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Woody Species for Biomass Production in Florida

Final Report
1983-1988

D. L. Rockwood
D. R. Dippon
M. S. Lesney

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Woody Species for Biomass Production in Florida

FINAL REPORT

prepared by:

D. L. Rockwood
D. R. Dippon
M. S. Lesney

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Department of Forestry
University of Florida, Gainesville

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ABSTRACT

From 1983 to 1988, this project's short rotation woody crop research enhanced the potential of Eucalyptus species in Florida. A fourth-generation E. grandis seed orchard could produce over 100 million seedlings annually for use in southern Florida. Seed from the 50 best trees in the orchard may double the average productivity in the preceding genetic base population. Three frost-resilient and rapid-growing E. grandis clones are being commercially propagated by tissue culture, and over 250 additional clonal candidates are under test. While rooted cuttings of selected clones could be mass produced in less than seven months, micropropagation may reduce the cost of vegetative propagation. Eucalyptus tereticornis and E. camaldulensis demonstrated vigor and frost-hardiness and may be suitable for sandhills sites in central Florida and wetter sites further south. For northern Florida, E. amplifolia had good frost-resilience and remained vigorous through four coppice rotations. Coppicing of other eucalypts, notably E. grandis, is very dependent on climatic factors. Biomass properties of the eucalypts vary due to genetics and age but appear suitable for certain fermentation and pulping processes. Economic analyses suggest that E. grandis and E. amplifolia may be profitably grown and that short rotation culture appears feasible for slash pine but cannot yet be advised for sand pine.

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1. INTRODUCTION

Florida is a rapidly growing state but has minimal fossil fuel resources. Currently the fourth most populous state in the country, Florida is increasing in population by some 900 people per day. Florida's own energy resources now meet only some three percent of the energy demands of its population. However, the State's large land base and favorable climate provide excellent opportunities to develop biomass energy sources.

Because of its abundance in particular areas and potential for high production, woody biomass is a promising alternative energy source in Florida. The over six million ha of commercial forest land in the State, largely in northern Florida, provide the basis for the wide availability of woody biomass. Many other agricultural and non-forest land types, especially portions of central and southern Florida, are suitable for certain woody species.

Woody biomass production potential in Florida is influenced by the wide climatic and edaphic variability in the State. Climatic conditions range from tropical in the extreme southern part to temperate in the northwestern portion of Florida. The unpredictable frequency and severity of freezes, notably in central Florida, constrain the broad use of fast-growing exotics such as Eucalyptus. While rainfall is normally high and predictably distributed throughout the year, soil moisture availablity can range seasonally from droughty in deep, rolling sandhills to wet in level "flatwoods" with shallow surface soils and impermeable subsoils.

The potential for maximizing woody biomass production in short-rotation systems in Florida has been the subject of research since 1978. A state-wide research program conducted from 1978 to 1983 by the project "Energy and Chemicals from Woody Species in Florida" installed field studies and conducted analyses (see references at the end of this section and Project Publications List) which indicated that, among other conclusions: 1) E. grandis produced more biomass than other species on drained muck and "palmetto prairie" soils in southern Florida, 2) E. robusta was second to E. grandis on muck soils but had better coppicing ability, 3) E. grandis, with fertilization on "palmetto prairie" sites, and E. robusta grew well in rotations as short as 18 months at close spacings up to 43,000 trees/ha, 4) genetic variability for biomass quantity and quality traits was present in several species, 5) E. amplifolia had promise for northern Florida, 6) slash pine and sand pine were suitable for biomass plantations but only at high planting densities, 7) the economics and energetics of short rotation systems with three species were favorable, and 8) longer-term research was needed to substantiate these conclusions and define management options.

The current project, focusing on these findings and utilizing established as well as new field studies throughout the State (Table 1-1, Figure 1-1), had, with emphasis on appropriate Eucalyptus species for Florida, goals of:

Table 1-1. Summary of studies[1] contributing to final report.

Study	(County) Location	Estab. Date	Species
DP-1	Alachua	04/81	*Eucalyptus amplifolia*, *Liquidambar styraciflua*, *Pinus clausa*, *P. elliottii*, *P. taeda*, *Platanus occidentalis*, *Sapium sebiferum*
ORNL-7	Glades	07/79	*E. grandis*
ORNL-10	Alachua	01/80	*Pinus elliottii*
ORNL-11	Gilchrist	01/80	*P. elliottii*
ORNL-13	Calhoun	01/80	*P. clausa*
ORNL-14	Taylor	01/80	*P. clausa*
ORNL-16	Palm Beach	05/80	*E. grandis*, *E. robusta*
ORNL-33	Glades	07/77	*E. grandis*
ORNL-34	Glades	79-80	*E. grandis*, *E. robusta*, *E. grandis* x *E. robusta*
ORNL-35	Palm Beach	07/85	*E. amplifolia*, *E. dunnii*, *E. grandis*, *E. robusta*
ORNL-36	Glades	07/86	*E. amplifolia*, *E. dunnii*, *E. grandis*, *E. robusta*
ORNL-37	Glades	08/82	*E. grandis* and hybrids
ORNL-38	Highlands	07/86	*E. camaldulensis*, *E. tereticornis*
ORNL-39	Alachua	09/86	*E. amplifolia*
ORNL-40	Glades	08/87	*E. grandis*
SS-8	Glades	07/84	*E. amplifolia*, *E. camaldulensis*, *E. dunnii*, *E. grandis*, *E. robusta*
SS-9	Alachua	09/84	*E. amplifolia*
SS-1	Palm Beach	06/82	*Sapium sebiferum*
SS-11	Alachua	07/85	*E. amplifolia*
SS-2	Highlands	07/83	*E. camaldulensis*
SS-3	Glades		*E. camaldulensis*, *E. tereticornis*, et al.
PT-1	Glades	07/82	*E. grandis*
MR-4	Polk	06/83	*Leucaena leucocephala*, *Pinus eldarica*, *Sapium sebiferum*

[1] Additional study details are provided in Appendix Table 7-1.

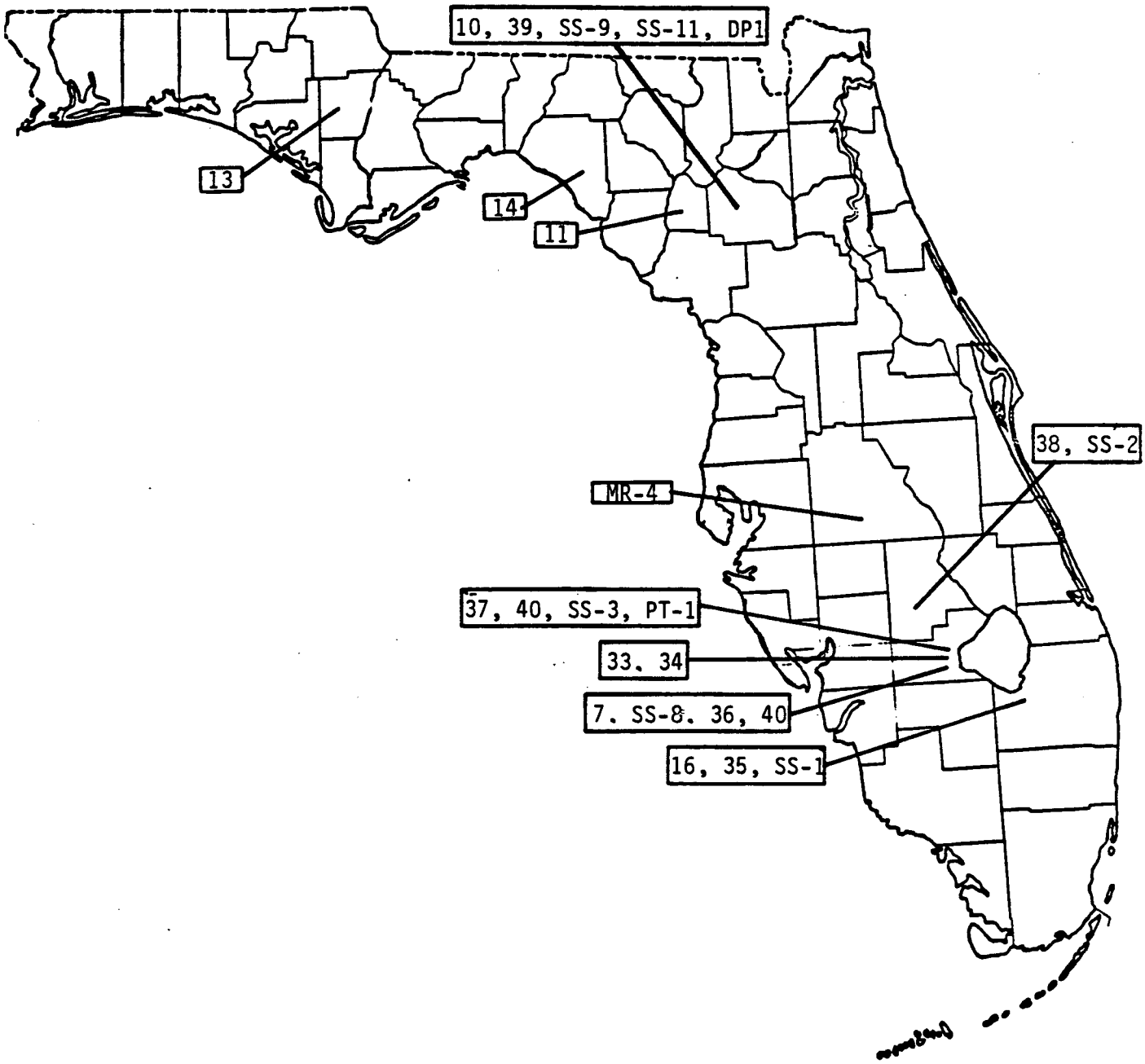

Figure 1-1. Location of research studies contributing to final report.

1. Development of genetically improved trees for biomass production,
2. Definition of management systems for intensive culture, and
3. Modeling biomass production and the resulting present net value of invested capital and energy for alternative short rotation strategies.

Specific objectives for the project from 1983 to 1988 were addressed by the following tasks:

Task A. Genetic improvement of *E. grandis*.

Task B. Screening of Eucalyptus species and sources.

Task C. Productivity and management of Eucalyptus species in coppice stands.

Task D. Clonal propagation and testing of eucalypts.

Task E. Economic evaluation of eucalypt biomass plantations.

Task F. Evaluation of biomass properties of Eucalyptus.

Task G. Continue assessment of other species for biomass production in Florida.

Methods, results, and conclusions for these tasks are presented in the following sections of this report.

References

Rockwood, D. L., C. W. Comer, L. F. Conde, D. R. Dippon, J. B. Huffman, H. Riekerk, and S. Wang. 1983. Final Report: Energy and Chemicals from Woody Species in Florida. Oak Ridge National Laboratory. ORNL/Sub/81-9050/1. 205p.

Rockwood, D. L., C. W. Comer, D. R. Dippon, and J. B. Huffman. 1985. Woody biomass production options for Florida. Fla. Agr. Exp. Sta. Tech. Bull. 856. 29p.

Rockwood, D. L. 1985. Development of woody biomass cultural systems for Florida. In: Biomass Energy Development:85-94.

TASK A. GENETIC IMPROVEMENT OF E. GRANDIS.

This task developed genetically improved E. grandis for mass seed production of good coppicing trees. Outstanding individual trees may also be used for clonal propagation.

Methods

The E. grandis genetic base population (GPOP77/ORNL-33) consisted of 529 progenies planted in July 1977 in a completely randomized design with single tree plots constituting 31,725 trees (approximately 60 trees/progeny) on 17.3 hectares near LaBelle. Spacing was 1.8 m between trees on paired beds spaced 2.3 m within pairs and 3.5 m between pairs, for a density of 1,916 trees/ha. The southern half of the plantation (a total of 15,510 trees) was harvested in August 1978. GPOP77 was developed through four generations of selection by the U.S. Forest Service (Figure A-1).

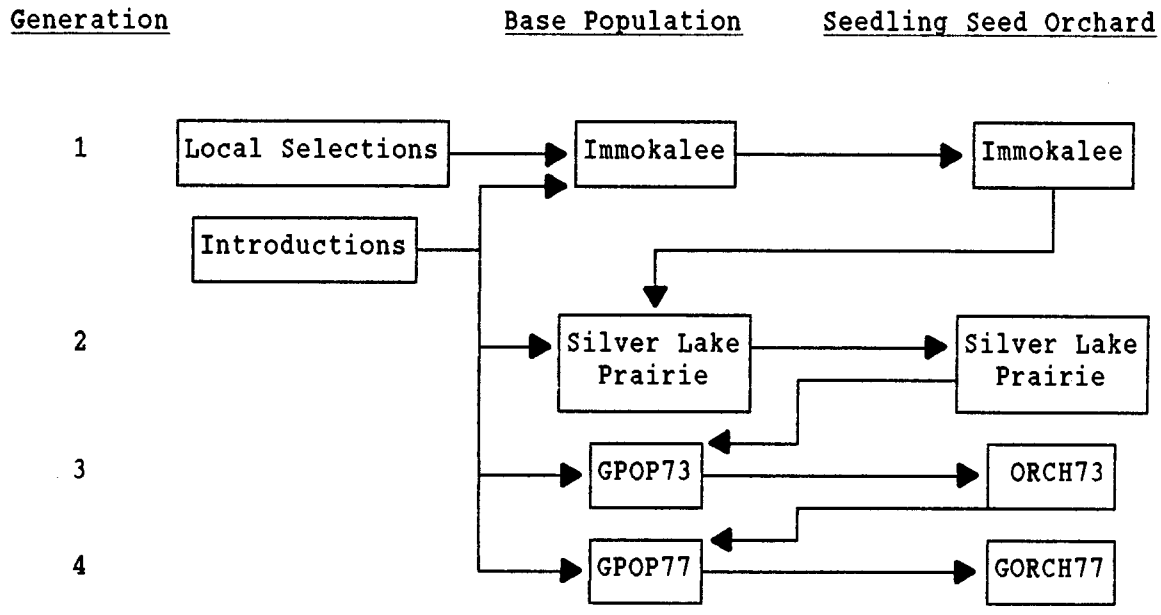

Figure A-1. Development of genetically improved E. grandis in Florida through four generations of genetic base establishment and conversion to seedling seed orchard.

Height and survival of seedlings at 7 months, height and survival of coppice at 3 months; height, DBH, volume, survival, and number of stems per stool at 30 months after cut; height, DBH, volume, survival, number of stems per stool, frost-resilience, frost-defect, coppice quality, and coppice defect of 64-month-old coppice were available for evaluating progenies and individuals in the southern half (Reddy, 1985).

Seedling and coppice growth was evaluated through 64-months for several traits. The analyses utilized only live trees at 64-months. Least Square methods were utilized and heritabilities were derived from the variance components estimated for half-sib families with Generations and Family (Generation) as independent sources of variation. The heritability estimates were used in predicting the genetic gains in the next generation using eight selection strategies. For each strategy the inbreeding coefficient (F) was calculated for all possible matings among the selected trees. The pedigree of each mating was traced to it's common ancestor, and the probabilities of relatedness at each level was computed.

Conversion of GPOP77 to a seedling seed orchard GORCH77 involved subdividing the population into selection areas of uniform microsites. Within each of 1575 selection areas, 45 composed of 25 trees and 1530 consisting of 20 planting positions (four rows by five trees/row), the best tree was retained, with a second tree from first-generation sources also included if possible from spacing considerations. In the northern half of GPOP77, the U. S. Forest Service had previously identified the best trees based on 2.5-year seedling performance and subsequent quality criteria at the time of selection. In the southern half, the top three trees in each selection area in terms of 64-month coppice volume were screened for form, frost-resilience, and coppice quality in the field to identify the best tree. The five largest trees of each first-generation source were considered for retention as the second leave trees in northern half selection areas. First-generation trees occurring as the top three trees in the southern half selection areas were retained if they met other criteria. Felling of trees began on February 18 and concluded in March 1986.

Seed were collected from GORCH77 in March 1987 (Figure A-2). Twenty-four of the top 50 trees in the southern half were seed producing, and seed capsules were obtained by shooting capsule bearing branches out of orchard trees. Seed were extracted by air drying of capsules for about two weeks.

The derived open-pollinated progenies were outplanted in August 1987 (refer to description of ORNL-40 in Task D for details on nursery propagation and test design). In row plots, the progenies were compared among themselves, against the best clones presently available, and against a previous generation seed orchard baseline of four progenies. Four of the new progenies (3517, 430, 4310, and 4050) were also established in pure and two-progeny mix block plots. Measurements were taken in December 1987 on height and survival.

Results

The various tests of E. grandis progenies conducted by this project, i.e., ORNL-7, -16, -33, -35, -36, provide standardized evaluations of certain seed trees in the third-generation seed orchard GORCH73. As tabulated in Appendix Table 7-4, these evaluations suggest the merit of certain parents and the avoidance of some of the 33 parents that have been progeny tested. Certain progenies performed well over the range of

Figure A-2. E. grandis seedling seed orchard GORCH77 at age 9.7 years (one year after roguing of GPOP77).

E. grandis planting sites in southern Florida (Figure A-3). To the extent that these evaluations are related to certain parent trees in GORCH77, these records suggest the genetic quality of GORCH77-derived seedlings. For example, seedlings for GORCH77 seed tree 3516, a progeny of GORCH73 seed tree 88 (Table A-4), may be expected to do reasonably well because half-sibs of 3516 have grown well in two of four progeny tests.

In GPOP77, the genetic base population derived from some GORCH73 seed trees and numerous introductions, four generations of selection significantly improved all coppice growth characteristics studied (Table A-1). At 64-months of age the average first-generation tree contained 7.04 dm^3 of stem wood. Second-generation trees were 206% larger averaging 21.54 dm^3, third-generation trees were an additional 20% larger at 25.91 dm^3 and the fourth-generation trees had yet another 55% gain with an average g 40.16 dm^3 of wood. Fourth generation families were also the best for frost resilience and coppice quality.

High individual and family heritabilities were observed for all growth traits (Table A-1). For 64-month coppice volume the individual tree heritability was 0.31 and the family heritability was 0.59. High

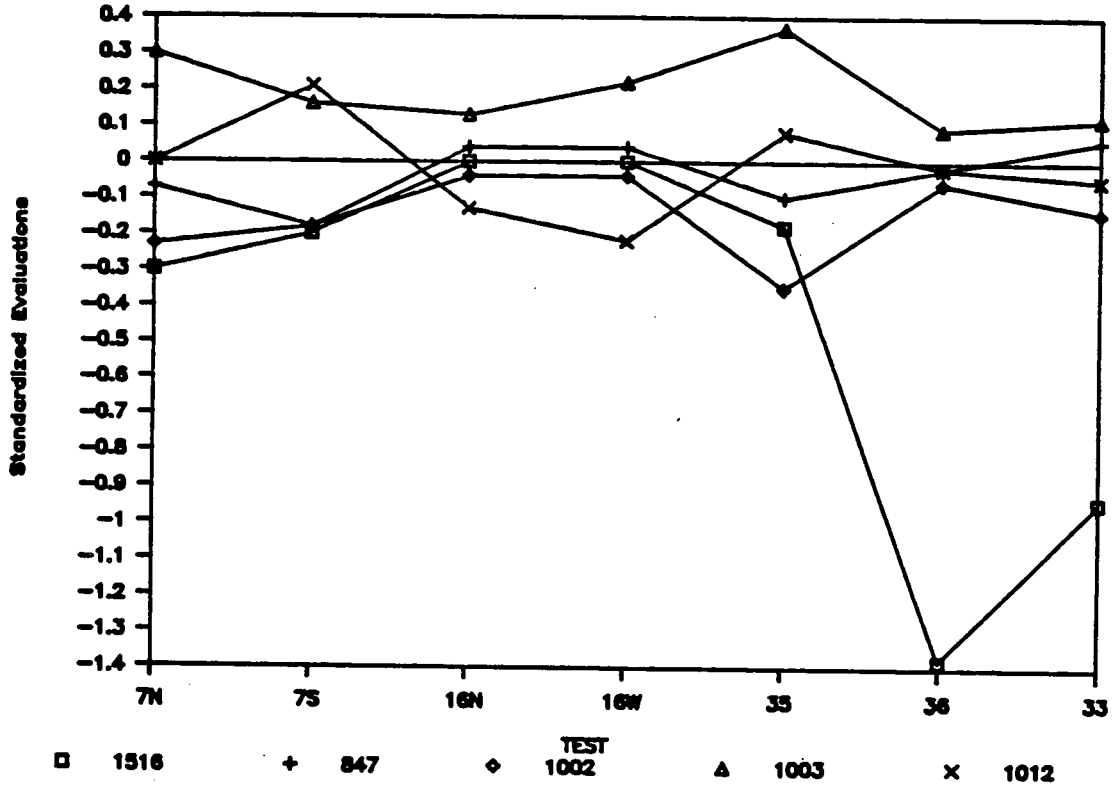

Figure A-3. Standardized parental evaluations of certain GORCH73 seed trees across various progeny tests.

individual heritability suggested high potential genetic gains through mass selection of the best trees. However, the family heritabilities suggested that higher gains could be achieved through combined selection of the best trees among the best families.

Some families in GPOP77 had common ancestors, thereby leaving a potential for inbreeding due to mating of related individuals. Genetic gains predicted for different selection strategies in GPOP77 were adjusted for inbreeding due to selfing as well as mating of related individuals. For each selection strategy, the inbreeding coefficient (F) was calculated for all possible matings by tracing the pedigree of each mating to its common ancestor and computing the probabilities at each level. The mean inbreeding coefficient for five selection strategies ranged from 0 to 1%. This was attributed to the fact that only a small percentage of families have an F greater than zero. In addition two to three generations have passed since direct relationship by common ancestry. So, the presence of related families in the seed orchard does

Table A-1. Generation means for 64-month coppice traits and associated heritabilities in E. grandis genetic base population GPOP77.

Trait	Overall	Generation 1	2	3	4
SHGT7M(m)	1.75	1.6a	1.79b	1.81b	1.83b
CHGT64M(m)	7.36	5.00a(.63)	7.75b(.31)	8.32c(.29)	9.39d(.38)
CHGT64M(cm)	6.66	4.03a(.59)	7.09b(.33)	7.75c(.29)	9.18d(.33)
CVOL64M(dm3)	20.16	7.04a(.37)	21.54b(.27)	25.91c(.25)	40.16d(.25)

*Numbers in parenthesis indicate heritabilities. Generation means not followed by the same letter are significantly different at 5%.

Table A-2. Genetic gains in 64-month E. grandis coppice volume adjusted for inbreeding for alternative operational seed collection options for GORCH77.

Seed Collection Option	Genetic Gain[1/] (%)
All orchard trees	54
30 trees per each of 10 top progenies	41
300 best trees	69
10 trees per each of 30 top progenies	61
200 best trees	80
1 tree per each of 300 top progenies	86
3 trees per each of 100 top progenies	90
Best tree in each of 50 top progenies	179

1/ Compared to GPOP77 average.

not seem to significantly effect the predicted gains through loss from inbreeding depression. However, the gains were not only adjusted for relatedness of families but also to selfing, which is reported to be 30% in E. grandis (Van Wyk, 1981).

The predicted genetic gains (adjusted for inbreeding) through different selection strategies are given in Table A-2. A gain of 90% in coppice volume over the population mean was predicted for a combined selection of the top three trees of the top 100 families.

As a possible aid in the selection process in GPOP77, selection index equations were developed and compared. The traits used in the equations included seedling height at seven-months, coppice height at three-months, coppice volume, coppice quality and frost resilience scores at 64-months. The ten index equations developed varied with the economic weights used for the five traits. Considerable range in the values of indices found between the individuals agrees with the significant genetic variation observed in the traits. To test the significance of the relative economic weights assigned for each index equation, the ten index values of an individual were subjected to Spearman's rank correlations. The results showed highly significant correlations between the ten index

values within an individual suggesting that the economic weights assigned did not affect the ranking of individuals.

Development of GORCH77 was a compromise between capturing the maximum potential identified above and maintaining the broadest possible genetic base. Conversion to achieve the greatest predicted gain would reduce the genetic base to 100 progenies, considered to be too few for long-term improvement. Retaining all 529 progenies would eliminate one of the primary means for generating gain. The compromise practiced favored the best families by retaining proportionately more trees, while many of the first-generation progenies were represented by only one tree.

Consequently, 1309 trees in 374 progenies were retained (Tables A-3 and 7-2). Fourth-generation progenies are nearly all represented in GORCH77 with an average of some six trees per each of 48 progenies. First-generation progenies, on the other hand, average 1.5 trees each for 38 progenies. In the southern half, however, only 27 first-generation progenies had acceptable trees. In addition selected trees in GORCH77 include 13 trees with unknown pedigrees.

Table A-3. Summary by generation of E. grandis trees retained in GORCH77.

Generation	No. of Selects	No. of Progenies	Number/Progeny Mean	Number/Progeny Range
?	14	1	1.3	-
1	56	38	1.5	1-8
2	480	172	2.8	1-8
3	463	115	4.3	1-14
4	296	48	6.2	1-15
Total	1309	374		

This genetic composition of GORCH77 would result in a estimated gain of 54% in coppice stem volume over the GPOP77 average (Table A-2). Achieved gain is expected to be higher due to further roguing to be done and to selective seed collection. Some trees could be removed due to poor coppicing of 9-year-old trees (northern half) and/or 8-year-old first-coppice stools (southern half). Additional tree removal may be necessary for general spacing consid-erations in the orchard and reducing proximity of half-sibs. The impact of these removals on gain will be relatively minimal compared to selective seed collection, however.

