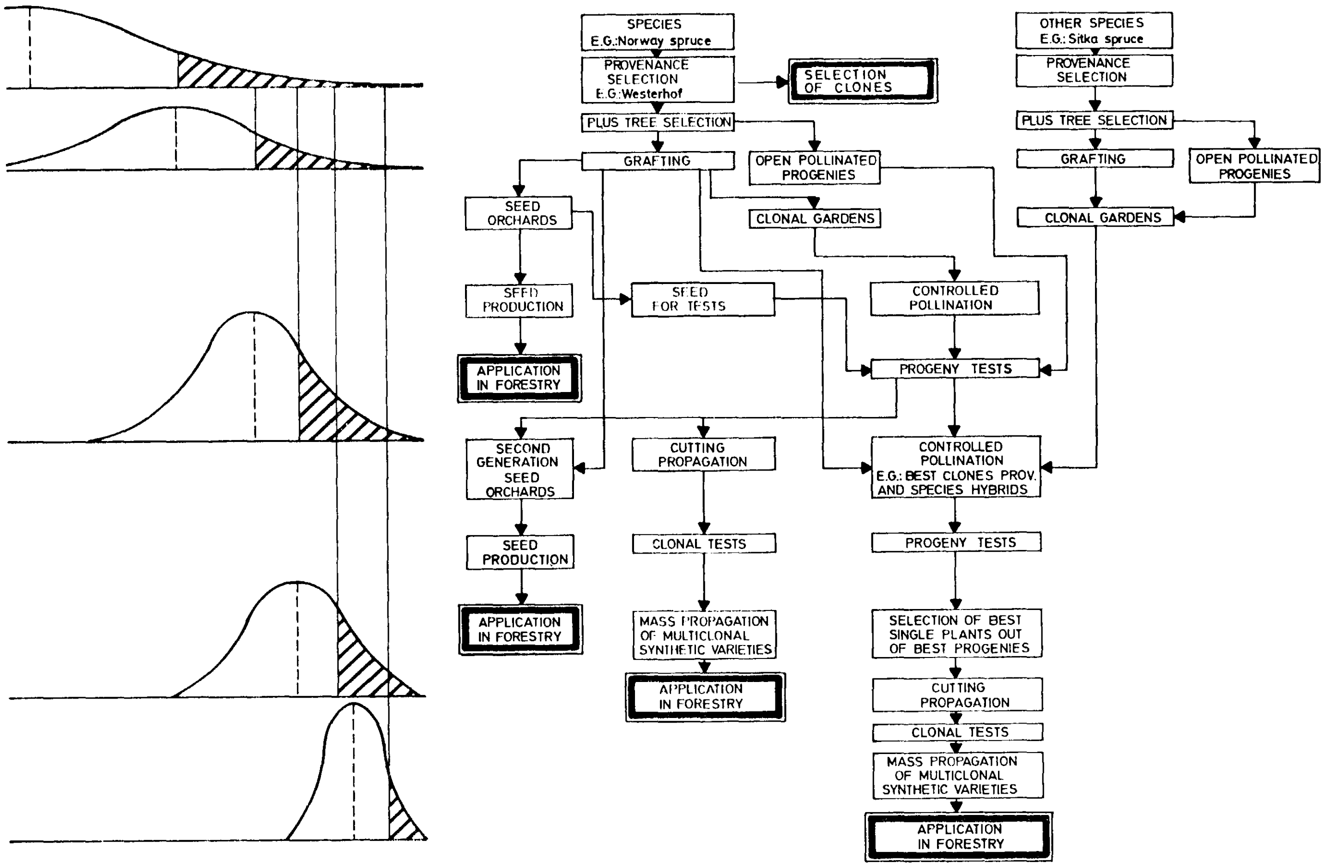

Fig. 5. — **Differences in genetic gain.**

program enables the breeder to transfer every improvement of his material immediately into application. The possibility to compose special clonal mixtures for special silvicultural aims guarantees a high flexibility of the breeding program. About one million cuttings have been rooted in Germany in 1977.

