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United States
Department of
Agriculture

Forest Service

Southeastern Forest
Experiment Station

General Technical Report SE-23

# GROWING EUCALYPTS IN FLORIDA FOR INDUSTRIAL WOOD PRODUCTION

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Cover Photo

Robusta plantation 12 years after planting on palmetto prairie.

1983

Southeastern Forest Experiment Station
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# GROWING EUCALYPTS IN FLORIDA FOR INDUSTRIAL WOOD PRODUCTION

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## Contents

## 'reface

This paper describes the technology ›f eucalyptus culture in Florida. It is .ntended to help landowners decide if :hey want to grow eucalypts for .ndustrial wood production, to help :oresters prescribe silvicultural prac- :ices, and to inform the world's euca- .yptus technologists of new methods leveloped in Florida. The strategy used .n Florida to domesticate a new wood :rop in a difficult environment could be ı model for others to follow, not only vith eucalypts but with other species.

Practices in Florida are developing :apidly, and our purpose is to provide :urrent information. Previously ınpublished research results are :eported from the Lehigh Acres labora- :ory of the USDA Forest Service, and :rom the Florida Forests Foundation, vhich was absorbed by the Lehigh Acres Laboratory. Cooperator's experimental :esults are drawn upon as needed.

The work described was done with the ıelp of many cooperators. Several of :hem participated in a formal eucalyptus :esearch cooperative and are mentioned ın the section on history. Other :ooperators in field experiments have ɔeen Alico, Inc., Babcock Florida Company, Collier Corporation, Georgia-Pacific Corporation, Turner Corporation, and Walt Disney World.

Jackson Burgess, founder of the Florida Forests Foundation, started for- nal research on eucalypts in Florida. C. P. Lykes and Ben Swendsen of Lykes Bros., Inc., have provided solid support for the research over the years. The Florida Division of Forestry has partly financed the research, and many of its personnel have participated in a variety of research studies. Employees of the vided much assistance describing soils in the field.

The Australian common names of euca- lypts are seldom descriptive of species characteristics in Florida, and a separate convention for names has devel- oped here. The common name of a euca- lypt in Florida usually comes from its scientific name. Thus *Eucalyptus grandis* Hill ex Maiden is known simply as "grandis." That convention is used in this publication. Occasionally, a more descriptive nickname is used in Florida; for example, Spanish camaldu- lensis to designate a strain of camaldulensis that came from seed imported from Spain. The scientific names of eucalyptus species mentioned in the text are listed in the Appendix.

**Summary**

Eucalyptus trees have been planted on 4 million ha (10 million acres) in the world because of their rapid growth, adaptability to diverse sites, and abil- ity to coppice. Eucalypts were first planted in Florida in 1878, but no industrial plantations were established until 1972. By 1981, 6,000 ha (15,000 acres) of eucalyptus pulpwood plan- tations existed in southern Florida due to a cooperative research and develop- ment effort by government, private land- owners, and industry. The area in eucalyptus plantations may expand rapidly in Florida as strains of trees and suitable silvicultural methods are developed for central and northern Florida, and the coastal plain of other Southern States.

Proper species selection, site selection, and site preparation are crit- ical to plantation establishment. Grandis and robusta are recommended for planting on palmetto prairie and acid flatwoods of the southern planting zone. Camaldulensis and tereticornis are recommended for ridges. Grandis and robusta grow excellently on subsided muck soils, but these soils are not pres- ently available to forestry. Lack of suitable strains of eucalypts or proven silvicultural techniques prevent recom- mendations for other landtypes in the southern zone.

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Camaldulensis, macarthurii, nova-anglica, tereticornis, viminalis, and a saligna X tereticornis hybrid are suitable for plantations in the central zone. However, lack of genetically improved seeds and insufficient knowledge of site requirements and silvicultural techniques restrict planting to small test plantations. Grandis and robusta might be suitable for the central zone despite damage from freezes, because more wood might be produced in plantations of these species than in plantations of slower growing, more freeze-resistant species.

Macarthurii, nova-anglica, and viminalis show exceptional promise in the northern zone, but a lack of genetically improved seeds precludes commercial planting at this time.

Soil type and site drainage have a pronounced effect on eucalyptus growth, and the effect varies with species. Even on flatlands there is enough soil variation that soil mapping prior to planting to delineate priority soils for planting would be beneficial.

Plantations in Florida should be established with eucalyptus strains bred in Florida, because plantations established with imported seeds have been unsatisfactory for industrial wood production. Selection for freeze resistance is important in the Florida breeding work. However, striving for complete resistance may reduce yields too much, so some risk of freeze damage can be acceptable.

Genetically improved seeds and seedlings of grandis, robusta, camaldulensis, and tereticornis are available from the Florida Division of Forestry. A breeding system that uses recurrent selection in successive generations of open-pollinated families is most advanced for grandis, which in Florida is a landrace from three generations of selection.

Methods have been developed for seed collection, extraction, cleaning, germination testing, and storage. Pelleted seeds are precision-sowed in nursery containers that are designed to air-prune roots. Seedlings are removed from the containers and are shipped to planting sites in cardboard boxes.

Experience in site preparation is concentrated on palmetto prairie in tl southern zone, and to a much lesser extent on cutover and stumped acid fl woods in the southern and central zon Standard site preparation on these la is to either double chop, cross disk, root plow. Ground rock phosphate (GR is broadcast if grandis or robusta ar to be planted (GRP is toxic to camaldu lensis and tereticornis), and beds ar constructed. Beds are essential on sites that may be flooded at summer planting time. Bedding also often controls some types of competing vege tion but not the grasses found on old-field sites.

Planting is typically done in summ in the southern and central zones, because it is the only season in which adequate soil moisture is certain. M planting is done with bare-root machi planters designed for pines.

In Florida, plantations are not tended after planting, but weed contr would probably be very beneficial. Application of nitrogen fertilizer to young stands also might greatly stimulate growth.

Plantations of grandis and robusta in the southern zone are currently producing pulpwood at a rate of 16 $m^3$ per ha per yr (2.5 cords/acre/yr). Much higher yields of total biomass can be achieved by intensifying silvicultural practices and planting at high seedlin densities. Yields of other species an in other planting zones are unknown.

Little harvesting of eucalyptus ha occurred in Florida. Chain saws or shears will probably be satisfactory for harvest as long as stump bark is n damaged. Whole-tree chipping would reduce fire hazard, keep debris off stumps, and reduce regeneration from seed, although nutrient drain is a concern. One major problem to face foresters is the unreliable coppicing grandis in Florida, especially after a summer harvest.

Cattle and deer damage newly established plantations, and fire can l a problem in plantations of any age if an understory of saw-palmetto or other flammable vegetation is present. Insects, diseases, and lightning are nuisances, but they are not serious limiting factors in growing eucalypts in Florida. Hurricanes could cause serious plantation losses.

The eucalypts selected for growing in Florida are good furnish for pulp. They would be a good choice for fuelwood plantations, and other uses are possible.

Use of rooted cuttings and tissue culture plants from cloned superior trees promises large gains in adaptability and productivity.

## Introduction

Eucalypts are evergreen hardwood trees and shrubs of the genus *Eucalyptus* in the family Myrtaceae. The genus includes about 500 species (Boland and others 1980; Chippendale 1976; and Hall and others 1970), almost all native to Australia and adjacent islands. Several are native to Indonesia, Papua, New Guinea, and the Philippines (FAO of the UN 1981), but only two of these species, deglupta and urophylla, are not also native to Australia. The genus has attracted worldwide interest, because eucalypts have grown exceptionally rapidly in short-rotation plantations when planted in countries where they are not native. Moreover, the stumps of most plantation species sprout after harvest, making coppice regeneration possible. Because of high productivity and ease of regeneration, eucalyptus plantations occupy 4 million ha (10 million acres) worldwide (FAO of the UN 1981)--probably more plantation area than that of all other hardwoods combined. Among the hundreds of eucalyptus species, no more than 30 have shown potential for high-yielding timber plantations (FAO of the UN 1981). Almost all the world's acreage of eucalyptus plantations is planted to just 10 species: camaldulensis, globulus, grandis, maculata, paniculata, robusta, saligna, tereticornis, urophylla, and viminalis (FAO of the UN 1981).

In southern Florida, eucalypts grow much more rapidly than other hardwoods or pines on a variety of sites. Rapid growth might make eucalyptus forestation profitable on land presently not replanted following timber harvest and on rangeland with low carrying capacity. Demand for accessible hardwood supplies when bottom lands are flooded in northern Florida, and the adaption of eucalypts to available low-quality rangeland in southern Florida led to the establishment of 6,000 ha (15,000 acres) of eucalypts west of Lake Okeechobee between 1972 and 1981.

Possibly a million hectares in southern Florida and a far larger area in the State as a whole have potential for eucalyptus plantations. Planting stock and cultural techniques are available to plant eucalypts operationally in southern Florida and on a pilot scale in central Florida. Freeze-tolerant stock is not available for planting farther north but soon may be. Thus, eucalyptus planting could expand rapidly over the next 10 years in Florida and in the warm coastal regions of neighboring states.

## History

The earliest documented planting of eucalypts in Florida was in 1878 on Merritt Island. In 1910, Zon and Briscoe (1911) found eucalypts growing at 27 locations, and 16 species were represented. They urged caution in establishing commerical plantations because of insufficient information on matching species to sites, silvicultural practices, and yields, and an uncertain market for the wood. They pointed to a need for systematic introduction of species and planned experiments.

Zon and Briscoe's caution was heeded. Through the first half of the 20th century, some eucalypts were planted in Florida for shade, ornamentals, and windbreaks, especially around homesteads in southern Florida, and a few small plantations were established. However, Zon and Briscoe's call for scientific research went unheeded until 1959.

In 1959 in Fort Myers, the private Florida Forests Foundation started scientifically based eucalyptus research that included species selection for various landtypes, site preparation, fertilization, spacing, weed control, and nursery practices. The Florida Forests Foundation was absorbed by the

USDA Forest Service in 1965, and the eucalyptus research was continued but at a reduced level. In about 1966, the Florida Division of Forestry (FDF) published a planting guide for eucalypts in Florida (Schory [n.d.]). However, until 1972, only research plantations had been established.

At that time, some pulpmills in northern Florida wanted eucalyptus wood, but they did not own land suitable for growing it, because only southern Florida appeared to have acceptable frost risk for growing eucalypts. Some southern Florida landowners wanted to grow wood, but they were uncertain about markets, silvicultural practices, and yields. The FDF had a bare-root pine nursery in southern Florida but could not invest in eucalyptus container facilities without an assured market, and the technology was lacking for mass producing seedlings at low cost. The Southeastern Forest Experiment Station, USDA Forest Service, had the research expertise needed to develop the technology, but it was not certain that there were sufficient clients for the research.

Impetus for major planting came in 1971 with formation of a eucalyptus research cooperative designed to aid Forest Service scientists at Lehigh Acres, Florida, to develop genetically improved planting stock, nursery practices, and establishment techniques. Cooperating formally with the Forest Service for various periods of time were Buckeye Cellulose Corp., Perry, Fla.; Container Corp. of America, Fernandina Beach, Fla.; the FDF; Hudson Pulp & Paper Corp., Palatka, Fla.; International Paper Co., Bainbridge, Ga.; ITT Rayonier, Fernandina Beach, Fla.; Lykes Bros., Inc., Tampa, Fla.; and St. Regis Paper Co., Jacksonville, Fla. The cooperative effort shared the risks and broke the barriers that had prevented commerical eucalyptus planting (Uhr 1976).

In 1972 a quality facial tissue with ideal strength and softness was manufactured in a Florida pulpmill from a mill-scale run of grandis grown in Florida, and this added confidence to commerical eucalyptus growing (Uhr 1976). Also in 1972, the North Carolina State University (NCSU) Hardwood Management Cooperative began systematic testing to find eucalypts hardy enough to withstan the freezing temperatures of northern Florida and the coastal plain of other Southern States.

## Species and Sites

Proper species selection, site selection, and site preparation are critical to plantation establishment. Species trials and planting tests suggest three planting zones in Florida, based on the severity of freeze damage to several eucalyptus species (fig. 1).


*Figure 1.— Provisional eucalyptus planting zones in Florida.*

### *Southern Zone*

In the southern zone, five species and two hybrids stand out in vigor and freeze resistance (table 1). Four of these--camaldulensis, grandis, robusta, and tereticornis--are currently used for plantations. Rudis has been excluded because its poor form makes it unsuitable for pulpwood. The camaldulensis

Table 1 — Eucalyptus species that are suitable after genetic improvement for industrial wood plantations in Florida.

| Species and origin | Planting zone suitability | | | Adaptability and site selection criteria | Utilization qualities | Availability of genetically improved seed (alternative propagation method) |
|---|---|---|---|---|---|---|
| | Southern | Central | Northern | | | |
| **Camaldulensis** | | | | | | |
| Israel | Yes | Probably | No | Good growth rate on a variety of sites, freeze resistant (?) in southern zone | Mediocre form; pulping not tested | None. (Propagate with rooted cuttings or tissue culture plants) |
| Spain | Yes | Yes | No | Good growth rate except on wet sites; plant on excessively drained sites in southern zone and on all but wet sites in central zone; good choice for reclaimed strip mines; very freeze resilient in central zone | Fair form; as good as native hardwood pulp furnish, if not better (Franklin 1977) | Scarce - sporadic seed production from first-generation seed orchard. (Can propagate with rooted cuttings or tissue culture plants) |
| Western Australia | Yes | Probably | No | Vigorous growth on a variety of sites; exceptionally freeze resistant in southern zone | Crooked, limby; pulping not tested, but thick bark may be a problem | None. (Propagate with rooted cuttings or tissue culture plants) |
| **Camaldulensis X grandis** | | | | | | |
| Morocco and Florida | Yes | Probably | No | Very vigorous growth on a variety of sites; freeze resistant (?) in southern zone | Good form; pulping not tested | None. (Propagate with rooted cuttings or tissue culture plants) |
| **Grandis** | | | | | | |
| Many | Yes | Provisionally | No | Very vigorous growth on acid flatwoods and palmetto prairie; freeze resilient in southern zone; freeze susceptible to moderately freeze resilient in central zone; coppices poorly from summer harvests | Excellent form; as good as native hardwood pulp furnish, if not better (Franklin 1977) | Abundant from third-generation of selection; fourth-generation seed available soon. (Rooted cuttings and tissue culture plants are an option) |
| **Grandis X robusta** | | | | | | |
| Florida selections | Yes | Provisionally | No | Apparent hybrid vigor and better coppicing ability than pure grandis | Probably similar to grandis and robusta | None. (Propagate with rooted cuttings or tissue culture plants) |
| **Macarthurii** | | | | | | |
| Many | No | Yes | Yes | Very freeze resistant; preferred sites not defined | Fair form; pulp quality unknown | None. (Propagation by rooted cuttings or tissue culture plants might be possible) |
| **Nova-anglica** | | | | | | |
| Many | No | Yes | Yes | Very freeze resistant; preferred sites not defined | Fair form; pulping properties similar to native hardwoods (Hunt and Zobel 1978) | None. (Propagation by rooted cuttings or tissue culture plants might be possible) |
| **Robusta** | | | | | | |
| Many | Yes | Provisionally | No | Grows as well as grandis on wetter soils of palmetto prairie and flatwoods; probably more freeze resilient than grandis; coppices more reliable than grandis, especially in summer | Good form; as good as native hardwood pulp furnish, if not better (Franklin 1977) | Abundant from third-generation of selection. (Rooted cuttings and tissue culture plants are an option) |
| **Rudis** | | | | | | |
| Western Australia | Yes | Probably | No | Vigorous growth on a variety of sites; exceptionally freeze resistant in southern zone | Crooked, limby; pulping not tested | None. (Propagate with rooted cuttings or tissue culture plants) |
| **Saligna X tereticornis** | | | | | | |
| Unknown | Maybe | Provisionally | No | Grows slower than grandis, but is more freeze resilient | Good form; probably good pulp | Tenuous; single tree in Orlando. (Propagate with rooted cuttings or tissue culture plants) |
| **Tereticornis** | | | | | | |
| Unknown | Yes | Yes | No | Good growth rate; plant on excessively drained sites in southern zone, good choice for reclaimed strip mines in central zone; freeze resistance slightly less than that of Spanish camaldulensis; growth rate less than that of Spanish camaldulensis on better drained soils, but might be the better grower on poorer drained soils | Good form; good only for NSSC pulp (Franklin 1977); densest wood of selected eucalypts | More abundant than camaldulensis, but supplies sporadic; two first-generation seed orchards--St. Leo and Fort Meade; the latter is the more freeze-hardy strain. (Rooted cuttings and tissue culture plants are an option) |
| **Viminalis** | | | | | | |
| Many | No | Yes | Yes | Best prospect for northern zone; freeze resistant; sites not defined | Fair form; pulping properties similar to native hardwoods (Hunt and Zobel 1978) | None. (Propagation by rooted cuttings or tissue culture plants might be possible) |

X grandis and grandis X robusta hybrids are desirable, but $F_1$ hybrid seeds cannot be mass produced. Camaldulensis planting is restricted to a strain that originated from seed collected in Spain, because this strain has superior form.

