

FOREST TREE BREEDING AND DANISH EXPERIMENTS

by

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Denmark is a small country where we have to utilise every possibility for the most intensive cultivation of our soil. This applies to all cultivation, be it agriculture, horticulture or forestry. In earlier times the forest had to give way to agriculture, but during the last century our area of forest land increased from 4 to 8.2 percent, i.e. almost one fifteenth of the whole country is now under forest. This is chiefly due to the extensive forestation of heath and sand dune areas, and in spite of the modest return from such areas, the production now averages about 63.6 million cubic feet as against half this quantity 50 years ago, and the amount of timber has risen from 3.2 million to nearly 17.7 million cubic feet a year during the same period.

Various methods have been employed in utilizing forest products in the general economy of life. The area as a whole has been more closely employed, better methods of cultivation and thinning have made great strides, but the key factor, undoubtedly, is to be found in an increased use of foreign conifers. Mountain pine now occupies about 45 per cent of the area allotted to conifers, and norway spruce about 50 per cent, while larch and Douglas are valuable species though only used sparingly compared with the former. Apart from conifers plantations consist chiefly of beech, then oak, to a lesser degree of ash, elm and alder, all native species. The advance of conifers has not caused a corresponding decline in hardwoods, but is almost entirely due to new plantations and the intensive use of forest areas.

The increase in forest production, however, is not only sought through the introduction of foreign species, but to a great degree by the utilisation of the most suitable types within the foreign as well as our own native species. Besides seed from our best plantations, we use Hungarian and Czechoslovakian beeches, which are of a particularly upright and fine form. During the last 40—50 years a great quantity of Dutch acorns has been used resulting in fine plantations, and similar work has been carried out as to other species. This does not apply specially to Denmark, but has been a general tendency of modern forestry, spurred on by experiments carried out about 1900, and causing a prolific development after the differences in the "nature" of the species, their hereditary qualifications, the genotype, and the appearance dictated by the climatic etc. circumstances had been established. Of special importance in this research may be mentioned Engler, Hesselman and our Danish A. Oppermann who further accentuated the importance of utilizing the results gained in a deliberate work of tree improvement.

On the whole, however, the selection according to free, non-controlled pollination, was maintained.

In this connection, I should like to emphasize the great work done by A. Oppermann and its importance to Danish forestry. At the Forest Research Station in North Seeland, he originated various experiments which later bore rich fruits in his publications and not least by the numerous demonstrations carried out during his enthusiastic lectures.

If we define as *the aim of plant improvement* the endeavour to procure plants which solely by their hereditary qualifications are able to improve production as compared with other trees of the same species, one cannot include the introduction of foreign species in this work. To a certain degree one must include the great work done and still being done, to find the most suitable provenances of the various species and the search of such types which, as regards style and other qualifications, are most useful to the general practice of forestry. As far as Denmark is concerned the work of A. Oppermann is of fundamental importance. The aim of the intensive improvement of plants must, however, consist of a deliberate attraction or elimination of races, types or individuals, which to a considerable degree differ from those found in nature, and to find ways and means for the further extension of such.

Let us return to the Dutch oaks. They appear to be the result of generations of selection of the most upright and beautiful trees of the avenues from which the most valuable acorns are now collected. All are planted as "heesters" (i.e. big plants, several times trans-planted. All are to make possible a selection of the finest specimens before the final planting. This material is so unique as to demand the closest scrutiny. As a similar instance, one must mention the Scots larches, regarding which Gunnar Schotte explained the uniform type of the "Dunkeld" larch as originating from few isolated trees by Dunkeld cathedral. This same type is represented by the magnificent larches at Sandviken in Norway. The young plants are said to have come from Scotland about 1800.

As regards Douglas we have another example in the Scots Douglas, originating from 2 trees at Scone, which in the eighteen-sixties found its way to Denmark.

The two trees (*Pseudotsuga taxifolia*) at Scone originate from seed sent home by David Douglas during his stay in Western America in 1825—27. In 1844 the first cones were collected from the trees but they yielded no plants. In the course of the following eight years seed to an amount of £ 500 at the prevailing market price was collected. In 1873 it was computed that so far the trees had yielded 200000 cones in all, or 4 million plants, but a loss of 25 per cent was reckoned with. All Douglasses of before 1877 are doubtless from seed of the Lynedoch trees at Scone or their offspring.

In this connection I should like to call attention to the importation of European trees to the U.S.A., which took place in earlier time. For instance I can mention the old often discussed question of the mysterious *Larix pendula*, Soland.

