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RISTO SARVAS

ESTABLISHMENT AND REGISTRATION OF SEED ORCHARDS

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Risto Sarvas

ESTABLISHMENT AND REGISTRATION OF SEED ORCHARDS

PREFACE

The following instructions concerning the establishment of seed orchards were completed gradually on the basis of results of investigations carried out over a number of years. They were first issued in the Finnish language and distributed among persons engaged in tree breeding in this country in 1968. English language instructions were dublicated in 1970 and they were for the main part similar to those contained in the Finnish language issue. The instructions given below have been slightly revised.

The main purpose of these instructions is to draw attention to the many different factors to be considered in connection with the establishment of seed orchards. They are also intended to illustrate that most of the problems arising in this connection, and which as late as some 10 years ago had to be settled by using the rule of thumb, can now be solved on the basis of investigatory data.

The author takes this opportunity to thank his numerous fellow workers who took part in the investigations involved. Special thanks are due to Mr. Olavi Helenius, Forest Officer, and Mr. Jaakko Rokkonen and Mr. Veikko Silander, Forest Technicians, and Mr. Pauli Värtinen, who led and supervised the very exacting field work.

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Risto Sarvas

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INTRODUCTION

The term seed orchard refers to a stand established for the production of seed. It should perhaps be added: especially for the production of large quantities of seeds. The concept of seed orchard should be confined to open-pollinated stands. For the sake of clarity, artificially pollinated stands should be termed "plus tree collections" or "special tree collections". When undertaking the establishment of a seed orchard, it should be borne in mind that the seed to be produced is expected to be genetically and physiologically good, or at least better than average stand-produced seed. The production of a heavy seed crop of high genetic and physiological standard is the primary objective of seed orchards. In addition, the orchards, as a rule, render services to tree breeders in the work they do to increase the improvement degree. Production of seed in stands planted for this purpose only has long been practised in farming. The idea has thus existed for so long that it is relatively unimportant who it was that first suggested it in forestry. It is perhaps more important to give credit to the researchers who first began to apply it on a fairly large scale in forestry. Mention should be made especially of Syrach Larsen who in his dissertation (1934) pointed out the special possibilities offered by the use of grafts for the production of racially high-standard seeds, and Holger Jensen (1943) and Bertel Lindquist (1948) who developed the methods further.

In this connection it is appropriate to point out that in practical silviculture, for reasons of economy, it is difficult to meet even modest requirements in respect of the racial quality of the seed to be used in reforestation. This is due to the fact that it is almost always necessary to collect this kind of seed from standing trees. This has been the bitter experience in Finland in the last few years. It is, therefore, obvious that even though no greater genetic demand is made on the seed than that it originates from a good tree in a racially good stand, the establishment of seed orchards is well warranted in order to rationalize the collection of seed of this quality.

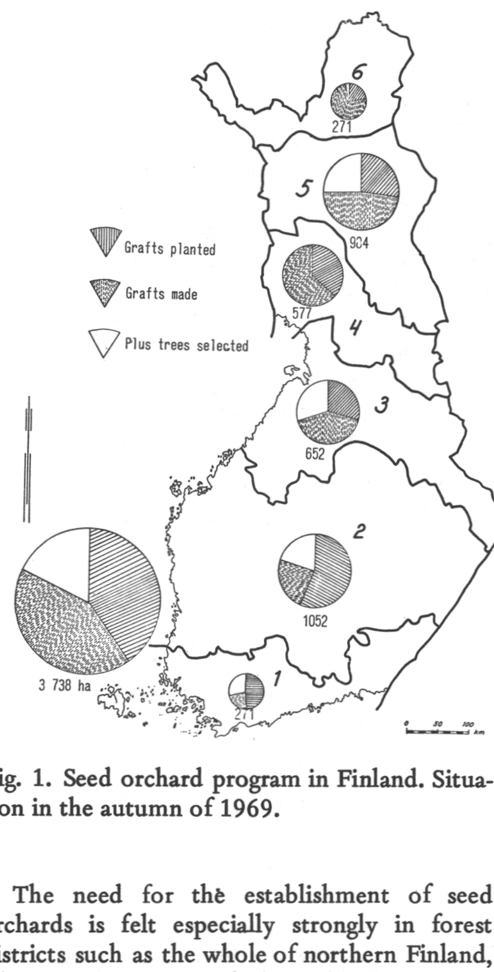

Fig. 1. Seed orchard program in Finland. Situation in the autumn of 1969.

The need for the establishment of seed orchards is felt especially strongly in forest districts such as the whole of northern Finland, where, on account of the cold climate, the seed does not mature regularly. By establishing, in warmer climates, seed orchards designed to serve these areas it is possible to ensure annual maturation of the seed.

As a rule, the seed produced by a given seed orchard can be used successfully only in a certain geographical area that can be marked out on the map. This area is called "the utilization area of the seed orchard".

On the basis of the principles applied in the attempts to meet the objectives set for seed orchards, these orchards can be grouped into different types of structure. Thus, two main groups can immediately be distinguished: 1. Graft orchards and 2. Seedling orchards. These main groups can further be divided into sub-groups. Besides this type-grouping, a classification system can be employed. The purpose of this system is to classify the orchards on the basis of the genetic quality of the seed produced by them. Below, the type-grouping and quality-classification will be dealt with in a more detailed way.

SEED ORCHARD TYPES

In practical tree breeding, the significant seed orchard types can preliminary be grouped, for instance, as follows:

A. Graft orchards (synonym: clone orchards)
   a. Phenotypic graft orchards. The trees have mainly been selected on the basis of phenotype. The general principle of breeding is usually mass selection.
   b. Genotypic graft orchards. The choice of trees essentially depends, in addition to phenotype, on the data obtained on genotype. The general principle of tree breeding is usually family selection.

B. Seedling orchards
   a. The trees in the seedling orchard originate from open pollination.
   b. The trees in the seedling orchard originate from controlled crosses between phenotypic plus-trees.
   c. Progeny test seed orchards. The starting point can be a seed produced by open pollination or by controlled crosses. The orchard should be established in such a way that at first it puts into effect the principles of the progeny test but later, as a result of thinning, changes to serve, to an increasing degree, the seed production,

In this brief discourse it is not possible to penetrate into the details of all the different types of seed orchards mentioned above, or to weigh the advantages and disadvantages of the various seed orchards types. The seed orchard program, which is about to materialize in Finland, is for the time being almost exclusively based on a graft orchard of the type which gradually changes from a pheno- to a genotypic orchard; therefore, in the following pages most attention is paid to this type. In addition it must be kept in mind that Pinus sylvestris seed orchards constitute the main part of the Finnish seed orchard program.

The initial cost of a graft orchard is considerably higher than that of a seedling orchard. To counterbalance this, the graft orchards afford certain significant advantages. Above all the genotype of the trees remains unchanged in propagation. Also graft orchards can be established irrespective of the trees' genetic inclination for flowering. Many of the best plus trees flower so seldom and scantily that efforts to obtain adequate amounts of seed for the establishment of seedling orchards are met with considerable, if not almost insurmountable, difficulties, especially if the seedling orchard is established from seed produced by means of controlled crossings. This is particularly true of the plus trees of northern Finland. It appears, therefore, that seedling orchards designed to serve northern Finland can only be established at the expense of the effectiveness of selection (selection differential, cf. also Gustafsson 1950, p. 118). In this connection it should be pointed out that poor genetic inclination for flowering, as such, is no insurmountable obstacle in forest tree breeding. By grafting the plus trees which flower scantily in their natural habitat and by transferring the grafts to grow in a warmer climate, flowering can usually be improved sufficiently to reach a satisfactory level.

The line between the phenotypic and genotypic graft orchards is gradual rather than clear-cut. The genotypic information forest tree breeders seek to obtain can in the first place be divided into two groups:

1. Information on the heritability of certain phenotypic traits, important from the forest economy point of view, such as height and diameter growth, branchiness, percentage of summer wood, and the annual developmental cycle, and

2. Information on the general and special combining ability of the trees used for breeding.

The forest genetic research work done so far has proved that the heritability of certain phenotypic traits important from the breeding point of view is generally high (for example, the heritability of the annual developmental cycle). The phenotypic observations made in respect of this kind of traits accordingly provide far reaching information on genotype. So far, however, the heritability of several of those traits which are most important from the breeding point of view, such as growth, has proved to be low. Therefore, at least for the time being, the only possible way to obtain information on this subject is to clarify the general and specific combining ability of the selected trees. It is, however, reasonable to emphasize that our notion of phenotype is, so far, very vague. It seems that by increasing the number of the phenotypic traits to be studied and by splitting collective traits, such as growth, into an increasing number of components, more restricted physiologically, it is possible to obtain a clearer notion of phenotype. It is also reasonable to anticipate that this procedure enables important phenotype traits with low heritability to be split into components with considerably higher heritability. The more far-reaching the conclusions drawn on the basis of phenotype from the genotype of the trees used for breeding, the lighter will be the load on progeny tests. The load will in any case be very heavy.

QUALITY CLASSIFICATION OF SEED ORCHARDS

The main purpose of the registration of seed orchards is to ascertain to what extent a seed orchard reported for registration meets the objectives generally prescribed for seed orchards, with regard to the genetic and physiological standard of the seed produced by them. This applies particularly to the genetic quality of the seed, because, as a rule, it is not possible to draw conclusions about this on the basis of the fenotypic parameters of the seed. Of the physiological standard, however, the opposite is to a great extent true.