Sites suitable and available for planting in the southern zone are sandy soils of the palmetto or dry prairie, pine flatwoods, pine-oak forest, and scrub ridges (Davis 1943). The palmetto prairie and the pine flatwoods are similar in soils and vegetation with the exception that the prairies have always been treeless. Pine flatwoods are either forested now or cutover. Many sites of the types described have been farmed temporarily and are known as old fields.

*A palmetto prairie, a preferred land type for planting eucalypts in the Southern planting zone.*

Prairie and flatwoods soils that are suitable for planting range from poorly drained, and occasionally flooded, to moderately well drained ridges. Interspersed are areas of wet prairie (Davis 1943) unsuitable for planting. On raw land, saw-palmetto, *Serenoa repens* (Bartr.) Small, is a helpful indicator of natural drainage suitable for eucalypts. The lack of saw-palmetto indicates the site is too wet. Some flatwoods have thin soils over calcareous materials--often marl or limerock. Very little research has been done on these sweet flatwoods soils, but growth of the few eucalyptus plantings has been poor. There are no recommended species or establishment techniques for sweet flatwoods.

On the palmetto prairie and acid flatwoods, recommended species are grandis on all except the wettest soils and ridges, robusta on the wetter soils, and camaldulensis and tereticornis on the ridges. Camaldulensis and tereticornis are also recommended for the major ridges such as the Highlands Ridge (Davis 1943). Subsided muck soils (Snyder and others 1978) can be planted with either grandis or robusta, which grow outstandingly on these soils, but intensive agriculture currently occupies almost all drained mucklands.

*Central Zone*

Camaldulensis, macarthurii, nova-anglica, tereticornis, viminalis, and a saligna X tereticornis hybrid have sufficient resistance to freezes for the central zone (table 1). However, lack of genetically improved seeds and insufficient knowledge of site requirements and establishment techniques restrict planting to small trials. Camaldulensis and tereticornis appear to be the best species for reclaimed phosphate strip mines, which are a common landtype in the central zone, but success is difficult to predict because of the variability of reclaimed soils.

Grandis and robusta planted in the central zone often are frozen to the ground in the first winter after planting, but most individuals coppice the following spring and the vigorous coppice growth frequently survives freezes in subsequent winters, even though there is often substantial crown damage. These trees have produced more wood than slower growing, more freeze-resistant species. Flatwoods are best suited for grandis and robusta in the central zone, and planting of these species should be continued in small areas for selection of outstanding individuals. Kirtoniana and a robusta x rudis hybrid show potential for the central zone, but little research has been done on them.

*Northern Zone*

Macarthurii, nova-anglica, and viminalis show exceptional promise in the northern zone (Hunt and Zobel 1978; table 1). A lack of genetically improved seeds precludes commercial planting at this time. Dalrympleana and rubida also might be selectively bred into suitable species for planting. Camphora, cinerea, and neglecta are exceptionally freeze resistant in the northern zone, but their growth rate and form are too poor for consideration as plantation species.

*Edaphic and Silvicultural Effects*

Soil type has a pronounced effect on eucalyptus growth, and the effect varies with species. Even on the very flat land of southern Florida, there is substantial variation in soil type over short distances. The result is "microsite" variation in tree growth within plantations. For example, in one 67-ha (168 acres) plantation on palmetto prairie in Glades County, 50 percent of the area contains 73 percent of the volume. In this plantation, at least four different soils occur, and these form a continuum in characteristics from Ona fine sand, which has the poorest internal drainage and the highest summer water table, to Immokalee fine sand, which has the best internal drainage and the lowest summer water table. Grandis and robusta alternate in strips six beds wide over the plantation. Grandis has grown best in the drier areas of the plantation (fig. 2). Robusta growth was affected less than grandis by soil type, but it has grown much slower than grandis on the drier soils. These relationships of grandis and robusta to soil type and drainage status have been observed in other plantations. Therefore, soil mapping can be beneficial in selecting areas and species to plant, although not all poor microsites can be excluded from a plantation because of their scattered occurrence and small size.

Drainage characteristics also are important in matching species and sites in central Florida, but indicators are not as well known as in southern Florida. The growth of Spanish camaldulensis and tereticornis from the St. Leo seed orchard in Florida was measured on a bedded flatwoods in central Florida that ran from a pond edge to a ridge top (fig. 3). The trees grew faster ini-

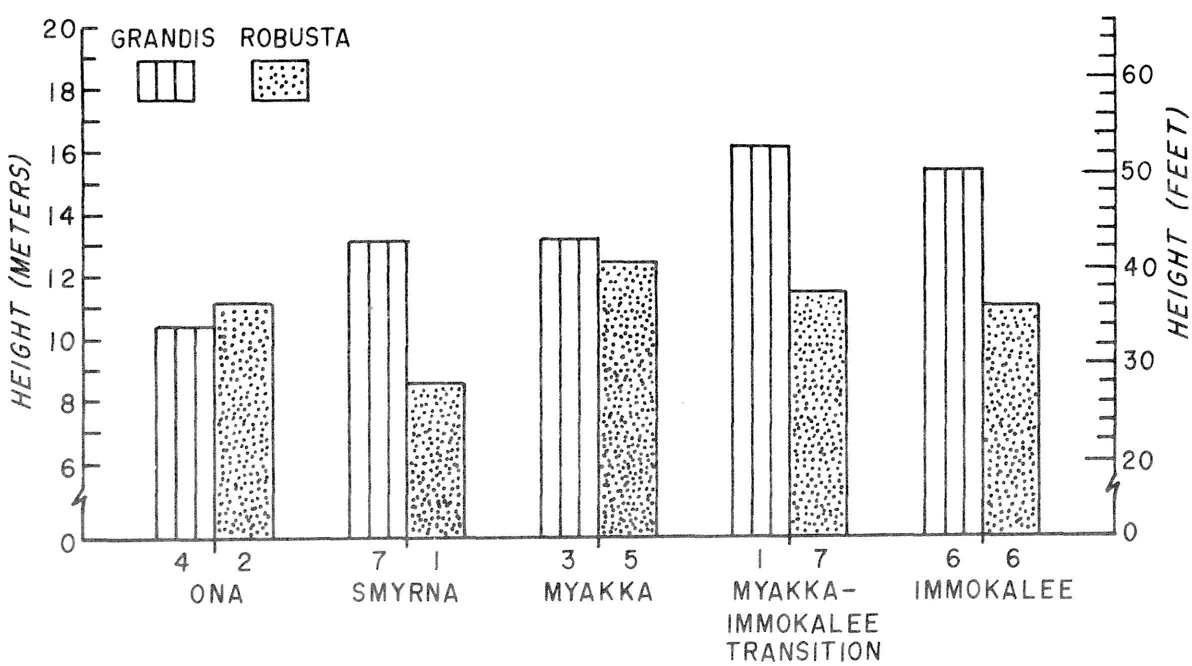



*Figure 2.—Height of 4.5-year-old grandis and robusta on different soil series of palmetto prairie in Glades County, Florida. The number at the base of each bar denotes the number of plots representing each species on each soil series. All the soils are poorly drained, sandy, siliceous, hyperthermic representatives of the Great Group of Haplaquods. Soils are arranged according to depth to a spodic horizon: Ona, less than 25 cm; Smyrna, 25 to 50 cm; Myakka, 50 to 75 cm; and Immokalee, 75 to 125 cm—this gradient also corresponds to drainage, with Ona most poorly drained and Immokalee least poorly drained. (S. McCollum of the USDA Soil Conservation Service described and mapped the soils.)*

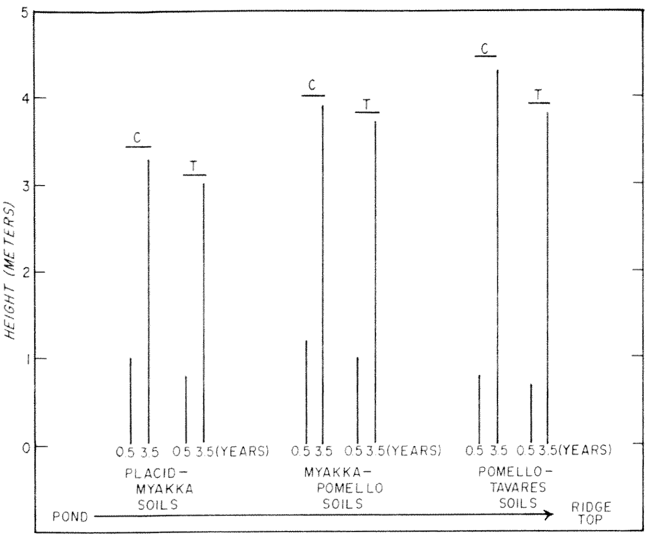



*Figure 3.—Growth of Spanish camaldulensis (C) and St. Leo tereticornis (T) on a bedded flatwoods in central Florida with a soil gradient from very wet to very dry.*

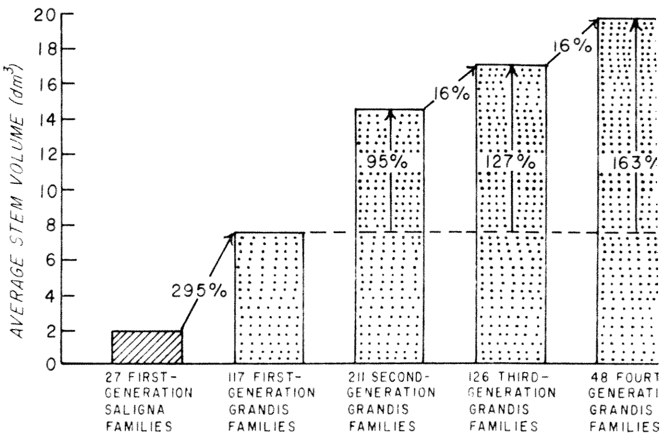



*Figure 4.—Improving growth of grandis by successive generations of selection.*

tially in the intermediate area of the plantation, probably because the beds on the ridge were too dry (but bedding was needed to control vegetative competition). Later, growth became faster on the drier areas.

In recent years lowered water tables due to extensive drainage and aquifer pumping have obscured the relationships of growth to soil series in some areas. In other areas, weirs installed on drainways keep water tables artificially high during the dry season. Therefore, soil series, while important in species and site selection, can at times be a poor guide without additional information on present drainage conditions.

Introducing species from Australian climates matched to Florida's climate has been successful (i.e., grandis and robusta) but not conclusive. A common generalization holds that species native to areas of Australia with dry summers and wet winters (Mediterranean climate) adapt poorly when introduced to areas with wet summers and dry winters, like southern Florida. Generally the rule has held, with dozens of Australian winter rainfall species failing in southern Florida trials. But there are notable exceptions; sources of camaldulensis and rudis introduced from the Mediterranean climate of Western Australia display broad adaptability in southern Florida, as have sources of these species from trees growing as exotics in the Mediterranean Basin (Israel, Spain, Morocco).

Species respond to site treatments differently. On sites fertilized with GRP, grandis responded with added growth, but camaldulensis and tereticornis became stunted and the leaders died back. But without GRP, camaldulensis often grew as fast as grandis, if not faster.

## Plant Locally Improved Stock

When someone reads about the amazing productivity of some species or strain of eucalyptus in some other part of the world, the tendency is to want to plant the same material in Florida to get the same yields. That approach is a mistake. Eucalyptus plantations established from imported seeds have been unsatisfactory for industrial wood production in Florida, because most of the introduced individuals were poorly adapted to Florida conditions. But selection and breeding of the best individuals in these plantings has resulted in locally adapted strains and large gains in productivity (fig. 4). Therefore, plantations should be established only with improved strains selected in Florida.

Orchards for the production of genetically improved seeds are established on private land. The FDF maintains these orchards and collects the seeds. The seed orchards are the final product of the Forest Service's long-term breeding program that will be described later in this paper. The NCSU Hardwood Cooperative has a similar program for developing eucalyptus strains suitable for the northern zone and the coastal plain of other Southern States.

*Selection for Freeze Resistance*

Eucalypts do not have annual resting buds. Instead they have indeterminate shoots that grow continuously as long as conditions are favorable; there is no requirement for rest or overwintering (FAO of the UN 1981; Hillis and Brown 1978). In southern Florida, eucalypts grow through the winter except for periods of extraordinary cold or drought. Continuous growth maximizes wood production, but it also maximizes freeze hazard.

Freeze resistance is a critical selection factor in Florida. The need for freeze resistance increases from south to north and inland from either coast. Testing is chancy because of year-to-year variation in the type, timing, and intensity of freezes. The larger a tree is at the time of a freeze, the greater its resistance.

Assessments of eucalyptus freeze resistance in other parts of the world often are not fully predictive of results in Florida. In their native Australia and in some other countries where eucalypts grow as exotics, cool weather precedes freezes and hardens the trees. In Florida, swift-moving cold fronts turn balmy afternoons into freezing mornings overnight, severely challenging the tender, growing eucalypts.

Two types of freezes occur in peninsular Florida--radiation freezes and blowing colds (Johnson 1970). Radiation freezes are most common, with a layer of freezing air extending from ground level to a height of only a few centimeters or meters. Tree crowns and stems may or may not be damaged, depending on their height and bark thickness. Blowing colds are less common but more destructive, with freezing air churning through the crowns of even the tallest trees.

In general, fast-growing eucalyptus species are less freeze resistant than slower growing species. Growers and tree breeders must decide how much freeze damage to risk in striving for high yield.

*Resistant Individuals*

Some trees of a species are more freeze resistant than others, and these make valuable breeding parents for improving tolerance to freezes. We select for two types of tolerance--freeze resistance and freeze resilience.

*Freeze-resilient eucalypts which froze to the ground in their first winter and withstood subsequent freezes. On most stools, several coppice shoots self-thinned to a single main stem, but some original competing shoots can still be seen.*

The crowns of resistant selections are lightly damaged, if at all, by severe freezes. Other selections are only freeze resilient. Their stems may be killed to the ground by a hard freeze in their first winter, but they resprout swiftly and gracefully. In subsequent winters they suffer only superficial damage. Individuals neither resistant nor resilient simply die or freeze to the ground and resprout year after year.

In practical terms, a plantation of fully freeze-resilient trees may lose 6 months of growth to a severe freeze, but it is not destroyed. In central Florida, moderately freeze-resilient selections from species like grandis and robusta that are on average freeze-susceptible in the central zone, often produce more wood than selections from slower growing, freeze-resistant species, even after subtracting freeze losses. Almost all select trees have been picked within the past 9 years, and all have been subjected to severe freezes. They may not have been tested as yet, however, by the strongest freeze that might occur.

## The Breeding Strategy

Large variations among trees in resistance to freezing and in other characteristics make eucalypts good candidates for genetic improvement. It should be recognized, however, that the selection and breeding process is complex. Many species have a wide ecological and geographical range, and seed sources from throughout the range should be tested before rejecting a species as unsuitable. Eucalypts hybridize readily under some conditions. The hybrids complicate determination of the quality of the affected species, for first cross ($F_1$) hybrids often show hybrid vigor, whereas trees grown from seeds collected from hybrids are often inferior.

Since commerical planting began in Florida in 1972, seedlings supplied by the FDF nursery for each planting season have been the best genetic stock available from an ongoing tree improvement program of the Forest Service. The breeding system uses recurrent selection to derive seedling seed orchards from successive generations of open-pollinated families (Franklin and Meskimen 1975). Eucalypts are basically insect pollinated (Pryor 1976), and beehives are stationed in the orchards during flowering season. Commercial seed is harvested from the orchard's best mother trees as identified by progeny testing. All seed is stored separately by mother trees, so in any crop year the latest progeny test results are used to select seed from the best mother trees for the current season's nursery crop.

Breeding populations presently involve four species: grandis, robusta, camaldulensis, and tereticornis. Grandis breeding is most advanced and best illustrates the system.

### *Grandis Breeding Population*

Grandis planted in Florida constitutes a landrace developed through three generations of selection and progeny testing in the local environment. The fourth-generation breeding population is ready for conversion to a seedling seed orchard. The breeding system has combined species trials, provenance testing, and progeny testing in the same plantings (see fig. 4--saligna included in a third-generation breeding population of grandis). Species trials are phased out during roguing to a seedling seed orchard. The best species is retained in the seedling seed orchard, while the other species are eliminated.

As many grandis seedlots as possible have been imported. Ideally, seedlots represented select single trees in Australia, but some bulk lots have been included along with many lots from exotic populations outside Australia. Each seedlot (called a family) contributes about 60 seedlings to a large outplanting called the genetic base population. All individuals of all families are completely randomized in single-tree plots.

Stocking is 1,916 trees per ha (775 trees/acre) in a precise row X column grid, mapped to preserve the location and pedigree of each tree. Planting beds are paired, with 2.3-m (7.5 ft) spacing within a pair and 3.5-m (11.5

t) spacing between pairs, and seedlings lanted 1.8 m (6 ft) apart along the eds. The 3.5-m (11.5 ft) spacing be-ween pairs allows access to any tree by ork vehicles, particularly bucket rucks for seed collection. The two loser spacings promote dense stocking n the base population, which later ranslates to a reasonable stocking of eed trees and pollinators in the eedling seed orchard.

