STRATEGY FOR THE DEVELOPMENT OF CONSERVATION BANKS AND BREEDING PROGRAMS FOR CONIFEROUS SPECIES FROM CENTRAL AMERICA AND MEXICO

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Abstract.--The urgent need to save populations of coniferous species in Central America and Mexico led several private forest industries in North and South America to form the Central America and Mexico Coniferous Resources Cooperative (CAMCORE) at North Carolina State University in 1980. In 1982, CAMCORE collected seed from over 800 selected trees in Guatemala and Honduras of 5 species: *Pinus tecunumanii*, *P. oocarpa*, *P. ayacahuite*, *P. pseudostrobus*, and *P. caribaea*. In 1983, collections will include 7 species of conifers, some of which are extremely endangered and have never been tested on a wide scale (e.g. *Abies guatemalensis*). Seed from these collections are planted on Cooperative members' land in conservation banks and provenance/progeny tests. The conservation banks are designed and managed as specialized breeding populations based primarily on site adaptability traits. Long-term breeding strategies are being developed to fully utilize this valuable genetic material for future generations. The provenance/progeny tests serve to locate the best provenances and families for further testing and development of adapted land races. Provenance x environment and genotype x environment interactions will be monitored in the provenance/progeny tests, which in the future, will be established on as many as 24 sites throughout Mexico, Central and South America, and Africa.

Additional Keywords: Conservation banks, multiple breeding populations, provenance/progeny tests, endangered species

INTRODUCTION

More coniferous species and varieties can be found in Mexico and Central America than in any other region of similar size in the world. Over 70 species, varieties, and forms of pines alone have been identified in this region (Jasso, et al., 1978). New coniferous species are still being identified in Mexico and Central America, and as more of the pieces of this evolutionary puzzle fall into place, species and varieties originally assigned to one taxonomic complex will be reclassified and placed in more appropriate taxonomic

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groupings. The complex evolutionary puzzle is far from complete because species are still in the process of developing through intensive natural selection under a wide range of environmental conditions. The continuing process of speciation makes coniferous regions in Mexico and Central America some of the most genetically diverse in the world.

This tremendous genetic diversity of forest populations in Mexico and Central America gives foresters the opportunity to select and test a number of promising species and provenances to find those which are best suited for commercial plantations and reforestation programs in tropical and subtropical regions throughout the world. Many forestry organizations with low-elevation land in tropical regions currently plant thousands of hectares annually of Pinus caribaea var. hondurensis and Pinus oocarpa, species native to Mexico and Central America. Species from mid-elevation regions (1500-2000m) in Mexico and Central America such as Pinus patula and Cupressus lusitanica have also proven successful, as exotics, in parts of South America and Africa. Other species and varieties will undoubtedly prove valuable in exotic plantations and local forestry programs in the future.

Unfortunately, with each passing year, the chances diminish to test and utilize promising forest populations of endangered coniferous species from this region. The loss of these valuable genetic resources result from an onslaught of fuelwood cutters, shifting agriculture practices, sawmill activities, uncontrolled fires, over grazing, and disease and insect attacks (Gallegos, et al., 1980). A decade ago, 70% of all families living in Guatemala used wood as their main source of fuel (Venator and Munoz, 1974). As a result of the increased population pressure and the high cost of petroleum, the demand for wood is even more intense today. It has been estimated that the pine forests in Guatemala are being reduced at the rate of 2.5%/year (Plant Resources Institute, 1981).

Are entire species and provenances in danger of being lost? In some cases, yes, especially in the fertile highland regions of Mexico, Guatemala, Honduras, and El Salvador. The need for more land on which to produce crops to sustain increasing populations requires conversion of forests to farm lands (Veblen, 1978). For example, Pinus tecunumanii stands are being methodically clear cut by farmers to make way for the planting of annual crops in the mountains of Guatemala and Honduras. Only small stands of several hundred trees still remain in some areas. Provenances of Pinus ayacahuite and Pinus pseudostrobus are also in danger of being lost in the highland areas.

Complete loss of a species or provenance is usually not the problem. The most common occurrence in Mexico and Central America is the reduction of forest populations into groups of remnant, highly degraded stands that retain little value as a source of genetic material for productive forestry programs. The disastrous reduction of these gene pools jeopardizes the chances for finding well adapted species and provenances for the marginal areas now being used for reforestation and plantations in the tropics and subtropics.

In 1980, several progressive forest industries from North and South America: Aracruz Florestal (Brazil), Cartón de Colombia, International Paper Company (U.S.A.), and the Weyerhaeuser Company (U.S.A.) began an immediate action program to preserve genetic material of coniferous species in Central America and

Mexico. These organizations formed the Central America and Mexico Coniferous Resources Cooperative (CAMCORE) at the School of Forest Resources, North Carolina State University. Between the time of its formation in mid-1980 to 1983, the Cooperative has grown to include ten active members from both the private and government forestry sectors in Brazil, Colombia, Venezuela, South Africa, and the United States, three honorary members from Central America and Mexico, and one contributing member (see Table 1). Initial conservation work began in Guatemala (1980) and expanded to include Honduras (1982) and Mexico (1983).

