

TEN YEARS OF INDUSTRIAL TREE IMPROVEMENT  
IN COLOMBIA

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Abstract. Tree improvement is being carried out at three levels: 1) species, 2) provenance and 3) mother tree selection. Grafted seed orchards have been established for Cupressus lusitanica (5 ha.,1977) and Pinus patula (5 ha.,1981). Over 200 species have been tested and seed stands or improved seed stands exist for P. kesiya, P. oocarpa, Gmelina arborea, Eucalyptus grandis and E. camalduiensis. Important aspects of the program include cooperation in international provenance tests, local Colombian cooperation in progeny tests and an open-door policy with respect to research information, with reports distributed in both Spanish and English in many parts of the world.

INTRODUCTION

Cartón de Colombia, S.A., has been supplying paper packaging products for Colombian commerce since its conception in 1944, when the first paper was produced exclusively from recycled wastepaper. In 1959, with increasing demand for packaging and with government support, the Company established the first kraft pulp mill in the world to use mixed tropical hardwoods to produce a uniform short fiber kraft pulp, and in 1970 began a reforestation program in the Andean region, planting tropical conifers on marginal agricultural lands as a means of replacing imported long fiber pulp with a nationally grown product. As a support for this forestry effort, a formal forest research program was established in 1973 with one of the objectives being tree improvement. Current planting goals are 2300 hectares per year (1400 with coniferous species and 900 with broadleaf species), and the forest plantation utilization has now been expanded to include, not only pulp for paper packaging, but also bleached pulp for writing papers, as well as solid wood products, including treated posts and poles.

There are several limitations on tree improvement research and the development of a tree improvement program within the industrial situation just described. First, with a calculated plantation land area totalling approximately 30,000 hectares, the forest research staff must be kept modest, which in our case is three professionals and two technicians. Although tree improvement in its broadest sense is the largest function of this research group,

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it is still only a part of the overall research program. Third, due to varied site conditions, many species are used for operational reforestation, several for the first time in Colombia on an operational basis, which in itself injects a rather large risk factor into investment decisions. Likewise, since industrial forest management as well as tree improvement are new fields in Colombia, and since Cartón de Colombia is the leader in both, we cannot turn to local government or university organizations for much technical assistance or information, but rather have to depend heavily on imported education, experience and technology.

Tree improvement strategies have been developed by which to deal with the variables and limitations mentioned (Ladrach, 1982), the main elements of which are 1) species selection and utilization, 2) provenance research and 3) land race mother tree selection. Tree improvement is carried out simultaneously at all three levels in the research program, depending upon the species, the accessibility of seed and the relative importance of the species being considered.

## SPECIES SELECTION AND UTILIZATION

### Plantations

Initial species selections were based on observations of limited plantation areas in other parts of Colombia and by comparison with other tropical countries with similar ecological conditions, especially in East Africa which has a long tradition of reforestation. In the conifer program, four species were used initially: Cupressus lusitanica Mill., and Pinus patula Schl. et Cham., both of which had been planted previously in Colombia, and Pinus oocarpa Schiede and Pinus kesiya Royle ex Gordon, which had not been used for commercial reforestation, the last being introduced by the Company in 1971.

Plantation observations also resulted in some initial provenance improvement and seed source improvement. For example, it was early recognized that P. oocarpa provenances from Central America performed better in Colombia than those from Mexico, and seed was purchased accordingly. Likewise seed purchases were concentrated with dealers who personally supervised their own collections from good phenotypes as opposed to intermediaries who purchased open market seed. Considerable improvement in form and growth of P. patula was obtained in this manner. We now know personally most of our international seed suppliers and have visited several areas of seed collection.

### Species Trials

More than 200 tree species have been or are being tested for their potential use in reforestation. At this initial species selection level, major differences are being evaluated for a large number of

species on many sites and the design used is an arboretum, in which each species is planted as a square plot, usually of 36 trees, without replication, on a uniform site. Ten such arboreta have been established, the largest with over 100 species.

Initially in the arboretum, the species is given maximum care including intensive site preparation, fertilization, regular weedings and sometimes initial irrigation to insure first year survival; once a promising species has been identified, then further testing under normal operational conditions is employed. In addition to the technical aspects, the arboreta are usually situated where they have demonstrative value as well. Field tours through the arboreta have become everyday programs with favorable public reactions; visitors have included students, employees, foresters, environmentalists, legislators, generals, cabinet ministers and presidents.

