LOBLOLLY AND SLASH PINES AS EXOTICS

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Abstract. Loblolly pine, *Pinus taeda* L., and slash pine, *Pinus elliottii* Engelm. rose to some prominence as exotics in five countries outside their native U. S. A.; Africa, Argentina, Australia, Brazil, and China. The earliest trials in these countries were established about the turn of the century. Tree improvement programs were initiated where there was promise that planting would continue in the long term. However, these programs were often begun without thorough provenance trials and many misconceptions about the adaptability, particularly of loblolly pine, arose. This, and problems with pathogens, insects, and predators have resulted in reduced interest in plantation establishment and consequently, tree improvement of both loblolly and slash pine in Africa and Australia.

Slash pine has been more widely planted in Africa than any other southern pine because of its many desirable attributes. However, often another pine species will produce more volume. Loblolly pine was not widely planted until erroneous beliefs about growth and wood quality were dispelled by genetic testing. Both species have a reduced status at present because of recently recognised deficiencies, susceptibility to diseases, and predation by baboons.

Loblolly pine is planted widely in the higher elevations or latitudes of Argentina and adjacent areas of Brazil, while slash pine is favored on lower elevation, poorly-drained sites. Tree improvement programs have been initiated in both countries, but the adequacy of their genetic bases is questionable.

Both loblolly and slash pines were widely planted on the infertile coastal lowlands of southeast Queensland, Australia and required the addition of phosphate fertilizer for normal growth. Because the site requirements for loblolly pine were greater, it fell into disfavor and tree improvement was discontinued in the mid 1900s. Slash pine is still in use as a parent of hybrids *(Pinus elliottii* var. *elliottii* x *P. caribaea* var. *hondurensis)* which exhibit better growth than either parent while combining several of their complementary characteristics.

Both loblolly and slash pine are used for reforestation at low elevations in the subtropical region of the China from 21° N to 33° N. In the south slash pine is the better alternative. In the central subtropical zone loblolly and slash pine perform equally well while in the northern Subtropical zone loblolly pine performs best. A major goal of breeding programs for both species is to accumulate sufficient genetic resources to maintain a long-term breeding program.

Keywords: Loblolly pine, slash pine, exotics, Africa, Argentina, Australia, Brazil, China.

INTRODUCTION

Southern pines were introduced into a number of countries beginning around the turn of the century. Loblolly pine, *Pinus taeda* L., and slash pine, *Pinus elliottii* var. *elliottii* Engelm. were subsequently widely planted in some of these countries and continue to be a significant component of regeneration efforts in several countries today. Loblolly pine is native to the Coastal Plain and Piedmont of the eastern and southeastern USA from Delaware south to central Florida, west to central Texas, and north in the Mississippi valley to southeastern Oklahoma, Arkansas, and southern Tennessee (approx. 28 ° N to 39 ° 30' N and 75° to 97 ° W) . Slash pine (var. *elliottii)* occurs on the Coastal Plain of the southeastern USA from southern South Carolina to central Florida and west to southwestern Louisiana (28° N to 33 ° N and 79 ° 30' W to 91 ° W) (Critchfield and Little 1966). In their native USA loblolly pine is generally better adapted to moist, but well-drained soils while slash pine is adapted to more poorly-drained soils. Both species have been most successful as exotics when planted within the same longitudinal range (N or S longitude). However, they have been successfully planted to about 15° S by increasing the elevation at which they are planted and ensuring adequate moisture during the growing season. We discuss herein the history of introductions, status at present, genetic improvement efforts, and the outlook for the future, by country.