Table 1--Members of the CAMCORE Cooperative

Active Members	
Aracruz Florestal (Brazil)	EMBRAPA/IBDF (Brazil)
Cartón de Colombia	Jari Florestal (Brazil)
Cartón de Venezuela	PIZANO/Monterrey Forestal (Colombia)
CONARE (Venezuela)	South African Forestry Research Institute
COPINUS (Brazil)	Weyerhaeuser Company (U.S.A.)

Honorary Members
BANSEFOR/INAFOR (Guatemala)
ESNACIFOR/COHDEFOR (Honduras)
INIF (Mexico)

Contributing Member
Crown Zellerbach (U.S.A.)

OPERATION OF THE COOPERATIVE

The CAMCORE program is divided into two phases, both of which occur simultaneously. Phase I deals with the collection of seed from species and/or provenances in Mexico and Central America that are being degraded, some of which are endangered. Phase II deals with using the seed collected from these endangered populations to establish conservation banks and provenance/progeny tests on the land of Cooperative members in Mexico, Central and South America, and Africa. The purpose of the conservation banks is to both maintain existing gene complexes and to produce new genetic combinations for use in breeding programs. The provenance/progeny tests serve to locate the best provenances and families for further testing and development of adapted land races (Dvorak, 1982). The underlying assumptions made in the CAMCORE program are:

The conservation effort is long-term, which, by necessity, requires dynamic advanced generation planning.

Gene conservation and breeding efforts can best be made compatible by designing and managing conservation banks as specialized breeding populations based on site adaptability and/or speciality traits (Namkoong, et al., 1980).

Population Sampling

Seed collection activities in Central America and Mexico need to be concentrated in the populations where the probability of obtaining the greatest array of alleles is the highest. The greater the diversity of alleles conserved the better the chances for developing widely adaptive breeding populations in the future. Unfortunately, no "genetic maps" exist which show where the magnitude of genetic variation is the greatest. When CAMCORE collections are made in mountainous areas, sampling is in the direction of the greatest elevation gradient. For example, in a recent seed collection of P. tecunumanii on the mountain of Celaque in Honduras, sampling occurred through the elevation range of the species from 1520 to 2030 meters. Whenever possible, outlying populations are also included in the sampling.

CAMCORE selects between 35 to 50 of the phenotypically best dominant and codominant trees in a stand. It is the phenotypically best trees, not random ones, that are used in the program because both the conservation and testing of genetic material are the objectives. This system is possible because characteristics of adaptability are nearly always genetically independent of those of economic value (e.g. tree straightness) (Zabel and Talbert, 1983).

The highest priority in selection is given to stem straightness and branch habit because these are both reasonably highly heritable traits, and sizeable genetic gains can be made in the first generation through simple mass selection. Stem volume is given a lower priority in the selection system, although it is of importance. Seed, which are kept separate by mother tree, are collected from as many provenances of a species as possible. The seed are then distributed to CAMCORE members to establish conservation banks and the provenance/progeny tests.

Strategy for the Development of. Conservation Banks

Cooperative members' forestry programs differ in many respects. Some CAMCORE organizations are just beginning species and provenance tests, while other agencies are well into advanced generation breeding programs. Some organizations have low-elevation lands and are planting P. caribaea and, P. oocarpa, while others have high-elevation lands and are primarily interested in such species as P. patula, P. pseudostrobus, and P. tecunumanii. Some members are producing kraft-quality paper and cardboard boxes to meet local internal demands while other organizations are producing fine-quality paper for the competitive European market.

With the varied interests of CAMCORE members in mind, it was felt gene conservation and breeding efforts could best be made compatible by designing and managing conservation banks for each species in sets of multiple-breeding populations based primarily on site adaptability characteristics. Therefore, CAMCORE's first conservation banks of P. caribaea are being divided into wet-site and dry-site populations. Dry-site collections of P. oocarpa from Honduras and Guatemala have been grouped together in one bank but kept physically separate from the genetically different P. oocarpa from Mt. Pine Ridge, Belize. Species with a large elevational range such as Pinus maximinoi will be divided into high- and low-elevation populations. Other populations may be developed for adaptability to high pH soils, wind firmness, etc. Development of banks for speciality traits such as disease resistance will be done on an organization-by-organization basis depending upon individual needs. For those species which have never been adequately tested before such as *Abies guatemalensis,* only one conservation banks (population) will be initially established by each member.

The multiple population system is particularly advantageous because intensive development may be pursued in those sub-populations which justify more attention (Namkoong, et al., 1980). In the banks which prove to be of most value, controlled crosses will be made and the best performers incorporated into the next generation. For banks which contain a species and/or sub-population of secondary importance, management will be *less* intensive and include only open-pollinated seed collections to establish adaptive land races. Another option is to make crosses among banks to generate new and possibly more useful genetic combinations.

