RESPONSE OF PINE SPECIES TO VARIED SITE CONDITIONS IN NORTHEASTERN ARGENTINA AND IN OTHER SUB-TROPICAL REGIONS

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ABSTRACT

RESPONSE OF PINE SPECIES TO VARIED SITE CONDITIONS IN NORTHEASTERN ARGENTINA AND IN OTHER SUB-TROPICAL REGIONS

By

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Argentina annually imports U$S 110 million worth of coniferous wood. Productivity of native conifer forests could be increased by better management but still would not satisfy the increasing demand of the internal market. Planting of native species is limited by their slow growth rate and site requirements. The cultivation of fast growing exotic species is the best way of increasing the softwood supply. Their excellent performance in humid regions of Argentina leads towards expectation of successful development of those areas into large industrial-integrated units.

The Northeast Pine Species Trial, begun in 1962, was Argentina's first formal experiment in tree introduction. This trial includes 27 varieties or provenances of 17 warm temperate and subtropical pine species native to Mexico, the Caribbean Islands, and southeastern and western United States.

One-year-old nursery seedlings grown in Castelar near Buenos Aires were transferred to 14 plantations in

the provinces of Misiones, Corrientes, Chaco, Entre Rios and the Delta of the Parana River, all in northeastern Argentina. Each seed source was represented by a 36- or 64-tree plot at each location. A 3 X 3-meter spacing was used. Leaf cutting ants were controlled for 3 years and the plantations were weeded for 2 years. Three plantations failed because of flooding or insufficient care.

Of the 11 successful plantations, 7 were located in a warm temperate (mean annual temperature: 19 to 22°C) region with no or infrequent frost, abundant rainfall uniformly distributed throughout the year or with greater frequency in spring and fall. Two plantations (Saenz Peña and Marcos Juarez) were located farther west in a warm temperate (mean annual temperature: 19 to 22°C) region with a continental type of climate, with temperature extremes varying from 45 to -10°C and a dry winter. Two southern plantations (Atucha and Castelar) had a temperate climate (mean annual temperature: 15 to 17°C), frequent freezing temperatures in winter and abundant rainfall uniformly distributed throughout the year.

Mortality was high 1 year after field planting for the slow growing, grass stage species (*Pinus palustris*, *P. tropicalis*, *P. montezumae*, *P. michoacana* and *P. rudis*). These species were characterized by a long juvenile stage with a dormant terminal bud and a grass appearance. The tropical species (*Pinus caribaea*, *P. oocarpa*, *P. cubensis* and *P. occidentalis*) had low survival at temperate stations with less than -7°C. Southeastern United States species (*Pinus elliottii* and *P. taeda*) and Mexican species (*Pinus patula*, *P. douglasiana*, *P. pseudostrobus*, and *P. tenuifolia*) had high survival.

There was no relationship between height at time of planting and height 1 year after planting. However height at age 1 was strongly correlated with height at 5 years of age.

Seven seedlots had higher average heights at age 5 for the warm temperate, humid stations than the commonly cultivated slash pine (*Pinus elliottii* var. *elliottii*), but only *P. caribaea* var. *hondurensis* and *P. patula* were significantly taller (5% level). Caribbean pine from Honduras also had significantly (5% level) thicker stem and greater volume. Analysis of variance for height for all species and locations indicates that little variance was due to species X site interaction, but primarily to species and plantations. When considering only the warm temperate, humid stations of the trial, 77% of the variance was due to species.

From the 5-year results, the following species were found the most promising: *Pinus caribaea*, *P. patula*, *P. elliottii*, *P. oocarpa* (from Honduras), *P. douglasiana*, and *P. insularis*.

Climates of the test regions were compared with climates of the region from which the most successful species were derived. Warm temperate or subtropical climates, abundant rainfall uniformly distributed throughout the year or with a greater occurrence in summer, were common to both donor and recipient regions. No species which grew well in northeastern Argentina came from a region with a cold climate or having winter rainfall. Successful donor areas also yielded poorly growing species under Argentine conditions.

The species which grew well in northeastern Argentina also grew well in subtropical areas of Brazil, Union of South Africa, Malawi, Rhodesia, Australia and New Zealand where the minimum temperature was higher than -7°C and rainfall was abundant and evenly distributed. Failures were also the same in Argentina and those regions. The literature data indicates that four species (*Pinus greggii*, *P. lawsonii*, *P. leiophylla* and *P. merkusii*) not previously planted in Argentina should be tested there.

An experimental design of a future species trial considers the factors: number of species and provenances to be tested, seed supply, sites and land area, trained personnel, number of trees per provenance, number of replicates, spacing, design and border rows. The compact family design tests 60 provenances of 13 taxa at each of 10 sites, with 5 replications per site and with one 5-tree plot per provenance per replication. A border row of slash pine will surround all plots of a single species.

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CHAPTER I

INTRODUCTION

Total internal consumption of forest products in Argentina during the 1961/65 quinquennium reached a yearly average value of 200 million U.S. dollars, of which 55% was imported. Forest product imports were about 10% of the total imports of the country. Lumber, which comprised 62% of the forest imports was mainly of Parana pine (*Araucaria angustifolia*) from Brazil, Monterey pine (*Pinus radiata*) and Araucaria pine (*Araucaria araucana*) from Chile, and a small amount of Spruce pine (*Picea abies*) from Europe. The remaining 38% was of pulp, paper and hard-board of long-fibered conifer wood. Nearly all imports were of conifer products.

The present Argentine consumption of conifer wood has been calculated as 2.1 million cubic meters per year (Castiglioni and Tinto, 1968). The consumption of paper products is 25 pounds per capita per year, whereas in the United States paper consumption was 514 pounds per capita in 1969. An increasing trend of wood use is true in most of the developed and developing countries of the world. Food and Agriculture Organization of the United Nations has predicted that in 10 years Europe will be importing wood instead of exporting it. Brazil, which provides 95% of the conifer lumber imported by Argentina will exhaust its Parana pine forests in less than 15 years (Takacs, 1968; Boggiano and Marinelli, 1963).

Native conifer forests now provide less than 5% of total conifer wood consumption in the Argentine Republic. There are 9 native species of conifers of which four have some commercial importance. Their distribution and importance are as follows. *Araucaria angustifolia* covers 40,000 hectares in a mixed forest in northeast Misiones. The estimated usable volume is 390,000 m^3. On a sustained yield basis, with 3% annual increment, yield could be 12,000 m^3 per year. *Podocarpus parlatorei* covers 100,000 hectares of pure and mixed forest in the northwestern Andes, in the provinces of Jujuy, Salta and Tucuman. There is enough wood to supply raw material to a 100-ton-per-day paper mill. *Araucaria araucana* covers about 80,000 hectares of mixed forest at 900 to 1,800 m at the Cordillera de los Andes in Neuquen. Most of the forest is in National Parks and is more than 200 km from the nearest railroad. *Austrocedrus chilensis* grows in pure or mixed forests in a narrow strip 5 to 15 km wide and 300 km long in the Cordillera de los Andes. The wood is used locally for construction (Giordano, *et al.*, 1964; Tortorelli, 1956).

The remaining native species, <u>Fitzroya cupressoides</u>, <u>Saxegothaea conspicua</u> and <u>Podocarpus nubigenus</u>, are associated with hardwoods in the southwestern Andes. The rain forest containing these species covers a total area of about 30,000 hectares. Most of the timber must be transported 100 km over lakes and unpaved mountain roads and unbridged rivers to the nearest railroad. <u>Podocarpus andinus</u> and <u>Pilgerodendron uviferum</u> are small trees of limited distribution in the Andes (Covas, 1938).

There is a possibility of increasing native forest production by better management and by industrial development of remote areas. This could double or triple the present production.

Extensive commercial cultivation of most native species has been rejected because of their slow growth as compared with exotics. The only native species which is cultivated extensively is Parana pine which is planted in northern Misiones. In deep red permeable clay soils it grows at a rate of 18 m^3 per hectare per year. The extent of its cultivation is limited by soil and climate requirements. Slash pine (<u>Pinus elliottii</u> var. <u>elliottii</u>) and loblolly pine (<u>P. taeda</u>) when planted in Misiones are able to grow on a larger variety of soils, producing 25 to 35 m^3 of wood per hectare per year. The native Andean conifers when under cultivation grow 0.5 to 2.5 m^3 per hectare per year whereas in the same region cultivated

Pseudotsuga menziesii, Pinus radiata and P. ponderosa have growth rates of 18 to 25 m^3 per hectare per year.

To summarize, better management of native conifer forests could increase production to satisfy 15% instead of 5% of present consumption. By planting native species, production could be increased further to 30%. But in the meantime the desire for wood will also increase. Therefore the gap between production and consumption will also increase. It is reasonable to expect that the production of conifer wood can equal or surpass the consumption by planting faster growing exotic species.

There is a general knowledge as to which species should be planted in each region but little information is available on which is the best species, provenances within species, for each of the planting sites.

Due to the economic importance of this knowledge, research should be undertaken in this field. The search for the best planting material should have priority over all other types of forest research. This is the reason for the present work.

CHAPTER II

HISTORY OF CONIFER TESTING IN ARGENTINA

Pre-1940 Conifer Introductions

In spite of the great importance of the cultivated conifer forest to the economy of Argentina, introduction of forest trees did not until recently follow scientific methods.

Probably the first pine species introduced into Argentina was *Pinus halepensis*, brought by the early Spanish settlers with their grapes and olive trees. Little is known in this regard about the three hundred years of the Spanish occupation. From what can be seen in the old Spanish cities of northwestern Argentina there were little interest in tree introduction. Toward the end of this period, Roman Catholic influence was noticeable in churches, convents and cemeteries in which were planted Italian species such as *Pinus pinea* and *Cupressus sempervirens*.

Interest in planting trees increased in the 19th century with the settlement of Buenos Aires Province by European colonists. They planted species from all parts of Europe. Mediterranean species were best adapted and later became the most common. But the important tree collections started after 1850, when large ranches called "Estancias" were installed in what is now the Argentine corn belt (Buenos Aires and adjoining parts of La Pampa, Santa Fe, and Cordoba provinces). Most landowners were influenced by French culture. They hired French landscapers to design large parks and gardens. The plants were obtained from important French nurseries such as Andrieux Vilmorin at Les Barres. A good example is the park of the Estancia "Huetel" in Bolivar (Buenos Aires). It covers 400 hectares and was built in a modern Versailles style with more than 200 forest tree species. Many species are naturalized and reproduce naturally. Due to the internationality of Vilmorin and other large European nurseries of this time, the collections gathered at these estancias, although predominantly European, also had American and Asiatic species which were grown in Europe at the time. Most species were chosen for ornamental rather than forestry purposes.

At the beginning of the 20th century, German and English immigration resulted in greatly increased interest in small diversified parks and gardens which required a large variety of ornamental conifers. At this time, many fully loaded ships came from France, Holland and Germany with grafted conifers. There were large nurseries dedicated to the multiplication of ornamental conifers. The same trend continued until 1940 (Peluffo, 1902-38). It is no longer possible to find such a large variety of Chamaecyparis, Juniperus, Thuja, Cupressus and other ornamental conifers in such nurseries as it was 30 years ago. Present emphasis is toward fewer varieties produced in larger quantities.

Experience gained in neighboring Uruguay can be applicable to Argentina. Antonio Lussich, a ship captain and owner of a shipping company, was responsible for much tree introduction. Between 1880 and 1900 he planted 2,000 hectares along the Atlantic Ocean coast, in the low mountains of Punta Ballena, 10 miles west of Punta del Este. Those plantations, mostly of conifers, are the most important tree collection in South America. They contain the common European trees and constitute the most complete collection of Mexican pines found in a single place. Approximately 40 Mexican species were planted in groves or in groups of several trees. Rare Asiatic conifers such as Pseudolarix, Sciadopitys, Thujopsis were mixed with more common Asiatic species (Del Castillo Lussich, 1960). A. Lussich and J. Pira, founder of Piriapolis, were responsible for most of the pine plantations along the Uruguayan coast. The forested coast is now the main tourist and recreation resource of Uruguay.

Botanists, botanical institutions, botanical gardens and other official agencies, made less contribution to Argentine conifer introduction. Most botanical gardens such as the one in Buenos Aires, were planned more as a public recreation park than a collection.

The National Park Administration made an important contribution at the Forest Station of Isla Victoria located in Lake Nahuel Huapi in the foothills of the Andes. The park was created in 1925. During the first 10 years its officers built up an important collection of conifers, including the most interesting species adapted to cool climates and heavy winter rainfall. Nearly 50 species were planted in rows or in small forest plots. The nursery of this station distributed seedlings to the entire southwestern region as far south as Tierra del Fuego. Most of the conifers cultivated in western Patagonia came from Isla Victoria. The nursery distributed seed of the most successful forest species such as *Pinus ponderosa*, *P. contorta*, *P. radiata* and *Pseudotsuga menziesii* (Barrett, 1954).

Two Decades (1940 to 1960) of Failures and Successes in Forest Planting

The early cultivation of coniferous species was basically done for ornamental purposes. Interest in large-scale commercial forest plantations arose in the early 1940's. Both government and industry realized the need for long-fibered wood which could be supplied in quantity only by planted conifers. Many large plantations were extablished, particularly in the northeastern part of the country. Often there was little knowledge of possible performance or ecological requirements of the species used.

Monterey pine (Pinus radiata) was one of the first species to be planted extensively, and also was one of the biggest mistakes. This species was chosen because seed was cheap and easily available, nursery growth was rapid, initial survival in plantations was high, and early growth was rapid.

In 1944, Celulosa Argentina S.A. planted 50 hectares of Monterey pine at Puerto Piray, Misiones. A few years later Fiplasto S.A.I.C., a hardboard manufacturing company, planted 80 hectares along the Parana River at Ramallo, Buenos Aires. Their example was followed by other private landowners. The owner of "Estancia San Ramon" near Saladillo, Buenos Aires, also planted 80 hectares of Pinus radiata. In all of these cases Monterey pine growth was good for a period of 6 to 8 years. Thereafter, the plantations became affected by many kinds of diseases and insects. After an additional period of 3 to 4 years the plantations were abandoned or destroyed. This happened whenever the species was planted in areas without cool moist winters or permeable soils (Golfari, 1959; Barrett and Garbosky, 1960).

In the same year, 1944, Celulosa Argentina planted several hectares of European Pinus pinaster, P. halepensis, and P. pinea, species which were common in Buenos Aires.

These species grew slowly, had poor form, and did not survive well (Celulosa Argentina, 1958). After a few years they were clearcut to use the land for other purposes.