Each tree in the base population is easured for growth rate and scored for reeze resistance, stem straightness, ranch habit, and general adaptation. At age 2.7 years (one-third of planned rotation age for plantations), the best phenotypes are selected and the rest are rogued in the first stage of converting the base population to a seedling seed orchard. The best families usually contribute three or four selects to the seedling seed orchard, and the maximum number allowed for one family is based on a sliding scale derived from its relatedness to other families. Most families contribute only one or two selects, and about a third of the families drop out of the breeding population for lack of any worthy candidates.

Select trees exchange pollen in the first massive bloom at age 3+ years, and the following spring the seeds are collected and used to establish the next generation's base population, which is also the progeny test of the seedling seed orchard. Thus, a generation is turned in 4 years. Progeny test results identify the best commercial seed trees as well as poor seed trees to be rogued from the orchard.

Each generation of selection enhances the landrace's adaptation to local conditions (fig. 4), but new families must be imported to broaden the genetic base and guard against inbreeding depression. The current genetic base population (fourth-generation seed orchard) consists of 31,725 trees representing 529 families on 17.3 ha (43 acres). Nine percent of the families are fourth generation (great grandmothers selected for excellence in a Florida plantation); 24 percent, third generation (grandmothers selected in Florida); 40 percent, second generation (mothers selected in Florida); and 27 percent, first generation (newly imported families).

The Florida landrace is predominantly grandis, but a few seed orchard trees and scattered offspring display traits from robusta, tereticornis, camaldulensis, and saligna. Some of the interbreeding originated in early species trials in Florida, but hybridity also occurs occasionally in seedlots from natural stands in Australia.

Three generations of selection have enhanced freeze resistance and dramatically increased growth capacity (fig. 4). The select trees demonstrate superior adaptation to Florida and can transmit that adaptability to their progeny. However, predicting gains in commercial wood production should be verified in yield plots rather than inferred from the genetic base population. This is because a base population is a competition matrix of elite, average, and poor families; whereas commercial plantations include only elite families--a much more competitive population. A grandis yield experiment compares the following three populations:

*Premier*--Six advanced-generation families (average 3.5 generations of selection) that are top ranked for the combined traits of volume production, freeze resistance, form, and coppicing.

*Commercial*--The 33 advanced-generation families (average 2.9 generations) included in the seed mix for the 1979 commercial planting season.

*Ancestral*--Four imported seedlots from which all six premier families descend and 21 of the 33 commercial families.

At age 1.5 years, heights of premier and commercial trees exceeded those of ancestral trees by 23 and 13 percent, respectively. During the second winter of the study, damage from a severe freeze was scored on a scale of 10 = undamaged, 9 down through 5 = increasing degrees of foliar damage, 4 down through 1 = increasing degrees of wood damage, 0 = frozen to ground but sprouting, and -1 = frozen dead. The three populations differed significantly in their mean freeze damage scores: premier, 6.8; commercial, 4.8; and ancestral, 2.0.

### *Breeding Populations of Other Species*

Robusta breeding is not as advanced as grandis. The progeny of trees selected in Florida, however, grew 68 percent faster in volume than the original, imported seedlots (Franklin and Meskimen 1973). Robusta stock for commerical planting comes from a second-generation, progeny-tested seed orchard and from a third-generation orchard of phenotypic selects that have not been progeny tested. The third generation robusta seed orchard is interplanted with grandis to generate $F_1$ hybrids, which appear to be more productive in Florida than either pure species.

Progeny tested, first-generation seed orchards exist for Spanish camaldulensis and two strains of tereticornis. Second-generation offspring for these two species have been mixed in a combined base population along with several rudis families. This combined base population is not yet selected and rogued.

*Eucalyptus capsules, seeds, and chaff.*

## Seed Collection and Handling

### *Seed Collection*

The time of seed maturation in Florida varies by species and year. Samples of seed capsules should be cut and examined before any large-scale collection. Immature seeds are white, mucilaginous, and stuck together. Mature seeds are firm, free, and dark brown to black, except for camaldulensis seeds, which are yellowish brown.

Grandis seeds have been collected as early as mid-February to meet a March 15 nursery sowing deadline, but the seed crop is not completely mature before March 15. Robusta seeds do not mature before April 15. Since the seeds of these two species remain on the tree for a full year, seed crops from 2 years can be obtained by collecting every other year.

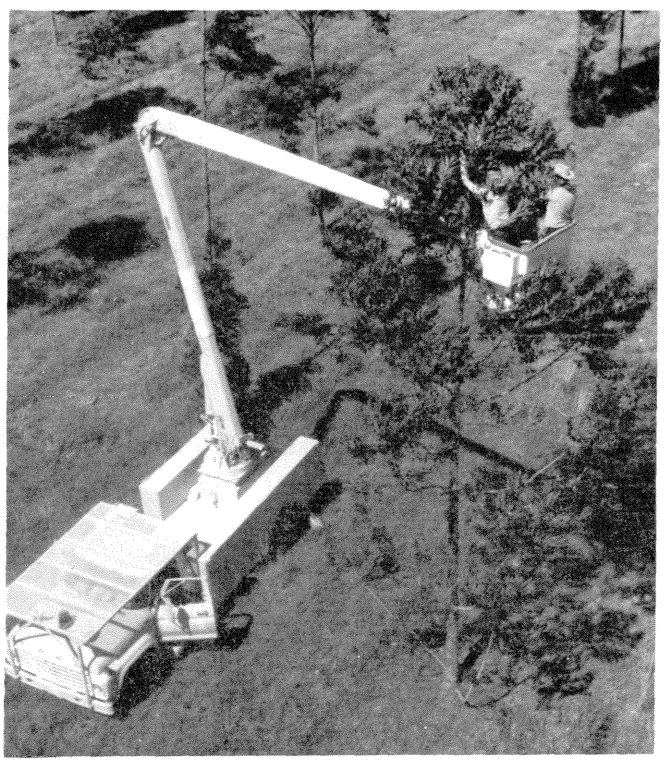
The collection window for camaldulensis and tereticornis is narrow because their seed capsules open a short time after the seeds mature. Collection cannot begin before late May and must be completed by mid-June. Each seed orchard of these species has its own distinct collection time, and the orchards must be watched closely to avoid loss of seeds. Viminalis and other freeze-resistant eucalypts have not flowered abundantly in Florida, so their seed collection dates are unknown.

Operational quantities of grandis seeds can be harvested from an orchard at age 3.7 years, and production increases through about age 10. (Trees are topped to keep them in range of bucket trucks, so eventually crown size stabilizes.) Large crops are produced every year, but individual trees vary greatly in the quantity, purity, and viability of seeds. In 1980, 38 grandis trees were selected for commercial seed collection from a 7-year-old orchard of 285 trees. The mean, coefficient of variation (CV), and range in seed production were:

| | Mean | CV(%) | Range |
|---|---|---|---|
| Volume of raw seed (l) | 1.70 | 81 | 0.02-5.99 |
| Weight of raw seed (kg) | 0.99 | 79 | 0.01-3.28 |
| Healthy germinations per g of raw seed | 688 | 57 | 140-1,591 |
| Healthy germinations per tree | 694,000 | 86 | 23,000-2,518,000 |

Robusta seed crops vary widely. In some years, much chaff but few seeds are produced. The seed crop of Spanish camaldulensis is generally sparse, because a twig dieback during winter and spring causes loss of capsules. Seed crops of other camaldulensis strains and tereticornis have been abundant, but many seeds have been lost in central Florida due to freezing of the flowers and immature capsules.

Seed capsules are collected from tree crowns by workers raised by bucket trucks whenever possible. Genetic collections are sometimes made by clipping branches of small trees with pole pruners, or by shooting branches from tall trees with a .222 caliber rifle with 9 X scope and soft point bullets.



Collecting seeds in an 8-year-old grandis seed orchard. The trees have been topped to keep the crowns within the range of the bucket truck.

In Florida seed orchards, seed capsules are shucked into the bucket of the bucket truck. The bucket, if of open design, is lined to retain the capsules. Shucking is done by running a gloved hand down the branch, while the other hand holds tension on the branch tip. Trees are topped lightly after they grow too tall to be reached with a bucket truck, and fallen tops are shucked on the ground. Epicormic branches form new seed-bearing crowns on topped trees.

Collection methods tried but rejecte include felling the seed trees, severing seed-bearing twigs, and shucking the capsules from the crown for collection on ground cloths. Felled trees, if they coppice, take at least 2 years to resume flowering and at least 5 years to rebuil full seed-bearing crowns. Similarly, twig pruning drastically reduces the next bloom crop. Capsules shucked to the ground are often lost because those with leaves attached often sail beyond the dropcloth.

Seed capsules are bagged at the tree as collected because they can open rapidly on hot, dry days. In Florida, large collections are put in mattress covers, and small collections in kraft paper bags. The baggers try to remove free leaves and twigs as they bag. Capsules from each tree are bagged separately, and the bags are labeled and protected from rain.

*Seed Extraction*

Capsules are delivered to the extractory within a day of collection tc prevent heating and molding in the tightly packed collection bags. At the extractory, capsules are transferred to many loosely packed kraft paper bags or mattress covers for drying. Capsules mixed with leaves and twigs can be spread to a depth of 15 cm (6 in) in the drying bags, but clean capsules, which pack tightly, should not be more than 1( cm (4 in) deep to promote drying and to dissipate heat.

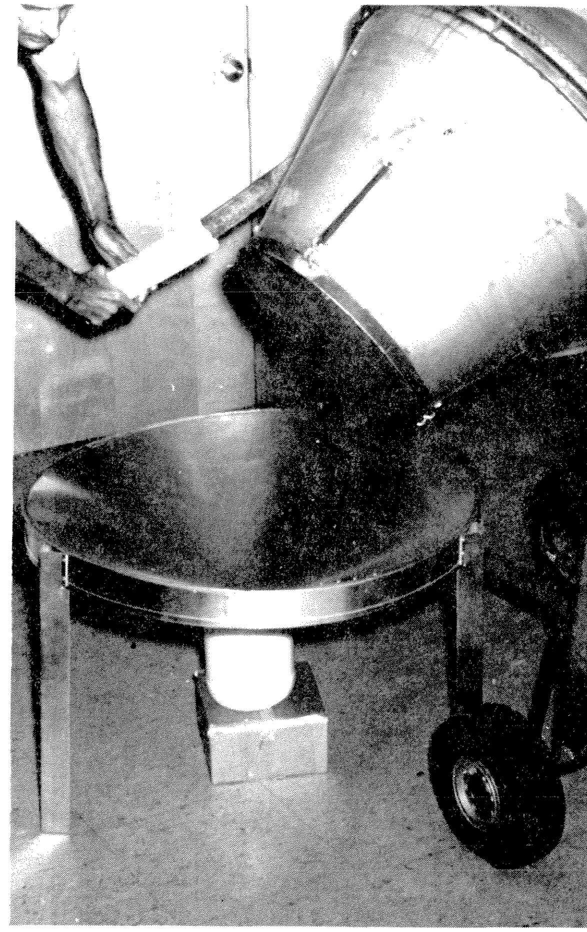
*Drying seed capsules in mattress covers.*

Mattress covers are placed lengthwise on decked racks of wire mesh. Kraft bags rest open-topped on wire shelves lined with paper to prevent seeds of one mother tree from sifting into a lower bag of another mother tree. The kraft bags are cut to a height of 20 cm (8 in) to allow closer spacing of the shelves.

The valves of mature capsules open through dessication. The extractory should simulate hot, dry, windy days in the forest--heating from 30° to 35° C, dehumidification, and air circulation to drive moisture-laden air from around the capsules. Capsules open in 1 to 2 weeks, depending on their maturity. Drying outside is not dependable in Florida, but efficient solar dryers could undoubtedly be developed.

Shaking extracts the seeds from the opened capsules. Capsules of small seedlots are put in a stovepipe-like cylinder that fits snugly inside a No. 16 U.S. Standard sieve. A pan is put on the bottom of the sieve and a lid on the top of the cylinder, and the unit is shaken. Seeds, chaff, and some small trash pass through the sieve, but most trash is trapped.

Large seedlots are dumped from the drying bags into a cement mixer which is capped with a frame of hardware cloth. The mixer tumbles the capsules for about 10 minutes; then seeds, chaff, and fine trash are poured through the hardware-cloth cap into a large funnel over a collection bucket. With the cap



*Extracting seeds and chaff from capsules.*

removed, the mixer is emptied of leave twigs, and spent capsules, then vacuur cleaned before receiving capsules fror different seedlot.

The extracted seeds and chaff are sieved through a No. 16 U.S. Standard sieve and the quantity passing througt the sieve becomes the recorded weight and volume of the raw seedlot. A larg opening sieve might have to be used fc standardizing yields of viminalis and some other species that have larger seeds than the established species.

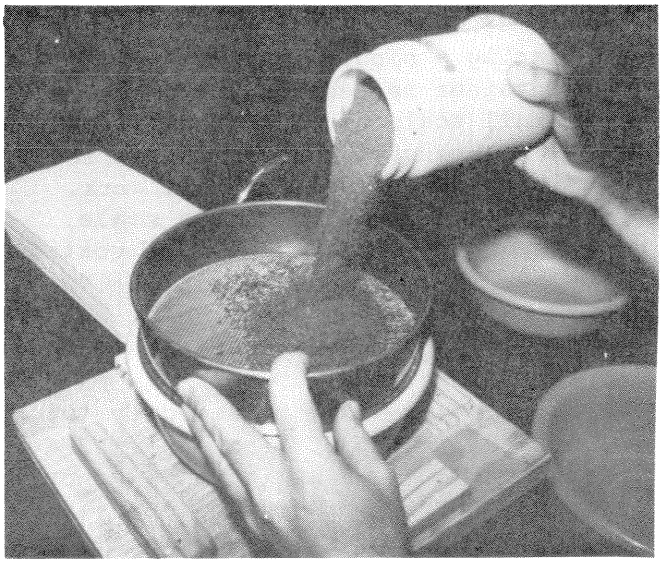
### *Seed Cleaning*

Raw seed is a mixture of fertile seeds in a much greater mass of chaff, which consists of sterile and unfertilized ovules (Boland and others 1980 plus tiny particles of capsules and leaves. Seed purity is usually less than 10 percent, and often as low as 1 or 2 percent. The tiny seeds must be separated from chaff and other impurities before seeds can be sowed singly in each nursery container.

Some seeds are larger and heavier than any chaff and, therefore, are separated readily; some other seeds and chaff differ either in size or weight and can also be separated; but some seeds and chaff are equal in both size and weight and cannot be separated. Therefore, a goal of 100 percent seed purity is unrealistic, and losses of some seeds with the chaff must be anticipated.

Seeds from different trees are cleaned separately because the size of seeds and chaff vary from tree to tree. Combining raw seeds from different trees can create a matrix of overlapping sizes of seeds and chaff that defy separation.

Raw seeds are sieved into size classes, which are processed separately



*Sieving raw seed on a vibration table to produce partially cleaned seeds for later blowing.*

in a batch-type seed blower, because the force of air needed to remove light chaff differs by size class. Sizing reduces the amount of seed blown away with the chaff. For lots larger than 4 l (1 gal), cleaning is made easier if the lightest chaff is removed with a continuous-type seed blower before sieving. Blowing before sieving releases much dust in the air. A quick sieving on a fine sieve reduces this problem. Sieves are agitated by a vibrating table to hasten sieving. Shaking sieves is not as effective as vibration.

U.S. Standard soil sieves 18, 20, 25, and 30 have the greatest utility fo grandis, robusta, camaldulensis, and tereticornis. Seeds that pass through No. 30 sieve usually are difficult to separate from chaff. Sieve No. 18 primarily catches large trash, although seeds are sometimes caught. Sieve Nos. 14 and 16 are needed for cleaning lots of larger seed species, such as viminalis.

Cleaning eliminates the smallest an lightest seeds, but cleaned seeds collected from Florida seed orchards still vary greatly in size and weight, both within and between seedlots. Cleaned grandis lots contain from 2,000 to 6,500 seeds per g. Tereticornis seeds weigh the same as grandis seeds, camaldulensis seeds are somewhat heavier, and robusta seeds are distinctly heavier. Imported viminalis seeds are much bigger and heavier than even robusta seeds.

### *Testing Seed Viability and Purity*

At the Forest Service laboratory, seeds are germinated on standard 100-indentation, blue germination blotters in closed plastic boxes, lined on the bottom with tissue paper for extra water storage. Known weights of uncleaned seeds are sprinkled on the surface of the blotters, and results ar expressed as number of germinations per gram of seeds. In tests of cleaned seeds, one particle (either seed, chaff or trash) is placed in each blotter indentation, after the 100 particles ar weighed. Therefore, the germination test is also a purity analysis. Germination will occur in a room open to daylight, but to standardize results, germination is routinely tested in a chamber maintained at 25° C and lightec for 8 hours each day. Germination of all species used in Florida has been rapid under these conditions.

### *Storage*

Eucalyptus seeds have retained viability during long periods of storag under a variety of conditions at the Forest Service laboratory. Seeds stored at room temperature for 2 years have not noticeably lost viability. Seeds refrigerated for 8 years, then frozen 11 more years, remained viable, although losses in germination percentage and in vigor of germination were suspected.

