CLONAL OR SEEDLING SEED ORCHARDS?

Ernst J. Schreiner[1]

We can expect considerable discussion of clonal vs. seedling seed orchards during the next few years; and in regard to genetic improvement of timber trees the arguments pro and con will probably be theoretical. The primary purpose of this paper is to point out that there is a source of information on the use of seed orchards over a long period of years that could be of great value to forest tree improvement- - if it can be tapped.

In past years I have been accused of being perhaps the only forest geneticist who has not recommended large-scale clonal seed orchards for the improvement of our native species. This lack of enthusiasm stemmed back to the middle 1920's, when I was a graduate student at Columbia University and read several papers on Cinchona culture in Java as part of a genetics assignment on breeding methods with horticultural trees. Later, in 1945, on an assignment in Guatemala to advise on Cinchona improvement, I had an opportunity to review a number of publications that had been translated for the Office of Foreign Agricultural Relations. This review strengthened my original suspicion that the improvement possibilities of clonal seed orchards are rather limited (7).

Although clonal seed orchards were the basis of the extensive quinine culture started in 1865 in the Dutch East Indies, there seems to be a mistaken notion among forest geneticists that this method was something new that foresters have invented within the past 40 years. Larsen (4), in his chapter on Seed-Gardens, does not mention the use or efficiency of clonal seed plantations for improving the production of

[1]In Charge, Forest Genetics Research, Northeastern Forest Experiment Station, U. S. Forest Service, Upper Darby, Pennsylvania. The forest genetics work is in cooperation with the Morris Arboretum of the University of Pennsylvania, Philadelphia, Pennsylvania.

quinine, Zobel et al (11), in their excellent and comprehensive discussion of the development of the seed-orchard concept, date their earliest historical reference from Bates, in 1928 (1); and in their literature cited (104 items) there is no reference to Cinchona.

Admittedly quinine culture is horticulture rather than silviculture. But the Dutch did start with progenies of a wild forest species, and the results attained since 1865 should be of interest to forest geneticists.

THE JAVA METHOD

Commercially successful quinine culture in Java started with the seed collected by Charles Ledger and purchased by the Dutch Government from his brother George in 1865, Approximately 20, 000 seedlings were grown from this seed at the Government Cinchona Plantations in 1866, and in 1872 a small amount of bark was harvested. Moens, the Station chemist (later Director), tested this bark and discovered that it was superior in quinine content to anything known at that time. The trees varied greatly in growth, bark characteristics, and quinine content even when grown under similar conditions; the quinine sulfate content of the trunk bark was reported to vary from 4 to 16 percent. From these original Ledger seedlings Moens, and later Romunde assisted by van Laersum, selected what they called "the strongest specimens" to establish clonal seed plantations. This was the beginning of the Java method.

In 1882 Moens (5 p. 331) recommended that all planters should select and vegetatively propagate the best trees for seed production in isolated plantations. The following quotation is from the translation of Moens book by J. C. Fagginger Auer:

> "From this may be derived, that in connection with the cultivation of Cinchonas most attention should be paid to the nature of the tree from which seed is won. Such trees should be chosen which represent botanically the type of species in the purest way and contain chemically the largest amount of alcaloid wanted, which is quinine, Furthermore hybridization should be prevented by isolating the excellent mother-trees as much as possible, All Cinchona-planters should follow the advice to try to obtain a few plants of the best Cinchona Ledgeriana variety. If one has one tree which contained f, i, more than 10 percent of quinine, a greater number can be obtained by means of cutting or grafting,. Such trees should be planted in a separate spot, as far away from other Cinchona - trees as possible, and later seed can be gathered from those stems, which has the additional advantage that grafts soon blossom, often within 2 or 3 years, This seed can be used for further cultivation and one can be certain that although a varying content will be found in the descendants, the average from all plantations will be certain to coincide with the content of the mother-tree."

According to Moens (5 p. 159, as translated by Fagginger Auer) some of the earliest selected Cinchona trees were multiplied by the method known for many years as marcottage, now called air layering by forest geneticists:

> "Often the branches, used as layers, are attached too high to the trunk or they are too brittle to be bent to the ground, Then the earth should be brought toward the branch., This method of making layers is very well known in Java, it is called tjangkok.

It is used generally by natives for the propagation of good specimens of fruit-trees. A ring of bark is removed from the branch and the cambium-zone destroyed, by rubbing it with the dull part of a knife. Then a clod of earth is put on the naked spot and fixed by tying some moss or indjoek around it, These tjangkoks have to be kept moist always and therefore have to be made at the beginning of the rain-monsoon. Apparently this method required a great deal of time in the Cinchona- plantations. While tjangkoks rooted in the warm lowlands in 6 to 8 weeks, in the cooler climate, where Cinchona is cultivated, 4 to 5 months were needed. As soon as the roots show through the moss the layers are cut off and planted first in pots or baskets and later in open ground. Already in 1857 Jugnhuhn had multiplied the first Cinchona-trees of Tjibodas by this method. "

Sands (6) mentioned the use of small isolated seed plots limited to two selected clones, one clone with long-styled flowers, the other with short-styled flowers. Under the heading "Seed-Gardens and Seed Production" he stated that, for the production of large supplies of C. ledgeriana seed on the government plantations, about 1, 000 grafted trees were grown in isolated seed gardens in the proportion of 8 long-styled types to 2 short-styled types. The large private estates used long- and short-styled types in the same proportion. Many strains of Ledgers (C. ledgeriana) were selected for particular purposes or characters, and the various types differed widely. In selection, strong healthy growth, erect stem and erect branching habit, size and color of the leaves, quinine content of bark, thick bark (provided quinine content was not below average), flowering age, and resistance to pests and diseases were the main considerations.