As suggested by the gain estimates in Table A-2, maximum progress can be made by utilizing the better progenies, such as the top 100, and best individuals in those progenies. Such selective collection would result in about a 90% gain. A more selective set of seed trees, e.g., the best 50 trees (presumably from the top 50 progenies) would further increase genetic quality. While the background pollen in GORCH77 would on the average be poorer quality, of course, the potential for commercial

seed collection from a limited number of seed trees has been demonstrated by Forest Service commercial collections through 1980 (Meskimen, 1983).

Using the selection index values, the top 50 trees from among the trees in GORCH77S (for which coppice growth and frost data were available) were selected for seed collection. However, only 24 of these produced seed in 1987. These trees were mostly third- and fourth-generation trees (Table A-4). The seed was processed and sown for outplanting in an August 1987 progeny test (ORNL-40) described in Task D.

Table A-4. Location, mother tree, generation and pedigree of 23 *Eucalyptus grandis* seed trees in GORCH77 from which seed was collected in 1987.

Seed Tree	Location Row/Col	Mother[1] Tree	Gen.	Pedigree[2]
3336	32-137	1175	2	G73) Pomona Qld. Australia
3424	39-145	1544	2	G73) South Africa
3516	42-190	88	3	SLP)IMOK) Gympie Qld. Australia
3521	45-204	953	3	G73)SLP) Coffs Harbr NSW Australia
3517	49-192	1007	4	G73)SLP)IMOK) Gympie Qld. Australia
3674	61-169	1754	1	Choma Zambia
3641	65-69	1020	4	G73)SLP)IMOK) Gympie Qld. Australia
3706	66-202	955	3	G73)SLP) Coffs Harbr NSW Australia
3698	66-221	1124	2	G73) Conglomerate NSW Australia
3873	82-225	1019	4	G73)SLP)IMOK) Gympie Qld. Australia
4159	112-222	1020	4	G73)SLP)IMOK) Gympie Qld. Australia
4050	105-181	1136	2	G73) Conglomerate NSW Australia
4157	108-221	1010	4	G73)SLP)IMOK) Gympie Qld. Australia
4160	115-224	987	4	G73)SLP)IMOK) Gympie Qld. Australia
4161	118-224	873	3	G73)FFF) Urunga NSW Australia
4268	126-182	857	3	G73)FFF) Urunga NSW Australia
4249	129-129	1199	2	G73) South Africa
4274	129-200	1011	4	G73)SLP)IMOK) Gympie Qld. Australia
4304	131-166	881	3	G73)SLP) Urunga NSW Australia
4310	133-149	1480	2	G73) South Africa
4242	135-197	1547	2	G73) South Africa
4305	136-165	1052	2	G73) Mulberry Florida
4360	139-121	1012	4	G73)SLP)IMOK) Gympie Qld. Australia
4361	141-124	1161	2	G73) Bell Thorpe Qld. Australia

[1] Seed tree identity in 3rd-generation seed orchard G73.
[2] Previous generation sources.

Early results from ORNL-40 suggest no differential between seedlings from GORCH77 and GORCH73. At 4 months in row plots, the 21 GORCH77 progenies averaged .83 m in height and 71% survival, while four GORCH73 progenies were .84 m tall and had 77% survival (Table D-6). The range among the GORCH77 progenies represents variability within the 1720 seed orchard trees that can be exploited to maximize genetic gain. Similarly, variability among the four GORCH77 progenies included in pure and mixed

block plots (.54-.72 m in height and 56-79% in survival) suggests gains that can be made by progeny testing GORCH77.

The opportunity for maximizing gain by selective seed collection in GORCH77 will depend on the seed quantities needed. Using as a guide the estimates that a mature seed orchard tree will produce 2 kg of seed annually yielding 75,000 plantable seedings, trees in GORCH77 could eventually produce over 100 million seedlings per year. Assuming that operational E. grandis biomass plantations would be established at 5,000 trees/ha, GORCH77 could support the planting of more than 20,000 ha/year. GORCH77 trees may develop crowns capable of full seed production by March 1989.

GORCH77 has numerous candidates for clonal propagation and testing (Figure A-2). As described in Task D, four clones from 32 selected in GPOP77 surpassed 23 clones selected elsewhere and are the best E. grandis clones currently available. Since the Forest Service clonal selection effort in GPOP77 in 1982 was necessarily limited, the ready accessibility and further performance data of GORCH77 trees now provide even better prospects for finding vigorous, frost-resilient clones.

Conclusions

This task developed genetically improved E. grandis for mass seed production of vigorous, somewhat frost-resilient, good coppicing trees. The appreciable genetic gain potential of GORCH77 can now be realized. Exceptional individuals are candidates for clonal propagation to capture the full genetic potential in GORCH77.

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TASK B. SCREENING OF EUCALYPTUS SPECIES AND SOURCES.

The genetic resources needed for long-term genetic improvement of several species, particularly E. grandis, E. amplifolia, E. camaldulensis, and E. tereticornis, were acquired and evaluated in this task.

Methods

Northern Florida

SS-9: Seed sources of four eucalypts considered promising for northern Florida were outplanted near Gainesville in September 1984. Sources, each generally a bulked seedlot from several trees in a portion of a species' range, were obtained from CSIRO and other seed suppliers in Australia. Twelve, 12, one, and 51 sources for E. amplifolia, E. dunnii, E. nitens, and E. viminalis, respectively, were represented in 10-tree row plots with three replications in a randomized complete block design. Spacing was 1 x 1 m. Survival was determined in December 1984 and in April 1985.

SS-11: Ten E. amplifolia sources previously in SS-9 were planted near Gainesville in August 1985 in two 25-tree plots at 1 x 1 m spacing. This "source bank" was measured for height and survival in December 1985. Frost damage from a January 1986 freeze with a low of 17°F was evaluated using a scoring system adapted from Wilcox (1982). On February 8, foliage damage was scored on a 0 (no damage) to 5 (killed by frost) scale, and stem damage was graded on a 0 (no damage) to 3 (lower 1/3 dead) scale. Trees having minimal (0 - 1) scores on both scales were classified as resistant, trees with 4 (90% killed) or above on the foliage scale and 2 (middle 1/3 killed) or 3 for stem damage were grouped as susceptible, and trees between these two categories were considered to be moderately resistant. While the 1986 freeze was not as rigorous as the January 1985 freeze, it provided an opportunity to reassess the sources. Height, DBH, and survival were assessed in September 1987.

ORNL-39: Based on performance of certain E. amplifolia sources, new seed collections were arranged to broaden the genetic representation of the species. Kylisa Native Seed Suppliers in Weston Creek, ACT, Australia, searched nine preferred source areas and eight more southern sources for superior phenotypes bearing enough seed for adequate testing. Trees selected in a stand were of superior size, good form, disease-free, and separated by at least 100 m from other selects in the same stand. Stands were typically separated by at least 10 km. Progenies of these selects, plus four sources which had performed well in studies SS-9 and SS-11, were established near Gainesville in September 1986 (Table 7-1). In a randomized complete block design with three replications, each progeny was planted in a 7-tree row plot randomly located within source subsets randomly assigned within a replication. Sources 1-92, 1-93, 2-1, and 2-3 evaluated in SS-9 and SS-11 were included in an additional subset to serve as genetic checks. Post-planting survival and apparent vigor (1 to 4 scale: 1=<15 cm, 2=15-20, 3=20-25, 4=>25 cm in height) were measured in September 1986 and tree height and survival in September 1987.

Central Florida

SS-2: Of several species planted as part of a GRI-supported species screening trial near Lake Placid in June 1983, three survived two very damaging freezes and were remeasured in December 1985. *Acacia mearnsii* and *Grevillea robusta* were represented by one replication with 100-tree plots. The same replication plus two replications with 36-tree plots were used for *E. camaldulensis*; five micropropagated clones derived from outstanding trees in commercial plantings (Howland et al. 1986) were involved. One *E. tereticornis* source was planted in a similar design with other species in July 1982.

SS-3: Of several species planted as part of a similar species screening trial near Palmdale, two *Eucalyptus* species survived two very damaging freezes and were remeasured in May 1987 in one replication with 100-tree plots and two replications with 36-tree square plots. *E. camaldulensis*, represented by three of the micropropagated clones used in SS-2, was established in June 1983. The same *E. tereticornis* source used in SS-2 was planted in August 1982.

SS-8: This study expanded the testing of *E. amplifolia* and *E. dunnii* over sites and broadened the genetic evaluation of *E. grandis* and *E. camaldulensis*. The test site typified "palmetto prairie" in south Florida and was adjacent to Study ORNL-7. Intensive site preparation and bedding on 1.5 m centers was completed in May 1984. The randomized complete block design with three replications of 8-tree row plots was planted July 1984. Individual progenies/sources were assigned to the row plots, and species or source groups were utilized to avoid competitive effects. Spacing was 1.5 x 1 m. A total of 32 *E. grandis*, one *E. robusta*, four *E. amplifolia*, three *E. dunnii*, and 18 *E. camaldulensis* sources were outplanted. Northern sources of *E. grandis*, 21 from the Atherton area in Queensland not represented in the Florida base population, were emphasized. The *E. camaldulensis* sources were primarily CSIRO collected seedlots. The *E. amplifolia* and *E. dunnii* sources had been previously tested in SS-9 and SS-11. Survival and height were measured in February 1985, December 1985, and March 1986.

ORNL-38: Twenty sources of *E. camaldulensis* and 75 sources of *E. tereticornis* were established near Lake Placid, Florida, in July 1986. Because seed of the *E. camaldulensis* sources used in SS-8 was depleted with that sowing, 20 different *E. camaldulensis* sources were used in ORNL-38. Similarly, the *E. tereticornis* source used in SS-2 and SS-3 was not represented here. The experimental design was a randomized complete block with three replications of 10-tree row plots grouped into species blocks. Ten *E. camaldulensis* clones selected by the U.S. Forest Service (Table D-10) were represented in two replications. Survival and height were measured in December 1986. Damage from a February 1987 freeze was evaluated in March 1987 using a four point severity scale. Thirteen-month height and survival were assessed on August 9-10, 1987.

Southern Florida

ORNL-33: Seventeen first-generation provenances of *E. grandis* in GPOP77 were analyzed. Each provenance was represented by different number of

families (total 93). They constituted 61.0 % of the total first-generation families included in GPOP77. Data analyzed were the same as described for GPOP77 in Task A.

ORNL-35: This study was established in July 1985 near Belle Glade and included progenies/sources of *E. grandis*, *E. robusta*, *E. amplifolia*, and *E. dunnii* in 10-tree row plots in six replications. Survival and tree size were measured at 5, 12, and 17 months of age. Three replications were felled in December 1986, and coppicing rate was determined 10 weeks later.

ORNL-36: The same progenies/sources of *E. grandis*, *E. robusta*, *E. amplifolia*, and *E. dunnii* as in ORNL-35 were planted in 10-tree row plots in three replications in July 1986 in LaBelle, Florida. The study also included seven *E. tereticornis* sources in row plots. Tree height and survival were measured in December 1986 and August 1987.

Results

Northern Florida

SS-9: *Eucalyptus amplifolia* survived the rigorous January 1985 freeze, a 100-year event, far better than three other previously promising species (Table B-1). Before the freeze, *E. amplifolia* sources averaged 83% survival, and several *E. dunnii* and *E. viminalis* had good survival. After the freeze, none of the *E. dunnii*, *E. nitens*, or *E. viminalis* sources had acceptable survival. Six *E. amplifolia* sources exceeded 50% or more survival, with four of these sources incurring 30% or less apparently freeze-related mortality.

Table B-1. Three- and seven-month survival (%) of seed sources of four *Eucalyptus* species in SS-9.

Species	No. of Sources	3-months Mean	3-months Range	7-months Mean[1]	7-months Range
E. amplifolia	12	83a	70-93	48a	30-70
E. dunnii	12	60a	40-77	2b	0-7
E. nitens	1	13b	-	0b	-
E. viminalis	51	39b	7-83	1b	0-7

[1] Species means not sharing the same letter are significantly different at the 5% level.

SS-11: The 10 *E. amplifolia* sources reestablished in SS-11 grew well through five months and varied in response to the more typical January 1986 freeze (Table B-2). Source 2-3 was exceptionally vigorous with some trees as tall as 1.8 m. No trees were totally undamaged by the freeze, but Sources 1-93 and 2-4 had more than 70% "resistant" trees. Sources 2-1 and 2-7 had lower proportions of "resistant" trees but were very frost resilient in SS-9.

After 25 months, individual trees were as large as 7.0 m and 6.8 cm, and source variability was considerable for all traits. Overall survival decreased to 32%, due to freeze mortality or the failure of many trees to sprout after the 1986 freeze. Non-sprouting trees were commonly observed to lack lignotubers. Heavy herbaceous competition caused additional mortality. Sources 1-93, 2-4, and 2-8 had above average survival, but only 1-93 had above average tree size. Source 2-3 had the largest trees, on the average, but had only 26% survival. Source 1-93 best combined the necessary attributes of frost resistance, competition tolerance, and tree vigor.

Table B-2. Evaluation of 10 Eucalyptus amplifolia sources in SS-11 at 4, 6, and 25 months.

				--2/8/86 Frost Evaluation--					
	No.	4-month			Mod.		25-month		
Source	Planted	Surv.	Ht.	Resist.	Resist.	Susceptible	Surv.	Ht.	DBH
		(%)	(m)	----------(%)----------			(%)	(m)	(cm)
1-93	50	78	.7	14	61	25	42	3.5	2.2
2-1	50	82	.7	0	36	64	32	2.0	1.5
2-2	25	60	1.0	0	0	100	4	3.2	4.3
2-3	50	82	1.3	0	54	46	26	5.1	4.2
2-4	50	90	.5	0	73	27	50	1.9	1.1
2-5	50	44	.6	0	12	88	20	2.9	2.2
2-6	50	32	.9	0	16	84	10	2.8	2.5
2-7	50	76	.7	5	16	77	34	2.3	1.6
2-8	50	94	.7	0	48	52	70	2.3	1.4
2-9	50	70	.9	0	27	73	38	3.2	2.6
	Mean	71	.8				32	2.8	2.1

ORNL-39: A total of 69 E. amplifolia seedlots were established in this study, which may serve as a genetic base population (Table B-3). One previously tested CSIRO sources (Source 2-5=Woolomombie) was represented by six selections. No suitable seed bearing trees were found in the other CSIRO source areas represented in SS-8, SS-9, SS-11, ORNL-35, and ORNL-36. Six new cold-site sources (Paddy's River, Muswellbrook, Nerriga, Cessnock, Nymboida, Mainsfield), more southerly or higher in altitude than previously tested sources and with recorded lows from -6 to -9°C, contributed 32 seedlots.

After planting, survival was high, in spite of generally suboptimal seedling vigor that varied among seedlots (Table B-3). Overall survival after the very hot weather at and following planting time exceeded 97%, as most seedlots had no mortality and the lowest survival was 81%. Seedling vigor averaged 2.6, indicating a seedling height of approximately 20 cm. The best seedlings were more than 25 cm in height and had firm, well-developed root systems. Several seedlots averaged above 3.0 in vigor, while the poorest seedlots had short, low-vigor seedlings. In general, seedling quality reflected the relatively short nursery time and small container size (Ray Leach fir-size container) that characterized the propagation of these E. amplifolia.

Table B-3. Average and range among progeny means for 1-month survival and vigor and 12-month survival and height of E. amplifolia sources in ORNL-39.

		1-month				12-months			
	No. of	Survival (%)		Vigor		Survival(%)		Height (m)	
Source	Prog.	Ave.	Range	Ave.	Range	Ave.	Range	Ave.	Range
Checks	4	100	-	1.0	.8-1.0	62.5	43-79	.87	.6-1.1
Paddy's River	10	96.7	86-100	2.5	1.7-3.0	85.7	71-100	1.21	1.0-1.5
Wilberforce	6	94.0	81-100	2.9	2.0-4.0	81.3	57-100	1.27	1.0-1.5
Putty Road	12	96.0	86-100	3.1	2.3-3.7	85.3	67-100	1.35	1.1-1.6
Muswellbrook	2	95.2	91-100	3.3	3.0-3.7	90.5	-	1.99	1.9-2.1
Stroud	1	100.0	-	2.0	-	71.4	-	2.10	-
Nerriga	8	99.3	95-100	2.8	1.5-4.0	89.5	76-100	1.02	.5-1.3
Cessnock	3	96.8	91-100	2.2	1.7-2.5	81.0	71-91	1.23	.9-1.4
Nerong	9	99.4	95-100	2.7	2.0-4.0	98.3	71-95	1.20	1.0-1.4
Nymboida	6	99.2	85-100	2.4	1.5-3.7	82.9	64-100	1.20	.8-2.1
Woolomombie	6	100.0	-	2.4	1.8-3.0	81.7	57-100	1.48	1.1-2.3
Mainsfield	4	95.2	86-100	2.0	1.7-2.3	75.0	48-91	.99	.9-1.1
Overall	69	97.4	81-100	2.6	.8-4.0	82.6	43-100	1.22	.5-2.3

After twelve months, survival had decreased to 83%, and average tree height was 1.2 m. The Winter 1986-87 freezes caused only foliage damage to a few trees; most trees retained their leaves through the winter. Replication influences, also the result of confounding seedling vigor with replication, were observed for tree height and survival (e.g., Rep 1 - 2.9 seedling vigor, 1.4 m, 92% survival; Rep 3 - 2.1 vigor, 1.2 m, 75%). Several trees exceeded 3 m in height, with the tallest being 3.8 m.

Progeny variability was significant, as the new selections performed better than the checks included to represent the best performers in SS-9 and SS-11. The four checks, including Sources 1-93 and 2-3, averaged 62% survival and .8 m height and were among the poorest of the seedlots. The new selections, in comparison, averaged 85% survival and 1.2 m height. Of the 65 selections from 11 sources, the two progenies from Muswellbrook were superior for height and survival, and progenies from the Nymboida and Woolomombie areas were also exceptional. To date, these selections have not been evaluated for tolerance to extreme cold such as occurred in 1983 and 1985, but they have tolerated more typical freezes in northern Florida.

Central Florida

Earlier research by the U.S. Forest Service indicated that of four eucalypts suited to southern Florida, E. camaldulensis was the best choice for dry sand ridges (Geary et al., 1983). Genetic improvement efforts with this species were limited initially to three small first-generation seed orchards. From these orchards and other introductions, the genetic base population CT-74 was developed by the Forest Service and converted to a seedling seed orchard in 1984 (Figure B-1). The current composition of CT-74 involves 243 trees representing 150 ortets selected

in CT-74 and elsewhere in central and southern Florida after the 1982 freeze (Table D-10). Forty-five of these selections are represented by two to five ramets. The orchard has not been progeny tested.

SS-8: SS-8 compared species primarily for frost-hardiness and, to a much lesser extent, vigor. At seven-months, *E. amplifolia*, *E. camaldulensis*, *E. dunnii*, *E. grandis*, and *E. robusta* ranged from 82 to 95% in survival (Table B-4). Height of *E. camaldulensis* was significantly greater than all other species.

Figure B-1. 11-year-old *Eucalyptus camaldulensis* seed orchard CT-74 near LaBelle.

Table B-4. Comparison[1] of mean height and survival of five *Eucalyptus* species at 7-, 17-, and 20-months in SS-8.

Species	No. of Sources	7-month Survival (%)	7-month Height (m)	17-month Survival (%)	17-month Height (m)	20-month Survival (%)
E. amplifolia	4	94 (88-100)[2]	.34c (.24-.40)	60b (54-63)	.31b (.2-.4)	21b (17-26)
E. camaldulensis	18	95 (83-100)	.60 (.24-.86)	82a (0-100)	.97a (.5-1.4)	69a (0-100)
E. dunnii	3	82 (71-92)	.27d (.15-.32)	11c (0-29)	.43b (-)	8c (0-25)
E. grandis	32	83 (50-96)	.32c (.16-.42)	16c (4-42)	.58ab (.3-.8)	1c (0-13)
E. robusta	1	100 (-)	.44b (-)	54b (-)	.66ab (-)	21b (-)

[1] Species means not sharing a common letter within a trait are significantly different at the 5% level.
[2] Range among source means is given in parentheses.

The superiority of E. camaldulensis in SS-8 increased during the 1985 growing season (Table B-4). After 17 months, all but one E. camaldulensis source surpassed an E. grandis progeny (1012) checklot for survival, while 16 E. camaldulensis sources were taller than this check. Individual E. camaldulensis trees were frequently more than three times as tall as the best tree of 1012.

After the December 1985 freeze, only the survival of E. camaldulensis was acceptable, some three times more than that of E. amplifolia and E. robusta. Very few E. grandis sources had survival above 10%. Nine E. camaldulensis sources exceeded 70% survival.

The strong performance of E. camaldulensis both in terms of frost-hardiness and general vigor was unexpected. While there had been earlier indications of its adaptability to central Florida (Geary et al. 1983), worldwide experience (e.g., in South Africa (Nixon, 1983; Darrow, 1983), Argentina (Mendonza and Alliani, 1983)) with E. camaldulensis provided no basis for expecting high survival after unusually low temperatures. Its apparent frost-hardiness and good early vigor in comparison to the E. grandis standard suggest that E. camaldulensis may be an alternative species for "palmetto prairie" sites. Conversely, E. amplifolia and E. dunnii were not promising.

SS-2: Three species, and particularly some E. camaldulensis clones, exhibited good frost tolerance in SS-2, a central Florida site representative of some 250,000 acres of sandhills that formerly supported citrus. While Grevillea robusta had 73% survival after the cold winters of 1983-84 and 1984-85, it did not have rapid height regrowth, averaging only 1.2 m in height after 29 months. The 32% of Acacia mearnsii that survived had excellent vigor, 4.0 m in height and 5.1 cm in DBH at 29 months, but the species may not be adequately frost resistant. Survival of E. camaldulensis however was excellent with good growth as individual trees were up to 9 m in height (Table B-5, Figure B-2). The five clones varied in performance, and clone 172 had particularly exceptional survival and vigor.

Table B-5. Survival, height, and DBH of five E. camaldulensis clones and one E. tereticornis source at 29-months in SS-2 and 47-months in SS-3.

	SS-2				SS-3			
Species/Clone	No. Planted	Survival (%)	Height (m)	DBH (cm)	No. Planted	Survival (%)	Height (m)	DBH (cm)
E. camaldulensis	172	84	3.7	3.1	172	61	2.3	1.9
171	52	74	3.8	3.4	88	57	2.6	2.1
172	9	100	6.1	5.2	-	-	-	-
174	43	94	4.1	3.5	43	75	2.3	1.9
178	25	84	1.9	1.6	-	-	-	-
BH	43	79	3.8	2.9	41	54	1.5	1.1
E. tereticornis	172	69	1.1	-	172	85	2.6	3.5

Figure B-2. 2.5-year-old Eucalyptus camaldulensis clones in SS-2.

SS-3: On this "palmetto prairie" site, three E. camaldulensis clones averaged 61% survival and over 2 m in height after 47 months (Table B-5). The one E. tereticornis source had higher survival and was larger in size. No other species of 16 tropical and subtropical species planted (Rockwood and DeValerio, 1986) survived the 1983 and 1985 freezes and grew well. None of the E. camaldulensis clones had ramets as large as the best E. tereticornis trees, which were up to 7.8 m tall with a 11.3 cm DBH. Thus, while the E. tereticornis source was not equal to E. camaldulensis in size and survival on the sandhills, it was much better than E. camaldulensis on the wetter site.

ORNL-38: The E. camaldulensis and E. tereticornis sources in ORNL-38 had good early vigor and survival on this sandhills site (Table B-6). After four months, both species averaged about 70% survival and over .8 m in height. Variability among sources within species was considerable, with the better sources in each exceeding 80% survival and 1 m in height.

The February 1987 freeze, with a low of 23°F after a long period of above average temperatures, provided a rigorous frost-hardiness test. Overall, about 22% of the trees were undamaged. Tree size appeared to be

unrelated to frost damage. Frost-hardiness of E. camaldulensis, with 4.7% of the trees completely undamaged, was less than that of E. tereticornis with 24.7% undamaged trees. Generally, E. camaldulensis also received more serious stem damage than E. tereticornis. Ten E. tereticornis sources had excellent frost-resistance, with 50 to 79% undamaged trees.

Growth during the second growing season was frequently vigorous, with individual trees nearly 3 m in height at age 13 months. Trees that had been killed to the ground by frost generally coppiced vigorously, demonstrating good frost resilience. Survival, which decreased about 2%, was again similar at the species level but varied considerably among sources within species. Twenty-two sources had survival above 80%. E. tereticornis was similar to E. camaldulensis in height, with source differences again significant.