Eucalyptus seeds remain viable despite wide fluctuations in storage temperatures. Seeds stored at 7° C have retained viability after several periods at 32° C when the refrigerator malfunctioned. Seeds repeatedly frozen and thawed from movement in and out of a freezer have not shown any noticeable loss in viability.

Humidity and seed moisture content influence seed deterioration. Jones (1967) recommended a moisture content of 2.5 percent or less for storage of eucalyptus seeds of some species. In Florida, however, seed moisture content is not reduced beyond that obtained during extraction, and the storage moisture content is not known.

Eucalyptus seeds are stored in a variety of containers. Screw-capped containers, such as plastic milk jugs, are used for storing uncleaned lots. Seeds destined for long-term storage are cleaned to reduce volume, then sealed in plastic packets which store more compactly than bottles.

Large lots of uncleaned seeds are stored at 7° C. Clean seeds, genetic samples, and other research lots are freeze-stored at -18° C. However, freeze storage has not been shown to have any advantage over cold storage for preserving viability. Experiences with seed storage in Florida are similar to those in Australia (Boland and others 1980).

### *Stratification*

Seeds from Florida trees do not need stratification for good germination. Freshly collected seeds and those stored for long periods germinate with similar vigor. The advice of the supplier should be sought in deciding whether to stratify imported seeds.

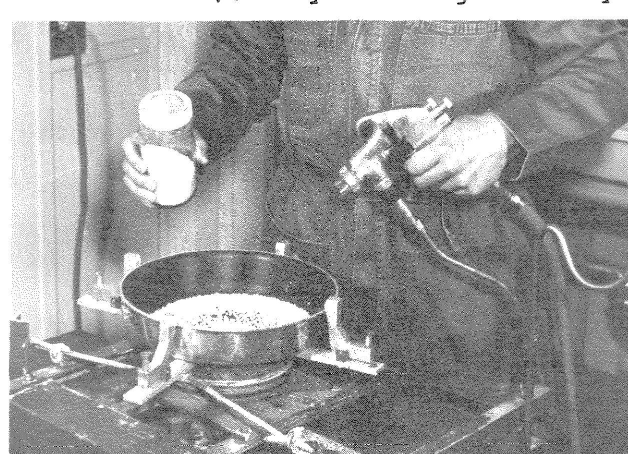
### *Seed Mixtures for Commercial Planting*

Nursery seedlings for commercial eucalyptus plantations in Florida are raised from a mixture of seeds from ma selected trees. The number of parents is not fixed, but to maintain genetic diversity in the plantations, a good rule is to obtain no more than 8 perce of the seeds in a mixture from any one parent. An effort is made to have the same number of viable seeds of each ch sen seedlot in the sowing mixture. Du to shortages, these rules have been br ken for some species in some years in Florida. The number of viable seeds p gram of cleaned seeds is known; therefore, seed mixtures are prepared by weighing out the calculated quantity o each seedlot.

### *Pelleting*

Placing a single seed in each nurs ery container is tedious but possible on a small scale, such as for a researc study. Dispensers that sow a few seeds by tapping are useful for this work. For single seeding on a large scale, however, the tiny seeds must be coated to form pellets of convenient, uniform size. Pellets permit the use of mechan ical sowers and greatly facilitate hand sowing.

Florida seeds are pelleted by the FDF with a coating of fine sand and a water-soluble polyvinyl alcohol binder in a custom-built apparatus (Geary and Millier 1982). A yellow vegetable dye



*Pelleting seeds with fine sand and a polyvinyl alcohol in a reciprocating-rotating pan.*

is added to the sticker solution to make pellets more visible. These pelleted seeds germinate as well as bare seeds in the nursery. Some other pellet coatings decrease germination.

## Seedling Production

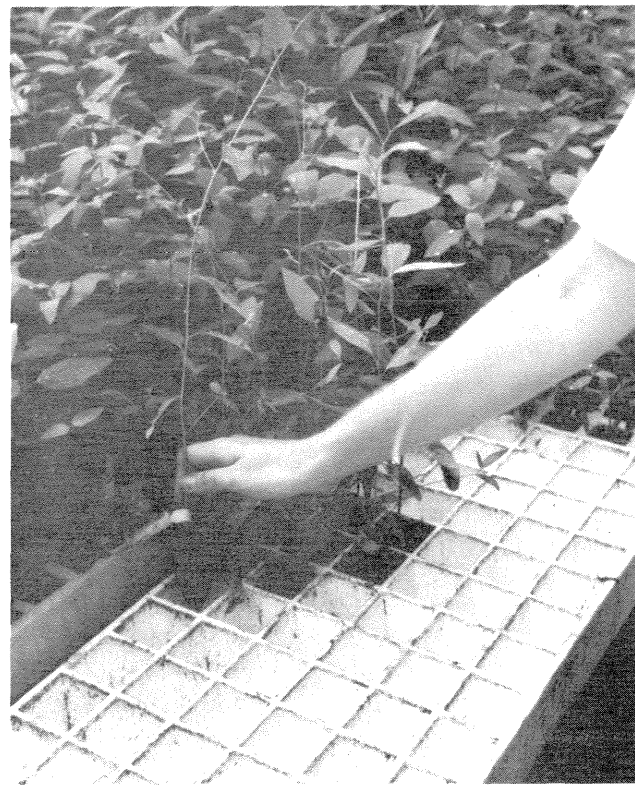
### *Containers*

As in most of the world, eucalyptus planting stock in Florida is grown in containers. Florida containers range in volume from 47 to 78 $cm^3$ (2.8 to 4.8 $in^3$), which is small by world standards.

Containerization developed because survival of bare-root seedlings was inconsistent in Florida. In one study, 99 percent of seedlings grown in 1-l (1 qt) containers survived summer planting, while only 71 percent of the bare-root seedlings survived. The growth rate of bare-root seedlings initially lagged behind that of container-grown seedlings. Although growth rates were equal by the fifth month after planting, the container-grown seedlings were still taller, and height is a critical factor in surviving freezes and capturing sites from competing vegetation.

Since it is too expensive to grow and plant seedlings in containers as large as 1 l (1 qt), container size was reduced. Survival of bare-root seedlings has not been compared to that of seedlings in the containers currently in use. Improvements elsewhere in managing bare-root eucalyptus seedlings with improved root-pruning equipment suggest that research on bare-root eucalypts in Florida be reactivated. The lower costs associated with production and planting bare-root stock are always appealing. An experiment in Georgia with bare-root eucalyptus seedlings demonstrated that planting bare-root seedlings is promising (Hunt 1980).

Containers used in Florida are designed to prevent root spiraling, and they are suspended to air-prune seedling roots. For its eucalyptus research the Forest Service uses styrofoam Todd Planter[1] blocks almost exclusively



*Eucalyptus seedling and its root plug pulled from a Todd Planter*

because of the ease of fertilizing, watering, and pulling seedlings at packing time; the ease of planting; and the reliable field survival. The block is a 34.5 by 66.5-cm (13.6 by 26.2 in) rectangle that contains 72 cavities, each shaped as a truncated, inverted pyramid. Internal dimensions of a cavity are 5 by 5 cm (2 by 2 in) wide at the top, tapering over a 7.5-cm (3 in) depth to a 0.9- by 0.9-cm (0.35 by 0.35 in) drain hole. Cavity volume is 75 $cm^3$ (4.6 $in^3$), and spacing is 330 cavities per $m^2$ (31/$ft^2$).

Seedlings at the FDF nursery are grown in Leach Cone-tainers (Tinus and McDonald 1979) and LaBelle planter blocks.[2] The Leach Cone-tainer used is a plastic tube that has a volume of 47 $cm^3$ (2.9 $in^3$) and is 12.5 cm (5 in) long, with a 2.5-cm (1 in) top diameter, tapering to a 0.8-cm (0.32 in) bottom diameter drain hole. The inside of the container is ribbed.

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[1] Speedling, Inc., P.O. Box 7098, Sun City, FL 33586

[2] LaBelle Plant World, Inc., P.O. Box 398, LaBelle, FL 33935

The LaBelle styrofoam block is a 42- by 66.5-cm (16.5 by 26.2 in) rectangle; it contains 77 tubular cavities and fits the suspension system developed for the ubiquitous Todd Planter. Each cavity in the LaBelle block is 3.6 cm (1.4 in) in diameter at top, tapering slightly over a 10-cm (4 in) depth, then tapering more sharply in the last 2 cm (0.8 in) to a 1-cm (0.4 in) drain hole. Cavity volume is 78 $cm^3$ (4.75 $in^3$). Each cavity contains 3 ribs to prevent root spiraling, and the cavity spacing is 270 per $m^2$ (25 $ft^2$).

Leach tubes have an advantage of being independently movable. A tube in which germination has failed can be replaced, and spacing of the growing crop can be tailored to the requirements of the species grown. A disadvantage is that it is difficult to get water and nutrients into the tube after the seedling foliage forms an umbrella over the tube opening. This inefficiency in liquid collection occurs because the tubes are held in wire racks, rather than the custom Leach racks, which pack tubes too tightly for growing eucalypts to planting size.

With a block planter, nutrients and water that run off the foliage fall onto the block surface and run into the cavities. The Todd Planter, which has a top surface that is almost all potting mix, is very efficient in collecting applied liquids. The LaBelle block has more styrofoam at the top surface than cavity opening, making it less efficient in liquid collection than the Todd Planter (water can run off the edges of the LaBelle block) but more efficient than Leach tubes in wire racks.

The greater amount of open area of the Leach system permits much better aeration than that with block planters. As a result, killing of seedlings by the fungus, *Cylindrocladium scoparium*, is a greater problem with the LaBelle block than with Leach tubes. However, *Cylindrocladium* disease has not been a problem with the Todd Planter.

*Potting Mix*

Through the years, the Forest Service and the FDF nursery have used a commercially prepared potting mix of peat and vermiculite. A mixture of sand, peat, and vermiculite was tested by the FDF, but sand increased the amount of watering required and did no give a firm root plug. Viminalis is t only species grown with sand at the FD nursery; its growth is improved considerably by adding sand. The FDF nur ery currently uses a commercially prepared mixture of 50 percent peat, 2 percent vermiculite, and 25 percent perlite. The perlite addition is base on proprietary information that perlit increases retention of nutrients. Thi potting mix does not contain starter nutrients, but it does have a wetting agent.

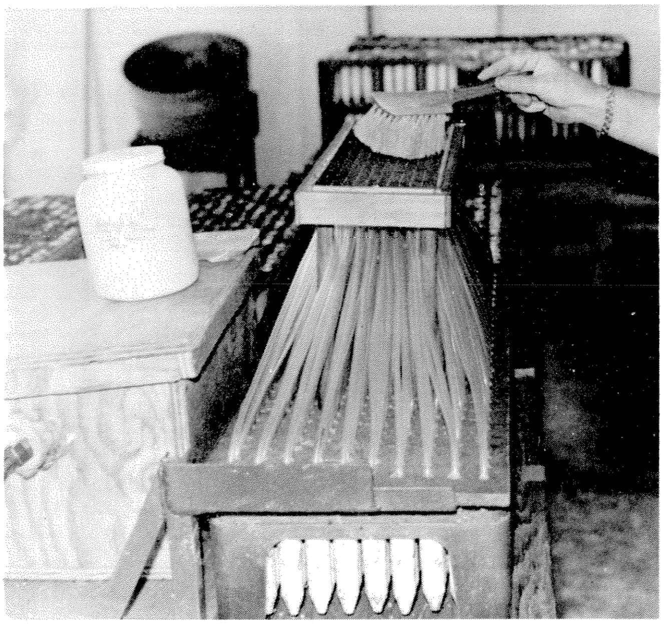
The mixture is packed moist, pressed, topped up and repressed,

*Packing potting mix in Leach Cone-tainers to form depressions for pelleted seeds.*

leaving a depression of about 5 mm (0. in) to hold pelletized seed and mulch. Careful filling and pressing are neede If the sowing depression is too deep, germinated seedling cannot emerge, and if too shallow, the mulch is easily lost.

*Sowing*

Research seedlings are raised from cleaned seeds sowed by hand or with a



*Sowing pelleted seeds into Leach Cone-tainers with a gravity seeder.*

seed dispenser. One to three seeds are sowed in a cavity, depending on study objectives, seed quantity, and expected germination. In commercial operations pelleted seeds are sowed with a gravity seeder or by hand. Vacuum seeders proved unreliable.

Sowing strategy, which varies with the crop, is based on labor availability, quantity of seeds, expected germination, and type of container. Leach tubes may be used efficiently by sowing one pellet in a tube. Then tubes in which germination fails can be removed and resowed. By this method, hand thinning of excess seedlings is avoided. Double sowing is done at times, however, to increase the percentage of tubes with a seedling and to avoid a germination time gap in the crop.

The two alternatives to single seeding directly into containers--transplanting from germination flats to containers, and broadcast sowing the containers with raw seed and then thinning to one seedling per cavity--proved to be too labor intensive for Florida. Broadcast sowing and then thinning also wasted valuable genetically improved seeds.

Block containers usually are sowed with two or three pellets per cavity in order to obtain a high percentage of cavities with a seedling. The exact number to sow is difficult to estimate because germination is always poorer i the nursery than in the laboratory. Oversowing is needed because it is not feasible to resow cavities in a block, if for no other reason than the younge seedlings cannot compete with those first sowed. Occasionally, excess seedlings are transplanted to cavities without a seedling during thinning.

Sowed cavities are mulched with coarse vermiculite to a depth of 5 mm (0.2 in). Fine vermiculite is avoided because it restricts aeration and germination. Chopped pine needles performed well in the past but are now difficult to obtain.

*Water Quality*

The biggest problem with growing eucalyptus seedlings in southern Flori has been water quality. It is difficu to obtain well water with less than 70 p/m total dissolved solids (TDS). If the water has TDS greater than 700 p/m eucalyptus will germinate slowly, then die. Water that is even slightly alkaline or high in lime will also serious retard seedling growth. If water is alkaline, it can be acidified, or acid compounds can be applied periodically the crop, as is done at the FDF nurser at Lake Placid.

*Germination*

Sowed cavities are placed under a plastic or shade cloth shelter to protect them from torrential rain and win not to provide shading to improve germination. Good germination occurs in full sun. The Forest Service germinat and grows seedlings in an unheated, plastic-topped plant house of a design similar to that used by the vegetable industry in southern Florida.

At the FDF nursery, seeds are germinated under 25 percent shade. Leach tubes are closely spaced at germinatic in the custom Leach tray, or in every opening of a palletlike, chicken-wire mesh rack (1.2 by 2.4 m) (4 by 8 ft). Leach trays and LaBelle Blocks are placed on hardware cloth pallets for transporting. Pallets are transported with a pallet grabber designed and built by the FDF; it operates off the power takeoff of a tractor.

Germination can occur in 4 days under favorable conditions, but cool temperatures can result in a month or more passing before seedlings break through the mulch. Watering is done with a trolley boom in the Forest Service plant house and with fixed overhead sprinklers in the FDF shade area.

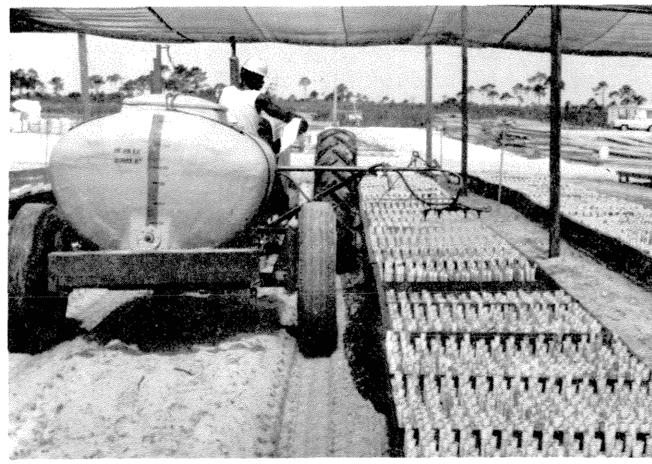
When seedlings are 3 to 5 cm (1.2 to 2 in) tall, they are moved from the shade area to raised racks in an open field at the FDF nursery. Containers with more than one seedling are thinned by pulling or scissoring when they are moved from shade to the open.

*Growing Seedlings to Planting Size*

Seedlings of grandis, robusta, and tereticornis will grow to the desired planting height of 30 cm (12 in) in 12 weeks after sowing under optimum conditions. An average of 16 weeks to planting size from mid-March sowing is normal. Camaldulensis grows more slowly. Production times of other species are not well established.

Density should not exceed 300 seedlings per $m^2$ (28 $ft^2$) for broad-crowned grandis, robusta, and tereticornis seedlings to reach planting size. Narrow-crowned camaldulensis can be grown at somewhat closer spacing. Seedlings grown in Leach tubes are placed in chicken-wire racks at a spacing of 227 per $m^2$ (21 $ft^2$) when they are moved from shade house to open nursery.