Breeding Program

The final aim in our region is to produce 30—40% cutting plants of the total need in Norway spruce *(Fig. 4)*. The different steps within the breeding program where clones are selected *(Fig. 5)* demonstrate the differences in genetic gain obtainable. A more limited gain which is the base for the above estimation may be expected from selection of individuals within tested provenances, a higher gain from provenance hybrids using specific combining ability and a still higher gain from species hybrids. Forest tree breeding

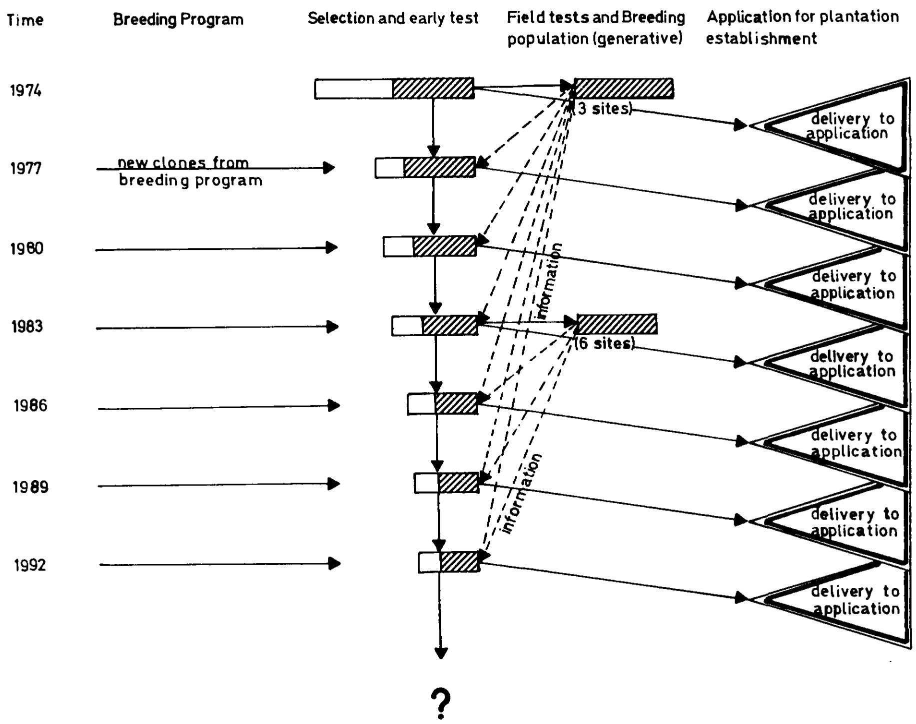

Fig. 6. —

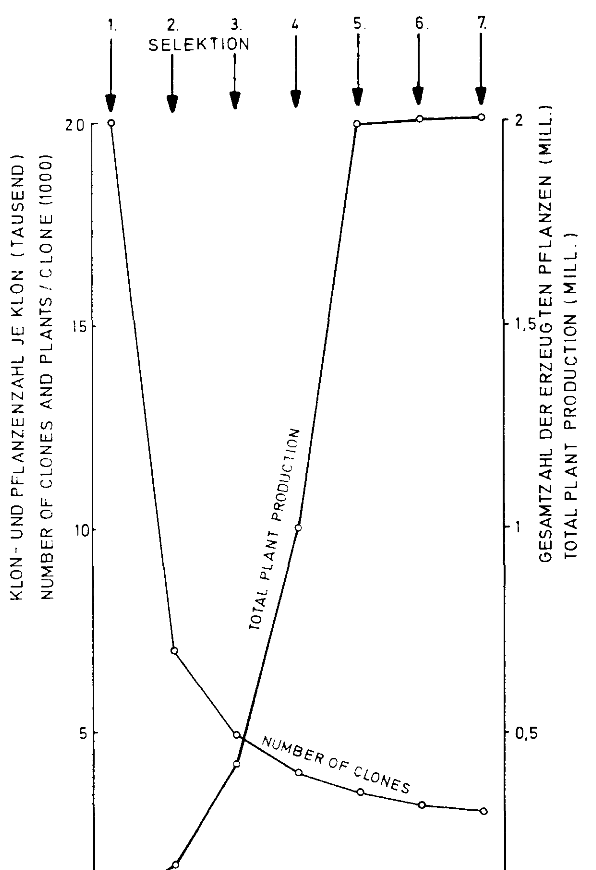

Fig. 7. — Selection of Norway Spruce clones, Time table (simplified). Selektion von Fichten-Eliteklonen.