Overall in ORNL-38, only E. tereticornis sources had more than 50% frost-resistant trees and exceeded 70% survival and 1.4 m in height after 13 months. These promising E. tereticornis sources tended to originate in Queensland, Australia. Interestingly though, the 10 E. camaldulensis clones selected by the Forest Service from various studies and plantations performed very well in frost resistance and were the tallest trees in the study, due in part to their larger size at the time of planting.

Table B-6. Four-month height and survival, six-month frost resistance, and 13-month height and survival evaluations of 20 Eucalyptus camaldulensis and 75 E. tereticornis sources in ORNL-38.

Trait	E. camaldulensis Mean	E. camaldulensis Range	E. tereticornis Mean	E. tereticornis Range
Four-month Survival (%)	69.5	46.7-86.7	70.7	43.3-96.7
Four-month Height (m)	.84	.65-1.04	.83	.52-1.06
Six-month Frost Resistance (%)	4.7a[1]	0.0-27	24.7b	0.0-100.0*
Thirteen-month Survival (%)	68.0	40-86.7*	68.9	33.3-96.7*
Thirteen-month Height (m)	1.20	.91-1.62*	1.24	.56-1.85*

[1] Species means not sharing the same letter are significantly different at the 5% level.
*Variability among sources within species significant at the 5% level.

Southern Florida

In SS-8, none of the E. grandis sources had better survival than progeny 1012, which agrees with comparisons in GPOP77 of first-generation trees to subsequent generations. Of the 31 new sources, 10 exceeded 20% survival after the January 1985 freeze. Such inversion freezes in southern Florida can be especially damaging to short trees, leading to differentials in assumed frost resistance actually being related to tree size (Franklin and Meskimen, 1983). Within E. grandis after seven-months however, no meaningful height differences existed among the sources.

While only one of these 10 was taller than 1012, they like other new introductions retained in GORCH77 have good potential for broadening the E. grandis population and imparting some frost hardiness.

ORNL-33: Additional guidelines for selecting E. grandis sources for introduction were developed through analysis of first-generation material in GPOP77. Significant provenance and families within provenance effects were detected (Table B-7). The percentages of the total variation for height due to provenance and family within provenance were 5.4% and 5.0% at age 7 months and 15.9% and 14.5% at age 30 months. For DBH at age 30 months, provenance contributed 14.8% and family within provenance 16.5%. Duncan's test results are given in Table B-8. Ranking of provenances based on family means was pretty consistent at both ages showing that provenances from northeastern New South Wales (i.e., Urunga and Coffs Harbour) and southeastern Queensland (i.e., Bellthorpe and Gympie) were among the best performers. However, difference within that region may be expected, as illustrated by Kenilworth (from a geographic area close to Bellthorpe), which was significantly inferior to Bellthorpe in height at 30 months.

Table B-7. Mean squares and variance component contribution (%) of sources of variation for seedling height at seven-months (sh7), height and DBH at 30-months (sh30 and sd30) and coppice height at three-months (ch3), height and DBH at 30-months (ch30 and cd30), and height, DBH, volume, frost score, and number of stems/stool at 64-months (ch64, cd64, cv64, cFr64, and cns64) for E. grandis provenances in GPOP77.

	Provenances			Family(prov)			Error		
Traits	Df	Mean Squares	Var Comp.	Df	Mean Squares	Var Comp.	Df	Mean Squares	Var Comp.
sh7	16	1.67**	5.4	76	0.38**	5.0	2422	0	89.6
sd30	16	10484**	14.8	76	2378**	16.5	2483	314	68.7
sh30	16	9164**	15.9	76	1790**	14.5	2483	266	69.6
ch3	16	635	0.2	75	713*	1.3	1939	555	98.5
ch30	16	1494**	9.7	75	4371**	13.8	1682	330	76.5
cd30	14	934**	11.9	71	409	14.3	257	231	73.8
cd64	16	7726**	8.0	74	2590**	10.7	1254	879	81.3
ch64	16	6274**	11.1	74	1722**	11.1	1254	552	77.8
cv64	16	7596**	4.6	74	2873**	4.8	1254	1605	90.6
cFr64	16	39.23	0.7	76	31.89**	8.2	2507	9.06	91.1
cns64	16	1.35	0.9	74	1.42**	4.3	1255	.85	94.8

** Significant at the 1% level.

The contribution of provenance and family within provenance for both 7 and 30 months seedling height were almost the same (Table B-7). These results would indicate genetic gain can be obtained from selection among provenances and individual trees within provenances.

Juvenile-mature correlations were strong for seedling performance. Pearson correlation coefficients, based on provenance means, between height at 7 months and DBH-height at 30 months were 0.83 and 0.82, respectively, and 0.98 between DBH and height at 30 months (Table B-9). The genetic correlation between height at 7 and 30 months was 0.92.

There was no significant provenance effect for coppice height at 3-months, but family within provenance effect was detectably significant (Table B-7). The percentages of the total variation due to provenance and family within provenance were 0.2% and 1.3%, respectively. The height and DBH differed significantly for both provenance and family within provenance effects at age 30 months (Table B-10). The percentages of the total variation due to provenance and family within provenance were 9.7% and 13.8% for height, respectively, and 11.9% and 14.3% for DBH, respectively.

Table B-8. Duncan's multiple range test of seedling height at 7-months and DBH and height at 30-months (northern half only) of E. grandis provenances in GPOP77.

Provenance	Height (m) at 7 months (northern)	Height (m) at 7 months (southern)	DBH (cm) at 30 months	Height (m) at 30 months
Urunga(NSW)	1.47 a[1]	1.76 ab	6.10 a	6.69 a
Gympie(QLD)	1.38 ab	1.63 abc	5.09 abc	5.85 ab
Cooloolabin(QLD)	1.36 abc	1.76 ab	4.92 abcd	5.40 abcd
Bellthorpe(QLD)	1.36 abc	1.72 abc	6.61 ab	6.05 ab
Mapleton(QLD)	1.33 abcd	1.82 a	4.74 abcd	5.45 abcd
West Cooroy(QLD)	1.31 abcd	1.67 abc	4.97 abcd	5.51 abc
Como(QLD)	1.30 abcd	1.66 abc	4.89 abcd	5.49 abc
Coffs Harbour(NSW)	1.29 abcd	1.64 abc	5.59 ab	6.07 ab
Mid-North Coast(NSW)	1.28 abcd	1.63 abc	5.11 abc	5.62 abc
Danbulla(QLD)	1.27 abcde	1.71 abc	4.61 abcd	5.25 abcd
Kenilworth(QLD)	1.21 abcde	1.58 abc	4.21 abcd	4.72 bcd
Mt Mee(QLD)	1.20 bcde	1.65 abc	5.01 abcd	5.43 abcd
Crediton(QLD)	1.15 bcde	1.45 abcd	3.72 bcd	4.54 bcd
Conondale(QLD)	1.10 cde	1.42 abcd	3.20 cd	3.83 cd
Mt Glorious(QLD)	1.07 de	1.11 d	3.37 bcd	4.32 bcd
Styx River(NSW)	1.06 de	1.40 bcd	3.50 bcd	3.81 cd
Gladfield(QLD)	1.01 e	1.31 cd	2.85 d	3.51 d
Mean	1.20	1.56	4.19	4.78

[1] Provenance means sharing a common letter within a trait are not significantly different at the 5% level.

Table B-9. Pearson correlation coefficients among seedling DBH and height of E. grandis provenances at 7- and 30-months in GPOP77 (based on provenance means).

	Height at 30 months	DBH at 30 months
Height at 7 months	0.82**	0.83**
Height at 30 months		0.98**

**Significant at the 1% level.

There were significant differences for provenance and family within provenance effects for all the variables considered at coppice age 64 months (Table B-7). The percentages of the total variation due to provenance and family within provenance were 8% and 10.7% for DBH, 11.1% and 11.1% for height; 4.6% and 4.8% for volume, respectively.

The provenances did not differ for frost resilience score and number of stems/stool (Table B-11). Family within provenance did show significant differences for both (Table B-7). The percentage of the total variation due to provenance was 0.7% (frost resilience) and 0.9% (number of stem/stool) and due to family within provenance 8.2% (frost resilience) and 4.3% (number of stems/stool) (Table B-7).

Table B-10. Duncan's multiple range test of coppice height and DBH of *E. grandis* provenances at 30- and 64-months in GPOP77.

Provenances	Height(m) 30-months	DBH (cm) 30-months	Height(m) 64-months	DBH (cm) 64-months
Urunga(NSW)	4.38 a[1]	3.85 a	7.03 a	6.19 a
West Cooroy(QLD)	3.78 ab	3.91 a	5.60 abc	4.96 ab
Como(QLD)	3.58 ab	4.26 a	5.87 ab	5.08 ab
Mapleton(QLD)	3.52 ab	4.23 a	5.86 abc	4.49 abc
Cooloolabin(QLD)	3.48 ab	4.34 a	5.48 abc	4.82 abc
Mid-North Coast(NSW)	3.29 ab		4.28 bcd	3.03 bc
Gympie(QLD)	3.25 ab	3.50 a	5.76 abc	4.76 abc
Mt Mee(QLD)	3.15 abc	3.65 a	4.79 abcd	3.78 abc
Danbulla(QLD)	3.07 abc	4.12 a	5.06 abcd	4.21 abc
Bellthorpe(QLD)	2.97 abc	5.13 a	4.35 bcd	3.25 abc
Crediton(QLD)	2.94 abc	3.66 a	4.48 abcd	3.41 abc
Coffs Harbour(NSW)	2.50 abc	4.77 a	5.07 abcd	3.48 abc
Kenilworth(QLD)	2.47 abc	3.65 a	4.08 bcd	2.93 bc
Gladfield(QLD)	2.34 abc	3.65 a	3.39 bcd	2.62 bc
Conondale(QLD)	2.04 bc	2.77 a	3.50 bcd	2.46 bc
Styx River(NSW)	1.65 bc		3.27 cd	2.10 bc
Mt Glorious(QLD)	1.00 c	0.50 b	2.50 d	1.70 c
Mean	2.84	3.61	4.57	3.62

[1] Provenance means sharing a common letter within a trait are not significantly different at the 5% level.

Coppice DBH and height were highly correlated at the same age and across ages (Table B-12). At age 30 and 64 months, correlation coefficients between DBH and height were 0.80 and 0.93, respectively. Coppice height and DBH at age 30 months were highly correlated with coppice height, DBH and volume at age 64 months.

No appreciable changes in rank among provenances for seedling height at 7 and 30 months were observed. At age 7 months 11 provenances were above the mean; at age 30 months 10 of these provenances were also above the mean. The worst provenances for seedling height at age 7 months (i.e., Styx River, Mt Glorious, Conondale, and Gladfield), were also the worst at age 30 months (Table B-8). The correlation coefficient based on

Table B-11. Duncan's multiple range test of coppice volume, frost score, and number of stems/stool for E. grandis provenances at 64-months in GPOP77.

Provenances	Volume	Frost Score	No. of Stem/Stool
Urunga (NSW)	46.23 a[1]	2.50 a	1.45 a
Como(QLD)	34.43 ab	3.55 a	1.87 a
West Cooroy(QLD)	29.70 abc	4.02 a	1.68 a
Cooloolabin(QLD)	28.55 abc	3.81 a	1.77 a
Gympie(QLD)	26.02 abc	4.27 a	1.45 a
Mapleton(QLD)	24.93 abc	4.46 a	1.70 a
Danbulla(QLD)	22.78 abc	4.17 a	1.57 a
Mt Mee(QLD)	20.63 abc	4.26 a	1.88 a
Coffs Harbour(NSW)	15.11 abc	3.91 a	1.81 a
Bellthorpe(QLD)	13.20 bc	4.77 a	2.14 a
Crediton(QLD)	12.50 bc	3.78 a	1.72 a
Mid-North Coast(NSW)	11.15 bc	4.43 a	1.58 a
Kenilworth(QLD)	10.36 bc	4.15 a	1.93 a
Gladfield(QLD)	9.43 bc	5.16 a	2.03 a
Conondale(QLD)	7.57 bc	5.52 a	1.68 a
Styx River(NSW)	2.38 bc	6.29 a	1.33 a
Mt Glorious(QLD)	0.72 c	7.21 a	3.00 a
Mean	18.09	4.29	1.78

[1] Provenance mans sharing a common letter within a trait are not significantly different at the 5% level.

Table B-12. Pearson correlation coefficients among seedling height at 7-months (sh7), coppice height at 3- (ch3), 30-(ch30), and 64-(ch64) months, coppice DBH at 30- (cd30) and 64- (cd64) months, volume (cv64), frost scores (cfr64) and number of stems/stool (ns64) at 64-months of E. grandis provenances in GPOP77 (based on provenance means).

	ch3	ch30	cd30	cd64	ch64	cfr64	ns64	cv64
sh7	-0.19	0.69**	0.63**	0.61**	0.62**	-0.22*	0.0 7	0.46**
ch3		-0.13	-0.07	-0.18	-0.19*	-0.22*	-0.18	-0.16
ch30			0.80**	0.89**	0.84**	-0.46**	-0.12	0.76**
cd30				0.69**	0.67**	-0.26**	-0.06	0.60**
cd64					0.93**	-0.28**	-0.11	0.92**
ch64						-0.22*	-0.10	0.86**
cfr64							0.32**	-0.22*
ns64								-0.17

provenance means between the two ages for height was 0.82 (Table B-9). Supporting the early selection in E. grandis in Florida, Skolmen (1986), working in a E. grandis provenance trial in Hawaii, reported that the best and the worst performers were apparent at age 1 year and were definite by 3 years. Darrow (1983), comparing 16 E. grandis seedlots

growth data from the four and eight year measurements in South Africa, reported a correlation coefficient of only 0.41 between the two measurements and concluded that rank position at 4 years was not a good indicator of rank position at age 8 years. However, when only the best 50% of the seedlots were considered, there were fewer changes. In other words, superior seedlots of E. grandis selected at 4 years generally maintained their superiority to 8 years (Roeder, 1985). As the species is likely to be grown on a relatively short rotation age it is reasonable to assume that the most vigorous 20% of the provenances at age 5 years will include the most productive provenances at rotation age (Griffin, 1983).

For coppice height and DBH at all ages considered, family within provenance variation was more important than provenance variation. The only exception was height and volume at age 64 months (Table B-7) where both provenance and family within provenance variance components were similar. The same results were obtained in the analysis of the number of stems/stool and frost resilience scores where significant differences were detected only for family within provenances variation. Skolmen (1986) analysing the results of a coppice study in a provenance trial with E. grandis in Hawaii, concluded that variation from tree to tree was larger than seed source, and he recommended vegetative propagation of selected individuals as means of improving propagation of selected individuals as means of improving coppice ability.

As pointed out by Reddy (1985), GPOP77 had some recognized limitations. The experimental design used (CRD) was not the best to avoid the microsite variation caused by planting 529 open-pollinated families in 60 single tree plots on 17.3 ha. Slow growing trees at early stages may be suppressed by the fast growing ones. This could be important since the 93 families representing 17 provenances selected for this research represented only 31% of the total number of families in GPOP77, the rest being second, third, and fourth-generation selections. The imbalance in the number of families per provenance causes some provenance means to be better estimated than the means of those provenances with only one or few families (Sniezko, 1986). Finally, the absence of replication over different sites precluded estimation of site by provenance interaction. The fact that most of the provenances from Australia considered in this research were from Queensland and that the few originating from New South Wales were represented by only one family limited the study of variation for any trait associated with latitude or altitude of origin.

Overall, the performance of E. grandis provenances in SS-8 and GPOP77 suggests important source differences for growth but not frost-resistance. Sources from northeastern New South Wales and southeastern Queensland appear to offer more vigor, but no general recommendation on provenance is apparent. Within preferred sources for growth, family differences may be utilized for further growth and frost-resistance improvement. Intensive representation of these preferred sources through individual tree seedlots seems warranted in future introduction of E. grandis germplasm.

ORNL-35 and ORNL-36: On the drained organic soil in ORNL-35 and the "palmetto prairie" of ORNL-36, *E. amplifolia* did not grow as well as *E. grandis* or *E. robusta* (Tables B-13 and C-4). This differential was influenced by the considerable improvement accruing from four and three generations of selection, respectively, that have been practiced with

Table B-13. Five-month and 12-month means and ranges for height and survival of five *Eucalyptus* species in ORNL-35 and ORNL-36.

Species	ORNL-35 Surv. (%)	ORNL-35 Hgt. (m)	ORNL-36 Surv. (%)	ORNL-36 Hgt. (m)
	5-month			
E. grandis	87.8 (71-100)[1]	2.26 (1.39-2.49)	97.9 (90-100)	.99 (.74-1.39)
E. robusta	92.1 (83-100)	2.39 (2.04-2.68)	96.0 (70-100)	1.05 (.85-1.22)
E. amplifolia	75.0 (63-85)	1.96 (1.71-2.20)	98.8 (95-100)	.73 (.48-.95)
E. dunnii	55.0 (40-63)	1.36 (1.26-1.44)	72.3 (56.7-95)	.52 (.46-.58)
E. tereticornis	- -	- -	97.1 (90-100)	1.30 (.50-2.10)
	12-month			
E. grandis	83 (68-98)	5.4 (4.3-6.1)	96.2 (86.7-100)	1.59 (1.17-2.28)
E. robusta	88 (70-98)	5.3 (4.6-5.9)	95.8 (70-100)	1.56 (1.34-1.84)
E. amplifolia	70 (58-92)	3.9 (3.5-4.5)	95.4 (93.3-100)	1.18 (.59-1.82)
E. dunnii	40 (27-48)	4.2 (4.0-4.5)	72.3 (56.7-95.0)	1.12 (.81-1.28)
E. tereticornis	- -	- -	95.2 (90-100)	1.92 (1.15-2.73)

[1] Range among 27 and 16 progenies of *E. grandis* and *E. robusta*, respectively, and 6, 5, and 7 sources of *E. amplifolia*, *E. dunnii*, and *E. tereticornis*, respectively.

these two species (Reddy et al. 1985, Dvorak et al. 1981). However, under the relatively warm and dry conditions that followed the December 1986 harvest, E. amplifolia had a much higher coppicing rate (58% vs. 9% or less, Table C-4). Consequently, for coppice rotations, E. amplifolia may have greater long-term potential. Across both sites, E. dunnii performed poorly for survival and height.

The strong performance of the seven E. tereticornis sources in ORNL-36 (Table B-13) suggests that the species may be suitable for "palmetto prairie" sites as well as the sand ridge sites represented by ORNL-38. The species was equal to or better than E. grandis and E. robusta progenies at 5 and 12 months. However, the sources in ORNL-36 were not common to ORNL-38.

Conclusions

New genetic materials were introduced and evaluated for eight Eucalyptus species. The E. grandis genetic base can be broadened with sources appropriate for use in Florida. Sources from northern New South Wales and southeastern Queensland are preferred for further evaluation. With these sources of E. grandis in the next base population, relatedness among progenies can be diluted, and the potential for obtaining superior hybrids can be increased.

Representation of E. amplifolia should be adequate to complete evaluation of the species for use in frost-frequent areas and to support long-term improvement. E. amplifolia appears suited for closely-spaced, short-rotation, multiple coppice systems on fertile sites. Excellent regrowth from frost damage may be expected, and E. amplifolia may provide for a longer harvesting season. Additional frost resistance must be developed before frost hardiness can be assured.

E. camaldulensis has shown promise as a frost-hardy, rapidly growing species for south-central Florida. Some sources of E. camaldulensis appear adaptable to sand ridge and "palmetto prairie" sites. Further genetic testing of these sources is needed. A second-generation seed orchard may provide suitable planting stock, subject to the completion of progeny testing. Certain clones appear to have excellent growth and frost-tolerance.

Similarly, E. tereticornis has demonstrated potential in south-central Florida as a frost-hardy species with good growth. Various sources have proven frost-hardy on dry sandy sites and other sources are comparable to other species on "palmetto prairie" in growth. Further evaluation is needed.

Task References

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TASK C. EUCALYPTUS COPPICE PRODUCTIVITY AND MANAGEMENT.

This task assessed coppice yields of E. grandis, E. robusta, their hybrids, E. dunnii and E. amplifolia in response to genetics, spacing, site, site amendment, time of harvest, and age of stand.

Methods

DP1: One Eucalyptus and two other species were coppiced in a University of Florida-sponsored demonstration planting established near Gainesville in April 1981 with each species in a 100-tree square plot at a 1 x 1 m spacing. The first coppice rotation of E. amplifolia was induced by a January 1982 freeze that killed the seedlings to the ground. The December 1983 freeze killed the 23-month-old first coppice to the groundline, and a first coppice of P. occidentalis and S. sebiferum was initiated at the same time the E. amplifolia plot was cleared. The E. amplifolia coppice was again killed by the January 1985 freeze, as were most of the S. sebiferum, thereby producing a third E. amplifolia and second S. sebiferum coppice. Tree height and diameter breast height (DBH) on the interior 36 trees and survival on the whole plot were measured through December 1985. Biomass yields were estimated from dry weights derived from trees harvested in December 1983 and January 1985.

ORNL-34: The study was conducted near LaBelle, Florida, in adjacent commercial plantations of E. grandis and E. robusta planted in July 1974 and 'hybrids' planted in July 1973. Spacing was 3.7 m between rows and approximately 3 m within rows (900 trees ha^{-1}). The E. grandis and E. robusta seedlings originated from bulked seedlots derived from selected seed trees in operational seed orchards of each species. 'Hybrids' evaluated in this study were bulked progenies of seven selected hybrid seed trees in the E. grandis orchard (Meskimen and Franklin 1984).

Harvesting was conducted at mid-month for 13 months from March 1979 to March 1980 in 10-row wide strips within each plantation. Harvest plots were sequentially cut from south to north within each strip to minimize shading of coppice by adjacent trees. Each harvest plot consisted of 10 rows of at least 10 trees per row for a minimum of 100 trees within a rectangular area of c. 0.111 ha. Trees were felled by chainsaw producing a moderately slanted cut at an c. height of 10 cm.

At felling, stump height, tree height and diameter at breast height (DBH) were measured. Height of the tallest coppice shoot on each stool was measured at 4, 8, and 12 months after harvest, and the coppice shoot was classified as dead, alive, or missing. Measurements taken in December 1983 were height and DBH of the tallest stem, DBH of two other stems at least half the DBH of the tallest stem, and total number of such stems per stool. To reduce border effects, measurements from the interior six rows only were analyzed.

The December 1983 measurements, at coppice ages ranging from 45 to 57 months, were adjusted so that all plot values represented 48 months from harvest. For example, March 1979 height and DBH data, representing growth for 57 months, was multiplied by 48/57 so that the data represented growth for 48 months.

Percentage survival, means of height, DBH, and number of stems, and correlation coefficients between preharvest and coppice variables were calculated. The DBH and height of the trees at harvest were correlated with height at coppice age 12 months and height and DBH at coppice age 48 months. All correlations were made on a plot mean basis.

Heights at 48 months were generated for all counted coppice stems using height-DBH formulas derived from measurements of the tallest stem on each stool. Where the stem count on a stool exceeded the three measured, the excess stems were assigned the DBH value of the smallest measured stem. The calculated heights (in m) and DBHs (in cm) were used to estimate the dry weight of all counted stems one each stool, using formulas developed by Rockwood et al. (1982):

E. grandis:	Stem + Branch Dry St. (kg) = $-0.364 + 0.0163D^2H$
E. robusta:	Stem + Branch Dry St (kg) = $0.612 + 0.0149D^2H$

The E. robusta formula was used for the 'hybrids'. Yield (ha^{-1}) for each plot was obtained by dividing the summed weights of all coppice stems in a plot by the reciprocal of the effective plot area.

ORNL-35: Eucalyptus grandis, E. robusta, E. amplifolia, and E. dunnii were planted in July 1985 at Belle Glade to estimate the effects of genetics, spacing, rotation length, and time of harvest on coppice productivity. Until the two rotation lengths and two harvest times were imposed in December 1986, the study effectively has six replications of 10-tree row plots of 27 E. grandis progenies, 16 E. robusta progenies, six E. amplifolia sources, and five E. dunnii sources and 7 x 10 m plots of E. grandis at 1 x 1 m and 1 x 2 m spacings. Two replications also include 25-tree square plots of five E. grandis progenies and a third spacing of E. grandis at 1 x .5 m. Survival and height were measured semiannually from December 1985 to December 1986. Three replications were harvested in December 1986, and the resulting coppice was monitored in March 1987 and December 1987. A fourth replication was harvested in March 1987 and was assessed in December 1987.

SS-1: Of the 12 species initially established in this species screening trial at Belle Glade (Rockwood and Devalerio 1986) and harvested in December 1985, S. sebiferum survived the freeze and coppiced well. Its coppice productivity was determined in December 1986.

ORNL-16: Of seven species established at 1 x 1 m spacing at Belle Glade in May 1980 and harvested periodically to induce coppicing, E. grandis, E. robusta, and Taxodium distichum had acceptable coppice survival. Concluding measurements of the yield of T. distichum were taken in December 1986.

Results

DP1: Both E. amplifolia and S. sebiferum demonstrated excellent coppicing potential (Table C-1). The vigor of the third E. amplifolia coppice was similar to earlier coppices (Figure C-1), and stool survival, which decreased slightly after the first coppice, has remained constant from the second coppice. Each stool typically retained one well-formed stem

Table C-1. Seedling (S) and Coppice (C) performance of three species in DP1, *Sapium sebiferum* in SS-1, and *Taxodium distichum* in ORNL-16.

