Forest Tree Breeding in Sweden and Other European Countries[1]

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The University of Wisconsin in cooperation with the Wisconsin Conservation Department in 1948 began a program of forest tree breeding research. The main objective of the work was to improve the genetic quality of the planting stock going into the state's reforestation program. In order to gain first hand information that would be helpful in the planning of a broad program of forest tree breeding research in Wisconsin, a six months trip was made by the author to Sweden and other European countries in early 1951 to study the methods and objectives of European tree breeders. The following portion of the general report of the trip discusses the various factors relative to the establishment and successful operation of a program of forest tree breeding in Sweden and also mentions briefly some of the work in progress at other stations in Europe.

THE TOTAL LAND AREA of Sweden is somewhat less than that of the combined states of Michigan, Wisconsin, and Minnesota. About 55 percent of Sweden's 173,359 square miles is forest land and of the forest area two-thirds is located in *Norrland* or northern Sweden. Each year over 150 million logs are floated down the streams to the mills on the coast. Here pulp, paper, and timber products are manufactured for use in Sweden and for her great export trade. During the period between the two world wars, the value of the Swedish forest export products ranged between 168 and 196 million dollars, or from one-third to one-half of the country's annual export. Sweden is the world's largest exporter of pulp, and is surpassed only by the United States and Canada in production. Over 20 percent of the wage earners in Sweden find employment in some phase of the forest industry.

The immense drain of Sweden's natural forest resources by its industries' desire to supply foreign export markets, plus the slow growth of the trees in the north, caused leaders in the industry to become alarmed. Surveys in central Norrland had indicated that cutting must be reduced about 60 percent in order to prevent serious depletion of the growing stock, especially of trees felled for timber. This cut-back in production would present serious economic and social problems. Something had to be done to increase rate of growth and volume production.

In the search for a solution to this problem, industrial leaders, foresters, and forest owners were impressed by the great strides made in the field of plant breeding in Sweden. An instance of this was the estimated 30 percent increase in yield of winter wheat through progressive plant breeding methods. Plant improvement research is estimated to have added an annual increment of 28 million dollars to the farm income. In terms of the relatively small area suitable for agriculture in Sweden (about nine percent), this represented a significant increase. Why then could not the same results be obtained through a well-planned program of forest tree breeding research? Prominent plant breeders such as Prof. Nilsson-Ehle, Prof. N. Sylven, Prof. A. Gustafsson and others agreed that it could be done. True, the results would not come as quickly as they had in plant breeding, but then this was probably another reason why the work should be started immediately. Further interest was aroused by some work Prof. Nilsson-Ehle had already begun with a naturally occurring giant aspen he had found in southern Sweden. In 1936, therefore, the Swedish Tree Breeding Association was organized. Since that time two additional forest tree breeding research groups have been started in Sweden: the Society for Practical Forest Improvement started in 1941, and the Genetics Department of the State Forest Research Institute started in 1947-48.

Organization

The Swedish Forest Tree Breeding Association is a private organization. An 11-man board of directors, elected at a general meeting, serve for a period of two years and handles the affairs of the association. An executive committee made up of several of the members of the board is ready at call to assist with the routine affairs of the association. The administrative office is located at the breeding station for southern Sweden, at Ekebo, Källstorp, Skåne. The association also operates two branch stations, one in central Sweden at Brunsberg, in Värmland, and one in northern Sweden at Sundmo, Inforsmo, in Ångermanland.

The Society for Practical Forest Improvement is another private organization. The membership includes a number of large forest industries located in central and northern Sweden. In addition several district forestry boards have joined the society. The policies of the society are handled by a board of directors chosen from its membership. Headquarters are at Uppsala in Uppland. Most of the practical and theoretical research is carried out using the lands and facilities of the membership. One center for grafting and other research is at Kratten in Göstrikland. The forestry board of Göteborg, Bohus County has also started work in central Bohuslän. In addition, most of the member companies have some work in progress on their own lands.