Larix pendula was first described in 1789 by Solander as *Pinus pendula* in Aiton: Hort. Kew. and cultivated in England in 1739 by Peter Collinson (Mill Hill), from which Lambert reproduces material (Genus *Pinus* 1803, pl. 36). In a previous paper Ostenfeld and I follow Henry in his theory of *L. pendula* as a hybrid between *L. decidua* and *L. laricina* arising in cultivation, and "we do not, however, think that any proof

exists of its having been found in North America in the wild state".

At this point, however, I should like to add an item of information which I have found later on in a note by the Swedish botanist Kalm. It refers to a day of Sept. 1748, when he visited John Bartram at Philadelphia. This note informs us that Bartram sent material of larch to Peter Collinson's garden at Mill Hill, from which the material for the description of *Larix pendula* originates. The seeds were gathered in East New Jersey where it occurs in the wild state and it is the only place from which Bartram knows it. John Bartram was an English farmer who in the first half of the 18th century laid out a botanical garden on a ground at Schuylkill River about 3 miles from Philadelphia. To this garden he imported many of the trees of the Old World and he also sent seed of North American species of trees to Europe on a large scale. On his death in 1777 he had been "appointed botanist to the King of England". In this connection Kalm mentions various plants already imported from Europe at that time and about these plants it was difficult to decide whether they occurred in the wild state originally or they had been imported.

When these statements are compared with the fact that *L. laricina* is not stated to be found in East New Jersey, which, at any rate now, is somewhat outside the natural distribution of this species, and with the fact that this was one of the first districts to be colonized, we may be justified in supposing that *L. decidua* was first introduced into America at that time.

Furthermore, as we have in Denmark plantations of *L. pendula* imported about 1800, showing a uniform type which to a marked degree differs from our ordinary *L. decidua* plantations, the possibility exists that by isolation in North America, a new type of Eur. larch has been created, as in the case of the "Scots larch". The growth appears somewhat slower in Denmark, but of an upright type and it seems to have a greater resistance to *Dasyscypha Willkommii* than the Scotch larch.

In older literature one finds several scattered observations and experiments which might have been the starting point of a genuine work of improvement without this seemingly having happened. The first real forest "Improvement Station" was founded in 1925 at Placerville, California, and became the fore-runner of the present "Institute of Forest Genetics". Later on similar work was taken up by the Kaiser Wilhelm Institute at Berlin, and in Sweden Nilsson-Ehle found the triploid aspen in 1935. The German works issued during the years previous to the late war, such as "Rassenzucht auf natürlichem Wege", "Forstliche Individualzucht" and works on seed from elite trees after non-controlled pollination, are in a way good works, but they should be viewed as a contribution to the search for the best possible seeds and be included in the intensive and valuable work of organisation which one endeavoured to construct.

If we satisfy ourselves with this as a mean forestry improvement, we shall only cloud the picture with all its difficulties. It is better, therefore, to exclude it and look truth in the face, i.e. that genuine plant improvement makes quite different demands, to the solution of which we luckily have several ways, though so far only used to a small degree.

Some methods of improvement, as used in Denmark, may be mentioned as follows:

Artificial pollination on a foundation of previous studies of the flowering of forest trees.

Hybrids, especially the utilisation of hybrid vigour.

Cytological work to define trees having chromosome-numbers differing from the normal, as well as reproducing such.

Finely there is the *vegetative propagation*, which anyhow is of the greatest importance as a technical mean of forest improvement, but which may also be of special importance for the utilisation of species of a desired character (so called clones).

A comparison has often been made between the improvement of forest trees and that of agriculture and horticulture, quite naturally in a way, as in all cases living plants are concerned, and perhaps with a certain amount of envy one may have regarded the very great strides made by the two latter in this respect. Unfortunately, when similar projects were contemplated in forestry, one was often stopped by the considerable obstacles. For instance, when reckoning with 1 or 2 year generations in agri- and horticulture, one had to reckon with 25—30 years for each generation of trees to reach maturity, and when considering the number of generations necessary for the former to attain certain desired qualifications, the corresponding generations for trees ran into such high numbers of years, that one lost all interest in carrying on. This view is quite wrong, as obviously the slower the procedure, the sooner a start must be made, as the improvement of species is a matter which cannot be neglected if forestry is to meet the constantly rising demand for production. Also, it is a fact that only when one really seriously tackles a question, one finds the right ways i.e. the shortest and best ones.

First and foremost, we should aim at preserving for the future the best possible types of economically important forest trees, and as regards the U.S.A., this applies not only to the best types according to appearance, but also to providing such specimens within a sufficiently large number of climatical types. In Denmark, the work is carried out by the State Arboretum, and according to its forest-botanical nature it is a work which naturally comes under the range of the various countries arboreta or whatever the forest-botanical collections are called and whether they are attached to forestry colleges, research stations or other institutions. Let us get away, as soon as possible, from all the old collections with all their curiosities. It was the practice to collect weeping ash, snaky spruce, globular spruce and colum-shaped trees instead of concentrating chiefly on individuals which showed — and preserved — within each species the most valuable qualifications in a forest-botanical and economical sense.