The most essential point in the classification lies in the type grouping dealt with in the preceding chapter. Certainly the genotypic seed orchards quarantee the genetic quality of the seed with much greater certainty than do the phenotypic seed orchards. For the time being, however, more attention is given to the classification of the phenotypic seed orchards. This is due to the fact that in Finland almost all the existing seed orchards belong, so far, to this group.

It is evident that most, if not all, of the existing phenotypic seed orchards meet, at least in some respect and to a certain degree, the requirements generally prescribed for phenotypic seed orchards. It is, however, equally evident that they differ greatly from one another in this respects. Under the circumstances, it is appropriate to divide the phenotypic seed orchards, for instance, into three classes. The decisive factor in the classification is how well they have succeeded in meeting the requirements prescribed for a good phenotypic seed orchard, especially in respect of the characteristics affecting the genetic quality of the seed. It seems best to employ the same principles as in the classification of plus trees: parameters important in this respect are listed and the seed orchard concerned is given 0—3 points for each parameter depending on how well they have succeeded in meeting the goal. The total number of points received by the orchard determines the class in which it will be registered. The classes are identified by letters A, B, or C. The highest class in A and the lowest, C.

Each parameter to be considered in the classification will be dealt with in the following pages. Also, the principles employed in granting points will be stated.

PHENOTYPIC SEED ORCHARDS

Clones

Tree breeding that applies to phenotypic seed orchards is based on the so-called phenotypic mass-selection principle. This means that a large number of trees, let us say hundreds of thousands, are taken as a starting point. On the basis of economically important phenotypic traits, a minor portion of these trees is selected and used as parents for a new generation. By repeating this procedure in progenies, the degree of improvement (genetic gain) can be increased. The genetic gain of mass-selection depends on the heritability of the trait to be improved and on the selection differential of the selection. The term selection differential refers to the difference between the respective mean values of a given trait calculated on the basis of an individual tree and on the basis of the subpopulation in question. The selection differential can be expressed as absolute or as divided by the standard deviation (normalized) on the given trait in the subpopulation concerned. If the genetic gain of mass-selection is marked with G, heritability with h^2 and the selection differential with i, the following equation prevails:

$$G= ih^2$$

For the time being, however, our knowledge of i and especially of h^2 is so poor that we cannot obtain a clear picture of the benefit that forest tree breeding can derive from mass-selection.

The principles concerning phenotypic selection or the selection of plus trees will not be dealt with in this paper but reference is made to earlier presentations (cf., for instance, Sarvas 1953 c, Anderson 1966). It is, however, reasonable to emphasize the obvious fact that the threshold values for different important traits employed in the selection of plus trees determine the selection differential of the mass-selection employed. If the threshold values are low, the selection differential is low, too, and the genetic gain remains small.

In connection with the registration of the seed orchards, points are given on the basis of the threshold values employed in the selection of the clones used in the orchards. The following traits are considered:

1. Cubic content of plus tree candidate
2. Knottiness of plus tree candidate
3. Specific gravity of plus tree candidate

There are thus only three traits on which the evaluation of the phenotype of plus trees is primarily based. This is due to the fact that a large number of them would render the evaluation ineffective. However, it is, of course, important that the plus trees are at least average as regards most of those traits which are important from the forest economy point of view.

Each clone is evaluated separately and given 0—3 points for each of the traits mentioned above. If the data necessary for the evaluation are not available (not measured) the score is 0. The seed orchard concerned receives the mean value of the points given to the clones. If any of the above-mentioned traits has been checked by means of a clone test, the point-value obtained should be employed.

Phenotypic selection can be checked by means of clone tests. It should be observed that the significance of clone tests is reduced to the checking of phenotypic selection (except for traits with high general heritability); they do not provide any far-reaching data on genotype. However, the fact that the phenotypic selection can be checked by means of clone tests is a valuable step forward in the efforts to increase the degree of improvement. Clone tests are essentially subjected to the same rules as progeny tests: they have to be established in the seed's utilization area. In proportion to the high initial cost and the high cost of maintenance of clone tests, the information provided by them is rather scanty. On account of this, the number of clone tests is fairly small the world over. Unless treated in a manner differing sharply from the general practice in silviculture, seed orchards and plus tree collections can, to a certain degree, serve as clone tests. It should, however, be borne in mind that if their location differs from the utilization area of the seed, certain reservations will be necessary.

Topophysis and Cyclophysis

It has transpired that the different parts of the crown of a certain individual tree have developed into more or less permanently different reaction norms. For instance, grafts made of the lower branches of a full-sized Norway spruce usually grow upwards less readily than grafts made of branches at the top of the crown. This phenomenon is called topophysis. There are great differences in topophysis between the various tree species and even between different individual trees and also between different traits.

There are differences also between the various ages of an individual tree. For example, the upper branches of a young tree behave differently from those of an old tree. If grafts are made of the upper branches of an old tree and of a young tree, the former flower more profusely on an average than do the latter. This difference in the different ages between topophysically comparable parts of the same genotype is called cyclophysis.

For the good vegetative development of grafts it is useful in regard to topophysis to take the scions from the upper third of the crown. This is true particularly of the Norway spruce, which appears to have the most strongly developed topophysis of the Finnish tree species. There are, in addition, many indications that grafts made of the upper third of the crown flower more profusely on an average than grafts from lower down.

On account of cyclophysis, grafts probably flower more profusely than seedlings of the same age or the same size. This is very apparent from a comparison of small-sized grafts and seedlings, e.g. under 5 m in height. However, cyclophysis and topophysis have a common feature, they are not very sharply fixed. The larger the graft grows, the smaller are the effects of cyclophysis and topophysis of the ortet and the stronger are the cyclophysis and topophysis dictated by the graft itself.

It does not seem probable that we can estimate from the information now available the extent of the increases in seed crop that are achieved in graft seed orchards as a result of cyclophysis and topophysis. Possibly the greatest importance of these increases is that it may be possible to obtain considerable seed crops some 10–15 years earlier than in, say, seedling orchards. This in itself would naturally be quite noteworthy achievement. On the other hand, it is uncertain whether we shall derive any benefit from cyclophysis and topophysis when the seed orchards have achieved an advanced age and a productivity of considerable magnitude.

Physiology of Flowering

Research concerning the flowering of forest trees has proved that in autochthonous naturally regenerated subpopulations it is not the individual tree but the population that must be considered the unit of flowering. As a matter of fact, this stands to reason. Gene exchange is the basic object of the flowering process. Propagation as such could materialize in a much simpler and safer way on the basis of vegetative propagation. Gene exchange is not possible within one individual tree (only a certain regrouping, recombination, of genes is possible); it can only materialize if several individual trees or an entire population participates in the flowering process. As a unit of flowering, autochthonous populations are a beautiful illustration of how the flowering times of the various individual trees, although differing somewhat from one another, are synchronized sensibly, and form, from the point of view of flowering physiology, an efficient whole.

Research concerning the flowering of autochthonous wind-pollinated populations has further proved that the pollen production must be considered the minimum factor in the pollination process, although it seems that forest trees produce pollen in profusion. For instance, in mature Pinus sylvestris subpopulations pollen production is at its maximum. It is very much higher than, for instance, in middle-aged subpopulations, to which at least 30– to 50–year old seed orchards should in the first place be compared. However, even on sites of medium fertility (Myrtillus-site type), in the mature subpopulations approximately 40 % of the ovules fail to develop on account of lack of pollen (Sarvas 1962, p. 159). It goes without saying that if in a subpopulation the flowering times of the individual trees were not at least satisfactorily synchronized, the pollination would prove even less efficient.

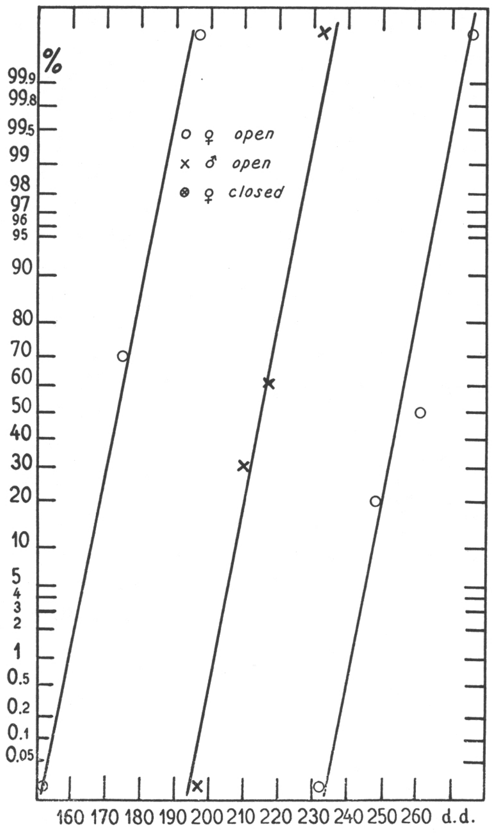

Fig. 2. Pinus sylvestris. Distributions of the temperature sums (d.d.) of the opening and closing of female flowers and of the opening of male flowers at clonal level. Tree No 1, Tuusula, sample plot XXXII. Flowering year 1966. Scale: frequency paper.