A 20-20-20 liquid fertilizer has been applied, beginning as soon as seedlings have emerged from mulch. Fertilizer concentration is 708 p/m N, and is applied at the rates of 0.6 g N per $m^2$ (0.2 oz/100 $ft^2$) to small seedlings and up to 2.8 g N per $m^2$ (1.0 oz/100 $ft^2$) for larger seedlings. To maintain rapid growth, liquid fertilizer must be applied two or three times a week for Leach tubes in chicken-wire racks, because much liquid fertilizer falls to waste. Block planters require much lower fertilization rates.



*Applying liquid fertilizer to eucalypt seedlings in Leach Cone-tainers that are suspended in chicken-wire racks and arranged at growing spacing.*

Since frequent fertilizer application is a nuisance, controlled release fertilizers are now routinely used to supplement liquid feed. Controlled release fertilizer provides steady growth, while supplements of liquid fertilizer speed growth as needed. At the FDF nursery, 4.3 kg of Osmocote 14-14-14 controlled release fertilizer are added per $m^3$ (7.3 lb/$yd^3$) of potting mix.

Watering is critical because seedlings can easily die from desiccation. During hot, dry, windy afternoons of late spring, the seedlings can be lost by failure of one afternoon watering.

*Cylindrocladium* blight at the FDF nursery is controlled by a weekly fungicide treatment developed by FDF personnel. Benomyl and chlorothalonil are sprayed on the seedlings in alternate weeks.

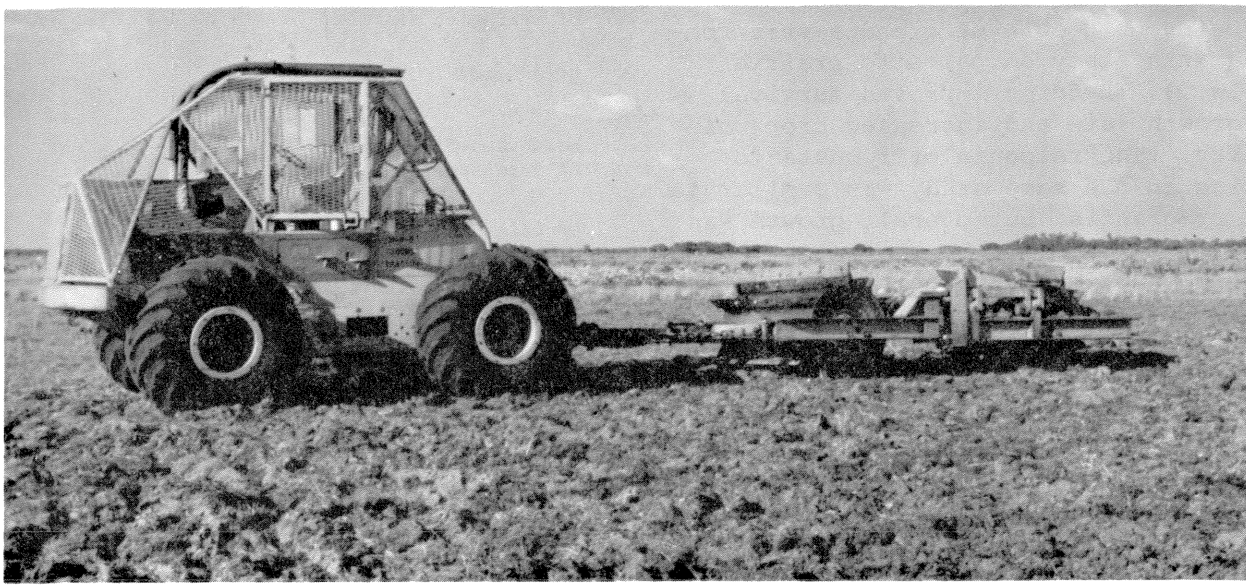
At planting time, seedlings are pulled from containers at the nursery and packed in vented, waxed-cardboard boxes. A seedling's roots and the potting medium form a firm plug that usually remains intact from seedling pulling through planting.

## Site Preparation

Control of competition is important in establishing eucalypts because they need full sunlight for good growth and they compete poorly for water and nutrients against grasses. Eucalypts often survive competition to eventually dominate the site, but growth is slowed and the stand structure of the plantation becomes very irregular. Bedding is often the best approach for controlling competition, particularly on sites where water may stand for extended periods during the rainy season.

*Bedding*

Prior to bedding, the site must be thoroughly cultivated to kill the existing vegetation and to chop roots and other debris into small pieces tha will not impede machine planting of seedlings. Root raking is not



*Preparing a palmetto prairie planting site by chopping.*

recommended; it tends to remove topsoil, of which there is precious little on most plantation sites. The entire plantation area must be cultivated where there is saw-palmetto, because leaving strips of saw-palmetto creates a serious fire hazard.

Broad, high beds made with a forestry bedding harrow and hourglass packer are preferred. Low beds of the type made by the vegetable industry ar not adequate, and beds made with fire plows are too steep and too close together.

*Bedding a flatwoods planting site.*

Bedding improves root aeration and normally gives an unflooded place to plant when water stands on the site at planting time. Although bedding controls competing vegetation for a while, it prevents cultivation after planting. Most planters presently are bedding to prepare sites.

The effects of bedding and flat harrowing on growth of grandis were compared in a study on palmetto prairie (table 2). Bedding improved survival and growth rate and increased crop uniformity. The response of robusta to bedding in the same study was similar to that of grandis, but overall growth was less.

Bedding enhanced growth of both Spanish camaldulensis and St. Leo tereticornis on a flatwoods in central Florida (table 3). Even on a ridge of Pomello-Tavares soil, growth on beds exceeded growth on a flat harrowed area. The improvement on this dry ridge was probably due to control of competition. After a year, hardly any seedlings survived on the flat harrowed area, becaus of intense competition.

Table 2.--Effects of bedding or flat harrow site preparation on a palmetto prairie on establishme and growth of grandis through 4.5 years

| Characteristic | Bedded | Flat |
|---|---|---|
| Survival (%) | 75 | 62 |
| Survival coefficient of variation (%) | 7 | 25 |
| Height (m) | 12.2 | 9.8 |
| (ft) | 40.0 | 32.1 |
| Height coefficient of variation (%) | 30 | 41 |
| D.b.h. (cm) | 5.6 | 3.3 |
| (in) | 2.2 | 1.3 |
| D.b.h. coefficient of variation (%) | 39 | 82 |
| Merchantable trees (%) | 90 | 76 |

Table 3.--Effect of bedding or flat harrow site preparation on 6-month height growth of Spanish camaldulensis and St. Leo tereticornis on a central Florida flatwoods

| Species and site preparation | Soil series[a] | | |
|---|---|---|---|
| | Placid/Myakka | Myakka | Pomello/Tavares |
| | *m (ft)* | *m (ft)* | *m (ft)* |
| **Camaldulensis** | | | |
| Bedded | 1.0 (3.3) | 1.3 (4.3) | 0.8 (2.6) |
| Flat harrowed | 0.6 (2.0) | 0.7 (2.3) | 0.5 (1.6) |
| **Tereticornis** | | | |
| Bedded | 0.8 (2.6) | 1.1 (3.6) | 0.6 (2.0) |
| Flat harrowed | 0.4 (1.3) | 0.5 (1.6) | 0.5 (1.6) |

[a]The soils represent a gradient of improving drainage, running from a Placid soil at a pond edge to a ridge of Tavares soil.

*Spacing*

The distance between beds is dictated by the desired plantation stocking as well as physical restrictions. In the only long-term study on spacing in Florida, increases in grandis planting density from 840 to 3,362 seedlings per ha (340 to 1,361/acre) led to increases in total volume of wood produced (Meskimen and Franklin 1978). However, the merchantable volume, based on conventional size restrictions on pulpwood, was the same over the range of initial planting densities. In a subsequent study, as of 33 months increasing planting densities up to 40,000 seedlings per ha (16,000/acre) produced increasing amounts of wood (Rockwood and others 1982). Again these large amounts of volume produced at high planting densities cannot be used for conventional pulpwood, but they suggest opportunities if total biomass can be utilized.

While the lower cost of planting only 840 seedlings per ha (340/acre) seems attractive, this number is probably too few considering the risks of planting mortality and coppice failure. Planting 1,500 seedlings per ha (607/acre) seems a safe hedge against mortality and for future efficiencies in harvesting total biomass.

Spacing between beds is constrained by the width of bedding harrows, cost per unit of bed length, and need for vehicle access into the plantations. Conventional forestry harrows prepare beds from 2.2 to 3.2 m wide (7 to 10.5 ft), depending on the harrow's width, so 3.2 m (10.5 ft) is the closest practical spacing between beds for owners of the largest harrows. Each bed, however, represents distance to be traveled by a tractor with bedding harrow, and then later with seedling planter. The greater the distance between beds, the shorter the distance to be traveled over the plantation. Beds have been spaced as wide as 4.3 m (14 ft) in some plantations, but at this width it takes crowns a long time to shade out vegetation between the beds, and the spacing of seedlings on beds seems too close. A spacing of 3.7 m (12 ft) between beds appears to be a reasonable compromise among all factors. At that distance, seedlings must be placed 1.8 m (6 ft) apart to get 1,500 seedlings per ha (607/acre). It is practical for a worker to develop the rhythm to plant at that spacing on a fast-moving tree planter. Vehicles can, in an emergenc drive through the plantation when beds are spaced at 3.7 m (12 ft) intervals, but such travel is not recommended, as bed edges and roots will be damaged.

On nonbedded sites, 2.5- by 2.5-m (8.2- by 8.2-ft) is a good spacing. I allows room for cross cultivating with small tractor and disk, and gives 1,60 seedlings per ha (648/acre). For cros cultivating, exact spacing is required hand planting is not necessary--International Paper Co. has done it by machine, by scoring of the earth in on direction to mark the planting spot.

*Fertilization*

The only operational fertilization practice in eucalyptus plantations in Florida is the application of ground rock phosphate (GRP). Florida soils tend to be very phosphorus deficient, very acid (pH can be as low as 3.8), a do not retain soluble phosphorus. GRP dissolves slowly in the acid soils and thereby furnishes a long-term supply o phosphorus. GRP application, however, is useful only on very acid soils.

In only one study of GRP applicati have trees reached rotation age. In that study, grandis receiving 1,400 kg per ha GRP (1,250 lb/acre) grew more rapidly initially than nonfertilized trees on palmetto prairie (table 4). Eventually, nonfertilized trees starte to catch up, but at 8.75 years after planting, phosphated trees contained 1 percent more volume than nonphosphated trees. The volume gain on an area bas cannot be calculated, because the stud design was not suitable for area projections.

Grandis responded similarly to GRP on sweet flatwoods, wet prairie, and d ridge sites, but overall growth was le than on palmetto prairie. Robusta als responded to GRP, but a camaldulensis grandis hybrid and rudis did not; pure camaldulensis seedlots developed terminal dieback from the GRP.

Table 4.--Effect of ground rock phosphate (GRP) fertilizer on growth of grandis eucalyptus on palmetto prairie, by treatments, tree characteristic, and age

| Treatment | Height | | D.b.h. | Volume[a] | Dry weight[a] |
|---|---|---|---|---|---|
| | 1.5 yr | 8.8 yr | 8.8 yr | 8.8 yr | 8.8 yr |
| | *m (ft)* | *m (ft)* | *cm (in)* | *$m^3$ ($ft^3$)* | *kg (lb)* |
| GRP | 5.1 (16.7) | 19.4 (63.6) | 18.0 (7.1) | 0.182 (6.4) | 70 (154) |
| No GRP | 3.9 (12.8) | 18.5 (60.7) | 17.3 (6.8) | 0.154 (5.4) | 59 (130) |
| Difference | 1.2 ( 3.9) | 0.9 ( 2.9) | 0.7 (0.3) | 0.028 (1.0) | 11 ( 24) |
| Gain (%) | 31 | 5 | 4 | 18 | 19 |

[a]Volumes and weights are for all aboveground wood; bark is excluded.

Table 5.--Height, d.b.h., and basal area of three eucalyptus species 3.5 years after planting on palmetto prairie in plots fertilized with ground rock phosphate[a]

| Species[b] and application (kg/ha) | (lb/acre) | Height | | D.b.h. | | Basal area | |
|---|---|---|---|---|---|---|---|
| | | *m* | *(ft)* | *cm* | *(in)* | *$m^2$/ha* | *($ft^2$/acre)* |
| **Grandis** | | | | | | | |
| 0 | (0) | 5.3 | (17) | 4.5 | (1.8) | 2.1 | ( 9) |
| 560 | (500) | 5.8 | (19) | 5.0 | (2.0) | 2.5 | (11) |
| 1,120 | (1,000) | 8.1 | (27) | 7.5 | (3.0) | 4.6 | (20) |
| 1,680 | (1,500) | 8.1 | (27) | 7.5 | (3.0) | 4.7 | (20) |
| **Robusta** | | | | | | | |
| 0 | (0) | 5.7 | (19) | 5.6 | (2.2) | 3.0 | (13) |
| 560 | (500) | 5.6 | (18) | 5.9 | (2.3) | 3.6 | (16) |
| 1,120 | (1,000) | 5.5 | (18) | 5.8 | (2.3) | 3.3 | (14) |
| 1,680 | (1,500) | 5.7 | (19) | 6.3 | (2.5) | 4.0 | (17) |
| **Viminalis** | | | | | | | |
| 0 | (0) | 3.8 | (12) | 3.6 | (1.4) | 1.1 | ( 5) |
| 560 | (500) | 4.3 | (14) | 4.2 | (1.7) | 1.8 | ( 8) |
| 1,120 | (1,000) | 4.0 | (13) | 4.2 | (1.7) | 1.8 | ( 8) |
| 1,680 | (1,500) | 3.6 | (12) | 3.5 | (1.4) | 1.1 | ( 5) |

[a]E. Underhill and K. Imse of Hudson Pulp and Paper Corporation (now Georgia-Pacific Corporation) installed this study.

[b]The three species are planted in separate experiments and cannot be compared by analysis-of-variance techniques for two-way tables.

In a more recent experiment on palmetto prairie, three rates of GRP were applied. Grandis responded strongly at a young age (table 5). The response by robusta was not as pronounced. Viminalis was damaged by the heaviest application of GRP applied, but it did respond positively to lesser amounts.

It appears, then, that GRP stimulates early growth of grandis, and to a lesser extent robusta, helping the trees to more quickly reach sizes that are more resistant to freezes and weed competition. The increases in yield of grandis and robusta due to GRP over a rotation are not known. It is not advisable to apply GRP to camaldulensis, tereticornis, or viminalis, and it should be applied cautiously to species not yet tested.

Farmers in Florida often apply lime to acid soils to increase soil pH to a point were soluble phosphate fertilizers are retained. This practice was attempted in a grandis planting on palmetto prairie. Dolomitic limestone was broadcast prior to bedding, and superphosphate was broadcast after planting to simulate aerial application the planned operational practice. Ther was no significant response in growth t superphosphate or limestone alone or in combination in rates of application of up to 4,500 kg per ha (4,000 lb/acre) o dolomite and 202 kg per ha (180 lb/acre of superphosphate (45% $P_2O_5$). Banding of superphosphate on the beds to provid a heavy concentration needs testing.

Little is known about effects of applying nutrients other than phosphoru (and the calcium-magnesium in dolomite) before or at planting. Fifteen g (0.5 oz) of controlled-release fertilizer applied in the planting hole has increased early growth (table 6), but also has increased first-year mortality. Whether mortality of winter-planted

Table 6.--Effect of Osmocote 14-14-14 controlled release fertilizer placed in the planting hole on establishment and growth of grandis eucalyptus[a]

| Characteristic and planting time | Quantity of Osmocote per seedling | | |
|---|---|---|---|
| | 0 g (0 oz) | 15 g (0.5 oz) | 30 g (1.0 oz) |
| | *Percent* | | |
| Survival 3 months after planting | | | |
| August | 92 | 95 | 88 |
| December | 99 | 73 | 34 |
| | *dm (ft)* | | |
| Height growth 9 months after planting | | | |
| August | 15 (4.9) | 21 (6.9) | 20 (6.6) |
| December[a] | 6 (2.0) | 9 (3.0) | 10 (3.3) |

[a]Seedlings were planted in August and December on an August-harvested grandis stand that failed to coppice. Seedlings planted in December were subjected to more competition than those planted in August.

seedlings was due to toxicity of fertilizer in the planting hole or to greater freeze mortality of the more succulent fertilized seedlings is not clear. Long-term effect of this initial growth boost is not known. Application of controlled-release fertilizers in a hole a short distance from the seedling, or perhaps dribbled into the planting trench with an apparatus yet to be developed, is worth trying on a small scale to gain experience.

In summary, the growth rate of eucalyptus can be boosted by applying fertilizers before or at planting. But the nutritional requirements for eucalypts in Florida are not known well enough to make optimal fertilizer prescriptions, nor can expected yield increases from fertilization be predicted.

*Burning*

Burning prior to mechanical site preparation has been done, but the danger of escape is high. It may make mechanical vegetation control easier, but it will not kill competing root stocks. Therefore, burning should be avoided unless needed to reduce debris that would interfere with planting.

