PERFORMANCE OF LOBLOLLY PINE SEED SOURCES IN ARGENTINA

Timothy La Farge[1], Floyd E. Bridgwater[2], and Mirta N. Baez[3]

Abstract:--Four test series of loblolly pine (*Pinus taeda* L.) were evaluated to determine the performance in northeastern Argentina of seed sources from three breeding populations in the southeastern United States. Three half-sib progeny tests of seed sources from Florida and Louisiana demonstrated strong genetic gains for height, dbh, and volume growth. However, full-sib progeny tests in three test series of seed sources from Texas, Louisiana and Mississippi performed poorer than checklots from land races in Argentina. To build a greater genetic base of loblolly pine for Argentina it would be better to sample other seed sources from the southeastern USA.

Keywords: Test series, seed source, land race, progeny test, checklot.

Loblolly pine (*Pinus taeda* L.) is the most important commercial forest tree species in the southeastern United States. It is also planted as an exotic in other regions of the world. One of those regions is northeastern Argentina, where it is the preferred species for planting in the provinces of Misiones and Corrientes.

Provenance trials for loblolly and slash (*Pinus ellottii* var *ellottii* Englm.) pines were initiated in Argentina in the late 1960's (Bridgwater and others 1997). The early results from these trials encouraged the introduction of commercial seeds of both species. However, slash pine was preferred for plantation establishment through the 1980's because it is relatively easy to grow in nurseries and has better form and appearance than loblolly at young ages. As plantations grew older it became clear that loblolly pine grew faster on well-drained sites in northeastern Argentina. A tree improvement program was initiated in the late 1980's to provide a steady supply of seeds adapted to sites in Argentina. Selections were made in the plantations, often of unknown origin, to start a land race for Argentina. Seed orchards were established, but they do not provide sufficient amounts of seeds to meet the regeneration needs in Argentina. Nor are the seed orchards always established with parents from the best-adapted provenances. Thus, genetically-improved seeds from rogued first-generation seed orchards in the southern USA are the preferred source of seeds for plantations establishment in Argentina. The loblolly pine seed sources most sought after are from Marion County, Florida and Livingston Parish, Louisiana. However, sufficient quantities of seed for plantation establishment have been difficult to obtain due to high demands and limited supplies. Seeds from the most desirable seed orchards are most often purchased in bulked lots. With adequate testing in Argentina only seeds from the most desirable parents could be purchased, thus increasing genetic quality of plantations in Argentina. It is clear that the best course of action for Argentina is to enlarge their breeding populations with new selections from the best-adapted provenances and reduce their dependence on seeds produced in other countries.

However, achieving this goal is problematic, as collaborators in industrial tree improvement programs in the southern USA own the genetically improved parents from the best-adapted provenances. These collaborators are often private forest industries that view Argentina as a competitor in global markets for

[1] Southern Region, USDA Forest Service, 1720 Peachtree Rd., Atlanta, GA 30367.
[2] Southern Institute of Forest Genetics, Texas A & M Univ., College Station, TX 77843-2585.
[3] Centro de Investigaciones y Experiencias Forestales, Junin 2076-8vo Piso Dept B, 3300 Posadas Misiones, Argentina.

wood products. Thus, access to the best material for enriching breeding populations in Argentina is limited.

A two-pronged strategy was adopted to: 1) identify the best parents in seed orchards in the southern USA from the best provenances to improve the quality of purchased seeds in the short term; and 2) introduce control-pollinated crosses among first-generation genetically-improved parents from the southern USA into Argentina to enlarge the genetic base of the breeding population.

MATERIALS AND METHODS

To meet the first objective, open-pollinated seeds from parents in two rogued first-generation seed orchards were provided for trials in Argentina. These two orchards contained parents from northern Florida and southeastern Louisiana, the most desirable provenances in Argentina. That is, the most southerly provenances from the USA.

Control-pollinated seeds were not available from the best provenances for testing in Argentina. However, such seeds were available from provenances that were adjacent to (north of) the best provenances. These were part of an active breeding program for loblolly pine in the Southern Region of the United States conducted since 1960 by the USDA Forest Service. Remnant control-pollinated seeds available from three of seven breeding populations of loblolly pine in the Southern Region's Tree Improvement Program were provided for testing in Argentina. Breeding Population 2 (BP2) is composed of parents from eastern Texas and Louisiana. BP3 represents southern Mississippi, and BP4 the Coastal Plain of North Carolina and South Carolina. All three breeding populations are based on superior phenotypes that have been tested in the United States since 1978. These are full-sib progeny tests in which the parents were crossed in 6 x 6 partial diallel crossing groups and compared with appropriate General Forest Area (GFA) check lots. Usually, each year since 1978, 20 to 30 families were tested on up to 4 test sites in each breeding zone.