ARGENTINA

History of Introductions

Provenance trials for both loblolly pine and slash pine were initiated in 1968 on sites from Buenos Aires to 30 km south of Iguazú in northernmost Misiones. The early results from these trials encouraged the importation of commercial seeds of both species. The relative ease of handling slash pine in the nursery and establishing it in plantations as well as its better form and appearance led to its preference over loblolly pine during the period from 1970-1988. However, loblolly pine exhibited faster growth rates on well-drained sites and the Argentineans began to import commercial seeds from the best seed sources in North Florida and Southern Louisiana and to establish a second series of loblolly pine provenance trials in Misiones and northern Corrientes in 1982. The results from plantations and provenance trials led to the initiation of a tree improvement program and the realization that the genetic base of loblolly and slash pines would have to be increased to support breeding in the long term. Thus, in 1984, 120 open-pollinated slash pine families were introduced into Argentina in cooperation with the Cooperative Forest Genetics Research Program at the University of Florida, USA. In 1990, 44 half-sib families of loblolly pine from wind-pollinated seed orchards of the Northern Florida and Southern Louisiana provenance were introduced into Argentina in cooperation with the USDA-Forest Service. These were to provide guidance for future seed purchases. As part of the same cooperative effort more than 100 controlled-pollinations representing breeding populations from East Texas to Eastern North Carolina were introduced to broaden the genetic base of the breeding population. These did not include the favored provenances, but did represent the families which had performed best in progeny tests in the Southern USA. A second collaboration in the same

year with the USDA-Forest Service introduced more than 100 half-sib families from wind-pollinated seed orchards of slash pine from Mississippi and Florida provenances into Argentina (Schmidtling *et al.,* these proceedings).

Status of Loblolly and Slash Pines in Argentina

Loblolly pine and slash pines are adapted to approximately 1 to 1.25 million hectares in the Misiones, Corrientes and Entre Rios Provinces of Northeast Argentina. Slash pine is preferred on poorly drained sites which occur primarily in Corrientes and Entre Rios. Yields for slash pine on these relatively poor sites are about 15-20 m^3/ha/yr. On more fertile soils the rainfall patterns, and the rarity of low temperatures (primarily in Misiones) result in almost continuous growth of loblolly pine where trees from unknown provenances reach mean annual increments of 20-25 m^3ha/yr. The best provenances of unimproved loblolly pine from Northern Florida and Southern Louisiana yield 28-32 m^3/ha/yr (Pers. Comm. Sra. Mirta Báez), while slash pine planted in Argentina exhibits no strong seed source differences. Slash pine was planted more frequently than loblolly from about 1970 to 1988. Currently, about 80% of new plantations are being planted with loblolly pine. About 282,000 ha total have been planted to loblolly (56%) and slash (44%) pines to date (Pers. Comm. Sra. Mirta Báez). Primary pests are defoliating ants (Atta spp. and Acromrymex spp.) and Sirex noctilio which recently arrived from Brazil (Pers. Comm. Sra. Mirta Baez). Planting stock arises from seed production areas and first-generation seed orchards in Argentina and from commercial seeds purchased primarily from the Southern USA.

Genetic Improvement

The first selections of loblolly pine were made from plantations in Argentina in 1986 under the direction of the Centro de Investigaciones y Experiencias Forestales (CIEF). Selections were made in plantations of unimproved northern Florida and southern Louisiana provenances in Argentina. The first grafted seed orchard of loblolly pine was established in 1988 and open-pollinated progeny tests of the selected parents were established. This grafted seed orchard was expanded in 1988-1989 with further selections from plantations of the northern Florida provenance in Argentina. At present, the preferred source of seeds for planting in Argentina is from improved seed orchards in the USA because straightness and branch habit are better. Seedlings from unknown provenances are no longer planted (Pers. Comm. Sra. Mirta Báez). The need to increase the genetic base of the breeding population for loblolly pine was perceived to be critical since the genetic sample from the best provenances was limited. However, private companies in the USA were reluctant to share gene resouces from these provenances or to allow collections from their lands (Rogers and Ledig 1996) and another strategy was adopted. In 1990, 100+ controlled crosses each for loblolly and slash pines from the breeding programs of the USDA-Forest Service were introduced for testing their potential in Argentina. Unfortunately, these breeding populations do not include the best provenances, but should provide some opportunity to enlarge the breeding population.

