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PROPOSED TREE BREEDING PROGRAMME IN FINLAND, 1976—1985

ABBREVIATION OF THE REPORT ISSUED BY THE TREE BREEDING COMMITTEE
(COMMITTEE REPORT 1975: 25)

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Abbreviation of the report issued by the Tree Breeding Committee
(Committee Report 1975: 25)

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ABSTRACT

The article is an abbreviation of a Committee Report (1975: 25), which contains a proposal for genetic tree improvement in Finland during the period 1976–85. Genetic improvement began in 1947, but failed to reach any considerable extent until the 1960s. Thanks to the introduction of the Seed Orchard Programme and a Tree Breeding Development Programme a fairly large volume has been reached during the last decade. The new ten-year programme seeks to raise the intensity of breeding and to increase the number of the tree species and characteristics to be improved. The species covered by the programme are *Pinus sylvestris L., Picea abies (L.) Karst., Betula verrucosa Ehrh.,* and *B. pubescens Ehrh., Populus tremula L., Populus spp. (poplars), Alnus glutinosa (L.) Gaertn.* and *A. incana (L.) Moench, Salix spp., Larix spp., Pinus contorta var. latifolia Wats.,* and certain other conifers and deciduous trees. The properties to be improved are the rate of growth, adaptation and resistance, quality of stem and wood and, to a small extent, certain special properties. The methods of breeding are based mainly on sexual reproduction, and the most important phase of work is progeny testing. Progeny tests are simultaneously carried out at nurseries, testing orchards and field tests. Other methods of breeding, such as hybridization and artificial mutations, are being investigated. A forest-genetic research project is prominent in the proposal. The practical work towards the realisation of the project is divided between the National Board of Forestry, the Forest Research Institute, the Foundation for Forest Tree Breeding, central and district forestry boards and forest industry companies. The funds required to support the project between 1976 and 1985 have been estimated at 140 million Fmks and the investment costs at 23 million Fmks (January 1975). It is proposed that the project be almost exclusively financed by allocations from the State budget.

PREFACE

On 28th November 1973 the Ministry of Agriculture and Forestry appointed a committee commissioned to update the National Tree Breeding Development Programme approved for the period 1967–1976, as necessitated by the rapid progress in the field of tree breeding and to submit revised proposals. The Committee was also to draft a continuation programme, to cover the years 1976–1985, for the development of national tree breeding. The Ministry appointed Mr. PENTTI A. RITONIEMI chairman of the Committee and the following members: Mr. ILKKA J. AUTIO, Mr. ANTTI ISOAHO, Professor MAX. HAGMAN, Mr. EERO HYVÄRINEN and Mr. PAAVO KOTKANEN. Later, ILKKA J. AUTIO resigned and he was replaced on 18th December 1974 by Mr. MIKA LAMPINEN. The Committee was later supplemented by appointing Mr. MATTI J. OKSANEN on 22nd January 1975. Dr. VEIKKO KOSKI has been the permanent expert member of the Committee. Its secretaries were Mr. AIMO AUTIO, Mr. MARTTI LEPISTÖ, Mr. JOUNI MIKOLA and Miss. TUULIKKI SIMOJOKI.

The Committee made several excursions to various parts of Finland to familiarise itself with field activities. During excursions and meetings the Committee heard 55 outside experts. The report of the Committee was

completed at the end of May 1975 and was presented to the Minister of Agriculture and Forestry, HEIMO LINNA, on 3rd June 1975.

Since tree breeding is new and of growing importance, the Committee found it necessary to include in the initial part of its report a description of the fundamentals and methods of tree breeding. The proposal of the Committee covers all activities related to tree breeding, from research to final application. Publication of the proposed programme in English in one form or another was also considered necessary at the Committee meetings, since international cooperation in this field is important. However, the report consisted of 200 typed pages, and its translation as such was not regarded as appropriate. The Committee commissioned Dr. KOSKI to prepare an abbreviation of the programme. This text has been compiled from the report by condensing its language and leaving out explanations intended for non-experts. In this connexion the original report was modified by reducing its 14 chapters to only 8. The measures proposed by the Committee are contained in chapters 4–7 of this abbreviated report. The extent to which the proposed work is actually carried out depends primarily on the annual allocation of funds by the Finnish State budget for the purpose.

The text was checked by Prof. MAX. HAGMAN and Prof. YRJÖ VUOKILA. The Finnish original was translated into English by Mrs. HILKKA KONTIOPÄÄ, M.A. (Helsinki) and the translation was edited by Mr. ASHLEY SELBY, B.Sc.

1. THE STATUS OF TREE BREEDING IN 1975

Tree breeding in Finland began as a separate sector of forestry in 1947, although extensive trials related to tree breeding had been initiated within forestry research much earlier. The most important of these were the series of provenance trials and cultures of exotic tree species established in the 1920s and 1930s. The Foundation for Forest Tree Breeding, established in 1947, was commissioned to make tree breeding well-known and to start practical tree breeding in Finland. Its earliest steps consisted of the selection of plus stands and plus trees from the forests in different parts of Finland, and improvement of the methods of seedling cultivation and grafting. The financing of tree breeding in the initial years was based on direct grants by the forestry organisations, such as the National Board of Forestry, central forestry boards, Forest Research Institute and forest industries, or on purchases of breeding material from the Foundation. Since 1958 the Foundation has received an allocation from the State budget for its work.

The shortage of funds kept tree breeding achievements at a modest level up to the early 1960s. The fundamental work, such as selection of seed collection stands and plus trees, and grafting for seed orchards was, however, well under way. The great expansion in silvicultural activities during the 1960s, aimed at increasing future timber production, included activities in tree breeding. Not only the Foundation for Forest Tree Breeding but also other forestry organisations began to contribute to tree breeding with their own labour inputs. The Forest Tree Seed Orchard Programme of 1963 presupposed the establishment, mainly by the National Board of Forestry, of seed orchards exceeding an area of 3,500 ha by the end of 1976. The Tree Breeding Development Programme for 1967–1976, the first combination of targets to cover the whole country, united the targets in other sectors of tree breeding. The financing of these mutually supplementary programmes was based exclusively on budgetary allocations, and its implementation on systematical cooperation between the National Board of Forestry, Forest Research Institute, Foundation for Forest Tree Breeding and central forestry boards.

The long-term programmes have expanded and stabilized tree breeding in Finland. The conditions for education and research have also decisively improved. A department of plant

breeding has been established in connexion with the University of Helsinki, and a department for forest genetics in connexion with the Forest Research Institute. The tangible targets of the programmes have been achieved on many points although some have remained unachieved. By sectors, the following summaries can be given.

A sufficient amount of initial breeding material of the main tree species has been selected from natural forests in Finland. Selection abroad has been started only to a limited extent, but foreign material is available through international cooperation. Spruce and pine seed orchards have been established in accordance with an advanced timetable, and the total targets of the programmes will be achieved by the end of 1976. Studies of the flowering biology and annual cycle of forest trees have led to remarkable results. Collection of a uniquely extensive material for these investigations has been completed. Several scientific papers have been published on the subject, and their results have already been applied to practical tree breeding. Very significant results have been reached in flower induction; the birch can be induced to flower and yield an abundant seed crop at the age of 2–3 years. The success has enabled considerable acceleration in birch breeding. The methods and techniques of controlled crossings have been improved to such an extent that the earlier difficulties in obtaining pollen and in pollination no longer restrict the number of controlled crossings made. However, unfavourable weather conditions may still produce failures in some years. Only about one-fifth of the planned total of 4,600 ha of field trials, mainly provenance and progeny trials, have actually been established. This striking deficit is largely due to the fact that less work could be done than was foreseen in the programme principally, because allocations of money were not granted as proposed. The main reductions were made in field trials. Furthermore, restrictions were caused by non-availability of suitable trial areas and even of trial material. The improvement of the characteristics of wood material has been delayed. Not until recent years were preliminary investigations started into variations in wood density. Resistance breeding has not begun in the planned form and extent. The work in this sector is limited to preliminary inventory of damage and to the establishment of a few field trials related to breeding.