When seed orchards are being established, for the reasons stated above, it is necessary to give the pollination process (i.e. the synchronization of anthesis and gynesis of the different clones) serious consideration. We know, for instance, that poorly pollinated female flowers of Pinus sylvestris drop during the first summer without ever developing into seed bearing cones. Therefore, unless the flowering times of the clones are satisfactorily synchronized, it is, generally speaking, realistic to anticipate that it will not be possible to collect from Pinus sylvestris seed orchards any appreciable amounts of seed cones, at least not until the orchards have reached a mature age, by which time the pollen production has reached its maximum.

How, then, is the synchronization to be accomplished? When making observations on the female and male flowering of an individual tree, it has been established that almost all the female flowers are open before a single one of the pollen sacs is open and that almost all the pollen in the pollen sacs has been dispersed before the earliest female flowers are closed (Sarvas 1967a, p. 334, Fig. 1). Thus, at the individual level, the probability of pollination of the female flowers (selfing) has been maximized. This is surprising but becomes understandable when one realizes that this is the price which must be paid in order to maximize the probability of pollination of the female flowers expressly at the population level (cf. Sarvas 1967a, p. 334, Fig. 2). The results of our

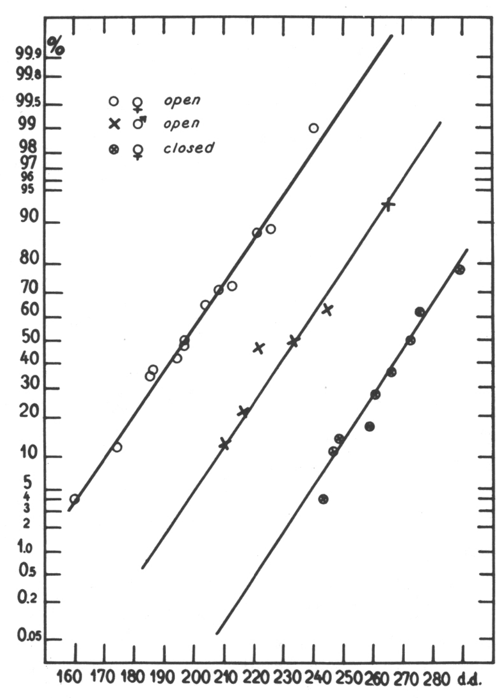

Fig. 3. Pinus sylvestris. South Finland. Temperature sum (d.d.) distributions of the opening and closing of female flowers and of the opening of male flowers at population level. Scale frequency paper.

investigations also provide the answer to the question stated above: It is evident that the probability of the pollination of the female flowers become the greater the less the average heat sums (e.g. period unit sums, cf. Sarvas 1970) of the flowering (for instance, of anthesis) of the clones included in the seed orchards differ from one another (cf. Sarvas 1967b).

The condition mentioned above is particularly well fulfilled by the seed orchards composed of clones originating from northern Finland, since in northern Finland the differences between the annual active periods of the different individual trees are generally small (cf. Sarvas 1966a, pp. 3—5). Consequently, the seed orchards established for northern Finland do not pose any problems as regards the synchronization of the flowering times of the clones. Actually, as regards the efficiency of pollination the flowering times of these orchards have been synchronized more efficiently than, for instance, those of the autochthonous Pinus sylvestris populations in southern Finland.

The further south the natural habitats of the clones included in the seed orchards are, the bigger generally are the differences in their annual active periods (except for the southern marginal and transitional zones of the range of Pinus sylvestris). On the basis of the available data it is easy to estimate to what extent the efficiency of pollination is affected by the increasingly differing flowering times (heat sums). Fig 4 elucidates this question. The diagram shown is based on research concerning the anthesis and gynesis of Pinus sylvestris in southern Finland.

Fig. 4 gives a general picture of the efficiency with which two different Pinus sylvestris populations with differing average length of annual active periods[1]) will become crossed between themselves. On the horizontal axis is marked the difference in the annual active periods of the populations concerned, and on the vertical axis, the efficiency of the female flowers of clones belonging to the population that is to become pollinated by the clones belonging to population B. By maximal is meant, as far as synchronization is concerned, the efficiency which the pollen of clones belonging to population B would have in open pollination if the female strobili of clones belonging to population A were open all the time that clone B is disseminating pollen. Maximal efficiency is

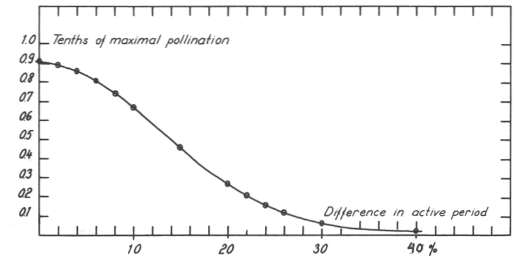

Fig. 4. Pinus sylvestris. The efficiency of clones from two different natural populations to become crosspollinated. The horizontal axis shows the average differences between the populations in the active period. The figures on the vertical axis show the efficiency of wind pollination as tenths of the maximal efficiency.

denoted by 1.0 and other degrees of efficiency as its parts. When the heat sum distributions of the opening and closing of female strobili (means and standard deviations, Fig. 3) and the difference in active periods are known it is possible to calculate how the pollination efficiency decreases when the period difference increases (Fig. 4). It can be seen that as long as the difference in the active periods is small, varying from 0 till 6 %, the possibilities of windpollination are good; more than 0.8 of the maximal efficiency of windpollination is achieved. As soon as the difference in the active periods exceed 6 %, there is an increasingly sharp reduction in the efficiency of windpollination. When the difference has risen, for instance, to 14 % the efficiency of windpollination is only about 0.5 of the maximum; and when the difference is as great as 30 %, the efficiency is only 0.05.

If the goal set for the pollination efficiency within a seed orchard is about 0.8 of the maximum, according to the diagram shown in Fig. 4 the difference permitted in the average

1) The period difference between two clones, A and B, is calculated by determining the p.u. sum with which clone A and clone B reach a certain cardinal phase whatever it may be (that is, the midpoint of the heat sum distribution of this cardinal event is determined separately for both clones), deducting from the greater p.u. sum the smaller one and calculating how many hundredths the difference is from the smaller sum. Cardinal phase refers here to a physiologic developmental status to be included in the active period from which it is possible accurately to determine whether it has already been passed (plus-observation) or not (minus-observation).

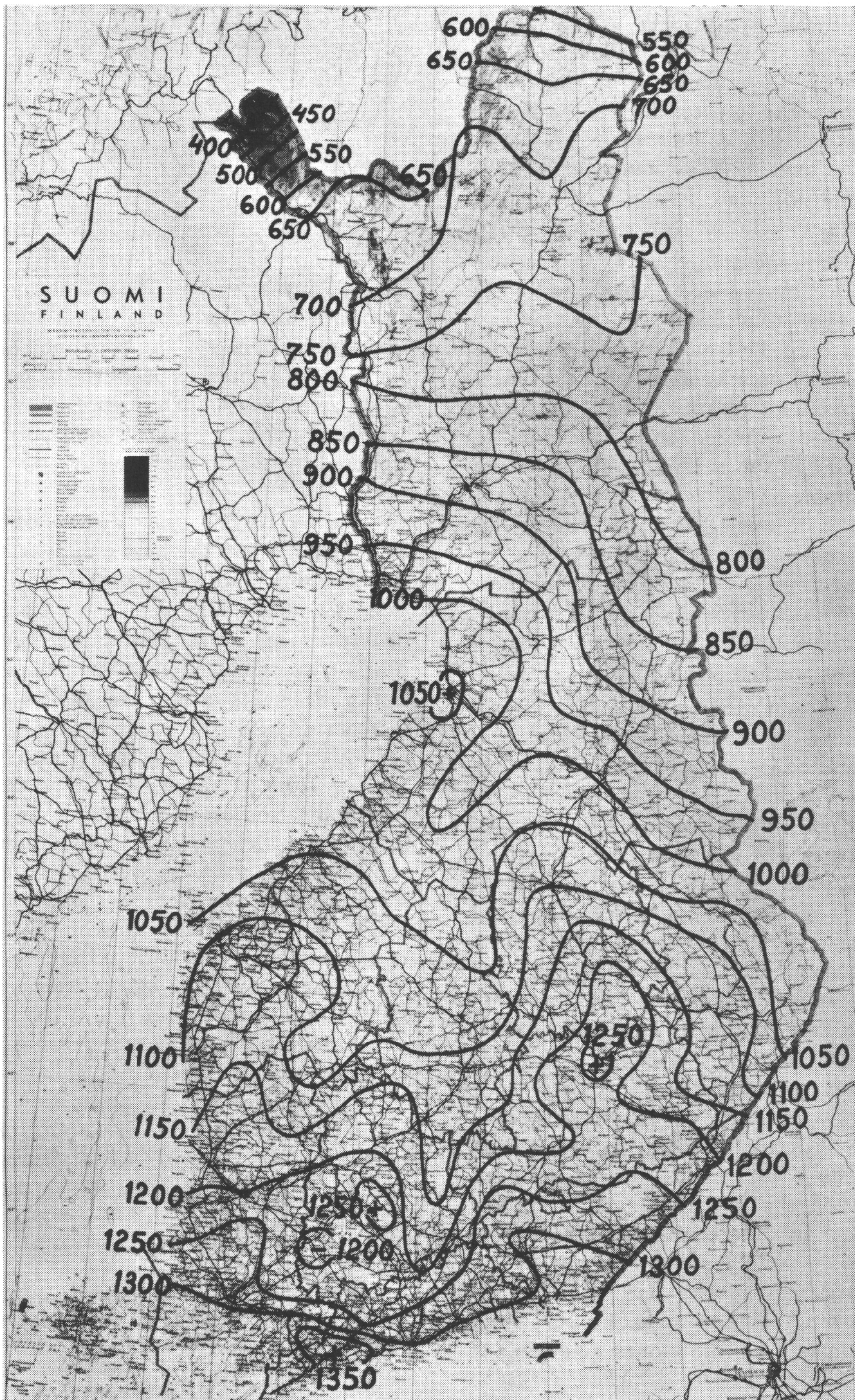

Fig. 5. Isograms at 50 d.d. -intervals in respect of the average yearly heat sums (degree days-scale) in Finland. The isograms refer to the average natural heights above sea level. Mean of years 1931–1960. Osmo Kolkki. 1969. Katsaus Suomen ilmastoon. Ilmatiet. lait. tiedonant. 18, s. 50.