Outlook

Interest in both loblolly and slash pines for plantation establishment remains high. A breeding strategy has been adopted for loblolly pine which includes a breeding population of about 600 selections managed in 12 sublines of 50 selections per subline. Subline composition will favor northern Florida and southern Louisiana provenances (Báez this proceedings). Plans for slash pine tree improvement include grafting three seed orchards in 1997 and development of a breeding strategy.

AUSTRALIA

History of Introductions

Loblolly pine and slash pine *(P. elliotti* Engelm. var. *elliottii)* were introduced to Queensland in 1917 and 1925, respectively. Both became important species for planting in the early 1930s (Rogers 1957). Seeds for plantation establishment were deliberately imported from north of the Ocala National Forest in northeastern Florida until seed needs were met (after 1936) by collecting from seed trees in Australian plantations (Rogers 1957). Provenance trials for both loblolly and slash pine were initiated in 1955 using 13 provenances from the Southwide Pine Seed Source Study. Results were typical of such trials for both species (Nickles 1962). Differences among slash pine provenances were minimal (at least through 1962), but loblolly provenances exhibited variation. The best provenances were from the coastal lowland sources from the southern USA with the best being from North Florida (Nikles 1975).

Status of Loblolly and Slash Pines in Australia

Both loblolly and slash pines were planted on sites not suitable for the native Hoop Pine *(Araucaria cunninghamii)* to augment the softwood supply (Rogers 1957). The sites on which they were planted were the infertile coastal lowlands of southeast Queensland and in frost pockets because seedlings of Hoop Pine were not frost resistant. Both exotic species required the addition of phosphate fertilizer for normal growth, but the requirements for loblolly pine were greater. The total area planted with loblolly pine approached 4,000 acres (Rogers 1957), but by 1952 only about twenty acres per year were being planted with that species (Nikles 1962) because it exhibited worse symptoms of phosphate deficiency than slash pine (Haley 1957). The number of acres planted with slash pine had risen to about 21,000 in 1956 (Rogers 1957) and it was planted until the 1980s when it was replaced by *P. caribaea* Morelet var. *hondurensis* Barrett and Golfari which grew much faster on all but the most poorly drained sites (Toon *et al. 1996).*

Genetic Improvement

The genetic improvement of loblolly pine began in 1941 with the establishment of the first clonal seed orchard and open-pollinated progeny trials of parents selected in plantations in Australia (Nikles 1962). By 1953 it was virtually dropped from the planting program and the

tree improvement program because of its poor performance on phosphate-deficient sites (Haley 1957).

The first slash pine seed orchard was grafted in 1953 using selections from stands planted in Australia in 1941. Genetic trials of both open- and control-pollinated progenies were established (McWilliam and Florence 1955) and a second slash pine seed orchard was established in 1957 when results were available from progeny tests (Nikles 1962).

Hybrid matings were attempted between slash pine and loblolly, palustris, radiata, and patula, but only slash x loblolly was successful (in 1957). In March, 1957 apparently fertile seeds were collected from a slash x caribaea cross (Haley 1957). *Pinus elliottii* var. *elliottii* x *P. caribaea* var. *hondurensis* hybrids were tested in 1958-1962 and exhibited better growth than either parent while combining several complementary characteristics of the parents (Nikles 1995).

Pinus caribaea var hondurensis replaced slash pine during the 1980's on all but the most poorly-drained sites and slash pine tree improvement languished until it was revitalized to support the hybrid program (Toon *et al.)*

Outlook

Three populations of slash pine are being maintained: 153 first- and second-generation parents (and their progeny) which are represented in genetic tests; 300 new first-generation parents selected between 1993 and 1995 in 30-year-old-plantations; and wind-pollinated seeds from 216 individuals selected in 25-30-year-old plantations for gene conservation (Toon *et al. 1996* and Dieters and Nikles these proceedings).