Strong healthy growth was regarded as especially important because some strains that grew well in one locality did not grow satisfactorily in others; for this reason estates in different districts had developed quite distinct types. A close and erect habit of growth was desired because such trees could be grown at closer spacings and thus provide a larger yield of bark per unit of plantation area, The age at which a tree flowered was considered important because early flowering was correlated with loss of vegetative vigor. Since the richest bark is produced 6 to 8 years after planting, trees that flowered early were not selected. (This early evidence of potential quinine production would also permit juvenile selection.)

A critical evaluation of original data and reports on genetic improvement of quinine in Java since 1872 could be expected to provide valuable guidelines for forest tree improvement, particularly with reference to the possibilities and limitations of seed orchards. Such data and reports may be available in The Netherlands, the headquarters of the Kina Bureau, and/or in Java. I do not have sufficient detailed information on methods and results to be certain how closely the design, progeny testing, and management of seed orchards on government and private plantations approached the procedures presently recommended for forest trees. It is possible that both clonal and seedling seed orchards were used in Java. And the only criterion that I have for guaging the practical success of the Java method is the average percent quinine in the bark from commercial plantations . Obviously, such figures may also reflect the effect of improved cultural methods.

The quinine sulfate content of the original Ledgers, tested for the first time in 1872, varied from 4 to 16 percent and averaged about 8 percent, Thirty-five years later, Detmer (2) reported that not infrequently the bark of mother seed trees produced 12 to 15 percent quinine sulfate. Production by the descendents of the seed orchards, however, was only moderately high. The bark of a good Ledger plantation averaged only 5 to 7 percent. In 1922, Sands (6) stated that a well managed plantation of selected types averaged about 8 percent quinine sulfate in the fifth year,. that later yields were not appreciably increased, and that as a general average 6 percent was a fair estimate. Sands' figures were confirmed by Spruit's report (8) that plantations capable of producing bark averaging 5 to 6 percent quinine sulfate may be considered very good. These may be good maintenance results, but they hardly indicate that the Java method resulted in improvement in quinine production. The original Ledger seed provided stocks capable of a sufficiently high average quinine production to make their culture profitable; but, until the early 1920's at least, the clonal seed gardens barely managed to maintain what Nature had provided.

WHICH TYPE OF SEED ORCHARD?

Theoretical mathematical evaluation of the genetic improvement possibilities of clonal seed orchards had to await the development of appropriate statistical models. Unfortunately my own mathematical training was not sufficient to develop such models; but this has now been done by my former colleague, Jonathan W. Wright. Wright (9, 10) has discussed the theoretical genetic quality and costs of clonal seed orchards, open-pollinated progeny tests, tests of selected parents x standards, and full-sib selection (2-parent progeny tests). He has also calculated the theoretical relative genetic gains to be expected from eight types of plantings including mass selection methods, family selection methods, and clonal seed orchards, and has noted that:

> "The genetic gains are less in seed harvested from clonal seed orchards than from the progeny tests which they accompany. This is because the clones belong to the parental generation. They are the same clones used to produce the superior family in the progeny test but there is no opportunity for practicing selection in two successive generations.'"

Goddard and Brown (3) also have discussed the genetical and practical aspects of clonal and seedling seed orchards. They have reported that:

> "... the tree improvement program of the Texas Forest Service in the spring of 1959 inaugurated a program of controlled breeding to (1) produce seedlings for immediate seed orchard establishment, and (2) initiate the first cycle of a method of breeding adaptable to wind- pollinated, heterozygous pine species. As in other programs, trees have been selected on the basis of desirable phenotypic characteristics. Pollen was collected from the selected trees, appropriately mixed, and used to pollinate each of the individual mother trees," The seedlings will be planted at close spacings, they said:
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> "...to permit the removal of approximately 90 percent of the population at the first thinning" and further, "... on the basis of first generation progeny performance, i.e., test for general combining ability, entire mother tree lines that are inferior may be eliminated. In addition, poorer phenotypes of the better lines may also be eliminated,"

Seed orchards of our important native forest trees certainly cannot be ruled out of the picture; they undoubtedly can be effective for maintaining and slowly improving genetic quality. The question to be considered is which type of seed orchard will be best as to costs and returns for both practice and research. In my opinion the odds are strongly in favor of seedling seed orchards. On the basis of Wright's models, seed orchards representing selection of the best individuals within half-sib families may be expected to provide the greatest relative genetic gain at costs that will probably be lower than for clonal seed orchards. And the use of full-sib families would provide the greatest relative genetic gain at costs that might still be commensurate with maximum practical seed- improvement objectives. In addition, this is the only procedure that will provide exact information on the mode of inheritance, Clonal propagation of superior phenotypes (plus trees) should be continued on a small scale for research and for the preservation of germplasm that may be useful in a breeding program.

Seed orchards are necessary; they represent good forest management. With reference to their establishment and maintenance costs, we must not overlook the fact that commercial production of seed from a well-managed, easily accessible orchard probably will be cheaper than collection in the wild, with the possible exception of seed collected on logging operations. But in view of accomplishments in this scientific age, even the most efficient types of seed orchards may give us only a horse-and-buggy ride along the road to maximum genetic improvement.

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