literature gives a lot of examples that show a high potential for genetic gain on the different levels within spruce.

Figure 6 shows how the cuttings are selected and repropagated within our program and how testing takes place. The repeated selection and repropagation shall guarantee juvenile material for rooting and immediate translation of progress in the breeding program into application without increase of risk. The field tests on the other hand ensure that the losses by mistakes of early selection are diminished.

Since at all stages new clones from the breeding program enter, there remains the possibility to exclude clones if their vigour decreases because of aging. In addition it is possible to get a shift in the clonal composition as time goes on. The risk of narrowing down the genetic variation is balanced in this way. The field tests are thinned according to the clonal performance and they serve as seed orchards as well as base material for the second breeding generation. In this way a broad genetic base is carried along for future breeding work.

The development of number of clones, number of plants per clone and total plant production is given in *fig. 7*. This figure demonstrates that in our program the total plant production per clone never exceeds some thousand plants. It shows too how long it takes to rise the plant production to a commercial scale. This time can be shortened by intensive culture of the stock plants in greenhouses or phytotrons.

Problems

Differentiation and aging

The influences of differentiation and aging on the behaviour of the cuttings have two results: During the time of physiological change the cutting maintains its branch habit for a shorter or longer period depending on the age of the stock plant. After the change to an orthotropic growth the influence of topophysis is reflected in differen-

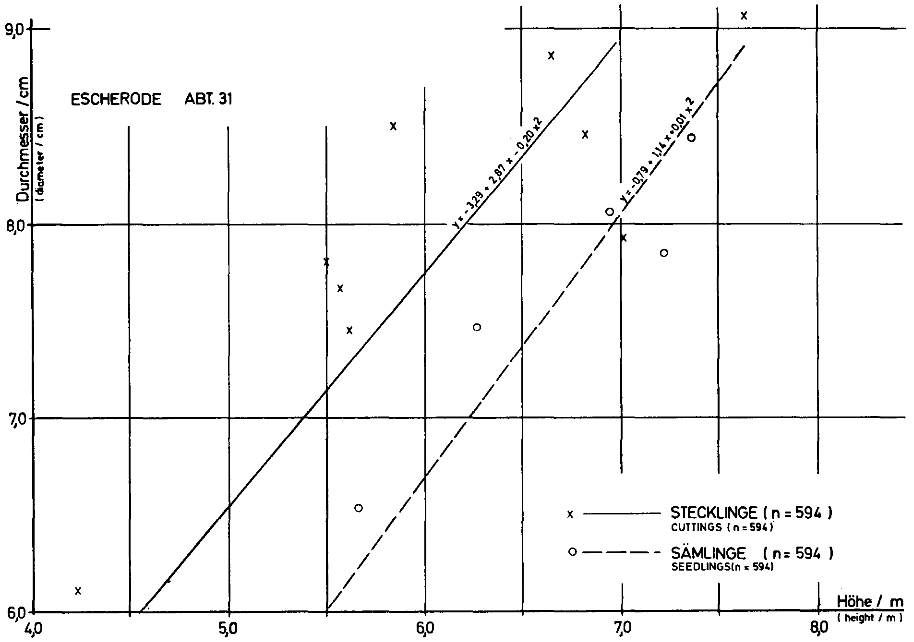

Fig. 8. — Comparison of seedling and cutting diameter at age 15.
Durchmesservergleich von Sämlingen mit Stecklingen im Alter von 15 Jahren.