Study/Species	Age-Rotation	Ht. n	Ht. Mean (m)	DBH n	DBH Mean (cm)	Surv. n	Surv. Mean (%)	Biomass Yield (Mg $ha^{-1}yr^{-1}$)
DP1-								
E. amplifolia	8-mo S		1.6		-	100	81	-
	23-mo 1st C		7.9		8.2	100	76	22.8
	10-mo 2nd C		3.7		2.0	100	69	9.7
	10-mo 3rd C		3.8		2.6	100	69	-
	24-mo 3rd C	42	4.07		2.64	100	68	-
	5-mo 4th C	9	3.38	23	1.77	100	66	-
P. occidentalis	33-mo S		5.6		3.4	100	97	-
	22-mo 1st C		4.2		-	100	95	-
S. sebiferum	33-mo S		5.7		4.3	100	100	-
	10-mo 1st C		2.5		1.4	100	100	8.3
	10-mo 2nd C		2.6		1.4	100	100	-
	24-mo 2nd C	64	4.14	64	2.72	100	99	-
	5-mo 3rd C	16	1.77	36	1.58	100	99	-
SS-1								
S. sebiferum	36-mo 1st C	-	8.3	-	7.9	-	37	-
ORNL-16								
T. distichum	24-mo 1st C	-	3.9	-	3.5	-	73	-
	9-mo 1st C	-	1.6	-	-	-	82	-

(Figure C-2) from an initial proliferation of shoots. Annual productivity in the first year was more than doubled by the second year's growth, indicating that coppice rotations should be at least two years. The 23 dry Mg/ha/yr, however, must be confirmed in further studies.

Vigor of *S. sebiferum* was less (Table C-1), and coppice form was different, with three stems per stool (Figure C-2). Coppice survival, on the otherhand, was better. Because other progenies/sources of *S. sebiferum* have shown better form and growth in other trials, the prospect for improving coppice performance is good.

Growth of *P. occidentalis* coppice slowed considerably in 1985, and after the second growing season was only slightly taller than 10-month-old *E. amplifolia* coppice. The trees added about one m in height after the first year, although survival remained high.

ORNL-34: Averaged over the 13 harvest plots in ORNL-34, the 56- to 68-month-old *E. grandis* and *E. robusta* were of similar preharvest height, but the *E. robusta* had larger DBH (Table C-2). Preharvest height and DBH varied more across harvest months for *E. grandis* than for *E. robusta*. The 'hybrids,' which were a year older than both species, had slightly larger tree height and DBH.

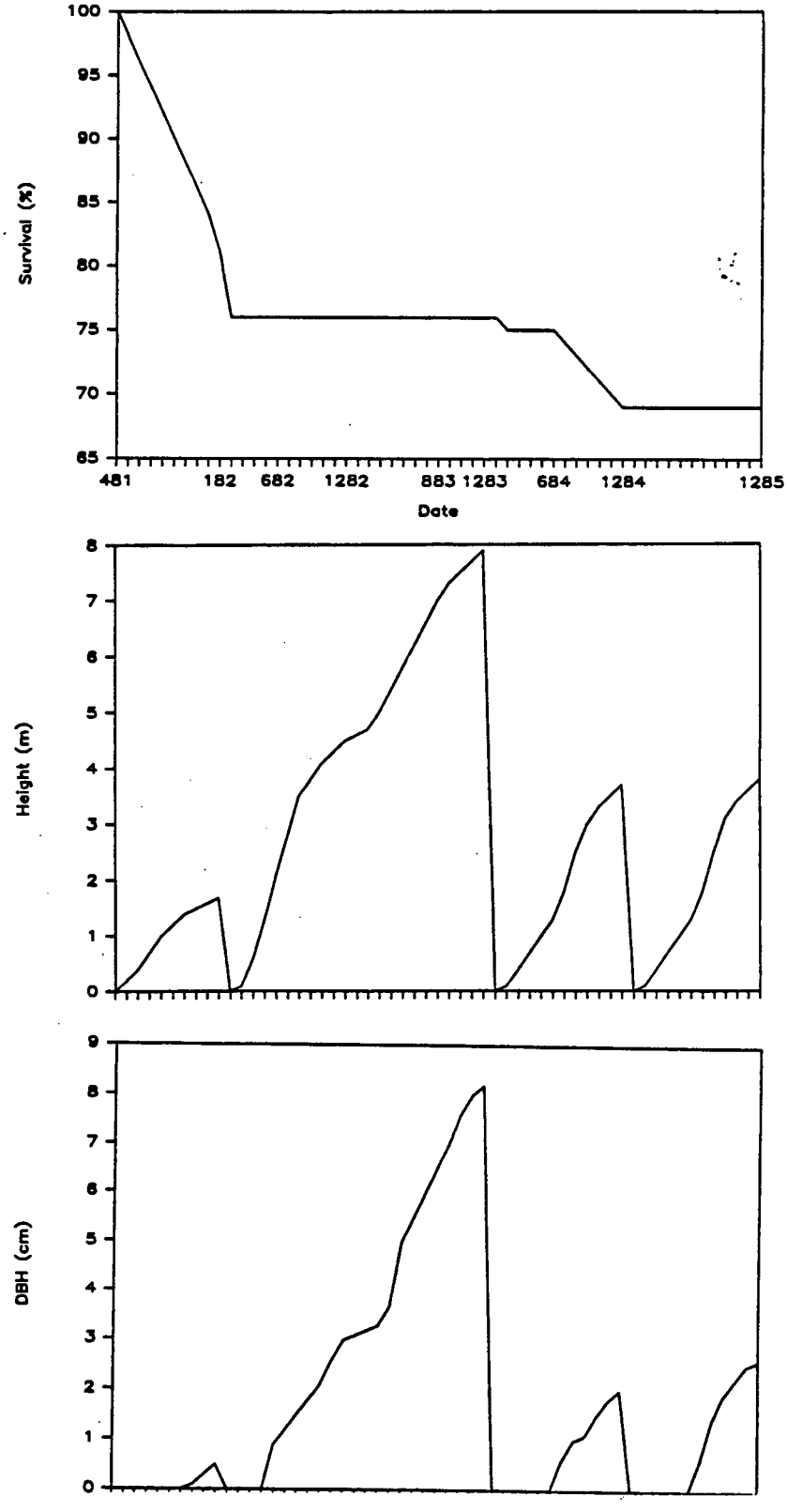

Figure C-1. Survival (top), height (middle), and DBH (bottom) of Eucalyptus amplifolia over a seedling and three coppice rotations in DP1.

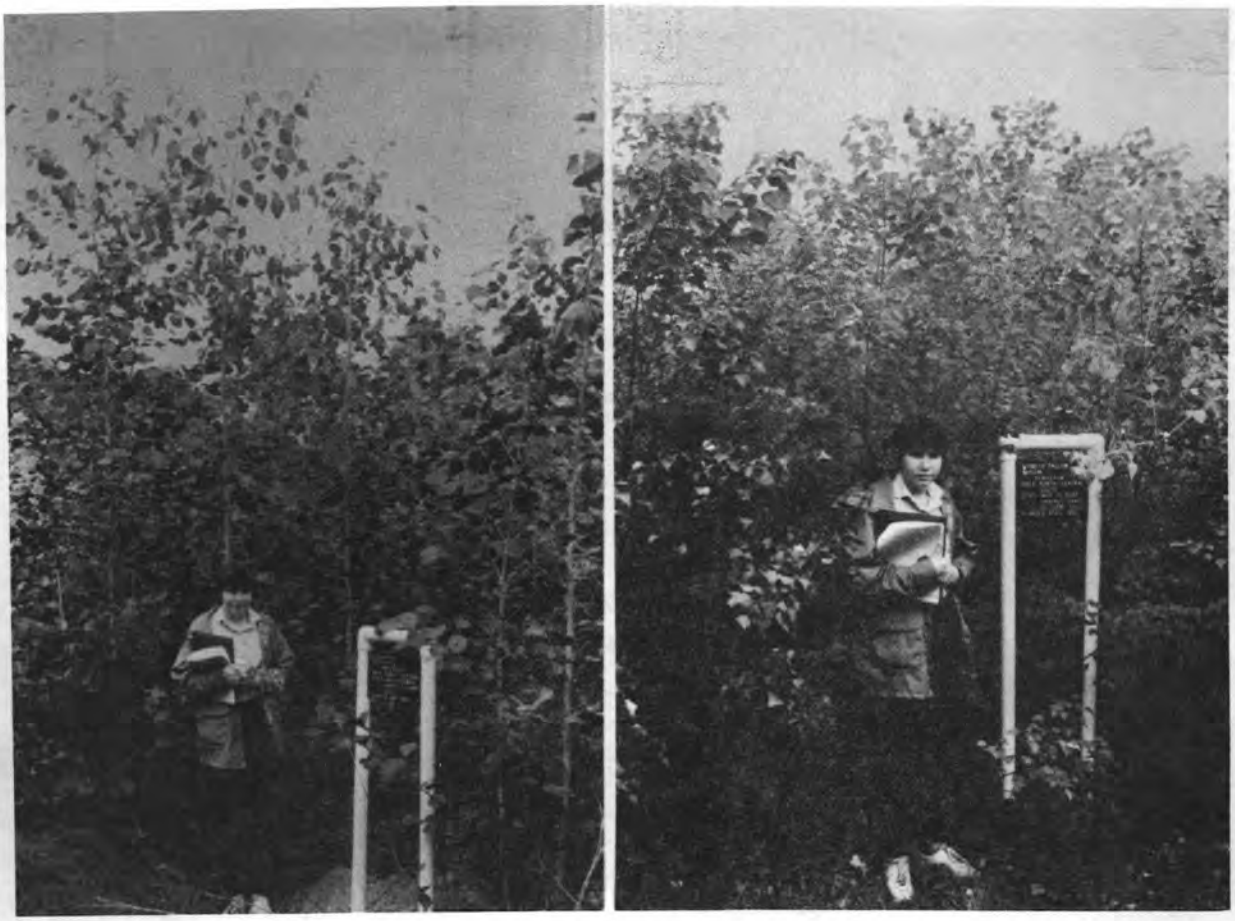

Figure C-2. Ten-month-old coppice in DP1: Eucalyptus amplifolia (left), Sapium sebiferum (right).

Significant correlations between preharvest and coppice traits (Table C-2) indicated that seedling size, and therein tree age or environment, may have influenced coppice growth. Preharvest height and DBH of E. grandis were correlated with coppice size from 4 to 48 months. Preharvest size of E. robusta and the 'hybrids' was correlated with coppice height and DBH at 48 months but not with coppice height at 12 months. Increasing coppice size with increasing seedling diameter has been noted for E. grandis in South Africa (Stubbings and Schonau 1980) and for sycamore (Platanus occidentalis) (Belanger 1979).

Coppice survival was as low as 21% with summer harvests (Fig. C-3). Between June and August, survival of E. grandis was much lower, while the 'hybrids' had a similar decrease from July to September. Survival of E. robusta exceeded 70% for all months except August.

The three eucalypts differed in their failure to coppice and in coppice mortality; two different phenomena leading to inadequate coppicing (Fig. C-4). Overall, E. grandis averaged 3.7% of stools with no coppice, while E. robusta and the hybrids' had less than 0.4% non

coppicing stools. However, the E. grandis mean reflected a high failure to coppice following harvesting in April and May. For the other 11 harvest months, the three eucalypts behaved similarly. In general, failure to coppice was less common than coppice mortality.

The 'hybrids' had the greatest coppice mortality after 12 months, E. grandis was intermediate, and E. robusta was lowest (averages of 31.6%, 22.5%, and 10.9% respectively). Mortality for the 'hybrids' was 15% or higher from April through January and more than 54% for July to September. Mortality for E. grandis was more concentrated in the summer rainy season months with 37% to 68% mortality from June to August. While E. robusta coppice mortality was typically less than 8%, the August harvest resulted in 49% mortality. Most of the coppice mortality observed at 12 months had occured by 8 months after harvest. Responses of the three eucalypts suggest that summer harvests adversely affect coppice regeneration primarily through death of coppice stems.

For all three eucalypts, correlations between early and 48-month coppice survival were high (Table C-3). Correlations changed little from 4- to 12-months, except for a slight increase for E. grandis from 4- to 8-months. These values suggest that rotation-length survival can be predicted from as early as 8 months after harvest. Since these stands were subjected to severe freezes capable of killing coppice back to the ground, early first coppice survival may be applicable to freeze-induced subsequent coppice.

Table C-2. Correlations between preharvest tree height and DBH and subsequent coppice height and DBH for E. grandis, E. robusta, and hybrids.

			Correlations with Coppice		
			Height		DBH
Preharvest Trait	$\bar{X}$	s	12 mo.	48 mo.	48 mo.
E. grandis					
Height (m)	10.6	1.55	0.76**	0.70**	0.63*
DBH (cm)	9.8	.95	0.85**	0.75**	0.67*
E. robusta					
Height (m)	10.4	.81	0.13	0.80**	0.77**
DBH (cm)	10.7	.69	0.36	0.87**	0.77**
'Hybrids'					
Height (m)	11.6	1.16	0.26	0.82**	0.79**
DBH (cm)	11.7	1.08	0.14	0.78**	0.88**

* and **, significant at the 5% levels, respectively.

Other authors have noted an influence of the season of harvest and species on subsequent coppice survival. Rockwood et al. (1982) and Rockwood and Geary (1982) in Florida reported that E. grandis coppice survival after a December cut averaged 92% after 12 months, was virtually nil after an August cut, and after a February cut reached only 31%. E. robusta had better survival than E. grandis (Rockwood et al. 1982, Rockwood and Geary 1982, and Comer and Rockwood 1984). Survival of pure

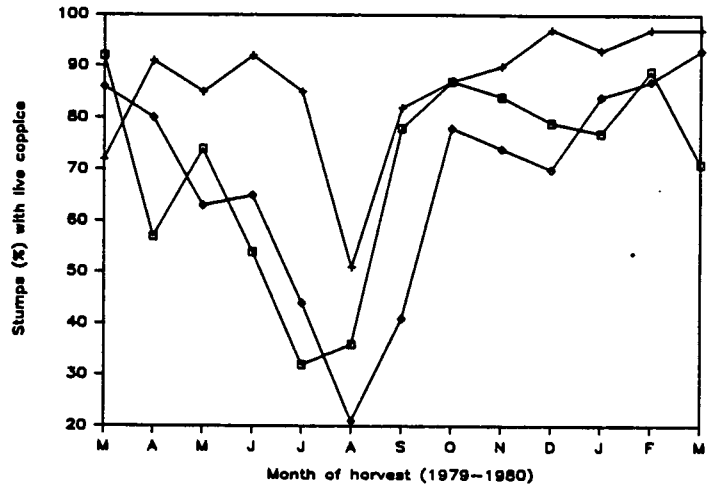

Figure C-3. Percentage of stumps with live coppice at 48-months after harvest for E. grandis (▫), E. robusta (+), and the hybrids (◆).

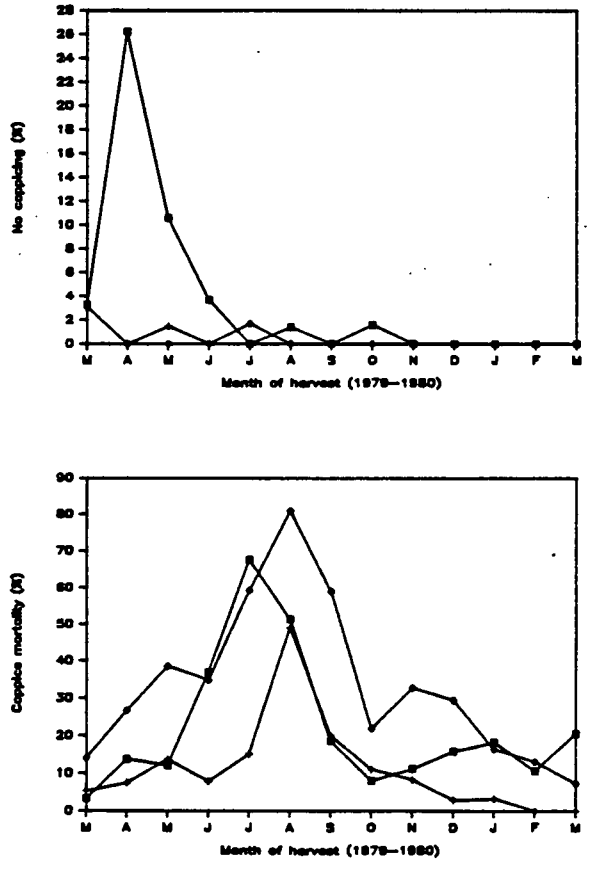

Figure C-4. Coppicing responses of E. grandis (▫), E. robusta (+), and the hybrids (◆): failure to coppice at 4-months after harvest (top), coppice mortality at 12-months after harvest (bottom).

Table C-3. Correlations between early and 48-month coppice survival and height for E. grandis, E. robusta, and hybrids.

Age	E. grandis	E. robusta	'Hybrids'
		Coppice Survival	
4	0.85**	0.86**	0.99**
8	0.99**	0.89**	0.98**
12	0.99**	0.89**	0.99**
		Coppice Height	
4	0.70**	-0.48	-0.15
8	0.89**	-0.01	0.17
12	0.82**	0.52	0.40

**, significant at the 1% level

E. grandis was much lower than that of hybrids from E. grandis mother trees in a mid-May harvest in Florida (Meskimen and Franklin 1984). However, the 'hybrids' in their study had slightly higher coppicing survival than E. grandis. In Brazil the best time of year to harvest the seedling trees is in the winter dry season (Ayling and Martins 1981). Coppicing in South Africa decreases during the dry winter (Stubbings and Schonau 1980). In New South Wales, Australia, coppicing of E. grandis is not adequate even in the autumn and winter months (Clarke 1975). Pereira et al. (1984) observed greater stump mortality of E. globulus during the winter rainy season than during the spring. In Israel regeneration of E. occidentalis, a lignotuberous species, was dependent on climatic factors and was greatest between September and March (Zohar et al. 1978). Coppice survival of a poplar hybrid in France was greatest for October to April harvests (Bonicel 1984). Blake (1983), in reviewing various factors influencing coppicing in short-rotation intensive forestry, concluded that dormant season harvests gave best results, the ability to resprout varied among species, and breeding may be able to combine coppicing ability with other desirable characteristics.

Hormonal influences can affect coppice survival. Taylor et al. (1982) found different levels of cytokinin and gibberellin production in E. camaldulensis, a strongly coppicing species, and a seed source of E. obliqua which coppices weakly. Pereira et al (1984) suggested that the cold season and waterlogged soils altered the ratio of inhibitors and growth promoters, resulting in inhibition of sprouting in E. globulus. Excessive soil moisture during the wet summer months in southern Florida (e.g. 215 mm per month of flat terrain) may contribute to decreased survival of Eucalyptus coppice.

Coppice height and DBH of E. grandis at 48 months responded differently to harvest month compared to E. robusta and 'hybrids'. Eucalyptus grandis shoots were bigger for March to May, decreased compared to the others till December, and then increased and were again comparable to those of E. robusta and the 'hybrids'. Coppice size of E. grandis was also more variable within and between harvest plots than that of E. robusta or the 'hybrids'. Variability within and between plots generally increased between 12 and 48 months.

Meskimen and Franklin (1984) found that hybrids from E. grandis mother trees had taller coppice shoots than E. grandis but that hybrid seed trees produced bulked progenies whose coppice was comparable to that of E. grandis. Summer harvests of E. globulus resulted in reduced coppice growth (Pereira et al 1984). Larger sycamore sprouts were produced from stumps cut during the dormant season than those cut during the growing season (Belanger 1979).

Coppice height achieved within 12 months was related to coppice height at 48 months after harvest only for E. grandis (Table C-3). Early growth trends of E. grandis, particularly the growth depression during the summer months, were strongly maintained through 48 months. The more consistent early postharvest growth of E. robusta and the 'hybrids', coupled with somewhat variable subsequent growth, contributed to the non-significant correlations observed. Coppice DBH was an adequate predictor of coppice height for all species. Relationships between coppice height and DBH were similar to those between preharvest height and DBH.

The mean number of live coppice stems per stump 48 months after harvest varied considerably from month to month, ranging from 1.9 to 3.4 stems per stump. With the spring and summer harvests, E. grandis had more stems that E. robusta and the 'hybrids'. Winter harvests resulted in E. robusta and the 'hybrids' having greater numbers of stems. 'Hybrids' harvested in mid-May in Florida had a number of shoots per stump similar to E. grandis, whereas hybrids from E. grandis mother trees had more (Meskimen and Franklin 1984). The largest number of sprouts for sycamore resulted from cutting in July (Belanger 1979).

Productivities (ha^{-1}) at 48 months reflecting the combined influences of survival, coppice size, number of stems per stump, and effective plot area, reemphasized the effects of harvest month and species (Fig. C-5). Coppice yields generally declined with summer harvests, with yields of E. grandis most reduced in terms of amount and duration. Yields of E. robusta were least reduced during August and were relatively stable over a large portion of the 13 harvest months. The frequently good yields of the 'hybrids' were largely attributable to the occurrence of vigorous individual stems. These productivities, averaging 2 dry t ha^{-1} annually, are one-third the volume produced by eucalypts at conventional spacing in southern Florida in 8 years (Geary et al. 1983).

The coppicing characteristics of these three eucalypts may be related to the presence (E. robusta) or absence (E. grandis) of lignotubers. The 'hybrids' presumably were composed of some trees with lignotubers and others without, which could have made survival of the 'hybrids' similar to that of E. grandis.

Several factors could have influenced the results reported here. Although at least two severe inversion freezes between 1980 and 1983 did not cause appreciable stump mortality, e.g. 48-month survival was about 3% lower than 12-month survival, they did damage tree crowns and stems. This damage, in turn, may have affected subsequent tree size and growth rate, particularly of smaller trees. In addition, the harvesting was not replicated in time or space. Any microsite variation and varying tree

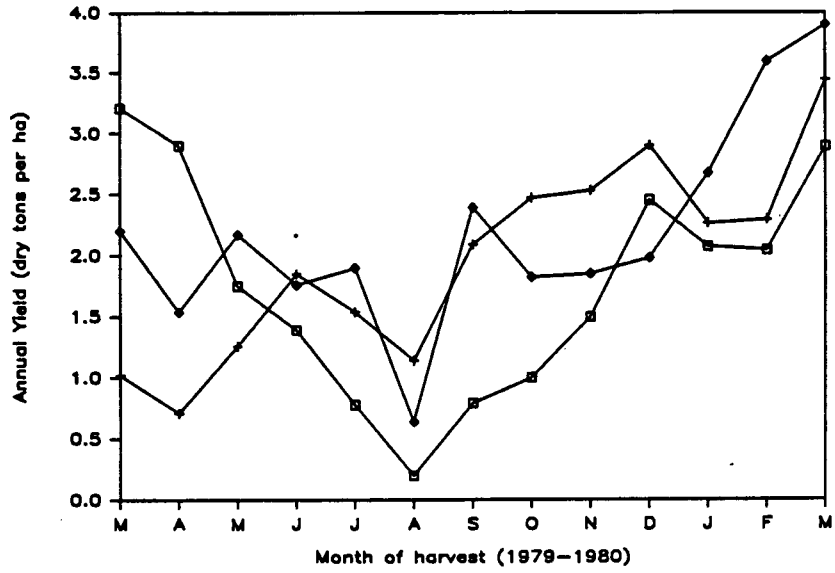

Figure C-5. Variation with harvest month of coppice productivity at 48-months after harvest for E. grandis (□), E. robusta (+), and the hybrids (◆).

ages were confounded with harvest date, and year-to-year variation in climate such as in represented by the March 1979 and March 1980 harvests and by post-harvest freezes, may influence performance.

ORNL-35: Before the first coppice rotation was initiated at age 18 months, species ranking for tree height was E. grandis, E. robusta, E. dunnii, and E. amplifolia (Table C-4). Species means for tree DBH were 4.9 cm for E. grandis, 4.6 cm for E. robusta, 3.5 cm for E. dunnii, and 3.7 cm for E. amplifolia. In survival, however, E. robusta was first at 75%, E. grandis second, E. amplifolia third, and E. dunnii had only 36% survival. This comparison between E. grandis and E. robusta was the same as previously observed in the adjacent study ORNL-16.

Preharvest size of E. grandis was inconsistent across spacing plots, while survival decreased with planting density. The trees in the densest spacing were taller than those in the two lesser densities, and trees planted at 10,000 trees/ha were the shortest. Survival was the highest at the 5,000 trees/ha density, resulting in 3,400 trees/ha after 18 months. The 37% survival at the 20,000 trees/ha density produced more than twice that density at 7,400 trees/ha at the time of harvest.

Species' coppicing rates following the December 1986 harvest differed considerably. At 68% overall and with one source having 94% of live trees coppicing, E. amplifolia was the only species to coppice adequately. No E. dunnii source exceeded 50%, and most E. grandis and E. robusta progenies failed to coppice (Figure C-6).