At the International Forest Congress in Budapest in 1936, I propounded the above ideas and endeavoured to start an international work in this direction. I did not succeed in creating enough interest in the matter, though later on I received enthusiastic approbation from a well-known dendrologist, but all was stopped by the dark clouds which were then already gathering. But now this matter should be seriously grappled with. Each country should register its most valuable stands, preferably amongst virgin forest or outstanding individuals, and bring them into cultivation: either by seed or preferably by vegetative propagation (conserving the



Eik, een van de mooiste exemplaren in Denemarken. 1910.

Oak (*Quercus robur*), one of the finest specimens in Denmark (Oppermann, Fig. 66, Det forstl. Forsøgsv., 1932). Ostofte 1910.



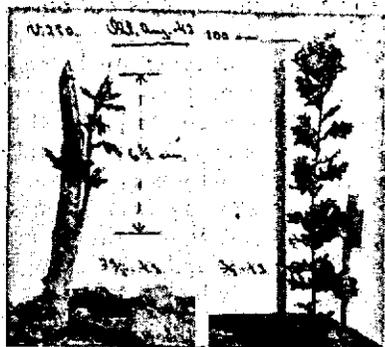
Ent van denzelfden boom op ouden onderstam („Instandhouden van een waardevol genotype”) Geent 22/5 1942; foto 31/7 1942.

Grafting from the same tree on old stock ("preserving the valuable genotype"). Grafted May 22, 1942, fot. July 31, 1942. Arboretet, Hørsholm



Ent van denzelfden boom op jongen onderstam („zaadboom"); geent voorjaar 1938 in kas; foto 2/9 1943 met 18 eikels, lengte 83 cm.

Grafting from the same tree on young stock ("seed tree"). Grafted spring 1938 in greenhouse. Fot. Sept. 2, 1943 with 18 acorns, height 83 cm. Arboretet, Hørsholm.



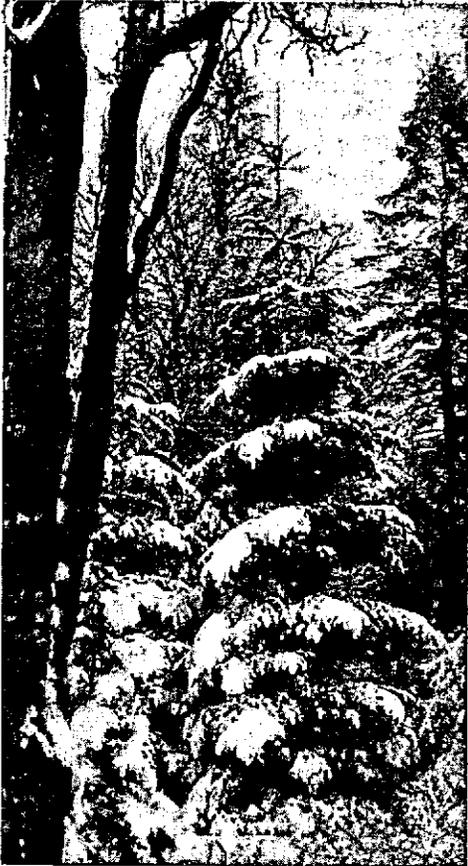
Oculatie van denzelfden boom. Geoculeerd Augustus 1942, foto 29/5 1943 en 3/9 1943.

Budding from the same tree. Budding August 1942, fot. May 29, 1943 and Sept. 3, 1943.

valuable genotypes) in order that an international exchange may take place between the various arboreta.

But we must go further than that, the good trees should not only be preserved but also be used for further work.

By artificial pollination and selection we must try constantly to attract better types, in the way used in agriculture and horticulture. It may be



Abies Lowiana x *grandis*, onze eerste hybride, kunstmatige bestuiving 26/5 1924, gezaaid 1925, foto 1/1 1940. Lengte 9.0 m.

Abies Lowiana x *grandis*, our first hybrid, artificial pollination May 26, 1924, sown 1925, Jan 1, 1940. Height 9.0 m. Forest Botanical Garden, Charlottenlund.

slow progress, but any way it *guards us against decline*, and the brilliant results obtained with other plants for instance fruit trees, should spur us on in our endeavour to obtain similar far-reaching results in our own sphere.