With limited resources, the simple design of the arboretum has permitted the testing of a large number of species and, in spite of the lack of statistical analyses, they have produced valuable information (Table 1). Arboretum growth data have served as a reliable first indication of plantation performance and, in the case of the arboretum in the Caribbean Coastal Plain, alternate and highly successful species were found for operational use where initial species selections for reforestation had failed.

Table 1. Species Developed For Reforestation in Colombia.

<u>Species</u>	<u>Altitude</u> meters a.s.l.	<u>Stage</u>
Cupressus lusitanica Mill.	1500-2300	Operational
Cupressus sempervirens L.	2000-3000	Operational
Pinus patula Schl. et Cham.	1500-3000	Operational
Pinus kesiya Royle ex Gordon	1300-2200	Operational
Pinus oocarpa Schiede	1500-2500	Operational
Pinus taeda L.	2000-3000	Pilot Project
Pinus caribaea Morelet	1000-1700	Pilot Project
Pinus chiapensis Andersen	1600-2000	Pilot Project
Pinus pseudostrobus Lindl.	1500-2500	Final Research
Pinus maximinoi H.E.Moore	1500-2500	Final Research
Eucalyptus grandis Hill ex Maid	1500-2000	Operational
Eucalyptus globulus Labill.	2200-2700	Operational
Eucalyptus tereticornis Sm.	0-1400	Operational
Eucalyptus camaldulensis Dehn.	0-1400	Operational
Gmelina arborea Roxb.	0-1000	Operational
Cassia siamea Lam.	0-1000	Pilot Project
Bombacopsis quinnata (Jacq) Dugand	0- 500	Pilot Project
Tabebuia rosea D.C.	0- 500	Pilot Project

### Seed Stand Development

Seed stands are being utilized for the local production of seed as a means of reducing dependence on imported seed and also as a means of capturing some land race adaptive traits. Unimproved seed stands have been developed for pinus kesiya, P. oocarpa, Gmelina arborea, and Eucalyptus camaldulensis. These have been thinned from below and reduced, generally, to 100 trees per hectare; they are fertilized annually and maintained free of weeds.

Trees resulting from seed of the G. arborea and E. camaldulensis stands are equal to or better than those of the best non-selected provenances in comparative tests. No such differences have yet been observed for the pines, but it is hoped that the trees from the P. kesiya seed stands will show a lower incidence of fox-tail than those from imported seed.

## PROVENANCE TRIALS

### Species/Provenance Trials

Besides the arboretum species trials, additional studies have been established where several species are tested in replicated designs but with several provenances per species. In some tests a single species is predominant with many provenances represented while other species are included with only one or two provenances to serve as comparable checks. These tests are usually replicated on more than one site.

Most of these studies have been developed through cooperation in international trials sponsored by C.F.I., Oxford, England; C.S.I.R.O., Canberra, Australia; and DANIDA, Humlebaek, Denmark. Since these are considered as intermediate studies and, again, due to limited resources in personnel, funds and homogeneous areas for installing them, only three replications per site are used in most cases (Table 2). Likewise, since early and fairly large differences between provenances are expected, and often found, individual plots are usually in rows of from 6 to 10 trees, and the studies are carried for short periods of time, usually to half rotation age which for Pinus and Cupressus is 8 years and for Gmelina and Eucalyptus, 3 years.

An advantage of this design is the potential for conversion of the trials into improved seed stands after the final evaluation. A selection is made leaving only the best species, the best provenances of that species and the best individual in each rowplot of the best provenances. Improved seed stands have already been developed by this procedure for Eucalyptus grandis Hill ex. Maiden and Eucalyptus camaldulensis Dehn. Additional stands will be developed this year for Gmelina arborea Roxb. and Eucalyptus globulus Labill. Initial commercial plantings with seed from these seed stands show visible advantages in growth over non-improved plantings from imported and locally produced seed.

Table 2. Species/Provenance Trials Installed By Cartón de Colombia.