BRAZIL

History of Introductions

Loblolly and slash pine were introduced into Brazil in the late 1940s on an experimental basis. In the early 1950s both species were planted on sites formerly planted to Araucaria. The first provenance trials were initiated in 1972-73. These included slash pines *(P. elliottii* var. *elliottii* Engelm.) from Coastal Louisiana, Alabama, Georgia and South Carolina and Florida. Loblolly pine provenances from the entire range of the species west of the Mississippi River were tested. In 1978, 55 seedlots representing good general combiners of loblolly pine from the Southeastern United States were introduced along with half-sib seedlots of both loblolly pine and slash pine open-pollinated in seed orchards from land races of both species in Zimbabwe. In 1982, 66 open-pollinated slash pine seedlots were introduced into Brazil in cooperation with the Cooperative Forest Genetics Research Program at the University of Florida, USA.

Status of Loblolly and Slash Pines in Brazil

Fiscal incentives from 1967 through 1986 encouraged the establishment of most of the pine plantations in place. Current estimates are almost 1,000,000 ha of loblolly pine and almost 200,000 ha of slash pine established. The demise of the fiscal incentives effectively ended the planting of both loblolly and slash pines in Brazil except by the large companies and annual planting rates are about 10,000 ha for loblolly pine and 2,000 ha of slash pine (Pers. Comm. Dr. Jarbas Shimizu).

Loblolly pine is planted primarily on well-drained sites along the coastal plains in the Southern States of Paraná, Santa Catarina and Rio Grande do Sul. South Carolina coastal provenances are among the best in Southern Brazil while more Northern provenances, for example the Piedmont of North Carolina grow equally well in cooler, highland climates (Pers. Comm. Dr. Jarbas Shimizu). The best provenances of loblolly pines are from North Florida and South Louisiana. Slash pine is better adapted to wet sites in Paraná, Santa Catarina and exhibits no significant differences among provenances (Pers. Comm. Dr. Don Rockwood).

Plantations from genetically unimproved seedlings produce 18-20 m^3/ha/yr on 16-25 year rotations. Genetically improved (first generation) plantations produce about 7 ton/ha/yr more than unimproved material (42 versus 35 tons/ha/yr). Plantations from rogued first-generation clonal seed orchards produce about 50 tons/ha/yr (Pers. Comm. Sra. Mirta Báez).

Genetic Improvement

Genetic improvement programs are conducted cooperatively among private companies through the Instituto de Pesquisas e Estudos Florestais (IPEF) at the University of Sao Paulo, Piracicaba, SP. Supporting research is conducted by Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA). Few companies have established seed orchards and most of these are first-generation unrogued orchards (Pers. Comm. Dr. Jarbas Shimizu). However, the oldest among these established about 1978-80 have been rogued and provide seeds for plantation establishment. Beginning in 1990 selection began to establish a second-generation base population. The breeding strategy is to maintain populations derived from the better provenances separately from those derived from slower-growing areas.

Outlook

Since fiscal incentives for reafforestation ceased (after 1986), plantations other than those made by large companies have virtually ceased. Ten years have passed without significant increases in plantation area in Brazil and a timber shortage is forecast for Brazil by 2005 (Pers. Comm. Dr. Jarbas Shimizu). Planting genetically improved seedlings is one way to rapidly increase forest yields and will likely play an important role in averting or ameliorating the expected timber shortage.