As a result of the financial deficit referred to above, personnel are too few and the suggested building of breeding stations has not been fulfilled. Consequently, some of the proposed tasks have had to be postponed to a later date, and they had to be taken into account when the new ten-year programme was considered. Progeny testing the selected breeding material involves the greatest amount of work. Among the other postponed tasks, the improvement of the wood material and the improvement of disease resistance deserve a special mention.

Full benefit cannot be obtained from the breeding work and investment carried out to date unless tree breeding is continued according to the programme. The obvious need for utilization of all possible efforts to increase timber production is an incentive for substantial expansion of tree breeding. The preconditions for continued tree breeding are much better now, in many respects, than when the first ten-year programme was launched. Knowledge of the genetic structure of trees and forests, and of characteristics of breeding material has increased remarkably during the past ten years. Skilled personnel of various educational levels is now available. Breeding stations are in operation, and the biological breeding material in their neighbourhood has quantitatively increased. Furthermore, other materials (seed orchards, collections and field trials) are available), and owing to their concentrated location easily accessible.

2. FORMS OF WORK, TREE SPECIES AND CHARACTERISTICS TO BE IMPROVED

The close cooperation of research on forest genetics, genetic improvement of trees and production of genetically improved planting material was considered indispensable to the programme. Steady progress in breeding and utilisation of its results presuppose that all tree stages function effectively and stay in close interaction. Genetic research refers to the study of the general laws of nature governing breeding process, and it serves the planning of practical work. Genetic improvement is contained in the breeding proper, i.e. selection, testing of material and expansion of variation. Production of genetically improved planting material means the reproduction of improved and tested material for practical forest cultivation, of unchanged form, of guaranteed origin, and in sufficiently large quantities. In this connexion it must be decided, how far the field of breeding extends and where forest cultivation begins. In the present programme, tree breeding was understood to cover all the steps to improve the genetic level of the seed, whereas routine production of seed and seedlings was not counted as breeding.

Until recent years, the pine (*Pinus sylvestris*), spruce (*Picea abies*) and birch (*Betula verrucosa and B. pubescens)* have been the only species considered valuable to Finnish forestry. For this reason, pine, spruce and birch held pride of place in the seed orchard programme referred to earlier, and specified breeding programmes were drafted only for them. The other tree species were treated as one group. However, the number of tree species usable as industrial raw material has increased and is still on the increase owing to the heavy demand for roundwood. The tendency to grow timber on sites once considered unsuitable for afforestation, the demands made by environmental protection and pollution tolerance qualities, and the need to find more hardy tree species to grow in the timber line regions require an expansion of the number of tree species once considered for economic use. The programme not only outlines an intensification of pine, spruce and birch breeding but also presents separate breeding projects for alder (*Alnus*), aspen and poplar (*Populus*), willow (*Salix*), larch (*Larix*), and lodgepole pine (*Pinus contorta var. latifolia).* Certain other conifers and deciduous trees are discussed as one group.

Breeding is intended to improve all the properties of economic significance. The properties are grouped as related to rate of growth, resistance, technical stem quality and wood quality. The importance of the various groups of qualities can be very different depending on the tree species or the locality where the trees are grown.

The rate of growth is a highly appreciated quality. The predicted shortage of roundwood necessitates an increase in timber production, and the benefit from breeding can be most tangibly demonstrated in the rate of growth. The annual growth period is short in Finland, and consequently the average annual increment (3 cu.m./ha/year) is very modest compared with many southern countries engaged in intensive forestry. The short duration of the growing period cannot be compensated for by breeding, and the differences in growth rates will always remain. The wood material obtained as a result of the accelerated rate of growth must be of high quality in order to obtain the greatest financial returns from even relatively small quantitatively increases. Rapid growth also has other advantages related to forest cultivation. A fast-growing seedling rises above the ground vegetation in a short period time, out of reach of various harmful winter fungi. A fastgrowing stand yields timber both on thinning and final cutting within a shorter period of time than a slowly growing stand. The goal in breeding for improved incremental rates is to develop trees which in stand conditions produce the maximum dry weight of timber per unit area.

The stem quality of the commercially important tree species in Finland is, on average, good.

The objective of breeding is to ensure that the technical quality of timber produced in cultivated forests is a least as good as that of trees growing in natural forests. The technical quality is of great importance in pine and birch, since large quantities of them are used as raw material in the mechanical wood processing industry. For timber used as raw material in pulp industry, the technical quality of stem is not of the same importance for the final product, although a good stem form is obviously not disadvantageous; on the contrary, it is an advantage both in the forest growing phase and in timber harvesting.

The qualities of the wood material, such as density, fibre length and contents of various extractives affect the manufacturing process as well as the quality and quantity of the final product in chemical wood processing, and the strength qualities and external appearance in mechanical wood processing. Little attention has so far been devoted in Finnish forest tree breeding to the properties of the wood material. The quality of wood material is composed of numerous components, with very different effects in the various forms of wood utilization. Increased density of wood can, however, be considered one of the general aims of breeding regardless of the potential uses of the wood.

The adaptability of trees, and their resistance to pests and pathological agents are qualities which increase in importance as breeding advantaces and forest cultivation becomes more common. This aspect has been taken into account in Finland mainly by using local provenances in cultivation and always collecting the seed from several trees. From now on it is necessary to make sure that improvements in growth and quality characteristics do not take place at the expense of adaptability and resistance. Climatic adaptation is particularly important when yield is to be increased by geographical transfer, or in the norther marginal forest region. The target in resistance to disease and damage is not a complete resistance to a given agent but the restriction of injuries to only a few individuals, and the maintenance of an equilibrium.

When trees are bred for uses other than timber production, aspects other than those listed are involved. For example, it trees are to be used for environmental management and ornamental purposes, their tolerance to pollution of various kinds and their outward appearance play an important role. In special cases the ability to take root or to sprout can be the object of breeding, though not in the first instance.

None of the listed properties or groups of properties can be discussed in breeding as if they were separate and independent of others. If several properties are considered at the same time, this usually means that direct maximized breeding profit cannot be set as the target for any one property.

3. METHODS USED

The starting point in the choice of breeding methods is that consideration must be given to the population structure and genetic system of the tree species to be bred. The allogamy of the trees in the breeding programme and their reproduction almost exclusively through seed, as well as the very great effective population size aret typical characteristics. Forest tree breeding in Finland to date has mainly been an application of mass selection, which still plays a considerable part in breeding work. Simultaneously, and as its continuation, family selection can soon be used. There are also other methods. The possibilities contained in provenance transfers are extensively applied using both indigenous and foreign tree species. Hydrid breeding is applied both between and within species. The possibilities of mutation breeding will also be studied.

In mass selection, phenotypical selection in natural and cultivated forests will be continued to a small extent. Selection is used to eliminate chance defects or, for various reasons, to replace removals e.g. overmaturity.

Seed collection stands are being marked by selecting the best trees of thoroughly good stands as seed collection trees. Phenotypical plus trees are selected for the establishment of clonal seed orchards. The establishment of such seed orchards is continued using previously selected plus tree material.

With regard to breeding material obtained from foreign countries, often little can be done to accept that which is available through international exchange. The possibilities of applying the selection principle in the collection of material are less good than for indigenous material. For foreign material, individual selection can usually only be carried out in the first generation that has grown in Finland.

Hybrid breeding is largely at an experimental stage. Only the so-called hybrid aspen (*Populus tremula x P. tremuloides*) has been used for forest cultivation, and even then its proportion of the total cultivated area is very small.

