HOW MUCH FOREST TREE IMPROVEMENT CAN WE EXPECT FROM GENETICAL METHODS

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In my discussion under genetical methods, I will include various approaches which can be classed under the broad terms of "genetics", "selection", "breeding", or "tree improvement". In my interpretation, genetical methods include all the approaches which recognize variation below the species or variety level. Included are those which, through judicious selection practices the worker chooses either one or both parents, and those which attempt to manipulate the germ plasm and induce permanent genetic changes in an individual.

The "genetic" methods used in forest tree improvement can be divided into three main categories. The first is based on the recognition and multiplication of existing superior germ plasm. In the second category we have those methods which intensify or combine desirable traits into one individual. These desirable traits can exist in various individuals of the same species or in individuals of different species. In the third category we have those methods which develop new types (genotypes) with the help of mutagenic agents.

I would like to consider the various methods, briefly discus their extensive and intensive applications, and speculate on the type and amount of improvement one can expect. It is very difficult at this stage to made sound economc predictions because tree improvement is still in its infancy and only very limited basic knowledge has been accumulated.

I. Multiplication of Existing Superior Germ Plasm

The first methods I would like to consider are the silvicuitural systems which are based on natural regeneration from seed. In discussing the improvements to be gained in natural regeneration, one has to be cautious in separating the recommendations made by a geneticist from those made by a forester who is practicing intense silviculture. If the final product is of high quality, such as sawlogs or piling, the geneticist's recommendations would be similar, or vary but little from those of the silviculturist. Both the silviculturist and the geneticist would leave the straightest and cleanest trees, which are free of disease, for future growth and as parents for the next generation. Unless carried out over many generations, it seems to me impossible to gain detectable improvement in growth over present existing stands. However, by selecting against minor diseases, susceptibility to which is controlled by one or a small number of genes, this type of selection should raise the level of resistance to that partic ular disease in stands so regenerated. Bass selection can also be beneficial by selecting for or against polyploid races as are found in white ash.

In these natural regeneration systems, we also should keep in mind that the male or pollen parent contributes one half of the germ plasm in the formation of the seed. So if the best parents are to reseed an area, the seed or regeneration cut should be preceeded by an improvement cut during which the culls are either cut out or poisoned, and thus eliminated as a possible pollen source. In pine forests, this should occur at least 2 years ahead of the regeneration cut.

From our experiments with the controlled pollination of forest trees we observed several facts which will be helpful in obtaining more and better seed. In most of the forest tree species tested, a decrease in viability of the seed was observed, along with a loss in vigor of the result ing seedlings, when a tree was pollinated with its own pollen. We also observed great lags in pollen shedding between trees growing immediately adjacent to each other. We should obtain significant benefits by leaving enough trees in a seed tree cutting for adequate cross-pollination between the seed trees. Adequate pollen dispersal can well be the factor which determines in some cases the success of natural regeneration.

There is ample evidence in American and European literature of the serious financial losses which occurred when no attention was paid to origin of seed source in artificial regeneration. Henry Baldwin's Scotch Pine plantations of which he and Jonathan Wright spoke yesterday, are an excellent illustration of the amount of variation which can be present in a species. Another striking example is the Bogalusa, La. loblolly pine seed source study. The trees from the local seed source at age 28 contained three times as much Pulpwood per tree as those from the Texas source, and about five times the volume of the average Arkansas trees. If we translated these figures into dollars and cents, we should run well up into the millions. By setting up a judicious seed purchasing; program, a forester can prevent sizable financial losses in his operations.

We know that such attributes as stem form, branching habit, strength, and disease resistance, to name just a few, are under genetic control. In a controlled experiment with slash pine, we observed that 76 percent of the progeny from a mother tree with an "S" - shape sweep in its bole, also had crooked stems. Even when used as a pollen parent, the resulting progeny had a significantly higher number of undesirable trees. This is by no means an isolated example. When seed is collected for artificial reforestation one should select against the undesirable specimens, rather than select for them. I grant you that without a. progeny test we do not know whether a deformed tree is also genetically poor. But why take chances, gamble against unfavor-able odds, and collect cones from these trees when the prospect of possible gains is lacking? Isolated trees should also be avoided during cone collection as they probably were not adequately cross-pollinated. The financial gains resulting from eugenic seed collection practices, which would include the recognition of variations due to geographic location as well as individual tree variations, should be quite sizeable.

Perhaps the seed procurement problem, and it is a serious problem indeed, can be alleviated by better planning. Cone collection or seedling purchases should be planned several years ahead. Reserve funds should be set up to enable cone collectors to take advantage of bumper seed crops which could be stored until needed. Rush purchases should be avoided whenever possible. The planting programs should be trade flexible so that changes can be made if satisfactory seed or seedlings are not available.

To minimize the effect of poor seed crops under natural conditions, and to insure a more regular seed supply, seed production areas should be established. These are stands which are managed solely for the production of high-quality seed. I helped to set up such an area in a slash pine stand. The area is 86 acres in size, and it is expected that the pulpwood company which owns and manages the stand will collect 2000 bushels of cones in a good year. It will assure seed of known origin, from selected parents, at a lower cost than seed bought from cone brokers.