PEOPLE'S REPUBLIC OF CHINA

History of Introductions

Loblolly and slash pines were introduced into the People's Republic of China in several stages from the 1920's to 1989. Early introductions were small amounts for experimentation. In 1974, large quantities of seeds, usually of unknown provenance, began to be introduced for plantation establishment. The use of seeds of unknown seed source for plantation establishment arose because of a lack of information from provenance tests and because the availability of seeds in the People's of China was limited. In 1981, ten unimproved seed sources, identified only by state and county, were established in provenance trials in seven locations in China. A larger provenance trial was planted at eighteen locations in 1983. This second provenance trial included 31 lots of bulked seeds from first-generation seed orchards in the southeastern United States and 22 cold-hardy seedlots. In 1988 and 1989, a limited range collection was introduced. Fifty lots of wind-pollinated seeds from one wind-pollinated, Australian seed orchard and fifty wind-pollinated seedlots from two Zimbabwean first-generation seed orchards were introduced and established in 1989 in half-sib genetic tests. Seeds from 87 slash pine controlled crosses representing 41 unrelated parents and 83 loblolly pine controlled crosses representing 112 unrelated parents were introduced into the breeding populations in 1995 from selected parents that were progeny tested in the southern USA by the USDA-Forest Service. An additional 111 seedlots of loblolly pine and 126 of slash pine not previously tested in the USA were introduced into the breeding populations in 1996.

Status of Loblolly and Slash Pines in the China

Loblolly pine is planted in China in the southern, central and northern subtropical zones of the China from 21° N to 33° N. In the southern subtropical zone (21° to 24° N) slash pine is widely planted although loblolly pine may be a better alternative (Pan 1995), but in the large, central and northern subtropical zones (25° to 33° N) loblolly pine grows better than both slash pine and the indigenous Masson pine *(Pinus massoniana L.)* at elevations greater than 500 meters (Pan 1989). By 1992, about 1.5 million hectares of loblolly and slash pine plantations had been established in the proportions 20% and 80%, respectively (Pan 1995). However, loblolly pine performs better on many sites which have been planted with slash pines (Pan 1995). Plans are to establish 200,000 hectares of plantations annually through the 1990s. Early (6 to 8 years) results from provenance trials indicate that seed source is important for loblolly pine, but not for slash pine. The best sources of loblolly pine for the Southern and Central Subtropical zones of the People's of China are northern Florida and southern Georgia, Alabama, Mississippi, and Louisiana south of 32° N and coastal Georgia and South Carolina to about 34° N (Pan 1995 unpublished report). The Piedmont or upper coastal sources from the same regions are best for planting in the northern Subtropical zone of the China where freeze damage presents problems.

Genetic Improvement

The Hongling slash pine seed orchard, established in 1965, was the first seed orchard in China. Selections were made from mostly from naturalized plantations established from the 1947 and earlier introductions. Loblolly pine tree improvement began in 1983 with the initiation of the Qiaotou seed orchard in Yingde county. Plans for plantation establishment cannot be met from projected seed orchard yields and more hectares of both loblolly and slash pine are under establishment. New seed orchards promise substantially improved genetic gains since they will be established with the benefit of data from provenance trials and progeny tests planted in the 1980's. Seed supplies for slash pine are adequate at present because slash pine was the preferred species until field trials demonstrated the superiority of loblolly pine in the Central and Northern Subtropical Zones, particularly at elevations greater than 400 m (Pan 1989). For the same reason, loblolly pine seeds are now in greater demand and new seed orchards are being established to meet the expected demands. Seeds are still being purchased from abroad primarily because the older, most productive seed orchards were derived from land race plantations from early introductions and do not perform as well as unimproved seeds from the best provenances (Pan 1989). More hectares of slash pine seed orchards are being established to provide better genetic material for replanting plantations that will begin to be harvested within the next 10 years. Breeding strategies for both species have been adopted to ensure the continued genetic improvement of seedlings for plantation establishment in China.

Outlook

The outlook for both loblolly and slash pine in China is promising. Fusiform rust, *Cronartium quercuum* (Berk.) Miyabe x Shirai f. sp. *Fusiforme,* is apparently not a problem. However, *Diplodia* spp. has caused significant damage in plantations in the Northern Subtropical zone of China and *Oracella acuta* Lobdell has caused significant defoliation in southern plantations. *Dioryctria splendidella* H.S. is also an insect pest on loblolly and slash pines in China. The future success of loblolly and slash pine plantations in the China will depend in part on controlling both of these pests.

