BREEDING STRATEGY FOR THE FIRST-GENERATION OF PINUS TAEDA IN THE NORTHEAST REGION OF ARGENTINA

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Abstract: A strategy for the Genetic Tree Improvement Cooperative of the northeast region of Argentina was developed to start with a broad genetic base to ensure maximum genetic gain in the long-term as well as provide insurance against new diseases or traits that may become important in the future. The breeding strategy for the first-generation is simple, cost-effective and yet as powerful as possible, using well-known technology for the species. The primary objective is to make near-optimal genetic gain in two traits (volume growth and straightness). At the same time, the strategy is flexible enough to permit each member to pursue traits of special interest. Also, it will provide for mixing and interchange of alleles among many sources and types of selections (different provenances, plantation selections, backward selections). The aim is to produce, in one or two generations of breeding, a well-adapted and genetically improved land race for Argentina that combines the best alleles from the many different types of selections and sources. The strategy relies on use of open-pollinated seed from each selection for the first-generation, but will permit open pollination or control pollination for breeding and testing in the second-generation. The main breeding population will be composed of 600 selections and sub-divided in twelve unrelated lines of 50 open-pollinated families in each line.

Keywords: Loblolly pine, breeding population, backward selection, forward selection, sublines.

INTRODUCTION

The Cooperative Forest Genetic Improvement Program of the Centro de Investigaciones y Experiencias Forestales (CIEF) began in 1984 with the genetic improvement of the two more widely planted conifers in the country. At that moment *Pinus elliottii var. elliottii* was the most planted species in the northeast region of Argentina. Nevertheless results from old trials proved and the new ones confirmed that *Pinus taeda* displays important provenance variation and that the best provenances (from Florida) were much more productive than *Pinus elliottii* especially in the more fertile red-argilic soils. Now *Pinus taeda* is preferred and more than 80% of the pines planted in this are. is with *Pinus taeda.*

In 1986 a breeding program for *Pinus taeda* began with selections made from a plantation of an unimproved source from Marion-FL. In 1986 the first clonal seed orchard from this

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source and the first OP progeny tests were established. Other sources, such as Livingston Parish-LA, also proved to be superior in volume growth in relation to the unknown provenance commercial seedlots planted up to that moment. Over the past two years (1995-1996) more selections were made, not only in commercial plantations of Marion-FL, Columbia-FL, Livingston Parish-LA and other sources, but also in old provenance tests so as to screen all the local genetic base of the species.

Today the CIEF, in the northeast of Argentina, has six members whose main products are pulp and solid wood. Plantations were planted in the past years at densities of approximately 1800 trees per hectare and managed for a 20 to 25 year rotations. In 1996 the *Sirex noctilio* was detected for the first time in some plantations and the density was lowered to 1400 to 1100 trees per hectare as a sanitary decision. Commercial thinning is a normal practice with commonly two over the rotation. The mean annual increment ranges from 18 m^3/ha.-yr to 28 m^3/ha.-yr in the more fertile sites. The plantation area operated by the associated members is approximately 60,000 ha located in the northeast of Argentina (provinces of Misiones and Corrientes). In the last two years new companies in the region have raised annual forestation to 20,000 ha. Most of the seed utilized to establish these commercial plantations has come from *clonal seed* orchards *from the United States (Marion and* Livingston sources) and a little is produced by a local seed production area from Marion-FL provenance. The first clonal seed orchard (Marion clones) began to produce seed for operational plantation this year.

This paper describes the process to establish the first-generation breeding population for the CHIEF.

BIOLOGICAL, GENETIC, AND ORGANIZATIONAL PREMISES

Biological Characteristics

Most trees of *Pinus taeda* are producing flowers by age six years in the northeast region of Argentina. Flowering and pollination occur in June and July and cones ripen in March and April. *Pinus taeda* grafts easily and all clones flower five years after the establishment of the orchards with estimated full seed production by age 10. All propagules for operational plantations are currently seedlings. Control pollination is a well-known technology with *Pinus taeda* for use in breeding programs. *P.taeda* has been a recalcitrant species in terms of vegetative propagation. There are few if any company in the world using vegetative propagules (such as rooted cuttings or tissue culture plantlets) on an operational basis. As, with most of conifers, *P.taeda* suffers inbreeding depression (Bridgwater and Franklin, 1985; White et.al., 1986). Thus inbreeding will be avoided in seed orchard seed destined for operational plantations.

Genetics premises

Differences among provenances are very important in *Pinus taeda.* In the northeast of Argentina as well as in other sub-tropical climates (such as southern Brazil, Zimbabwe and

South Africa), provenances from Florida grow fastest. In Argentina, the Marion county source has been widely planted with good success, but Marion is only one of many Florida sources that would do well in Argentina. Further, the Livingston Parish source does well in the region. Thus, the first-generation breeding population should include a wide variety of material from the southern and coastal areas of the *Pinus taeda* natural range with emphasis on the Florida provenances.