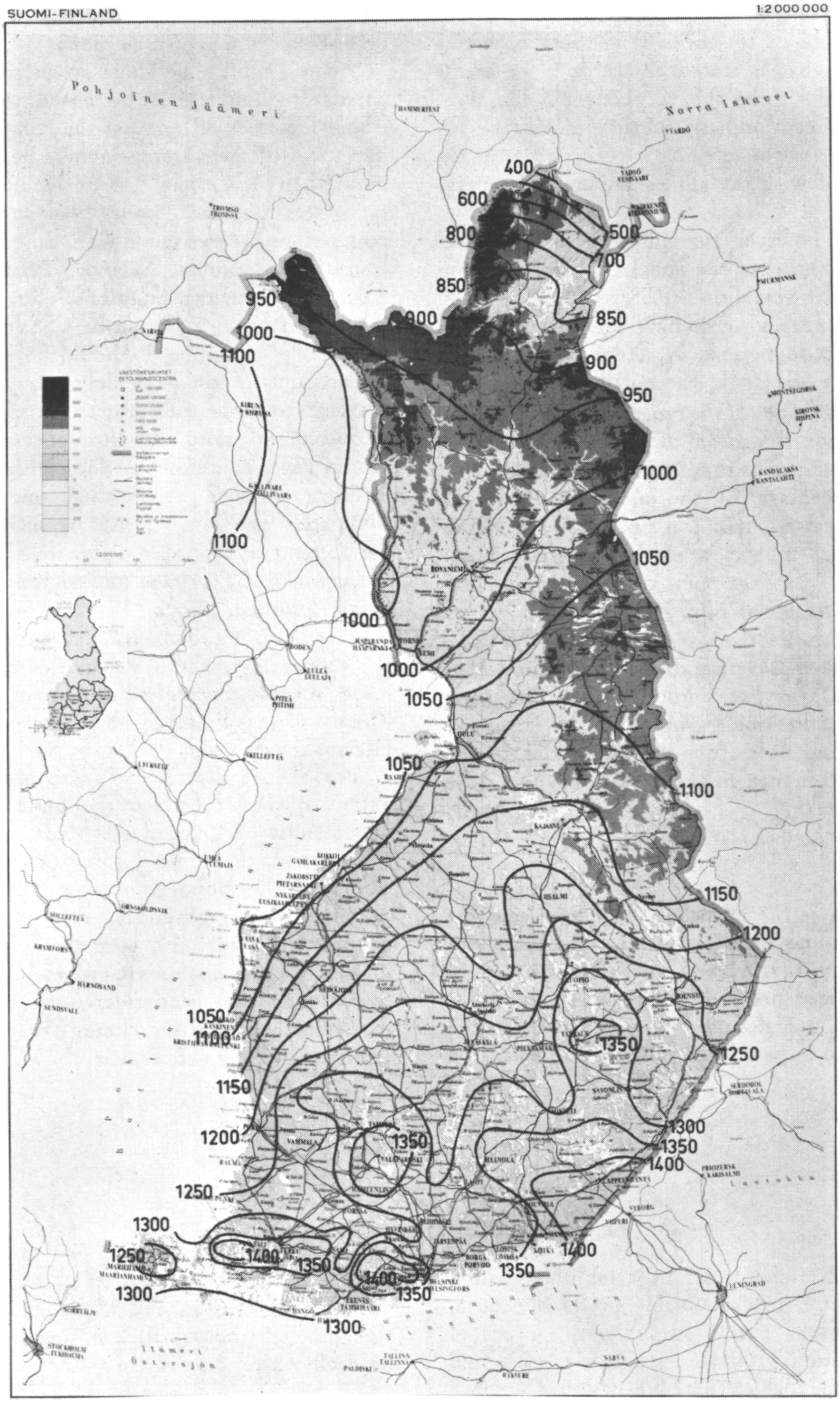

Fig. 6. Isograms at 50 d.d. -intervals in respect of the average yearly heat sums (degree days-scale) in Finland. The isograms refer to the sea level. Copied from a map calculated and drawn by Kolkki but not yet published. Mean of years 1931—1960.

active periods of the populations amounts to about 6.0 % of the mean of the seed orchard.

From what is stated above, it is apparent that in order to be able to plan the pollination within a seed orchard so that it may be as efficient as possible it is necessary to be acquianted with the clones' annual active periods.

So far, however, the p.u. sums of the active periods of most of the plus trees have not been clarified. However, on the basis of the localities of the plus trees we do have some information on the active periods of all of them. Let us recall that, except in the northern transitional and margin zones of the range of Pinus sylvestris, for instance the mean of the distribution of the heat sum of anthesis is, as a rule, about the same percentage of the mean of the local average heat sum (Linsser's principle) and that the variance coefficient of the frequency distribution of the heat sums of anthesis is about 6 % (cf. Sarvas 1967b, p. 223).

From the above it follows, in the first place, that the average difference in the active periods (D) of two autochthonous Pinus sylvestris populations growing in two different areas (A and B) is of the same magnitude as the relative difference in the average heat sums of these areas:

$$D \simeq 100\,(T_A - T_B) : T_B$$

where T_A is the average annual heat sum for locality A and T_B the average annual heat sum for locality B ($A > B$). If one wishes to ascertain that the seed orchards are pollinated with 0.8 efficiency, it is necessary to make sure that the differences in heat sums of the localities of the plus trees of which the seed orchard is composed do not exceed 6 % of their mean.

When establishing Pinus sylvestris seed orchards it should thus be noted that clones whose localities differ from the common mean in respect of their average annual heat sums by more than 6 %, may not be included in the same seed orchard. Transitional and marginal populations are exempted from this rule. In the transitional zone, as we move from south to north, the percentage mentioned above increases gradually from 6 to about 12 %. As regards the marginal populations, it should be noted that on account of an extremely heavy selection pressure towards the shortest possible active period, there exists very little genetic variance in this trait. Therefore, all the clones from the different parts of the marginal zone have approximately the same length of active period. On account of this, all the plus trees growing in areas where the average annual heat sums are below 950 d.d. can be included in the same seed orchard, without having to anticipate that the clones in respect of their flowering physiology may not become adjusted to one another. There might, however, be other restrictive circumstances.

For the registration of seed orchards the extent to which they meet the conditions stated above must be determined. Since, in seed orchards, poor flowering physiological synchronization of the clones inevitably leads to poor pollination with genetically deleterious consequences, orchards with poor flowering physiological synchronization are given a minus-grade. Synchronization is considered to be poor if more than 10 % of the clones fail to meet the minimum requirements stated above.

Geographical Location of Seed Orchards

A seed orchard can be established within its utilization area or outside, preferably south, of it. From a purely administrative point of view, location within the utilization area would be recommendable. There are, however, weightly reasons speaking in favour of the seed orchards being established in a climate warmer than that of their utilization area. By this move advantages can in the first place be gained in three respects: 1. maturation of seed, 2. inclination for flowering, and 3. physiological isolation of seed orchard. Each of these points will be dealt with separately in the following pages.

In the optimum zone of the Pinus sylvestris range, the mean of the frequency distribution of the heat sum of the maturation of the seed is 77 % of the local average annual heat sum (Sarvas 1967a, p. 230). In absolute heat sum units, the temperature sum requirement of the southern races is very much higher than that of the northern ones. For instance, in the Punkaharju area the maturation requirement is calculated as follows:

The average annual heat sum is 1248 ± 27 d.d. and its standard deviation 116.2 d.d. (the variance coefficient is 9.3 %). Since the relative mean of the frequency distribution of the maturation is 77 %, in Punkaharju 50 % of the seed will thus have matured by the time the heat sum reaches 77 x 1248 d.d.: 100 = 960 d.d. Since the variance coefficient of the different cardinal phases of the active period is generally about 6 %, the standard deviation is thus about 6 x 960 d.d.: 100 = 57.6 d.d. By adding 2 standard deviations to 960 d.d. one finds the heat sum at which the seed in Punkaharju will be 98 % mature: 960 + 2 x 57.6 = 1075 d.d. (= 86 % of the annual average heat sum in Punkaharju).