SOUTHERN AND EAST AFRICA

History of Introductions

The four principal southern pine species, loblolly pine, slash pine, longleaf pine, *P. palustris* Mill., and shortleaf pine, *P. echinata* Mill., were first introduced into the southern and east African region through South Africa around the turn of the century. The earliest record is of longleaf pine being planted in 1884, followed by loblolly pine later in that decade, shortleaf pine in 1899 and slash pine in 1918 (Poynton, 1979). Seed of these four species was later imported for establishment of trial plots in Southern Rhodesia (now Zimbabwe), loblolly pine in 1920, slash pine and shortleaf pine in 1929 and longleaf pine in 1930. Introductions were also made into Zambia, Malawi, Tanganyika (now Tanzania), Kenya and Uganda and also

Mozambique and Angola, mostly with seed from South Africa. The other southern pines, *viz*., *P.glabra, P. pungens, P. rigida, P. serotina* and *P. virginiana,* were not introduced into the region until the mid 1960s when there was a concerted effort to carry out comparative tests of representative provenances of all the southern pines (Prevôst *et al.*, 1973a & 1973b; Mullin *et al.*, 1978). However, by this time, there were well-established breeding programs for slash pine and loblolly pine in the region and major gains in productivity and stem and branch form had been made through selection of plus trees in the early plantations.

Status of the Southern Pines in Southern and East Africa

Slash pine has been more widely planted in the region than any other southern pine. Provided it is not off-site, particularly at higher altitudes, slash pine has a long list of desirable attributes compared with other pines used operationally in the region. It is adaptable to a wide range of sites and tolerant of low soil fertility and poor drainage; it is relatively resistant to frost, fire, browsing by animals, *Hylastes* spp., *Pineus pini, Cinara cronartii, Eulachnus rileyi* and *Sphaeropsis sapinea;* it is tolerant of grass competition and high stocking and responds to delayed thinning; it is easy to establish and has a light crown habit that minimizes the problems of replanting in the slash; stem and branch form are good in bred populations and wood density high when planted at lower altitudes and these attributes result in the production of high quality lumber and high yield of pulp with good strength characteristics on short rotations (Morris *et. al.);* there is a high yield of oleoresin and tall oil production at the pulp mill. Its silvicultural disadvantages are that it is susceptible to *Armillaria mellea* and to bark-stripping by baboons and it is slow to capture the site. The resinous timber makes the species unsuitable for the production of groundwood pulp and resin-filled heart shakes can develop and seriously degrade the timber of rotation age trees (Darrow, 1982; Christie and Tallon, 1991). However, its most serious deficiency is that in almost any situation in which it will grow, there is always another pine species that will out-produce it and, although that species may have many other comparative disadvantages, it is usually productivity that wins the day when it comes to species choice.

Slash pine is silviculturally well adapted to climatic and edaphic conditions at the lower altitudes in the higher rainfall parts of the eastern escarpments in southern Africa. At the higher, coolest altitudes, however, where mean annual temperature is below 16.0°C, it is severely out-yielded by *P. patula.* However, its comparatively high tolerance of drought, frost, poor drainage and infertile soils gives it an edge over other species where these conditions occur singly or in combination.

Loblolly pine has been a neglected species in southern Africa from the time of its earliest introduction. The reasons for initial neglect were manifold and included an erroneous belief that it was tolerant of a wide range of sites; an ignorance of the importance of provenance in achieving the best performance of the species; excessively poor stem form and coarse branching of unimproved stock, especially when planted at high altitude; and an ill-founded reputation for the production of brittle timber that was unsuitable for sawn timber or pulp. Genetic improvement programs that included provenance testing and selection and breeding plus a better understanding of site requirements dispelled most of these reservations by the 1970s. It

was then seen as having many desirable attributes including very high volume production on the right site, good stem and branch form from bred material, resistance to *Sphaeropsis sapinea* and to *Hylastes* spp. and good litter breakdown on the higher, cooler sites. Disadvantages were seen as its susceptibility to drought death, *Pineus pini* and *Cinara cronartii.* Recently two additional concerns caused the virtual cessation of planting of the species. These were firstly, the development of a large number of "bottle-shaped" trees in South African plantations with associated abnormal wood formation that seriously affected utilization of the logs for sawnwood or pulp and secondly, the sudden discovery by baboons that the cambium on the main stem just below the live crown was palatable and an alternative source of food in the plantation environment where their natural sources of food had been exterminated.