Many of the existing plantations of loblolly pine in Argentina came from unknown provenances in the US. Further, most plantations originated from sub-optimal provenances because the Florida sources have only recently been used. Therefore, both to increase the genetic base and to increase genetic gains it will be necessary to screen all the local genetic resource (in local provenance trials) and infuse external genetic material from the US or other parts of the world.

Genetic variation among families within each provenance is also a very important source of genetic variation in *Pinus taeda.* The heritability for volume growth is in the range of 0.15 to 0.20, while that for straightness is between 0.25 to 0.35. The two most important traits for the cooperative breeding program are volume growth and stem straightness. Other traits as wood density and branch quality are being considered and probably will be given emphasis with different stress in each members' breeding program depending on the final products.

Fusiform rust has not been detected in Argentina. No species of *Quercus* is planted commercially in the area, nevertheless some trees are occasionally grown in public areas and parks. It seems very unlikely that the disease will become important in the region, but the breeding population will have a wide range of resistant and susceptible genotypes. So it would be possible to breed for resistance.

Some genotype x environmental (g x e) interaction exists within the *P.taeda* planted range of northern Argentina if we consider the extreme soil types more fertile and deep soils in the north and more shallow soils in the south of the area. Some early results from progeny tests support this idea (Bunse et.al. 1992).

The CLEF breeding strategy will rely on recurrent selection for general combining ability. The appropriate age to make selections depends on many factors. In the current mass selection from local plantations ages more than seven years were preferred. For progeny tests, six to seven years seems like the best age to rank families, make within-family selections and use the data to rouge seeds orchards. Measurements from these ages should be taken before the first thinning. Evidence indicates that family rankings after these ages should be stable with high juvenile-mature correlation after age seven (Lowe and van Buijtenen, 1989). Also this age of seven years-old is one-third to one-half of the final rotation. In the future, new information from the progeny tests being established may indicate that an earlier age is better.

Organizational Decisions

These decisions were made jointly by the associated members of this breeding program: 1. The breeding strategy for the first-generation should be as simple, cost-effective and yet powerful as possible, using well-known technology for the species. 2. The primary objective is to make near-optimal genetic gain in the most important traits. The major characteristics for breeding are volume growth and straightness; but the first generation strategy must be flexible enough to permit each member to pursue traits of special own interest. 3. All breeding and testing efforts will be conducted cooperatively with free exchange of genetic material among members. 4. The production population (seed orchards in the first-generation) for commercial production of propagules will be developed individually by each member. 5. The strategy will maximize gain for clonal seed orchards as this is the primary type of production population.

FORMATION, COMPOSITION, STRUCTURE AND SIZE OF THE FIRST-GENERATION BREEDING POPULATION

Formation of the main population

The material potentially available for inclusion in the main-breeding population consists of:

- Selection from genetic resources already present in Argentina. This includes: 1. Selections in commercial plantations from age seven to age twenty-five (rotation-age). 2. Backwards selection from selected trees from 1984 to 1992. 3. Forward selections from new progeny tests whose parents are not present in the country.

- Selections from a new seed collection from the native range. This collection will be made probably in 1997 or 1998. The only requirement will be that the trees been healthy and dominant growing in wild stands from the southern area of the native range.

Composition

The first-generation main breeding population will consist of 600 OP-families established at up to nine test locations **(Figure 1).** Half of the families will be from local selection and the other half from the new US collection. The final composition of the main breeding population will have a clear emphasis on the Florida and Livingston Parish sources (70%) with lesser representation of the local unknown provenance (20%), other American provenances (5%) and Zimbabwean and South African (5%) provenances.

Structure and size

The main breeding population of 600 selections is sub-divided into 12 sublines of 50 OP-families in each subline. Each subline should be formed with 50 OP-families from a variety of sources with the intent of starting with 12 genetically-equivalent sublines. That is, each subline will have 50 different OP-families sampled systematically, with a few families from each source, to ensure that the mean genetic values of the twelve sublines are similiar. This will allow gene mixing in each subline meaning that each subline will have the potential to develop into a well-adapted and genetically-improved land race **(Figure 1).**