However, a comparison between trees and other vegetative plants should not be encouraged. We should not gaze at other plant improvers' more favoured position in the work with vegetative plants but rather turn the matter upside down. Let us not contemplate their swiftly changing generations, but rather the short life of their plants compared to that of our forest trees. Paradoxically, one might say, that as regards short-lived plants one must attract types of seed-consistency in order to preserve them, whereas in forest trees one can preserve valuable hereditary

tendencies in the same individuals, may be for centuries. *Therefore, do not shed tears at the slowly changing generations, but rejoice at the long life of the individuals.*

The longevity of forest trees may be the basis for the *establishing of Seed Plantations*. By the selection of seeds from specially fine trees plants are produced, and after careful sorting placed in areas protected against foreign-pollination. When maturity has been reached, a very valuable seed collection will be assured from such plantations, sufficient for a great number of years, and at the same time seeds may be obtained by artificial pollination amongst the finest trees, resulting in probably still better seed plantations. If one has special confidence in existing trees, graftings may be taken and within a few years planted out in new seed plantations. They may be planted in separate rows and be constantly subjected to research with artificial inter-pollination, and gradually, the less promising individuals may be removed.

The long life of forest trees, however, may also be utilised in other methods of improvement, by the use of the so called F_1 -generation with its frequently very pronounced vegetative development, so called *hybrid vigour* or *heterosis*. It is a well-known phenomenon that by crossing closely related species, hybrids result, which during the first generation tend to a particularly prolific vegetative development. This method has lately been adopted in the American maize production, and it is a well known fact from the poultry yard, that a cock of one breed and hens of another produce the best table birds. It is these fine "table birds" that we should aim at in forestry in a very big way, and then collect the seed production in smaller, limited areas, where from year to year we may have our seed-stores.

Seed from the hybrids may be subjected to continued research, but they will *generally* prove less valuable than the first more uniform generation and they should not, even if they should be viable at all, be used for forest cultivation. One exception to this may perhaps be found in the hybrid Japanese-European larch, and possibly other cases may exist, but it must be regarded as an exception.

The production of hybrid seeds follows these lines: If by previous experiments with artificial pollination a valuable hybrid has been created, — such as for instance the Jap.-Eur. larch where strong growth is combined with a fine appearance and where resistance to *Dasyscypha Willkommii* is presumed — the required number of plants of the one species most suitable to act as mother are grafted as seed-trees. Plants grafted in this way, which may be considered as one and the same individual only distributed on a greater number of roots, will therefore flower in the same way and at the identical time, as for instance the various apple varieties each have their own individual blossoming time. As the selected mothers have been chosen from a metandric tree, they will all produce their female flower at a time when their own male flowers are still unopened, and if they have been planted with a mixture of larch of the desired father species, the pollination of the female flowers will be as desired. Once such a plantation has been established in a satisfactory isolated locality, the desired valuable seeds may be obtained year after year, and as the majority of forest trees yield an abundance of seeds, only small areas are required to cover the yearly demand.

As an example of strong growth of a hybrid larch may be mentioned some trees in the Forest Botanical Garden.

Seeds of Jap. Larch received from Dunkeld, partially pollinated by Eur. Larch (15 years) after thinning, autumn 1940, average height of Hybrids 11.4 m and of Jap. Larch 9.7 m. (thinning 11.0 and 6.4 m).



Europeesche lariks. Geent voorjaar 1936 en 1937 van een boom, mogelijk het mooiste exemplaar in Denemarken. Isolatie der vrouwelijke bloemen in papieren zakken 30/4 1940.

European larch (*Larix decidua*). Grafted spring 1936 and 37 from one tree, possible the finest specimen in Denmark (Opperman, Fig. 8, *Det forstlige Forsøgsvaesen i Danmark*, 1923). — Isolation of female flowers in paper bags. Arboretet, Hørsholm April 30, 1940.

Another example from the experiments in the Arboretum likewise shows the greater growth dimension of the hybrids. We have some even aged larch-groups, all originating from seeds, artificially pollinated, sown in spring of 1934. These groups were measured during the winter of 1942—'43 (9 years), some trees being removed at the same time, and the bulk production of the hybrids was 37% higher than that of the pure reces, and they also seemed to be healthier.

In Denmark with her intensive forestry this latter way of seed production is one of the methods to which I attach the greatest importance. On the other hand, it is possible, that the former method of merely isolating a selection of the best seed plants or graftings of one single species may be of special importance. I should like to take as an example the Scotch pine (*Pinus sylvestris*) in Norway and Sweden, which I have had occasion to examine further. In Scandinavia, the *Pinus sylvestris* shows great variation in development and flowers at different times in

the various districts partly owing to the place of growth and partly to hereditary deviations. If this tree is moved from high northern localities to more southern and favourable conditions, or vice versa, the trees thus removed may flower at different times than the native pines of the district. It is possible that by establishing seed plantations, i.e. isolation of the best trees, one may obtain an effective protection against foreign pollination by making use of such transfers. In the far North, near the forest boundary, this pine only succeeds in flowering and bearing cones in favourable seasons. One might possibly, by establishing a seed plan-



De hybride Japansche Europeesche lariks vergeleken met de oorspronkelijke soorten, alle gezaaid 1934. Foto 8/2 1940.