*Common Site-Preparation Practice*

Experience on site preparation is concentrated on palmetto prairie in the southern planting zone, and to a much lesser extent on cutover, stumped, acid flatwoods in the southern and central zones. Sites are either double choppe cross disked, or root plowed (locally called webbing) to kill palmetto. In the south, March and April are usuall hot and dry, and drought adds to the effectiveness of mechanical treatment those months in killing vegetation.

Next, 1,100 kg per ha (1,000 lb/acre) of GRP are broadcast on area to be planted with grandis and robust Application is usually restricted to early morning, before breezes develop After phosphate is applied, beds are constructed with a bedding harrow and hourglass roller. Bedding needs to b completed prior to heavy summer rains because mud is difficult to bed, and beds need time to settle before plant

*Old Fields*

Abandoned agricultural fields and pasture often are available for planting. This land is dominated by hardy, creeping grasses which are impossible to eradicate mechanically. Once summer rains begin, these grasse and in some fields tall herbaceous weeds, compete strongly with eucalypt and retard their growth substantially Two, three, and sometimes more years pass before the eucalypts, one by one break free of the competition. A pra tical treatment to control the competition has not been developed, but herbicides appear promising. A safe application system that does not leav toxic residue is needed, and the cost must be reasonable.

*Weed-free beds of grandis on old field that was treated with granular atrazine after seedlings were planted.*

In one experiment, granular atrazine (8% active) was broadcast over grandis seedlings at a rate of 4.48 g active ingredient per $m^2$ (0.13 oz/$yd^2$). Seedlings had been planted with their root collars 7 cm (2.8 in) below the soil surface. Beds were weed free at the time of herbicide application. The seedlings were dry, so atrazine granules did not stick to leaves. Atrazine kept the beds free of weeds until the grandis could expand their crowns and shade out weeds (in about 3 months). Grandis grew much more rapidly on treated than on untreated beds. Heights and stem volumes of treated and untreated seedlings at 13 months were:

| | *Height* | | *Volume* | |
|---|---|---|---|---|
| | *m* | *(ft)* | *$m^3$/ha* | *($ft^3$/acre)* |
| Atrazine | 4.2 | (14.0) | 9.2 | (132.0) |
| No atrazine | 1.6 | (5.2) | 0.2 | (3.0) |

In another experiment, glyphosate herbicide (41% active ingredient) was applied[3] in meter-wide (3.3 ft) strips at a variety of rates directly to a pasture that had a vigorous stand of bahia and bermuda grasses (*Paspalum notatum* Fluegge and *Cynodon dactylon* Pers.). Twenty days after application, grandis seedlings were planted directly into the turf to test no-till establishment in the hope that dead turf would retard invasion by weeds. There was a light rain 5 hours after the final spray application, and even the highest rate of application did not kill all grass. The grasses eventually began to compete strongly with the eucalypts, but growth in the sprayed strips greatly exceeded that in controls by 4.5 years after planting:

| *Quantity of Glyphosate Applied* | | *Mean Plot Basal Area* | |
|---|---|---|---|
| *l/ha* | *(qt/acre)* | *$m^2$* | *($ft^2$)* |
| 0.0 | (0) | 0.01 | (0.1) |
| 4.7 | (2) | 0.26 | (2.8) |
| 7.0 | (3) | 0.36 | (3.9) |
| 9.3 | (4) | 0.49 | (5.3) |
| 18.7 | (8) | 0.43 | (4.6) |

[3]Dr. D. Baird of Monsanto Chemical Co. applied the herbicide.

## Planting

The climate of peninsular Florida is subtropical. However, frosts and freezing temperatures can occur during the late fall, winter, or early spring in any inland area that might be plant to eucalypts (Johnson 1970). There is distinct rainy season from mid-June to mid-September, and a dry season the re of the year. Occasional rains occur i the dry season in association with col fronts, but they are not dependable. Summer is the only time when it is certain that soil moisture will be adequa for successful planting in the souther and central zones. Seedlings can be grown in the nursery during spring for summer planting with assurance that th can be planted without any long holdov period in the nursery. Rainless perio of a week or more in summer create drought conditions, and seedlings planted then are likely to die. Therefore, summer planting at times must st until soil moisture is restored. It i moisture at planting time that is critical; a dry spell after planting does n kill seedlings.

The earlier in summer that planti starts the better, to take advantage o the lack of weeds on the site at the start of the rains and to allow as muc growth as possible prior to the first freeze of the year. Mid-June is the earliest predictable date that plantin can begin, but if the spring was exceptionally dry, beds may not be wet enou to plant until late July. The rule is to be prepared to plant in June, but also be prepared to wait and to start and stop if the rains stop.

Although summer planting is standard practice, fall and winter plantings have been done experimentally (Geary 1977; table 6) and operationally with grandis in the south in at least 2 yea with good success. Bare-root stock ma have to be planted in cool weather (Hu 1980). Freezing and drought are hazar in fall and winter planting. However, if the seedlings are planted deep enough, the below-ground stem should survive freezes and sprout, so that th crop will not be lost. Fall and winte plantings need to be studied further t extend the planting season. Spring ha the least chance of success. Spring is usually hot and dry, and, if the preceding winter was cold, seedlings could not be grown to planting size for spring planting. A wet spring, which occurs occasionally, would be ideal for planting.

Spring may be more suitable for planting in the northern zone, for that zone has wetter winters and springs than the other zones. Even winter planting looks promising in the northern zone, despite the frequent hard freezes (Hunt 1980).

Planting in the summer rainy season presents two complications in addition to the potential lapse of rains--heat and mud. Seedlings must be shaded and ventilated while awaiting planting. The quicker they are planted after being pulled from containers in the nursery, the better. Seedlings have been stored in a refrigerated van at the planting site, but whether that preserved seedlings better than just shade and ventilation is not certain. Occasional sprinkling with water is necessary if storage is prolonged. The foliage can dry out without harm, but a seedling will die if its root plug dries. Furthermore, if seedlings are not well aerated, they will rot or overheat. Seedlings are hardy and will survive i they are packed loosely in boxes--a shipment of experimental seedlings sur vived 1 week of storage in a vented bc in the storage room of a bus station.

One must be prepared to plant whe the areas between beds are muddy or ev flooded, because the removal of vegetation from a site raises the water table. Operational planting is almost all done with planting machines--standard bare-root pine planters that have been modified to carry boxes of seedlings. Because of the mud, high-clearance tractors that can straddle beds are needed. Planting machines mu have a three-point hitch or straddle tl bed on their own wheeled frames. Drag machines will not work on beds--they fall off and tear down beds. Planters need frames to hold enough boxes of seedlings to make it from one end of t plantation to the other and return.

*Machine planting eucalyptus seedlings from cardboard boxes in which they were packed at the nursery.*

*Hand planting a eucalyptus seedling with a tubular root plug into a hole dibbled with a broom handle.*

Hand planting is an option; it is easy--all that is needed is a dibble to punch a hole in the soil (a broom handle will do for tubeling seedlings). Root plugs slip easily into the hole, which can be pressed closed with a foot.

Seedlings should be planted so that the cotyledons are well below the soil surface; burying the stem at least 5 cm (2 in) deep is usually adequate. Exposed plugs lose moisture through wicking action, and some stem tissue should remain below ground after settling and erosion of the bed surface. Stem tissue below the cotyledon will not produce epicormic shoots, so it is the below-ground tissue above the cotyledons that is the source of shoots, should the stem be killed to the groundline by freeze, fire, or sun scald.

Good survival and uniform spacing are more important in a plantation to be managed for coppice than in a plantation to be felled and replanted. Irregularities in stand structure become progressively exaggerated in subsequent coppice crops (FAO of the UN 1981). Unfortunately, survival of machine-planted seedlings in summer is variable--running from zero to near 100 percent survival over short distances on one landownership in one planting season. Serious losses are due to planting when it is too dry, to flooding (the seedlings can drown, or float out of the soil), and occasionally to fungal infection of seedlings in packing boxes. When conditions are ideal for planting, the seedlings will survive very poor planting, but such conditions rarely prevail. Hand-planted seedlings have a better chance of survival than machine-planted. In research studies, survival of hand-planted seedlings usually exceeds 90 percent; at times survival is 100 percent.

Planting delays in summer result in oversized seedlings because it has been impossible to stop eucalypts from growing in the nursery in hot weather without risk of killing them. Oversize seedlings can be too tall to fit in the packing boxes, even if the stems are bent. Seedlings that are too tall can be damaged also by the planting machine as it passes over them. Tall seedlings are usually topheavy and can lean severely after planting, causing basal sweep. Under dry planting conditions, oversize seedlings may have too great a shoot-to-root ratio for good survival.

Clipping seedling tops may be a solution, but results of a test are not encouraging. Grandis seedlings averaging 60 cm (24 in) tall and robusta seedlings averaging 55 cm (22 in) tall were clipped to 30 cm (12 in) the day before planting. Planting was in August during a break in the rains. The soil was too dry to have recommended commercial planting. Survival of unclipped grandis and robusta seedlings was 70 and 57 percent, respectively; survival of clipped grandis and robusta was substantially less--41 and 27 percent, respectively. Seedlings clipped a few weeks in advance of pulling might survive planting well, because they will have had time to recover from the shock of clipping. Clipping is not expected to increase double leadering or stem malformation (Horne 1979).

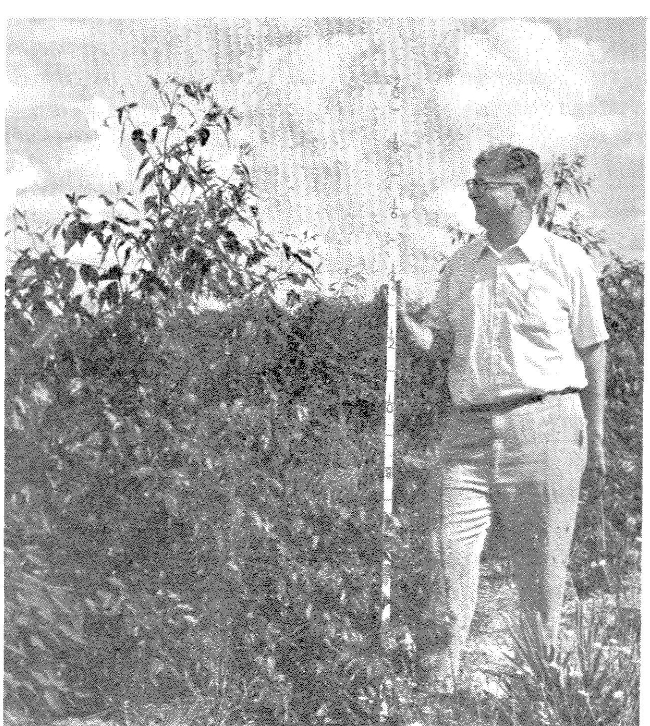
**After-Planting Care**

Eucalyptus plantations receive after-planting weed control in most parts of the world (FAO of the UN 1981). Weeds are usually controlled by cross-disking with tractor and harrow, then tending by hand around boles of trees. The site is kept clean of weeds until crowns shade out competition, usually in the second year after planting.

Florida and New South Wales, Australia, are exceptions to after-planting weed control. In New South Wales, the initial site preparation treatment is sufficient to prevent competition (Clarke 1975). In Florida, it often is not. However, in Florida, cross-disking of bedded areas is impossible; diskinc the areas between beds is of little help, and hand weeding is too expensi Weed control after planting on bedded sites awaits an effective system of ap plying herbicides.

In Florida, if high beds are made in dry weather and planting starts in the early rains, broad-crowned eucalyp like grandis and robusta develop wide enough crowns by 3 months after planti to shade out weeds on beds. Rapid sha ing occurs only on beds that remain fr of weeds during those months. Unfortu nately, beds are not always weed free for months; sometimes weeds develop or them before planting. Rapid invasion beds by weeds is most serious on old-field sites and on wet soils, where standing water allows seeds on the su face of beds to germinate and grasses creep over the beds.

Weed competition is particularly serious with the narrow-crowned camal-dulensis, tereticornis, and viminalis. Even though these species may grow rapidly in height after planting, the take much longer than grandis and robusta to develop crowns that can shade out competition. Young plantations of



*Grandis 5 months after planting on bedded and phosphated palmetto prairie.*

*Grandis plantation 4 years after planting on a bedded palmetto prairie site. This stage of stand development might be the time to fertilize with nitrogen.*

these species often become choked with weeds, which appear to retard growth. Workable solutions are needed badly. An operational system for herbicide treatment has not yet been developed, but it could be highly useful.

Fertilizer application after planting may prove practical. In the only major study in Florida, University of Florida scientists in cooperation with the Forest Service and its cooperators applied isobutylidene diurea (IBDU) and ammonium nitrate at rates of 0, 100, 200 kg N per ha (0, 89, and 178 lb/acre) on a 3-year-old grandis plantation on palmetto prairie to which GRP had been applied prior to planting. The most effective treatment, ammonium nitrate at 200 kg N per ha (179 lb/acre), increased height growth 69 percent and diameter growth 76 percent over controls in the 18 months after treatment (Barros and Pritchett 1979).

Control of weeds after planting and application of nutrients in addition to phosphorus promise substantial increases in production and need to be researched. Weed control after planting promises be the single most effective treatme it may be a substitute for normal le of fertilization (Schonau and others 1981). Without good weed control, e cessive quantities of fertilizer are needed to stimulate growth of eucaly (Meskimen 1970; Schonau and others 1981).

## Growth and Yields

Annual growth of eucalypts in F ida has been observed on a variety o: sites. The product yield, however, still a guess, because most plantati have not reached the anticipated har age of 8 years and most have stockin well below that needed for highest p ductivity. Performance of a 1969 ro- busta and a 1972 grandis plantation palmetto prairie in the southern zone may be indicative. Height growth was initially rapid, but it decreased sharply at about age 3 (fig. 5). Sta basal area increased through at least

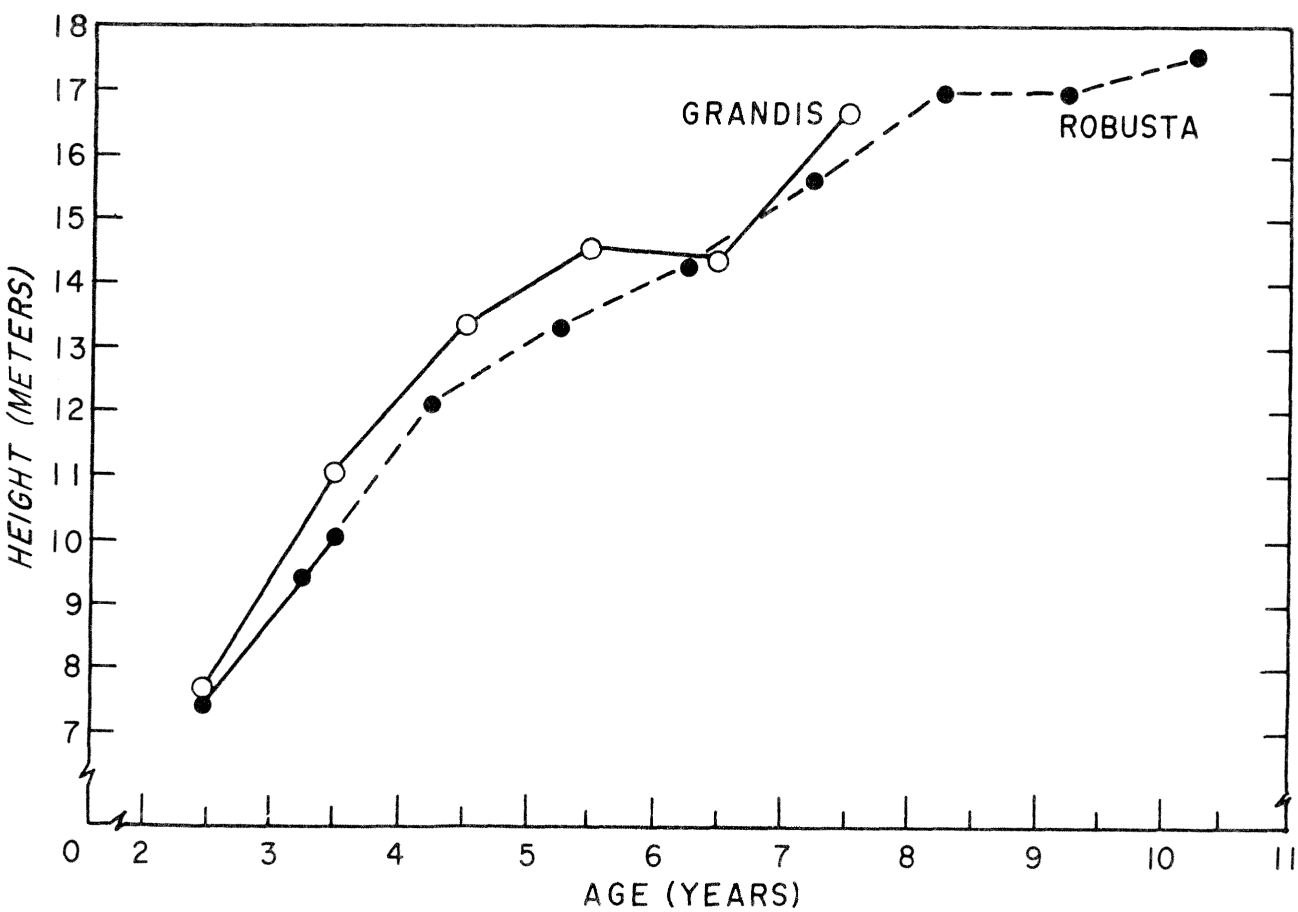



*Figure 5.—Mean height of tallest stem on each stool.*

age 10, but increment in basal area peaked in 4 to 6 years (fig. 6). Stand volume also increased for at least 10 years (fig. 7). The time when mean annual increment in volume peaks is uncertain, but it probably occurs within 8 years (fig. 8). Plantations, then, might be expected to be harvested by age