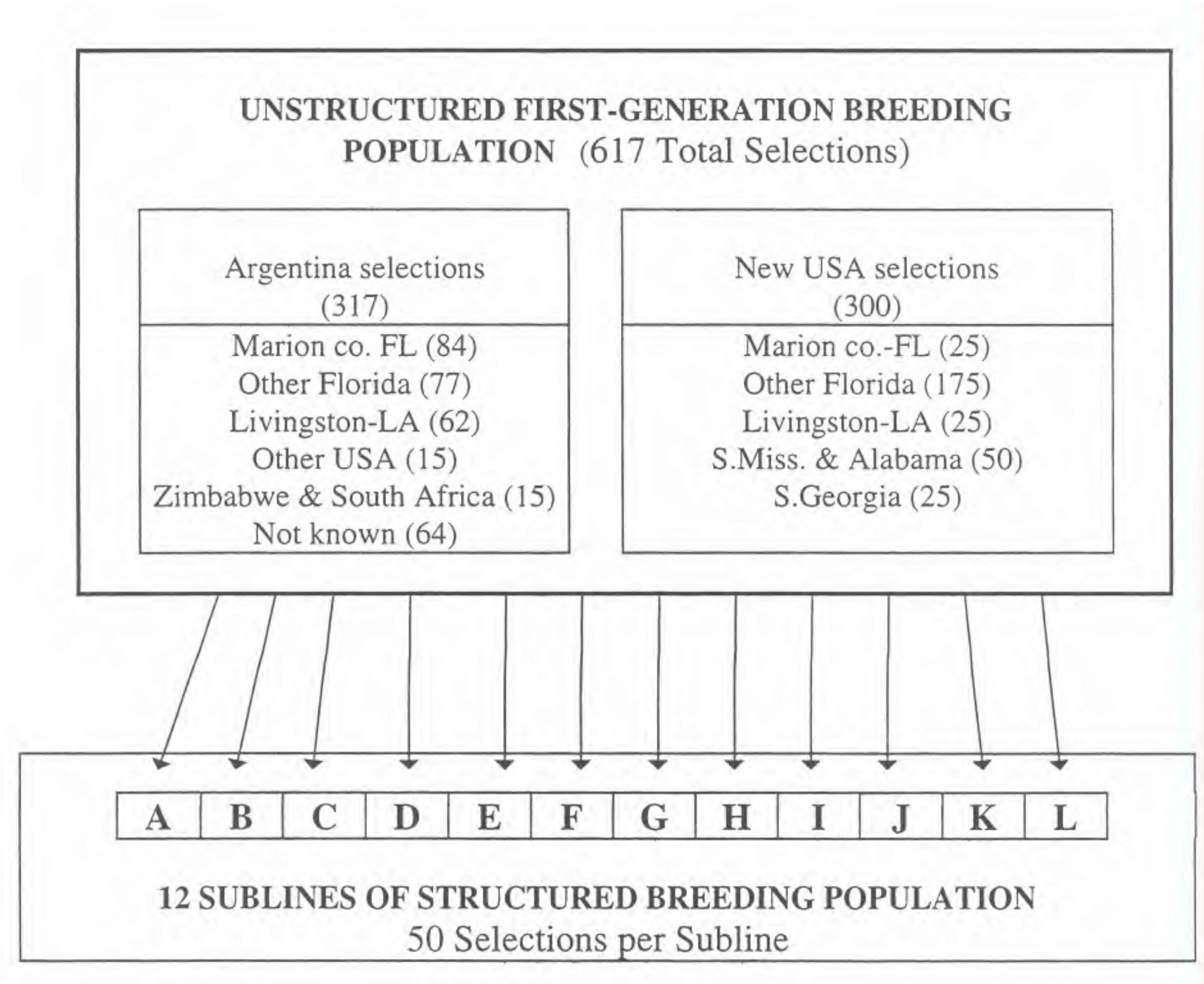
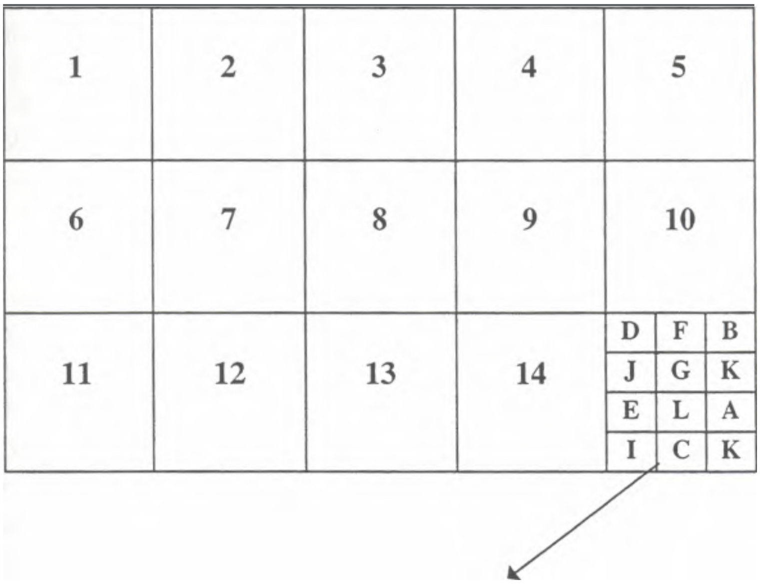


Figure 1. The first-generation breeding population of 600 OP families is subdivided into 12 sublines of 50 OP families in each subline. The goal is to mix genes from all provenances and types of selections by forming each subline with a few families from each source.