The hybrid Japanese x European larch compared with the species, all sown 1934. Arboretet, Hørsholm, February 8. 1940.

tation in a more favourable climate obtain a more abundant or frequent fructification, whilst still protecting the trees against foreign pollination, so that the seeds would become of the same climatical type as if they had been produced in their real native district, but even better as they would be produced from selected trees. Preliminary experiments in this respect may possibly be carried out with graftings, which in any case are useful for an indoor controlled seed production, to which question I shall revert later.

Before leaving the question of hybrids, I should like to mention that comprehensive experiments in natural as well as cultivated plantations, should not be neglected, as valuable impulses and directions may be obtained in this way. The hybrids are not at all rare. In Denmark we have our two native birches, *Betula verrucosa* Ehrhart and *B. pubescens* Ehrhart; the pure types are rarely found. Amongst our oaks — the ordinary summer oak, *Quercus robur* L. and the more rare winter oak, *Quercus sessiflora*, Salisb. — the hybrids are very common, they are even found amongst our oldest, possibly thousand-year-old oaks. It is, however, by no means always the valuable F_1 — generation one finds in such cases, where the types have grown side by side through the ages. The frequent crosses taking place in the forest may be compared with the

old-fashioned mixed poultry yards. This should not be our aim. Crosses are very good, but they should be under control, and it would be quite unreasonable, in view of experience gained from the mixed poultry yard, to deny the value of crosses and proceed with exaggerated talk on pure races.

Furthermore, I should want to emphasize that poplars afford a very profitable chapter within the studies of hybrids. Like most forest trees, they are wind pollinated whilst at the same time being dioecious plants i.e. each tree bears one kind of flower only, being thus male or female. In contrast to our ordinary forest trees, they are chiefly propagated by cuttings, and as crossing furthermore, is easy and several varieties have long been cultivated in gardens, along roads and in woods, the result is that within this species the most terrible confusion exists, which may give even the systematic botany hard nuts to crack. It is not saying too much that it also holds unsolved problems. What is of greatest interest is, however, that those particularly vigorous and most of poplars are not to be found in nature, and they must be considered crosses casually produced under cultivation. By their easy vegetative propagation, a great number of progeny may arise from a single casual individual. In America especially, with the support of the Oxford Paper Co. McKee, Stout and Schreiner have worked with poplars and in Germany von Wettstein of the Kaiser Wilhelm Inst. and in Canada Heimburger have done good work. In Scandinavia the Norwegians are experimenting with aspen (*Populus tremula* L.) in connection with the Norwegian Match Factories, and a considerable work has lately been taken up in Sweden, in respect of aspen as well as poplars.

Considerable results have been obtained — patent rights have even been taken for a number of cross-products of poplars — and no doubt strides will be made. The reason why poplars were chosen as a subject for improvement may no doubt be found in favourable biological conditions which these species possess to a marked degree, as well as in the vigorous growth of the species and the tempting example of the casual hybrids.

Quite other ways to those mentioned here —, i.e. the raising of improved types by the aid of artificial pollination and the production of hybrids — may be followed. When Nilsson-Ehle discovered the triploid aspen in 1935, the so-called "Giant Aspen", new perspectives opened up for the improvement of forest trees by the aid of cytology.

Here it may be advisable to advance a few remarks. Cytology is the science of cells. The plants, like all other living organisms are built up by cells, and each cell contains some stainable bodies called chromosomes. These chromosomes are inherited elements and they appear in characteristic numbers so that the vegetative cells contain twice the number of chromosomes as the generative cells. The number of chromosomes in the latter is called the haploid number and that in the vegetative cells the diploid number. As an exception, it may occur that an individual arises with 3 sets of chromosomes in the vegetative cells, such plants being termed triploid. One may also find tetraploid plants with 4 sets of chromosomes in the vegetative parts and the diploid number in the generative cells of these plants. Plants with a still higher set of chromosomes will not be considered here.

The number of chromosomes of the aspen (*P. tremula*), the diploid number, is 38, whilst that of the "Giant Aspen" is 57 (3 times 19). A particularly vigorous growth is often found in such triploid plants, and this is also the case with the "Giant Aspen". Nilsson-Ehle discovered it by its exceptionally large leaves. The economical importance attributed to the "Giant Aspen", may be explained by the fact that plants (rooted shoots) from the first found plantation were valued at 10 Kr. each. In Sweden several other triploid aspen were found later, male as well as female trees, and some of exceedingly fine appearance.