Coppicing after the March 1987 harvest was even less overall. Species ranks changed as E. robusta averaged 26%, and E. amplifolia had only 2% coppicing. The rates for E. dunnii and E. grandis were virtually the same as for the December harvest. For E. grandis, most progenies

Table C-4. Five- and 18-month seedling height and survival and 3-month coppice survival following a December 1986 harvest, and nine-month survival following a March 1987 harvest of *Eucalyptus grandis*, *E. robusta*, *E. dunnii* and *E. amplifolia* in ORNL-35.

Species/Age	No. of Progenies/Sources	Survival Mean	Survival Range	Height Mean	Height Range
		(%)		(m)	
ROW PLOTS					
E. grandis:	27				
18-mo. Seedlings		60.6	20-86	8.10	6.10-10.40
3-mo. Coppice		3.6c	0-15	-	-
9-mo. Coppice		3.3c	0-33	2.56	2.05-4.20
E. robusta:	16				
18-mo. Seedlings		75.2a	57-96	7.41	5.70-8.01
3-mo. Coppice		6.0c	0-31	-	-
9-mo. Coppice		25.8	0-43	2.69	1.90-3.45
E. amplifolia	6				
18-mo. Seedlings		49.4c	17-70	5.88	5.44- 7.11
3-mo. Coppice		68.0a	22-94	-	-
9-mo. Coppice		2.0c	0-11	3.55	-
E. dunnii	5				
18-mo. Seedlings		36.0	13-50	6.26	8.60- 4.80
3-mo. Coppice		20.86	0-46	-	-
9-mo. Coppice		16.7b	0-57	2.79	2.12-3.26
SPACING PLOTS					
E. grandis:					
5,000 trees/ha					
18 months		74.1	-	8.45	-
3 months		16.0	-	-	-
10,000 trees/ha					
18 months		51.0	-	8.03	-
3 months		7.0	-	-	-
20,000 trees/ha					
18 months		37.3	-	8.67	-
3 months		6.0	-	-	-

1/ Species means within a trait/age sharing the same letter are not significantly different at the 5% level.

again failed to coppice. The poor performance of *E. amplifolia* may be due to extremely heavy herbaceous competition in that portion of the harvested replication.

Environmental stress may have contributed to the poor coppicing of the December harvest. The weather was abnormally dry and warm (Table C-

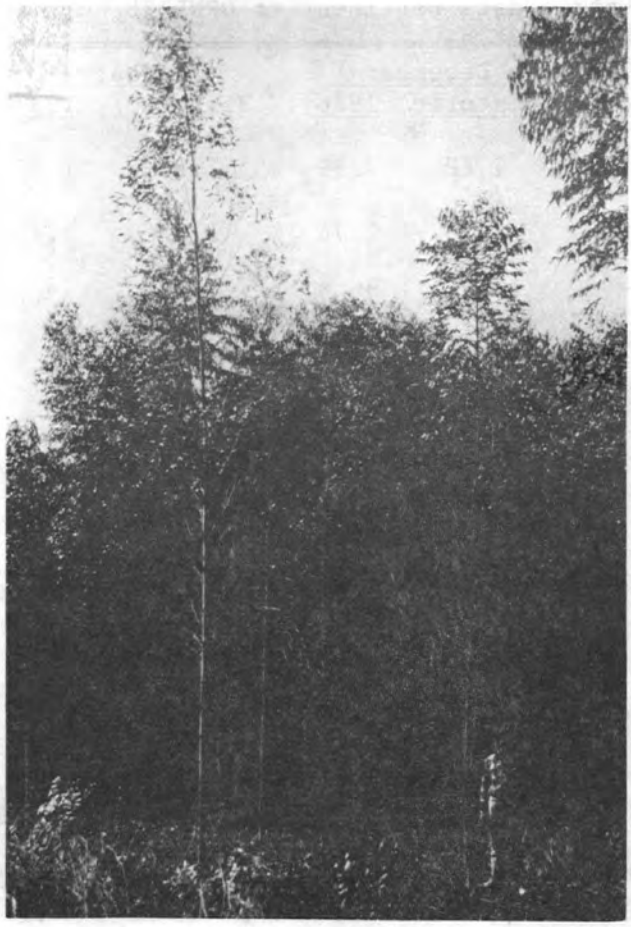

Figure C-6. 18-month-old E. grandis in ORNL-35: at the time of harvest (top), 3-months after harvest (bottom).

Table C-5. Climatic data pertinent to ORNL-35 coppice results.

	December		January		February	
	Historic	1986	Historic	1987	Historic	1987
Rainfall	1.68	3.99	1.90	1.18	1.85	1.69
Evaporation	3.20	2.76	3.42	3.83	4.06	3.71
Average Max.	75.6	77.7	74.5	73.2	76.1	76.6
Average Min.	53.5	59.6	51.5	47.8	51.8	53.0
STU(1000s)	55	64	41	30	50	50
Solar Radiation (ly/dy)	266	222	291	307	341	5
Wind Travel @ 2'		67		82		558
AM Soil Temp.		69.6		61.6		63.9
PM Soil Temp.		74.2		67.7		70.4
1986 Rainfall (in.)		49.8(-6.7)				
1986 Temperature		10m abv. avg.				

5) in January and February, with an extended period without rain. The block organic soils when open to the sun would have warmed markedly during this time and adversely affected the very shallow root systems. Another factor that may have contributed is a low level of P in the soil, which typically contains less than 2 ppm.

Other species evaluated on the muck soils at Belle Glade have coppiced adequately when the eucalypts have failed. Coppice survival of S. sebiferum in SS-1 after a harvest in March 1984 at age 20 months was low, but surviving stools had stems over 8 m tall and nearly 8 cm DBH after 24 months. The same stools regrew vigorously after a March 1987 harvest (Table C-1). Taxodium distichum in ORNL-16 had excellent coppice survival following two harvests (Table C-1). Survival after a March 1985 harvest of 58-month-old trees was over 70% with coppice stems approximately 4 m tall after two years. A harvest initiated in March 1987 of 82-month-old trees resulted in 82% survival and trees 1.6 m in height after nine months.

Conclusions

Coppice management and associated productivity are essential elements to short-rotation biomass plantations. Coppice yields of Eucalyptus species may be influenced by genetics, spacing, site, site

amendment, time of harvest, and age of stand. Month of harvest and species are important determinants of coppice survival and growth, and, hence, productivity of Eucalyptus for southern Florida. E. grandis was highly sensitive to month of harvest, as shown in decreased survival, height, DBH, and productivity for summer harvests. E. robusta was less sensitive to month of harvest with survival decreasing only after the August harvest, and growth remaining relatively constant. The 'hybrids' survived similarly to E. grandis but grew like E. robusta. Thus the 'hybrids' in this study are different to the desirable hybrids identified by Meskimen and Franklin (1984) from E. grandis mother trees. For northern Florida, coppicing of E. amplifolia may be less influenced by harvest date.

These results suggest that harvesting schedules of E. grandis, and to a lesser extent E. robusta, in southern Florida must be restricted for adequate coppice regeneration. For E. grandis, summer month harvests (June to September) should be avoided. For E. robusta, all harvest months, except August, appear generally suitable. Coppicing of E. amplifolia may surpass that of E. grandis and E. robusta in southern Florida.

Genetic strategies for increasing coppice productivity and possibly extending harvest time in southern Florida include: use of species with broader climatic tolerance (perhaps E. amplifolia); development of faster growing E. robusta which not only produce coppice reliably but grow like E. grandis (Dvorak et al. 1981); development of E. grandis with a more reliable coppicing capacity (Rockwood and Geary 1982); and obtaining hybrids with the fast growth characteristics of E. grandis and the coppicing reliability of E. robusta (Meskimen and Franklin 1984).

Task References

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TASK D. SELECTION, PROPAGATION, AND TESTING OF EUCALYPTUS CLONES.

Task D selected, propagated, and evaluated clones of various eucalypts. Selection was accomplished in commercial plantations and research studies. Propagation options studied were grafting, rooted cuttings, and tissue culture. Field testing of cloning candidates involved four studies.

Methods

Cloning Candidates: From 1982 to 1985, severe freezes not experienced in southern Florida since 1962 - January 12, 1982 (8 hour freeze with low of -11°C), December 25, 1983 (freeze of more than 12 hours with low of-5°C), and January 22, 1985 (low of -6°C during a freeze lasting more than 18 hours) - provided unique opportunities to select frost-resilient eucalypts. In February following the January 1982 freeze, 100 phenotypically superior *E. grandis*, *E. grandis* hybrid, and *E. saligna* Sm. x *E. tereticornis* Sm. hybrid ortets ranging from 2- to 12-years-old were selected at seven sites in southwestern and central Florida and girdled 1 m above the ground to induce juvenile basal sprouts. Selection criteria included exceptional tree size, good form, and minimal damage by a freeze in January 1982. From March 31, these sprouts were collected, sectioned into cuttings, and rooted in mist beds. Cuttings were removed from mist in mid-June and transferred to containers for hardening until mid-August.

In late August 1982, 55 successfully rooted clones were planted in study ORNL-37 near Palmdale. This site represented a landtype known locally as palmetto prairie, a mosaic of soils in the Great Group of Haplaquods. Site preparation consisted of double chopping, burning, disking, and bedding.

Ramets were planted 1.8 m apart on beds four m apart. Immediately after planting, 15 g of Osmocote fertilizer (13-13-13 plus 17-7-12) was placed in a dibble hole about seven cm deep and 1 dm from each planting hole. Triple super phosphate broadcast at 56 kg/ha P about a month after planting was ineffective due to heavy rainfall following application. When available in May 1984, 1120 kg/ha of ground rock phosphate, the usual amendment for successful culture of eucalypts on palmetto prairie (Geary et al. 1983), was broadcast between beds to correct the P deficiency.

ORNL-37 consisted of two interlocking designs: 18 clones in single-clone blocks of 16 trees replicated four times; and these 18 clones plus 37 additional clones as completely randomized, single-tree plots in mixed-clone modules. Two rows of randomized ramets bordered the study. This report considers all 55 clones as evaluated by 1,204 ramets in the mixed-clone, single-tree plots. One clone was represented by only one ramet, and another by two; the other 53 clones had 11 to 42 ramets.

Through 2.7 years, 14 traits were evaluated. To assess response to a hard freeze in December 1983:

Prefreeze height (H1.3),
Prefreeze survival (S1.3),

Cold damage three months after the freeze at age 1.6 years (CD1.6) on a -1 (worst) to 10 (best) scale, and Post-freeze survival (S1.6) were measured in March 1984. At 2.7 years, four months after a second major freeze in January 1985,
Height (H2.7),
DBH (D2.7),
Survival (S2.7),
Frost resilience (FR2.7) on a 0 (dead, no sprouting) to 10 (current growth initiated at 95% of previous height) scale,
Frost damage (FD2.7) on a 0 (killed to ground, no sprouting) to 10 (undamaged) scale,
Number of stems (N2.7) greater than 1/2 DBH of main stem per stool
Stem form (SF2.7) on a 0 (very crooked) to 3 (straight) scale,
Stem volume (SV2.7) and
Dry weight (DW2.7) as calculated by the formulae (Rockwood et al. 1982, with DBH in cm and H in m):

$$dm^3 = .0403*DBH^2H \qquad kg = .0196*DBH^2H,$$

Stem volume (SVPH2.7) and dry weight (DWPH2.7) per hectare as the respective sum over all planting positions for each clone converted to a per ha basis were evaluated in April 1984.

Standardized clonal evaluations were generated by subtracting the overall clonal average for a trait from each clone's mean and then dividing by the standard deviation among clonal means. An index to summarize composite performance through 2.7 years averaged the standardized evaluations for nine traits: H1.3, CD1.6, H2.7, S2.7, FR2.7, FD2.7, SV2.7, SF2.7, and DWPH2.7.

In April 1986, survival (S3.7) was determined, and vigorous ramets were remeasured for height (H3.7) and DBH (D3.7). Stem form (SF3.8) of the six best clones was assessed in May 1986 as the percent of ramets that were acceptable (straight stem with relatively thin, few branches) or unacceptable.

Analyses of variance were performed on certain variables based on a completely randomized design. Broad-sense heritabilities were calculated and gains estimated for quantitative traits through 2.7 years using techniques outlined by Shelbourne (1969). Selection intensities for the gain calculations were derived from culling rates observed in ORNL-37.

A second set of cloning candidates were partially derived from two commercial eucalypt plantations near Palmdale -Ferguson 72 and Ferguson 73 SW-initially searched by the U. S. Forest Service in Summer 1984 for clonal candidates. In February 1986, 136 candidates were reevaluated in response to the January 1985 freeze, and suitable trees were remonumented to save the clones from plantation harvesting. The remainder of the new clonal selections were located in an *E. grandis* pilot test (PT-1) of short-rotation intensive culture established near Palmdale in August 1982 with progenies from eight of the best seed trees (90, 905, 987, 999, 1001, 1002, 1003, 1010, 1012, 1020) in GORCH73. Within the 25 ha test, superior phenotypes were located in December 1986, measured for height, DBH, and frost-resilience, and classified by pedigree as *E. grandis*, *E. grandis* x *E. robusta*, or *E. grandis* x redgum.

These candidates were girdled by chainsaw at a 1 m height from January 29 to March 5. Shoots formed below the girdle were collected between April 3 and May 12. Typically, the shoots were put into plastic bags immediately after collection, stored in a cooler with ice, and transported within four hours to the nursery where they were transferred to another cooler and stored for between two and 24 hours, usually no more than 4. The shoots were then sectioned into cuttings approximately 4-6" in length with two leaves. The base of a cutting was a diagonal cut through a node, and the leaves were cut in half. Cuttings were soaked in 8% Benlate solution for 15 minutes, dipped in Hormodin-3 (.8% Indole-3-Butyric Acid), and stuck in Ray Leach Super Cell (147 cm^3) containers filled with a potting mix prepared as 8 cu. ft. of peat, 2 cu. ft. of perlite, and 14 oz. Osmokote 14-14-14. The cuttings were put in a mist house provided by the Florida Division of Forestry for up to a month. Hardening-off was done over a two-month period by moving the cuttings to a progressively drier and more exposed regime. Observations by clone included 1) the number of cuttings stuck and 2) the percentage of outplantable ramets, typically, from 49 cuttings.

These ramets, plus the progenies from GORCH77 detailed in Task A and certain genetic checklots, were outplanted in ORNL-40 from August 7-10, 1987, in the Palmdale-LaBelle area. Within a randomized complete block design with three replications, subplots were used for 1) clonal testing, 2) progeny testing, 3) yield/intergenotypic competition estimation, and 4) genetic gain approximation. Clonal test subplots were subdivided into seven sets, each typically containing 40 4-tree row plots of 37 new clones and the three top clones determined in ORNL-37. Progeny test subplots consisted of 10-tree row plots of 21 GORCH77 progenies, four progenies from the previous orchard GORCH73, ramets of the four top clones in ORNL-37, and progenies of four E. amplifolia accessions. Three of the GORCH77 progenies were derived from the ortets producing the three top clones. The yield component was composed of eight 24-tree block plots (4 rows of 6 trees) of four GORCH77 progenies and four clones (with three ortets contributing both progenies and ramets) in pure and competition plots. For each progeny or clone pair, a 75%:25% and 25%:75% competition plot was established. To establish a genetic baseline for the previous generation progenies, a systematic mixture of two GORCH73 progenies in a 24-tree block plot was planted in one replication with the other block plots. Within-row spacing was 1 m; between-row spacing was 2.85, 2, and 1 m, respectively, in the three replications. Very hot and dry climate conditions at the time of planting in moist soils were moderated by some 2.3" of rain on August 10. No additional rain fell until September 6, and the next appreciable rainfall occurred in early October, with several heavy rains thereafter. Height (HO.3) and survival (SO.3) were measured in December 1987.

Rooting: Clonal propagation through rooting of stem cuttings of E. amplifolia, E. grandis, E. camaldulensis, and E. tereticornis was evaluated. A pilot study was conducted with E. amplifolia stem cuttings on September 23, 1985. Vermiculite and Metromix 350 (Terralite) were used as growing media. Nested within these media were two sizes of cuttings: diameter of 2 mm or less and diameter bigger than 2 mm. Treatments with auxins using IAA, 2, 4-D and the commercial rooting media "Rootone", which contains 0.2% NAA and 0.1% IBA, were applied to

30 and 15 cuttings of the small and large diameter, respectively. Cuttings were collected on September 23, 1985 from coppicing branches from different trees in Study DP1. The cutting were then grown in a mist greenhouse. All cuttings were removed after 40 days.

E. grandis cuttings were collected from five of the best trees in GPOP77 on September 29, 1985. Rooting was attempted on Vermiculite media using rootone, Agrobacterium rhizogenous, and a combination of both. Twenty-eight cuttings were assigned randomly to each treatment. Cuttings from E. camaldulensis clones H-174 and BH and one E. tereticornis clone were collected from SS-2 at the same time and treated in the same manner. In July 1986, all four E. camaldulensis clones in SS-2 were recollected to develop sufficient numbers of rooted cuttings for inclusion in ORNL-40.

Agrobacterium rhizogenes has been known for some time to cause the formation of adventitious roots on the stems of numerous plants. This effect was recently shown to be correlated with the presence of a large plasmid, and subsequently named Ri plasmid for "root inducing". To study the effect of A. rhizogenes on rooting of E. camaldulensis a pilot study was conducted. A. rhizogenes strains A4 and 8196 were maintained in a simple media consisting basically of yeast extract (3 g/l), peptone (5 g/l), glucose (2.5 g/l), and agar (14 g/l) and kept at normal room temperature. Inoculation of E. camaldulensis stems was done three days after A. rhizogenes was subcultured.

Branches of E. camaldulensis were collected in July from coppice stems of clone BH grown in study SS-2 at Herren nursery near Lake Placid. They were stored in a cold room for two weeks. Stems were divided into cuttings of 20 cm length and all the leaves were trimmed except the top two leaves in each cutting. The cuttings were wounded between the cut end and the first node and left overnight in a suspension of A. rhizogenes. Thirty cuttings were assigned for each strain and a control which received similar treatment except inoculation was excluded. The cuttings were put into containers containing Metromix "350" and left in a mist green-house for seven weeks.

Grafting: Scions from five E. grandis clones from GPOP77 and five E. robusta trees in ORNL-35 were grafted onto rootstocks produced from four E. grandis and two E. robusta progenies. Grafting of scions collected on January 18, 1986, was completed by January 24 on rootstock propagated from seed in April 1985. Rind grafting (Van Wyk, 1977) was employed with three post-graft maintenance options - plastic bag, wax, or nothing other than grafting rubber and compared to cleft grafting (Pryor and Willing, 1963) using plastic bags as post-graft cover. The various combinations of scions, rootstock, and procedures were designed to determine influence of genotype and methodology on grafting success.

Tissue Culture: Regeneration of E. grandis and E. amplifolia plantlets through tissue culture has been evaluated through several efforts involving 1) direct enhancement of shoot multiplication and later initiation of roots and 2) indirectly through callus phase by somatic embryogenesis or organogenesis, i.e., initiation of shoots and/or roots on specified media.

Experiment 1A. Branches collected on January 18, 1986, from two selected E. grandis clones in GPOP77 were stored for five days in a cold room. Nodal segments of 1.5 cm length were chosen from branches free from insect or fungal damage. The segments were washed thoroughly in running water, surface sterilized with 20% clorox for 20 minutes, and rinsed four times with sterilized distilled water under aseptic conditions.

Experiment 1B. Explants (lignotubers and nodal segments) of E. amplifolia were obtained from nine-month-old seedlings of Source 2-7 raised in a greenhouse. To reduce the contamination frequency observed in E. grandis, a harsher sterilization treatment was applied. The explants were first washed and then submersed in 70% ethanol for 30 seconds, followed by surface sterilization with 20% clorox mixed with Alconox for 20 minutes. Along with clorox treatments, vacuum pressure was applied to rid any airspace on the explant surface. The explants were then rinsed four times with distilled sterilized water.

Murashige and Skoog (1962) media (MS) as a source for essential minerals and vitamins and sucrose, agar, and coconut milk as organic nutrients were used in Experiments 1A and 1B. For shoot multiplication, the respective composition was 1/2 strength, 2.5%, .7%, and 2.5%; the callus media composition was full strength, 4.0%, .7%, and 2.5%. A range of hormonal levels was tested for shoot and callus formation. For callus initiation, 1-, 2-, 3-, and 4-mg/L of 2,4-D were applied. In addition, .5 mg/L of benzylaminopurine (BAP) was added to all treatments. For shoot multiplication, a 2 x 6 factorial set of two levels of auxins (.5 and 1.0 mg/L of naphathleneacetic acid (NAA)) and six levels of cytokinins (0, .5, 1.0, 2.0, 3.0, and 4.0 mg/L BAP) was used. The media pH was adjusted to 5.8 and then autoclaved. The sterilized explants were placed directly on the shoot multiplication and callus media. For shoot enhancement, a 14-hour photoperiod plus 27°C and 25°C day and night temperatures were maintained. Callus cultures were maintained under 24-hour photoperiod and 22°C temperatures.

Experiment 1C. In 1987, the three top E. grandis clones (2814, 2817, and 2798) provided explant sources, specifically nodal segments from mature branches and from two-month-old sprouts. Sprouts were induced by girdling trees at one m above the ground in February 1987. Only healthy looking branches were cut into approximately 10 mm long sections. These sections were then washed with water and surface sterilized by immersion into 70% ethanol for one minute, and then 20% chlorox solution containing a small amount of detergent in a sterile container with constant agitation on a rotary shaker for 20 minutes. They were then rinsed in 5% chlorox solution and transferred directly to media. Initiation media to elongate axillary shoots contained MS with .5 mg/1 BAP and .05 mg/1 of NAA. Axillary shoots were transferred to multiplication media containing MS with different levels of BAP (.2, .6, and 1.0 mg/1), and a combination of .6 mg/1 BAP and .02 mg/1 of NAA. Elongation of shoots from the multiplication stage was attempted in a media containing high auxin to cytokinin ratio. To investigate rooting of elongated shoots (15-25 mm), 1/4, 1/2, and full strength concentrations of MS media were tried with 1, 2, 3, 4 mg/1 concentrations of IBA. In addition, the effect of adding .2 mg/1 of BAP to 1.5 and 2 mg/1 of IBA

was studied. Rooted propagules were transferred to a mist greenhouse for hardening for three weeks and then to a greenhouse.

Indirect micropropagation of E. grandis was investigated. Explants used in Experiment 2 were seedlings and floral buds. Seeds of E. grandis were surface sterilized by immersion in a 15-20% Chlorox solution (Chlorox bleach contains 5% sodium hypochlorite) for 15 to 20 minutes in a sterile container. They were then rinsed three times with sterile distilled water, and placed on solid MS medium in Petri dishes to germinate. One-week-old seedlings of E. grandis were then transferred to a callus induction medium. Floral buds collected from four top E. grandis clones (2817, 2814, 2798, and 2786) in ORNL-37 were also surface sterilized and placed on callus induction media.

Callus induction for all explants was tried using MS as a basal media with different combinations and concentrations of plant hormones. E. grandis seedlings were cultured on a different concentration of the auxin NAA with 1 mg/l of the cytokinin kinetin and 200 mg/l of glutamine. The floral buds of E. grandis, collected in July and August 1986, were also tried on a combination of different concentrations of the auxin 2,3-dichlorophenoxyacetic acid (2,4-D) and kinetin. Callus initiation and development in terms of quantity, color, and compactness were monitored. For attempted shoot and embryo induction, E. grandis callus was transferred to MS with no hormone.

Results

Cloning Candidates: Eucalyptus grandis was planted on 6,475 ha in southern Florida from the 1960's to the early 1980's for pulpwood production. During this same time, a genetic improvement program conducted by the U. S. Forest Service resulted in considerable increases in vigor and various quality characteristics of the species (Geary et al. 1983, Meskimen 1983, Franklin and Meskimen 1983, Rockwood et al. 1986). The 1982 to 1985 freezes identified the necessity for rapid development of frost resistance or resilience in E. grandis, possibly by vegetative propagation.

Overall, 87% of the 100 ortets girdled in 1982 had at least one rooted cutting, while only 34% produced the 30 or more rooted cuttings desired for testing in ORNL-37 (Table D-1). Hybrid ortets had the lowest proportion of basal sprouts and least amount (24%) of successful capture. All E. saligna ortets sprouted, and 69% were captured. Some 36% of ramets that had rooted by June were lost to infections caused by Amerosporium and Dothiorella spp. (E. L. Barnard, Florida Division of Forestry, personal communication). Sprout abundance and rooting success were unrelated (r = .17).

In addition to differences among ortet sources, considerable variability also existed within sources for sprouting and rooting (Table D-1). In terms of the number of cuttings obtained per ortet, E. saligna ortets were less variable and averaged more cuttings. Although some E. grandis and Hybrid ortets produced more cuttings than the best E.

Table D-1. Clonal variability among and within *Eucalyptus* groups in ORNL-37 and ORNL-40 for various propagation characteristics.