For members planning on using wind-pollinated clonal seed orchards as the primary type of production population, twelve sublines is an appropriate number for a strategy that will relay on OP seed orchards. In future generations, two members of each sublines could be selected to compose the seed-orchard ensuring at least 30 m separating among relatives (i.e., ramets of a clone or relatives from the same subline) (Lowe and van Buijtenen, 1986; White, 1992). Further, the size of each subline (50 OP-families) is large enough to ensure good genetic gains for at least 10 generations of breeding (Kang, 1979; Mahalovich and Bridgwater, 1989; review by White 1992).



15 Complete Blocks

12 sublines nested
as sets in each block
completely randomized

Expanded view of block 15

D	F	B
J	G	K
E	L	A
I	C	H

Expanded view of subline H of block 15

T102	C001	T543	T998	T640	T328
T403	T843	T452	T053	T479	T630
T006	T428	T067	T608	T740	T506
T126	T296	0001	T430	T412	T309
C002	T034	T548	T205	T583	T003
T043	T089	T567	T596	T569	T040
T678	T925	T894	T842	0002	T561
T203	T113	T106	T473	T443	T671
T056	T652	T203	T124	T678	T305

Figure 2. Diagram of one *Pinus taeda* first-generation progeny test containing 600 OP families. There are 15 complete blocks with each block containing the 12 sublines (A, B, L) nested as sets randomly placed within each block. Each set is composed of 54 seedling planted randomly: one seedling from each of the 50 OP-families forming that subline and 2 seedlings from each of the two checklots. In total there are 9,720 measured trees and approximately 1,300 buffer trees per location for a total area of nearly 7 ha.

ESTABLISHMENT OF THE MAIN POPULATION

The main breeding population of 600 OP-families will be planted and managed as OP-families for the first generation of breeding. In addition to the theoretical considerations, use of 12 sublines is convenient logistically: the 3 bigger companies will physically manage 2 lines each and the 3 smaller members 1 line each. Because the main population is subdivided into 12 sublines, it is desirable to have maximum statistical efficiency in the ranking of the 50 OP families within a given subline, even if this means that the ranking between sublines has slightly less precision. The field design of each test is a randomized complete block design with sets of 50 OP-families nested within blocks and single tree plots. Each location will contain the entire first-generation breeding population of 600 OP-families **(Figure** 2).

Only one series of genetic tests will be established and many objectives will be accomplished with it: 1. To rank the 600 families to permit rouging of seed orchards, establishment of 1.5 generation seed orchard with only the best clones and deployment of specific families best suited to specific sites and products. The large number of sites is needed for these objectives. 2. To describe the genetic structure and estimate important genetic parameters in the region: (i) heritability for all important traits; (ii) importance of g x e interaction; (iii) genetic correlations among traits; and (iv) juvenile-mature correlations to determine optimal selection age. All these parameters will be useful when designing *the* second-generation breeding strategy. 3. To rank the families to determine which should be eliminated from the second-generation breeding population due to their genetic inferiority. 4. To provide a source of genetic material in which to make forward selections for both the second-generation main population and the second-generation elite population and 5. To maintain a broad genetic base. There will be 600 families and 81,000 different genotypes which is a large genetic base. 6. To allow conversion of genetic tests into seedling seed orchards capable of producing commercial quantities of seed with substantial genetic improvement after second and third rougings. 7. To estimate genetic gains from the first-generation of the tree improvement in the northeast region of Argentina. This will be accomplished through inclusion of two checklots that will serve as the base or reference population against which future gains will be measured and quantified.

GENERATION INTERVAL AND WORKLOAD

Under the strategy described, we shall be able to complete the first generation in 8 years (from 1998 to 2006) and two years more for seed collection, sowing and planting the second generation. This seems an efficient period using a low cost alternative (relying on OP families to manage the breeding population) and a selection age of seven years.

In terms of loadwork it also seems reasonable in view of the actual capability of the members of the cooperative, but also allows flexibility to increase the breeding effort if the planted area enlarges in the future.

ELITE POPULATION AND SECOND-GENERATION BREEDING STRATEGY

Considering the fact that most members plan to rely on OP seed orchards to produce seed for commercial plantations, the use of an elite population will be reviewed when some techniques such as control pollination and / or vegetative propagation for mass production of plantlets for commercial plantation will be better developed among the members. We expect that by the time we arrive at the second-generation, these techniques will be more developed in our cooperative and the exact strategy will depend on the level of technology achieved.

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