The Swedes too have now gone into this matter of making use of them. Under the direction of Nilsson-Ehle and Sylvén a very energetic work of improvement was undertaken, in the first instance on the foundation of the first found triploid aspen. Sweden now has an economically sound research station at Ekebo near Svaløf, solely for the improvement of forest trees. Further experiments were undertaken with the aspen and they now have several tetraploid plants, which are especially attractive as, by a cross with diploid plants, seeds yielding triploid plants will result.

The cause of this emergence of plants with an increased number of chromosomes is as yet not quite clear, but they may be created by shocks of temperature or by wounding. Lately, the effect of chemical liquids has also been employed. In America, especially, fine results on herbaceous plants have been obtained by using Colchicine, and in Sweden comprehensive experiments have been undertaken with forest trees, and good results have already been obtained as far as the aspen is concerned. In Denmark at the Forest Botanical Garden so far we have only undertaken preliminary experiments with production of plants of an increased number of chromosomes according to the above methods.

By great good fortune, we have managed to get some winners in other ways. A triploid larch has been produced, and a triploid conifer I consider of especial importance, for reasons which I cannot expound here. It has emerged from a cross between European larch and Western American Larch (*Larix occidentalis*). I carried out the pollination in the spring of 1930, obtained 534 seeds which the following spring resulted in one single plant. This was a peculiar, long-neededled, robust plant, which at once attracted attention. Later on, after cytological examination, it proved to be triploid, and consequently it is now the object of continued experiments, which have produced plants of widely varied appearances. If it were possible, on this foundation to evolve tetraploid plants, and this seems quite feasible, much would be gained.

Some alders too have given favourable results. In my treatise in 1936 I mentioned a fast growing alder, which I considered to be a cross between two Southern-European species (*Alnus subcordata* x *cordata*), produced by free pollination between trees in the Forest Botanical Garden at Charlottenlund. This proved to be wrong. Further examinations, aided by systematical botany and cytology, proved the case to be much more involved, though certainly producing exceedingly interesting results. It appeared that we had in the above Garden an old *Alnus subcordata*, which was tetraploid. It was not, in itself, a very fine or large tree, but it produced through the years a handsome progeny, which proved to be chiefly triploid hybrids produced by pollination of the older tetraploid tree by diploid individuals of other species. These were formerly regarded as

vigorous young plants of the *Alnus subcordata*, their hybrid nature being difficult to detect owing to the fact that they were not a combination of the two parents like other hybrids, but all had received 2 chromosome-sets from *Alnus subcordata* and only one from other species, resulting in a predominating likeness to *Alnus subcordata*. Now the strange thing happens, that when we sow seeds from the *Alnus cordata* mentioned, after free pollination we get amongst the pure *A. cordata* a small number of diploid plants of vigorous growth which in their morphological character bear great resemblance to *A. subcordata*, and it was such a plant which I originally considered to be a hybrid from *A. subcordata* x *A. cordata*. The explanation of the origin of these plants is still somewhat obscure, but of some interest as the plants seem to be of forest importance, not only by their vigorous growth, but also as regards hardiness as compared with *A. cordata*.



a



b

Zaailingen van els (1-jar. verpl.), van dezelfde moederboom. a. Triploide planten, *Alnus cordata* (diploid) x *subcordata* (tetraploid). b. *Alnus cordata*, vrije bestuiving.
Foto 20/9 1941.

Seedlings of Alder (1/1), same mother-tree. a. Triploid plants, *Alnus cordata* (diploid) x *subcordata* (tetraploid). b. *Alnus cordata*, not controlled pollination. Arboretet, Hørsholm, Septb. 20. 1941.

They may be the results of pollination of diploid *A. cordata* by triploid hybrids, this, however, is the subject of continued research in connection with experiments on a number of alder crosses, established during recent years.

One more thing should be mentioned, i.e. the good old gardening methods of *vegetative propagation* by grafting and cuttings, as I am of opinion that these will be a *deciding factor in the improvement of forest trees*. Grafting, especially, occupies a prominent place as a technical means in connection with our experiments at Hørsholm.

Grafting is carried out by making an incision on a plant into which is introduced a sprig from another individual. If this operation is carefully carried out, the inserted sprig will grow on as if on its own roots. Generally, the whole top of the plant to be used as stock is removed, the new crown of the tree being entirely formed by the grafted

plant. It is in this way that most of our fruit trees, roses and many other garden plants are propagated. The use of grafts in seed production plantations has already been mentioned, but they should be used also in several other means of research.