<u>Year</u>	<u>Principal Genus</u>	<u>Species/ Provenances</u>	<u>Sites</u>	<u>Reps./Site</u>	<u>Trees/Plot</u>
1972	Pinus caribaea	2/6	1	2	200
1975	Gmelina	1/5	1	1	10
1975	Eucalyptus	6/16	2	4	10
1976	Pinus taeda	4/15	2	3	10
1977	Pinus <u>a/</u>	11/32	4	3	10
1977	Eucalyptus <u>b/</u>	5/32	6	3	10
1978	P. pseudostrobus	4/16	1	3	36
1978	Pinus <u>a/</u>	13/56	3	3	10
1979	E. grandis <u>b/</u>	4/44	2	3	8
1979	E. globulus <u>b/</u>	4/43	2	3	8
1979	E. saligna	4/25	1	3	8
1979	E. viminalis <u>b/</u>	2/11	1	3	8
1980	Gmelina <u>c/</u>	1/16	2	3	10
1980	Leucaena <u>d/</u>	2/13	3	3	10
1981	Eucalyptus <u>e/</u>	37/46	2	5	6
1981	Gmelina <u>c/</u>	1/14	2	3	36

a/ C.F.I., Oxford, England, international provenance trials.

b/ Seed obtained from C.S.I.R.O., Canberra, Australia.

c/ DANIDA/FAO, Humlebaek, Denmark, international provenance tests.

d/ Seed obtained from C.I.A.T., Palmira, Colombia.

e/ Seed supplied by Tasmanian Commission of Forestry and C.S.I.R.O., Australia.

### venance/Family Trials

Once a species and provenance are proven outstanding, trials are made of open-pollinated progeny of seed collected by mother tree in the original stands, or collected from select trees in seed orchards abroad. Carton de Colombia staff have made individual tree collections by provenance in Central America, but for the most part such seed is obtained through international cooperation with CAMCORE and N.C. State University, Raleigh, North Carolina; C.F.I., Oxford, England; and through exchanges with other national organizations including the Forest Research Centre, Zimbabwe; the Kenya Forest Department; Mondi Timber Company, Republic of South Africa; and the Forestry Research Institute, Malawi.

Many of these studies are designed with nine replications, grouping families by provenance, with individual rowplots of six trees each and are established on only one site (Table 3).

Under Andean conditions, where uniform topography is scarce and flat topography scarcer still, such studies present difficulties in their establishment. For example, the C.F.I. second stage Pinus oocarpa study installed in Colombia in 1982 involves 100 families, separated into two sets with 9 replications each; at a spacing of 2.5 x 3 meters and with two border rows for isolation, this study covers 5 hectares.

Table 3. Provenance/Family Trials Installed by Cartón de Colombia.

<u>Year</u>	<u>Species</u>	<u>Provenances</u>	<u>Families</u>	<u>Reps.</u>	<u>Trees/Plot</u>
1976	<i>Pinus taeda</i> <u>a/</u>	—	24	3	10
1977	<i>Cupressus lusitanica</i> <u>b/</u>	6	23	3	10
1978	<i>Pinus taeda</i> <u>a/</u>	—	52	6	6
1981	<i>Pinus oocarpa</i> <u>c/</u>	7	33	9	6
1981	<i>Eucalyptus grandis</i> <u>d/</u>	7	80	4	6
1981	<i>Pinus patula</i> <u>e/</u>	6	22	3	10
1981	<i>Pinus kesiya</i> <u>f/</u>	3	12	6	6
1981	<i>Cupressus lusitanica</i> <u>g/</u>	6	15	3	6
1982	<i>Pinus oocarpa</i> <u>h/</u>	1	113	9	6
1982	<i>Pinus tecunumanii</i> Sch. <u>c/</u>	2	25	9	6
1982	<i>Pinus oocarpa</i> <u>j/</u>	9	100	9	6
1982	<i>Pinus caribaea</i> <u>j/</u>	9	89	9	6
1983	<i>Pinus chiapensis</i> <u>c/</u>	1	8	9	6
1983	<i>Pinus oocarpa</i> <u>k/</u>	7	36	9	6

a/ N. C. State Pine Coop., good general combiners of loblolly pine, international trials.

b/ Seed supplied by E.A.A.F.R.O., Kenya, and Tropical Sci. Inst., Costa Rica.

c/ CAMCORE Cooperative study, Guatemala.

d/ Seed supplied by the Forest Research Centre, Zimbabwe, and Mondi Timber Co., South Africa.