Loblolly pine is well adapted to the better sites over a wide range of altitudes in the Eastern Districts where mean annual rainfall is over 1200 mm, preferably with an average of at least 25 mm in the driest months. Unlike *P. tecunumanii, P. oocarpa* and *P. maximinoi,* this species will tolerate frost. Provided the soils are also good, the yields will increase with decreasing altitude in relation to *P. patula* on similar sites but on the best high altitude *P. patula* sites, loblolly pine is unlikely to out-yield that species in the short rotations (< 25 years) currently used.

An estimate of the areas planted (in hectares) to the two operational southern pines, slash pine and loblolly pine, in southern and east Africa today are given below.

	Slash Pine	Loblolly Pine
South Africa	148,000	46,000
Zimbabwe	8,000	4,000
Swaziland	13,000	3,000
Malawi	4,000	100
Total	173,000	53,100

There have also been small commercial plantings in Kenya, Zambia, Tanzania, Angola and Mozambique, but the areas are small and unlikely to affect materially the total areas given above for the region. Slash pine probably constitutes about 23% and loblolly pine about 7% of the total softwood plantation area of southern Africa today.

Genetic Improvement

Provenance trials were planted in South Africa (Poynton, 1979), Zimbabwe (Prevôst *et al.,* 1973a & 1973b; Mullin *et al.,* 1978) and Malawi (Burley, 1966) in the 1960s. These trials soon showed the great importance of provenance in loblolly pine with the southern-most provenances hugely more productive than the northern provenances and these were not likely to have been represented in the original plantation from which the founders of the breeding populations had been chosen (Mullin *et al.,* 1978). However, the stem and branch form of these southern provenances was so poor that there was no question of immediate inclusion in the

breeding programs; and the strategy has been to import selected material from breeding programs in Florida and plant the material as resource stands in which to make selections later. Provenance variation was not so marked in slash pine although with this species as well, the southern provenances were generally demonstrably more productive, What the provenance trials did show was the folly of importing seed for operational planting from provenances of unproven performance. Between the time that Zimbabwe was importing seed from South Africa and producing its own from clonal orchards, there was a period when large amounts of both species were being imported from general collections in natural stands of uncertain origin. In loblolly pine progeny tests at seven years, controlled crosses from the bred material were eight times as productive as the imported material (Mullin *et al.,* 1978); much of this difference was due to suppression in the line plots of the test, but the mean height of the bred was twice that of the imported material at two years - before competition had set in. The Zimbabwe story with slash pine is very similar. The differences between the bred and imported material were not as great as they were in loblolly pine, but were still of sufficient magnitude to have highly significant economic implications.