The State Forest Research Institute located at Experimentalfältet, near Stockholm, has a new Department of Forest Genetics. The head of the department, in collaboration with the director of the institute and other members of the departmental staff, handle its affairs. In addition to its facilities at Experi-

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mentalfältet, the Genetics Department has access to a large area nearby which is being used for field testing and for the development of an arboretum. The station also works very closely with the Brunsberg Station of the Swedish Tree Breeding Association, utilizing certain of their crossing stages and field trial areas.

Physical Facilities

All the main breeding stations in Sweden have good physical facilities. The offices and laboratories are adequate, and all stations have one or more greenhouses for use in the breeding work. Two of the institutes have drawn plans and have the space available for additional greenhouse units. Nurseries ranging in size from several acres to over 30 acres provide the necessary facilities for growing the experimental material. In addition there are areas available on institute-owned land, or on the lands of private companies and individuals, for use in laying out progeny tests and seed plantations and for establishing breeding arboretums.

The most modern tree breeding station in Sweden is the branch station of the Swedish Tree Breeding Association at Brunsberg. This station was completed and dedicated in 1950 at a cost of slightly over $100,000, the money for its construction coming from the Swedish Diet, the Fund for Forestry Research, and grants from some of the pulp, paper, and timber companies operating in central Sweden. This institute, in addition to its fine offices and laboratories, has a large lecture and assembly room, a seed drying and extracting room, seed storage facilities, a well-equipped photographic laboratory and darkroom, a fireproof room for storing records, several workshops and storage rooms, and even a large laundry room for use by the station employees.

A long corridor connects the ground floor level of the institute building with the headhouse and two greenhouses. A locker and shower room is provided for the workers. The large headhouse provides an abundance of well-lighted and well-ventilated working space. Plans call for the addition of several more greenhouse units to the headhouse. A small nursery is maintained at the institute, with the main nursery located nearby. Several houses are located close to the institute for use by the research staff.

A number of the stations on the continent also have praiseworthy facilities. The Belgian subsidiary of the Swedish Match Company located in Grammont, Belgium, has recently completed a new building, a large part of which is used for tree breeding research. Many of the office, laboratory, and greenhouse facilities in this new building are patterned after those used in the station at Brunsberg. Other institutes on the continent having good physical facilities include the Institute for Poplar Breeding at Casale Monferrato, Italy, the Forest Research Station for Applied Scientific Research at Wageningen, Holland, and the Danish Forest Tree Breeding Research Station, Humlabaek, Denmark. Construction is either in progress or being planned at most of the other stations. Several of the institutes in Germany, Austria, and Italy suffered serious damage to their buildings, equipment, and field trails during the war years, and although reconstruction has been seriously delayed, there is growing optimism that new facilities will soon be available.

Financial Support

The three main sources for the support of the forest tree breeding research in Sweden are: the Swedish Diet, the Fund for Forestry Research, and grants from various pulp, paper, and timber industries, as well as from private contributions. By an act of the Swedish Diet, the Fund for Forestry Research was established in 1946. By this act a fund of nearly 2½ million dollars was appropriated from so-called "price-equalization-fees" collected on forest export products. The annual interest of the fund is used for supporting forestry research and to some extent even the capital may be used. The capital value of the fund, however, must not go below $1,800,000.

Since the Swedish Forest Tree Breeding Association is the largest and oldest tree breeding organization in Sweden, a brief discussion of its budget for the year 1950 may be helpful in indicating the importance of tree breeding in the over-all picture of Swedish forestry research. The total cost for forestry research during 1950, exclusive of that conducted on the refining of timber, i.e. forest products research, is estimated to be in the vicinity of a million dollars. It should not be construed, however, that this amount be considered proportional to the significance of the forests to Sweden's economy. The 1950 budget for the Swedish Tree Breeding Association was around $100,000. This money was used to operate the head station at Ekebo, and in addition the branch stations at Brunsberg and Sundmo. Thirteen professional and semi-professional persons and from 30 to 60 part- and full-time laborers were employed. A brief summary of the society's budget follows:

Expenses

Staff salaries	$32,000
Workers' wages	33,000
Pension contributions	3,800
Office expense	4,000
Insurance	630
Taxes and insurance fees	360
Light and heat	6,270
Travel and auto maintenance	9,000
Freight	545
Consumable items, instruments, and tools	4,570
Field work	1,040
Expenses for real estate	4,070
Inventory expenses during 1950	900
Other expenses	5,815
	$106,000