There is, however, a certain value below which the requirement does not go. This value is reached at the southern limit of the northern marginal area of the species, where 50 % of the seed will have matured by the time the heat sum has reached 845 d.d., and 98 % of the seed will have matured by the time the heat sum has reached 845 d.d. + 2 x 6 x 845 d.d. : 100 = 946 d.d. North of this limit, in the northern marginal zone of Pinus sylvestris, in most years, seed fails to mature. The lower the average annual heat sum of the area concerned, the more frequent is the failure. Particularly in regard to seed production for the northern marginal zone it is therefore necessary to establish the seed orchards south of the utilization area in order to ensure the maturation of the seed. The figures mentioned above also indicate the extent of the necessary transfer in order that the seed should meet the maturation requirement. Let us designate the average annual temperature

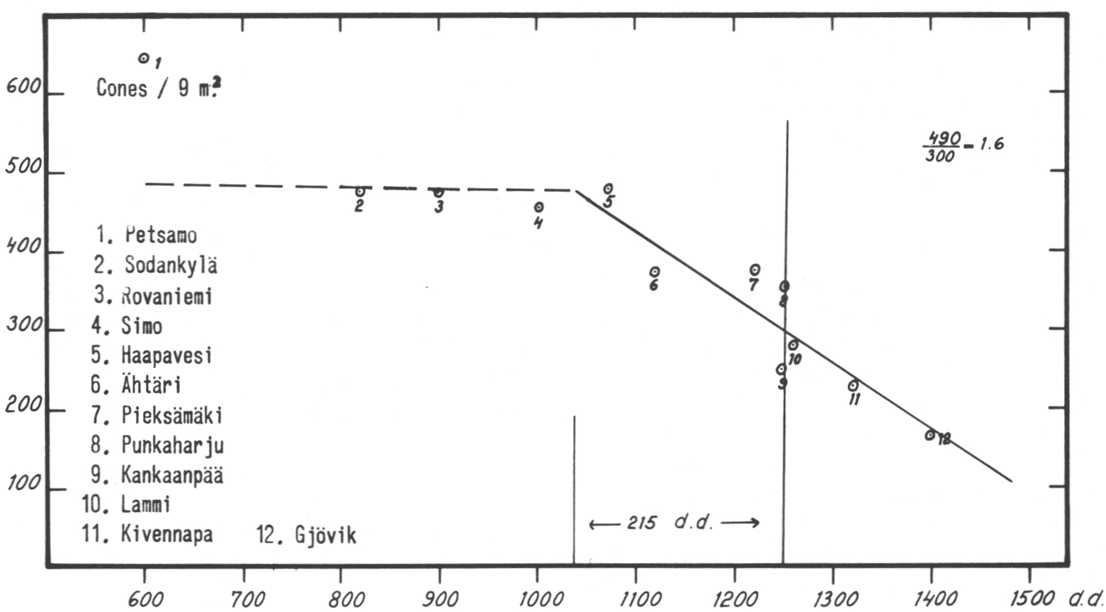

Fig. 7. Pinus sylvestris. The effect of the tarnsfer south on the cone crop of the progeny. The investigation was performed in the Punkaharju provenance test area by counting the cones that had fallen to the ground (36 squares á 0.25 m² in each provenance). The horizontal axis shows the average annual d.d. sum of the habitat of the seed; the vertical axis shows the number of cones on the ground per 9 m². The vertical line on the left is the d.d. sum of the intersecting point of the levelling lines of the point diagram; the vertical line on the right is the average annual temperature sum of Punkaharju. The difference in the vertical lines, 215 d.d., indicates the extent of the southward transfer that is necessary in order to achieve the maximum increase in the cone crop.

sum of that geographical area where the seed matures 98 % every year (in 98 years out of a hundred) with T. We then arrive at the following calculation:

$$946 = T + 2 \cdot 9 \cdot T : 100 = 0.18\,T$$
$$T = 946 : 0.18 = 1154 \text{ d.d.}$$
$$1154 - 946 = 208 \text{ d.d. (= the necessary southward transfer)}$$

From the heat sum map drawn by Kolkki, Fig. 5, it can be seen that in Finland this limit is reached south of the line running through Kauhava – Parkano – Keuruu – Laukaa – Pielavesi – Iisalmi – Juuka – Kontiolahti – Kitee.

It has long been known that when transferred south the northern races of Pinus sylvestris flower more abundantly than in their natural habitat and even more abundantly than the local races. This question has been studied at the Forest Research Institute in the course of a number of years and the results will shortly be referred to. In this study only results of importance to the purposes of the present problem will be made use of. Research has proved that southward transfer increases the flowering only up to a certain limit that cannot be exceeded, no matter how far south the transfer is made. The greatest average flowering intensity that can be obtained by transfer is about 160 % of the clones' flowering intensity in their natural habitat. The increase is thus quite remarkable. It can further be stated briefly that 98 % of this maximum increase has taken place when the difference between the average annual heat sum of the area of the orchard and that of the natural habitat is about 200-230 d.d. Since it has not so far been clarified whether still longer transfers may lead to weakening of the general vitality of the clones or have other deleterious consequences, it may be appropriate to recommend that only about 200 d.d. transfers should be undertaken. The increase in the average flowering intensity will then be about 70–90 % of the maximum increase that can be obtained.

All clones are not affected in the same way by southward transfer. Those flowering well in their natrual habitat and with a short annual active period display only a relatively small increase in their flowering intensity, whereas clones that have a long active period and only seldom flower in their natural habitat exhibit a considerable increase in their average flowering intensity. Thus, transfer has not only a quantitative but also a qualitative effect. Since many or, maybe, most, of the best plus trees have a long active period, the qualitative effect produced by transfer must be considered favourable. As a matter of fact, it may prove one of the most important results that can be obtained by the seed orchard method. In public discussions, this question has failed to attract due attention.

Clones that have been transferred south flower there at the same heat sum as in their natural habitat, from which it follows that these clones generally flower earlier than the local races. The difference in the flowering time can be so great as to cause the clones that have been transferred to become flowering physiologically more or less isolated from the local population of the same species. When the difference between the active periods of the population transferred and of the local population is known, it is possible to estimate the efficienty of this isolation on the basis of the results of investigations concerning gynesis and anthesis (Fig. 4). For instance, if a seed orchard designed to serve the northern marginal zone of Pinus sylvestris is established in Korpilahti (lat. 62,00, long. 23,35, height above sea level 175 m.) as has been done, the calculation is as follows: Anthesis, for instance, may be used for the calculation of the period difference. In the Pinus sylvestris populations in the marginal area, the mean of the frequency distribution of anthesis is 195 d.d. and in the Pinus sylvestris populations in the Korpilahti area, 220 d.d. The difference between the active periods is thus about 13 %. From Fig. 4 it can be seen that when the period difference is 13 %, the efficiency of the local pollination in a seed orchard drops to 0.55[1] of what it would be without the difference in the active periods. The isolation is thus quite considerable; if in the pollination of a seed orchard, the proportion of local pollen amounts to about 20 %, it drops on account of the period difference, to 10 %. However, the pollination of seed orchards requires further experimental study and measurements. Measurements are easy to perform when the seed orchards are young and their own pollen production does not complicate the picture.

1) The efficiency is in fact even smaller, about 0.4; the reason is that the standard deviations of the heat sum distributions of the opening and closing of female strobili in a seed orchard of a marginal zone are smaller than those shown in Fig. 3.

The physiological isolation brought about by the transfer of seed orchards to the south is thus worthy of consideration. It can further be established that the local pollen dispersed while the female flowers of a seed orchard are open is no random portion of the pollen of the local population but a fraction representing the shortest active period. In other words, it is that portion of the local population which, in respect of its active period, differs least from the seed orchard's active period.

While the advantage of physiological isolation is gained by transferring a seed orchard south, this move involves a risk that has previously attracted but little attention. For instance, Pinus sylvestris clones that have been transferred south flower at a lower heat sum that the local population, but it is to be noted that the longer their southward transfer, the more synchronous their flowering with that of the local Picea Abies population. Particularly, in years when a fraction of a local Picea Abies population representing a long active period flowers abundantly, which probably is not common, it is possible that its pollen becomes lodged in the female flowers of the Pinus sylvestris seed orchards, blocking the micropyle tubes and thus seriously hampering the pollination of the orchard. This question is being investigated at present.

Location of Seed Orchards

The location of a seed orchard influences production and quality of seed, isolation of seed orchard, and cost of seed collecting.