Provenance hybrids, as well as interspecific hybrids, are produced in several genera. The value of the hybrids is to be tested in the field.

In mutation breeding, the possibilities of polyploidy are studied, primarily in the genera *Betulus* and *Populus*. Vegetative propagation and possible cultivation of triploid individuals found in nature are studied. The possibilities of applying induced polyploidy are also being investigated.

The genotypes selected in the course of breeding are assembled for use and storage in the neighbourhood of the breeding stations. Natural genetic resources are also kept for future need. The storage is based on living gene reserves, i.e. various tree banks or collections and gene reserve forests. Vegetative progenies of individuals registered as basic breeding material are gathered for clone collections. Material of particular interest for continued breeding is gathered, in the form of seedlings, for progeny collections. Exceptional forms, extreme types and, for the sake of comparison, normal genotypes of various tree species are planted as grafts in special form collections. Particular gene reserve forests are maintained for preservation of the gene resources and population structure of natural forests. Gene reserve forests consist of forest areas large and continuous enough to keep the intra-stand pollination adequate regardless of the character of the surrounding forest and to ensure the maintenance of a normal age class distribution within these forests.

Controlled crossings are still necessary between mature trees e.g. for population-genetic studies. However, the majority of the crossings can be carried out in seed orchards or collections where the work is technically easier. The crossing work can also be situated in specialized breeding orchards and greenhouses. In these special conditions the trees can be induced to flower at an early age and while still small in size, and also at seasons different from those in nature.

The biggest item of work in the whole programme is the testing of seed orchard clones by progeny tests. By these tests, 10 % of the clones are separated by screening for establishment of elite seed orchards. The tests are carried out in different parts of the country so that the climatic conditions correspond to those of the future areas of cultivation. The testing of breeding material is based mainly on progeny tests. In field trials progeny tests occur in conditions corresponding to normal forest cultivation. The experimental designs are different in field trials and depend on the problem studied. Tree species, provenance, growth and yield tests use large plot sizes and a small number of blocks, whereas progeny tests require a small plot size (9—25 trees) and several blocks.

In the field tests established to date, the initial development of seedlings has often been slow compared with the needs of breeding. The microvariation in the soil of the test area results in a wide error variance and makes verification of genetic differences difficult. To reduce these two adverse factors, progeny tests are largely carried out in particular test orchards. In order to reduce the variation in environmental factors, these orchards are placed on carefully selected land areas on uniform quality. The plants in the orchards are spaced closer than normal and much material can thus be placed on a small area. By effective management the development of the trial material is accelerated compared with that of ordinary field trials. Results leading to practical steps are estimated to be obtainable from test orchards only when the mean height of the seedlings exceeds 2 metres. Before final conclusions are drawn, the results obtained from test orchards are compared with those obtained from field trials of earlier origin. A pre-selection

in testing is represented by short-term progeny tests in the nursery. Methods of indirect selection are also being promoted in connexion with early testing at test orchards and normal nurseries. Such methods utilize the growth rhythm or chemical properties of the seedlings to forecast their development in maturity.

In these early years, the practical application of breeding results still rest mainly on the selected seed collection stands. The seed output of seed collection forests is being increased using suitable silvicultural measures and thinnings. The seed collection stands can probably be gradually abandoned during the 1980s as the established seed orchards reach productive age. A proper transfer of provenances of Norway spruce (*Picea abies*) results in significant increase of productivity, at least in South Finland. A practical step is to obtain seed from the Baltic region for South Finland.

Short-term main obligations in seed procurement include the all-round acceleration of the development of the established seed orchards as well as increasing and security their seed production. The most feasible method of vegetative reproduction involved in the production of genetically improved material is by the rooting of cuttings. For spruce, a technical preparedness to produce cuttings has been reached and can be applied in practice as soon as tested clones are available. With the other tree species, reproduction by cutting is still being developed.

4. RESEARCH INTO FOREST TREE BREEDING

Sufficiently extensive forest-genetic research in Finland could not precede practical forest tree breeding. Research, therefore, must largely investigate the effects of the work done to date and simultaneously create a foundation for more advanced methods of breeding. The importance of research is enhanced by the fact that the effects of tree breeding are multiplied over extensive surfaces and will persist for many decennia. Foreign forest-genetic research is closely observed, but all necessary information is not available. Studies related directly to practice can only be carried out in our own conditions and with the tree species growing here. The research requirements of tree breeding are divided into eight groups, and genetic registration accompanies all research.

1. The research methods of *physiological genetics* are largely based on various laboratory, growth chamber and greenhouse tests. A large number of controlled crossings and progeny tests is necessary for heredity studies. Investigations cover the range of genetic variation in fundamental vital functions, such as photosynthesis, respiration and nutrient intake, as well as the functioning of the genes regulating the differentiation of cells and onset of flowering with advancing age and increasing size of each tree individual, and the way in which the regulation of growth and flowering is linked together at the gene level.

2. Research into *ecological genetics* of forest trees measures the interactions of different site factors and different provenances in natural and controlled conditions, greenhouses and growth chambers. The ways in which the annual rhythm of trees is inherited, and the range of the variation between the parts of the annual cycle are studied. The chances of composing, by crossing, a breeding product capable of adaptation to the timberline regions or other conditions are also studied. Furthermore, the studies cover the genetic variation in adaptability to various soils and the capacity to withstand pollution from soil and air.

3. *Population-genetic* research is pursued to create reliable breeding models for different tree species. Studies serving this purpose comprise the provenance studies, the studies of crossing systems and genetic load, and the measurement of the range of hereditary variation in the characteristics to be improved. These studies require investigations of flowering and pollen dissemination, controlled crossing series, and progeny tests in greenhouses and in the field.

4. Research into *methods of selection* aims at developing selection indices and methods of

indirect selection. Thus, the breeding goals now include the simultaneous improvement of several properties, including resistance and adaptation, and the properties of the wood material. The importance of indirect selection lies in the fact that breeding can be significantly accelerated provided the early tests can be made reliable.

5. *Seed orchard research* studies the problems related to seed orchard established through grafts, the seed to be collected from them, and the raising of the genetic level of the seed. The methods are studied by which the initial development of the grafts can be accelerated so that flowering and seed production begin as soon as possible after establishment, and pollination conditions at each phase of development of the seed orchard are examined. The tending and thinning of seed orchards are studied in order to make their seed crops as high as possible both as regards genetic value and quantity. The principles related to seed orchards based on recurrent selection are studied.

6. *Hybrid breeding research* investigates not only how controlled crossings can be carried out within and between tree species, but also how opportunities of expanding hereditary variation in the breeding material can be found. The methods of collecting and storing pollen, the methods of isolation and pollination, and the mechanisms of incompatibility are studied in order to make progress in this sector. The possibilities of breeding by heterosis and combination are investigated with the aid of progenies produced by intra-species provenance crossings and inter-species crossings.

7. *Mutation breeding research* is mainly engaged in the possibilities of polyploidy. The results will not be able to be applied in practice until well into the future, but combination of polyploidy with species crossing has displayed certain possibilities for development in the genera *Betula and Populus*. The polyploid forms of pure species, such as triploid individuals found in nature, are also tested and their vegetative reproduction by means of cuttings or root suckers is developed.

8. *Resistance breeding studies* try to find out how far the improvement of economically important properties can be continued in forest tree breeding without changing the equilibrium between forests and various pests and diseases by man. Also, the chances of increasing the resistance of bred products to the worst pathogenic and decay agents are investigated. Hereditary variation in virulence and in the resistance of trees is studied, especially with a view to whether the results of breeding are more exposed to damage than wild trees. The methods of indirect selection in resistance improvement and the ecological balance between trees and harmful agents are studied.