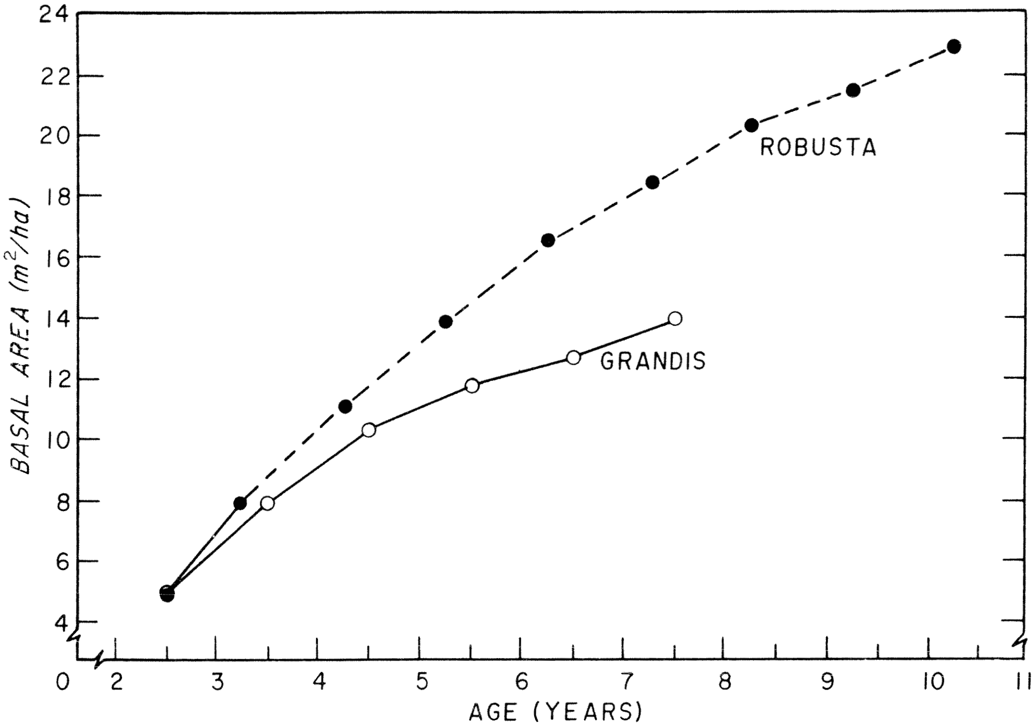



*Figure 6.—Stand basal area.*

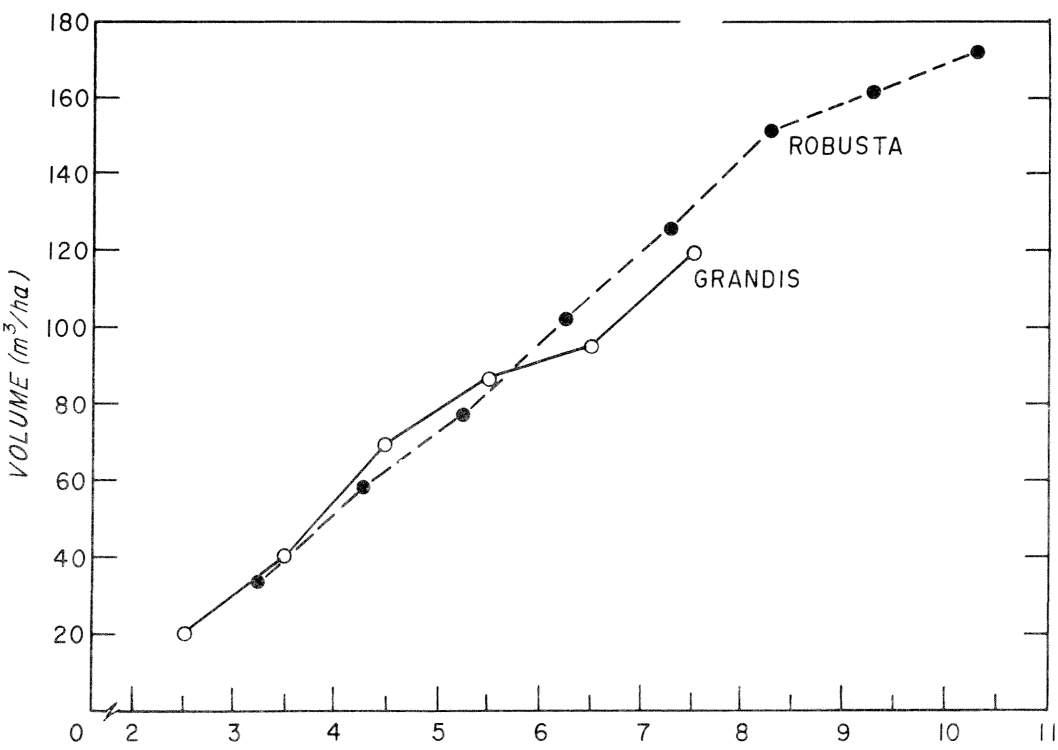



*Figure 7.—Stand volume of stem wood and bark to a 5-cm top.*

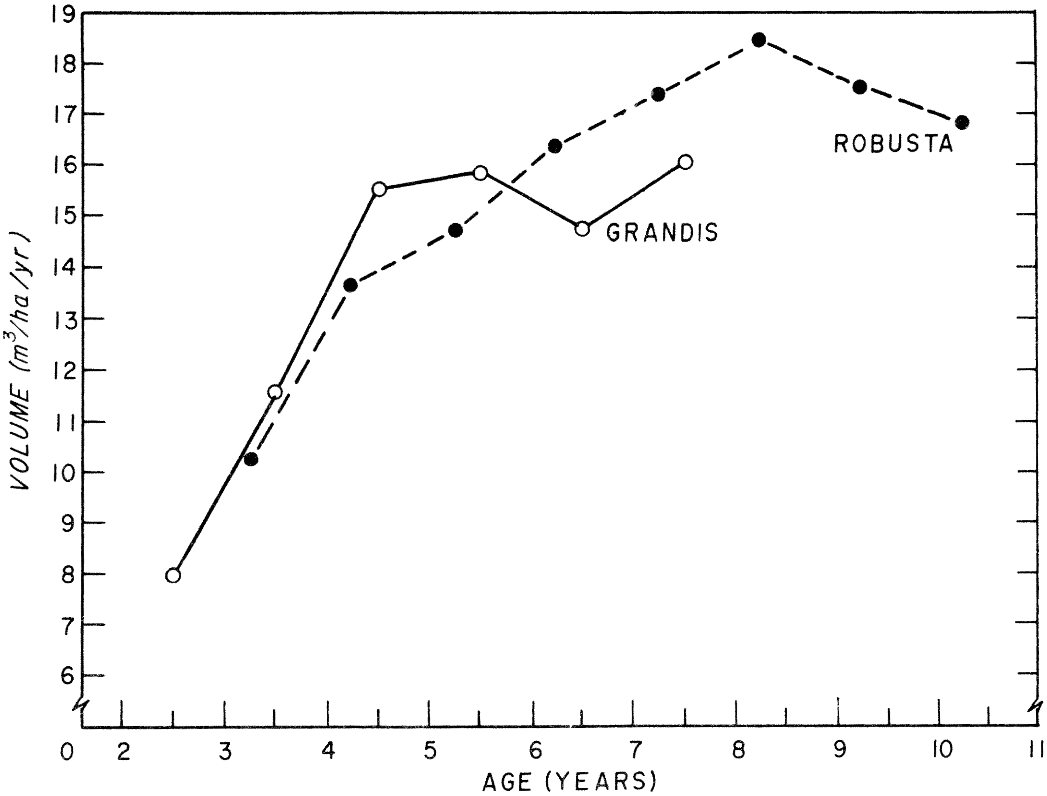
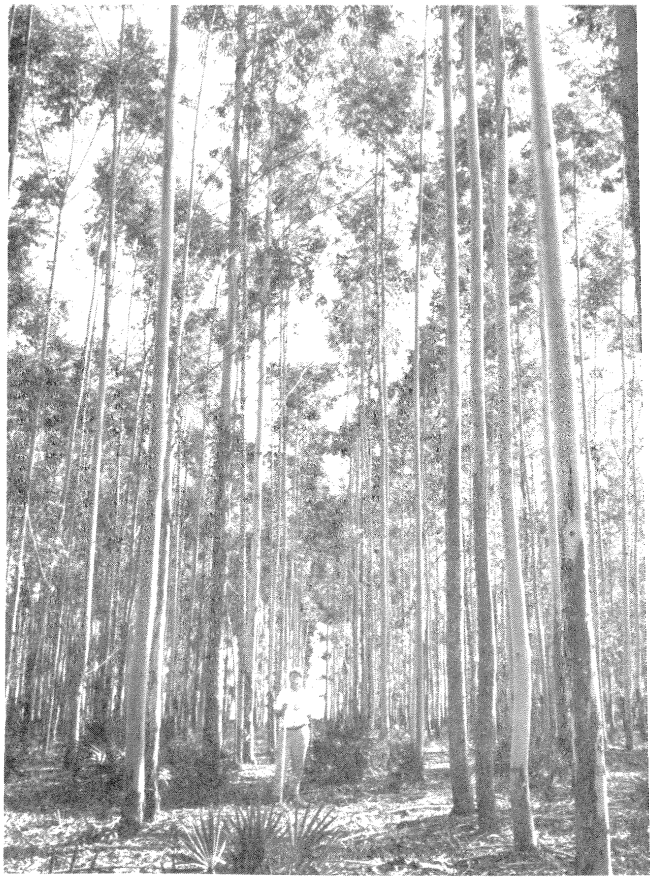



*Figure 8.—Mean annual increment of stand volume of stem wood and bark to a 5-cm top.*

8, and at that age will have produced pulpwood at a rate of 16 $m^3$ per ha per yr (229 $ft^3$/acre/yr or 2.5 cords/acre/yr). These yields are low by world standards for grandis plantations, which average perhaps 26 $m^3$ per ha per yr (372 $ft^3$/acre/yr) and range from 14 to 50 $m^3$ per ha per yr (200 to 715 $ft^3$/acre/yr) (FAO of the UN 1981). However, yields of grandis in Florida have reached 25 $m^3$ per ha per yr (372 $ft^3$/acre/yr) on palmetto prairie and 56 $m^3$ per ha per yr (800 $ft^3$/acre/yr) in under 3 years at very high planting densities (Rockwood and others, In Press).

The yields of camaldulensis and tereticornis growing on ridges will be less than those of grandis and robusta on palmetto prairie and acid flatwoods. Weight yields of grandis stands as possible biomass fuels have been calculated, and the standing dry weight of a typical 8-year-old pulpwood stand (whole trees without leaves) is predicted to be 74 t per ha (29 ton/acre).

In central and northern Florida, plantings are too small to estimate possible yields. Furthermore, current performance may be far less than that to be expected from strains that are being



*Grandis plantation 8 years after planting on a cutover flatwoods. The shallow beds made by an agricultural bedding harrow are barely visible.*

bred. In general, freezing problems in central Florida probably will cause yields to be somewhat lower than for similar sites in southern Florida. In northern Florida, somewhat better soils are available for planting, and this advantage may offset losses caused by the colder climate.

## Harvesting and Coppice Tending

Eucalypts in Florida will either be harvested mechanically by severing stems with anvil shears or chain-saw heads on grapple-fellers, or by hand with chain saws. In either case, stump bark must be left intact. Anvil shears must cut sharply so that the bark is not torn from the stump as the bole is pulled off, and the stumps should not be struck by mechanical equipment. Debris should be kept off the stump, because it causes deformities of coppice shoots as they snake their way through it. Whole-tree harvesting is a way to avoid the debris problem as well as reduce fire hazard, and it facilitates replanting of stands in which coppicing is inadequate. Whole-tree harvesting, however, may cause nutrient drain by taking away nutrients stored in leaves and branches.

Stump height is also important. The higher the stump, the greater the chance of coppicing, but high stumps tend to produce shoots that are not windfirm. A stump height of 10 to 12 c (4 to 5 in) is recommended (FAO of the UN 1981). A slanted cut is recommended to facilitate water runoff.

In much of the world, eucalyptus stumps coppice prolifically, and in short rotation plantations two to four coppice crops are anticipated before re planting is necessary (FAO of the UN 1981; Poynton 1981). Dying of stumps following harvest, rather than loss of vigor of living stumps, is the usual cause of a need to replant after the second or third coppice crop (FAO of t UN 1981). Eventually such mortality causes the stand to be understocked.

In Florida, coppicing of grandis not as reliable, and the season of har vest affects it (fig. 9). In summer, coppicing ability drops drastically in grandis, and to a lesser extent in ro- busta. In the Republic of South Afric a major growing area for grandis, 95 percent coppicing success is expected, except in the dry season when success somewhat less (Stubbings and Schonau 1980). Grandis coppices reliably in so parts of Brazil (Ayling and Martins 1981) but not in others (Campinhos and Ikemori 1980). In its native New Sou Wales, Australia, grandis coppices poorly through fall and winter, and

*A eucalypt being harvested with anvil shears.*

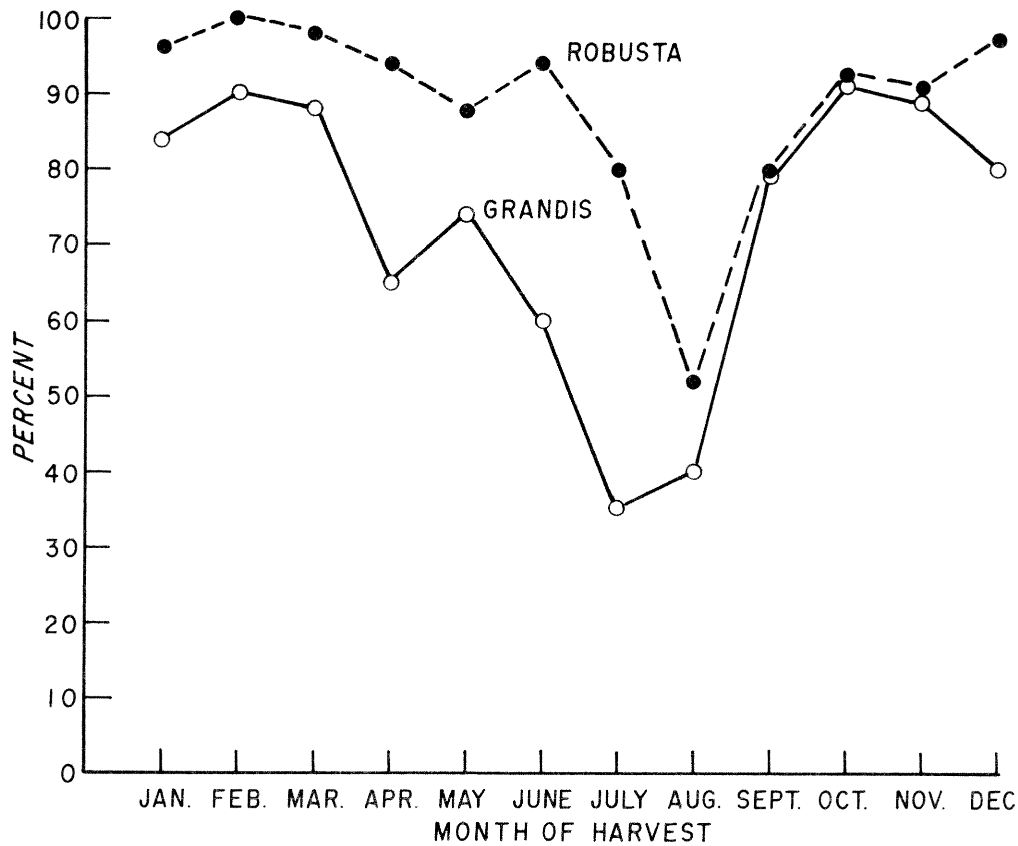



*Figure 9.—Percentage of stumps of 5- to 6-year-old grandis and robusta that coppiced after harvesting in different months on palmetto prairie in Glades County, Florida.*

apparently grandis plantations there cannot be managed by coppicing (Clarke 1975; Hillis and Brown 1978).

Coppicing ability was assumed and was not a selection factor in genetic improvement efforts in Florida. A recent progeny test revealed genetic variation in coppicing ability. Trees that originated from South African seed coppiced with twice the frequency of trees grown from Australian seed. Moreover, the seedlings used in the earliest plantations of grandis came from trees with poor coppicing ability. There is a tendency for the fastest growing grandis trees to produce progeny with below-average coppicing ability. Coppicing success is greater in trees that are hybrids with robusta, camaldulensis, or treticornis. Coppicing does not seem to be a problem with camaldulensis or tereticornis, but the experience with these species is insufficient to be sure.