Investigation on the flowering and seed crop of forest trees has revealed that on fertile sites, flowering is more abundant and seed production considerably heavier than on barren sites. In a 100-year old Myrtillus-site type Pinus sylvestris stand (dominant height 27 metres) the average annual seed crop is more than twice that of a Calluna-site type stand of the same age (dominant height 19 metres) (cf. Sarvas 1962, p. 159, Fig. 61). Not only numerically, for instance, per sq. meter, are the fertile site crops heavier than those prodused on barren land, but also in respect of the weight of filled seeds. Since a heavy crop is one of the principal objectives, seed orchards should be established on fertile sites. Areas more barren than the Myrtillus-site type forest land should not, as a rule, be considered. It should, however, be noted that the requirements of the different tree species regarding site fertility vary. For instance, Picea Abies and Betula verrucosa are eutrafents and can, therefore, profit by all the benefits afforded by the most fertile sites. Pinus sylvestris, again, being an oligotrafent has on a mere Myrtillus-site type forest land optimal opportunities for development. As far as the flowering intensity is concerned, it is hardly possible to gain anything by establishing a Pinus sylvestris seed orchard on Herb-site type land instead of a good Myrtillus-site type land. Also, the species'

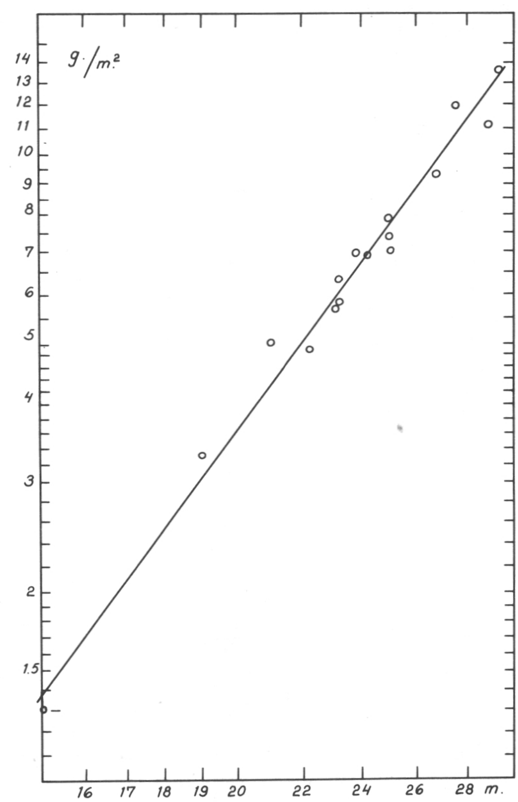

Fig. 8. Pinus sylvestris, southern Finland. The regression of the amount of male flower residue (g./m.²) on the dominant height in silviculturally low thinned stands.

ability to resist disease would be impaired. Another negative point to be considered is that if located in an overly fertile area, a Pinus sylvestris seed orchard would not prove very serviceable when the phenotype of clones is being checked.

In this connection it may also be reasonable to establish that in respect of fertility, poor arable land may be considerably poorer than good forest land and even poorer than Myrtillus-sites.

When about to burst and even during flowering, the flower buds of forest trees, especially those of female flowers, have proved sensitive to frost. Since the trees in a seed orchard never grow tall, their flowers come to be located lower and, therefore, closer to the frost region than the flowers of mature forests. Frost hazards merit, therefore, special attention, which means that seed orchards should never be established in areas where the frost peril is great. Particularly undesirable are low, level loams and hollows in rolling terrain.

Table 1. Catch of Pinus sylvestris pollen in four young Pinus sylvestris seed orchards and in mature stands.

Locality	Sample stand no.	Year	Pollen/mm^2
Pinus sylvestris seed orchards			
Kyröskoski	-	1966	77
Korpilahti	-	1966	109
Oitti	-	1966	156
Sippola	-	1958	142
Mean			121
Mature Pinus sylvestris stands			
Vilppula	2 a	1966	144
Kuorevesi	XXIII	1966	274
Heinola	566	1966	222
Tuusula	XXIII	1958	332
			243

121/243 = 0,5

Investigations concerning the pollen dispersal of forest trees have revealed that isolation of a seed orchard against the pollen dispersed by the same tree species outside the orchards is a more difficult task than is commonly believed. Measurements carried out in reletively well isolated Pinus sylvestris seed orchards have shown that the outside pollen amounts to about 1/3—1/2 of the amounts measured in pure, mature stands (cf. Sarvas 1967a, p. 340).

To isolate a seed orchard to some extent, is by no means an impossible task. The physiological isolation brought about by transfer to the south was touched upon above. By establishing a sufficiently large (at least 5 hectares in area) seed orchard on a fertile site, the pollen production of the orchard can be improved to such an extent that outside pollen will be of little significance in the pollination. It would also be well to arrange a 300 to 500 metres wide isolation belt consisting of a different tree species.

The shape of the orchard is also of importance. With a view to efficient pollination, the seed orchard should be designed as isodiametric as possible; and it is expressly the isodiametric portion of the seed orchard that the 5-hectare minimum requirement stated above refers to. Furthermore, it is necessary to reserve a treeless belt-area around the seed orchard. (The width of this area should be at least about one and a half times the height of the trees on the edge of the orchard). This area, the object of which is to prevent the clones on the edge of the orchard from beign shaded by the surrounding stand and to eliminate root competetion, must not be confused with the isolation belt.

When deciding on the location of the seed orchard, harvesting, i.e. seed collecting should also be considered. It is obvious that seed collecting will involve the use of mechanical devices. On account of this, the site to be chosen for a seed orchard should be almost level or slightly rolling with little or, preferably, no rocks. If there happen to be rocks on the site, they should be removed before the planting of the orchard is started. Large stubs should also be removed or destroyed.

Also, all the necessary tasks for the upkeep of a seed orchard including cutting of grass, spreading of fertilizer, and spraying of insecticides, are easier to carry out on a level terrain.

In addition to facilitating seed collecting, a level seed orchard site is advantageous in other respects, too. Microclimate can be measured and the active periods of the clones included in the seed orchard can be determined much more easily on a level than on a heavily rolling terrain. On a level tarrain, even one meteorological station is enough for the measurement of the microclimate within a large area, whereas on a rolling terrain, it is necessary to have several stations, and yet the results may often prove unsatisfactory.

Clone Structure of Seed Orchards

In the foregoing, the clone structure of seed orchards has been touched upon from the pollination efficiency point of view and it has been established that certain important restrictions are necessary. For instance, the so-called provenance seed orchards, in which plus tree clones originating from areas with an essentially different climate are combined, are not likely to answer the purpose, biologically, except in a few special cases. They can, of course, be established but wind-pollination will hardly function satisfactorily.

In the 1930's and 1940's when the seed orchard idea was first being developed, it was considered that the number of clones to be combined in a seed orchard could be quite small. Later on, however, various view points have spoken in favour of increasingly large numbers of clones. It would seem difficult to determine by any objective methods the minimum number of clones required. Generally, the minimum requirement decided upon has varied from about 30 to 50 clones. These figures apply, however, to sanitized seed orchards. It is reasonable to assume that as a result of the progeny tests or, maybe, earlier, on the basis of clone tests and following the checking of the phenotype of the seed orchard it will prove necessary to remove about 1/3 or 1/2 of the clones originally planted. When establishing a seed orchard it should be borne in mind that the clones remaining in the seed orchard after the sanitation will have to number 25 to 30 and that the original number of clones must, therefore, be correspondingly larger, i.e. 35—100 clones.

The principle of a seed orchard embodies the idea that all the clones should stand an equal chance of becoming pollinated by one another. In order to realize this idea to the highest possible degree, it is necessary when the clones are being planted to intersperse them with one another as completely as possible. The practice is to divide the planting-site into blocks large enough to provide space for one graft from each clone and to allow them to be spaced in accordance with the plan agreed upon. The location of each graft in the block is chosen randomly or the grafts are planted in the order they are lifted. It is prerequisite for a system of this kind that each clone to be included in the seed orchard can provide the same number of grafts. This condition is also important on account of the fact that it prevents clones that for some reason are more easily grafted than others, from becoming over-represented in the seed orchard.

It is not possible to state accurately the spacing to be employed. The number of the grafts remaining in the seed orchards after the sanitation should not be less than about 200 to 300 per hectare. If it is estimated that about one third or a half of the grafts originally planted will in the process of sanitation be removed, it is necessary to start with about 300 to 600 grafts per hectare. The spacing should be 6 to 4 metres. 5 meters may be considered a recommendable average spacing. In view of the usage of machinery, 4 x 6-meter and 4 x 7-meter spacings can also be recommended, but even 5 x 5-meter spacing provides satisfactorily elbow room.

As soon as the planting has been completed, the clones involved should be mapped. The scale to be employed is 1:250. The position of each graft should be marked with a small ring on the map and the No. of the plus tree concerned should appear beside this ring. The north compass point and the scale employed should be indicated. In order that the seed orchard may readily be located the map of the clones should be provided with an index map indicating clearily the site of the orchard and the roads leading there. This index map should also show the isolation belt of the orchard, even if the belt should then be only at the planning stage.

The map of the clones should be appended to the registration documents along with a "Description of the clones included in the seed orchard" stating the most essential measurements concerning the clones.

SEED ORCHARD'S UTILIZATION AREA

The term "Seed Orchard's utilization area" refers to a geographical area that can be delimited on the map and within which the usage of the seed produced by the seed orchard is recommended. It should be noted that it is possible and even desirable that the utilization areas of the different seed orchards should partly overlap one another.

It should be emphasized that the principle employed in Finland differs from the one adopted in many other countries. According to that principle the entire area of a country is beforehand divided into seed areas and for each of them a sufficient number of seed orchards are established. Although this system at first appears very logical and is, no doubt, practical, it must be considered to have one drawback: it does not do justice to the cline-structure of the geographical races of forest trees. A state-wide seed area division easily leads to a situation where there are adequately or even plenty of seed orchards well serving the centers of the seed areas, and few, if any, of those taking care of the transitional areas. And yet the total of the transitional areas is at least as large as that of the centers.