Genetic registration attempts to record for present and future times, the origin of each cultivated stand or breeding material. The Finnish forests have, to date, been almost exclusively naturally grown and where cultivation has taken place it has been based mainly on local seed. The computer register of the new forest cultivations will contain an origin code by which the cultivation material can be traced. The Forest Research Institute has already kept an up-to-date register of the breeding material, such as plus trees, seed cultures, progeny tests and material imported from abroad in different forms.

5. BREEDING PROGRAMMES BY GENERA OF TREES

The proposed targets of genetic tree breeding between 1976 and 1985 are presented in the form of breeding programmes by genera of trees. Classification based on genera was considered more meaningful than one based on individual tasks, since the breeding of different genera makes up sharply defined entities, whereas the character and performance of the tasks vary from one genus to the next. The given targets apply mainly to practical breeding work, that is, the application phase of tree improvement. The borderline between research and applied breeding is, however, diffuse. Hence the following targets also contain

research, e.g. as regards obtaining of material and crossing. The targets for the testing of breeding material are also taken to cover the bulk of the trial cultivation involved in research. The development of breeding techniques is in many respects much like research. Numerical targets, or targets measurable in terms of surface area, are almost impossible to define, for this reason only the most important needs of development are considered for breeding techniques. The amount of work required in the breeding of tree species between 1976 and 1985 is assembled in Table 1. The figures include the continuation of work started before the year 1976, and also the field work resulting from the establishment of the research programme. A short description of the role and breeding of each tree species is given to supplement the numerical data.

Scots pine *(Pinus sylvestris)*

The pine has lately amounted to about 70 % of the forest cultivation area in Finland, i.e. approximately 100 000 ha per year. It is the most reliable tree species alternative throughout Finland, considering the target of cultivation is to grow saw timber or to produce long-fibre pulpwood on medium good and barren sites. On the basis of the mean fertility of Finnish forest soils and the recent sales conditions for pine it seems evident that pine will remain one of the principal tree species of Finnish forestry. Most of the genetic tree improvement in Finland during a quarter of a century has consisted of pine breeding. 7 000 plus trees have been selected to serve as basic material for breeding. A large number of seed orchards have been established from them within the seed culture programme. The set target of 3 200 ha will be achieved by the end of 1976. Within the next few years nursery seed can be obtained from the seed orchards, and by the late 1980s for direct sowing also.

During the period 1976–85 the emphasis in pine breeding will lie on further improvement of the seed orchards. For this purpose, the breeding values of phenotypical plus trees will be tested by progeny tests. From about 1985 onwards, selected seed orchards of tested clones can be founded in the southern half of the country on the basis of these results. The elite seed orchards, on average, are expected to yield a genetic gain of a 20–30 % increment increase compared with unselected material. In order to secure an even greater genetic gain, preparations are made for establishment of second-generation seed orchards and for application of hybrid breeding. The methods of pine improvement are based exclusively on sexual reproduction. A procedure based on breeding by selection and on extensive seed orchard will predominate during the period covered by the programme.

The principal target in pine improvement is to increase the yield of wood. The immediate target is to develop a material which grows within the shortest period possible to meet the size and quality requirements of a timber tree. Phenotypical selection has already improved the originally good stem form of pine, and in the future resources can therefore be focused on increasing the increment. In the growing of saw timber, the maintenance and improvement of quality must be given attention in all phases of breeding. Not only the external qualities of stem but also the quality of the wood must be considered. Investigations into the inheritance of the wood characteristics will be continued, and density will be determined at least for trees being considered as elite trees. Also investigated is, how density and volume increment are correlated with a view to maximum possible dry matter yield. In the north of the country, maintenance and improvement of climatic resistance ranks at least as high as increment increase among the breeding targets. An important tasks of pine improvement is to create material reliable for cultivation in the timber line region of North Finland. The target of resistance breeding is to inhibit the common and severe fungal diseases (*Phacidium infestans, Scleroderris Lagerbergii, Melampsora pinitorqua, Fomes annosus*).

The spruce *(Picea abies)*.

Together with pine, the spruce forms the bulk of the raw material basis of the Finnish forest industry. Because of its long fibre, spruce is the tree species best suited for paper production, but is also extensively used in sawmills and plywood factories, and in other sectors of wood processing industry. During the 1970s, the area of spruce planting has been 20 000–40 000 ha annually, i.e. around

Table 1. Tabulation of the targets of the tree breeding programme 1976-85

Tree species or genus	Obtaining of breeding material				Maintenance of breeding material				Crossing	Testing			
	Stand selection	Individual selection from natural and cultivated forests	Recurrent selection of breeding material	Obtaining of foreign material	Establishment of arboreta		Management of tree collections 1)	Reservation of gene reserve forests		Establishement of tree species and provenance trials 2)		Establishment of progeny tests	
	1	2	3	4	5	6	7	8	9	10	11	12	13
		clones		batches	clones or batches				total	trial batches	field trials	trial batches	fie tri
	ha	no.	no.	no.	no.	ha	ha	ha	no.	no.	ha	no.	ha
Pine	300	300	7000	1000	2000 kl 4000 e	75	145	1000	3500	1000	350	8500	300
Spruce	200	300	13000	1000	10000 kl 4500 e	105	135	1000	6500	500	100	5000	140
Birch	30	300	2000	400	2000 kl 2500 e	40	45	500	4000	150	30	4300	145
Aspen	-	200	800	300	800 kl 600 e	20	35	100	1000	100	20	700	45
Poplar	-	100	400	300	700 kl 200 e	15	15	-	500	100	10	300	15
Alder	10	500	800	300	1000 kl 800 e	15	20	100	1200	100	15	1500	40
Willow	-	500	750	500	1200 kl 500 e	10	10	-	1000	200	5	600	15
Larch	20	100	1500	200	1200 kl 700 e	20	40	-	1800	100	20	1300	80
Pinus contorta	20	100	500	400	300 kl 300 e	10	10	-	500	250	30	600	30
Other conifers	5	300	150	300	400 kl 200 e	10	10	-	200	250	30	200	20
Other deciduous trees	15	300	400	300	800 kl 700 e	20	25	100	500	250	10	500	20
Total	600	3000	27300	5000	20400 kl 15000 e	340	490	2800	20700	3000	620	23500	850

1) The area to be managed includes the arboreta, trials or seed cultures established in 1967-75 and those to be established in 1976-85

2) All field trials include, in the initial phases, the growing of test seedlings, totalling c. 38.000 batches in 1976-85

3) Tests to compare the results of breeding, growth and yield tests, short-rotation culture tests and sample plots

f b r e e d i n g m a t e r i a l

Establishment of clone tests		Establishment of testing orchards	Other trial cultivations 3)	Maintenance of field trials 1)	Measurement of field trials and analysis of the results	Early tests in nursery + measurement and analysis		Testing of other breeding material	Breeding nursery jobs: Breeding nurseries under plastic	Breeding nurseries on open ground	Management of breeding nurseries, and breeding nursery jobs	Application of breeding results to practice: Preparation of seed collection stands	Establishment of seed cultures under plastic	Establishment of seed cultures on open ground	Improving management of seed cultures 1)
14	15	16	17	18	19	20	21	22	23	24	25-26	27	28	29	30
clones	field trials					trial batches	surface area	trial batches							
no.	ha	ha	ha	ha	ha	no.	ha/yr	no.	ha	ha	ha				
-	-	80	230	1520	1910	10000	4.0	3000	0.2	15	15	5000	-	25	3165
5000	35	90	200	850	960	10000	5.0	3000	1.2	10	11	1300	1.0	15	290
100	5	30	100	470	900	4000	2.6	1000	1.2	9	10	135	1.1	-	15
300	15	5	50	160	330	1000	1.0	1000	0.5	4	5	-	0.1	-	-
400	20	-	30	75	150	700	0.7	600	0.3	2	2	-	-	-	-
300	15	10	50	145	290	1000	1.0	500	0.5	5	6	20	0.3	5	8
300	10	-	20	50	150	1200	0.8	500	0.3	3	3	-	-	-	-
300	15	10	40	190	210	1000	0.8	400	1.0	5	6	10	1.0	15	82
100	5	5	40	140	170	700	0.4	1000	0.1	5	5	10	-	15	15
100	5	-	20	75	75	700	0.4	-	-	-	-	5	-	5	5
200	5	-	20	55	55	500	0.3	-	0.2	2	2	20	-	20	20
7100	130	230	800	3730	5200	30800	17.0	11000	5.5	60	65	6500	3.5	100	3600