Such failures retarded the commercial planting of pines. Most tree planters preferred the faster growing and more adaptable *Eucalyptus* species. Between 1950 and 1960, nearly 80,000 hectares were planted with eucalypts in Argentina. Successful plantations were established in different regions of the country. *Eucalyptus camaldulensis* had an excellent growth on moderately permeable clay soils; *E. viminalis* grew successfully in Buenos Aires province; *E. tereticornis* grew very well in Santa Fe; *E. grandis* grew fast in Entre Rios and *E. saligna* did the same in Misiones. These last two species had growth rates of 40 to 45 m^3 per hectare per year. But all these plantations were established on the basis of growth rate, without considering future use. Due to the small local markets and limited industrial use of the wood, eucalypt planting lessened after 1960.

In the last decade, there was an upsurge of interest in conifer plantations. Some of Celulosa Argentina's introductions were successful. In the late 1950's, this company planted plots of slash pine (*Pinus elliottii* var. *eliottii*) and loblolly pine (*P. taeda*) of unknown origin, at Puerto Piray (Misiones), Rosario (Santa Fe) and in the Delta of the Parana River. These trees grew well. After a few years, the company promoted their cultivation. These few plots were the starting point for the present plantation area of 30,000 hectares in Misiones, of 5,000 hectares in Concordia, and of 3,000 hectares planted in the Delta and along the coast of the Parana River.

The recent need for long-fibered wood has increased interest in pine cultivation in many different areas of the country. This is the case in the large humid region of the northwestern mountains of Jujuy and Salta and also the Sierra de Cordoba. Those regions are now at the same initial stage of tree introduction as Puerto Piray was in 1944. There is no previous experience as to what species should be planted. Foresters are following the same steps that Celulosa Argentina took earlier, and are not taking advantage of the experience gained in the northeast. As an example, an 800-hectare plantation of Monterey pine was established at Rio de los Sauces in Cordoba. After 10 years, most of the trees are dead.

The federal government encourages forest planting by means of liberal credits and tax exemptions. The general policy is to produce raw materials to satisfy Argentine consumption through plantations. This policy is successful in provinces such as Misiones and Entre Rios where past experience can reasonably insure that most plantations will yield usable products. However, where there is no such experience, many failures are apt to be subsidized.

Present Status of Forest Planting in the Northeast

The Argentine Republic has 1,072,745 square miles of land area, extending north to south for more than 2,000 miles from 22° to 55° South Latitude. This longitudinal extension is the cause of a large variety of climates; they vary from sub-tropical to sub-boreal.

The best commercial growth of conifers is obtained in the humid regions which occupy nearly 20% of the total land area. The humid regions are located in the plains of central and northeast of Argentina, in the mountains of the Cordillera in the northwest, in the "Sierras de Cordoba" and in a narrow strip along the Andes in the southwest, from Neuquen to Tierra del Fuego (Figure 1). From these areas, due to ecological and economical reasons, the northeast of Argentina has been considered the best suited to initiate a conifer tree species introduction program.

For the present purposes, northeastern Argentina can be described as the region extending 1,300 km north and east from the Parana Delta. It includes "Mesopotamia" (provinces of Entre Rios and Corrientes), or the region between the lower Parana and Uruguay Rivers. It includes parts of Chaco, Santa Fe and Buenos Aires provinces to the immediate west of the lower Parana River. In the northeastern tip of the country, between Brazil and Paraquay, it includes Misiones province, bordered by the middle portions of the Parana and Uruguay Rivers (Figure 2).

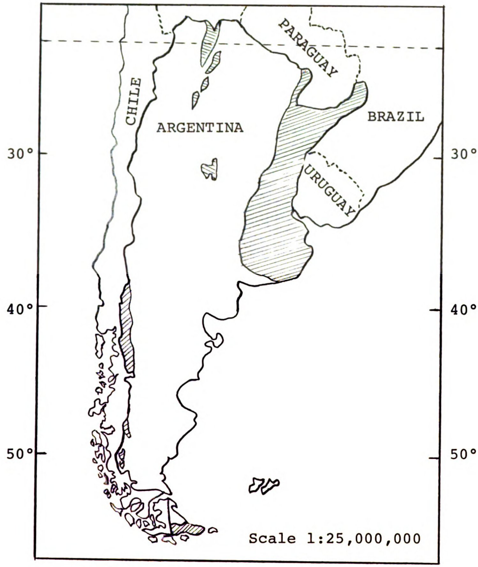

Figure 1.--Humid regions (shaded) of Argentina suitable for planting conifers. Climatic data from Burgos and Vidal, 1951.

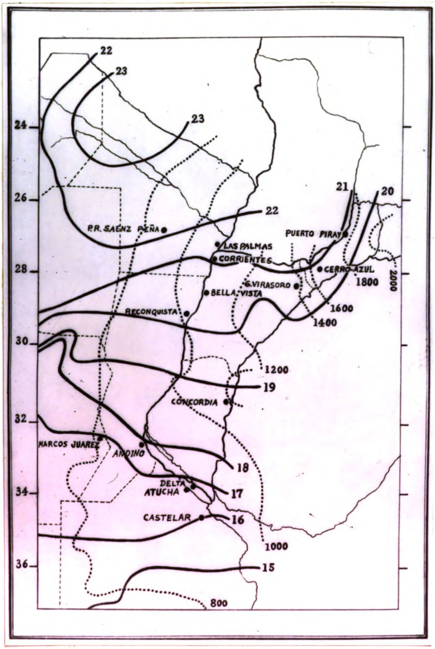

Figure 2.--Site locations in the northeast of Argentina. Solid lines correspond to annual mean temperature in °C; dotted lines to average annual precipitation in mm. Climatic data from Servicio Meteorologíco Nacional, 1958.

This northeastern region is warm and humid, capable of supporting excellent tree growth where soil conditions are favorable. The large navigable rivers provide economical access to the large population centers. Although there were large areas of natural forest, these have been overcut and are of low value. Industrial forestry is nearly synonymous with "plantation culture." Five subdivisions of the region can be recognized as follows.

Northern Misiones.--The northern half of the province was covered originally by a subtropical humid forest. The most important timber trees such as *Cordia*, *Balfourodendron* and *Cedrela* were cut more than 20 years ago. Logging left a degraded forest with few usable stems per hectare. The land is still forested but the species are of little commercial value.

The forest was for many years the main resource of northern Misiones. Later, farmers cleared the forest for agricultural use. They planted oranges, tung trees, yerba mate (*Ilex paraguariensis*), maniot and maize. One plantation of two hectares of the native araucaria was established in 1930. Ten years later, large landowners started extensive plantations which now total 23,000 hectares. In 1949, Celulosa Argentina, after unsuccessful trials with other species, started planting slash and loblolly pines. Other large landowners and farmers did the same. Due to the low market value of tung and yerba mate in recent years, the popularity of pine afforestation increased. There were 20,000 hectares of planted pines in 1967 (Asociación de Plantadores Forestales de Misiones, 1968).

Parana "pine" or araucaria (Araucaria angustifolia) when planted in deep red soils of the lowlands, grows between 18 and 25 m^3 per hectare per year. Its growth rate is much less in shallow, stony or impermeable soils. For this reason its profitable cultivation is limited to a total area of 100,000 hectares. Part of that 100,000 hectares is occupied by the large National Park of Iguazu, and part is preferred for agricultural crops. Another factor which limits cultivation of araucaria is the shortage of seeds. Brazil stopped seed export and Misiones plantations produce few seeds because they are young and have not been thinned enough (Golfari, 1966).

Little has been done concerning the improvement of araucaria. In 1964, A. C. Frith, FAO expert from England, started a provenance study with six origins. The study was abandoned in 1966 when Frith left.

Many different pine species were tested by Celulosa Argentina under the direction of L. Golfari between 1944 and 1965. The method followed was to plant large unreplicated plots of 1 to 50 hectares, depending on the amount of seed available. In 1957 Celulosa Argentina sent Golfari and a manager of the company to Central

America and the Antilles to collect seeds of Caribbean pines for testing in Misiones. As a result of this trip a 50-hectare plot of P. caribaea from Cuba and a similar amount of P. caribaea from Guatemala were planted for the first time. The results of these introductions were reported by Golfari and Barrett (1967).

Slash and loblolly pine are intensively planted as a result of the good growth obtained by the first Celulosa Argentina plantation in 1944. Of the present 20,000 hectares, 95% is planted to P. elliottii var. elliottii. This species is preferable to loblolly pine in speed and percentage of germination, resistance to damping off and juvenile growth. Loblolly pine would be preferable if judged on plantation growth rate.

Southern Misiones and northeastern Corrientes.--This region is partially subhumid subtropical forest and partially "Campos" grasslands with occasional patches of forest. The forest area is greatest in the north and along the rivers. The extensive "Urunday" forest type, dominated by Astronium urunday (Anacardiaceae), grows on soils only 5 to 10 cm deep, and thus not suited for afforestation.

Cattle grazing and agriculture are most important in the Misiones-Corrientes region. In addition to the crops grown in northern Misiones tea, tobacco, forage, and grapefruit are cultivated.

In this region it is not possible to grow good araucaria. Forest plantations are limited to slash and loblolly pines, _Eucalyptus saligna_ and "Chinaberry" (_Melia azedarach_). A 200-ton-per-day paper mill is being installed on the Parana River.

Western and northern Corrientes.--This is an area dedicated to general agriculture; specifically to tobacco and citrus on the sandy soils, and rice and cattle on the loam and clay soils of the lowlands. It is characterized by practically no frost, and by low rainfall in winter and summer. There are few forest plantations of _Eucalyptus_. Recently one slash pine plantation of 1,000 hectares was established.

Concordia, Entre Rios.--Near Concordia is a 100 km wide strip of sandy soils bordering the Uruguay River. The main crop is citrus, with some general agriculture and horticulture. _Eucalyptus grandis_ was planted with extraordinary success. By 1967, 16,000 hectares had been planted with this species. Seed for most plantations came from a row of trees planted on the local golf course.

Before 1955 the only pine species present were the slow growing European _Pinus pinea_, _P. halepensis_ and _P. pinaster_ planted in parks and citrus farms. In 1955 Celulosa Argentina gave a citrus farmer 1,000 seedlings of slash pine which survived and grew well. As a result, a eucalyptus planter-contractor promoted pine plantations.

With the help of federal credits, 4,000 hectares of pine plantations were established near Concordia in 1964. After dry 1965, when slash pine survived poorly, many planters switched to *P. taeda*.

Delta of the Parana River.--Horticultural crops and fruit trees were cultivated formerly in the fertile alluvial soils of the delta. Frequent floods made this cultivation hazardous. For this reason landowners have changed to forestry, planting 100,000 hectares of willows and poplars. Slash and loblolly pines grow at the rate of up to 40 m^3 per hectare per year. Because most of the young plantations are destroyed by floods, their planting is not recommended. A solution would be to construct a 4 m high dike, but then pines would compete with more profitable horticulture.

CHAPTER III

RECENT FORMAL EXPERIMENTS WITH SUB-TROPICAL PINES IN THE NORTHEAST

Objectives

The principal experiment, known as the "Northeast Pine Species Trial" was undertaken in 1962 as a first step toward genetic improvement of forest planting stock in the Northeast. This trial includes simultaneous tests of several pine species from sub-tropical parts of North and Central America at a number of test sites in the north-eastern part of Argentina. It was started in order to learn the best species for the varied site conditions in the region. A few additional species were planted at some localities for the same purpose.

These trials were meant to give practical information to tree planters. They also serve to show which species deserve more intensive tree improvement work.

The experiments were limited to the Northeast for practical reasons. Experience gained, however, can be used in the planning of rational testing and planting programs in other parts of the country.

Material and Methods, Northeast Pine Species Trial

The seeds were obtained in 1960 when I attended the FAO Seminar and Study Tour of Latin-American Conifers. I had the opportunity to visit and obtain seeds from Mexico, British Honduras (Belize), Cuba and southeastern United States. The seedlots with their origin are listed in Table 1. Accessibility of the parents was the only criterion for parental selection.

Planting stock for the permanent field tests was grown in the Instituto Nacional de Tecnología Agropecuaria (INTA) nursery at Castelar, Buenos Aires province. Seeds were sown in a loam-sand mixture in July 1961. The seedlings were transplanted, using the same soil mixture, to tarpaper pots of 6 cm diameter and 12 cm height after 3 months. Field planting was performed between May and July 1962. For location and characteristics of the test sites see Figure 2 and Tables 2 and 3. The Parana Delta plantation, destroyed by flooding, is excluded.

Prior to planting, sites with loam and clay-loam soils were plowed and disked. Sandy soils were disked only. Chemicals were used to control the ants which if not controlled can eat all bark and leaves of young trees. During the first 2 or 3 years after planting, the plantations were kept free of weeds by disking and by hoeing around the individual plants. Ants were controlled

Table 1.--Origin of seedlots included in the pine species trial in northeastern Argentina.

Species or variety[a]	Country and locality of origin
SPECIES FROM SOUTHEASTERN UNITED STATES	
Pinus elliottii Engelm.	
var. elliottii	U.S.A., Florida, Baker County
var. densa Little and Dorman	U.S.A., Florida, Hendry County
P. taeda L.	U.S.A., Georgia, commercial seed
CARIBBEAN SPECIES	
P. caribaea Morelet	
var. caribaea	Cuba, Pinar del Rio, Lomas de Cajalbana
var. hondurensis Barrett and Golfari	Belice, Stann Creek, coastal provenance
idem	Belice, Augustine 500 m alt.
P. cubensis Grisebach	Cuba, Oriente, Sierra de Ñipe 500 m alt.
P. occidentalis Sw.	Haiti, Forêt du Pin 1,500 m alt.
MEXICAN SPECIES	
P. patula Schiede and Deppe	Mexico, Veracruz, Jalapa, Perote 1,600 m alt.
idem	Mexico, Puebla, Aytola 1,600 m alt.
P. oocarpa Schiede	Honduras, Comayagüela, Siguatepeque
idem	Mexico, Jalisco, Ciudad Guzmán 1,500 m alt.
idem	Mexico, Mexico, Valle de Bravo 2,000 m alt.
idem	Mexico, Mexico, Valle de Bravo 2,300 m alt.
idem	Mexico, Michoacán, Morelia, Bosque Guatemoc

Table 1 (Continued)

Species or variety[a]	Country and locality of origin
MEXICAN SPECIES (Continued)	
P. pseudostrobus Lindl.	
var. pseudostrobus	Mexico, Michoacán, Aguacate
var. oaxacana Martinez	Mexico, Oaxaca, Sierra de Oaxaca 2,500 m alt.
P. douglasiana Martinez	Mexico, Michoacán, Morelia
P. cooperi Blanco	Mexico, Durango to Mazatlán 2,500 m alt.
P. engelmannii Carr.	Mexico, Durango to Mazatlán 2,200 m alt.
CALIFORNIAN SPECIES	
P. radiata D. Don	Commercial seed from Chile
SPECIES WITH GRASS STAGE	
P. tropicalis Morelet	Cuba, Pinar del Rio
P. palustris Miller	U.S.A., Georgia, commercial seed
P. montezumae Lamb.	Mexico, Mexico, San Rafael, 2,600 m alt.
P. michoacana Martinez	Mexico, Michoacán, Uruapan
P. rudis Endl.	Mexico, Mexico, San Rafael

[a]Nomenclature of P. caribaea Morelet and varieties follows Barrett and Golfari, 1962; P. pseudostrobus Lindl. and varieties, P. tenuifolia Benth. and P. rudis are as in M. Martinez, 1948; the remainder are as in Critchfield and Little, 1966.