In practice, the most important difference between the two methods is that in the one applied in Finland, the same parent tree can be used, at least in theory, in several seed orchards and it can thus serve many utilization areas, whereas in the other, a certain plustree serves only a given utilization area.

It has been established above that a seed orchard combining clones with greatly differing active periods cannot function as a flowering physiological whole. The limits that should not in this respect be exceeded have also been stated. Flowering physiology is thus the factor that determines how large an area can be served by a single seed orchard. In pracatice the boundaries of the area are determined in the following way:

First, the average annual heat sum ($\bar{x}_n$) of the habitat of each plustree combined in the seed orchard should be obtained by interpolation, for instance, from the new heat sum map prepared by Kolkki (unpublished), Fig. 6 (the isograms referring to sea level) and, considering the heat sum gradient 1.1 d.d/m. Those places, the average annual heat sums of which deviate from this less than 6 % make up the utilization area of the seed orchard concerned. An exception is, however, constituted by the seed orchards that serve the northern transitional zone and the northern marginal zone of Pinus sylvestris. The most recent investigative results indicate, furthermore, that greater restrictions than have been previously regarded as necessary must also be imposed on the seed transfer in the east-west direction.

When a seed orchard is registered, a description and a map (scale 1: 4 000 000) of its utilization area should be appended to the registration documents. In addition to the boundaries, the map should indicate the growing-sites of all the plus trees combined in the seed orchard. The sites should be marked with small rings; beside each of these rings should appear the No. of the plus tree concerned and the altitude of the growing-site measured form sea level.

CARE OF SEED ORCHARDS

The care of seed orchards involves various tasks designed to help bring about a heavy seed crop as soon as possible.

In newly-established seed orchards, the most important tasks are, no doubt, the cutting of grass and removal of sprouts. This may be done in the entire area or within a radius of about 2 meters from each graft. Cutting the grass from the entire area is advantageous in that it deprives moles of their protection against a multitude of enemies and is thus conductive to the reduction of the stock of moles. The grass should preferably be cut twice a summer. The first cutting must take place before the end of June, preferably as early as the middle of the month.

Fertilization is probably the most efficient way to force the development of grafts. It is not started until 2—3 years after the planting of the grafts. Point-fertilization is to be preferred in the beginning. As to the brand of fertilizer, Oulu sapleter is recommendable and the amount is 20 grams per graft (= 5 grams pure nitrogen, 1/2 ammonium nitrogen and 1/2 nitrate nitrogen). Fertilizer is spread on about a 0.5 m^2-area around each graft. It should be noted, however, that no fertilizer should be applied within a radius of 5—10 cm. from the stem. The time best suited for the application of fertilizer is between May 15 and June 15 and the application should be repeated every third year. As soon as the grafts have reached a height of 2–3 meters it is necessary to spread fertilizer on the entire orchard site. The brand to be used is Y-forest fertilizer and the amount is 350 kilos per hectare. The fertilization should be repeated every third year. The question naturally arises in this connection whether there might exist a special fertilizer combination which would further flower production in particular. Rohmeder (1959, p. 200) suggests that potassium phosphate might be one. Studies in Finland have, however, been unable at least so far to corroborate this view.

Protection of seed orchards against various destructive animals and insects involves a great deal of work. The worst devastators include moles and Lophyrys spp. In Pinus sylvestris seed orchards, snow blight (Phacidium infestans) and Melampsora pinitorqua also causes serious damage. Methods designed to prevent damage of this kind will be dealt with in another connection.

As is well known, in other contries some scientists claim, others do not, that appropriate clipping of grafts is conductive to an improvement in flowering abundance and that seed collecting will also in due course be simplified thorough this operation. In Finland, cutting has so far been done exclusively to secure scions for grafting purposes and it has been established that at least the removal of scions from the lower branches of the young grafts in the orchard has lowered the vitality of the trees involved. Secondary grafts should therefore be derived from plus tree collections expressly established for that purpose. Although the removal of scions and the cutting of grafts for the benefit of flowering are seemingly somewhat similar operations, there is an essential difference between them. When cutting grafts for the benefit of flowering, it is necessary to remove only the terminal buds of a few main branches. The actual assimilation surface is thus not appreciably affected by this operation. The removal of scions, again, if large numbers are involved, interferes seriously with the assimilation mechanism. Observations made in recent years have revealed the surprising fact that even the cutting of seemingly insignificant number of green shoots definitely has a lowering effect on the vitality of the grafts. Also, the grafts thus affected have subsequently proved susceptible to hazards of various kinds.

Arrangements should also be made for continual guard duty. Orchards might be exposed to unforeseen danger which can be averted if precautionary steps are taken in time; at least the amount of damage can be reduced. The person in charge of the measurements and observations can act as guard. He should have lodgings in the immediate vicinity of the seed orchard and, if possible, a telephone. If there are no lodgings there, it may be necessary to erect mobile barracks in the center of the orchard or just outside it.

Seed orchards will also have to be thinned. Sanitation based on genotypic and phenotypic testing is recommended. However, for reasons of flowering physiology, thinning will anyhow have to be done in due course; if it is left undone, the inclination for flowering will greatly decrease. Often, the first thinning must be done 15–20 years after the establishment of seed orchards.

MEASUREMENTS TO BE MADE IN SEED ORCHARDS

Although seed orchards are mainly established for the production of genotypically valuable seed, they also serve as a source of information valuable in connection with the efforts that are being made to increase the degree of genetic improvement. This is mainly due to the fact that seed orchards can, at least to some degree, serve as so-called clone tests and that they provide an opportunity to carry out concentrated and otherwise rationalized crosses necessary for the determination of the genetic value of plus trees.

Clone tests afford an opportunity to check on the phenotypic choice of the plus trees. In about 10-year old seed orchards and plus tree collections it may become obvious that, with regard to their reaction norm, some plus trees are likely to have a greater tendency to branchiness than was expected when the plus trees concerned were chosen. Among the first measurements to be made in seed orchards are those concerning the thickness and length of the branches of the grafts. These measurements are made according to separate instructions. The principal rule is that the thickness (at base) and the length of the three thickest branches of each graft are measured: the dominant thickness and the dominant length of the branches. At the same time, observations should be made concerning the grafts' susceptibility to diseases: evidence of diseases such as pine blister rust (Cronartium pini), shoot rust (Melampsora pinitorqua), snow blight (Phacidium infestans) etc. should be recorded.

Plus trees have an additional important phenotypic trait which can be clarified more reliably in seed orchards than in original plus trees (ortets). This trait is the genetic inclination for flowering in which respect plus trees differ greatly from one another. The inclination for flowering is, of course, an important and also a very favourable trait from the improvement technique point of view. However, from the genetic gain point of view, the inclination for flowering may not be a favourable trait; on the contrary, it might be a negative.

Since the inclination for flowering is a trait of great importance, it is necessary to have numerical information on it in respect of each plus tree. It can best be obtained by keeping records of the flowering abundance of each clone included in the seed orchard. It should be noted that it is expressly the flowering abundance that is to be recorded, since, for instance, in Pinus sylvestris seed orchards where the pollination is, at least in the first decades, poor, the cone crops only poorly reflect the true flowering abundance. It is the responsibility of the Seed Registry to organize the keeping of these records.

In clarifying the active period of plus trees, a program is followed which differs somewhat from the one worked out for the measnrements referred to above. A prerequisite for this is a precise knowledge of the heat sum curve of the seed orchards involved. Thus, the active period of plus trees can be clarified only in those seed orchards where temperature measurements are being carried out at crown level. Separate instructions are provided concerning the observations to be made in connection with the measurements of the active period. The length of the active period is one of the plus trees' most important measurable phenotypic traits and acquiantance with it greatly facilitates the programming of the tasks to be performed in seed orchards in connection with artificial crossings which are necessary in view of genotypic testing of plus trees. Another physiological trait, closely connected with the length of the active period, is the length of dormancy (dormancy II, to be exact; cf. Sarvas 1970). Seed orchards (and plus tree collections) obviously afford the best opportunities for performing measurements on this parameter, too. More experimental physiological evidence is nevertherless needed before large scale measuruments are feasible.

In seed orchards, certain clarifications concerning the genotype of plus trees can and, in fact, will have to be performed as early as a few years after planting. These include clarification of the lethal load of plustrees and clarification of the general combining ability by the polycross method.

By lethal load is meant the frequency of recessive lethal genes. For instance, in Pinus sylvestris and Picea Abies, lethal genes are so numerous that they cause about every fourth fertilization to end in embryo abortion. Different plus trees differ greatly from one another in respect of the lethal load. It seems that plus trees with light lethal load afford a more gratifying starting point for tree breeding than plustrees with heavy lethal load. As indicated above, a light lethal load is generally conducive to a higher fertility rate. Furthermore, every kind of breeding where selfing is employed as the technical agent is successful only with plus trees with a light lethal load.