a quarter of the total forest cultivation area in Finland. Spruce grows best in the southern parts of the country and on better-than-average soils. Therefore the relative importance of cultivated spruce stands in wood production exceeds their proportion of the cultivated forest area. Improvement of spruce has, to date, been centered on breeding by selection as with pine. Over 1 000 ha of seed collection stands have been selected. The total number of plus trees selected is c. 2 000 and 3 00 ha of seed orchards have been established from them. Breeding based on seed orchards has proved more difficult than expected, due to the slow initial development of grafts and the weak flowering in youth. On the other hand, provenance selection has yielded good results with spruce, and considerable increment increases can be reached in forest cultivation by means of provenence transfers.

Spruce breeding is divided into two main lines: material can be produced either through seeds or by the vegetative reproduction method. For the next few years, provenance transfers will be the most effective mean of increasing the yield of cultivated spruce stands. Seed orchard methods are being developed, since valuable results can also be expected in this line. A heavy seed crop affords possibilities for breeding by crossing. The chances of reproduction by cuttings seems very promising with spruce, and hence the development of high-productive multiclone varieties seems possible.

The main target in spruce breeding is to increase the yield of wood. Studies at home and abroad justify the assumption that, mainly by the use of provenance selection, a profit of over 20 % is within reach in the South Finnish cultivated material. The end results produced by other breeding methods will obviously yield at least the same genetic gain, but it may take many years before they can be commercially applied. With a view to growing saw timber and to harvesting techniques, care must be taken that the stem form does not deteriorate and the number and thickness of branches increase at the expense of increased wood material output. As far as possible, the quality of the wood will be given attention in breeding work. Especially the role of the density of wood will be investigated and the findings applied to practical breeding. Resistance characteristics play a leading role in spruce breeding, for the use of foreign provenances and clone cultivation may occasion great changes in the equilibrium between the trees and natural pests. Resistance to climate must be particularly borne in mind in connexion with provenance selection and crossing. The chances of breeding for resistance to the worst agents of decay (*Fomes annosus, Chrysomyxa ledi)* will be investigated. To maintain field resistance it is important to preserve in all phases of breeding a sufficient amount of genetic individual variation. The multiclone varieties developed for reproduction by cuttings must be composed of several tens of genotypes to make them safe in cultivation. Breeding of any special forms of spruce, and trees intended for environmental managements, is based on selection and on crossing combining different types of varieties.

The birch *(Betula verrucosa, B, pubescens)*

The cultivation of birch became common in Finland in the 1960s. In recent years the cultivation area has been c. 7 000–8 000 ha, i.e. about 5 % of the annual forest cultivation area. The diminution of birch resources and the raw material shortage of birch using industry favour an increase in cultivation. Birch is used by board, pulp and furniture industries and for the manufacture of certain other products as well.

Practically all birch breeding in Finland has been based on the weeping birch (*B. verrucosa*). Around 1 500 plus trees have been selected from natural forests to serve as basic material for breeding. Breeding is based on reproduction from seed and cultivation of seedlings. Breeding has two targets: completion of the testing of the selected plus trees, and testing of the materials of the second and later generations following breeding. New breeding populations and seed cultures are essembled on the basis of the test results. As for the practical application of the results of birch breeding, it seems evident that all seed required for cultivation can be produced in covered seed orchards that have undergone progeny tests. Birch improvement has, to date, been based almost exclusively on material selected from Finland. In the beginning of the present ten-year period, provenance trials of birch form an important role in the efforts to achieve better cultivation material. Selection is

associated with extensive experiments with species and provenance crossings.

The target in the breeding of weeping birch is to develop cultivation material which reaches the timber tree size within a short time and meets the quality requirements of good saw timber or veneer logs. Improvement of the external quality of stem form affects the standard and output of the final product, especially in the plywood industry. The role of quality is therefore more important in birch breeding than in the breeding of conifers. The targets for resistance breeding have not been specified, but climatic factor, plant pathology and pests are given attention as limiting factors in the efforts to improve the growth and quality characteristics of birch. The profuse morphological variation of birch stem affords good starting points for the development of ornamental forms and environmental management trees.

The aspen *(Populus tremula)*

The aspen grows naturally throughout Finland but represents only a minor part of the timber resources of the forests. Its universally known industrial use is for the manufacture of matches, but in actual fact 90 % of the aspen used industrially goes as admixture especially to the mechanical but also chemical wood processing industry. It is getting difficult to obtain good-quality aspen required for match production, a reason why the cultivation of aspen should become more general. The annual cultivation areas in recent years have been under 1 000 ha. Aspen has been bred in Finland, by crossing the species *Populus tremula* x *P. tremuloides,* since the early 1950s. Some of the ten combinations have exceeded the growth rate of the indigenous aspen used for comparisons by up to 2–3 times. All cultivated stands established in recent years consists solely of the hybrid aspen. Its widespread cultivation has been restricted by the susceptibility of the hybrid aspen to many diseases and pests. By breeding and correct management the aspen can be made safer in cultivation.

Also in the future the cultivation of aspen will be based on the use of seedlings. The most important line of breeding to further improve the hybrid aspen, e.g. by back-crosses. Significant results can probably be reached within the *Populus tremula* species by making use of polyploids found in nature or produced artificially, and by geographical transfers. The most important breeding target for aspen is a large wood crop. The aspen is well suited for pulpwood production within a short rotation period on soils rich in nutrients. The external stem quality and the properites of the wood material play a role when aspen is used as raw material for match manufacture. Breeding for climatic adaptation and resistance to decay is particularly important with aspen. Development of vegetative reproduction techniques will be important especially if polyploidy yields favourable results in the breeding of aspen. In the practical application of the results, seed production aims at permanent seed cultures under plastic.

The poplar *(Populus spp.)*

No poplar species grows naturally in Finland but many trees of various species, or species hybrids have grown to considerable height here. Poplar has to date been planted only for environmental and ornamental purposes. It seems possible to develop, by breeding, such poplar varieties as can withstand the Finnish climate, not only for environmental uses but also for timber production. Breeding should be based on vegetative reproduction of individuals that have grown well in Finland, and on trials with new crosses of species and provenances. The targets of poplar breeding are much the same as those of aspen breeding. Fast-growing varieties could be used to produce pulpwood within a short rotation period, also good-quality trees could be used as raw material for match industry and, further, for shelter plantations and ornamental purposes.

The alder *(Alnus glutinosa and A. incana)*

The alder has little economical importance in Finnish forestry. This is due to the low proportion of alder in the growing stock and to the fact that alder is seldom capable of growing to be a large, good-quality tree. On suitable sites alder is a fastgrowing species, and thanks to its nitrogen-binding capacity it has a soil-improving effects. Of the alder species growing in Finland, *Alnus glutinosa* is

the more valuable economically, because it reaches a larger size and usually grows a stem. For the purposes of breeding, a few good stands of both species have been selected as seed collection stands, and a few tens of plus trees have also been selected. Increasing the rate of growth is considered an important target for breeding because the alder grown within a short rotation period can probably be used to produce pulpwood, assuming a whole-tree method of harvesting is available. A good stem quality and the characteristics of the wood material are also of importance when alder is used for special purposes by sawmill industry.