Table 2.--Location and climatic characteristics of test sites.

Locality	S. Lat.	Temperature			Precipitation		Amount and season of moisture deficit
		Average year	Average January	Absolute minimum	Average annual	Distribution	
	°	°C	°C	°C	mm		
Puerto Piray Misiones	26.4	20.1	25.3	- 7.0	1,750	Uniform	None
Saenz Peña Chaco	26.9	21.3	27.3	- 6.3	931	Least in winter	180 mm, June to February
Las Palmas Chaco	27.0	21.9	27.5	- 6.0	1,258	Least in winter	10 mm, summer
Cerro Azul Misiones	27.5	20.8	25.2	- 6.6	1,700	Uniform	None
El Sombrerito Corrientes	27.8	21.7	27.1	- 1.1	1,204	Least in winter	10 mm, summer
Gob. Virasoro Corrientes	28.0	21.0	25.6	- 8.0	1,348	Least in winter	10 mm, summer
Bella Vista Corrientes	28.4	20.7	26.8	- 1.6	1,042	Least in winter	30 mm, summer
Concordia Entre Rios	31.3	18.8	25.7	- 7.4	1,119	Uniform	30 mm, summer
Marcos Juarez Cordoba	32.7	17.0	24.5	-10.0	791	Least in winter	70 mm, summer
Atucha Buenos Aires	33.9	16.7	23.7	- 7.0	980	Uniform	15 mm, summer
Castelar Buenos Aires	34.6	16.7	23.5	- 8.0	975	Uniform	12 mm, summer

Table 3.--Soil and vegetation of test sites in northeastern Argentina.

Locality	Soil	Vegetation
Puerto Piray Misiones	Semipermeable deep red-brown clay loam, stony, hilly	Subtropical humid forest
P.R. Saenz Peña Chaco	Semi-permeable gray clay loam, shallow, level	Subtropical dry forest
Las Palmas Chaco	Semi-permeable gray clay loam, deep, level	Savanna
Cerro Azul Misiones	Semi-permeable brown, clay loam, hilly	Subtropical humid forest
El Sombrerito Corrientes	Semi-permeable deep black gray clay loam, level	River-border forest
Gob. Virasoro Corrientes	Permeable deep red clay, level.	Mixed subtropical forest
Bella Vista Corrientes	Permeable deep sand, hilly.	River-border forest
Concordia Entre Rios	Permeable deep sand, hilly	Mixed palm forest with grassland
Marcos Juarez Cordoba	Semi-permeable shallow gray-black loam to clay, level.	Grassland
Atucha Buenos Aires	Semi-permeable shallow black clay-loam, level	Prairie
Castelar Buenos Aires	Semi-permeable shallow black clay-loam, level	Prairie

chemically for the first 5 years after planting at most stations.

Permanent field plantations contained one 36- or 64-tree plot per seedlot. A 3 x 3-meter spacing was used. In most plots of fast growing species, the crowns had closed after 5 years. Most seedlots are represented at Puerto Piray, Bella Vista, Concordia and Castelar. The number of species was reduced at other stations due to limitations of seed and planting stock.

Soils were selected for each test site choosing the most suitable for pine, based on local experience. They also were chosen because they are representative for large areas. Therefore results of the test could apply directly when planning the installment of future industrial units. The Northeastern Pine Species Trial was not planned to test for soil differences as much.

Results from the "Northeast Pine Species Trial"

In general, the plantations looked excellent at age 5. They were like checkerboard forests with heterogeneous plots of different color, shape and size. The growth of some species was outstanding. The care given to most plantations was also excellent. Unhappily not all of them received the same treatment. The care given at some stations was far from ideal. Many plants were lost and others grew more slowly than was to be expected under the prevailing soil and moisture conditions.

Mortality

First-year mortality (Table 4) was due mostly to lack of care and ants. Transplanting shock was negligible because the seedlings had been potted prior to field planting. Greatest mortality occurred in species with a "grass-stage." Such species have a period of little height growth and general appearance of a grass plant. They could not compete with the weedy vegetation and were most apt to be cut by the laborers who hoed the grass around the trees. The grass-stage species with high mortality were *Pinus tropicalis*, *P. palustris*, *P. montezumae*, *P. michoacana* and *P. rudis*.

Plantations receiving little care were apt to suffer heavy damage from ants. Most pine species were eaten a little. The most sensitive was *P. patula* which suffered mortality of 53% at El Sombrerito and 45% at Las Palmas.

The planting was performed after the low-temperature period had passed, so frost damage was negligible during the first year, except at Saenz Peña and Marcos Juarez. At those plantations, four tropical pines suffered mortality of 25 to 97% whereas hardy pines suffered only 3 to 6% losses.

Table 4.--Mortality at age 1 of *Pinus* species planted at eleven stations in northeastern Argentina.

Species of *Pinus*	Mortality in percent									
	Warm-temperate, humid stations					Temperate or sub-humid stations				
	CA	GV	ES	BV	CO	SP	LP	MJ	AT	CA
	MISIONES	CORRIENTES			ENTRE RIOS	CHACO		CORDOBA	BUENOS AIRES	
SPECIES FROM SOUTHEASTERN UNITED STATES										
elliottii var. elliottii	3	-	0	0	0	0	3	6	3	0
elliottii var. densa	0	2	27	0	2	3	3	3	59	0
taeda	6	0	0	0	5	0	6	28	8	0
CARIBBEAN SPECIES										
caribaea var. caribaea	3	16	17	5	14	25	16	94	59	14
caribaea var. hondurensis (Coast)	8	0	53	0	9	91	12	97	31	3
caribaea var. hondurensis (Mountain)	6	0	33	0	5	94	5	94	42	0
cubensis	61	78	91	33	-	-	72	-	-	61
MEXICAN SPECIES										
patula (Veracruz)	11	5	53	0	6	11	45	6	16	0
patula (Puebla)	-	0	-	3	0	-	3	-	-	0
oocarpa (Honduras)	-	28	-	0	6	-	-	-	-	8
oocarpa (Jalisco)	-	0	-	0	0	-	-	-	-	0
oocarpa (Mexico, 2,000 m)	6	19	33	2	-	53	42	57	55	6
oocarpa (Mexico, 2,300 m)	-	-	-	-	6	-	-	-	-	19
oocarpa (Michoacan)	-	23	-	3	19	-	-	-	-	3

Table 4 (Continued)

Species of *Pinus*	Mortality in percent									
	Warm-temperate, humid stations					Temperate or sub-humid stations				
	CA	GV	ES	BV	CO	SP	LP	MJ	AT	CA
	MISIONES	CORRIENTES			ENTRE RIOS	CHACO		CORDOBA	BUENOS AIRES	
MEXICAN SPECIES (Continued)										
pseudostrobus var. pseudostrobus	-	-	-	-	3	-	-	-	-	14
pseudostrobus var. oaxacana	-	-	-	-	-	-	-	-	-	0
douglasiana	0	0	33	0	0	3	6	36	19	0
tenuifolia	-	-	-	-	11	-	-	-	-	0
cooperi	-	-	-	-	17	-	-	-	-	4
engelmannii	-	-	-	3	11	-	-	-	-	0
CALIFORNIAN SPECIES										
radiata	-	-	-	-	3	-	-	6	6	0
GRASS-STAGE SPECIES										
palustris	-	-	27	-	-	-	12	-	-	33
montezumae	25	26	80	3	17	33	58	50	83	2
michoacana	0	3	30	2	11	28	33	25	-	3
rudis	25	-	-	3	17	-	-	50	-	6

Explanation of station symbols: CA = Cerro Azul; GV = Gobernador Virasoro; ES = El Sombrerito; BV = Bella Vista; CO = Concordia; SP = Saenz Peña; LP = Las Palmas; MJ = Marcos Juarez; AT = Atucha and CA = Castelar.

By comparing first and fifth-year mortality (Tables 4 and 5) it is clear that most subsequent mortality involved tropical pines such as *P. caribaea* and *P. oocarpa* at stations with cold winters. Others, including the grass-stage species, had a relative low increase.

Table 6 shows the percentage of mortality of groups of species at the eleven stations of the trial. The high mortality of the temperate species is probably associated with poor soil drainage. Low survival in "grass-stage" species seems to be associated with damage due to cultivation or winter cold. The high mortality at the fifth year of "tropical" species is due to their susceptibility to frost. Therefore it was low at sub-tropical stations and high at the others.

Growth Rate

Age-age height correlations.--According to the height of the planting stock, species of this trial were grouped in three categories. The tallest (0.25 to 0.50 m) included *P. elliottii*, *P. caribaea* var. *hondurensis*, *P. oocarpa* and *P. radiata*. The medium category (0.15 to 0.25 m) included *P. taeda*, *P. elliottii* var. *densa*, *P. patula*, *P. caribaea* var. *caribaea* and others. The shortest category (less than 0.15 m) included species such as *P. palustris*, *P. montezumae*, *P. michoacana*, *P. pseudostrobus* and *P. engelmannii*.

Table 5.--Mortality at age 5 of Pinus species planted at eleven stations in northeastern Argentina.

Species of Pinus	Mortality in percent										
	Warm-temperate, humid stations						Temperate or sub-humid stations				
	PP	CA	GV	ES	BV	CO	SP	LP	MJ	AT	CA
	MISIONES		CORRIENTES			ENTRE RIOS	CHACO		CORDOBA	BUENOS AIRES	
SPECIES FROM SOUTHEASTERN UNITED STATES											
Elliottii var. elliottii	0	3	-	0	0	5	0	3	11	3	3
elliottii var. densa	5	0	6	30	2	3	3	9	11	62	3
taeda	2	6	0	0	0	5	3	9	28	8	0
CARIBBEAN SPECIES											
caribaea var. caribaea	4	3	16	17	5	14	55	55	100	100	100
caribaea var. hondurensis (Coast)	17	28	2	53	0	9	100	67	100	100	100
caribaea var. hondurensis (Mountain)	13	8	0	39	0	5	100	51	100	100	100
cubensis	12	83	80	94	55	-	-	81	-	-	100
occidentalis	25	-	-	-	-	-	-	-	-	-	-
MEXICAN SPECIES											
patula (Veracruz)	25	11	5	53	0	6	22	48	6	16	0
patula (Puebla)	15	-	0	-	3	0	-	9	-	-	0
oocarpa (Honduras)	25	-	28	-	2	11	-	-	-	-	100
oocarpa (Jalisco)	20	-	0	-	0	0	-	-	-	-	100
oocarpa (Mexico, 2,000 m)	22	6	19	39	3	-	100	81	69	100	100
oocarpa (Mexico, 2,300 m)	22	-	-	-	-	6	-	-	-	-	84
oocarpa (Michoacan)	-	-	26	-	16	25	-	-	-	-	94

Table 5 (Continued)

Species of Pinus	Mortality in percent										
	Warm-temperate, humid stations						Temperate or sub-humid stations				
	PP	CA	GV	ES	BV	CO	SP	LP	MJ	AT	CA
	MISIONES		CORRIENTES			ENTRE RIOS	CHACO		CORDOBA	BUENOS AIRES	
MEXICAN SPECIES (Continued)											
pseudostrobus var. pseudostrobus	28	-	-	-	-	3	-	-	-	-	17
pseudostrobus var. oaxacana	5	-	-	-	-	-	-	-	-	-	0
douglasiana	22	6	0	33	2	0	28	11	39	21	0
tenuifolia	12	-	-	-	-	11	-	-	-	-	0
cooperi	-	-	-	-	-	19	-	-	-	-	6
engelmannii	50	-	-	-	23	11	-	-	-	-	3
CALIFORNIA SPECIES											
radiata	-	-	-	-	-	3	-	-	8	6	0
GRASS-STAGE SPECIES											
tropicalis	83	-	-	-	-	-	-	-	-	-	-
palustris	32	-	-	30	-	-	-	28	-	-	35
montezumae	12	28	31	86	5	25	42	62	53	84	28
michoacana	20	3	6	36	2	11	28	41	33	-	3
rudis	34	28	-	-	5	25	-	-	53	-	6

Explanation of station symbols: PP = Puerto Piray; CA = Cerro Azul; GV = Governador Virasoro; ES = El Sombrerito; BV = Bella Vista; CO = Concordia; SP = Saenz Peña; LP = Las Palmas; MJ = Marcos Juarez; AT = Atucha and CA = Castelar.

Table 6.--Mortality at age 5 of pine species at eleven test sites in northeastern Argentina.

Location of plantations	5-year mortality			Reasons for mortality
	Temperate species[a]	Grass-stage species[b]	Tropical species[c]	
WARM TEMPERATE, HUMID STATIONS				
Puerto Piray Misiones	10	21	14	Lack of care, disease
Cerro Azul Misiones	5	16	13	
Gob. Virasoro Corrientes	3	12	18	
El Sombrerito Corrientes	23	51	36	Lack of care, ants, poor soil
Bella Vista Corrientes	1	4	2	
Concordia Entre Rios	4	18	10	
TEMPERATE OR SUB-HUMID STATIONS				
Saenz Peña Chaco	11	35	89	Lack of care, ants, cold
Las Palmas Chaco	27	44	64	Lack of care, ants, poor soil
Marcos Juarez Cordoba	19	43	92	Lack of care, ants, cold
Atucha Buenos Aires	22	84	100	Lack of care, ants, cold
Castelar Buenos Aires	1	22	100	Cold

[a] *P. elliottii* var. *elliottii*, *P. elliottii* var. *densa*, *P. taeda*, *P. patula* and *P. douglasiana*.

[b] *P. palustris*, *P. montezumae* and *P. michoacana*.

[c] *P. caribaea* and *P. oocarpa*.

There was no relationship between height at time of planting and height 1 year after planting. Most of the species which were of medium height in the nursery were taller after one year in the field than some species which were tallest in the nursery.

Height at age 1 (from planting) was strongly correlated with height at age 5 (Table 7). The correlations were calculated for seven stations and were significant at the 1% level. The values varied from $r = 0.73$ at Castelar to $r = 0.94$ at Gobernador Virasoro. The 1-year heights accounted for 53 to 88 percent of the 5-year variance.

The low 1-to 5-year correlation obtained at Castelar was mostly due to the fast growth of sub-tropical pines during the first year before they were affected by frost. The effects of winter cold during the second year caused these non-hardy types to decline.