In this connection it may be reasonable to establish that a heavy lethal load, which is apt to intensify gene exchange in natural populations, is from the evolution point of view a favourable factor. Yet, from the tree breeder's point of view it seems to be a negative factor. The tree breeder has other means of taking care of the efficiency of gene exchange; he actually wishes to control gene exchange to suit his own plans. Evolution operates with a long-range aim, i.e. millions of years, while the tree breeder may be concerned about only a few hundred years. All in all, lethal load is an important genotypic trait which should be individyally clarified in respect of each plus tree. For the clarification of the lethal load it is necessary to take x-ray photographs of seed produced by outbreeding and to determine, on the basis of these photographs, the relative frequency of embryo abortions. Separate detailed instructions are available for the determination of the lethal load. Clarification of the lethal load is the responsibility of the breeder of the species involved.

It is characteristic of the majority of conifers that they produce female flowers at an earlier age than they produce male flowers. This is also true of Pinus sylvestris seed orchards. As early as a few years after the establishment of seed orchards, they may be found to contain a fairly large number of female flowers, whereas there will be hardly any male flowers. At this stage of development, seed orchards are comparatively easy to castrate (to remove the male flowers). When a seed orchard has been castrated, all the seed produced by it is a certain kind of polycross seed. On the average, they are pollinated by the same father, the approximate genotypic composition of the wood lands surrounding the seed orchard. Selfing and inbreeding have been completely eliminated. Seedlings produced by polycross seed of this type are well suited for the determination of the general combining ability of the plus trees. It does not, however, provide any information on the special combining ability of the different clones. However, since only the general combining ability of the plus trees can be utilized by the seed orchard method, very much will, no doubt, have been achieved, if it is possible through such a simple and inexpensive procedure, as the polycross method, referred to above, to obtain a picture, if only an orientative one, of the general combining ability of the plus trees composing the seed orchard. The method is put into practice in the following manner: As soon as the male flowers begin to appear they are picked off. Later, when the seed has matured, all the cones that have been produced as a result of open pollination are collected and the seed is stored for polycross progeny tests. The tasks necessitated by the polycross method, i.e. castration, collection of cones, seed analyses, and progeny tests should be planned and performed by the breeders of the tree species concerned.

When applied in the manner prescribed above, the polycross method embodies one serious weakness: in the population surrounding a seed orchard is a very significant annual variation in the average genotypic composition of the pollen. In different years flower genetically different fractions of the population. In some years may flower only trees with short active periods, in others, again, in addition trees with long active periods, and so forth. On account of this, it is necessary to repeat the polycross method in a sufficient number of years and the seed must not be sown in the progeny tests until the surrounding population participates, to the greatest possible extent, in the pollination, as fathers. Where a seed orchard is located considerably further south than the habitat of the plus trees, the condition mentioned last cannot be met at all. This may already have become apparent from what has been stated above (flowering physiological isolation). However, under these circumstances, it must be considered an advantage that in the population surrounding the seed orchard, only the fraction with short active period can be father. When a seed orchard has been transferred outside (to the south) of the utilization area of the plus trees used for it, polycross tests based on open pollination have to bee checked by means of polycross tests based on controlled pollination.

REGISTRATION OF SEED ORCHARDS

The main object of seed orchard registration is to protect the interests of land owners. It is, therefore, desirable and, perhaps, even necessary that the registration takes place in an office that is as neutral as possible, i.e. in one with no interests in a business dealing in seed or seedlings.

For the time being, the registration takes place at the Forestry Research Institute, Department for Tree Breeding, and is carried out by a special team. This team, its archieves and the research equipment placed at its disposal form a whole called the Genetic Registry. The head of the Department for Tree Breeding nominates one member of the team to supervise the operations of the Genetic Registry.

By the owner of a seed orchard is meant a corporation or private person in control of the orchard concerned.

When the owner wishes to have his seed orchard registered, he should send in an application to the Genetic Registry. Forms for this purpose are available at the Registry. The applications should be accompanied by a map of the clones, in triplicate, and a list of plus trees, in triplicate. On completion of the registration, one copy of each document will be sent to the owner of the seed orchard, one filed at the office of the Registry and one stored in a place of maximum safety. Furthermore, the Registry will draw a map (in triplicate) of the utilization area of the seed orchard and issue a calculation (in triplicate) clarifying the grading of the seed orchard: one copy of these documents will be attached to each of the sets of documents referred above. The cost incident to the registration is defrayed from Government funds granted to the Forestry Research Institute for this purpose.

The owner of a registered seed orchard is entitled to identify the quality of the seed collected form his orchard by the grade mark assigned to it by the Genetic Registry, and it should be preceded by the phrase "officially registered", e.g. Officially registered Bl-seed.

Seed orchards are divided into three grades, i.e. A, B, and C, in accordance with the genetic grade of the seed crop they are expected to yield. A represents the highest and C the lowest, grade. When seed orchards are being graded, they receive points in accordance with their ability to meet the standard requirements prescribed for seed orchards. The main characteristics to be considered are: 1) Phenotypic selection of plus trees and 2) Flowering efficiency. The maximum number of points that can be given for each of these characteristics is 3. Consequently, the total maximum number of points a seed orchard can receive is 6. The distribution is: Grade A, 6—5 points, Grade B, 4—2 points, and Grade C, 1—0 point.

Points are given on the basis of the following:

1. Degree of phenotypic selection of plus trees: Each plus tree included in a seed orchard is individually rated with regard to the degree of its phenotypic selection and is given on the basis of this rating 0—3 points. Then the mean value of the points given to the individual plus trees is calculated.

2. Seed orchard's flowering efficiency: In rating orchards in this respect, the following factors are taken into consideration:

a) Synchronization between the active periods of the clones
b) Effect produced by transfer southward
c) Size of seed orchard
d) Isolation of seed orchard.

Each one of these factors is given 1—3 points according to the principles stated below:

a) Sychronization between the active periods of the clones: When all the clones in the seed orchard meet the synchronization reguirement specified in the present instructions, the score is 3; when 90 % of the clones meet this requirement, the score is 2; when 80 % meet the requirement, the score is 1, and when less than 80 % of the clones meet the requirement, the score is 0.

b) Effect produced by transfer southward: Where the transfer represents an increase of more than 200 d.d. in the average annual heat sum, as compared with the average annual heat sum of the locality of the plus trees, the score is 3; where the increase is 150—200 d.d., the score is 2, and where 100—150 d.d., the score is 1, and where the increase is less than 100 d.d., the score is 0.

c) Size of seed orchard: When the area of a seed orchard is in excess of 5 hectares, the score is 3; when a seed orchard is between 3—5 hectares in area, the score is 2; and when between 1—3 hectares, the score is 1, and when the area is less than 1 hectare, the score is 0.

d) Isolation of seed orchard. In rating the isolation of a seed orchard, attention is paid to the local freqyency (within a 10-km. radius from the orchard) of the species involved as well as to the width of the isolation belt. These factors are given 1—3 points each and then the mean value of the scores is calculated. The points are given on the following bases:

1. Local frequency of the species involved. Where the frequency is below 30 %, the score is 3, where 30—40 % the score is 2, and where the frequency is 40—50 %, the score is 1. If the frequency exceeds 50 %, the score is 0.

GRADING OF A SEED ORCHARD

Seed orchard 21 — Pinus sylvestris

Locality : Korpilahti — Origin : Tornionlaakso

			Points
1. Degree of phenotypic selection			0,9
2. Flowering efficiency			
a. Synchronization of the active periods all clones from the region	< 1025 dd	3	
b. Effect of the transfer	260 dd	3	
c. Size of seed orchard	4,8 ha	2	
d. Isolation			
- local frequency of pine	30–40 %		
- width of isolation belt	500 m		
5 divided by 2 = 2,5		2,5	
		10,5	
10,5 divided by 4 =			2,6
Total			3,5

Grades

A 5 - 6 points

B 2 - 4 "

C 0 - 1 " — Seed orchard belongs to the grade B

Fig. 9. Example of the grading of a seed orchard.

2. Width of the isolation belt. Where the isolation belt is wider than 500 meters, the score is 3, where between 200–500 meters, the score is 2, and where between 100–200 meters, the score is 1. If the isolation belt is less than 100 meters in width, the score is 0.

So far, there are in Finland no official regulations concerning the grading of the genetic quality of forest tree seed. However, the Seed and Seedling Counsil for Forestry (an unofficial coordinating organ) approved on March 2, 1966, that the classification given in Appendix 1 be used for the present. It is the same in its principal features as the classification previously adopted in Sweden (Kungl. Skogsstyrelsen 1950). According to this system, the seed collected from orchards established on the basis of phenotypic selection is graded A3. The grade mark referred to above indicating the genetic standard of a seed orchard is incorporated into this sign as a subindex. For instance, seed collected from an orchard that on the basis of its genetic standard has been classified B, is marked: officially registered A_b3-seed.

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1 enclosure

SEED CLASSES

A. Special seed

A 1. Elit seed (genetic superiority established by means of progeny tests)

A 2. Seed obtained by controlled crossing

A 3. Seed orchard seed

A 4. Plus-tree seed

B. Stand seed

B 1. Plus-stand seed from sanitised plus-stands

B 2. Plus-stand seed, stand officially registered, not sanitised

B 3. Seed from normal stands of known origin, not registered, not sanitised. Best controlled seed collections from cutting areas

B 4. Seed of known origin. Average controlled seed collections from cutting areas. Uncontrolled seed collections from cutting areas, the origin of which is known by parish

C. Seed of unknown origin or seed from minus-stands

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