The willow *(Salix spp.)*

Several tens of *Salix* species grow naturally in Finland, and several foreign species and crossings of species are cultivated. To date, the willow has been of no significance in forestry. However, it is possible that pulp production within a short rotation, and whole-tree harvesting may bring the willow into industrial use. The target of breeding is to create varieties with rapid growth and a good dry matter yield. The techniques of breeding need to be developed in many respects since the willow is a new breeding object. The application of the breeding results to practice will be based on vegetative reproduction and clone cultivation.

The larch *(Larix spp.)*

Most of the dozen or so *Larix* species grow in Finland if cultivated, although none belong to the natural vegetation. The Siberian larch (*Larix sibirica Ledeb.)* is particularly suitable and thrives throughout most of Finland. The larch, in cultivation tests, has proved to grow very fast compared with pine and spruce, and the wood material it yields is very valuable. The small wood volumes available have reduced its potential industrial uses, but the situation will change if larch growing increases. There are numerous cultivated larch stands in Finland, many of them grow fast and are of very good quality. Over 300 plus trees have so far been selected as breeding material and uses to establish some 40 ha of seed orchards. The main aim of breeding is to increase the wood material yield. The external quality of the stem of larch varies within a wide range. Efforts are made to keep the quality as high as that of the so-called Raivola variety of the Siberian larch. With this provenance, the adaptation to climate and resistance to diseases and decay are quite good. In the phase when the rate of growth is to be increased by species and provenance crossings, it will be necessary to give attention to adaptation as a breeding goal.

The lodgepole pine *(Pinus contorta var. latifolia)*

The North-American lodgepole pine has proved one of the most valuable foreign tree species in the Nordic countries. On certain medium-good sites it produces, within a rotation period of c. 50 years, considerably more wood than the pine or spruce. Numerous stands of lodgepole pine, based on several provenances, were established in different parts of Finland in the early 20th Century. On the basis of these experiments, the provenances suited to this country are relatively well known. 200 plus trees have been selected from the best stands, and a seed orchard has been established from their grafts. The breeding of the lodgepole pine is based on the application of breeding by selection. New material for continued provenance and individual selection is obtained from North America. Seed collection stands and plus trees are selected from the material growing in Finland. Seed orchards will be founded and the testing of the breeding value of the plus trees started. Not only breeding by selection but also a potential breeding by crossing will be tested. The main target of breeding is to increase the yield of wood material. Improvement of the external quality of the stem is necessary for the lodgepole pine because originally it is much poorer than that of the ordinary pine. However, the quality requirements are not very strict because the lodgepole pine is used as raw material for pulp industry. Adaptation to the climate and resistance to damage are taken into account when provenance is selected.

Other conifers

The most important among the other conifers is the North-American Douglas fir (*Pseudo-*

tsuga menziesii). Some of its provenances, on fertile sites in South Finland, have produced wood more rapidly than the domestic spruce. The cultivated stands growing in Finland provide a good starting point for the breeding of the Douglas fir by selection. As an object of breeding by crossing and graft reproduction the Douglas fir is, technically speaking, similar to the spruce.

The other tree species in this category mainly have environmental uses. At least firs *(Abies)* are worth testing from the point of view of wood production. The numerous trial cultures of foreign conifers growing in Finland, as a result of over 50 years of experiments, afford valuable information and material for breeding.

The primary purpose of breeding is to ensure the availability of adapted cultivation material. This can be achieved by obtaining seed from thriving stands growing in Finland. Otherwise and breeding of the conifers of this category is limited to small-scale procurement of material, individual selection, reproduction and trial cultures. Crossing trials will be carried out with some species and the possibliities of vegetative reproduction will be tested, mainly applying findings obtained from abroad. Adaptation to climate and resistance to damage are the most important overall targets in the breeding of these trees. With Douglas fir, an additional target is to improve the rate of growth and the external quality of the stem in order to grow sawmill and plywood raw material. Most of the species are used for ornamental and environmental management purposes, and in genetic tree breeding it is necessary to consider the form growth of the crown, the colour of the needles and the resistance to pollution.

Other deciduous trees

This group includes the tree species growing naturally in Finland and not mentioned previously: oak *(Quercus robus),* ash *(Fraxinus excelsior),* elm *(Ulmus glabra, U. leavis),* maple *(Acer platanoides)* linden *(Tilia cordata),* rowan *(Sorbus aucuparia)* and some foreign deciduous tree species thriving in Finland. Most of these species grow naturally in the South of Finalnd and are relatively uncommon. Various species have been cultivated annually to some extent, mainly for purposes of environmental management. The total number of seedlings planted annually has been only c. 100 000. Their general significance to forestry will probably remain small in Finland, although in special cases they play a role in wood production. The most important tasks of breeding is to ensure culture material that is capable of adaptation, and resistant. In practice this means that a lookout should be kept for the best stands and tree individuals in order that seed may be collected from them, and that small-area seed orchards are established. Climatic adaptation and resistance to damage are the properties not needing improvement. Good growth characteristics and aesthetic appearance are more important in this group than in any other group previously discussed, since these tree species will be used mainly for purposes of environmental management and as ornamentals.

6. THE LOCATION OF TREE BREEDING

The work targets necessitate that breeding goes on in different parts of Finland. The work done to date, above all the selection of basic material and establishment of seed orchards, has largely involved roaming through the forests throughout the country. In the ten-year period covered by the present programme the biggest and most important task consists of the progeny testing of the breeding material. The testing takes place within the relevant district of timber production. Experience obtained to date from field trials shows that the progeny testing must be strongly concentrated on a few entities, and that it must be put to practice much more intensively than is possible in normal field trials. A few permanent tree

breeding stations are required in different parts of the country for regional experimental research and for hybrid breeding etc. To date, a considerable proportion of breeding has been carried out on the four stations now in operation. These stations alone cannot assume responsibility for all breeding work within their district, and they require a field organisation and other sites for practical work. Nurseries and seed stations are examples of such breeding sites.

The need for tree breeding stations and their location are determined by production districts according to the breeding requirements, the climatic conditions in different parts of the country and the effectiveness with which the breeding measures can influence the forestry of the whole country. In principle, breeding work must be carried out where the results of the work are to be applied in practice. However, from the point of view of flowering and seed crop, it is justified to concentrate a part of the breeding work on the more favourable climatic region of South Finland. A considerable part of the tree breeding has already been carried out in South Finland, since the intensity of forestry and timber production, thanks to the climatic conditions, are best in that region. The breeding stations now in operation (Haapastensyrjä, Ruotsinkylä, Punkaharju and Kolari) agree reasonably well with regional requirements, although their local situation is not always the best possible. It is very regrettable that Central Finland, which does form a very important timber production district, now has no tree breeding station. The amount of work involved in achieving the set targets imply an expansion and diversification of the activity of the stations. It will be necessary to considerably develop the conditions of work of the existing stations and additionally to establish a special tree breeding station for Central Finland.