The study was planted in Argentina in five test series. Forty-four open-pollinated seedlots were planted in Series 1, and ninety-eight control-pollinated seedlots were planted in Series 2 through 5. However, because of an inadequate supply of the desired seed and extensive fire ant damage to the progeny test of Series 5 (Test 114), representing loblolly pine BP 4 (coastal North Carolina and South Carolina), this test failed and no data were available for that part of the study. But data from eighty-seven controlled matings were available for the tests representing Series 1 through 4 (Table 1). The experimental sites were chosen to represent large acreages that are suitable for loblolly pine plantation management in Argentina.

Progeny Test Design

The tests in all four test series were arranged in randomized complete-block designs with 6 replications in each test. Plot size was 8-tree row plots in the open-pollinated tests in Test Series 1, and six-tree row plots in Test Series 2, 3, and 4. This design was chosen to allow thinning of half the trees in each plot when required. The latter test series comprised full-sib tests in which the mating scheme was a 6 x 6 partial diallel. These matings were made by the USDA Forest Service in the National Forests of Texas, Louisiana, and Mississippi.

Table 1. The numbers of parents, progeny tests, and check lots comprising each of four test series of loblolly pine in Argentina.

Test Series	Mating design	Parents	Progeny tests	Check lots
1	Half-sib	44	3	5
2	Full-sib	18	2	5
3	Full-sib	17	2	6
4	Full-sib	18	2	6

Initial spacing was 3m x 3m for all tests in Argentina, and one checklot, PeCom, was common to all tests. PeCom is a bulk collection from an unknown seed stand of unknown provenance, but probably from Georgia. Site selection and preparation was done by cooperators in the Centro de Investigaciones y Experiencias Forestales (CIEF). Families were sown in the nursery in August, 1989, transplanted to containers two months later, and planted in the field in June through September. Measurements, performed after four years in the field, included total height, diameter at breast height outside bark, and straightness on a scale of 1 = crooked to 6 = perfectly straight.

Test Series

Series 1: This test series is an open-pollinated progeny test of 44 families from two rogued, first-generation seed orchards. It comprises tests 105, 106, and 107. However, test 107 was found to have errors in plot location when measured at age 4. Test 107 was therefore dropped, and test 105 was remeasured at age 7 to provide a replacement data set for test 107. This replacement data set was named "test 115". One seed orchard was established with parents selected in Livingston Parish, Louisiana, the second with parents selected in northern Florida. Five checklots local to Argentina were included. PM and PeCom were bulked collections from naturalized stands in Argentina and T125, T189, and T235 were first-generation phenotypic selections made in plantations in Argentina. Their original seed sources are unknown.

Series 2: Test Series 2 is a test of crosses among 18 families and includes five check lots, PM, PeCom, T189, 902311, and 902611, planted in two test locations, 108 and 109. The latter two checklots are Seed Production Area (SPA) and General Forest Area (GFA) checks, respectively. These are National Forest System bulk collections in Breeding Zone 2 in the National Forests in Texas and Louisiana.

Series 3: This series of two tests, 110 and 111, consists of crosses among 17 parents and includes five checklots: PeCom, 902311, and 902611, T219 and Livingston. The latter two seedlots are a first-generation selection made in Argentina in a naturalized stand and a bulked collection of a first-generation Livingston Parish, Louisiana seed source from the USA, respectively.

Series 4: This series consists of crosses among 18 parents in two tests, 112 and 113 and includes six checklots, PeCom, T219, 903313, 903413, Libertad, and Marion. Checklots 903313 and 903413 are National Forest Seed Production Area (SPA) and General Forest Area (GFA) seedlots from BP3, from National Forests in southern Mississippi. Libertad is a bulked collection from an unknown seed source.

Marion is a random collection (without selection) from 20 trees in the commercial plantation of a Marion County (FL) provenance located at Alto Parana, Argentina. This information is briefly summarized in Table 1.

Analytical methods

Best Linear Prediction (BLP) was used to estimate breeding values for the parents in the study because it accomodates large data imbalances in genetic testing with a minimum degree of violation of basic statistical assumptions. The specific approach used was that of White and Hodge (1969), in which the Statistical Analysis System (SAS) was utilized to obtain variance components by means of the SAS VARCOMP procedure and to predict breeding values by means of the SAS Interactive Matrix Language (IML) procedure. However, the runstreams used to access and organize the raw data into manageable entities were developed by the senior author.