Breeding programs for exotic pines were started in South Africa (van der Sijde and Denison, 1967) and Zimbabwe (Armitage and Barnes, 1966) in the late 1950s with the selection of plus trees, the establishment of clonal seed orchards and planting of progeny tests. The plus trees were selected in rotation age plantations that were planted in the early 1930s or earlier and therefore, at the time, there was no certainty that the material was from the best natural provenance. However, the most serious deficiencies in both *Pinus elliottii* and *P. taeda* were poor stem and branch form and there were good prospects of being able to improve sawlog quality through selection for stem straightness and fine branching in a population that had had one generation of proven performance. This certainly proved to be the case and stem and branch form in the plantations raised from seed produced from the first generation clonal orchards was so much improved that neither trials nor even comparison stands were needed to demonstrate the improvement; and progeny tests also showed growth rate to be better (Mullin *et al.,* 1978). Well designed progeny tests indicated high levels of additive genetic variation for the traits controlling these important morphological traits for both slash pine (Pswarayi, 1993; Pswarayi and Barnes, 1994, Pswarayi *et al.)* and loblolly pine (Gwaze, 1996), However, having taken care of poor stem and branch form in one generation, the other more recently recognized deficiencies have assumed greater importance *viz*. slow growth, baboon damage and heart shake in slash pine and baboon damage, drought proneness, abnormal wood formation and susceptibility to *Cinara cronartii* in loblolly pine. In fact, collectively, these detriments have brought about not only the virtual demise of these two species as important elements in southern African plantations, but also a reduced status in the breeding programmes which have ended up with large areas of highly productive clonal seed orchards with no national demand for their seed. The future for both slash pine and loblolly pine as operational plantation species in southern Africa depends, therefore, upon being able to counter the disadvantages through silviculture or genetics to make them competitive with the tropical pines such as *P. patula, P.greggii, P. tecunumanii, P. kesiya* and *P. oocarpa.*

Outlook

The most serious problem with slash pine is its slow rate of growth. Selection for stem and branch form took precedence in the first generation of the breeding programs, and therefore it is likely that some gain could be made in growth rate if that were the prime selection trait in the second generation; but it is unlikely to give gains that will make the species competitive with its rivals. It is unlikely that any genetically controlled trait will be found that makes the tree less susceptible to baboon damage; this will be solved by managing the baboon population which will probably be necessary in the end because the animals will turn to other species if slash pine is not present. The resin-filled heart shakes are thought to be caused by encased nursery soil which distorts the tap root and aggravates shake (Darrow, 1982); and although the possibility of genetic control has been suggested (Christie and Tallon, 1991), shake is more likely to be controlled by good silviculture and correct siting. It seems, therefore, that growth rate is the crucial trait and it may be that the future for slash pine will be in hybrid combination with *P. caribaea* var. *hondurensis.* This hybrid is in full operational use in Queensland to the exclusion of all other tropical pines over a large area. The hybrid exhibits the site tolerance and some of the frost resistance of slash pine and the growth rate of *P. caribaea* var. *hondurensis.* Provided the wood quality is acceptable when grown under southern African conditions, it could be grown over almost the whole of the area that was originally planted to slash pine and this species would, in this form, contribute its many attributes to the low altitude pine plantations in the region. The hybrid between slash pine and loblolly pine has been made and tested in Zimbabwe (Barnes and Mullin, 1978), but there is no niche in which it can demonstrate hybrid vigour.

The most serious problem with loblolly pine has been the formation of bottle-shaped stems with associated abnormal wood that renders the trees useless for sawn timber or pulp. This problem has virtually stopped the planting of the species in South Africa. There is some argument as to whether this condition is caused by plant growth regulator changes in response to pruning and thinning (Herman, paper not found here) or whether it is a response to an attack by the black aphid, *Cinara cronartii.* The latter seems to be distinctly possible reason for the widespread occurrence of the abnormality because a count of annual rings shows that its first appearance in unpruned and unthinned stands in Swaziland coincided with the arrival of the aphid. If it is due to the aphid, the problem is likely to subside because a parasitic wasp, *Pauwesia* spp. as been successfully introduced for biological control and progeny tests in South Africa do show that resistance to aphid attack is under genetic control. Loblolly pine is more drought-prone than all the other pines used in southern Africa, but this should be controlled by proper site selection. This is the crucial issue because *P. patula,* the most important pine in southern Africa, grows best on the moist higher altitude sites. Loblolly pine would therefore have to out-produce *P. patula* on these sites if it is to be grown on a larger scale in the region. There is evidence that the material now coming from the loblolly pine breeding programmes will out-produce *P.patula* at the lower end of the latter's zone; and it will produce larger sawlogs if grown on a longer rotation. Its wide provenance variation might also be used to extend the altitude range over which it can be grown. It appears, therefore, that loblolly pine has the prospect of increasing very considerably in importance in southern Africa in the future.

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