The Punkaharju Tree Breeding Station (Forest Research Institute) with the surrounding experimental area provides a good framework for genetic tree improvement and especially for genetic research. The experimental area with its tree species and provenance trials established as early as in the 1920s is unique in Finland. However, all the buildings are old and were originally designed for other purposes. It is necessary to construct a new station building at Punkaharju and also obtain several hundreds of hectares of land for establishment of trial cultures and collections. The Ruotsinkylä Tree Breeding Station (Forest Research Institute) is the oldest tree breeding station in Finland. The experimental area surrounding the station contains many valuable trial cultures concerned with tree species, provenances etc. However, the premises of the station are crowded and inconvenient. The experimental area also is subject to pressures and wear caused by the near-by city of Helsinki. It would be appropriate to replace the Ruotsinkylä station by a new one to serve the research and tree breeding needs of Southwest Finland. Ruotsinkylä could still remain in operation as a breeding work centre with reduced responsibilities. The Kolari Research Station (Forest Research Institute) is quite modern as regards buildings and equipment. In cooperation with the Kevo research station, which belongs to the University of Turku, and the Pakatti nursery of the National Board of Forestry, it is excellently suited to cater for the needs of the whole of North Finland and especially the timber line regions. The Haapastensyrjä Tree Breeding Centre (The Foundation for Forest Tree Breeding) has, in 15 years, developed into a diversified unit of breeding in the greenhouse and nursery phase. The station is well adapted for development of the breeding techniques and to serve an intensive development of breeding results and short-term testing. However, the facilities for expanding activity are limited in the present land area. The Röykkä nursery, at the disposal of the Foundation for Forest Tree Breeding, at a distance of 20 km from Haapastensyrjä, affords a chance of expanding the breeding work. The Patama Central Nursery (National Board of Forestry) at Saarijärvi is engaged in normal nursery production but has also produced the bulk of the seedling material for the field trials of forest tree breeding. Patama has a large modern extractory and seed storages, and for this reason there are plans that it will be made into a national seed centre in a not too distant future. It would be appropriate to establish a breeding station in Central Finland so that its operations can utilise the existing unit at Patama. The Oitti Seed Centre (Central Forestry Board Tapio) contributes to supplementing the network of the activity centres in South Finland.

7. DIVISION OF WORK

Finland has no separate organisation for genetic tree improvement with its own necessary resources and territorial coverage for tree breeding throughout the country. The establishment of a new organisation with the necessary resources is an unrealistic project for the time being. The only possibility remaining is that work is divided as best it can between several organisations, and that each organisation assumes responsibility for the work assigned to it. Tree breeding is composed of many varying duties each with different requirements. A precondition for the division of work is that each duty is assigned to the organisation whose resources and character are best suited to handle it.

In order that tree breeding in its entirety should advance correctly balanced and with cooperation between organisations, it is necessary to have an official and permanent body of coordination. The Committee suggests that the existing Forestry Seed and Seedling Council, appointed by the Ministry of Agriculture and Forestry, be commissioned with the coordination of genetic tree breeding. The executive organisations are the same as have taken part in tree breeding to date: the Forest Research Institute, National Board of Forestry, Foundation for Forest Tree Breeding, central and district forestry boards, and forest industry companies.

The Forest Research Institute is a State establishment engaged in research, but it has the facilities for long-term work in tree breeding. The Institute employs trained personnel required for the many specialized duties and in particular research workers specialized in tree breeding. Three tree breeding stations and sixteen experimental areas in different parts of the country provide a fairly good basis for research work.

The National Board of Forestry is a central government office responsible for forestry in Finland. The Board has under its direct administration approximately one-quarter of the forest area of the country, although most of it is situated in the North. A large proportion of the existing seed orchards and field trials in Finland is situated on land owned by the National Board of Forestry. The Board has a sufficient number of personnel suited for practical work but the tree breeding specialists are too few. The National Board of Forestry has work centres throughout the country but it has no tree breeding station.

The Foundation for Forest Tree Breeding is a foundation by Civil Law, with about one-third of its annual budget covered by a government allocation. Its operations comprise not only the genetic tree improvement but also seedling production. The Foundation employs a staff well acquainted with tree breeding at all levels, and the Foundation runs a tree breeding station suitable for intense breeding work.

The central and district forestry boards form an organization with a statutory position and are subsidised by the State. Their main obligation is the promotion and supervision of private forestry. The opportunities for the boards to take part in tree breeding are limited by the wide sphere of their duties in other sectors of forestry, and the small land areas they own. Trial cultivations illustrating the possibilities of tree breeding and its practical application are their main concern.

Tree breeding by forest industries aims at increasing the timber production in their own forests, which produce only about 10 % of the raw material used in Finland. The industries do not carry out tree breeding in its total extent, nor do they employ special personnel for the purpose. They are best suited to carry out practical tree breeding, e.g. trial cultivations, planned by other establishments.

It is not possible, in dividing the work of tree breeding, to arrive at a sharply defined list where separate areas of activity are ascribed to certain organisations. Many tasks contain several phases to be carried out in different places. Broadly speaking, the various groups of tasks are divided between the organisations in the following way:

Table 2. Distribution of the operational targets of the 1976-85 tree breeding programme on different organisations

Type of work	Total target	Operational targets of the organisations					The relative shares of the organisations, % of the total target or cost of work				
		Forest Research Institute	National Board of Forestry	Foundation for Forest Tree Breeding	Central and district forestry boards	Forest Industry	Forest Research Institute	National Board of Forestry	Found. for Forest Tree Breeding	Central and district forestry boards	Forest industry
GENETIC TREE BREEDING RESEARCH	-	-	-	-	-	-	100	*[1]	-	-	-
ACQUISITION OF BREEDING MATERIAL											
Selection of stands	600 ha	480 ha	60 ha	-	60 ha	-	80	10	-	10	-
Selection of individuals	3000 kpl	2400 kpl	300 kpl	-	300 kpl	-	80	10	-	10	-
Recurrent selection											
- in field trials	4300 kpl	4000 kpl	-	230 kpl	-	-	95	*	5	*	*
- in early tests	23000 kpl	4600 kpl	-	18400 kpl	-	-	20	-	80	-	-
Obtaining of foreign material	5000 er.[2)]	3500 er.	-	1500 er.	-	-	70	-	30	-	-
STORAGE OF BREEDING MATERIAL											
Establishment of collections (incl. reproduction of material)	340 ha	100 ha	170 ha	70 ha	-	-	30	50	20	-	-
Management of collections	490 ha	147 ha	181 ha	147 ha	15 ha	-	30	37	30	3	-
Earmarking of gene reserve forests	2800 ha	2800 ha	-	-	-	-	100	*	-	-	-

CROSSING	20700 er.	10300 er.	2100 er.	8300 er.	-	-	50	10	40	-	-
TESTING OF BREEDING MATERIAL											
Early testing (incl. planning, establishment, management, measurement, output of results)	30800 er.	6100 er.	-	24700 er.	-	-	20	*	80	-	-
Planning of the tests	2630 ha	2500 ha	-	130 ha	-	-	95	*	5	*	*
Establishing field trials (incl. the raising of test seedlings)	2400 ha	240 ha	1680 ha	120 ha	120 ha	240 ha	10	70	5	5	10
Establishing testing orchards (incl. the raising of test seedlings)	230 ha	45 ha	127 ha	35 ha	23 ha	-	20	55	15	10	-
Management of the tests	3730 ha	745 ha	2240 ha	185 ha	185 ha	375 ha	20	60	5	5	10
Measurements of the tests and output of results	5200 ha	4700 ha	-	500 ha	-	-	90	*	10	*	*
Testing by special methods	11000 er.	9900 er.	-	1100 er.	-	-	90	*	10	*	*
BREEDING NURSERY WORK (in plastic geenhouses)	5.5 ha	1.1 ha	-	4.4 ha	-	-	20	-	80	-	-
DEVELOPMENT OF BREEDING TECHNIQUES	-	-	-	-	-	-	20	*	80	-	-
APPLICATION OF BREEDING RESULTS TO PRACTICE											
Preparation of seed collection stands	6500 ha	2900 ha	1000 ha	-	2300 ha	300 ha	45	15	-	35	5
Establishment of seed cultures in plastic greenhouses	3.5 ha	-	0.7 ha	2.8 ha	-	-	-	20	80	-	-
Establishment of seed cultures in open ground	100 ha	-	80 ha	-	10 ha	10 ha	-	80	-	10	10
Management of seed cultures from breeding point of view	3600 ha	1440 ha	1800 ha	-	180 ha	180 ha	40	50	-	5	5

1) * = the job requires utilization of the organisation´s land resources

2) er. = batches (of progeny, seed, crossing combination etc.)