BLP is useful to predict breeding values but does not provide a test of significance of differences among breeding values. However, the strength and validity of each breeding value can be verified in a relative sense by the inspection of a parameter called the "correlation between the predicted and true (but unknown) breeding values (Corr(g,g))" (White and Hodge 1989).

Breeding values were estimated for total height in meters (h), diameter at breast height in centimeters (d), and volume estimated as d^2h in cubic decimeters.

RESULTS

The average values for growth for the three first-generation parents selected from the land race in Argentina were greater than first-generation parents from the USA (Table 2). This was largely due to one Argentine parent, T189, which had a breeding value for volume of 281 dm^3 . The other two naturalized parents averaged 126 dm^3, about the same as the top 5 parents from the USA. Parents from the northern Florida seed source grew better than progenies from the Livingston Parish seed source. The northern Florida parents were selected from the same geographic region as the three parents from the Argentine land race. Progenies of all of the selected parents grew faster than progenies from the two Argentine checklots.

In Series 2, 3, and 4, the parents from the Argentine land race grew better than progenies of parents selected from natural stands in the USA (Table 3). In fact, the mean breeding value for the USA parents was lower than those for most of the bulked check lots from naturalized stands in Argentina. However, there were a few USA parents that did better than one or both Argentine checklots. In Series 2, from East Texas and Louisiana, there was one parent that had a higher breeding value for volume than the PM check lot, and six that were higher than the PeCom check lot. In Series 3, also from East Texas and Louisiana, there was one USA parent that had a higher breeding value than the PeCom check lot and one that was greater than the Livingston check lot. Only one USA parent in Series 4, from Southern Mississippi, had a greater breeding value than the local Libertad checklot. These results are summarized in Table 2.

Table 2. Deviations from Argentina unimproved check lots for Series 1.

Genetically Improved Seed Source [1]	Total Height (m)	Dbh (cm)	Volume (D^2*H) (dm^3)	Height (%)	Dbh (%)	Volume (%)
Argentina land race	5.79	8.7	426.4	103	81	794
N. Florida	4.11	6.0	261.8	73	51	488
Livingston Parish	3.66	3.6	178.3	65	33	332

[1] Argentina land race is the average of 3 parents selected in naturalized stands in Argentina. N. Floric and Livingston Parish are means of 35 and 9 parents, respectively, in rogued, first-generation see orchards in the USA.

Table 3. Mean breeding values for selected seed lots in Series 2, 3, and 4.

Seed lot	Total height (m)			Dbh			Volume (dm^3)		
Series #	2	3	4	2	3	4	2	3	4
T189	11.7	--	--	22.5	--	--	531	--	--
T219	--	10.0	9.4	--	21.9	22.4	--	447	499
PM	7.9	--	--	16.4	--	--	217	--	--
PeCom	7.7	8.4	8.7	15.0	16.7	15.4	178	240	233
Libertad	--	--	8.0	--	--	16.1	--	--	--
Livingston	--	8.0	--	--	15.9	--	--	220	--
Marion	--	--	7.8	--	--	15.0	--	--	186
GFA	7.2	7.5	7.0	14.2	15.8	12.9	149	201	119
Mean USA 1st Generation	7.5	7.5	7.8	14.6	15.0	15.3	165	181	196

DISCUSSION

If adequate supplies of first-generation genetically improved seeds can not be obtained from within Argentina, it is clear that seeds from first-generation seed orchards in the USA are a viable alternative if improved growth rate is the desired objective. Those parents that were selected in northern Florida provenances should be favored over those from the Livingston Parish, Louisiana provenance. Trees from the USA seed orchards should also be marginally straighter than those from the Argentine land race.

Despite the relatively poor growth rates of the full-sib families from Texas, Louisiana and Mississippi, these families are a pedigreed population that can be used to increase the genetic diversity of the base population in Argentina. The best of the USA families should be considered for inclusion in the breeding population in Argentina. Furthermore, if wood density is an important factor in selection, parents from the tested USA populations may have greater value than apparent from these trials. A negative relationship has been demonstrated between growth rate and wood density at the provenance level (Byram and Lowe 1988, Jett and others 1991). In particular, the northern Florida and Livingston Parish provenances, which had the greatest growth rates in Argentina, have been shown to have low wood density in provenance trials throughout the southern USA (Jett and others 1991). Conversely, the East Texas and northern Louisiana provenances have been shown to have high wood density in southwide trials (Tauer and Loo-Dinkins 1990).

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