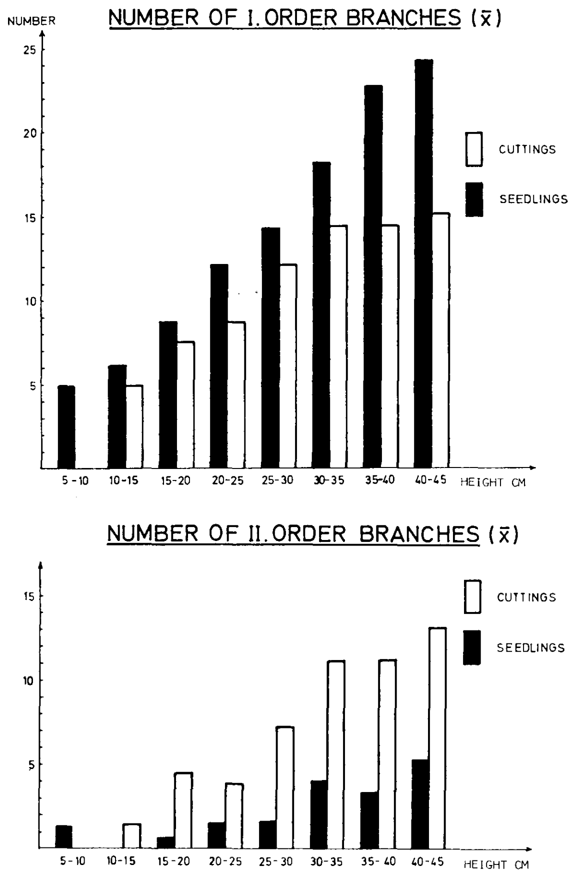

Fig. 9. — Number of I. and II. Order branches, Cuttings/Seedlings.
Anzahl der Zweige 1. Ordnung, Stecklinge/Sämlinge.

ces of morphological characters of the cuttings as compared to seedlings.

Using juvenile material the transition from branch habit to orthotropic growth in Norway spruce regulary doesn't take more than 2 years. More general influences from topophysis however last much longer. We found for example that cutting plants have a higher diameter at comparable height than seedling plants as well in the nursery as up to an age of more than 15 years *(Fig. 8)*. They also differ in the number of branches of first and second order, *(Fig. 9)*. Taking the absolut amount of dry matter the cuttings produce more roots, more shoots and more branches than the seedlings of same height *(Fig. 10)*. Regarding the relative amount, however, there is no difference between root per-

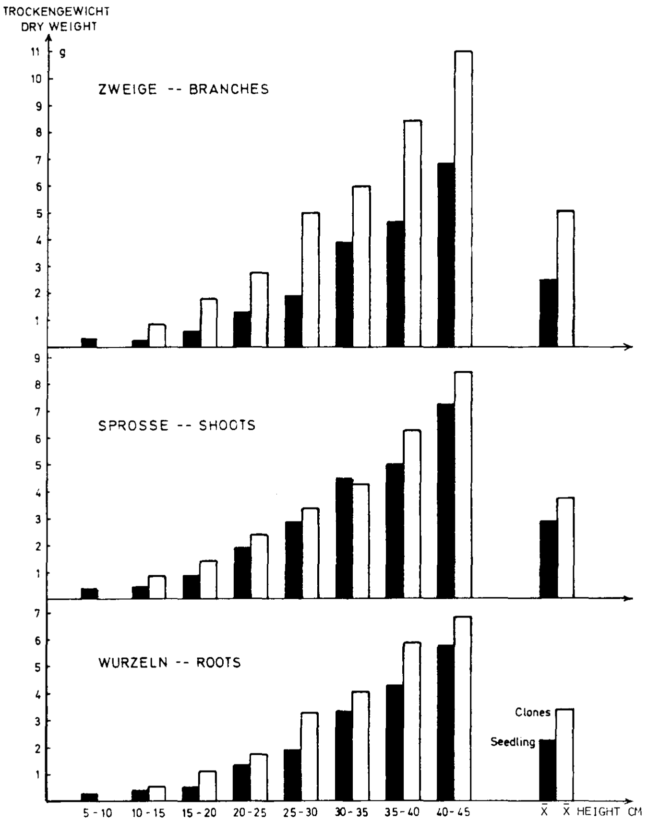

Fig. 10. — Total dry weight, Branches, Schoots, Roots; Cuttings/Seedlings.