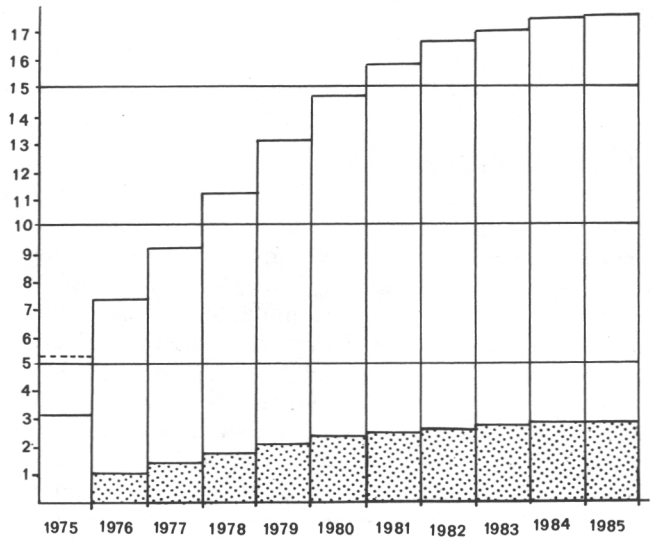
The Forest Research Institute takes care of tree breeding research, investigations into the fundamentals of tree breeding, the planning and supervision of the practical work, and the publishing of results. The National Board of Forestry is responsible for most of the long-term and extensive field work involved in tree breeding, and for application of the results of breeding to practice. The Foundation for Forest Tree Breeding takes care of the technical developments of tree breeding, and the creation and preliminary testing of the breeding results in its nurseries. The central and district forestry boards carry out a part of the field work, in the first place the establishment of trial cultures and, where applicable, take the responsibility of putting the results to practical use. Forest industry companies take part in field work and application of the results to practice, especially in work that involves foreign tree species and provenances.

The distribution of targets between the organisations is shown in greater detail in Table 2. The proposed research programme and the breeding programmes for the various tree species imply an expansion of almost all the forms of work. Furthermore, the intention is to intensify activities in order to obtain more rapid and more reliable results. Thus, manpower requirements will grow. The need for labour in the tree breeding work remains great compared with other tasks since the chances of mechanization, owing to the special nature of this work, are very small. The manpower increase can in no case be carried out all of a sudden because the necessary education and training takes time. In the years time approximately twice as many workers than now will be required. The estimated annual development of manpower representing different levels of education is shown in Table 3.

Education in tree breeding is at present only given at university level. Special training must be organized in the next few years for all staff by means of vocational courses.

Table 3. Labour input required to operate the 1976–85 tree breeding programme, by years of the programme period. The figures refer to man-years.

Group of personnel	Labour input, years of work										
	The 1975 situation	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
University trained	15	16	18	21	25	28	30	32	33	33	33
Technicians or similar	13	14	18	22	25	28	30	32	33	34	34
Work foremen or similar	28	27	29	33	38	43	46	49	51	52	52
Permanent assistants	50	50	72	97	120	140	160	175	186	190	193
Temporary assistants	70	65	70	80	80	75	73	70	65	59	56
Total	176	172	207	253	288	314	339	358	368	368	368



Expenditure on operation of genetic tree breeding, million mk.

Year	Tree breeding research	Applied tree breeding	Total
1976	1.1	6.2	7.3
1977	1.4	7.8	9.2
1978	1.8	9.4	11.2
1979	2.1	11.0	13.1
1980	2.4	12.3	14.7
1981	2.6	13.2	15.8
1982	2.7	14.0	16.7
1983	2.8	14.3	17.1
1984	2.9	14.5	17.4
1985	2.9	14.6	17.5
Total	22.7	117.3	140.0

Fig. 1. Expenditure on operation of genetic tree breeding in the period 1976–1985. The shaded areas represent the share of tree breeding research and the unshaded that of the applied breeding in the total expenditure.

Against 1975, column (a) refers to income received through the activities of the tree breeding development programme for 1967–1976, and column (b) to estimated income received through other activities.

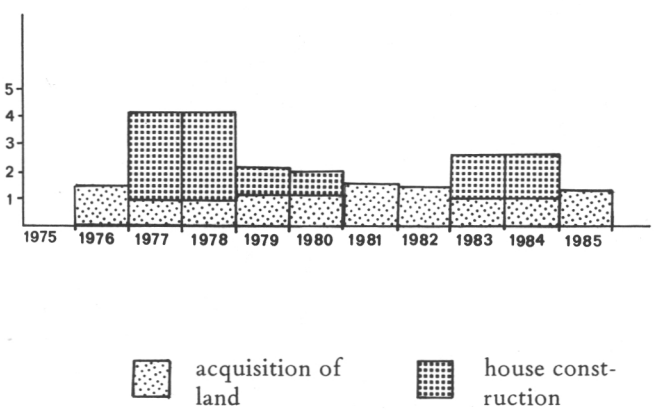


Fig. 2. Distribution on investment, 1976–1985

Investment, million mk

Year	Acquisition of land	Construction	Total
1976	1.4	–	1.4
1977	1.0	3.1	4.1
1978	1.0	3.1	4.1
1979	1.2	0.9	2.1
1980	1.2	0.8	2.0
1981	1.5	–	1.5
1982	1.4	–	1.4
1983	1.0	1.5	2.5
1984	1.0	1.5	2.5
1985	1.2	–	1.2
Total	11.9	10.9	22.8

8. COSTS AND PROFITABILITY

The cost of the implementation of the ten-year genetic tree improvement programme has been calculated at January 1975 values. The fundamental need for funds during the period 1976–85 rises from the need to continue certain tasks which have been started and must be continued. The continuation of the tasks already in progress means a financial requirement of 40 million mks. The bulk of the new work contained in the programme belongs to the genetic testing of the tree breeding material. The genetic testing of the phenotypically selected basis material for breeding requires 63 million mks. New needs have manifested themselves in forestry demanding an extension of the breeding sector. This extension means inclusion of numerous new tree species as well as a number of properties that need to be improved. The financial needs arising from the extension of the sector amounts to 36 million mks, of which 20 million mks is to cover the increase in the number of tree species and 16 million mks the increase in the number of properties to be improved. In addition to this total financial requirement of 140 million mks, another 23 million mks is required for purchase of land necessary for the implementation of the breeding programme and for the building of the breeding stations. The distribution of the costs of operation and investment of the different years is shown in Fig. 1.

The financial requirements arising from the implementation of the purposed programme totals 163 million mks in the course of ten years. As investment in qenetic tree breeding is a very long-term investment, the question arises whether it is profitable to use public funds for such purposes. A separate calculation, completed whilst the programme was being compiled, shows that investment of the amounts proposed on genetic tree breeding is profitable for tne national economy.

The appraisal is based on the assumption that tree breeding in a ten-year project increases the growth of forest cultivation material by an average of 10 %. During this period, a total of 100 million mks will be invested on raising the level of tree breeding. The interval from the beginning of tree breeding to the beginning of the use of improved material is assumed to be 20 years. After this period the breeding begins to yield a profit and the profit continues until the end of the rotation of the stands concerned. Assuming that the annual area of cultivation is not less than 150 000 ha and that the stumpage price of one cubic metre of roundwood is 41 mks, tree breeding produces a minimum internal rate of interest of 9 %. The improvement of quality through tree breeding obviously increases the profitability of breeding. The delay can perhaps be shortened by intensified work and improved methods, and as a result the internal rate of interest will be even better.

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