At Cerro Azul, the relatively low value of r in the 2- to 5- and 3- to 5-year correlation was due mostly to fast growth in the last years of _P. elliottii_ var. _densa_ and _P. douglasiana_ which started off slowly and to slow growth in later years of _P. taeda_ which started off rapidly.

At the subtropical stations such as Bella Vista and Gobernador Virasoro, fast growing species at the first year were also tallest in the fifth year; the age-age correlations were high. Although the grass-stage species did

Table 7.--Correlations between heights at different ages from planting at seven stations of the Argentine Northeastern Species Trial. All correlations were significant at 1% level.

Stations	Number of species	Correlation between year		
		1 and 5	2 and 5	3 and 5
		r	r	r
Cerro Azul Misiones	9	.85	.85	.86
Gob. Virasoro Corrientes	15	.94	.95	-
El Sombrerito Corrientes	13	.85	.92	-
Bella Vista Corrientes	18	.93	.95	.99
Concordia Entre Rios	24	.88	.93	.98
Las Palmas Chaco	13	.83	.89	-
Castelar Buenos Aires	22	.73	.84	-

not break their terminal bud dormancy during the first year, their low initial height did not affect the 1- to 5-year correlation because they were also shortest at the fifth year.

The 2- to 5-year correlations are higher than the 1- to 5-year values (Table 7). Their r values vary from 0.83 at Castelar to 0.95 at Bella Vista and Gobernador Virasoro. The 2-year data accounted for 71 to 90 percent of the 5-year variance.

Height measurements were made during each of 7 years at Concordia. The correlations changed from the first to the third year, but after the third year they changed very little (Table 8).

The growth of several species at Concordia, Entre Rios during the period 1962 to 1969 is shown in Figure 3. The species selected represent fast growing species (*P. patula*, *P. caribaea* var. *hondurensis*), the species most cultivated locally (*P. elliottii* var. *elliottii* and *P. taeda*), intermediate species (*P. pseudostrobus*), and slow growing and grass-stage species (*P. engelmannii* and *P. montezumae*).

Special attention should be given to the height growth trend in *P. radiata*. This species was the tallest during the first 5 years, with a growth rate of 1.7 m per year. After this age it started to decline and was passed by four other seedlots in the next 2 years. This trend

Table 8.--Correlations (all significant at 1% level) among mean heights of 24 pine species planted at Concordia, Entre Rios. Note that after the age 3 the correlations with age 7 are very high.

Age	Correlation between height at Age					
	2	3	4	5	6	7
1	.91	.90	.90	.88	.86	.74
2		.97	.94	.93	.93	.83
3			.98	.98	.97	.95
4				.98	.97	.97
5					.99	.97
6						.99

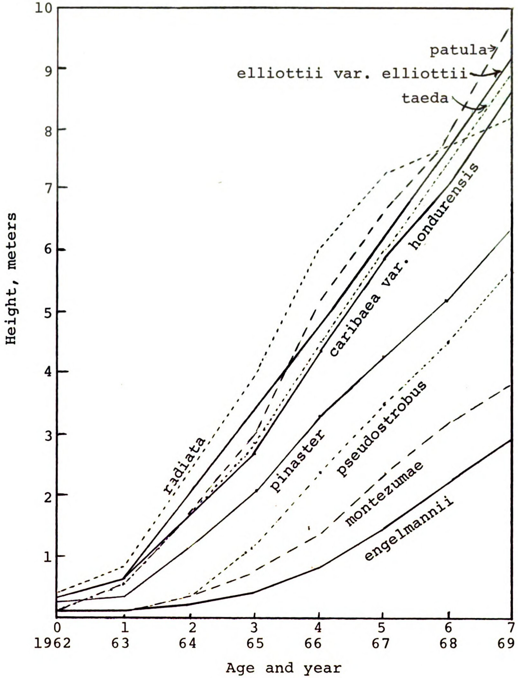

Figure 3.--Height at ages 1 to 7 of nine pine species planted at Concordia, Entre Rios.

is explained by the warm and humid summers of the Concordia area. *Pinus radiata* has failed in other areas with similar climates.

The age-age correlations are important because they indicate the trustworthiness of the data from relatively youthful test plantations. The one species (*Pinus radiata*) known to fail at later ages showed signs of decline by age 5. The trend observed by other species indicate that many valid predictions about growth at ages 10 to 15 (pulpwood rotations) can be made by age 5 (Nanson, 1968).

Height at age 5.--Height was measured in July 1967 at the eleven stations of the trial (Table 9). An analysis of variance was performed which indicates that 50% of the variance was due to species and 45% to plantations. Both species and plantation were significant at 1% level.

Species were grouped according to their origin and growth habit, and variance was partitioned separately for each group (Table 10). Variation within the southeastern United States species and Caribbean species groups was due more to plantation than to species. The Mexican pine group was more heterogeneous. It includes fast growing species such as *P. patula* and slow growing ones like *P. engelmannii*. In that group, 71% of the total variance was due to species. In the grass-stage group, variation was due to species and species x plantation interaction.

Table 9.--Height of pine species 5 years after planting at 11 stations in northeastern Argentina.

Species of Pinus	Height in dm										
	Warm-temperate, humid stations						Temperate or sub-humid stations				
	PP	CA	GV	ES	BV	CO	SP	LP	MJ	AT	CA
	MISIONES		CORRIENTES			ENTRE RIOS	CHACO		CORDOBA	BUENOS AIRES	
SPECIES FROM SOUTHEASTERN UNITED STATES											
elliottii var. elliottii	67	65	61	63	66	64	51	53	42	37	43
elliottii var. densa	71	70	61	60	66	54	56	51	37	-	30
taeda	66	74	61	60	66	62	45	35	39	43	44
CARIBBEAN SPECIES											
caribaea var. caribaea	71	66	61	70	70	57	Dead	45	Dead	Dead	Dead
caribaea var. hondurensis (Coast)	78	85	76	75	83	59	Dead	48	Dead	Dead	Dead
caribaea var. hondurensis (Mountain)	80	93	70	82	83	61	Dead	45	Dead	Dead	Dead
cubensis	47	44	47	-	-	-	-	Dead	-	-	-
occidentalis	43	-	-	-	-	-	-	-	-	-	-
MEXICAN SPECIES											
patula (Veracruz)	Dead	84	78	79	87	67	Dead	47	45	43	52
patula (Puebla)	Dead	-	78	-	73	62	-	63	-	-	48
oocarpa (Honduras)	62	-	68	-	76	59	-	-	-	-	Dead
oocarpa (Jalisco)	62	-	-	-	56	44	-	-	-	-	Dead
oocarpa (Mexico, 2,000 m)	48	51	50	45	51	-	Dead	Dead	29	Dead	Dead
oocarpa (Mexico, 2,300 m)	53	-	-	-	-	41	-	-	-	-	Dead
oocarpa (Michoacan)	-	-	-	-	37	46	-	-	-	-	Dead

Table 9 (Continued)

Species of Pinus	Height in dm										
	Warm-temperate, humid stations						Temperate or sub-humid stations				
	PP	CA	GV	ES	BV	CO	SP	LP	MJ	AT	CA
	MISIONES		CORRIENTES			ENTRE RIOS	CHACO		CORDOBA	BUENOS AIRES	
MEXICAN SPECIES (Continued)											
pseudostrobus var. pseudostrobus	48	-	-	-	-	36	-	-	-	-	33
pseudostrobus var. oaxacana	51	-	-	-	-	-	-	-	-	-	53
douglasiana	50	74	64	58	62	55	Dead	26	50	46	45
tenuifolia	38	-	-	-	-	41	-	-	-	-	24
cooperi	-	-	-	-	-	15	-	-	-	-	16
engelmannii	17	-	-	-	15	17	-	-	-	-	14
CALIFORNIA SPECIES											
radiata	-	-	-	-	-	72	-	-	45	55	56
GRASS-STAGE SPECIES											
tropicalis	17	-	-	-	-	-	-	-	-	-	-
palustris	29	-	-	38	-	-	-	Dead	-	-	16
montezumae	37	33	22	13	25	25	Dead	Dead	31	33	19
michoacana	32	35	33	32	36	34	Dead	Dead	31	-	30
rudis	19	-	-	-	25	24	-	-	Dead	-	19

Explanation of station symbols: PP = Puerto Piray; CA = Cerro Azul; GV = Gob. Virasoro; ES = El Sombrerito; BV = Bella Vista; CO = Concordia; SP = Saenz Peña; LP = Las Palmas; MJ = Marcos Juarez; AT = Atucha; CA = Castelar.

Table 10.--Variance components of height at age 5 for groups of species planted at 7 locations in northeastern Argentina.

Item	Percent of total variance			
	Southeastern U.S. species	Caribbean species	Mexican species	Grass-stage species
Species	0	12*	71**	56**
Plantation	68**	67**	12**	0
Interaction (Sp. x Plant.)	32	21	17	44

*Significant at 5% level.

**Significant at 1% level.

The mean relative heights of the 10 fastest growing origins planted at six warm-temperate stations are shown in Table 11. All were converted to a percentage of *Pinus elliottii* var. *elliottii*, the variety most commonly planted. Six origins exceeded the standard variety on the average for the six test sites. Analysis of variance of the data on which Table 11 is based, indicate that 77% of the total variance was due to species or variety, 10% was due to plantation, and 13% to species x plantation interaction. Both species and plantation effect were significant (1% level).

Diameter at age 5.--Diameter breast high (outside bark) was measured at three stations in the 5th year after planting on the 12 fastest growing species or varieties.

The analysis of variance at 3 stations indicates that 77% of the total variance was due to species, 5% to plantation and 18% was due to the interaction of species x plantation or error (Table 12). Although 5 species performed better than slash pine, only *P. caribaea* var. *hondurensis* was different at the 5% level.

At Concordia, the coolest of the three stations, the commonly planted *Pinus elliottii* var. *elliottii* exhibited the greatest diameter growth. It was considerably inferior to other origins at the two warmer stations.

Volume at age 5.--The complex trait volume is a function of diameter, height, and form. It gives the best

Table 11.--Actual and relative height at age 5 (expressed as percent of Pinus elliottii var. elliottii) of fast growing pine species at six warm-temperate, humid stations.

Species of Pinus	Relative height at Cerro Azul	Bella Vista	Puerto Piray	Gob. Viras.	El Sombr.	Con-cordia	Species Average
	---------------	Percent	of slash	pine	------------		
caribaea var. hondurensis (Mountain)	143	126	119	115	130	93	121
caribaea var. hondurensis (Coast)	131	126	116	125	119	92	118
patula (Veracruz)	129	131	-	128	125	104	123
taeda	114	100	99	100	95	97	101
elliottii var. densa	108	100	106	100	95	84	99
douglasiana	114	94	75	105	92	86	94
caribaea var. caribaea	101	106	106	100	111	89	102
oocarpa (Honduras)	-	115	93	111	-	92	103
eliottii var. elliottii	100	100	100	100	100	100	100
michoacana	54	56	47	54	51	53	52
	Actual height, decimeters						
Station mean	71.7	69.5	64.1	63.3	62.5	57.2	
elliottii var. elliottii	65	66	67	61	63	64	

Least significant difference at 5% level: For species, 9.6%; for plantations, 4.8 dm.

Table 12.--Actual and relative diameter (breast high) at age 5 (expressed as percent of P. elliottii) at three stations.

Species of Pinus	Stations: Cerro Azul	Stations: Bella Vista	Stations: Concordia	Species average
	---------Relative diameters, percent--------			
caribaea var. hondurensis (Mountain)	132	122	94	116
caribaea var. hondurensis (Coast)	125	127	98	117
patula (Veracruz)	119	115	86	106
taeda	128	101	90	114
elliottii var. densa	116	114	94	108
douglasiana	120	105	83	101
caribaea var. caribaea	109	107	80	99
elliottii var. elliottii	100	100	100	100
oocarpa (Honduras)	-	106	79	97
patula (Puebla)	-	100	79	95
michoacana	79	-	63	71
cubensis	54	48	-	48
	Actual diameter, cm			
Station mean	11.9	12.8	11.7	
elliottii var. elliottii	11.2	12.3	13.6	

Least significant difference at 5%: For species, 14.9%; for stations, 1.0 cm.

estimate of species performance not only because it combines three independent traits but because it is itself one of the most important objectives of cultivation.

The volume of each species was calculated on the basis of individual tree height and diameter measurements. As form factor I used a coefficient of 0.50 for all species. This value slightly favors conical species such as P. patula, P. douglasiana and P. taeda. Volume was calculated on the basis of single trees rather than amount per hectare.

Volume data accentuate the differences among species. For example, P. caribaea var. hondurensis (mtn.) at Cerro Azul was 43% taller, 32% thicker and 151% greater in volume than the standard species, slash pine. The same provenance of the Caribbean pine at Cerro Azul had approximately 700% greater volume than P. michoacana whereas height and diameter were only 150% and 68% greater respectively. Sometimes small differences in height and diameter caused large differences in volume. At Cerro Azul, P. taeda had 14% greater height and 28% greater diameter than P. elliottii var. elliottii; the volume was 97% greater.

Considering three stations, there are seven pines with more volume on the average than slash pine, although only P. caribaea var. hondurensis was significantly different at the 5% level (Table 13). Approximately 24%

Table 13.--Actual and relative volume at age 5 (expressed as percent of P. elliottii) at three stations.

Species of Pinus	Stations			Species average
	Cerro Azul	Bella Vista	Concordia	
	---------Relative volume, percent-----------			
caribaea var. hondurensis (Mountain)	251	190	86	165
caribaea var. hondurensis (Coast)	222	207	90	165
patula (Veracruz)	202	177	80	143
taeda	197	105	78	119
eliottii var. densa	148	135	73	114
douglasiana	167	117	63	109
caribaea var. caribaea	121	130	61	100
elliottii var. elliottii	100	100	100	100
	Actual volume, dm^3			
Station mean	58.2	58.1	38.5	
P. elliottii var. elliottii	33	40	49	

Least significant difference at 5%: For species, 48%; for stations, 12.0 dm^3.

of the variance was due to species, 36% to plantation and 40% to interaction of species x plantation and error. F values for species and plantation were significant at the 5% and 1% levels respectively.

Variation within species.--Slash and loblolly pines were characterized by uniformity in individual height growth and growth habit. All trees had straight stems at all sites of the test. The coefficient of variability for 5-year height varied from 10 to 13%.

The varieties of *P. caribaea* were more variable. Coefficient of variability varied from 13 to 22% for 5-year height. Form was also variable. Only 10% of the tree had straight stems. Long branchless terminal shoots ("fox-tail" growth habit), appeared in 15 to 25% of the trees of var. *hondurensis*.