Income

Membership fees	$ 580
Grants	
Diet	51,250
Fund for forestry research	30,000
Swedish Match Co.	3,750
South Swedish wood industries	1,250
Plant sales	7,270
Income from real estate	2,910
Interest	1,450
Miscellaneous	7,540
	$106,000

The Swedish Tradition in Plant Breeding

One of the outstanding agricultural plant breeding institutions in the world is maintained by the

Swedish Seed Association. The association was formed in 1886 in the parish of Svalöf in southern Sweden. A few years later a similar society was formed in central Sweden. The two organizations were amalgamated in 1894 to form the present organization.

The principal objective of the association is to breed better varieties of farm crops, and through the years scores of improved varieties have been produced and distributed.

The excellent past and current work in the field of farm crop breeding in Sweden can be attributed to the high caliber of the research staff that the association has always maintained. Such famous plant breeders as Prof. Nilsson-Ehle, Prof. Åkerman, Dr. Tedin, Prof. Gustafsson, Prof. Müntzing and others, have been engaged in breeding research at the institute. The association aims to be of the highest service to the farmers of Sweden, and has succeeeded by employing the best plant breeders available.

When the need for research on the genetic improvement of forest trees was recognized and plans were being made for the start of this work, the problem of finding qualified personnel to conduct the research became apparent. None of the professional foresters in Sweden had had t r a i n i n g in genetics, and few if any of the plant breeders were trained in forestry. Some of the strongest advocates for starting work in tree breeding were the agricultural plant breeders who realized from experience the gains that could be made. Since no qualified "forester" tree breeders were available, the men selected to take charge of the tree breeding work came from the ranks of the well qualified agricultural plant breeders. The significant results that have been obtained by Dr. Helge Johnsson, Dr. Enar Anderson, Prof. Åke Gustafsson, and others in Sweden or by Dr. C. Syrach-Larsen in Denmark and others, justifies the decision to employ qualified plant breeders to conduct the breeding work even though they were handicapped by a lack of training in forestry. The State Forestry Research Institute, in its desire to have the help of experienced geneticists in planning its program of forest tree breeding research, sought and obtained the services of Prof. Åke Gustafsson. Prof. Gustafsson, however, has not relinquished his duties as plant breeder with the Swedish Seed Association for whom he has worked many years. The excellent program of tree breeding research that Gustafsson has initiated for the State Forestry Research Institute is further evidence of the soundness of the policy of seeking the best plant breeders available for the job.

The attitude of leaders in the forest industry and forest officers is in general very favorable toward these men. One gains the impression, however, that they would like to see men enter the field of forest tree breeding in the future who have been trained in both genetics *and* forestry in order to insure a fuller consideration of the special problems in this field. This is especially important in view of the rather long-term character of forest tree breeding research, the slow growth of forest trees, and the urgent need for offsetting the ever increasing demands being placed upon the forests.

Tree Breeding Objectives

The three main objectives of the tree breeding research in Sweden, as well as in most of the other European countries are (1) to produce trees for reforestation and plantation culture that have improved wood qualities, a faster rate of growth, and which show increased volume production, (2) to introduce and test certain exotic species for possible use in the forest economy, and (3) to produce hybrid and polyploid material that will be of value in reforestation work.

In order to attain these goals, the general pattern of the research work has closely paralleled the methods successfully used in the breeding of farm crops. An inventory of the native forest trees is being carried out systematically as a prerequisite to obtaining the material necessary for evaluating the different climatic types within the country and to enable the workers to select from the natural populations individuals that show particularly desirable characteristics of form, growth, crown type, etc. Clones derived from the selected trees can then be used as parent stock for producing open-pollinated seed of improved quality. In addition, they can serve as foundation stock in producting control-pollinated hybrids.

Several thousand individual tree selections have been made. Scions from many of these trees have been propagated by grafting. The grafts are used for seed production, as parent stock for hybridization studies, as sources of scions for further propagation work, and for specialized studies such as flowering induction, etc.