What is to be done about the problem with grandis coppicing? Harvesting of this species could be restricted to the better months for coppicing, but even then the success rate does not reach a desirable 95 percent. Another approach is to harvest during summer, then replant. The new seedlings will b genetically superior to the old and wil have better coppicing ability. And last, local technology is being developed that will produce rooted cuttings and tissue culture plants from hybrids with superior coppicing ability, as has happened in Brazil (Campinhos 1980; Campinhos and Ikemori 1980).

Replanting should not require site preparation if planting is done by hand Immediately after harvest, beds are wee free and tend to remain that way for some time. If seedlings, rooted cuttings, or tissue culture plants are han planted, the stumps can be left in place. If replanting is delayed until stumps that will coppice are evident, planting next to living stumps can be avoided. Killing of the old, living stumps by burying or with herbicides might be done (FAO of the UN 1981), but may not be necessary, because interplanting in understocked grandis plantations immediately following harvest has succeeded in South Africa (Wattle Research Institute 1972). Since most plantations in Florida are already understocked by the recommended standard, replanting of the larger voids may be desirable. A test of replanting has been successful in Florida (table 6). The addition of 15 g (0.5 oz) of Osmocote controlled-release fertilizer in a

expected larger number of stems on a stool might be desirable, as it will tend to counter the problem of under- stocking. In an experiment in Morocc the total and salable volume of 6-yea old grandis coppice was greater in ur thinned coppice than in thinned coppi (Knockaert 1979).

When crowns with ripe seeds are left on the ground, some seedlings wi appear along with coppice regeneratic At the wide spacings in some Florida

Young coppice of robusta.

hole next to the new plant probably will be beneficial.

Stumps that coppice usually produce many shoots. Everywhere in the world where eucalypts are managed on coppice rotations, except in Florida, these shoots are reduced to three or less shoots a stool (FAO of the UN 1981; Poynton 1981). The number of shoots left on the stool depends on the product desired, site quality, and stool density.

In Florida, hand thinning shoots is thought to be too expensive, and no mechanical system has been devised. The few harvested plots are still too young to say precisely what the result of no thinning will be. But it appears that 2 to 4 stems per stool will dominate, and the remainder will be shaded out. The

Grandis coppice 6 years after felling of plantation. Coppice shoots were not thinned.

plantations, natural seedling regeneration can be dense and the seedlings will grow into trees. These trees will be of lower genetic quality than nursery seedlings, and they may obstruct row harvesting and plantation access, but they are free. Natural seedling regeneration cannot be predicted, so replanting should not be delayed in anticipation of it. Seedlings planted on beds suppress most natural seedlings, and whole-tree harvesting eliminates the seed source and the problem.

**Protection**

After planting, seedlings need protection from cattle. Cattle ordinarily do not eat seedlings, but they pull them out of the ground, break off their tops, and trample them. However, cattle did browse a fall-winter planting of grandis, where the grandis seedlings were the only green vegetation in sight. It is tempting to allow cattle to graze in plantations in the first year or two. The growth of grasses stimulated by GRP application makes good forage (Moore and Swindel 1981), and grazing reduces the fire hazard. But the damage cattle can do appears to outweigh the advantages. Once trees are 4 m (13 ft) tall and 4 cm (1.5 in) d.b.h., light grazing may be allowed to reduce fire hazard and utilize the residual vegetation. Once trees are large enough to resist cattle damage, however, the cattle become difficult to find and remove at roundup time.

A large deer population can seriously damage a eucalyptus plantation. Browsed trees eventually get ahead of the deer, but the resulting stand has an uneven structure and the stems are often badly forked. It may be impossible to get a satisfactory stand of eucalypts where deer browsing is heavy.

Plantations must be protected from intense fires, which cause substantial damage. In their native habitats, some eucalypts are part of a fire ecosystem, and experience with wildfires and experimental burns suggests that light fires will not cause serious damage. Prescribed burning might be useful, but little is known about fire effects on eucalyptus plantations in Florida. Clean weeding in the first year of pl tation growth is a good means of fire protection.

Insects have rarely been a probl Cone-headed grasshoppers (family Tett goniidae, subfamily Copiphorinae) destroyed one experimental planting of grandis the summer it was planted. T trees were expected to resprout, but they did not. No other examples of serious mortality from grasshoppers a known. A leaf-eating beetle, *Maecolaspis favosa* (Say), has seriously dam aged a number of seedlings and coppic shoots on a few occasions.

Diseases are a nagging, but apparently not serious, problem. Basal stem cankers on grandis caused by *Cry honectria cubensis* (Bruner) Hodges, c nov. (= *Diaporthe cubensis* Bruner) ar common (Barnard and English 1980). C kers do not kill trees, but might ret growth of some trees. The canker fun might be a cause of coppice failure f summer felling--the fungus thrives in hot, wet weather.

*A basal canker on a grandis tree.*

The fungus *Clitocybe tabescens* (Fr.) Bres. has been associated with sudden death of small patches of eucalypts in the southern zone. The major cause of patches of dead trees, however, is lightning. Over an 8.5-year rotation on a 67-ha (165 acre) plantation in the southern zone, 2.5 percent of permanent sample trees were killed by lightning and another 4.4 percent were injured. Many seed orchard trees are lost to lightning.

In late winter and early spring in the southern zone, twigs on roadside trees often die back. Seed trees of Spanish camaldulensis frequently lose their seed crop to twig dieback. A fungus is suspected.

No hurricane has struck the commercial plantations, but if one did, heavy breakage, windthrow, and lean would probably occur.

A condition called robusta breakup is found in a number of plantations. Tops tend to break out and trees start leaning. The cause is unknown. Top breakage may be due to decay at sites of freeze damage, and leaning may be a ph siological response. The problem does not exist with other species.

*Robusta breakup disease.*

**Utilization**

The properties of the slow-grown, mature wood of natural eucalyptus stan differ from those of the juvenile wood of fast-grown plantation trees. Only utilization of fast-grown, short-rotation trees is discussed here.

Properties of eucalypts differ su stantially by species. Even within sp cies, there are great differences in wood characteristics. For example, th cellulose content of 260 selected glob lus trees in Portugal varied from 36 t 57 percent; the wood density of those selected trees had a wider range than that of pine, spruce, or birch pulpwoo (Hillis and Brown 1978). Opportunitie to alter the wood properties of eucalypts by breeding, therefore, appear t be substantial. Wood properties are also affected by environment. For example, the formation of kino, a phen lic exudate that degrades pulping quality, can be induced by freezes, wind, and growth tension shakes (Hillis and Brown 1978).

At present, the most important ut lization characteristic in Florida is suitability for pulp and paper. In general, the eucalypts grown in the world's industrial plantations produce good-quality short-fiber pulp from a variety of pulping processes (FAO of t UN 1981; Hillis and Brown 1978). Euca lyptus wood can also be used to make dissolving pulp for viscose and acetat films and filaments (FAO of the UN 1981). Those eucalypts that are suitable for industrial plantations in Flo ida and have been tested for pulping quality are as good as native hardwood furnish, if not better (Franklin 1977; Hunt and Zobel 1978). Tereticornis, however, is good furnish only for the neutral sulfite semichemical process.

Eucalyptus wood is difficult to u for lumber because of growth stresses, shrinkage in drying, collapse, spiral grain, and proneness of sapwood to attack by post-hole borers (FAO of the UN 1981; Hillis and Brown 1978). Production of sawed wood from small-diameter eucalyptus logs is unlikely where better quality timbers are available (Hillis and Brown 1978). Quality products such as furniture and laminated beams can be made, however, from fast-grown eucalypts (Hillis and Brown 1978).

The use of eucalypts for veneers and plywood is still not on a large scale, but plantation-grown eucalypts are used for sliced decorative veneer, and plantation logs of grandis can be peeled for plywood because grandis wood does not collapse like that of many of the other eucalypts (FAO of the UN 1981). Eucalypts can be made into good hardboard and particleboard (Hillis and Brown 1978). Eucalypts are used extensively for mine timbers, railroad crossties, smelter poles, fenceposts, and utility poles (FAO of the UN 1981; Hillis and Brown 1978). The sapwood accepts preservation treatments, but care must be taken to reduce end splitting during drying (FAO of the UN 1981; Hillis and Brown 1978).

Thinning to maximize diameter growth and extending rotations of eucalyptus plantations to 15 to 25 years improves wood quality for lumber, veneer, and utility poles (Wattle Research Institute 1972), and might be an option for Florida growers.

The eucalypts are good firewoods and are used to make charcoal, including metallurgical charcoal in several countries (Ayling and Martins 1981; FAO of the UN 1981). Florida-grown grandis is easily whole-tree chipped for fuel use, and these chips are highly suitable for pyrolytic fuel systems (Purdy and others 1978). A good-quality activated carbon can be made from Florida-grown grandis (Smith 1979).

Eucalyptus honey can be of good quality (FAO of the UN 1981). Camaldulensis, tereticornis, and viminalis are good honey trees and are suitable for plantations in Florida. Tereticornis has sometimes been planted in central Florida as a winter flower crop to maintain hives. There is danger that the flower crop can be lost to a freeze, however.

Nearly all species of eucalypts have oil-producing glands in their leaves that give the leaves their characteristic odor (FAO of the UN 1981). These essential oils are useful in ph maceuticals, solvents, floating agent and perfumes. Fewer than 20 species produce oils in sufficient quantity f commercial production (Hillis and Bro 1978). Macarthurii has a good yield genariol and eudesmol for use in perfumes (FAO of the UN 1981), and this species is widely adaptable in Florid The premier essential oil producers i the world market--globulus, radiata, and dives--have not shown adaptabilit in Florida.

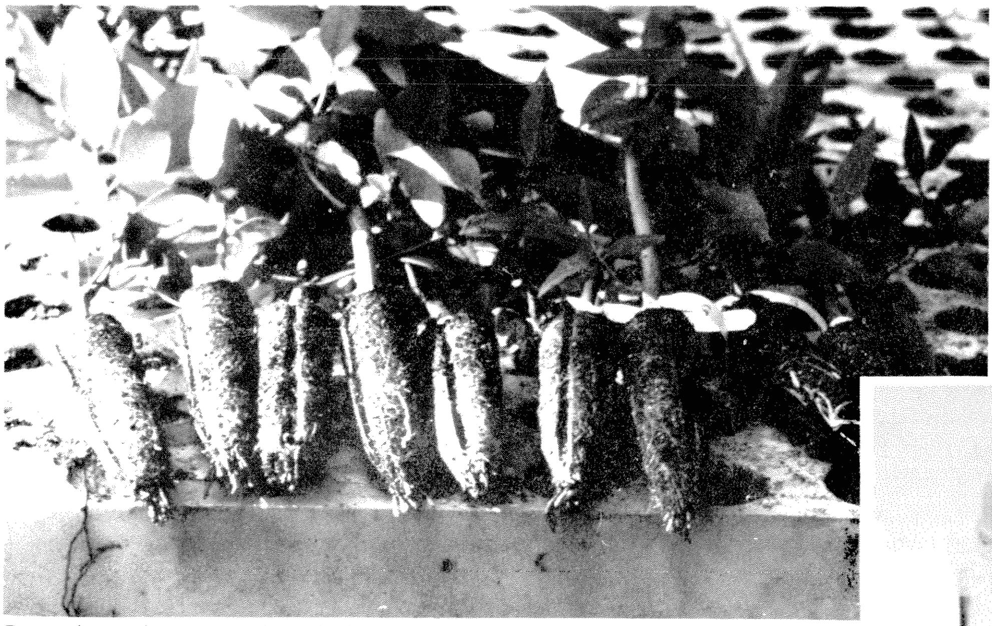
The juvenile foliage of young eu lypts is different from the leaves of older trees. Coppice and epicormic sprouts usually have juvenile foliage which for some species has suitable shape and color for floral arrangemen Unfortunately, the best species for t production of ornamental foliage, suc as pulverulenta, which is used in Cal fornia, are not well adapted to Flori However, neglecta, nova-anglica, cinerea, and perhaps a few other species that are adapted to Florida might be good substitutes.

## Prospects and Problems of the Future

Over the short term, planting of eucalypts in Florida will depend on t interest of pulp manufacturers in establishing captive supplies of hard wood fiber on accessible sites, on the need for close-by supplies of boiler fuel, and on the stumpage price for hardwood pulpwood. The current stumpa price in southern Florida is relativel low because the nearest pulpmill is in northern Florida. It is unfortunate that the farther the distance from pul mills in Florida, the more advanced is the technology for establishing short-rotation, high-yielding plantations. There is a world market for eucalyptus pulpwood chips, but the present volume of eucalyptus wood in southern Florida is insufficient to enter the market.

Over a longer term, the construction of wood-burning boilers by industries could have a great impact. Southern Florida, in particular, has a excellent potential for fuelwood plantations, once boilers that can use tha fuel are installed. Coal must be hauled an even greater distance to get to southern Florida than the distance traveled by southern Florida pulpwood to northern Florida. Thus, wood might be priced competitively with coal in the switch away from oil-fired boilers. Agricultural industries, with their vast landholdings in southern Florida, could establish eucalyptus fuelwood plantations close to their processing plants.

The technology for obtaining high yields from eucalyptus plantations can be improved greatly. This technology is just being born in northern Florida and has yet to walk in central Florida. In northern Florida, success rests with breeding. The germplasm of the few trees with good growth, form, and resistance to freezing must be multiplied, perhaps through propagation of rooted cuttings as in Brazil and the People's Republic of the Congo (Hartney 1980), or by tissue culture. Rooted cuttings are already being produced at the FDF nursery from superior trees by Forest Service developed adaptations of Brazilian methods of rooting cuttings, and a private research laboratory in Florida has succeeded in producing tissue culture clones of superior eucalyptus trees in Florida and is test marketing clonal plants. Only the present high costs of clonal plants is holding back substantial gains in adaptability and productivity of eucalypts in Florida. Selected clones could solve the problem of undependable coppicing of grandis in southern Florida. Clones that would exploit clean weeding and complete fertilization could make such treatments profitable. Hybridizing through controlled pollination and other intensive breeding techniques has yet to be tried in Florida, but it offers opportunities for developing unique strains for optimum performance in Florida.



*Rooted eucalyptus cuttings in LaBelle planter blocks.*

*Tissue culture plants produced from epicormic shoots of a select Spanish camaldulensis. (Photo courtesy of Clonal Resources, Inc., Lakeland, Florida.)*

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**Appendix**

Scientific Nomenclature of Eucalyptus
Species Mentioned in the Text

| Scientific Name[4] | Text Name |
| --- | --- |
| *Eucalyptus camuldulensis* Dehnh. var. *camuldulensis* | Camaldulensis |
| *camphora* R. T. Bak. | Camphora |
| *cinerea* F. Muell. ex Benth. | Cinerea |
| *dalrympleana* Maid. subsp. *dalyrmpleana* | Dalrympleana |
| *dives* Schau. | Dives |
| *globulus* Labill. subsp. *globulus* | Globulus |
| *grandis* Hill ex Maid. | Grandis |
| *macarthurii* Deane & Maid. | Macarthurii |
| *maculata* Hook | Maculata |
| *neglecta* Maid. | Neglecta |
| *nova-anglica* Deane & Maid. | Nova-anglica |
| *paniculata* Sm. | Paniculata |
| *pulverulenta* Sims | Pulverulenta |
| *radiata* Sub. ex D.C. | Radiata |
| *robusta* Sm. | Robusta |
| *rubida* Deane & Maid. | Rubida |
| *saligna* Sm. | Saligna |
| *tereticornis* Sm. | Tereticornis |
| *urophylla* S. T. Blake | Urophylla |
| *viminalis* Labill. | Viminalis |

[4] From Chippendale (1976).

☆ U.S. GOVERNMENT PRINTING OFFICE: 1983—651-976/4976

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Growing eucalypts in Florida for industrial wood production. Gen. Tech. Rep. SE-23. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1983. 43 p.

Eucalypt planting is practical on many sites in southern Florida, and strains resistant to freezes farther north are being bred. Methods have been developed for tree improvement, seed collection and handling, nursery management, plantation establishment and protection, and coppice regeneration. Guides to yields and utilization have been produced.

KEYWORDS: Reforestation, eucalyptus, tree improvement, seed technology, nursery practices, establishment methods, protection, coppice management, yields, utilization.

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Growing eucalypts in Florida for industrial wood production. Gen. Tech. Rep. SE-23. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station; 1983. 43 p.

Eucalypt planting is practical on many sites in southern Florida, and strains resistant to freezes farther north are being bred. Methods have been developed for tree improvement, seed collection and handling, nursery management, plantation establishment and protection, and coppice regeneration. Guides to yields and utilization have been produced.

KEYWORDS: Reforestation, eucalyptus, tree improvement, seed technology, nursery practices, establishment methods, protection, coppice management, yields, utilization.

The Forest Service, U.S. Department of Agriculture, is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.