Other species had intermediate height variation, but were uniform in growth habit, characterized by heavy branching. This is true for *P. douglasiana*, *P. pseudostrobus* and *P. tenuifolia*. *P. patula* with the same growth habit, had a more uniform height growth.

Variation in height in the grass-stage species varied with the duration of the grass-stage. *Pinus elliottii* var. *densa* with a grass-stage of only 1 year, was as uniform as *P. elliottii* var. *elliottii* at age 5. *P. montezumae* and *P. michoacana*, with grass-stages lasting 2 to 3 years were of intermediate variability in 5-year height. The grass-stage lasted anywhere from 2 to 5 years in *P. palustris* and *P. tropicalis*, with the result that individual trees varied from 25 to 400 cm tall at age 5.

From the standpoint of immediate utilization, the more uniform the stand the better. But from the standpoint of genetic improvement, very little can be gained from uniform stands. Variation can be due to environment or genetics. If most variation in a species such as *P. caribaea* is due to environment, by improving or finding the best nursery or cultural techniques or by finding the best site, the production could be increased easily. If the variation is due to genetics and is inherited, breeding through selection or hybridization will be the most promising way to increase production.

The same can happen with an irregular grass-stage species such as *P. palustris*. The variation may be due to the lack of knowledge of how to handle the seedling stage or the need of a specific type of cultivation. When the environmental cure is found, its application can increase rapidly the productivity of this species. On the other hand if this grass-stage is due mostly to inherited factors, by breeding methods a higher yield can be obtained easily.

Species Summary from the "Northeast Pine Species Trial"

Following is a summarized description of species and variety behavior at all stations of the trial after a 5-year period of observations.

SPECIES FROM SOUTHEASTERN UNITED STATES

P. elliottii var. *elliottii*. Uniformly fast growth at all stations; good form.

P. elliottii var. *densa*. Short grass-stage; slightly sensitive to frost; uniformly fast growth; good form.

P. taeda. Similar in growth to *P. elliottii* var. *elliottii* but heavier branching.

CARIBBEAN SPECIES

P. caribaea var. *caribaea*. Fast growth at frost-free sites; 30% of trees with good form.

P. caribaea var. *hondurensis*. Fast growth at frost-free sites; poor form, not uniform.

P. cubensis. Frost sensitive; poor survival; medium growth rate; good form.

P. occidentalis. Frost sensitive; poor survival; medium growth rate; good form.

MEXICAN SPECIES

P. patula. Fast growth; conical trees with dense branching.

P. oocarpa from Honduras. Frost sensitive; fast growth and many good stems.

P. oocarpa from Mexico. Frost sensitive; medium growth rate; poor form, crooked and forked stems.

P. pseudostrobus. Medium growth rate; poor form, dense branching.

P. pseudostrobus var. *oaxacana*. Medium to fast growth rate; poor form, dense branching.

P. douglasiana. Medium to fast growth rate; poor form, dense branching.

P. tenuifolia. Medium growth rate; poor form.

P. cooperi. Slow growth; good form; valuable as an ornamental.

P. engelmannii. Slow growth; poor form, dense branching.

CALIFORNIA SPECIES

P. radiata. Fast growth rate the first five years; decline in later years.

GRASS-STAGE SPECIES

P. tropicalis. Long (2- to 5-year) grass-stage, slow growing.

P. palustris. Long (2- to 5-year) grass-stage, but later medium growth; good form.

P. montezumae. Medium (1- to 2-year) grass-stage; medium growth rate; poor form, dense branching.

P. michoacana. Medium (1- to 2-year) grass-stage; medium growth rate; poor form, dense branching.

P. rudis. Medium (1- to 2-year) grass-stage; medium growth rate; poor form.

Results of Other Trials in the Northeast

Puerto Piray, Misiones.--Celulosa Argentina S.A. tested many other pine species and other conifers during the last 25 years. Besides the native araucaria which is extensively planted, other species such as *A. bidwillii* and *A. cunninghamii* and also *Cunninghamia lanceolata* and *Cryptomeria japonica* have been planted. *Araucaria angustifolia* and *Cunninghamia lanceolata* had relative good growth, although slower than that of pines. Other non-pine conifers were not successful.

Among the pines, *Pinus caribaea* var. *bahamensis* and *P. insularis* were the best. Height data for the most promising conifers are given in Table 14. Among the many other pine species planted by this company, the following were considered inadequate: *P. ayacahuite*, *P. canariensis*, *P. cembroides*, *P. densiflora*, *P. halepensis*, *P. merkusii* (very poor survival), *P. pinaster* and *P. radiata* (Golfari and Barrett, 1967).

Concordia, Entre Rios.--At the Experiment Station of INTA, other pine species were planted in 1964. The most outstanding species were: *Pinus caribaea* var.

Table 14.--Relative height at age 5 of best pines and other conifer species planted at Puerto Piray, Misiones by Celulosa Argentina S.A. (Height expressed as percent of _P. elliottii_; 67 dm = 100%.)

Species	Height	Remarks
	Percent of slash pine height	
Pinus caribaea var. bahamensis	112	
Pinus insularis	105	Poor form
Pinus taiwanensis	98	Poor form
Pinus massoniana	93	Poor form
Pinus luchuensis	90	Very poor form
Cunninghamia lanceolata	80	Multiple stems
Araucaria angustifolia	72	Good form

bahamensis which at age 5 had 20% greater height than slash pine; *P. luchuensis* had the same height as slash pine but poor form; *P. glabra* had 90% of slash pine height. Recently introduced was *P. clausa* which in sandy soils grew 1.90 m in 2 years. Slow growing species were *P. thunbergiana* and *P. halepensis*.

Oliveros, Santa Fe.--Along the Parana River in south of Santa Fe province, 17 species were tested in 1958 by Celulosa Argentina. The results were similar to those at southern stations of the Northeastern Pine Species Trial. Other species planted which were not included in the trial were slower in growth as compared with slash pine. These others are: *Pinus echinata*, *P. roxburghii*, and *P. canariensis*. Others such as *P. cembroides*, *P. densiflora* and *P. strobus* had very poor growth and low survival. (Golfari and Colombo, 1964).

CHAPTER IV

CLIMATIC RELATIONSHIPS BETWEEN AREAS OF ORIGIN AND AREAS OF PLANTING IN NORTHEASTERN ARGENTINA

Two guidelines which should be followed when introducing and testing exotics are: (1) Study climates of the world and select species from regions having climates similar to those of the regions to be planted; (2) evaluate growth and wood properties of the tree species in the climatically suitable regions and plan to introduce and test all species with desirable characteristics (Wright, 1963).

In this chapter, climates of the test-site regions in northeastern Argentina were compared with climates of the regions from which the most successful species were derived, to determine similarities between donor and recipient regions and guide future tree introduction programs in Argentina.

It would be desirable to correlate both soil preferences and performance of all introduced species with their performance in their native habitats. However, there are few such data in the literature for the Mexican and Caribbean pine species.

Climate of Northeastern Argentina

Northeastern Argentina is warm-temperate (average annual temperature 18 to 21°C, average January temperature 25.3 to 27.5°C, average July temperature 13 to 16°C with uniformly distributed rainfall (average annual rainfall 1,000 to 2,000 mm), with frequent winter frosts (minimum temperatures of 0 to -10°C) and frequent late-spring frosts. A zone bordering the Parana River (including the Bella Vista and Corrientes Stations) is sub-tropical, with little or no chance of frost but with an otherwise similar climate to the remainder of the region (Table 2).

Climate of Successful Donor Regions

The "Northeastern Argentine Pine Species Trial" included species from a wide geographical range and therefore from a large variety of climates. According to the 5-year results, successful species came from as far north as Maryland in the United States and as far south as Guatemala and Honduras. Some donor regions have continental-type (large summer-winter temperature differences) to maritime type (small temperature variation) climates. Moisture conditions in the donor regions vary from perhumid to subhumid. Climatic characteristics of the donor regions are summarized in Tables 15 and 16.

There was only moderate agreement between the general climatic conditions of these donor areas and the test areas. Both types of areas have warm-temperate to sub-tropical climates with uniform to summer-rainfall distribution. The greatest discrepancy involves *Pinus patula*. This species occurs at high elevations in central Mexico, a region with a cool climate, particularly in summer. The annual mean temperature in the native range of *P. patula* is about 9°C cooler than in the test area and the average temperature of the warmest month is almost 12°C cooler. In central Mexico rainfall occurs mostly in the summer whereas it is uniformly distributed in northeastern Argentina.

There is considerable variation among the climates of the regions yielding the most promising exotics for northeastern Argentina (Table 16). In the donor regions, the absolute minimum temperature varies from 5°C to -23°C; the annual mean temperature between 9 and 26°C; the average temperature of the warmest month between 12 to 28"C; the average temperature of the coldest month between 7 and 25°C.

Successful donor areas also yielded species which were unsuccessful or slow growing. For example, the same area which yielded *Pinus caribaea* var. *caribaea* yielded

Table 15.--General climatic characteristics of regions having species which grew rapidly in northeastern Argentina.

Donor region	Average temperature	Humidity	Rainfall distribution	Summer temperature
Southeastern United States	Temperate to warm-temperate	Humid to subhumid	Uniform to winter, dry	Warm
Antilles	Sub-tropical	Humid to subhumid	Winter, dry	Warm
Central America	Sub-tropical to warm-temperate	Humid to subhumid	Winter, dry	Warm
Low altitudes south and central Mexico	Warm-temperate to temperate	Humid to subhumid	Winter, dry	Warm to temperate
High altitudes central Mexico	Temperate	Humid to subhumid	Winter, dry	Cool
Southeast Asia	Warm-temperate to sub-tropical	Humid to subhumid	Winter, dry	Warm

Table 16.--Temperature and rainfall characteristics of regions having species which grew rapidly in northeastern Argentina.[a]

Pine species	Temperature				Rainfall average annual
	Average annual	Average July	Average January	Absolute minimum	
	°C	°C	°C	°C	mm
SPECIES OF SOUTHEASTERN UNITED STATES					
elliottii var. elliottii	18-22	25-28	9-17	-20	1,100-1,650
eliottii var. densa	22-24	26-28	15-21	- 8	1,000-1,500
taeda	13-22	24-26	12-15	-23	920-1,550
ANTILLEAN SPECIES					
caribaea var. caribaea	24-26	28	22	4	1,000-1,600
CENTRAL AMERICAN SPECIES					
caribaea var. hondurensis	20-27	22-28	16-35	5	1,000-3,000
oocarpa (Honduras)	19-24	22-25	17-20	2	800-1,500
LOW ALTITUDE SOUTH AND CENTRAL MEXICAN SPECIES					
douglasiana	12-20	15-22	10-17	-4	1,000-2,600
pseudostrobus	10-19	13-21	7-16	-6	
HIGH ALTITUDE CENTRAL MEXICAN SPECIES					
patula	9-16	12-17	7-11	-10	1,200-2,000
SOUTHEAST ASIA SPECIES					
insularis	15-23	16-24	12-20	4	1,400-2,500

[a]Data from FAO, 1962; Golfari, 1963.

the much less successful P. tropicalis and P. cubensis. And southeastern United States which yielded the successful P. elliottii and P. taeda also yielded P. echinata which has shown little promise in northeastern Argentina.

There can be several reasons why species from the same climatic region can grow at such different rates in northeastern Argentina. P. tropicalis and P. caribaea var. caribaea are sympatric in the low mountains of northern Cuba, often occurring in the same stands. They are unrelated, belonging to different sections. It is improbable that both evolved in their present habitats. It is more likely that one or both evolved elsewhere and migrated into Cuba at different times. P. tropicalis' closest relatives are in northern United States and in Eurasia, and this species probably migrated southward to its present range. The closest relatives of P. caribaea are from the Caribbaean area. It is logical to assume that, with different origins and different times of migration into Cuba, these species differ in their degree of adaptation to Cuban sites. If so, they would almost certainly differ in their degree of adaptation to totally new site conditions in northeastern Argentina.

Pinus palustris and P. elliottii var. elliottii are closely related species from southeastern United States. They often grow under the same climatic conditions. However, the former has become adapted to deep dry sandy soils with a low water table, and has also become adapted to fire. Young seedlings of P. palustris grow little in height their first few years but send down a long thick taproot which enables them to survive in the deep sandy soils. They also benefit by fire, which reduces the amount of inoculum of the very serious needle blight caused by Septoria acicola. P. elliottii var. elliottii on the other hand has become adapted to moister site conditions and is much less susceptible to the needle blight. It has thus evolved a very rapid growth rate, in both juvenile and older stages, and has not evolved a fire-protection mechanism.

Four pine species--P. ayacahuite var. brachyptera, P. leiophylla, P. lumholtzii, and P. cooperi--live sympatrically in one small valley near San Juanito, Chihuahua, northern Mexico. These species belong to three different sections and probably evolved under very different ecological conditions during middle and late Cenozoic times and have since migrated into the same area. Such migration has probably taken place at several different times, with the result that the species have had different lengths of time to become adapted to their present habitats. Possibly no one is as yet perfectly adapted to San Juanito conditions with the result that all are living together in a state of imperfect harmony. Thus, it is not unusual that Poynton (1959) in South Africa reported that *P. ayacahuite* var. *brachyptera* was very site-demanding and failed when tested under warm-temperate conditions, that *P. leiophylla* grew rapidly under warm temperate conditions but had bad stem form, that *P. cooperi* grew slowly but possessed excellent bole form, and that *P. lumholtzii* was very crooked and slow growing.

Climate of Unsuccessful Donor Regions

The earliest Argentine tree planters used trees from cold temperate parts of Europe and the United States. Most of such trees were planted near Buenos Aires and south of that city. The best of 50 cold-temperate conifer tree species--all of them commonly planted in the northern hemisphere--grew only 40% as fast as slash and loblolly pines. Therefore, it is reasonable to assume that introductions from cold-temperate climates, with average annual temperature less than 12°C, would not grow rapidly if planted in northeastern Argentina where the climate is warmer than in Buenos Aires. The lack of success of these species can be explained by their need for a cold winter season or their inadaptability to warm summer temperatures. Some introduced species grew as rapidly as in their native habitats. But this is not enough for commercial purposes when compared with the growth of warm-temperate or sub-tropical species.

The temperate species which were not successful in the Northeast Pine Species Trial came from regions with a Mediterranean climate. These regions are southern Europe and western United States. The climate of these areas can be described as temperate, sub-humid to humid, having rainfall mostly in winter and having cool summers and mild winters.

None of the southern European species grew successfully when planted in the test area. *Pinus pinaster* grew slowly in the Northeast but rapidly along the Atlantic coast, south of Buenos Aires. *P. halepensis* failed in Misiones but had a relatively good growth in dry-temperate zones. *P. pinea* was slow growing wherever planted.