The advantage of having the banks on many sties in a number of different countries is that destruction of one by natural or man-made causes does not jeopardize the loss of the genetic material. In addition, by planting the banks in different countries under varying environmental conditions, selection pressures will vary and favor different genetic combinations (Palmberg, 1981).

The CAMCORE conservation banks consist of completely randomized single-tree plots and are established in areas where cone and seed production are thought to be good. The size of the banks range from 1 to 4 hectares for each sub-population and contain between 50 and 300 families. For instance, the P. *oocarpa* collections of 1980, 1981, and 1982 sampled dry-site regions from 15 provenances in Guatemala and Honduras. Cooperative members which have been with the program since its beginning have a genetic base of approximately 300 families in their P. *oocarpa* dry-site conservation bank. Genetic bases are kept as large as possible. Some organizations will have as many as 3 to 4 separate sub-populations (700 families) for the more important species. CAMCORE members are also encouraged to incorporate extra seedling material from the Commonwealth Forestry Institute's (C.F.I.) second-stage provenance/progeny tests into the banks. Seed exchanges have already occurred with C.F.I., and more are planned. Seed exchanges are also planned with the Queensland Forestry Department, the Danish International Development Agency (DANIDA), the South African Forestry Research Institute, the National Program of Forest Research (PNPF) Brazil, and the Forestry Research Center, Zimbabwe.

Provenance/Progeny Tests

The provenance/progeny tests are planted in a randomized complete block design, replicated nine times with six-tree family-row plots. Enough seed is distributed to CAMCORE members to test provenances and families on a number of sites in several countries so that provenance x environment and genotype x environment estimations can be determined. The provenance/progeny tests are planted where plantation and reforestation activities are a prime concern, and therefore, mayor may not be in the same vicinity as the conservation banks. For example, the provenance/progeny tests and conservation banks of Aracruz Florestal (Brazil) are planted in the same region because the area is excellent for seed production and also happens to be the type of land on which plantations will be established. PIZANO/Monterrey Forestal (Colombia) has placed the majority of its provenance/progeny tests near the coast where its main planting activities are, and its conservation bank in the interior of the country, several hundred miles away. This is because the site in the interior of the country has higher and more consistent rainfall which offers more security for the long-term survival of the banks.

Approximately 60% of the families included in the conservation banks are also established in the provenance/progeny tests for any one organization. Those families not tested by one organization are tested by other members at different sites. Therefore, exchange of genetic material among members will play an important role in the development of breeding programs in the future as it has for the North Carolina State-Industry Tree Improvement Program. All data from the provenance/progeny tests are analyzed at North Carolina State University. Table 2 summarizes the similarities and differences between the CAMCORE provenance/progeny tests and conservation banks.

Table 2--Similarities and differences between provenance/progeny tests and conservation banks for each organization

	Provenance/Progeny Test	Conservation Bank
Purpose:	Find superior provenances and families	Hold and further develop genetic material for future use
Design:	Randomized complete block	Completely randomized single-tree plots
No. of provenances included:	All that were collected	All that were collected
No. of families included:	Approximately half of those collected	All that were collected for which there were enough seedlings
Spacing:	3m x 3m	3m x 3m
Location:	On sites to be used for wide scale reforestation or commercial plantations	On sites where cone and seed production are thought to be good

RESULTS

Since the beginning of the program in 1980, seed have been collected from approximately 1,000 selected mother trees of 5 coniferous species: Pinus ayacahuite, P. caribaea, P. oocarpa, P. pseudostrobus, and P. tecunumanii. In 1983, this list of species will also include P. chiapensis and A. guatemalensis. Exploration in Central America has led to the discovery of new areas of P. tecunumanii. In 1981, CAMCORE's first conservation banks and provenance/

progeny tests of P. tecunumanii and P. oocarpa were established in Brazil, Colombia, and Venezuela. In 1983, government forestry organizations in Guatemala, Honduras, and Mexico began establishing conservation banks of P. oocarpa. At present, approximately 25 hectares of conservation banks and 50 hectares of provenance/progeny tests have been established by CAMCORE members. Results from the provenance/progeny tests will be made available when studies become older.

SUMMARY

The Cooperative program has grown, even during a period of economic recession, because a group of progressive forestry organizations are aware that action must be taken now in order to preserve the valuable coniferous resources in Central America and Mexico. During the next several years, CAMCORE activities will be directed toward seed collections of endangered mid- and high-elevation coniferous species. Future success of the program rests on the continued cooperation from the honorary members in Guatemala, Honduras, and Mexico, the strong support from active members in North and South America, and South Africa, the development of dynamic strategy which coordinates gene conservation efforts and tree breeding concerns, and the exchange of seed with other international organizations to maintain broad genetic bases.

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