e/ Seed supplied by the Forestry Research Institute of Malawi.

f/ Seed supplied by C.S.I.R.O., Australia, and SAPPI, South Africa.

g/ Seed supplied by the San Lucas Toliman Parish, Sololá, Guatemala.

h/ CAMCORE Cooperative Study, Belize.

j/ C.F.I. second stage international provenance trials.

k/ CAMCORE Cooperative study, Guatemala and Honduras.

with this design, such studies are convertible to seedling seed orchards at half rotation age, which action is planned. This then, will allow for a rapid expansion in the local production of genetically improved seed, which amply justifies the installation efforts in such studies.

## LAND RACE MOTHER TREE SELECTION

### Species And Characteristics For Selection

The species to be chosen for an individual tree selection program, above all else, have to be commercially planted at a sufficiently large scale in order to recover the investments in the selection process, seed orchards and progeny tests. This is, perhaps, an obvious fact to geneticists, but it has been overlooked by some institutional administrators who program research goals. Secondly, there must already be a sufficiently large plantation base in existence from which to make mother tree selections, and which will result in a significant selection differential (Jett, 1975).

At the beginning of Carton de Colombia's tree improvement program in 1973, there were only two species which met these requirements, these being Cupressus lusitanica Mill. and Pinus patula Schl. et Cham. An additional reason for initiating mother tree selections of cypress was the large observable difference in height between trees in plantations, indicating great genetic variability within the species. Pinus patula, although more uniform in tree size than cypress, demonstrated wide variations in wood specific gravity between trees in initial samplings, thus indicating a sizeable potential gain in this trait through selection.

The tree selection system utilized is based upon that developed in the North Carolina State Tree Improvement Cooperative (Zobel, 1974). Five tree characteristics were selected for improvement: 1) resistance to insects and disease, 2) volume, 3) straightness, 4) wood quality and 5) crown form. Two grading concepts are utilized, these being relative and absolute. For example, crown form is graded relative to the best five neighboring trees whereas straightness is graded as an absolute value irrespective of the other trees. The wood quality is graded by both criteria, and must be equal to or better than the average established for that species and age but must also be superior to the average of the best five neighboring check trees (Figure 1).

### Grafted Seed Orchards and Progeny Tests

Scions from selected trees are grafted into clone banks, holding 5 ramets per clone. Grafting techniques for patula pine are similar to those used for loblolly pine, but cypress, having a much finer scion, presented difficulties and only 12 to 15% take was obtained initially. With the technical visit of Dr. Frederick Owino to Colombia in 1975, the grafting techniques used in Kenya were adopted and the average success for all the cypress seed

Figure 1. A select CuElessus lusitanica 15 years old in the Seminary of Medellin, Colombia, 1T676 meters taller than the average of the best five neighboring check trees.





orchard grafting in 1977 was increased to 92% (Figure 2).

The cypress seed orchard was planted according to a computer design created by N. C. State University for 30 clones. Five hectares of orchard were established, based on yield estimates from Kenya (Owino, 1975), utilizing an initial spacing of 5 by 10 meters. Final thinning should leave the orchard with a minimum of 15 clones and about 100 trees per hectare. Cypress is a heavy and early seed producer and the fifth year crop yielded 215 kilograms of seed from 22 clones. Forced air separation of good seed has resulted in a cleaned yield of 120 Kg. with an average germination of 23% which is still below the 40% germination which has been obtained from cleaned seed in older plantations.