Among the western United States species which have been tested are *Pinus ponderosa* and *P. contorta*. They grew poorly under Buenos Aires conditions but grew better in cooler, winter rainfall areas in the west of Argentina. Ponderosa pine was planted as an ornamental in the Northeast and failed completely.

The west coast of the United States is the native habitat of the most widely planted pine in the world. Monterey pine (*Pinus radiata*) is a good example of a species highly specialized to a particular environment in spite of the extension of its cultivation. The climatic conditions of its native area are:

Temperature:	average annual	13.5 to 14.5°C
	average of July	16.5 to 18 °C
	average of January	10 to 11 °C
	absolute minimum	-7 °C
Rainfall:	average annual	420 to 700 mm (92% in winter)

The climates of the areas in the world where this species is successfully planted match closely the climate of the native area. The species seems to be particularly sensitive to extreme warm summers or to cold winters (warmer than 20°C and colder than -7°C), and to prevailing summer rainfall. It has been planted repeatedly in Argentina without success if conditions were not as described above (Golfari, 1959).

Conclusions

Pine species which grew rapidly in northeastern Argentina came from regions with warm-temperate or subtropical climates, and abundant rainfall, distributed either uniformly throughout the year or more plentiful in spring and autumn. But those areas also yielded many species which did not grow well in the Argentine trials. To separate the potentially successful from the unsuccessful species it is necessary to conduct trials in Argentina and evaluate experience in other southern hemisphere countries. Such evaluation is done in the next chapter.

CHAPTER V

RESULTS OF PINE TRIALS IN OTHER COUNTRIES

The same species of pines which were tested in northeastern Argentina have been grown in many other parts of the world. In this chapter I review the literature for these other countries, to learn how their results can be applied in Argentina.

In selecting the literature for review, I chose reports from areas in which 20 or more pine species had been planted, and in which one or more of the species which had proven most successful in northeastern Argentina had grown well. There were usually several research reports issued over a period of years for any given country; in such cases I chose the most complete recent report. The most valuable general references of this type are listed in Table 17.

Most of these reports revealed that, if one of the species which grew well in northeastern Argentina grew well in another region, other species which grew well in northeastern Argentina also grew well in the other region, and the failures were also the same. Contrariwise, there was almost total disagreement between Argentine and other-region results if the fastest

Table 17.--Summary of trials with temperate and subtropical pine species in other southern hemisphere countries.

Country and author	Species tested No.	Age of tests Years	Climatic conditions of regions with successful species which: Were successful in the northeast of Argentina	Failed in the northeast of Argentina
South Africa;[a] Poynton, 1959	36	10.52	Temperate to subtropical, rainfall uniform or Monsoon[b]	Cool-temperate, rainfall uniform or Mediterranean[b]
Rhodesia;[a] Barrett and Mullin, 1968	43	1-7	Temperate to subtropical, rainfall Monsoon type	--
Malawi; Foot, 1967	40	5-53	Temperate to subtropical, rainfall Monsoon type	--
Australia, Queensland; Streets, 1962	24	-	Temperate to subtropical, rainfall Monsoon type	--
Australia, New South Wales; Burgess, 1967	41	2-42	Temperate to warm-temperate, rainfall Monsoon type	Cool-temperate, rainfall uniform

Table 17.--(Continued)

Country and author	Species tested No.	Age of tests Years	Climatic conditions of regions with successful species which: Were successful in the northeast of Argentina	Climatic conditions of regions with successful species which: Failed in the northeast of Argentina
Australia, Capital Territory; Brown, 1969[c]	35	4-35	Temperate to warm-temperate, rainfall uniform	Cool-temperate, rainfall uniform
New Zealand; Weston, 1957	34	10-55	Temperate, rainfall uniform	Cold-temperate to temperate, rainfall Mediterranean type
Brazil, Sao Paulo; Golfari, 1969	42	-	Warm-temperate to subtropical, rainfall Monsoon type	--

[a]Data were derived from 600 plantations in South Africa and 400 in Rhodesia.

[b]Monsoon: rainfall mostly in summer; Mediterranean: rainfall mostly in winter.

[c]Mr. Alan G. Brown of the Forest Research Institute of Canberra, Australia very kindly provided unpublished information on 35 species of pines.

growing species in the other region was one which had grown poorly or failed in northeastern Argentina. The exceptions were four reports from southeastern United States where Pinus elliottii and P. taeda (very successful species in northeastern Argentina) are native but all exotic pines succumbed to cold or grew slowly.

The major areas of the southern hemisphere which showed correspondence with northeastern Argentina results are: central and south Africa, east Australia, north of New Zealand and southeastern Brazil. Each of these countries have several different pine-planting zones, some of which are climatically similar to northeastern Argentina and some of which are not (Table 17).

Through a detailed study of those references I learned that the areas growing Argentine-successful pines can be subdivided into four regions with different species preferences. Those regions and the species most successful in them are summarized in Table 18.

In the temperate to warm-temperate areas of Africa and Australia all species listed in Table 18 grew well although some were better than others. This was not true, however, for the cool-temperate and sub-tropical parts of those countries. In the cool temperate areas where Pinus patula and P. pseudostrobus were the best, the three fast-growing sub-tropical species, P. caribaea, P. oocarpa, P. insularis succumbed to cold. Contrariwise, Pinus patula

Table 18.--Climatic conditions and most successful pine species in regions similar to northeastern Argentina as regards pine planting.

Temperature region	Annual mean temperature	Rainfall distribution	Most successful species
	°C		
Cool temperate	12 to 15	Highest in summer	Pinus patula, P. pseudostrobus
Temperate to warm-temperate	15 to 21	Uniform	P. elliottii, P. taeda
Temperate to warm-temperate	15 to 21	Highest in summer	P. eliottii, P. taeda, P. patula, P. pseudostrobus, P. douglasiana
Sub-tropical to tropical	20 to 25	Highest in summer	P. caribaea, P. oocarpa, P. insularis

and *P. pseudostrobus* were unhealthy when planted in subtropical areas.

Correspondence of Argentine Test Results with Results from Other Areas in the Southern Hemisphere

Most successful species of the Northeast Pine Species Trial also grew excellently in some other areas of the southern hemisphere. For instance *Pinus caribaea* had fast growth in low, subtropical humid areas of eastern South Africa, Rhodesia, Malawi and Queensland, Australia. *P. patula* was successful in mountainous summer-rainfall areas of eastern South Africa, where it was considered the best species. Poynton (1959) reported many very successful stands. Among the best was one at Nqadu. At 43 years of age it had a standing volume of 1,996 m^3 per hectare, for an average increment of 45 m^3 per hectare per year. This species was also successful in parts of Rhodesia and Malawi with cool summers. The southeastern United States species *P. elliottii* and *P. taeda* were fast growing in warm-temperate, uniform rainfall areas of south and east South Africa, Malawi, Rhodesia, Queensland, North New Zealand and Brazil. The Mexican *P. douglasiana* was reported by Poynton (1959) as a fast growing and well formed species in temperate summer-rainfall areas of South Africa.

Mexican provenances of *P. oocarpa* failed in several countries of Africa as reported by A. L. Lamb (Barrett and

Mullin, 1968), whereas the Central American provenances grew rapidly on warm-temperate and subtropical sites of South Africa and Rhodesia.

The slow growing species of the Argentine test were also slow growing under the climatic conditions described in Table 18. This was true for *Pinus montezumae*, *P. michoacana*, *P. engelmannii*, *P. rudis* and *P. cooperi*. They grew slowly at South Africa, Rhodesia, Malawi, Australia and Brazil. One exception was the fast growth observed by *P. pseudostrobus* in cool summer-rainfall areas of South Africa, Rhodesia, Malawi, and the Capital Territory of Australia. There, the species grew as well as *P. patula*, although with heavier branches. In Argentina, *P. pseudostrobus* had medium growth with poor form. It is possible that the seed source tested in Argentina was a poor one or that the best ecological conditions for this species are not found in northeastern Argentina.

Altogether, there was good general agreement between Argentine test results and test results obtained in four climatic zones of other southern hemisphere countries. Fifty-one pine species not yet planted in northeastern Argentina have been tested in these same four climatic zones of other countries. It is probable that the results for these other 51 species would also be applicable to northeastern Argentina. For that reason they are listed and described briefly in Table 19.

Table 19.--Pine species not included in the "Northeastern Pine Species Trial" but which were planted in other temperate and sub-tropical regions of the world with uniform or summer rainfall distribution.

Species	Country	Growth rate	Remarks	Climate in test area[1]
arizonica	S. Africa	Medium	Heavy branching	TE h MO
	Rhodesia	Slow	--	TE h MO
	Malawi	Slow	--	TE h MO
	Australia C.T.	Medium	--	TE h MO
attenuata	S. Africa	Medium	--	TE h U
	Australia C.T.	Medium	--	TE h U
ayacahuite	S. Africa	Medium	Forked	TE h MO
	Rhodesia	Slow	Form poor	TE h MO
	Brazil	--	Unsuitable	WTE h MO
banksiana	S. Africa	Slow	Unthrifty	TE h U
bungeana	Australia N.S. Wales	--	no survival	TE h U
canariensis	S. Africa	Very slow	--	TE h MO
	Malawi	Very slow	--	TE h MO
	Brazil	--	Failure	WTE h MO
cembra	Australia C.T.	Very slow	--	TE h U
cembroides	S. Africa	Very slow	--	WTE sh MO
	Australia C.T.	Very slow	--	TE h MO
	Rhodesia	Very slow	--	WTE h MO
contorta	Australia C.T.	Medium	--	TE sh U
	S. Africa	Slow	Stunted	TE h MO
clausa	Australia N.S. Wales	Medium	For dunes	TE h U
coulteri	S. Africa	Slow	--	TE h MO

Table 19.--(Continued)

Species	Country	Growth rate	Remarks	Climate in test area[1]
densiflora	S. Africa	Slow	Crooked	TE h MO
	Rhodesia	Slow	Neglected	TE h MO
durangensis	S. Africa	Slow to medium	Form good	TE h MO
	Rhodesia	Slow	Form good	TE h MO
	Australia New S. Wales	Slow to medium	--	TE h MO
	Brazil	--	Unsuitable	WTE h MO
echinata	S. Africa	Slow	Form poor	TE h MO
	Rhodesia	Medium	--	TE h MO
	Brazil	Medium	--	WTE h MO
flexilis	S. Africa	Very slow	Form poor	TE h MO
gerardiana	S. Africa	Very slow	--	WTE h MO
glabra	Australia New S. Wales	Medium	Ornamental	TE h MO
greggii	S. Africa	Medium	--	TE h MO
	Australia C.T.	Medium	--	TE h U
griffithii	S. Africa	Slow to medium	Form good	TE h MO
	Rhodesia	Slow	Ornamental	TE h MO
halepensis	S. Africa	Slow	Form poor	TE h U TE h MO
	Brazil	--	Unsuitable	WTE sh MO
hartwegii	S. Africa	Slow	--	TE h MO
herrerai	Brazil	--	Unsuitable	WTE h MO
insularis	S. Africa	Medium to fast	--	ST h MO TE h MO
	Rhodesia	Medium to fast	Form poor	WTE h MO WTE sh MO
	Brazil	Fast	Form poor	WTE h MO

Table 19.--(Continued)

Species	Country	Growth rate	Remarks	Climate in test area[1]
jeffreyi	S. Africa	Very slow	Stunted	TE h MO
khasya	S. Africa	Medium to fast	--	WTE h MO
	Malawi	Medium to fast	Crooked	WTE h MO
koraiensis	S. Africa	Very slow	Form fair	TE h MO
lambertiana	S. Africa	Very slow	--	TE h U
lawsonii	S. Africa	Medium to fast	--	TE h MO
	Rhodesia	Medium to fast	--	TE h MO
leiophylla	S. Africa	Fast	Crooked, forked	TE h MO WTE h MO
	Rhodesia	Fast	Form poor	WTE h MO
	Australia C.T.	Medium	--	TE h U
	Brazil	--	Unsuitable	WTE h MO
luchuensis	S. Africa	Medium	Form poor	TE h U
lumholtzii	S. Africa	Medium	Form poor	WTE h MO
massoniana	S. Africa	Medium to fast	Form poor	TE h MO
	Rhodesia	Medium	Form poor	TE h MO
	Australia New S. Wales	Medium to fast	Form poor	TE h U TE h MO
merkusii	S. Africa	Medium to fast	Form good	WTE h MO
	Malawi	Medium to fast	--	TE h U
monticola	Australia New S. Wales	Slow	--	TE h U

Table 19.--(Continued)

Species	Country	Growth rate	Remarks	Climate in test area[1]
muricata	S. Africa	Medium	Form good	TE sh MO
	Malawi	Slow to medium	Form poor	TE h MO
nigra	S. Africa	Slow	--	TE h MO
	Australia New S. Wales	Slow to medium	Form good	TE h U
	Brazil	--	Unsuitable	WTE h MO
pinaster	S. Africa	Slow	Form good	TE h MO
ponderosa	S. Africa	Slow	Stunted	TE h MO
	Australia New S. Wales	Medium	--	TE h U
pinea	S. Africa	Slow	Form poor	TE h U
	Rhodesia	Slow	--	TE h MO
pringlei	S. Africa	Medium	Form fair	TE h MO
	Australia Capital Terr.	Slow	--	TE h U
resinosa	S. Africa	Slow	Failure	TE sh MO
rigida	S. Africa	Slow	Form poor	TE sh MO
	Rhodesia	Slow	Neglected	TE h MO
	Brazil	--	Failure	WTE h MO
roxburghii	S. Africa	Slow to medium	--	TE h MO WTE h MO
	Rhodesia	Slow	--	TE h MO
	Malawi	Slow to medium	Form good	WTE h MO
sabiniana	S. Africa	Slow	Failure	TE h MO
	Australia C.T.	Medium	--	TE h U
strobus	S. Africa	Slow	Failure	TE h U

Table 19.--(Continued)

Species	Country	Growth rate	Remarks	Climate in test area[1]
strobus var. chiapensis	S. Africa	Medium	Poor health	WTE h MO
	Rhodesia	Medium to fast	--	TE h MO
sylvestris	S. Africa	Slow	Stunted	TE h MO
taiwanensis	Brazil	--	Failure	WTE h MO
teocote	S. Africa	Slow	Form poor	TE h MO
	Rhodesia	Medium	--	TE h MO
	Australia C.T.	Medium	--	TE h U
	Brazil	--	Failure	WTE h MO
thunbergiana	S. Africa	Slow	Crooked	TE h MO
	Brazil	--	Failure	WTE h MO
virginiana	Australia New S. Wales	Medium	Ornamental	TE h MO

[1]Climatic nomenclature follows, Holdridge, 1947; Thornthwaite and Hare, 1955 and Golfari, 1965.