Trockengewicht = Gesamt, Zweige, Sprosse, Wurzeln; Stecklingsklone/Sämlinge.

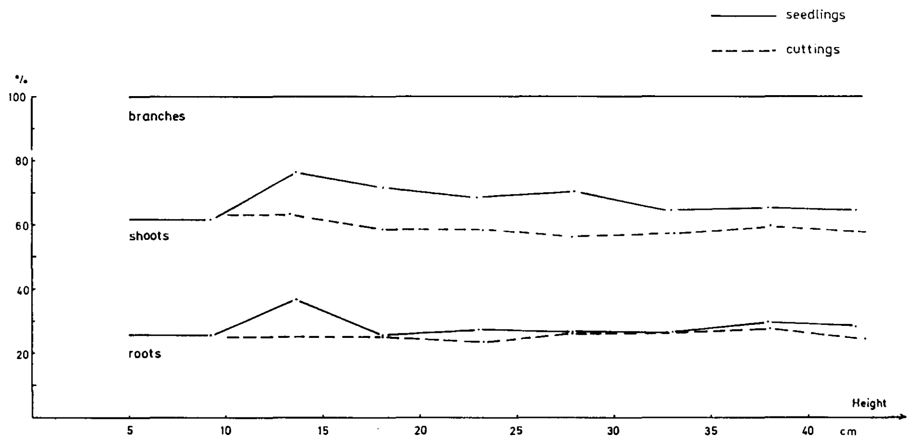

Fig. 11. — Dry weight % of roots, Shoots and branches in relation to height.
Trockengewicht von Wurzeln, Sproß und Zweigen in Relation zur Höhe.

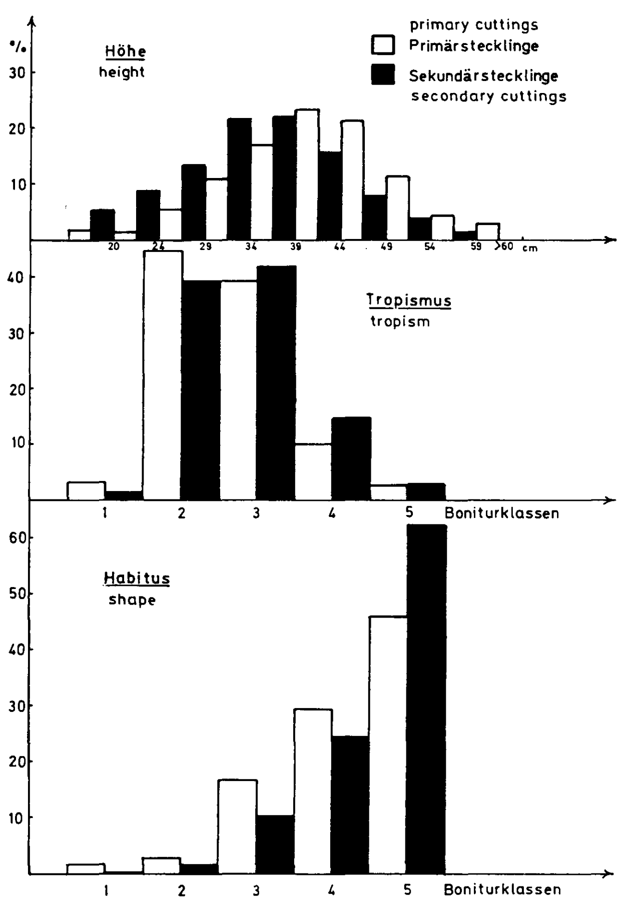

Fig. 12. — Douglas Fir Cuttings, rooted 1973, Test 1976 (February).
Douglasienstecklinge, bewurzelt 1973, Aufnahme Februar 1976.

centage of seedlings and cuttings *(Fig. 11)*. This is not true of the branch percentage in the same way.