Leaders in industry and other supporting agencies are joined with the tree breeder in Sweden in the realization that tree breeding research is a long-time undertaking. There are few if any shortcuts. They realize that as in many other phases of forestry, today's efforts and investments in tree breeding research will be posterity's gains. Depletion of present growing stock with little concern for replenishing it eventually would be disastrous to Sweden's forest economy. In planning for the future supply, the policy is generally accepted that the genetic quality of the stock must be a basic consideration.

The Swedish tree breeder is confident that by following the methods used by the agricultural plant breeder he will be in a position after a period of years to release to the state and private forest owners selections of forest tree stock of improved genetic quality. The first gains in tree breeding will not be as great percentage-wise as those obtained in the field of farm crop breeding. Even a 10- or 15-percent increase in volume and quality production, however, will mean a significant gain when the large acreages involved and the continually improving utilization methods are considered

Stage of Development of the Research Program

The work done in forest tree breeding research since the program was initiated in Sweden in 1936 is praiseworthy and encouraging.

The task of selecting from the indigenous forest species individual trees and stands showing better than the average performance for such characteristics as tree form, rate of growth, volume production, etc., and the inventorying of these trees and stands has been in progress for a number of years. Each stand is given a "plus," "normal," or "minus" rating. Only seed from normal and plus stands is collected for use in the reforestation work. Normal stands have improvement cuttings recommended for the removal of the poorer quality trees so they cannot serve as pollen parents. Individual tree selections are generally of the plus type only, although some selections have been made of normal and minus type trees for particular studies. On the basis of results from progeny tests, reclassification of certain of the selections will be made later, the distinctly superior individuals then being classified as "elite" trees. These trees will then form the basis for establishment of additional forest tree seed orchards. Many of the plus trees have been used in the field as parents for controlled pollinating work, and in addition scions have been collected from these trees for grafting. The grafts are used to establish breeding collections and as stock for potential seed orchards. At many of the stations in Sweden and at other stations on the continent grafted material now flowering is being used to great advantage in the controlled pollinating work (Fig. 1). Some stations, particularly the Danish Tree Breeding Station at Horsholm with Dr. C. Syrach-Larsen in charge, have been much interested in the program of "the estimation of the genotype" of individual forest trees by studying the performance of grafts made from selected trees. The station at Horsholm also has been working on the establishment of seed orchards for the production of forest tree seed of superior genetic quality.

Pine breeding in Sweden has been carried on mainly with the native species, Scotch pine (*Pinus sylvestris*). Crosses have been made between plus, normal, and minus trees in various combinations. Whenever possible these crosses have involved trees in the same general locality as well as trees from more distant regions. Scaffolds were erected around selected trees in a number of areas to facilitate the work until such time as the grafts from these trees begin to flower (Fig. 2). Some interspecific crosses are also being tried using pollen of lodgepole pine (*P. contorta var. latifolia*) of British Columbia origin. Open-pollinated seed of lodgepole pine from various areas in British Columbia has also been introduced to test this species for possible use in Sweden's reforestation program.

Fig. 2.—A crossing stage or scaffold erected around a "plus-tree" selection of *Pinus sylvestris* in central Sweden. Working from platforms on the crossing stage, the tree breeders are able to put 200 to 400 bags on a single tree for use in isolating female flowers for controlled pollinating work.

Fig. 1.—A field of *Pinus sylvestris* grafts flowering four years after grafting. The paper bags are used to isolate the female flowers for controlled pollinating work. One graft had 60 female flowers on it This area is near the Sundmo Station

Many of the other stations in Europe are doing some breeding work with various species of pine. The station at Wageningen, Holland is interested in working with Scotch pine in very much the same manner as the Swedish workers. Several German stations have some work in progress with this species while the station in Austria near Vienna is working with high resin producing Austrian pine (*P. nigra*).

Work with Norway spruce (*Picea abies*), the indigenous spruce of Sweden, closely parallels the pine breeding work. Selection of quality breeding stock, controlled pollinations, progeny testing, vegetative propagation, and seed production are the principal objectives of the research. Several stations in Germany are also working with this species.

Some interest has been aroused in Sweden over the possible use of Douglas-fir (*Pseudotsuga taxifolia*) in reforestation. The interest in this species as a possible forest tree is greater in Denmark, Holland, France, and to some degree in Germany, where many trials are being or have been started. The main efforts are directed toward finding suitable provenances or seed sources that can survive under local site and climatic conditions. In addition, attention is given to selections showing resistance to two different fungi that are known to cause defoliation and death of the trees.