Temperature regions	Humidity provinces	Rainfall distribution
TE = Temperate	h = Humid	U = Uniform
WTE = Warm-temperate	sh = Sub-humid	MO = Monsoon type (highest in summer)
ST - Sub-tropical		

Results in northeastern Argentina are based upon 5-year-old tests except for _P. taeda_ and _P. elliottii_. South African data are based upon plantations 25 to 55 years old, and 20 years' data are available from several other countries. Because of the close correspondence between Argentine and other-country data as regards which species grow well, it is logical to assume that some inferences about future performance in Argentina can be made from the older other-country data.

In these other countries _Pinus palustris_ grew slowly when young but reached considerable heights and had good stem form at older ages. This species also grew slowly when young in northeastern Argentina but nevertheless seems to have good potential for longer rotations.

Larguia (1967) noted that _Pinus caribaea_ var. _hondurensis_ grew rapidly but was variable and had poor growth form in Argentine tests. Lückhoff (1964) observed the same behavior in young stands in South Africa but found that the variability lessened and the form became good in thinned older stands. It is probable that the same thing will happen in Argentina. If so, the species should be favored there.

Mexican and Caribbean Pine Species in Southeastern United States and Argentina

In southeastern United States slash and loblolly pines are successful trees. The climate there is warm-temperate with uniform rainfall distribution. But the results from the cultivation of exotic pines do not agree with the results in the northeastern Argentine region.

Zobel et al. (1956) reported very poor growth and low survival of 18 Mexican pine species tested in east Texas and western Louisiana.

Kraus (1963) described the performance of native and exotic pines at Olustee, Florida. Five provenances of Caribbean pine were killed immediately by frost. Fourteen provenances of seven Mexican species were dead after a period of 3 to 4 years. The species which lasted longest was Pinus patula. It was highly susceptible to tip moth and had poor form characterized by multiple stems.

Saylor (1969) reported the result of testing 17 Mexican species in three southeastern States. Within-species mortality reached 50% after 6 months in Alabama, Tennessee and North Carolina. All trees were dead after 2 years. Species from high mountains which were not affected by the cold weather were affected by the high summer temperatures.

Grigsby (1969) in Arkansas reported similar results from 12 provenances of Caribbean and Mexican pine species. Only the 6 native species from the southeastern United States were successful among 49 pine species tested.

According to these papers, failure of the Mexican and Caribbean species was due to the extreme temperature conditions (-23° to +43.5°C), to which the native slash and loblolly pine are adapted. Wright (1962) considered southeastern United States as a successful donor region but a poor recipient for all forest trees.

Additional Promising Species for Testing in Argentina

From the study of the literature of southern hemisphere plantations I found some species not included in the Argentine Trial which deserve special attention. These are:

P. greggi. A native of Mexico, it was planted in southeastern Africa and Australia where it exhibited medium growth rate, good stem form and a heavy crown. Special attention should be given for future breeding work in areas where *P. patula* is planted. They are closely related and their hybrids grew rapidly in Australia.

P. insularis. A native from the Philippines it exhibited a medium to fast growth in South Africa when planted in warm and humid, summer rainfall areas with little frost. In Rhodesia it is considered one of the most adaptable pine species because it performed well under moist or dry conditions. The only complaint was the poor stem form in all plantations. Its cultivation in Argentina would be restricted to frost-free areas. It would be advisable to obtain seed sources better adapted to winter cold and also to test the related *P. khasya* and *P. yunnanensis*.

P. lawsonii. Originally from Mexico, it performed well under South African and Rhodesian conditions. Although not a remarkable tree in native stands, it grew to a considerable size with good form under cultivation and produced excellent quality wood.

P. leiophylla. Native to Mexico, it grew rapidly in warm-temperate sites of southeastern Africa and Australia. Most plantations are characterized by trees with poor stem form. On some cooler sites stem form was good.

P. merkusii. Native to southeast Asia, it exhibited medium to fast growth with fair stem form when planted in warm and humid, summer-rainfall region. In Argentina its introduction failed because of improper nursery handling. Research should be directed in this field.

Most other pine species which have not been included in any southern hemisphere plantations are from cold climates and are apt to be of limited commercial interest in Argentina.

CHAPTER VI

FUTURE SPECIES TRIALS IN NORTHEASTERN ARGENTINA

The Northeast Pine Species Trial showed which of 17 species were suited to northeastern Argentina in general, but failed to give desired information on species X site interaction or on genetic variability within species. Also, they did not include a number of species found to be promising when tested under similar conditions elsewhere. Therefore, new trials are necessary.

Species to be Included

According to the 5-year results obtained in the northeastern Argentina trial, the following species are most promising and should be included in new tests: *Pinus elliottii* var. *densa*, *P. caribaea*, *P. patula*, *P. douglasiana* and *P. oocarpa*. The average performance of those species was as good or better than of *P. elliottii* var. *elliottii* and *P. taeda* which are now commonly planted.

Encouraging results from plantations in other southern-hemisphere countries show that new tests should also include:

Pinus insularis, *P. leiophylla*, *P. merkusii* and *P. lawsonii*. Those species were not planted before in Argentina, but show good growth under similar ecological conditions in other places. A Mexican seed source of *P. pseudostrobus* was included in the northeastern trial but grew poorly whereas this species grew well in other warm-temperate localities. That discrepancy is due possibly to within-species genetic differences, and the species should be re-tested.

Up to 10 provenances of each species will be included if possible. According to personal experience when collecting Mexican seed, it will be possible to obtain more than 10 provenances of some species but not more than 3 of others. I estimate it is possible to obtain 50 provenances of 11 species in one year. Such a test should also include 5 selected provenances each from *P. elliottii* var. *elliottii* and *P. taeda* to be used as standards.

Sites

One of the main objectives of new experiments is to learn species X site interaction. The soil should be uniform and representative of the soil types to be used in the future pine afforestations. But convenience of the persons who will take care of the trials must also be considered because trained personnel are scarce. With these criteria in mind, sites in each of three northeastern provinces were selected, as follows:

Province of Misiones. Warm-temperate, humid, summer rainfall. Elevation, less than 300 m, except for (d).

(a) Zaiman. INTA Experiment Station; gray, alluvial, slightly permeable soils.

(b) Alem. Forest Service Experiment Station; deep red permeable soils.

(c) Puerto Piray. Celulosa Argentina; stony soils on slope.

(d) San Antonio. Forest Service Experiment Station; deep brown-red permeable soils, elevation 800 m (native area of Araucaria angustifolia).

Province of Corrientes. Warm-temperate, sub-humid, summer rainfall. Elevation, less than 150 m.

(a) Gobernador Virasoro. Establecimiento Las Marias; deep red permeable soils.

(b) Ituzaingo. Establecimiento Sangara; deep sandy soils.

(c) Corrientes Capital. INTA Experiment Station; black, semi-permeable soils.

(d) Bella Vista. INTA Experiment Station; deep sandy soils.

Province of Entre Rios. Temperate, humid, uniform rainfall. Elevation, less than 50 m.

(a) Concordia. INTA Experiment Station; deep sandy soils.

(b) Concordia. INTA Experiment Station; black-gray semi-permeable soil.

(c) Concordia. INTA Experiment Station; shallow sandy soils.

At these stations, limited amounts of land area are available. Individual parcels of land will probably be smaller than 3 hectares.

Number of Trees per Provenance

The total number of trees necessary for testing genetic differences is smaller than has generally been thought necessary in Argentina. Most forest researchers there advocated large plots in the belief they could learn about silviculture and management as well as genetic differences.

There is not a direct theoretical approach to estimation of optimum test size for provenances and species. The closest approach is that suggested by Robertson in 1957 (Falconer, 1960). He estimated optimum progeny size for half-sib family selection according to the following formula.

$$\text{Optimum half-sib family size} = \sqrt{.56 \frac{T}{N h^2}}$$

where

h^2 = individual tree heritability.

T = total number of trees per progeny test, determined by economical factors.

N = number of families to be selected.

To obtain approximate answers, I used Robertson's formula, using a between/over total variance ratio for provenances in place of heritability. Assuming a low heritability (10%), if 5 provenances are to be selected, and if the total number (T) of trees included in the test is 15,000, the number of trees per provenance should be 97. The initial number would be 194 if half are to be thinned.

It is understood that the larger the number of trees tested per provenance, the more accurately the genetical potential of the provenance can be estimated. But there is a limitation to the total size of an experiment. If we increase the number of trees per provenance, we must reduce the number of provenances. Selection differential associated with between-provenances differences must then decrease. Robertson's formula gives the balance to improvement within and between populations to be tested.

Therefore the number of 250-tree per provenance that I will use is not unrealistic and compromises maximum gain, number of provenances and land area available. The 250 trees will be split in 10 plantations. Each 3-hectare plantation will contain 25 trees of each of 60 provenances for a total of 1,500 experimental trees per plantation.

Plot Size and Number of Replications

The general idea, very common years ago, was that forest trees should be tested in large plots to provide forest conditions. However, it was found that plots of 64 to 100 trees were too small to give reliable silvicultural data and too large to be efficient statistically. Also, they require more land than is available for testing. A 60-provenance test, replicated three times with 100-tree plots would require 32 hectares.

Statistical efficiency decreases rapidly with increasing plot size, according to Wright and Freeland (1961). As measured in a yellow poplar tree plantation in Michigan, experimental efficiency for various plot sizes was as follows:

Trees per plot	Relative information per tree	Size of experiment needed to give same information as 100 1-tree plots
number	percent	number of trees
1	100	100
5	54.6	185
10	21.8	460
64	18.5	512

Optimum number of replicates can be determined according to the following formula if experimental variances are known and if one fixes desired precision beforehand (Wright and Freeland, 1961). For the example it is

assumed that one wishes to detect (at the 5% significance level) differences as small as 5% of the mean.

$$\text{Standard error of a provenance mean} = \sqrt{\frac{\text{Error Mean Square}}{\text{Number of replicates}}}$$

This equation can be solved for "Number of replicates" as follows:

$$N = \text{Number of replicates} = \frac{\text{Error Mean Square}}{\left(\begin{array}{c}\text{Standard error of}\\ \text{provenance mean}\end{array}\right)^2} = \frac{\text{EMS}}{(\text{SE})^2}$$

The desired "Standard Error of Provenance Mean" is calculated by dividing the "Least Detectable Difference" (fixed as 5% of the mean) by a value of the statistic "t" for the appropriate (5%) significance level and degrees of freedom.

For a sample calculation I used an "Error Mean Square" = 178 derived from a <u>Pinus elliottii</u> provenance test near Puerto Piray. The plantation mean was 154 cm and 5% of the plantation mean was 7.7 cm. Thus the formula for number of replicates is for $t_{.025;13} = 2.160$

$$N = \frac{\text{EMS}}{(\text{SE})^2} = \frac{178}{(7.7/t)^2} = \frac{178}{(7.7/2.160)^2} = \text{approximately } 14$$

This ideal number of fourteen 8-tree plots per origin per plantation is based upon the assumption that it is desirable to detect differences as small as 5% of the mean at each plantation. For the ten plantations, it would be necessary to plant a total of 10 x 14 x 8 = 1120 trees per provenance, a practical impossibility. Therefore it is necessary to either (1) change the assumption, or (2) improve experimental precision by reduction of the error mean square. Reduction of the error mean square can be accomplished only by improved experimental procedures--better care in the nursery, better transplanting, better soil preparation, better weed and ant control in the plantations. That is a worthy objective which may or may not be attained in the planned new provenance-species tests. If not achieved, the detectable difference with 5 replicates will be 10%.

The actual experimental design was determined by considering all the following factors.

1. The taxa to be tested. Thirteen taxa are promising enough to be included.
2. Probable variability within species and varieties. There is probably enough variability to warrant testing a total of 60 provenances.
3. Seed supply. A few hundred seeds can be obtained easily from each of 60 provenances. Requests for greater quantities of seed would reduce the number of responses.
4. Land area available. Individual land-parcels of 3 ha can be obtained at 10 locations. Parcels much

larger than 3 ha would be difficult to obtain.

5. Maximum gain. According to Robertson's formula maximum gain will result by testing about 194 trees per provenance if heritability is about 10% and total experiment size is 15,000 trees. This will permit testing of 77 provenances but it is doubtful whether that many can be obtained.
6. Maximum precision. The desired precision of detecting differences of 5% of the mean will not be achieved unless the total size of the experiment is increased beyond practical capabilities. With present techniques, using 5 replicates, differences as small as 10% of the mean can be detected.
7. Availability of trained personnel. Available personnel at most stations are not experienced in following sophisticated designs.

The final compromise design to be used is as follows:

60 provenances to be tested at each of 10 sites,
5 replications per site, each replication to
contain one 5-tree plot per provenance.

Spacing

Common planting distances for Pinus elliottii in commercial plantations in northeastern Argentina are 2.5 x 2.5 m, 3 x 3 m or 2.5 x 3 m. Spacing of 3 x 3 m was used in the Northeast Pine Species Trial. With such spacings, crown closure occurs at about the 5th year and serious competition occurs by the 6th or 7th year, when dealing with the fast-growing species. Volume production remains high but there is little possibility of early fruiting unless the stands are thinned heavily.

For the planned new species-provenance trials I have selected a 3.5 x 3.5 m spacing which provides each tree with 12.25 square meters of growing space. With that spacing, 50% of the experimental trees can remain until age 20. It is also expected that a 3.5 x 3.5 m spacing will provide good conditions for early flowering. A thinning at age 8 will reduce density to 600 trees per hectare, providing approximately 17.5 square meters growing space per tree.

Arrangement

In one mixed plantation, *Pinus radiata* grew rapidly at the start and almost crowded out *Pinus taeda*, although the latter species proved best in the long run. The competition was such that the difference in growth rates was much greater than if the two species had been tested separately. The same may happen in the new experiments, where species as different as *P. patula* and *P. caribaea* are grown in close proximity. It is less likely to happen if different provenances of the same species are grown in adjacent rows.

To minimize these undesirable competition effects, a compact family design will be used. Species will be randomly distributed through each block and provenances of the same species will be randomly distributed in adjacent rows. A border row of _P_. _elliottii_ var. _elliottii_ will surround the plots comprising a single species. If competition appears to accentuate growth differences at an early age, these single border rows will be removed. A double border row will surround each plantation.

The compact family design will also affect the statistical precision of the experiments. Because provenance of the same species will be planted in adjacent rows, precision will be greater when testing between-provenance than when testing between-species differences.

Seed Procurement

For each provenance, 250 seedlings will be required at the 10 stations. An additional 800 seedlings per origin are desired in order to establish small supplementary seed orchards (see later). The number of seeds per gram varies from 28 in _Pinus_ _elliottii_ to 60 in _P_. _patula_. Assuming 50% germination, 60 to 90 grams per origin should suffice.