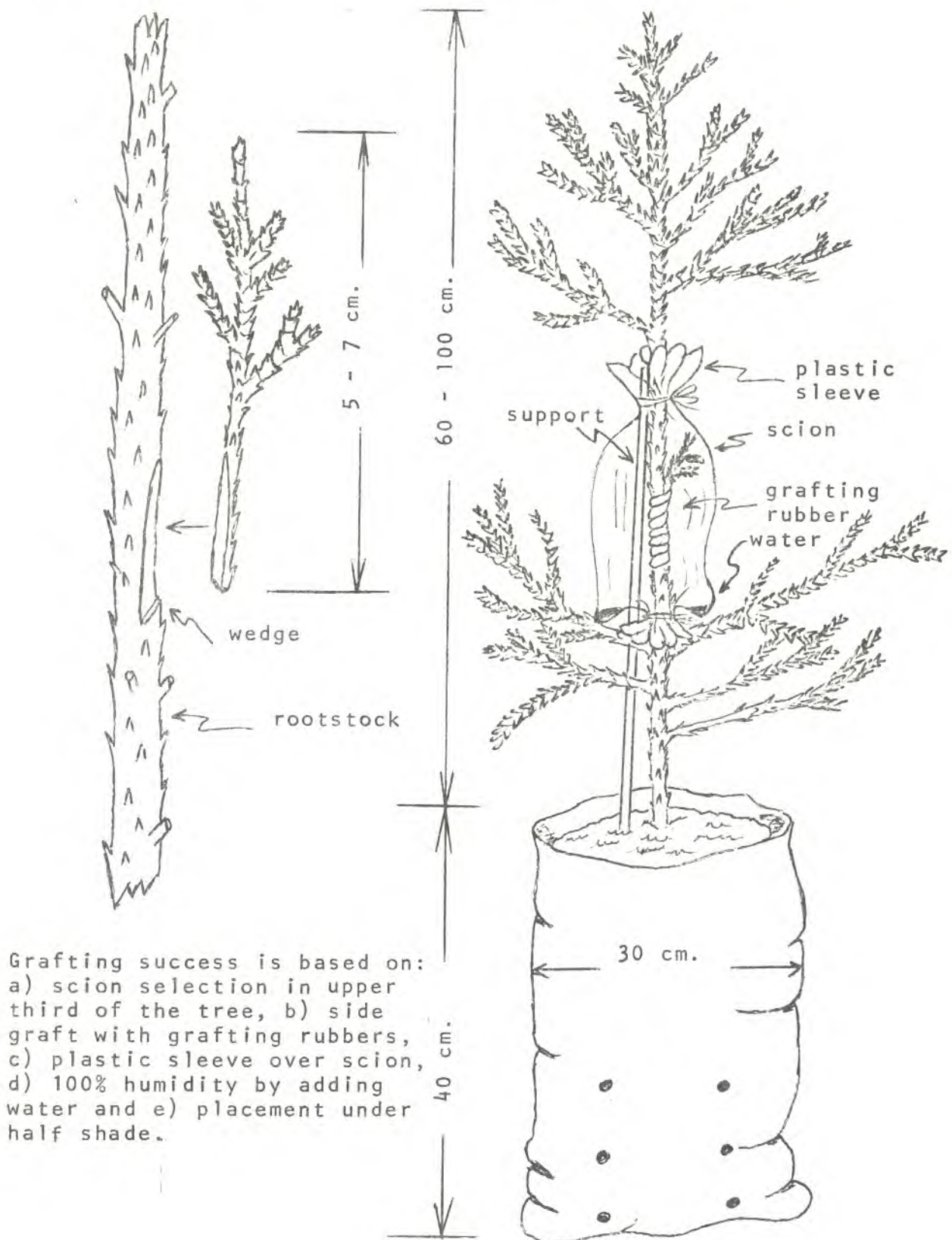
The patula pine orchard was initiated in 1981, again using the 30 clone N. C. State design. Five hectares are initially being installed, but additional area will be needed to produce all the seed required for reforestation. Mr. Neville Denison of Mondi Timber Company, South Africa, recommended during a visit in 1977 that we locate the patula pine seed orchards above 2000 meters altitude in order to obtain optimum seed production. Due to the lack of level terrain at these heights, the first orchard was located at 1850 meters, but all attempts will be made to comply with his recommendation for the expansion orchard. Incompatibility has not been a problem thus far for either cypress or patula pine; only one cypress clone was rejected after it could not be held successfully even when grafted on rootstock from seed of the same mother tree.

Not all trees selected had seed and, therefore, open-pollinated progeny tests have not been established to date for all select trees. Cypress o. p. progeny tests have thus far been established for 28 trees and tests have been established at 6 locations in Colombia, through cooperation by the Colombian forest service (INDERENA), the public utilities companies of Bogotá (C.A.R.) and Pereira (EE.PP. de Pereira), the secretary of agriculture in Antioquia (Medellin) and the Archdiocese of Medellin. Besides permitting the establishment of the tests on their lands, some organizations have actively participated in the site preparation, planting, care and measurement of the studies; especially important have been the efforts of INDERENA in Medellin and the C.A.R. in Bogota, this being accomplished with no formal written agreements.