Propagation Characteristic	Group			
Clones for ORNL-37				
	E. grandis	Hybrid	*E. saligna*	Total
No. of Ortets girdled	74	17	9	100
% of Ortets with basal sprouts	88	71	100	87
No. of cuttings per ortet				
-average	161	107	184	154
-range	6-684	6-380	55-280	6-684
Rooting percent per ortet				
-average	36	29	69	38
-range	0-100	0-77	41-84	0-100
% of Ortets with ≥30 cuttings	36	24	69	34
Clones for ORNL-40				
	E. grandis	*E. grandis* x *E. robusta*	*E. robusta*	Total
15-year-old Stools in Ferguson 72				
No. of Ortets Girdled	5	2	1	8
Cuttings/ortet				
-average	81	22	51	63
-range	19-203	13-31	-	13-203
Percent Rooting				
-average	69	74	78	71
-range	53-83	62-87	-	53-87
			E. grandis x Redgums	
4.5-year-old Trees in PT-1				
No. of Ortets Girdled	84	79	81	244
% of Ortets with basal sprouts	96	96	99	97
Cuttings/ortet				
-average	62	60	62	61
-range	28-145	20-196	17-160	17-196
Percent Rooting				
-average	71	76	71	73
-range	0-100	4-100	16-100	0-100
4.5-year-old Clones in ORNL-37				
No. of Ortets Girdled	4	2	2	8
Cuttings/ortet				
-average	40	76	32	47
-range	30-66	37-115	29-35	29-115
Percent Rooting				
-average	63	80	81	72
-range	38-78	-	80-82	38-82

saligna ortet, many ortets in these two sources yielded very few cuttings. Cuttings from E. saligna ortets rooted best overall, but the best ortets had twice the rooting success of the poorest. E. grandis ortets ranged from unsuccessful to 100% rooting. Hybrid ortets also ranged widely in rooting success.

Field conditions during the testing of the clones in ORNL-37 were generally characteristic with regard to rainfall quantity (1350 mm per year) and distribution but severe in terms of cold temperatures. In fact, the December 1983 and January 1985 freezes were ideal for determining clonal frost resistance/resilience under the coldest conditions that can be expected for southern Florida.

The 55 clones varied widely in response to the windborne freeze of December 1983, but the norm was severe damage. The overall mean cold score at 1.6 years was 2.1 of a possible 10 (Table D-2) with a standard deviation of 2.0. No clone was untouched, and none were destroyed. Only 1% of the ramets were undamaged, 20% were frozen to the ground, and .7% were killed. Clonal differences were highly significant (Table D-3), with CD1.6 scores for well represented clones (10 or more ramets) ranging from 0.0 to 6.0. Response within clones was variable. Ten clones exceeded the mean cold score by one standard deviation or more.

Early height differences among clones were also significant (Table D-3) but were less variable within clones. Only five of the 10 top-ranked clones for CD1.6 bettered the mean H1.3 by one standard deviation. H1.3 was about half the typical height of genetically improved seedlings on similar sites. This lag may be attributable to a P deficiency caused by the rapid loss of triple super phosphate applied after planting. Additional factors may be the exploratory and shortened nursery schedule for the cuttings resulting in less vigorous propagules than customarily grown seedlings (Geary et al. 1983) and the relaxed culling standards for the ramets. The planting date for ORNL-37 was also toward the end of the planting season.

The relationship between tree size and frost tolerance was significant at the clonal level but variable within clones. Based on means for 53 clones, a correlation of .33 between H1.3 and CD1.6 suggested that taller clones were more frost tolerant. Within these clones, however, correlations on an individual ramet basis ranged from -.58 to .80.

Survival was excellent before and after the December 1983 freeze (Table D-2). Pre-freeze survival was reduced less than one percent. Clonal means for S1.6 ranged from 80% (two clones) to 100% (24 clones). This high survival was unexpected because cutting root masses were generally fragile and poorly developed, in contrast to the fibrous, firm root plugs of seedlings.

At 2.7 years, clonal differences were significant for all traits (Tables D-2 and D-3), with much of the variability due to the further impact of the inversion freeze of January 1985. Three percent of the ramets were killed, 26% were frozen to the ground, and only 7% were undamaged. Survival following the freeze decreased to 90%. Conceptually, the average ramet lost 28% of its total height and all its branches

Table D-2. Performance of 55 Eucalyptus clones and three cloning candidates through 3.8 years in ORNL-37.

Trait	All Clones Mean	All Clones Range	Three Cloning Candidates Mean	Three Cloning Candidates Range
Age 1.3 years-				
H1.3 (m)	2.4	1.5-3.8	3.6	3.1-3.8
S1.3 (%)	96.2	82-100	100.0	-
Age 1.6 years-				
CD1.6	2.1	0.0-8.0	5.7	4.2-6.8
S1.6 (%)	95.5	80-100	100.0	-
Age 2.7 years-				
H2.7 (m)	1.7	0.5-6.0	5.4	4.3-6.0
D2.7 (cm)	1.6	0.0-6.0	5.2	4.2-6.0
S2.7 (%)	90.0	18-100	100.0	-
SV2.7 (dm^3)	1.64	0.0-14.4	11.6	7.7-14.4
DW2.7 (kg)	.87	0.0-7.0	5.6	3.7-7.0
SF2.7	2.6	1.7-3.0	2.6	2.5-2.8
FR2.7	2.8	0.2-9.0	8.1	6.4-9.0
FD2.7	1.7	0.2-3.6	3.0	2.1-3.6
N2.7	.3	0.0-1.2	1.0	1.0-1.1
SVPH2.7 (m^3/ha)	2.40	0.0-19.95	16.03	10.66-19.95
DWPH2.7 (Mg/ha)	1.17	0.0-9.71	7.80	5.18-9.71
Age 3.7 years-				
H3.7 (m)	-	-	10.7	10.6-10.9
D3.7 (cm)	-	-	10.9	9.8-12.1
S3.7 (%)	47.0	0-100	100.0	-
Age 3.8 years-				
SF3.8 (%)	-	-	83	72 - 97

Table D-3. Analyses of variance and broad-sense heritabilities for several traits of 55 Eucalyptus clones in ORNL-37.

Trait	Mean Squares Error	Mean Squares Clones	Broad-sense Heritability	Clonal Gains Untested	Clonal Gains Tested
				------(%)------	
H1.3	48.97	731.95**	.398	+32	+108
CD1.6	2.86	69.96**	.529	+36	+101
H2.7	79.22	4,315.54**	.731	+83	+196
SV2.7	8.43	256.56**	.599	+71	+186
SF2.7	.24	1.44	.202	+15	+78
FR2.7	2.64	133.69**	.716	+49	+118
FD2.7	.31	6.79**	.515	+58	+122

**-Significant at the 1% level of probability.

in the freeze. Ramets taller than the inversion freeze layer (subfreezing temperatures extending approximately 2 m above the ground) exhibited a wide range in frost tolerance (FR2.7), while those in the layer were less variable due to the uniformity of severe damage.

Broad-sense heritabilities and associated gains suggest the merit of vegetative propagation (Table D-3). While meaningful gains in frost resilience and tree size can be expected from clonal selection and propagation without testing, the additional gains derived from testing of clonal candidates, as has been done with Eucalyptus clones in France (Marien 1983), appear well worth the expense of the evaluation. These gains in volume are nearly double estimates developed for seedlings from GORCH77 (Reddy et al. 1985).

With the 1983 and 1985 freezes, ORNL-37 was exposed to both the rarer windborne and more frequent inversion freezes that occur in southern Florida. The respective assessments to these freezes ranked clones similarly (Table D-4). Although no clone was resistant to lethal temperatures in the inversion layer in 1985, two outranked all others. A windborne freeze in 1985 would have caused much more damage.

Table D-4. Correlations among frost damage scores at ages 1.6 and 2.7 years for 55 Eucalyptus clones in ORNL-37.

	FR2.7	FD2.7
CD1.6	.77**	.83**
FR2.7		.92**

The cumulative damage of the freezes resulted in a lower average tree height in 1985 (H2.7) compared to 1983 (H1.3) (Table D-2). Trees not above the 1985 inversion layer were caught in a freeze-sprout-freeze cycle that suppressed any reflection of growth potential in the absence of frost. While the average heights of 46 clones decreased, the levels of variability increased as some trees added height if they were above the inversion layer. Allowing for initial establishment problems in ORNL-37, the best clones approached the height attained by improved trees growing without frost damage in earlier studies.

Three of the five superior clones in 1984 remained top choices at 2.7 years. These three (2798, 2814, and 2817) grew impressively since age 1.3 years, adding some 2 m in height from December 1983 to April 1985 (Table D-2), indicating a good response to the addition of ground rock phosphate in May 1984. With respect to per ha productivity, the top four clones exceeded the average by more than five times.

Few clones were highly rated by the composite performance index involving nine traits. Only ten clones exceeded the mean of more than one trait by at least a standard deviation. Six clones surpassed the mean of six traits by one standard deviation, and three clones were equally superior in seven traits. Seven clones averaged more than one deviation above the clonal mean. Of these seven, Clone 2798 had inferior

stem straightness. Clones 2814 and 2817 typically were more than two standard deviations above the mean.

At age 3.7 years, average survival decreased to 47% (Table D-2). Variability among clones increased, with nine clones at 0% survival. Six clones, including the top-rated clones at 2.7 years, had 100% survival. The height of 212 vigorous trees in 25 clones averaged 8.6 m, with some individuals up to 14.4 m.

A final evaluation at 3.8 years established the freeze resilience and other merits of three clones for operational use. Of six candidates, Clones 2814 and 2817 rated well for vigorous regrowth from the 1985 freeze and had acceptable form, although 2814 tended to crook at the point of frost damage and 2817 was often limby (Figure D-1). Clone 2805 was also vigorous but tended to have ramiform branches at freeze recovery sites. Clones 2786 and 2787 had suitable vigor but unacceptable form. Clone 2811 had neither adequate vigor nor form. Clones 2814 and 2817 were hybrids of E. grandis with redgum eucalypts (E. camaldulensis or E. tereticornis), and Clone 2805 was a hybrid of E. grandis with E. robusta and redgums.

The new cloning candidates selected in 1986-87 were evaluated for phenotypic characteristics, variability in propagation, and early field performance. In comparison to neighboring unselected trees, the PT-1 candidates (Figure D-2) were typically much taller and larger in DBH. At 10.9 m in height and 14.0 cm in DBH, the average size of the PT-1 candidates (Table D-5) was similar to that of the best clones in the adjacent ORNL-37. Some candidates were nearly 15 m tall and 20 cm in DBH. Very few candidates were completely undamaged by the 1983 and 1985 freezes. At worst, however, the candidates had sustained minimal stem damage; all regrew magnificently, suggesting very suitable frost-resilience potential.

Because the PT-1 candidates were smaller in DBH and shoots were typically collected earlier than in 1982, the average number of cuttings per ortet was less (Table D-1). Percent of ortets with basal sprouts, though, was generally higher, with only seven ortets failing to yield cuttings in 1987. Differences in cuttings/ortet among the three types of ortets were minimal as E. grandis and E. grandis x redgum ortets averaged 62 cuttings compared to the hybrids with E. robusta which averaged 60. Variability levels within the three ortet groups on the other hand were high, typically ranging from about 20 to 160 cuttings per ortet.

Rooting percent for the PT-1 candidates was almost double the 1982 level, due to absence of fungus infections, was similar across ortet groups and was comparable to the best clones from ORNL-37 (Table D-1). As was the case with cuttings/ortet, variability within ortet groups was great. When combined for all PT-1 candidates, variation among clones ranged from 0 to 100% (Figure D-3). Numerous PT-1 candidates exceeded the standard of approximately 80% rooting achieved by the top four clones from ORNL-37. These top four clones were further notable for their rapid growth and firm root structure.

Figure D-1. Eucalyptus clones in ORNL-37 at 3.3 years.

Figure D-2. 4.5-year-old Eucalyptus cloning candidates selected in 1986-87.

Table D-5. Summary of height and DBH of Eucalyptus clonal candidates selected in 1987 in commercial plantations near Palmdale.

Pedigree	Number of Clones	Height (m) Average	Height (m) Range	DBH (cm) Average	DBH (cm) Range
15-year-old Stools in Ferguson 72					
E. grandis	5				
E. grandis x E. robusta	2	-	-	-	-
E. robusta	1	-	-	-	-
Total	8				
4.5-year-old Trees in PT-1					
E. grandis	81	11.1	8.3-14.3	13.9	9.5-17.9
E. grandis x E. robusta	81	10.9	8.0-14.7	14.2	9.3-19.5
E. grandis x redgums	79	10.6	8.0-14.5	13.8	9.8-19.2
Total	241	Mean 10.9	8.0-14.7	14.0	9.3-19.5

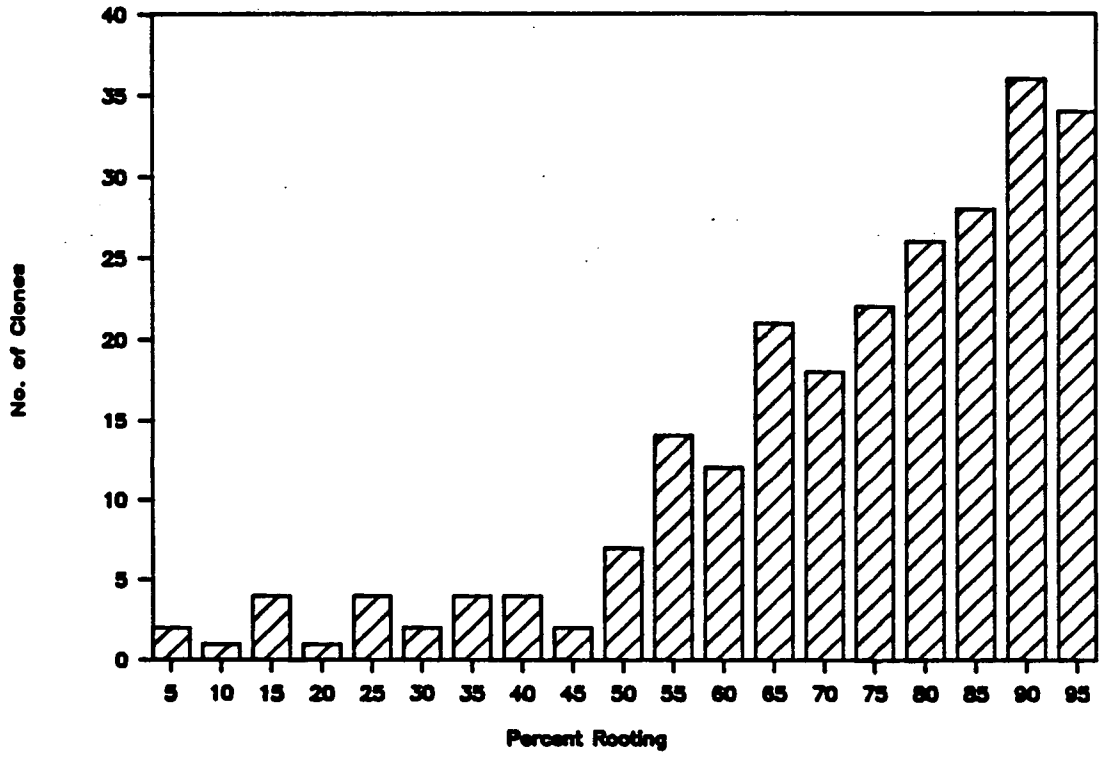

Figure D-3. Distribution of PT-1 E. grandis cloning candidates for rooting percent.

Through four months, the genetic entries in ORNL-40 varied little (Table D-6), while considerable variability between the three reps (planting sites) demonstrated the desirability of excellent site prepara-

tion. The site that had very thorough disking and high beds averaged 95% survival with trees 1.2 m tall. Some genetic entries averaged 1.6 m on this site, and individual trees were as tall as 2 m. The site on which it was impossible to form high beds had 88% survival, but the trees were only .4 m in height due to flooding caused by several periods of heavy rainfall. The third site, which had been herbicided to reduce herbaceous vegetation established since bedding in 1982, had only 32% survival with trees averaging .4 m tall.

In the clonal test component of ORNL-40, clones 2798, 2814, and 2817 displayed good survival and growth. In comparison to these three proven clones, the 232 new cloning candidates were similar overall in height but inferior for survival. Their generally low survival reflected the generally less extensive root systems they developed while in containers.

Wide variability among the new candidates, however, suggests that additional clones can be selected for vigor and good survival. In comparison to the height and survival standards of the clonal checks included in each set, 58 clones were better than the checks in height, and 22 clones had higher survival.

Comparisons among the genetic groups in the progeny test component suggested that only the new *E. amplifolia* introductions were inferior in vigor. The 21-progeny representation of GORCH77, the current *E. grandis* seedling seed orchard, was comparable to the four progenies which represented the previous seed orchard GORCH73. Clones 2798, 2805, 2814, and 2817 were not detectably better than either seed orchard's seedlings.

Table D-6. Four-month height and survival of *Eucalyptus* entries in ORNL-40.

Study Comp./Genetic Entry	No. of Entries	Height (m) Average	Height (m) Range	Survival (%) Average	Survival (%) Range
Clonal Test-					
Clones 2798,2814, 2817	3	.86[1]	.76-.99	82a	76-89
New Clones	232	.80	.20-1.70*	54b	8-100*
Progeny Test-					
GORCH73 progenies	4	.84a	.68-.93	77	63-97
GORCH77 progenies	21	.83a	.64-1.00*	72	60-80
Clones	4	.74a	.65-.87	68	63-70
E. amplifolia progenies	4	.56b	.52-.58	74	63-93*
Yield/Competition-					
Progenies	4				
Pure		.67b	.65-.76	71	59-76
Mix		.79a	.76-.84	65	57-75
Clones	4				
Pure		.78a	.60-.90	66	60-74
Mix		.78a	.58-.88	70	60-76

[1] Genetic entry means not sharing the same letter within a study component are significantly different at the 5% level.

* Variability among genetic entries significant at the 5% level.

Differences between clonal and seedling propagules were somewhat detectable in the yield/competition component of ORNL-40. In pure plots, progenies of four GORCH77 seed trees were smaller in height than clones 2798, 2805, 2814, and 2817 in pure plots. However, the same progenies in mixed plots were similar to the clonal mixes in height. No differences were noted for survival between progenies and clones, either on a pure plot basis or in mixed plots.

The influence of planting genotypes in pure blocks vs. two-pair mixes was uncertain. Progenies were shorter in pure plots than in paired mixes, while clones were equal in height across the two planting arrangements. No survival trends as a consequence of mixing were detectable, as would be expected at this young age. Additional measurements through three years in ORNL-40 will provide better bases for evaluating these various study components.

The ORNL-37 observations on girdling, propagation, and outplanting suggest a very rigorous schedule is necessary to complete the production cycle during one year under typical climatic conditions (Table D-7). Frost risk (usually until mid-February) to developing sprouts limits the date of girdling to no earlier than January 25, with lesser risk if girdling is delayed until early February. After the cuttings are stuck, rooted, and hardened, most of the rainy summer planting season (June 15 to August 15) has passed. At the latest, outplanting must occur by the end of August to insure enough growth to convey some hardiness to freezes that usually begin in mid-November. This required cycle of some

Table D-7. Proposed clonal propagation schedules based on *Eucalyptus* clones established in ORNL-37 and ORNL-40 in southern Florida.

Propagation Activity	Starting Date	Ending Date	Days from Last Activity
ORNL-37			
Girdling	January 25	February 14	-
Sticking	April 8	May 9	80
Weaning	June 21	July 11	54
Hardening	July 11	August 10	21
Outplanting	August 10	August 29	28
		Total	183
ORNL-40			
Girdling	January 25	March 1	-
Sticking	April 15	May 15	80
Weaning	May 15	June 15	30
Hardening	June 15	July 15	30
Outplanting	July 15	August 9	30
		Total	170

180 days allows few deviations from timely scheduling of the various propagation phases. Some opportunity to compress this typical schedule exists through the use of clones that require less time in the different phases.

The girdling, propagation, and outplanting schedule followed for ORNL-40 in 1987 suggests that the cycle can be compressed slightly and that field time can be minimized. Girdling of trees as early as January 25 appears safe, as very few shoot buds were observed in early March. A cool March inhibited shoot elongation, with some 80 days being necessary to produce shoots of suitable diameter. A lesser time to harvest appears likely in a warm spring. A longer period of shoot development seems undesirable due to shoots becoming too big. With a girdle equal to three chainsaw blade widths and securely through the cambium, no refreshening of the girdle is necessary before collecting shoots. Thus, time spent in the field may be limited to the time necessary for initial girdling and then for harvest only.

The 1987 cuttings developed roots and were ready for transfer out of the mist house more quickly, while two subsequent stages of development were similar. With time under mist shortened to about a month, the time from girdling to outplanting could be as little as 160 days for clones with rapid root and top growth. Accordingly, the length of growing time in the field before the likelihood of a November freeze is desirably increased.

Various inputs into clonal propagation by rooted cuttings identify that this form of vegetative propagation is more expensive than seedling propagation (Table D-8). The relatively high investment in girdling a tree reflects the travel necessary between trees when the frequency of candidates is about 10/ha. Girdling a typical 14 cm tree required an estimated three minutes, while the time spent traveling between trees on an all-terrain vehicle was some five minutes. Using a similar travel time between trees for shoot collection, the time invested in collecting shoots from candidates was about four minutes. The cuttings were transported 30 miles to the nursery. Prorating these estimates by the average number of cuttings/tree and number of cuttings hauled/trip, some .31 minutes was invested per cutting from girdling to nursery.

Table D-8. Estimated commitments to collect shoots from Eucalyptus cloning candidates, stick cuttings, and produce outplantable propagules.

Propagation Phase	Input	
	Average	Range
Girdle Tree (minutes/tree)	8	4-11
Collect Shoots (minutes/tree)	9	5-12
Transportation (minutes/trip)	40	-
Stick Cuttings (no./man-hour)	83	56-120
Produce Propagule (minutes/cutting)	.006	-

The nursery stages for cutting propagation were intensive for making and sticking cuttings and similar to seedlings for hardening. Shoots very likely could be sectioned into cuttings, treated, and stuck in containers at between 100 and 120 cuttings/man-hour for operational clones (Table D-8). Due to the use of mist and following transfers, an additional input of .006 minutes/cutting is needed. Thus, an individual cutting produced by the labor intensive method followed in 1987 had a total investment of 1.03 minutes plus about $.01 in operating costs. At a wage of $6/hour, the estimated cost to produce one cutting was over $.11, with approximately 65% of the cost incurred in the sticking phase. A preliminary economic analysis of using rooting cuttings is presented in Task E.

Both sets of cloning candidates provide estimates of the work needed and the options available for expanding the clonal pool and reducing the cost of cuttings. A considerable commitment was required to locate and evaluate candidates for ORNL-37. Some 80,500 trees on 54 ha were searched to develop 100 selections, for a selection intensity of one in 805, or 0.124%. Since only one in 1.8 of the selections were successfully propagated for testing, the selection intensity decreased further to 0.068%. Considering that three clones were actually retained after testing in ORNL-37, the overall "keep rate" was 0.0037% of trees initially searched.

The likelihood of finding successful clones within available germplasm in Florida can be improved, however. All 100 candidates were actually second-, third-, or fourth-generation trees developed from introductions into Florida. Such a collection of trees existed in the E. grandis fourth-generation genetic base population (GPOP77) recently converted to a seedling seed orchard in 1986 (GORCH77) (Reddy et al. 1986).

Because the three best clones came from GPOP77, the "keep rate" can be considerably improved when advanced generation material is searched (Table D-9). In practice, 58 of the 100 candidates were selected from 23,100 trees in GPOP77 (0.251%), 32 were successfully propagated (0.139%), and three were retained (0.013%). This rate is almost four times greater than the broader search that included many new introductions. However, it must be realized that a sizable investment was necessary to develop second- or more advanced generation populations from introductions of provenances into Florida (Rockwood et al. 1986).

The cloning candidates from PT-1 represent the advantage of considering advanced-generation populations. Through the propagation phase of clonal evaluation, these progenies of superior seed orchard trees yielded a proportion of candidates higher than that developed from GPOP77 (Table D-9). This would be expected as the PT-1 progenies on the average were better than the average in GPOP77. Only the completion of clonal testing in ORNL-40, with the identification of clones equalling or surpassing the three best in ORNL-37, can establish the final "keep rate".

Table D-9. Culling rates for developing frost resilient Eucalyptus grandis in Florida as observed in an advanced generation base population (GPOP77), projected to commercial plantations, and noted in selected progenies (PT-1).

	GPOP77		Commercial Plantations	PT-1	
	Number	Percent	Number	Number	Percent
Trees Planted	23,100	-	8,800,000	82,650	-
Cloning Candidates	58	.251	22,095	250	.302
Clones Propagated	32	.139	12,190	200	.242
Clones Qualified	3	.013	1,143	-	-

A further substantial resource of adapted eucalypts, the 6,475 ha of commercial plantations in the Palmdale area provides an excellent opportunity for immediate expansion of clonal candidates. All trees are derived from various advanced generation parents and have been subjected to the same freezes as ORNL-37. Consequently, the GPOP77 rates given above bracket the potential for rapidly developing more clones. Under these assumptions, over 1,000 clones (Table D-9) may be secured, but only with a major commitment of time and personnel.