The approaches described so far are classed under extensive methods and can be incorporated in progressive management programs without delay. Those which follow can probably be classed under intensive methods.

A standard method in other phases of agriculture is to multiply individuals by vegetative means. This method of multiplication can also be used with outstanding forest trees, such as some of the poplars, which strike roots without difficulty.

Collecting open pollinated cones from isolated selected trees, growing over a large area, has often been proposed as a way of obtaining large quantities of superior planting stock. One drawback of this method is, that if wind pollinated cones are collected, nothing is known about the male parent. Unless the desirable character for which the mother tree was selected is under strict genetic control, or is controlled by a dominant gene, little benefit will be obtained from this approach. The outcome of our studies with high gum yields in the naval stores pines illustrated this point very nicely. Open pollinated cones were collected from outstanding mother trees, some of which yielded more than twice the average of similar trees in the same stand. A progeny test showed that some benefit can be derived by this method. However, the increase in yield was very small. From an economic standpoint this method is not recommended, unless it has been determined that the desirable trait has a very high value for heritability. This approach, however, can be carried out by personnel having limited technical training and without delay. It should be used, by all means, at the start of a new program to find out about the heritability of a trait. With certain traits such as rubber yield, resistance to Mimosa wilt, form in slash pine, and possibly growth rate in locust, it has given good results. If applicable, this method can produce superior trees at a relatively low cost.

II. Combination of Desirable Traits Already Existing in Various Individuals of the Same Species or in Individuals of Different Species

The method of crossing selected individuals of the same species to maintain or multiply these desirable individuals, or intensify their desirable traits, forms the basis of many crop breeding and forest tree breeding programs. This method is especially effective when the "superior" trees were selected from a variable population because they were outstanding in a single trait, and when the standards of selection were relatively high. It is understood, of course, that the desirable character must be under genetic control. A good example of this promising approach is selection and controlled crossing to multiply disease resistant individuals of the same species. To cite a numerical example of the resits which can be obtained by this method, I will refer to the breeding of slash pines for high gum yield. One of our progeny groups, where both parents were outstanding gum producers, yielded on the average 1.8 times the amount of gum of similar-sized progeny from open pollinated average trees, and 2.5 times that of trees where both parents were average trees. One outstanding tree resulting from a controlled cross produced 5 times the amount of a similar-sized tree in the average X average cross. Practical steps have been taken, and clonal graft seed orchards have been set up, to obtain larger quantities of these improved crosses. The results just cited were obtained by careful selection for one single outstanding trait in a highly variable population. I am sure that similar examples can be observed for insect and disease resistance, sugar content in maple, and.other traits which are based on quantitative factors. If trees are selected for a multitude of superior factors, the selection phase has to be intensified, and the improvement will be slower unless there is some linkage between the desirable traits.

Very often one finds individual trees which are outstanding in one single characteristic, e.g., resistant to blister rust, but have an undesir able form from a lumber standpoint. In such instances it has been the practice to cross them with desirable timber trees, and combine into one individual the desirable traits of both.

The benefits derived through this type of selective intraspecific breeding will be particularly rewarding because the risks involved in this type of breeding are small. This approach can be used to intensify certain traits and obtain a greater percentage of superior progeny. The risks of failure in producing and testing the resulting progeny will be small, because there is a minimum of incompatibility between trees of the same species, and the resulting progeny should be well adapted to the local growing conditions. Consequently, seed orchards for random pollination with clones of the selected parents can be established at the very beginning of a program, and the harvested seed can be used for testing on a commercial scale. There should be a large enough number of clones present in the orchard to prevent a pauperization of the gene pool. These orchards can supply seed while the critical progeny testing of the selected parents takes place. As the results from these tests become available, the grafts from the poorer genotypes and unproductive clones can be cut out. In the Northeast, forestry organizations are trailing behind those of the Lake States, the South, and the Pacific Northwest, in this approach to improved seed.

However, the Northeast has been doing a great deal of pioneering work in the controlled crossing of trees belonging to different species. In nature, cross-pollination occurs if two trees are close enough to each other for the pollen of one to reach the female flowers of the other, if the flowering cycles of the two coincide, and if there are no incompatibilities between the two. Under controlled conditions many of these "ifs" are overcome, and even some of the inherent incompatibilities can be minimized by embryo cultures. Many of our important forest tree genera are found over relatively large geographical expanses, e.g., the spruces, pines, or aspens. The diversity of climatic and edaphic conditions found within the range of these genera is enormous. Poplars are found from the Mexican forests and the forests of North Africa all the way up to the timber line beyond the Arctic Circle; and the pines, especially, are found under the most contrasting; site conditions. Within these genera we have great genetic diversity, such as resistance to a particular disease or insect, ability to withstand drought, rapid growth, and a whole gamut of crown forms, just to name a few features. This genetic diversity of individual desirable traits presents unequalled opportunities to theoretically breed almost any type of tree suited to a particular situation. Crossing of genetically unequal trees can be brought about between trees of the same species which are separated geographically, or between individuals of different species. From past studies we know that some of the resulting hybrid progenies were not superior to their parents, whereas other crosses yielded seedlings which showed great promise. Very often a hybrid can be of greater value without being superior to either of its parents, solely by virtue of having a wider reaction range for certain critical traits. In some of the promising hybrids the desirable traits of two or three parent species are combined, such as growth pattern and resistance to pests. The successful hybrid crosses between forest trees are too numerous to mention at this point. It may be pointed out, however, that through hybridization there have been developed poplars and pines with faster growth rate than their parents, longleaf pines which do not exhibit a "grass stage" and pines with a high resistance to insects and disease. Interspecific hybridization will not be the,cure-all for silvicultural difficulties, nor can trees be produced at will without research and experimentation. It is, however, a powerful tool, and we should fully realize the possible benefits of its utilization. The amount of improvement in our forests which is possible by this method is quite significant, but a great deal of research is necessary before its potentialities can be appraised objectively.