As grown trees we find distributed in our own country — or abroad — the individuals on which to work, and as is the case with herbaceous plants, we cannot lift them and remove them to our research station. By grafts, however, we may bring home living twigs and produce new trees of the very specimen wanted and thus continue our research without having to climb tall trees or travel great distances. Furthermore, by varying the methods and the choice of twigs, one may either produce grafts which grow quickly into normal new plants, or which, at any rate



a



b

Douglas. — a. Boom no. 1, Wind River, Washington, gefotogr. 17/4 1946, toen enten werden gesneden. b. een van de enten (verzonden per vliegtuig) geent op ouden onderstam en Denemarken 29/4 en gefotogr. 25/9 1946.

Douglas Fir. — a. Tree No 1, Wind River, Washington, fot. April 17, 1946 when cuttings from the tree were obtained. b. one of the cuttings (send by air-express) grafted on old stock in Denmark April 29, and fot. Septb. 25, 1946.

for a number of years, retain the character of an old tree. These latter may even be induced to flower and produce seed, thus obtaining a most convenient material for research, in case one might want to undertake crossing of Scotch, Norwegian, Swedish and Danish pines, American and Danish alders, or American and various European birches, or anything else. The raising of plants from *Picea*, *Pinus*, *Larix*, *Pseudotsuga*, *Betula* and *Fraxinus* from seeds has been accomplished by these means. They may be used as small plants in flower pots and as larger ones grown in tubs, usually in the open, and only removed to the green house during the flowering. This latter method, for instance, we use for birch,

and considerable amounts of seeds may be obtained from such grafted birches growing in tubs indoors. After removing all male flowers from the grafts, they are pollinated without further isolation by pollen from the desired male, which may be introduced into the house as cut branches in bottles.

Grafts from selected older trees in the woods may, however, also be used in other ways. They are an exceedingly important means when determining the *true nature* of a tree, its *qualities governed by hereditary tendencies*. The shape of a tree growing in the wood is a combination of geno-type and pheno-type. Thus, the shape of a tree growing in liberty, should not haphazardly be compared with that of a tree growing at close quarters. If, however, grafts or other vegetative propagation (buddings, cuttings) from both trees are planted out at great distance and subjected to similar conditions, *the pheno-typical effect is eliminated*, we are able to undertake a direct comparison of the individuals, the different appearances of which are *genetically conditioned only*.

It should be noted, however, that comparison should not be made between single grafts from the various selected individuals, each tree should be grafted in rows of perhaps 10 to 50. Only when you are confronted by such clones where you are able to compare the single individuals row by row, the immense difference between the separate trees within each type will forcibly strike you. This is the way to get to know one's trees. The plant breeder learns to understand his material and is able to seriously compare the leafing and fall, the shape and speed of growth, the hardiness, the resistance to diseases and many other things. Once you have commenced this kind of work, you will be surprised not only what knowledge may be gained from it, but also how fast is its progress. Furthermore, the same tree may be experimented with under different climatical conditions, or we may turn it round and say that we register the different climates of the various localities on the same tree (which will be apparent from different seasons of leafing, damage by frost etc. etc., thereby obtaining a kind of living meteorological stations). To more extended countries it should be of interest, through such use of grafts to seek a verification of the importance of provenance. In grafts one has a most uniform material for such a check on the climate, but it is not satisfactory. The roots have different hereditary tendencies, so it would be better if we could raise fine uniform specimens of fir, spruce etc. by cuttings. However graftings are a good step forward, and at the moment they are quicker and more easily produced than cuttings of most danish forest trees. In many other ways, such genetically uniform individuals would be of value in forestry research. We should spare ourselves no trouble in order to gain a better understanding of the pheno-typical and geno-typical qualities in the above way. Finally, grafts may be used to test the various individuals in their resistance to diseases. On this subject I am working together with the plant pathologist Fabritius Buchwald, and we have so far studied the diseases of Norway spruce and Douglas. This is also an important factor in avoiding too serious surprises later on.

Cuttings i.e. getting a twig to strike root directly, may be of equal importance, and on some spheres even more valuable than grafts. It is possible that growth hormones may help us, but it also seems reasonable

to suppose that a great individual variation is found within each type in respect of the ease with which propagation by cuttings may take place. I have no doubt that several hybrids are of special importance, but this is as yet a field on which one is still a bit uncertain in respect of forest trees, and any endeavour in this sphere should be enthusiastically welcomed. As a contribution to this subject, a treatise was pre-



Groveden (*Pinus sylvestris*) oude opstand, Balmoral Schotland, foto 1926.
Scots pine (*Pinus sylvestris*), old stand, Balmoral, Scotland, fot. 1926.



Groveden, een van de mooiste exemplaren in Denemarken. 1922.

Scots pine, one of the finest specimens in Denmark (Oppermann, Fig. 39, Det fortl. Forsøgsv., 1922). Nødebo Holt 1922.

pared during the last years under the name of „Experiments with soft-wood cuttings” by C. Muhle Larsen from our Arboretum.