The oldest progeny tests will complete 8 years during 1983, at which time final evaluations will be made, this being considered half rotation age. Earlier evaluations at three years of age indicated gains of 50% in volume, 13% in height, 2% in straightness and no gain in crown form compared to commercial check lots (Ladrach & Gutierrez, 1980). These gains concur with those for cypress in Kenya after 10 years (Dyson & Raunio, 1977).

Controlled crosses have been tried with cypress on a pilot basis

Figure 2. Grafting Technique For Cupressus lusitanica.



Grafting success is based on:  
 a) scion selection in upper third of the tree,  
 b) side graft with grafting rubbers,  
 c) plastic sleeve over scion,  
 d) 100% humidity by adding water and  
 e) placement under half shade.

and have been successful, but controlled crosses have not been carried out by clone for progeny tests to date. Poor pollen production is a problem with cypress, but this has been increased to acceptable levels for pollen collection by spraying gibberillic acid GA3 on the foliage once per month for six months at concentrations of 100 p.p.m. in ethyl alcohol (Gutierrez, 1980).

### Tree Breeding Strategies

Continued tree selection must depend upon the introduction of additional material from outside Colombia and the provenance/family tests already described will be the primary source of this material. Even so, with the limited genetic base available, no more than two generations of mother tree selection are anticipated in the present program (Figure 3).

Nonetheless, early indications are that the genetic gains from this modest program with tropical species will be substantial and beneficial, due to the observable natural variation within the species and between provenances as well as to the response of these introduced species to Colombian conditions. Likewise, due to the rather large risk factor of working with introduced species, such a program is of key importance in assuring the future success of the overall reforestation effort.

### OTHER IMPORTANT CONSIDERATIONS

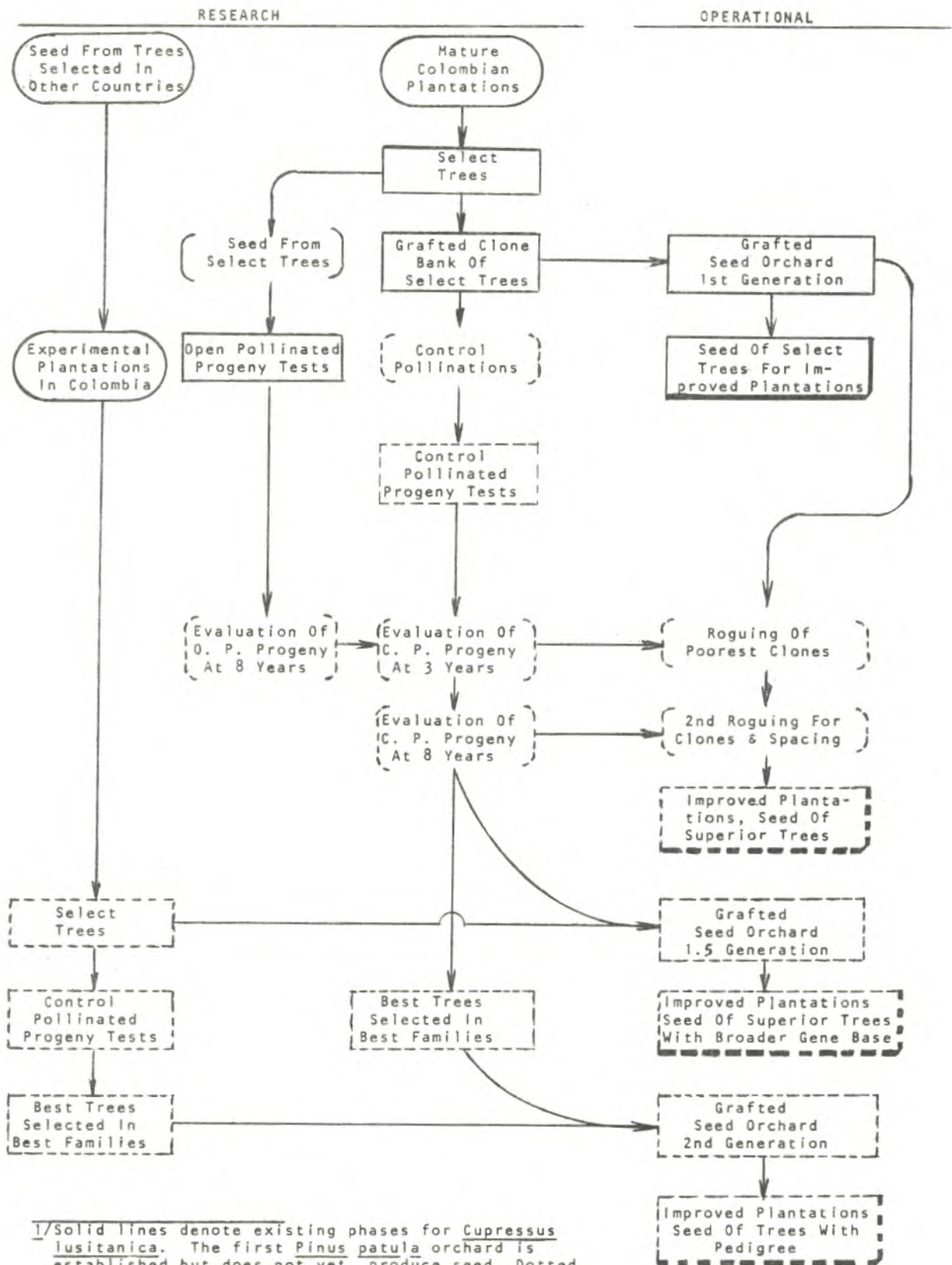
For a tree improvement program within one company to be successful, there must be constant contact with outside institutions working in this field on an international level. One of the best methods to achieve this contact is by participating in international provenance and progeny tests, where it is possible to obtain research lots of seed from many provenances, otherwise unattainable, and to compare results locally with the results of similar tests in other parts of the tropical world.