Breeding work with species of *Larix* is also carried on in Sweden. The crosses between European larch (*Larix decidua*) and Japanese larch (*L. leptolepis*) and between European larch and Siberian larch (*L. sibirica*) give promising results. One hybrid (*L. decidua* x *L. Sibirica*) produced by the Ekebo station in Sweden has excellent form, fine branches, and rapid growth, while another hybrid (*L. decidua* x *L. leptolepis*) produced in Denmark and now 15 years old has about 30 percent more cubic volume than does the *L. decidua* of the same age on the same site. The station at Horsholm also has produced some inbred lines of larch which it is hoped will show significant hybrid vigor when outcrossed. Dr. Langner at the station at Arboretum Tannenhoft near Hamburg also has some older hybrids of European and Japanese larch under test.

The line of tree breeding research in progress at all the stations visited (except the stations in northern Sweden and the one near Oslo, Norway) is poplar breeding. There are several reasons for the widespread interest in working with this group:

a. Some of the earlier tree breeding work began with poplar, and the results were impressive.

b. The methods for conducting a program of controlled pollination have been well developed. The work requires little equipment, can be carried out well in advance of the spring flowering season by working in the greenhouse, and the seed is ready for harvest 10 days to 2 weeks after pollination.

c. There are a great many species in the genus *Populus* to work with, and many inter-specific combinations can be made readily.

d. The pulp and match industries are vitally interested in this wood because of its rapid growth and the short rotation necessary.

One of the best hybrids as reported by a number of stations is that involving the European aspen (*Populus tremula*) and the American quaking aspen (*P. tremuloides*). The hybrid is reported to be two to three times as vigorous as either parent species.

Several stations are engaged in building up collections of high-quality trees before beginning large-scale controlled pollination programs. The Poplar Breeding Institute in northern Italy has been conducting a program of controlled pollination for a number of years with good results. Recent findings, however, indicate that selections from natural hybrids give even better results than artificial hybrids. By utilizing natural hybrids a great range of material becomes available from which to make selections, a higher seed germination of the natural hybrids is often encountered, and resistance to disease is found to be more frequent in this material.

Breeding work is in progress with a number of other hardwoods also. Several stations in Sweden and on the continent are interested in the "wavy" or "curly" birch. This characteristic occurs almost exclusively in *Betula verrucosa*, the European birch. The wood is valuable for use in the manufacture of furniture and veneer wood.

Alder (*Alnus spp.*) breeding is another line of tree breeding research in progress at several of the stations. The wood finds limited use in the wooden shoe industry, in the crystal industry, and in the furniture industry. It is a desirable species to use on marshy lands to help dry up the sites. Various stations are working with other hardwoods such as *Quercus, Ulmus, Fraxinus, Castanea,* and *Fagus.* The general objectives are to improve form, increase rate of growth and volume production, find disease resistant varieties, increase seed or fruit production, etc.

Most stations are engaged in one or another specialized research project designed to enlarge the opportunity for forest tree improvement. Several stations have tried colchicine treatments to induce polyploidy in various conifers and a few hardwoods. The results have not been encouraging. Flower induction trials have been undertaken with various species. The tests indicate that root pruning and transplanting give favorable responses. Some workers anticipate making treatments with various chemicals to determine their effect on flower induction. All stations are interested in finding improved methods for the vegetative propagation of breeding material, as well as in discovering better ways of making controlled crosses. The establishment of seed plantations on a scale large enough to be of substantial value in seed procurement is a practical problem which confronts most stations.

Important progress in forest tree breeding is being made in Europe, but particularly in Sweden. Swedish workers have had an advantage in that their country did not become engaged in the last war. The post-war period has been very difficult for most of the stations on the continent. Many of the buildings were damaged or destroyed. Loss of personnel has also hampered operations. In addition, many field trials were partly or completely destroyed. Now that most of these stations have been able to reorganize, it can be expected that in the years ahead many important contributions to the broad field of forest tree breeding research will emerge from them.