It is possible that grafts as well as cuttings may find a special use in the cultivation of trees with peculiar wood, for instance the flamed and curly wood of the birch. For this, in its finest qualities, is paid up to 8 dollars pr. cubic foot, so we are told by Finland, who is a chief exporter.

Finally, it should be emphasized that the cost of producing a plant should not be too closely watched when the extra good wood or the great advance of bulk is considered. According to the conditions of forestry in Denmark, I have made the following calculation :

1 kg Norway spruce seed (about 125,000 seeds) may be calculated



Groveden, zaailing van boom (x) in bovenstaanden opstand. Gezaaid 1928, verschillende malen verplant, bestuiving van vrouwelijke bloemen in de papierzakken. 4/6 1940.

Scots pine, seedling from tree (x) in the above stand. Sown 1928, several times transplanted, pollination of female flowers in the paper bags. Arboretet, Hørsholm, June 4 1940



Groveden, ent van bovenstaanden boom. Geent voorjaar 1937 Foto 8/11 1943. Let op de kegels.

Scots pine, grafting from the above tree. Grafted spring 1937. Arboretet, Hørsholm November 8. 1943. Obs. the cones.

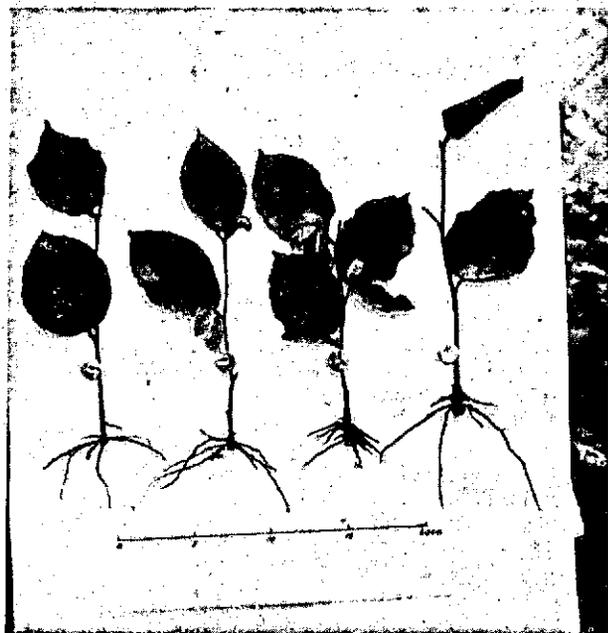


a b c

Esch. a. Oude boom, Stenderup, Denemarken. - b. Ent van denzelfden boom met vruchten in kas, 22/8 1939. - c. Zaaillingen uit de vruchten te zien in b, gekiemd 1941. Foto 25/6 1942.

Ash (*Fraxinus excelsior*). - a. Old tree, Stenderup, Denmark. - b. Grafting from the same tree with seeds in greenhouse, August 22. 1939. - c. Seedlings of the seeds shown in fig. b., germinated 1941. Arboretet Septb. 25. 1942.

to produce 48000 plants, sufficient for the plantation of 6 ha of 1 by $1\frac{1}{4}$ m. If one supposed now that the difference in production between two Norway spruce plantations was alone conditioned by the hereditary qualifications of the seed, and chose as examples two danish yield tables of Norway spruce (I an II), an increase of 12 per cent would be gained and reckoning with a 60 years term, 300 Kr. could be spent pr. ha, on better seed in order to raise the yield of II to that of I, or 1800 Kr. more for each kg seed, now costing about 20 Kr. If thus only 800 Kr. was spent



Stekken van beuk van 10/6 1939, gefotogr. 22/8 1939.

Cuttings of beech (*Fagus sylvatica*) from June 10. 1939, fot August 22 1939. Arboretet, Hørsholm.

on each kg seed, and the remaining 1000 Kr. capitalised, the result would be about 2000 Kr. for each ha, if by a genetic method only it were possible to obtain such increase, about 12 per cent. Such difference exists, I think, as regards the hybrid larch as against the European larch, besides more health of the former, and furthermore, a much smaller quantity of seed per ha would generally be used. One might perhaps mix hybrid larches with 2—4 times the number of other larches from ordinary forest plants.

There is not the slightest doubt that it would pay. The thing is to find the right procedure and go on finding new and better ones. In Denmark we are ready to receive such plants, as very intensive methods as regards planting, weeding, cleaning and careful thinning already exist, but no doubt similar work could be carried out in other contries with advantage.

Therefore, I must strongly recommend the work of plant breeding.

Collect in your Arboretum grafts from the most valuable individuals. Procure great numbers of grafts and seedlings from the best trees in order to establish seed production plantations, and as a further job, undertake preliminary experiments with the planting of grafts, possible cuttings, and let us use them in exchange and possibly we shall be able to select "standard-trees".

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