Equally important is to invite foreign experts to see and advise on the program in the field, and conversely, local personnel have to maintain themselves current of research in other parts of the world through publications and travel. Without this constant contact with the outside world, a small local program would be seriously handicapped in its scope and results.

Although there is no official tree improvement cooperative in Colombia, the cooperative efforts of local agencies have been instrumental in the gains achieved to date. Many of the initial tree selections are the result of preselections by personnel in governmental agencies and public utilities working on their own lands. Site preparation, planting and periodic measurements are in large part the result of close cooperation as well.

This type of open collaboration is, of course, a two-way proposition,

Figure 3. Tree Breeding Strategy For Land Race Conifers.



and the reports of field research are distributed freely in return. All research reports on all phases of forest research are sent out in both Spanish and English to agencies interested in tropical forestry in many parts of the world simultaneously with the distribution of these same reports to personnel within Carton de Colombia. Because of this open-door policy with regard to forest research information, the professional image of the Forestry Division has improved substantially in the past ten years as well as resulting in cooperation, seed received for international trials and many reports received in return for those sent. Besides technical report distribution, field tours and documents dealing with a particular phase of forest research are presented to about 250 Colombian professionals each year.

### CONCLUSIONS

An industrial tree improvement program not only can be, but must be carried out when working with introduced species to assure the selection of species and provenances which result in the maximum gain at minimum risk. Without such research the gain is less and the risk increases. Although the tendency is to initiate land race mother tree selections in a new program, and this is commendable, emphasis also has to be placed on species trials and provenance trials, especially for untested or little tested genetic material.

Study designs for testing of expected large differences, such as between species, can be simpler than designs to find finer differences, such as between families of the same provenance. A design for provenance tests and family tests which allows for these studies to be converted to seed production has a distinct advantage over other designs where operational seed needs must be met; but other, long-term studies must also be installed in order to obtain growth and yield information. Again, research risk versus research gain have to be balanced in order to maximize the return on the research investment.

The long term success of an industrial tree improvement program such as that of Carton de Colombia depends heavily on close contact and constant communication with institutions knowledgeable in the material. Without this contact, considerable time and effort can be wasted or utilized inefficiently and the risk of research error increases substantially. The dissemination of research information is of vital importance in creating and maintaining this communication, and the publishing of research information should be actively promoted at the administrative level to insure that long range research results are compatible with those of other international agencies and thereby will be beneficial to that particular company or industry in the long run.

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