III. Develop New Types (Genotypes) with the Aid of Mutagenic Agents

The variations we observe in nature within a species and between species originated through mutations, sudden changes of the germ plasm. These chromosomal changes have a genetic effect and are incorporated into the variation pattern through segregation and recombination. We have two types of chromosomal changes. Submicroscopic chemical changes which affect a small part of the chromosome, and alter a single hereditary element, the gene. In the other type of mutation, one can observe distinct irregularities in the distribution pattern during meiotic or mitotic cell divisions. Entire chromosomes or pieces of chromosomes are added or lost from the chromosome complement. The normal number of sets of chromosomes in most of our trees is fairly consistent. Occasionally, and the frequency depends greatly with the genus, we have spontaneous mutations where the basic number of sets of chromosomes changes. For example, in tetraploids, the entire complement is doubled. In cultivated agricultural crops, such as wheat, this multiplication of chromosome sets is a powerful tool for their improvement methods. In forestry, the discovery of the triploid aspen or "giant aspen", which occur naturally in Sweden, stimulated a breeding schedule to produce large quantities of these rapidly growing trees for reforestation. The resulting progenies have not been too satisfactory, mainly, because of the great range of variation between the resulting triploids. Polyploidy induction studies with mutagenic agents so far have not produced any improvement in forest trees, on the contrary they introduced lethal factors or induced dwarfing.

It is the great hope of some tree breeders that they may produce amphidiploid by rids that will be true-breeding. In amphidinloidy, each set of chromosomes from the 2 parents is doubled in its entirety without change. As a result of this, functional. reproductive cells are formed which despite random assortment will not produce new combinations. It is hoped that a technique might be developed whereby amphidiploidy could be induced in outstanding hybrids. This would eliminate one of the serious problems in the large-scale production of outstanding hybrids. The commercial implications of such hybrids would be quite sizeable.

As mentioned previously, polyploidy induction studies with forest trees brought about a decrease in total growth. Although cell sizes were increased, the overall number of cells produced was smaller with a resulting decrease in total yield. From inferences of the studies in progress now with agricultural plants, it would. seem that there are great benefits to be derived not through altering the total number, or bringing about gross structural changes of the chromosomes, but through changes at a submicroscopic level. This is especially promising for induction of disease and insect resistance, factors which are determined very often by the quantitative occurrence of a certain chemical substance in the plant cells. The amount of these produced is affected by the action of a single gene on the biochemical (enzymatic) activity in plant cells. With the rapid advances in types and methods of irradiation, this approach to plant improvement will no doubt receive more attention in the future, and the chances of inducing resistance factors to certain pests in some of our valuable forest tree species are very promising.

Summary

To sum up my remarks on the possible benefits which can be obtained by genetical methods, I can honestly say that the economical returns should be quite sizeable. This is true for when a certain improved strain or true-breeding hybrid has been developed, the gains will not be temporary and cease to exist after the improved trees have been harvested, but they can be used during a theoretically unlimited number of years to restock our forests. Specialization in industry and management will force some of these forests to become regular timber factories, in which a high degree of cultural management practices, based on sound genetic principles, will be carried out. It should he the aim of research organizations to develop and assemble the necessary basic information so that the practical aspects of tree improvement will not get too far ahead of theoretical knowledge. Unless further basic knowledge is gained, much of the practical applied work, such as the practice of selection or the establishment of seed orchards, will not produce the results which were anticipated.

A method used by some psychologists to test inmates in an asylum is as follows. An inmate is let into a room, the floor of which is partly flooded by water which is running from an open faucet. A mop and a pail are are handed to him he is asked to dry the floor. If he starts mopping right away without turning off the water, he has to stay in for a while yet. If, however, he turns the water off before he starts to mop the floor, he has a good chance of being; considered for release. Perhaps we can learn something from this story which might apply to forestry. Rather than eliminate the cause for disease or other pests by developing trees resistant to disease, we think nothing of spending large sums of money to eliminate the pests themselves temporarily. We must realize that an improvement obtained through cultural methods is of a temporary nature, while improvement through genetic means will be permanent and beneficial to the coming generations.