This amount of seed is feasible to obtain by mail request. This is possible to do because many government agencies such as the U.S. Forest Service provide seed and good origin data free or at reduced prices for research purposes. Many other countries are undertaking species and provenances trials. For this reason some cooperative seed collection expeditions have been organized. Among such cooperative efforts are those by FAO, by the Commonwealth Forestry Institute at Oxford, England (*Pinus caribaea* and *P. oocarpa*), by the Forestry Research Institute at Canberra, Australia (*P. insularis* and *P. merkusii*) and the Norway-East Africa expedition to Central America and Mexico. For a fee, as yet unknown, it will probably be possible to obtain seed and data from such agencies (Burley, 1969).

Special consideration should be given to the future seed supply of tested species and provenances. It is very probable that seed of the most successful provenances will not be available in large commercial quantities when the experiments are completed. In this case, from a practical point of view the experiments would not give maximum benefit. Therefore it is advisable to plant one isolated plot of one hectare of each provenance, in order to assure a minimum seed supply for any successful provenance. According to Argentine data, one hectare of a 25-year-old *Pinus elliottii* plantation near Rosario, Santa Fe produced a yearly average of 50 kg of seed, enough to plant 450 hectares per year. Thus minimal seed orchards established at the same time as the replicated plantations can supply some of the need for improved seed as soon as any provenance is proven satisfactory.

Organization and Expenses

This trial can be performed by present personnel and facilities of INTA as a part of its regular work. This includes assistance by seven experiment stations of INTA. In addition there will be collaboration with two stations of the Argentine Forest Service at Alem and San Antonio (Misiones), with Celulosa Argentina at Puerto Piray (Misiones), with Establecimiento Las Marias at Gobernador Virasoro (Corrientes) and with Establecimiento Sangara at Ituzaingo (Corrientes).

The new experiments will be supervised by myself and three INTA professional foresters. One at Cerro Azul (Misiones) will be in charge of all Misiones and the Virasoro plantations; one at Bella Vista will be in charge of the other three Corrientes plantations and one at Concordia, Entre Rios will be in charge of plantations there.

The experiment stations and extra INTA collaborators will supply land, facilities and some labor assistance. The INTA nursery of Castelar will supply labor and facilities.

The plants will be raised at Castelar, transplanted to tar paper pots and kept till the following year when they will be transported to the planting sites. The planting will be performed under the direction of INTA personnel with contracted labor.

Cost of the planned species trial is estimated as follows:

Expenses of INTA and other official and private agencies during five years

		Argentine pesos	
(a)	Nursery	m$n	125,000.-
(b)	Transport of seedlings	m$n	75,000.-
(c)	Planting and care at 10 stations	m$n	1,500,000.-
(d)	Travel expenses 4 men, 4 years	m$n	600,000.-
(e)	Seed collection, by mail	m$n	140,000.-
Personnel and facilities			
(a)	Nursery labor, 2 men, 1/3 time	m$n	500,000.-
(b)	Researcher, 1 man, 1/10 time, during 5 years	m$n	1,200,000.-
(c)	Technical assistance	m$n	1,600,000.-
(d)	Facilities and vehicles	m$n	250,000.-
	Total cost	m$n	5,990,000.-
		U$S	17,100.-

Anticipated Benefits

Considering that the result of this trial can increase total pine production 10%, I calculated the probable benefit from the species-provenance experiment. As a basis for calculation I took the expected planting rate of *Pinus elliottii* for the 10-year period 1975 to 1985 (Castiglioni and Tinto, 1968). Those authors expect an annual planting of 10,000 hectares for a total of 100,000 hectares through 1985.

The estimated yearly increment of *P. elliottii* is 25 m^3 per hectare. The 10% increase will therefore be 2.5 m^3 per hectare per year or a total of 250,000 m^3 for the 100,000 hectares. After a full rotation of 25 years this increase would represent 6,250,000 m^3 of wood.

The present value of a cubic meter of wood is m$n 2000. A 10% increase in volume of the plantations performed during 10 years would mean an increase in value of m$n 5,000,000,000 (equals U$S 14,000,000). If the cost of the species trial is about 6 million Argentine pesos (U$S 17,100), the benefit-cost ratio would be very large, about 850 to 1. The benefit-cost ratio will be appreciable even if there are large errors in estimating benefits or costs.

Cost Comparison Between Actual and Planned Introduction Programs in Misiones

The experience gained by Celulosa Argentina S.A. in introducing pines and other conifers to Puerto Piray led to the present forestry development in the whole Province of Misiones. Other private companies or official institutions such as Garuhape S.A.I.C. or the Instituto Agrotechnico de Misiones played a minor role in the introduction of exotics.

Celulosa Argentina started planting *Pinus radiata* and other species in 1944. By 1965, forty pine species and a few other conifers were introduced and tested. From the beginning, all plantations were destined to produce wood and pulp for the company's paper mill at Puerto Piray. However, many plantations failed. In the case of slash pine, the company proceeded from the first experimental plantation in 1944 to large scale planting in 1949. Therefore, for purposes of estimating experimental acreage, I regard the first 5 years' planting with any one species as experimental, and plantations made after such a 5-year test period as commercial.

Approximately 500 hectares of land were used for such experimental plantations between 1944 and 1965. This includes many plantations of native araucaria which failed because they were planted in shallow stony soils. To simplify comparisons I use Argentine pesos (m$n) at their 1969 values for all costs.

The planting cost of one hectare of pines, including clearing of native forest, planting stock, planting, and 2-years' after-planting care, was m$n 140,000. The professional who directed and evaluated the work earned m$n 2,500,000 per year. He dedicated approximately one-fourth of his time to his work, during a 22-year period. He also had some incidental expenses connected with plant introduction.

These three items can be summarized as follows:

Item	Unit cost	Total cost
Planting	m$n 140,000/Ha x 500 Ha	m$n 70,000,000.-
Professional Salary	m$n 2,500,000/yr x 22 yr/4	m$n 13,750,000.-
Incidental expenses		m$n 4,000,000.-
Total		m$n 87,750,000.-

This estimate does not include interest, value of land, etc.

At the time that Celulosa Argentina did its introduction and testing work, there was no realization that the work was experimental because there was full expectation that every acre planted would produce usable products. It is worthwhile to consider what might have happened if the work had been regarded as experimental. One professional forester could have been hired for 16 years and permitted to devote 25% of his time during that period to species introduction and testing. He could have tested 150 seedlots in each of 5 locations, with 5 replications per site, 8-tree plots and 12 square meters growing space per tree. To make such tests he would have needed approximately 150 x 8 x 5 x 5 x 12/10,000 = 36 hectare, or 40 hectares including border trees. He could have obtained most of his seeds at nominal cost, but might have needed to make special collecting trips to Mexico and Central America. The probable costs (in 1969 equivalents) of such a program might be summarized as follows:

Item	Unit cost	Total cost
Planting	m$n 160,000/Ha x 40 Ha	m$n 6,400,000
Professional	m$n 2,500,000/yr x 16/4	m$n 10,000,000
Incidental expenses, including travel		m$n 2,600,000
Total		m$n 19,000,000

The costs of this hypothetical program are only 25% as great as the amount actually spent. The largest saving was due to the use of smaller, more efficient plots.

As for results, the unplanned experimentation resulted in the introduction of 40 pine species in a 22-year period. Only two species--*Pinus elliottii* var. *elliottii* and *P. taeda*--were planted on enough sites to provide data on site preference. The experiments included only one or two origins per species, so that there was no opportunity to learn the best seed origins within species. If the research had been planned, more species could have been tested, and there would be data on variability within species as well as on site preferences. It is probable that growth-rate increases of 10% or more could have been obtained as early as 15 years ago, and that actual volume growth during the last 15 years could have been increased proportionately. The value of the increased volume would have been much greater than the cost of the experimentation.

This brief analysis shows that research of the type planned is expensive if calculated in terms of pesos. But it is inexpensive if calculated in terms of probable returns. It is likely to be least expensive and most productive if actually considered as research rather than as a series of casual experiments.

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APPENDICES

Analysis of Variance for height at age 5 of the Northeastern Argentina Species Trial.

Source	df	SSQ	MSQ	F	Expected mean square	%
For all 27 species at Cerro Azul, Bella Vista, Puerto Piray, Gob. Virasoro, El Sombrerito, Concordia and Las Palmas						
Species	23	25,333.74	1,266.68	26.96**	= Ve + 2.84 Vs; Vs = 9.14	50
Plant.	6	4,615.60	769.29	16.37**	= Ve + 1.85 Vp; Vp = 8.30	45
Sp x Pl	68	3,195.00	46.98		Ve = 1.00	5
Total	97	33,144.34			18.44	
Analysis of variance by groups of species						
SOUTHEASTERN U.S. SPECIES						
Species	2	19.17	9.58	0.35	= Ve + 6.66 Vs; Vs = 0.09	0
Plant.	6	1,083.36	180.56	6.77**	= Ve + 2.80 Vp; Vp = 2.41	68
Sp x Pl	11	293.22	26.65		Ve = 1.00	32
Total	19	1,395.75			3.50	
CARIBBEAN SPECIES						
Species	2	395.81	197.90	4.90*	= Ve + 7 Vs; Vs = 0.55	12
Plant.	6	2,535.46	422.57	10.47**	= Ve + 3 Vp; Vp = 3.15	67
Sp x Pl	12	483.99	40.33		Ve = 1.00	21
Total	19	3,415.24			4.70	

(Continued)

Source	df	SSQ	MSQ	F	Expected mean square	%
MEXICAN SPECIES						
Species	13	11,854.57	911.89	13.72**	= Ve + 2.69 Vs; Vs = 4.57	71
Plant.	6	1,805.49	300.91	4.53**	= Ve + 5.60 Vp; Vp = 0.80	12
Sp x Pl	47	1,859.92	66.42		Ve = 1.00	17
	66	15,519.98			6.37	
GRASS-STAGE SPECIES						
Species	2	391.5	195.7	5.43*	= Ve + 3.4 Vs; Vs = 1.30	56
Plant.	5	117.4	23.5	0.64	= Ve + 2.25 Vp; Vp = 0	0
Sp x Pl	9	324.3	36.4		Ve = 1.00	44
	16	832.2			2.30	

*Significant at 5% level.

**Significant at 1% level.

Height at age 5 (dm) of 10 taxa in warm and humid localities of the Northeast of Argentina.

	Puerto Piray	Cerro Azul	Bella Vista	El Somb.	Gob. Vira.	Concordia	Species Average
P. patula (Veracruz)	-	84	87	79	78	67	79.0
P. caribaea v. hondurensis (mtn.)	80	93	83	82	70	61	78.1
P. caribaea v. hondurensis (coast)	78	85	83	75	76	59	76.0
P. caribaea v. caribaea	71	66	70	70	61	57	65.8
P. oocarpa (Honduras)	62	-	76	-	68	59	66.2
P. elliottii var. elliottii	67	65	66	63	61	64	64.3
P. taeda	66	74	66	60	61	62	64.8
P. elliottii var. densa	71	70	66	60	61	64	63.6
P. douglasiana	50	74	62	58	64	55	60.5
P. michoacana	32	35	36	32	33	34	33.6
Stations average	64.1	71.7	69.5	62.5	63.3	57.2	

Item		SSQ	MSQ	F	Expected mean square	Percent
Analysis of variance						
Species	9	8,260,58	917.84	31.92**	= Ve + 5.26 Vs; Vs 5.87	77
Plant.	5	1,106.69	221.33	7.69**	= Ve + 7.69 Vp; Vp 0.74	10
Sp x Pl	42	1,121.57	28.75		Ve 1.00	13
Total	56	10,488.84			7.61	

LSD 5% $\pm 2.021 \sqrt{\frac{2 \times 28.75}{6}} = \pm 6.25$ dm for species

$\pm 2.021 \sqrt{\frac{2 \times 28.75}{10}} = \pm 4.28$ dm for plantation

Diameter at age 5 (cm) of 12 taxa at 3 warm and humid stations of northeastern Argentina.

	Cerro Azul	Bella Vista	Concordia	Species Average
P. caribaea var. hondurensis (mtn.)	14.8	15.1	12.7	14.2
P. caribaea v. hondurensis (coast)	14.0	15.8	13.4	14.4
P. patula (Veracruz)	13.3	14.1	11.7	13.0
P. taeda	14.4	12.4	12.3	14.0
P. elliottii var. densa	13.0	14.0	12.7	13.2
P. douglasiana	13.4	12.9	11.3	12.5
P. elliottii var. elliottii	11.2	12.3	13.6	12.3
P. caribaea v. caribaea	12.2	13.2	10.9	12.1
P. oocarpa (Honduras)	-	13.1	10.7	11.9
P. patula (Puebla)	-	12.3	10.7	11.5
P. michoacana	8.8	-	8.6	8.7
P. cubensis	6.0	5.9	-	5.9
Stations average	56.0	56.9	36.8	

Item	df	SSQ	MSQ	F	Expected mean square	Percent
Analysis of variance						
Species	11	133.04	12.09	11.41**	= Ve + 10.3 Vs; Vs = 1.01	34
Plant.	2	7.88	3.94	3.48	= Ve + 2.5 Vp; Vp = 0.99	33
Sp x Pl	17	19.30	1.13		Ve = 1.00	33
Total	30	160.22			3.00	

LSD 5% $\pm 2.11 \sqrt{\frac{2 \times 1.13}{3}} = \pm 1.83$ cm for species

$\pm 2.11 \sqrt{\frac{2 \times 1.13}{12}} = \pm 0.88$ cm for plantation

Volume at age 5 (dm^3) of 8 taxa at 3 station of Northeastern Argentina.

	Cerro Azul	Bella Vista	Concordia	Species Average
P. caribaea var. hondurensis (mtn.)	83	76	42	67.0
P. caribaea var. hondurensis (coast)	74	83	44	67.0
P. patula (Veracruz)	67	71	39	59.0
P. taeda	65	42	38	48.3
P. elliottii var. densa	49	54	36	46.3
P. douglasiana	55	47	31	44.3
P. caribaea var. caribaea	40	52	30	40.6
P. elliottii var. elliottii	33	40	49	40.6
Stations average	58.2	58.1	38.5	

Item	df	SS	MS	F	Expected mean square	Percent
Analysis of variance						
Species	7	2,466.95	352.42	2.80*	= Ve + 3 Vs; Vs = 0.60	24
Plant.	2	2,067.25	1,033.62	8.22**	= Ve + 8 Vp; Vp = 0.90	36
Sp x Pl	14	1,759.42	125.67		Ve = 1.00	40
Total	23	6,293.62			2.50	

LSD 5% $\pm 2.145 \sqrt{\frac{2 \times 125.67}{3}} = \pm 19.63\ dm^3$ for species

$\pm 2.145 \sqrt{\frac{2 \times 125.67}{8}} = \pm 12.02\ dm^3$ for plantation

VITA

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