These influences of differentiation may last for considerable time. It is interesting to note here that there are significant genetic differences in root formation between the different clones and that it seems to be quite possible to breed for higher root intensity in Norway spruce. We started more intensive research in this field some years ago. The results will be published elsewhere.

From our point of view the most severe problem in a large scale cutting propagation program is *aging*. With increasing age the rooting potential decreases, the time for physiological change from branch habit to orthotropic growth increases and the height growth during the transition phase decreases.

Only if it is possible to prevent aging in the selected material by technical methods, like repeated repropagation or hedging, breeding programs with cutting propagation can

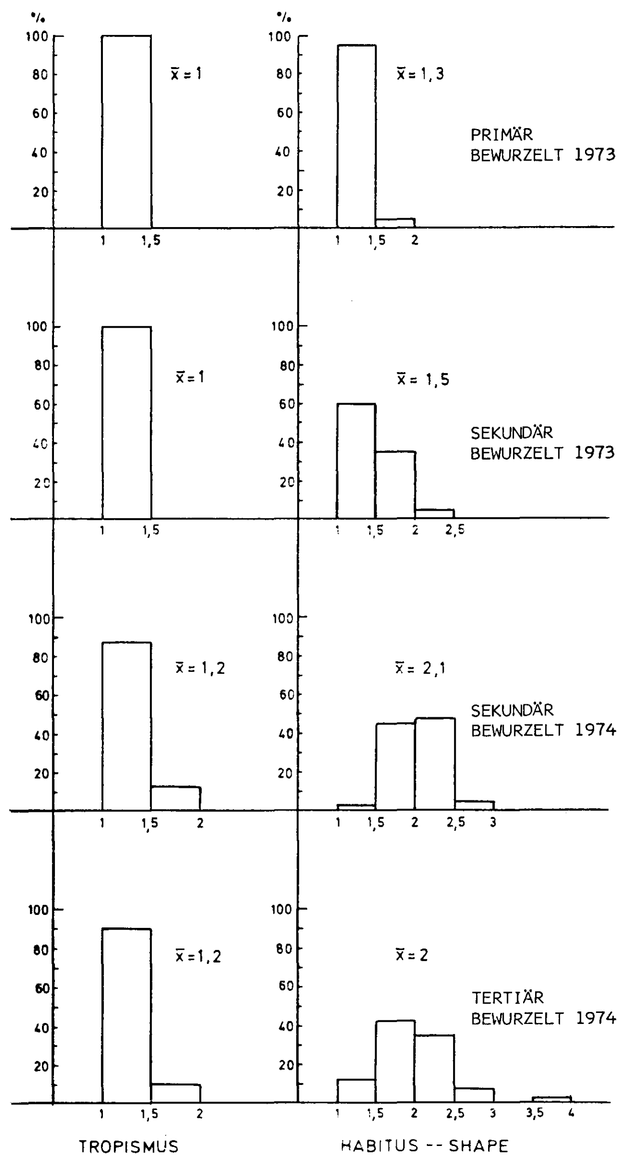

Fig. 13. — Norway Spruce Cuttungs, Autumn 1976.
Fichtenstecklinge, Herbst 1976.

guarantee maximum gain. The earlier aging takes place the less the potential genetic gain is and the more complicated this part of the breeding program will be. Douglas-fir may serve as an example of these problems *(Fig. 12)*. In tropism 1 is orthotrop and 5 is horizontal; in shape 1 is seedling shape, 5 is branch shape.

In Norway spruce we looked to the effect of repeated repropagation which is demonstrated in the following *figure 13*. There is a significant longer duration for change in shape from the primary cuttings to the secondary ones. These influences however are not to be found in the tertiary cuttings as compared to the secondary ones of the same age. Rooting potential is still better in secondary and tertiary cuttings as compared to primary ones, perhaps due to better preconditioning of the ortets.