For example, in two plantations totalling 60 ha, initial selection of 136 candidates during Summer 1984 required 15 man-days (0.11 man-days per candidate). Reevaluation after the January 1985 freeze to remonument 38 suitable trees involved another 4 man-days (0.11 man-days per candidate). Future propagation and testing would entail a man-day per candidate in girdling and cutting collection. Additional allocations for propagation, outplanting, and evaluation are likely to double these investments. In spite of these commitments, clonal propagation remains the only short-term alternative for insuring plantation survival.

The number of 1984 cloning candidates kept in 1986 after exposure to the January 1985 freeze suggests the value of intensive screening. Of the 112 E. grandis or hybrid candidates selected in 1984, only 38 were acceptable when revisited in February 1986. The majority of the 38 appeared to be pure E. grandis. Considering the substantial effort required to capture a candidate by rooted cuttings, this reduction greatly facilitates the screening process. Of these 38, only eight (Table D-5) were captured in 1987 due to poor sprouting of these older trees.

These may be a reasonable limit to the number of selections to make in the early commercial plantations in Florida. Because these plantations were derived from seed from relatively few and less improved parent trees, the general quality of trees expected in the older plantations in the Palmdale area is low. Younger plantations developed from seed collected from selected parent trees in GORCH73, i.e., plantations established after 1976, constitute more likely sources of superior trees.

Various other eucalypt clones were also propagated (Table D-10). Ramets obtained by the U.S. Forest Service in 1984 from

Table D-10. Other *Eucalyptus* clones maintained in Florida.

Clone	No. of Ramets	Clone	No. of Ramets	Clone	No. of Ramets
from the U.S. Forest Service-					
		E. camaldulensis/E. tereticornis			
366	2,-,-[a]	2580	4,1,-	2654	4,3,2
577	2,-,2	2517	2,-,-	2656	1,-,-
811	2,-,-	2617	-,1,2	2661	5,3,2
2514	2,1,-	2646	2,-,2	2662	4,2,2
2573	8,3,2	2647	4,1,2	2663	1,-,-
2574	7,-,-	2648	4,1,2	2689	1,-,-
2578	1,-,-	2650	2,-,2	2690	4,-,-
2579	5,-,-	2651	2,-,-	2752	6,5,-
		2652	-,4,-	TRT	2,-,-
				Total	78,25,20[a]
from Clonal Products, Inc. (Howland et al. 1986) via GRI-funded research project-					
		E. camaldulensis			
171	3, -[b]	172	2,3	174	2,2
BH	6,14				
from North Carolina State University-					
		E. viminalis			
034 MP-1	1,1[b]	113-1	3,2	080 R12-76	-,1
034 MP-2	3,1	008	-,1	2592	1,1
Bunn 3	1,1	023 #50	5,1	2594	1,2
Bunn 5	-,1	034 #42	-,1	2600	1,1
Bunn 6	3,2	034 #45	-,1	2601	1,1
Bunn 11	1,1	134 #59	-,1	2602	3,1
Bunn 15	6,1	054 #41	1,1	2604	3,1
13-76-11	-,1	070	-,1	2615	-,1
		E. nova-anglica			
1597 T2	-,1	1597 T3	4,1	1597 T5	3,2
		E. camphora			
		Camp 1	4,1		
				Total	45,32[b]

[a] Number planted in CT-74, ORNL-36, and ORNL-38, respectively, in July 1985.
[b] Number located in ORNL-40 Reps 1 and 3, respectively, in August 1987.

E. camaldulensis and *E. tereticornis* trees in central and southern Florida that had withstood the December 1983 freeze were interplanted in July 1985 in CT74, the current orchard of *E. camaldulensis/E. tereticornis*, and in studies ORNL-36 and ORNL-38. Four *E. camaldulensis* tissue culture derived clones that had performed well in studies SS-2 and SS-3 (Task B) were multiplied as rooted cuttings and outplanted for preservation in ORNL-40. An additional 27 clones of *E. viminalis*, *E. nova-anglica*, and *E. camphora*, the only remaining frost-resilient genotypes surviving from an extensive eucalypt program at North Carolina

State University (Cunningham and Mott 1985), were also clone banked in ORNL-40.

Rooting: Very poor rooting of E. amplifolia stem cuttings was observed with vermiculite, less than 10% in most of the treatments (Table D-11). However cuttings grown in Metromix 350 had higher rooting percentages. The larger size cuttings gave 53% rooting with IAA, 73% with rootone and less than 5% with 2, 4-D. The small diameter cuttings had much higher rooting with IAA and rootone than with 2,4-D. Based on these results, subsequent studies used Metromix 350 as a media and rootone as a growth regulator.

Table D-11. Rooting of two sizes of E. amplifolia stem cuttings on two media using three growth regulators.

	----Vermiculite-----			-----Metromix------			
Stem Diameter	IAA	2,4-D	Rootone	IAA	2,4-D	Rootone	Average
	(%)						
<2 mm	7	0	10	80	7	77	31
>2 mm	13	0	7	53	0	73	24
Average	9	0	9	71	3	76	28

Several studies have indicated the importance of seasonal effects and size of cuttings to rooting success (Hartney 1980). The effects of three monthly collections of two sizes of E. amplifolia cuttings (Table D-12) showed very low rooting percentages, which was expected for this time of year. As in the previous study, smaller stem diameters had better rooting, at least in October and November. Trees 2 and 4 rooted more successfully and suggest a genetic component may be important in E. amplifolia.

Table D-12. Rooting of two diameters of stem cuttings taken from five E. amplifolia trees at three months.

	10/27/86		11/29/86		12/27/86		
Tree	<2mm	>2mm	<2mm	>2mm	<2mm	>2mm	Average
1	16	0	6	0	0	0	4
2	35	0	35	6	23	24	21
3	6	0	0	0	0	0	1
4	26	6	35	13	38	16	22
5	0	0	6	6	6	13	5
Average	17	1	16	5	13	10	10

Rooting of E. grandis was lowest of three species in most of the growth regulator treatments (Table D-13). However a young branch obtained from tree (12-177) of progeny 1010 showed 61% rooting with

rootone, 43% with Agrobacterium and 64% with the mixture of rootone and Agrobacterium. Eucalyptus camaldulensis averaged 32% rooting with rootone, 9% with Agrobacterium and 36% with their combination. One E. tereticornis clone had 32% with rootone, 36% with Agrobacterium, and 36% with the combination.

Table D-13. Rooting of E. grandis, E. camaldulensis, and E. tereticornis on three growth regulators.

Species/Clone	Rootone	Agrobacterium	Combination	Average
	(%)			
E. grandis				
847-1	0	0	11	3.7
847-2	18	14	14	15.3
1010-1	18	11	18	15.7
1010-2 (young)	61	43	64	56.0
1010-3	11	7	14	10.7
1038	11	11	11	11.0
Average	20	16	24	20.0
E. camaldulensis				
H-174	28	7	41	25.3
BH	36	11	33	26.7
Average	33	9	37	26.3
E. tereticornis				
OP	32	36	36	34.7

A small callus appeared in the wounded areas after three weeks. Adventitious roots started to form a week later. Morphological and physiological differences were obvious (Table D-14). There was a significant increase in the number of roots for strains 8196 and A4 compared to the control. However, the root weight did not differ indicating that A. rhizogenes induces prolif- eration of small adventitious roots. Moreover, the leaves of the treated roots looked healthier and much greener, which indicate that these adventitious roots perform similar functions as normal roots. Preliminary analysis show that inoculated cuttings and roots synthesize mannopine, which indicates cell transformation. However, final proof of transformation should be done by DNA analysis.

Table D-14. Response of E. camaldulensis to two strains of Agrobacterium rhizogenes inoculation.

Strain	No. of Roots	Fresh Weight (g)	
		Roots	Shoots
A4	12 ± 1.2	0.42 ± 0.27	1.52 ± 0.63
8196	13 ± 1.68	0.43 ± 0.17	1.64 ± 0.56
Control	6 ± 1.21	0.44 ± 0.23	1.24 ± 0.40

Grafting: Early results showed a overall success rate of 27% (Table D-15). The interspecific grafts between the two species showed promising

results, with all grafts of ER-2114 (rootstock) and EG-1038 (scion) being successful. Differences were observed between different grafting techniques. Rind grafts without bags performed poorly, with only a 7% success. On the other hand, rind graft with bags had the most success (37%). Evaluation of the successful grafts after two months suggested incompatibility. Thus, grafting seems questionable as a means of producing clonal seed orchards E. grandis in Florida.

Table D-15. Grafting success of various eucalypt scions, rootstocks, and procedures.

Scion	Rootstock							
	E. grandis					E. robusta		
	847	1010	1038	1003	Mean	1941	2114	Mean
	%							
E. grandis								
847-1	5(20)[1]	40(5)	20(5)	80(5)	23	40(5)	20(5)	30
-2	20(5)	20(5)	40(5)	40(5)	25	-	-	-
1010-1	40(5)	15(20)	40(5)	20(5)	23	40(5)	80(5)	60
-2	40(5)	0(5)	0(5)	20(5)	15	-	-	-
1038	20(5)	40(5)	60(20)	20(5)	46	0(5)	100(5)	50
E. robusta								
1941	0(5)	0(5)	20(5)	0(5)	5	10(20)	20(5)	16
Mean	16(8)	18(8)	40(8)	30(5)		17(9)	55(5)	

Procedure	Scion/Rootstock					
	E. grandis					E. robusta
	847	1010	1038	1003	Mean	1941
	(%)					
Rind w/o bag	0	0	40	0	5	0
Rind w/ bag	20	20	43	30	28	20
Rind w/ wax	0	40	0	0	10	0
Cleft w/ bag	20	0	60	0	20	4

[1] Numbers in parenthesis indicate total number grafted.

Tissue Culture: Most of the E. grandis explants in Experiment 1A produced dark exudates within two to four days. A very high contamination rate was observed after seven to 10 days from the field materials. While this may indicate internal infection, the possibility of surface infection still exists.

To avoid this, alcohol and vacuum treatments were added to the sterilization protocol for E. amplifolia explants in Experiment 1B. After three weeks in culture E. amplifolia showed less contamination (50%). A swelling surrounded by a callus like structure was observed at the cut end of explants grown on 1.0, 2.0 mg/L of BAP. However, contamination was later observed on all explants. Tissue culture techniques for E. amplifolia have never been reported. Successful definition of the proper media and physical environment for this species would have great importance to the potential of the species.

Direct enforcement of numerous shoots/buds was successfully achieved in Experiment 1C on sprouts/explants collected in May 1987 from the three E. grandis clones on MS supplemented with 0.5 mg/l of cytokinin benzylaminopurine (BAP) and 0.05 of auxin NAA. On the other hand, 100% contamination was observed on the mature branches. Similar results were also observed with mature explants such as shoots and lignotubers of E. grandis and E. amplifolia. This points out that for eucalypts newly formed sprouts which were not exposed for a long time to field conditions proved to be more suitable explants which can be easily sterilized relative to other types of explants.

Multiplication of axillary shoots from sprout nodal segments was best achieved on .6 mg/l of BAP. More BAP caused yellowish of the shoots and reduction of their number. Also addition of NAA produced fewer shoots. It was also observed that subculture every 3-4 weeks of shoot clumps produced healthier and more shoots compared to single shoot subculture. This has practical implication since its easier to subculture clumps rather than single shoots.

Elongation of shoots was successfully achieved on the combination of 2.5-4 mg/l of IBA and 1 mg/l of the cytokinin zeatin. Reduction of zeatin to .5 mg/l resulted in production of much callus. Further reduction resulted in root formation. Also high light intensity was found to be important in producing stronger shoots. Shoots reached 15-25 mm length in three weeks and leaves tended to expand under such conditions. A clump of approximately 5x5 mm from the multiplication stage produced in a average about 30 elongated shoots.

Rooting of elongated shoots was observed to depend on the physiological state of shoots, type of media, and environmental conditions. Healthy shoots with 2-4 leaves had better rooting with higher percentage. In addition, reduction of the mineral nutrient to 1/4 of the full strength of MS improved rooting quality and reduced callus production. However, the concentration of plant hormones in the media were found to the most critical factors in the rooting process (Table D-16). Rooting was best with 2 mg/l of IBA. More IBA produced more callus and more hairy roots. Addition of only .2 mg/l of BAP resulted in complete inhibition of root initiation. Also incubation of the culture under dark conditions for the first 5-6 days in the rooting media improved the rooting quality and percentage. Rooted propagules were successfully hardened in a mist-greenhouse and then in a greenhouse with survival of 95% and 100%, respectively.

Hartman's Plants Inc., a subsidiary of Ciba-Geigy in Sebring, Florida, is using direct micropropagation for the commercial multiplication of certain E. grandis and E. camaldulensis clones (Table D-17). Initial propagation efforts in Summer 1986 with branches supplied by this project from some six top clones in ORNL-37 were generally unsuccessful due to the production of phenolic compounds by the explant material. Follow-up propagation in March 1987 involving different ramets of clones 2798, 2814, 1817, 2805 and others using modified propagation techniques has been successful.

Table D-16. Rooting of *E. grandis* clonal explant shoots on different MS and plant hormone concentrations in Experiment 1C.

MS (strength)	IBA (mg/1)	BAP (mg/1)	Rooting (%)	Roots[1]
1	1	0	75	4
1	1.5	0	76.2	3.5
1	1.5	0.2	0	-
1	2	0.2	0	-
1	2	0	79.2	4.3
1/2	2	0	85	7
1/4	2	0	93	6.7
1/4	4	0	95	>15
1/4	3	0	87.5	>15
1/4	2	0	92	>15
1/4	1	0	68.9	>15

[1] Average number of roots per shoot was calculated only for shoots which had roots.

Table D-17. Performance of 11 *Eucalyptus* clones in micropropagation at Hartman's Plants Inc.

Clone		No. of Ramets[1]	Relative Rate of Multiplication[2] (weeks)	Relative Rate of Elongation[2] (weeks)
E. grandis-				
	29	1	4	3
	37	1	4	3
	45	1	4	3
	2786	2	3	5
	2787	2	3	5
	2788	2	3	5
	2798	1+	3	2
	2805	3	4	1
	2814	3+	1	4
	2817	2+	2	2
E. camaldulensis-				
	174	1	4	2

[1] Number of ramets; +=mixture of ramets supplied in addition to individual ramets.
[2] 1=Best, 5=Worst.

While these four clones adapted readily to culture in 1987, differences were observed in several aspects of propagation. Generally, tissue maturation appeared unimportant to successful capture of the ramet by tissue culture, as buds from juvenile shoots, mature shoots and coppice material gave similar results within each clone. Although each of the primary clones gave adequate multiplication rates, there were

clear differences between the clones with respect to their response to the tissue culture environment. Relative sensitivity to cytokinin was the largest difference noted with 2814, 2817, 2798 and 2805 being the order of decreasing sensitivity. Some of the minor clones and 2798 had a tendency to produce callus on the apical meristem in conjunction with a vascular necrosis that killed small clumps of shoots. This problem was not resolved.

Once the clones were established in tissue culture, they were subcultured on increased cytokinin-containing media on a four-week cycle. Once adequate numbers of shoots had been initiated, the cultures were transferred to an elongation media and then to a rooting media. The rooted shoots were planted in the greenhouse from week 10 to week 14. Thirty-thousand plants will be supplied to Herren Nursery on week 26. At Herren Nursery, the plants will then be raised in Ray Leach "Stubby" containers for an additional eight to ten weeks before out-planting during the late summer. As this will be the first year for scale-up use of tested clones, experience acquired will guide micropropagation efforts of these and other clones in the future.

For the indirect approach in Experiment 2, formation of callus was observed on the one-week-old seedlings after three to four weeks on the callus induction media. Highly morphogenic callus was observed on the combination of 4 mg/l of NAA, 1 mg/l of kinetin, 200 mg/l of glutamine, and MS as basal media. This morphogenic callus was similar to the one reported by Quan (1981) for R. leichow, which is deep red, compact and superfically granulated. Upon transfer of this callus to MS with no hormone, smooth, red pigmented, and round structures started to form, which later gave rise to shoots, roots and whole plantlets in two to three weeks. While such callus was described as embryogenic, verification proof must come through cytological studies.

After three weeks in culture floral buds produced different amounts and kinds of callus (Table D-18). Compactness increased with increasing auxin concentration. Kinetin also increased compactness of the callus. The 2.0 mg/l of 2,4-D produced the largest amount of callus. No organization or root formation was observed. When calli were transferred to media with no or low 2,4-D no differentiation was observed, and the calli began to degenerate.

Conclusions

This task selected, propagated, and evaluated clones of various eucalypts. Selection in commercial plantations and research studies resulted in some 360 cloning candidates. Fifty-five of the initial 100 selected clones of E. grandis and hybrids were successfully propagated as rooted cuttings and exhibited significant clonal variation in frost-resilience, vigor, and quality through 3.8 years. Three of these are now recommended for commercial propagation. From the candidates selected and outplanted in 1987, additional clones with desirable features may be anticipated. Commercial plantations, the current E. grandis seed orchard, and other orchard situations provide longer-term options for developing clonal candidates.

Table D-18. Callus development in Experiment 2 of E. grandis floral buds on different hormonal concentrations of 2,4-D and kinetin (K) after three weeks on culture.

Hormonal Concentration (mg/l)	Quantity	Color	Compactness
1.0 2,4-D	++[a]	White & Yellow	+++++[b]
2.0 2,4-D	+++++	White & Yellow	++++
3.0 2,4-D	+++	Yellow	++
4.0 2,4-D	+++	Yellow	++
6.0 2,4-D	++	Pale Yellow	+
8.0 2,4-D	++	Pale Yellow	+
2.0 2,4-D & 1.0 K	+++	Yellow	+++++
3.0 2,4-D & 1.0 K	+++	White & Yellow	+++++
4.0 2,4-D & 1.0 K	+++	Creamy & Yellow	+++++
6.0 2,4-D & 1.0 K	+++	Creamy & Yellow	++++
8.0 2,4-D & 1.0 K	+	Creamy & Yellow	+++
10.0 2,4-D & 1.0 K	+	Creamy & Yellow	++

[a] Quantitative Scale: +=little to +++++=more callus.
[b] Qualitative Scale: +=soft to +++++=more compact.

Clones identified by testing will not be resistant to freezing conditions but will be resilient and greatly reduce the risks now associated with plantation culture in southern Florida. Development of frost-resilient clones using field evaluations requires considerable investment, much beyond the requirements for developing fast-growing clones alone. Large numbers of rooted cuttings can be produced from selected clones for outplanting in one year. Vegetative propagation of E. amplifolia was achieved through rooting of cuttings.

Propagation options studied included grafting, rooted cuttings, and tissue culture techniques. Grafting appears to be unsatisfactory for vegetative propagation. On the other hand, thousands of stem cuttings from sprout shoots were rooted with satisfactory results. Rooting of cuttings was found to be improved with juvenile material. Tissue culture was successful for selected clones of E. grandis hybrids and E. camaldulensis under certain conditions. Shoot explants taken from the upper parts of adult trees cannot yet be propagated due mainly to the high rate of contamination which in most cases can reach up to 100%. Another factor is the difficulty of propagating mature tissues. However, the majority of eucalypts can develop basal coppice shoots from mature trees which have shown superior traits, and these can continue to serve as a source of materials for vegetative propagation. We found that this can serve two purposes: 1) to provide relatively juvenile tissues, and 2) to provide materials which are less exposed to microorganisms and therefore less contaminated. Propagation of certain E. grandis hybrids which show hybrid vigor through direct enhancement of shoots from jevenile sprouts was very successful with a very high rate of multiplication. Also, propagation through callus phase of material from young seedlings from E. grandis and E. camaldulensis was very successfull. This indicates that material from young seedlings and rejuvenated shoots respond better to culture conditions.

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TASK E. ECONOMIC ANALYSIS OF BIOMASS PLANTATIONS.

This task estimated the present net worth and energetics of woody biomass produced in short-rotation plantations of Eucalyptus and pines.

Methods

Eucalyptus

Yield data used as a basis for economic analysis of Eucalyptus plantations were obtained from several trials. ORNL-35, described in Tasks B and C, was the primary data base for E. grandis. Growth functions incorporated row- and block-plot data up to 30 months and allowed preliminary production functions developed from ORNL-7 and ORNL-16 to be validated or corrected. Coppicing production functions were extrapolated from ORNL-7, ORNL-16, and ORNL-35 data. Pertinent data were also derived from studies ORNL-36 and ORNL-40. Additionally, a E. grandis pilot test, PT-1, established under a GRI-funded project, at Palmdale in August 1982, with 12.5 ha each of two planting densities, was referenced. The 5,000 trees/ha density employed a target spacing of 1 m between trees on beds centered 2 m apart, while the 3,333 trees/ha density targeted the same between tree spacing on beds at 3 m centers. Twelve 10 x 10 m permanent plots were systematically located in each density and monitored periodically until October 1985. Evaluations of other Eucalyptus species were based on data from the following studies: E. amplifolia - DP-1 and ORNL-35; E. camaldulensis - ORNL-38, SS-2, and SS-3.

For economic evaluation of Eucalyptus as biomass plantation species, four short-rotation, close-spacing systems were considered: E. grandis on muck and sandy soils in southern Florida, E. camaldulensis on sandhills in the southern/central sections, and E. amplifolia in the northern part of the state. Plantation establishment and management costs are reported on a per hectare basis except for the seedling propagation and planting costs (per seedling) and chipping and transportation costs (per dry Mg).

Most costs were common among the sites since the same types of equipment and methods should be employable. The sites are assumed to be fertilized once each time the plantations are re-initiated by planting since the intensive repetitive removal of biomass is expected to deplete nutrients in the soil. It needs to be emphasized that since there currently exist no operational short-rotation intensive-cultured plantation systems, the actual costs for seedling, planting, harvesting, processing, and transportation are based on small sample, experimental data. If these types of systems became more common, it could be expected that improvements in seedling propagation and equipment engineering could substantially reduce these costs.

A key cost that was variable among the four systems was the annual rental price for land. If acreage is to be placed into woody biomass plantations, then it must be sufficiently profitable as to pay the competitive price for the use of the land. The types of land on which the three eucalypts have been tested have different levels of agricultural profitability. The muck soils in southern Florida are

valuable vegetable cropping areas with land rentals varying between $190 and $380 per ha, depending upon the depth of the muck soil and therefore the type of vegetables which can be cropped. This analysis used a rental price nearer the lower end ($247 per ha) since E. grandis does not need to be on the best muck soils. The southern Florida sandy soil, "palmetto prairie," was less expensive with an average rental price of $128.50 per hectare. The northern Florida flatwoods are typically subdivided between row cropping, grazing, and timber activities. Common rental prices are about $64.25 per hectare. Finally, the central Florida sandhills are in a land-use transition since citrus has been extensively damaged by freezes over the past five years. Hence, rental prices have declined and landowners wish to keep the land in some form of managed agro/ forestry system in order to retain Florida's Green Belt Exemption, or a favorably modified property tax assessment scheme. Under these circumstances, a rental price of $25.70 per hectare per year was used. An implicit assumption is that the intensive silvicultural systems are only competing with other agricultural/grazing/forestry systems and not the commercial developmental use of the land.

Computations in determining the break-even costs per dry million grams (Mg) and per million BTU (GJ) were based on the assumption that 1000 ha are placed under intensive management for 35 years. The analysis for all four scenarios figured production and costs based on a planting density of 10,000 seedlings per ha. The E. grandis seedlings on the muck soils were assumed to grow for two years before the first coppice with a second coppice following two years thereafter. Geary et al. 1983 suggested that such a system maintained the site's biomass productivity before the original stools coppice vigor diminished and demonstrated that Eucalyptus coppice can grow more rapidly per unit of time as compared to the seedling stand.

Therefore, the analysis assumed that coppice growth would be 20 percent greater than seedling growth. Since site preparation and planting costs are a major operational cost, this strategy employed three harvests for each in a complete planting to replanting cycle. This schedule of activities resulted in a 2/2/2 growing and harvesting system where E. grandis seedlings were planted only once every six years. The other cropping systems employed in this analysis provided that the E. grandis on the "palmetto prairie" and the E. amplifolia were managed under a 3/3/3 year cycle while the E. camaldulensis was managed with a 5/5/5 year scheme.

The only other cost which varied by site was the seedling reestablishment of the plantation after a multiple rotation cycle has been completed. In all cases, this operation was considered to be much more expensive than that experienced by the initial establishment of the plantation. This assumption was made since the conversion from existing agricultural or grazing systems provide a site which is fairly easy to plant to the high intensity plantation. It is after the final harvest, when the site must be prepared for mechanical planting, that the remaining stems and root systems need to be removed or modified.

These data were used as input values for the program BIOCUT which is a comprehensive model designed to facilitate the investigation of the economics of short-rotation intensive-silvicultural energy plantation systems (Das et al. 1985).

Production and management assumptions are based on this and other research over the past years which provide a strong basis for cultural assumptions and rotation guidelines selected. The timing and complexity of SRIC operations varies by species and by broad soil type. The postulated series of operations in Figure E-1 is only for Eucalyptus on muck soils in south Florida. The drained muck soils encourage very rapid woody biomass accumulation, but for the most part this type of soil is currently under high-value agricultural cropping systems.