Alltogether it doesn't seem to be possible to prevent aging completely by our methods used. Perhaps tissue culture may be a good tool to get rid of the correlations and differentiation and so to give a real rejuvenation. Activities in this field should be enhanced. Heavy pruning to get adventious shoots at the base of older plants may be another possibility.

Variation

I shortly want to stress the need to maintain genetic variation within the clonal mixtures because of the early selection and the heterogeneity in space and time. These problems have been discussed in detail in a paper for the Canberra World Consultation (Kleinschmit 1977).

Unreflected use of vegetative propagation may have as result a quick, extreme loss of genetic variation. It is of outstanding importance in breeding programs and for practical application to prevent this extreme limitation of genetic variation. Toda (1973) states, that the practical forester tends to use only single clones. The breeder has to prevent this.

The aim has to be, maintain genetic information of the populations, to reduce the risk of damages, and to keep the bred materials stable over a large variety of growing sites.

Uniformity may be an economic advantage but it is definitely a disadvantage in heterogeneous environment — and this is true in nearly all forest sites. Natural populations therefore maintain high genetic variation and by this high adaptability to a broad range of environmental changes.

Finally it must be stressed that an applied breeding program in Norway spruce including cutting propagation needs close cooperation between the forest tree breeder and the silviculturist and that it is far of from being without problems today. Especially the question of aging has to be followed thoroughly to prevent reverses.

Abstract

After a short review of the earlier activities in the field of cutting propagation in Germany the present propagation methods are described. Mass propagation is done in plastic greenhouses in gravel.

A cutting transplant costs 20—52% more than a seedling transplant under German conditions. The development of the costs and the economic situation are discussed.

Within the breeding program cutting propagation is used at different levels, starting with selection from tested provenances and ending up with species hybrids. By repeated repropagation and maintaining a high variation problems of early selection and genotype — site interaction are reduced. The clonal field experiments are used as clonal tests, seed-orchards and base breeding population.

The problems of differentiation and aging in relation to an applied breeding program with cuttings is discussed for cutting propagation at the present time. The necessity of maintaining a high genetic variation within the clonal varieties is stressed.

Key words: Cutting propagation, aging, genetic variation, breeding program Norway spruce.

Zusammenfassung

Nach einem kurzen Überblick über die Entwicklung der Stecklingsvermehrung bei Nadelbaumarten in Deutschland werden die gegenwärtigen Vermehrungsmethoden beschrieben. Die Massenvermehrung wird im Plastikgewächshaus in Kies mit automatischer Sprühanlage durchgeführt.

Unter praxisnahen Bedingungen kostet eine verschulte Stecklingspflanze in Deutschland 20—52% mehr als eine verschulte Sämlingspflanze. Die Kostenentwicklung und die wirtschaftliche Situation werden diskutiert.

Innerhalb unseres Fichtenzüchtungsprogrammes werden Stecklinge aus geprüften Herkünften, aus Einzelbaumnachkommen, aus kontrollierten Kreuzungen und hierbei vermehrt auch aus Arthybriden ausgelesen. Alle Klone durchlaufen ein Prüfprogramm, das immer wieder eine Überprüfung der Entscheidungen zuläßt. Jeder Selektionsschritt wird unmittelbar in die Praxis übertragen.

Durch ständige Wiedervermehrung und die Erhaltung einer hohen genetischen Variation werden die durch Frühselektion und Genotyp — Standort Interaktion auftretenden Probleme verringert. Die Versuchsflächen werden sowohl als Klonprüfungen wie auch als Samenplantagen und als Züchtungspopulation behandelt und benutzt. Die Schwierigkeiten, die aus Differenzierung und Alterung für ein angewandtes Züchtungsprogramm mit Stecklingen entstehen können, werden diskutiert. Die Notwendigkeit, eine hohe genetische Variation in den Klonmischungen für die Praxis zu erhalten, wird unterstrichen.

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