Clear Site: (May-June)
-Double Chop

↓

Bed Site:

↓

Apply Fertilizer: (just before planting)
50 kg/ha of P as triple-superphosphate

↓

Plant Site: (June-August)
1,600-10,000 trees/ha

↓ (approx. 1-4 years)

Harvest Stand: (January-February)
Yields of approximately 23 dry metric tons/ha/year for stands planted at 10,000 trees/ha and yields of 12 dry metric tons/ha/year for stands planted at 1,600 trees/ha have been reported.

↓ (approx. 1-4 years)

Harvest Stand: (January-February)
Yields approximately 10-20% higher than the original harvest are expected.

↓ (approx. 1-4 years)

Harvest Stand: (Early Summer)
Yields are expected to be the same as the previous harvest.

Figure E-1. Management scenario for biomass plantations of Eucalyptus grandis on drained muck soil.

Since the sites are already under agricultural cropping methods, site clearing can be accomplished via disking operations. This prepares the site by reducing any herbaceous competition. However, we have assumed more intensive site preparation (chopping plus bedding) to better reflect likely stand establishment operations. No further weed control was assumed. Fertilizer is added in the form of triple-superphosphate to overcome future phosphorus deficiencies. The muck is rich in nutrients and no additional fertilization should be required for several rotations.

The planting density and rotation (growth) period has been estimated from planting densities of 1,600 to 10,000 trees per hectare to be one- to four-years. Woody biomass production should range from 12 to 23 dry tonnes per hectare per year for the respective spacings and rotation ages for the first growth cycle. Successive coppice regrowth are expected to match or even exceed the original production rates.

Height and diameter at breast height (DBH) measurements were collected quarterly for six progenies and two planting densities (1,600 vs. 10,000 trees/ha) over a four year period in ORNL-16. These measurements were used to derive volume equations used to estimate total plot volumes. Measurements for the six E. grandis progenies were pooled for estimating dry weight production. Total stem dry weight per hectare (Equation 1), volume per hectare (Equation 2) and percent survival (Equation 3) equations were:

```
      STEMDW = e**(4.5862 - 29.98989/AGE + 11.7744 * SPACE/AGE)      (1)
      STEMVOL = e**(5.1964 - 19.98989/AGE + 11.7744 * SPACE/AGE)     (2)
SURV = 1.0/[1.0 + e**(-3.0735 + 0.0536 * AGE + 0.0136 * AGE * SPACE)(3)
          Where:  STEMDW  = dry tonnes of woody biomass
                  STEMVOL = cubic meters of woody biomass
                  SURV    = percentage of surviving stools
                  AGE     = Age of plantation in months
                  SPACE   = Dummy variable for initial planting
                            density
                                0 for 1,600 trees per hectare
                                1 for 10,000 trees per hectare
```

Table E-1 shows that although the denser planting (10,000 trees/hectare) demonstrates a poorer seedling survival rate throughout the four years 46% at four years vs. 62% for the wider spacing, it consistently accumulates more volume and dry weight mass than the less dense (1,600 trees hectare) planting density. Even though the less dense planting accumulates less production per hectare, it appears that its growth could potentially equal or exceed the denser planting's net growth since the latter's mean annual increment (MAI) is declining at a more rapid rate. Both stand densities reach their respective peak MAI's before three years. Maximum MAI is obtained by the 18th month for the denser spacing with a production rate of 23.78 dry tonnes per hectare per year. The less dense stand maximizes its MAI at 14.44 dry tonnes per

Table E-1. *Eucalyptus grandis* survival, volume, and dry weight production by planting density through 48 months on drained muck soils.

	Planting Density					
	10,000 Trees/ha			1,600 Trees/ha		
Age (mos)	Survival (%)	Volume (m^3/ha)	Stem Biomass (mt/ha)	Survival (%)	Volume (m^3/ha)	Stem Biomass (mt/ha)
3	95	0.42	0.23	95	0.01	0.00
6	94	9.68	4.71	94	1.22	0.66
9	92	23.87	12.97	93	6.45	3.50
12	91	39.58	21.51	92	14.84	8.06
15	86	53.62	29.13	91	24.46	13.29
18	87	65.65	35.67	89	34.13	18.54
21	84	75.86	41.22	88	43.30	23.53
24	81	84.55	45.94	86	51.77	28.13
27	78	91.99	49.98	84	59.48	32.31
30	74	98.41	53.47	81	66.46	36.11
33	70	103.99	56.50	79	72.79	39.55
36	66	108.89	59.16	76	78.51	42.66
39	61	113.21	61.51	73	83.71	45.48
42	56	117.05	63.60	69	88.44	48.05
45	51	120.48	65.46	66	92.75	50.39
48	46	123.57	67.14	62	96.69	52.53

hectare 2.5 years after planting. It is important to note that the 1,600 trees/ha portion of ORNL-16 incurred heavy herbaceous competition adjacent to, and sometimes in, the *Eucalyptus* block plots.

Although the biological production function is of primary importance in studying a SRIC system, actual implementation will depend on the average delivered cost per dry tonne. This cost is a function of the operational costs incurred over the life of the system and the productivity of the system.

Table E-2. Base case cost assumptions for an *E. grandis* SRIC woody biomass system.

Initial/Annual Costs:		Plantation Cost:	
Area	1000/ha	Site Preparation	$177/ha
Lease	$124/ha	Seedling	$0.08/tree
Start-up	$50/ha	Planting	$0.04/tree
Managerial	$30/ha	Fertilization	$52/ha

Harvest Costs:	
Fixed Costs	$150/ha
Variable Costs	$6.60/dry tonne
Transportation	$3.30/dry tonne

The SRIC system was assumed to be comprised of 1,000 hectares with the entire area in plantations. The cost of such an operation is assumed to be divided into several components: regeneration activities at the start of each plantation and at coppices, initial and annual costs incurred, and the harvest/transportation cost incurred at the completion of each cycle. Table E-2 lists the costs by activity. Tax effects are not considered since they are a form of transfer payments, and liabilities and credits vary by ownership and circumstance. Costs are assumed to increase at a rate equal to that of the overall inflation rate.

Pines

Data for economic analysis of slash and sand pines, established in January, 1980, were derived from studies ORNL-10, -11, -13, and -14, respectively. These studies were divided into spacing tests as well as Nelder plots (refer to Table 7-1). Tree size (height and DBH) and survival were measured for the slash pine plots at 11, 17, 23, 29, 35, 47, 59, 71, 81, and 93 months after planting. Sand pine plots were measured at 11, 25, 34, 45, 59, 71 and 81 months after planting.

Separate regression equations were estimated for survival rate, DBH and height as functions of initial planting density, surviving density and the age of the stand. Slash and sand pine equations were estimated from block plot and Nelder data sets. Regression analysis produced estimates of biomass accumulation of the stands over time. Equations (4) and (5) are from Campbell (1983) for estimating slash pine weights while equation (6) from Taras (1980) provided the conversion of sand pine stand parameters to dry tonnes per hectare.

```
STEMDW1=[.001954-.0000829*ADBH2+(.000025*ADBH2*AHT)]*TREES          (4)

FOLDW1=[.002749-(.00009688*ADBH*AHT)+(.00001146*ADBH2*AHT)]*TREES   (5)

STEMDW2=[.10**(-.97356+.9872*LOG(.5042*AHT*ADBH2)]*[.0004536*TREES] (6)
```

The variables STEMDW1 and FOLDW1 provide the stem and foliage dry wieght estimates in dry tonnes for the slash pine, while STEMDW2 provides estimates for the stem for the sand pine. Average stand DBH (ADBH) and average stand height (AHT) along with the number of surviving trees per hectare (TREES) are the three descriptor variables.

If slash or sand pine are to be intensively managed for producing biomass for energy generating facilitites, the average cost of production must be comparable or less than the cost of alternative fuels. Table E-3 lists the financial parameters used in estimating the average cost per dry Mg and the average cost per gigajoule (GJ) of energy. The scenario for an intensively managed slash pine plantation assumes that the site preparation includes root rake, roller chop, burn and bedding at the start of each new rotation. Fertilization followed by planting will be the last activities, other than annual maintenance and monitoring activities, until the stand is harvested. The sand pine stands, because

of their dryer sites, will require far less activity to establish the stand. Only the roller chop and burning will be planned before the fertilization and planting activities. Although sand pine fertilization trials have not demonstrated consistent growth responses to fertilization (Rockwood et al., 1983), it is felt that the total removal of the biomass from a site over several rotations may adversely affect the productive capacity of the site, therefore fertilization will be scheduled at the initiation of each stand.

Table E-3. Intensive culture short rotation management scenario cost assumption for slash and sand pine.

Input	Slash Pine	Sand Pine
Total Area	1000 ha	1000 ha
Planted Portion	95%	95%
Planning Horizon	35 Years	35 Years
	----------$----------	
Lease	75/ha	50/ha
Infrastructure	50/ha	50/ha
Site Preparation	230/ha	75/ha
Management Expenses	30/ha	30/ha
Fertilization	100/ha	52/ha
Harvesting & Chipping	24/Mg	24/Mg
Transportation	4/Mg	4/Mg
	----------¢----------	
Cost of Seedlings	7/t	7/t
Planting Cost	5/t	5/t

Results

Eucalyptus: Growth

Table C-4 listed the growth of E. grandis and other species in ORNL-35. Figure E-2 depicts the average height and DBH growth in an earlier E. grandis test (ORNL-16) where the planting densities were at 1,600 trees/ha (1.6) and 10,000 trees/ha. Both E. grandis and E. robusta appear to be growing at fairly similar rates as the earlier studies.

While early survival of E. grandis in PT-1 was excellent (Table E-4), tree vigor was low due to P deficiency related to loss of triple-superphosphate fertilizer in the heavy rains that followed planting. Tree growth was further affected by the December 1983 freeze before the nutrient deficiency was corrected by the application of ground rock phosphate in May 1984. To date, productivity in PT1 is far below what had been previously achieved under more typical culture and environmental conditions.

Individual tree size in PT1 varied considerably. In spite of the fact that the planting stock was derived from the 10 best mother trees in E. grandis seed orchard GORCH73, uniformity in growth was lacking. Nevertheless, some outstanding individuals are present and rival the size of some of the better clones in the adjacent ORNL-37.

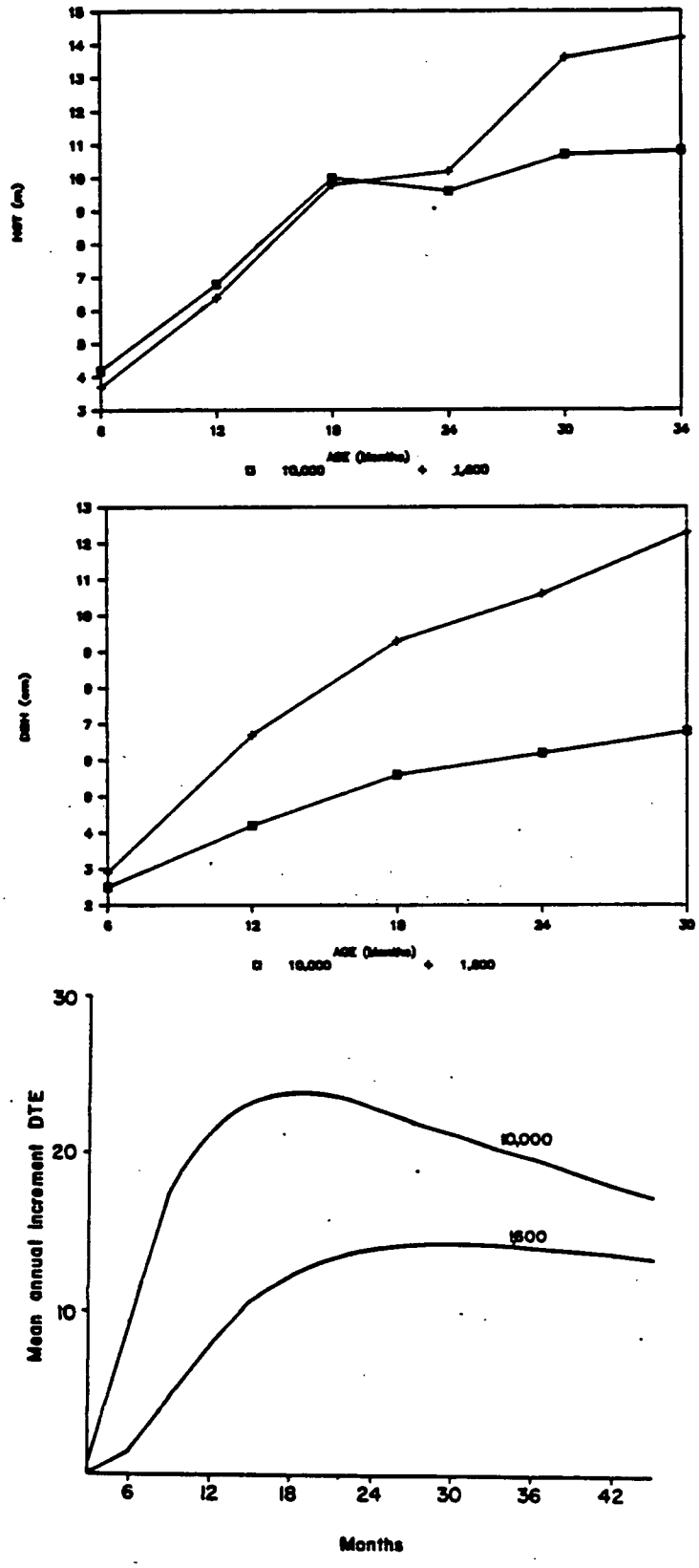

Figure E-2. E. grandis growth in height (top), DBH (middle), and weight (bottom) as influenced by age and spacing in ORNL-16.

Table E-4. Height and survival of Eucalyptus grandis at three spacings in ORNL-35 and two spacings in PT-1.

Spacing (trees/ha)	No. of Plots	5-months Surv. (%)	5-months Height (m)	12-months Surv. (%)	12-months Height (m)	DBH (cm)
ORNL-35						
5,000	6	84	2.0	80	4.1	3.9
10,000	6	76	2.2	71	4.5	3.7
20,000	2	60	2.3	52	4.7	3.4
PT-1						
		5-months		38-months		
5,000[1]	12	98	.8	98	2.1	1.4
3,333	12	99	.7	98	2.0	1.1

[1] Target densities in PT-1; actual planting densities were 3,674 and 2,848 trees/ha.

The ability of E. grandis to coppice, or to grow one or more new stems from a stool, increases its attractiveness as an energy source. Since Eucalyptus regenerates itself after each harvest operation, biomass accumulation can be generated over several growth cycles from the initial start-up cost of site preparation and planting. The effect is to reduce the average cost per dry tonne of woody biomass produced by foregoing future planting costs for two to three rotations cycles. The number of coppice stems per stool is influenced by the initial planting density, genotype, stump height and climatic conditions immediately before and after harvest. Total volume growth of the coppice may be greater than initial seedliing growth according to work by Geary, et al. (1983).

The E. amplifolia in DP1 was measured periodically for survival, height and DBH from April 1981 to the present. During that time span the planting suffered coppice-like removals of the upper stems due to freezes in 1/82, 1/84 and 1/85. The statistics of this study are presented under Task C. An analysis was initiated after the last re-measurement of the planting to determine whether the E. amplifolia is as productive in North Florida as the E. grandis seems to be in South Florida. Figure E-3 compares the field measurements of the E. amplifolia at a spacing of 10,000 trees/ha (A-10000) as compared to the estimated production functions of the older E. grandis study at two spacings (G-1600) and (G-10000). The first freeze hit the E. amplifolia after only nine months of growth. If the drop in production is ignored and the data is trended between the last measurement before the freeze and the first month where growth first exceeded before-freeze levels, than based on a very small sample size, E. amplifolia produced very well indeed. In terms of Survival, (Figure E-3, top), Cubic Ft Volume/ha (Figure E-3, middle), and Dry Mt/ha (Figure E-3, bottom) it seems even more productive than E. grandis on the South Florida muck soils.

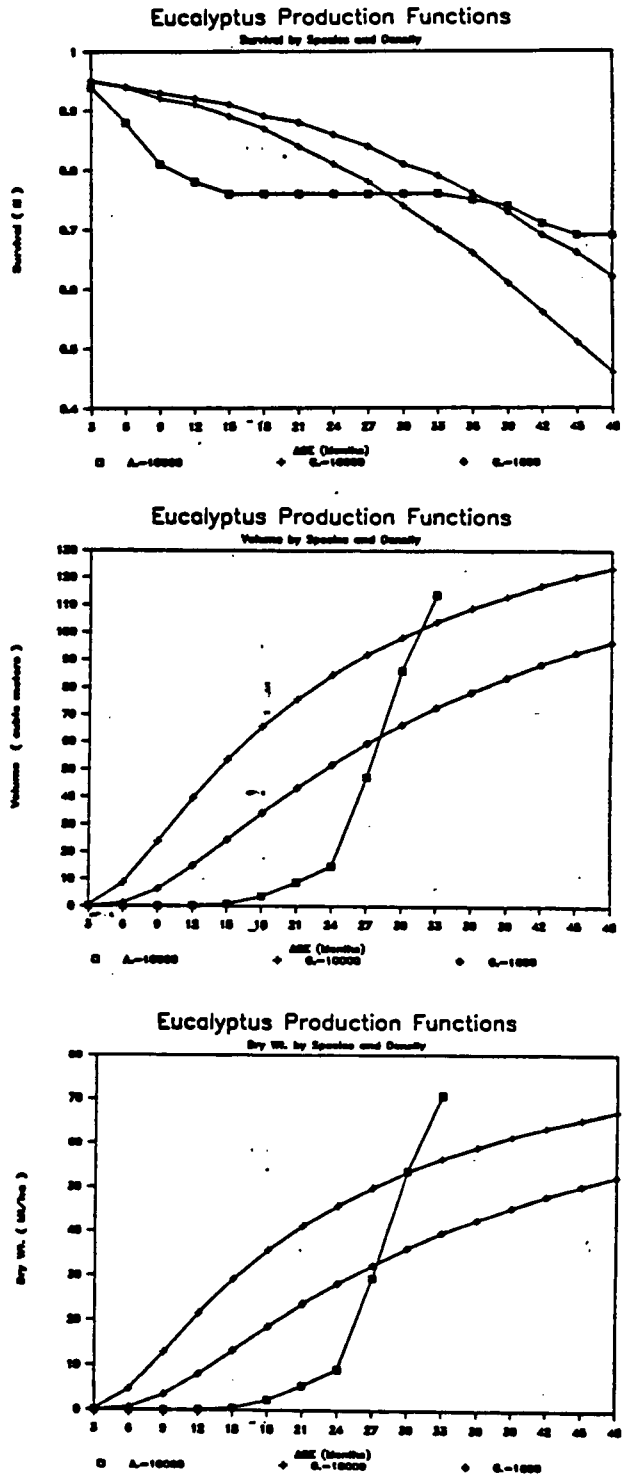

Figure E-3. Productivity of E. amplifolia (estimated from Study DP-1) in comparison to E. grandis in ORNL-16.

Roguing of GPOP77 provided an opportunity to evaluate a feller-buncher that may be ideally suited for harvesting medium-sized coppicing species. The Bell Model T feller-buncher is a relatively low cost ($40,000) harvester with low ground pressure, excellent maneuverability, and chain-saw cutting head designed to minimize damage to stumps. During the month that it was used to fell some 13,000 E. grandis up to 10 inches in diameter, fuel, labor, and maintenance inputs were monitored, and time studies were conducted in order to update previous estimates of harvesting cost. This activity was also monitored by Dennis Curtin of TVA as part of his evaluation of short rotation woody crop harvesters for ORNL.

Eucalyptus: Economic Evaluation

The relative break-even costs per GJ of woody biomass for the four systems in this analysis were calculated under the cost assumptions in Table E-6. The costs are nearly equal for the E. grandis on the southern Florida muck and the E. amplifolia in northern Florida (Table E-7). Both systems could deliver woody biomass at a cost of under $2.00 per GJ, if the discount rate net of inflation is equal to zero. Ranging the real discount rate up to 8 percent causes the estimated costs to increase by approximatly 11 and 16 percent, respectively. The net cost for E. grandis on "palmetto prairie" and E. camaldulensis on the sandhill sites are both significantly higher. Whether these systems can produce woody biomass for energy will depend on better matching planting density and productivity to these sites. It is not that the costs of management and implementation are significantly greater than those associated with the other site/species combinations. The factor which contributes to the poor cost per GJ is the relatively low productivity of biomass by weight over time which reduces the attractiveness of the latter two options.

The delivered costs per GJ of the four woody biomass systems can be compared to the prices reported by Asbury et al. 1983 of approximately $2.00 per GJ for delivered coal. Long term prices expected to remain below $3.00 through the end of this Century. Of course, very recent declines in crude oil prices have significantly dropped energy prices below these levels. Whether these prices will remain in the low teens per barrel assumes that the efforts of OPEC will fail and that the world's oil markets will never again be dominated by a cartel.

Table E-2 shows that the site preparation and planting costs are major components of the computed average discounted cost per dry tonne, comprising nearly 85 percent of the costs incurred with the 10,000 tree/ha plantation on a two-year rotation. To reduce the final impact of this cost component, various SRIC scenarios were evaluated. All the scenarios assumed two coppice rotations of equal length following an initial establishment period for a total of three harvests per cycle (Table E-5). In general, as the time period is increased, total production also increases and for any time period examined the denser plantation produces more total woody biomass than the less dense planting. With better weed control, the lower density stand might be expected to achieve the same yields as the higher density stand, though at a later time.

Table E-5. *Eucalyptus grandis* productivity for two planting densities and five cutting schedules.

Rotation (yr/yr/yr)	Density (trees/ha)	Years per Cycle	Total Volume (dry tonne/ha)
4/3/3	1,600	10	137.85
3/3/3	1,600	9	127.98
2/3/3	1,600	8	113.44
3/2/2	1,600	7	98.91
2/2/2	1,600	6	137.88
3/2/2	10,000	7	151.06
2/2/2	10,000	6	137.88
1/2/2	10,000	5	113.40
2/1/1	10,000	4	88.96
1/1/1	10,000	3	64.53

Table E-6. Costs associated with management of *Eucalyptus grandis* (EG) on muck soil and palmetto prairie, *E. camaldulensis* (EC) on sandhills, and *E. amplifolia* (EA) on crop and pasture land in short-rotation, close-spacing systems in Florida.

	EG on			
Management Activity	Muck	Prairie	EC	EA
Infrastructure Development	50.00	50.00	50.00	50.00
Site Preparation				
Initial	123.50	123.50	123.50	123.50
Replant	300.00	300.00	200.00	300.00
Fertilization				
Once/rotation	93.00	93.00	93.00	93.00
Establishment				
Propagules (per/tree)	.15	.15	.15	.15
Planting (per/tree)	.055	.055	.055	.055
Annual Activities				
Land rent	247.00	128.50	25.70	64.25
Taxes & Adm.	30.00	30.00	30.00	30.00
Removal				
Harvest+forward	150.00	150.00	150.00	150.00
Chip (per Mg)	6.60	6.60	6.60	6.60
Transport+Storage (per Mg)	3.30	3.30	3.30	3.30

The timing of operations substantially influences the annual average production. Planting the orginal stand requires that heavy equipment enter the site during the summer months (May-August). Since the sites are already engineered for drainage, soil water levels should not hinder these operations. Site preparation and planting during the summer will provide the seedlings time to establish under optimal growing conditions. Since south Florida is a subtropical environment other planting dates are feasible but the temperature/ moisture combination of summer appears to be optimal for establishing the plantation.

Table E-7. Projected breakeven prices per Mg and GJ for E. grandis (EG), E. camaldulensis (EC), and E. amplifolia (EA) as a function of interest rate.

		Interest Rate				
Species/Site	Basis	0	.02	.04	.06	.08
		(Dollars)				
EG/Muck	MG	38.82	39.87	40.94	42.02	43.12
	GJ	1.96	2.02	2.07	2.13	2.18
EG/Prairie	Mg	65.47	67.85	70.48	73.36	76.49
	GJ	3.31	3.43	3.57	3.71	3.87
EC/Sandhills	Mg	65.15	69.42	73.31	80.20	86.84
	GJ	3.30	3.51	3.77	4.06	4.39
EA/Cropland	Mg	38.07	39.36	40.80	42.37	44.10
	GJ	1.93	1.99	2.06	2.14	2.23

The timing of the harvest/coppicing activity also has a major impact on the productivity realized from SRIC plantations. Early studies have demonstrated near complete failure of stand regeneration through coppicing/harvest operations during the warm months of the year. Therefore, coppices should only occur during the winter months (January-February).

The restriction of coppice/harvest operations to certain periods of the year requires stockpiling of the harvested biomass. Whether the trees should be stored on the site, or chipped and stored in piles near the conversion facility, requires further study into their relative rates of decay and energy loss. Woody biomass will lose part of its energy potential as natural decay occurs. The optimal planting density and rotation length may be affected by the method chosen to stock-pile the fiber.

In Table E-5, coppice growth is assumed to be the same as seedling growth, but this assumption is probably incorrect. Therefore, production was examined for coppice growth projections of ±20 percent of seedling growth to determine the sensitivity of the average cost of dry tonne to the productivity of the coppice. Depending on the growth actually observed, the cycle which will maximize average annual production will be either five or six years, including the establishment and two coppice rotations for the denser spacing. The less dense spacing is more variable with average annual production maximized by either a seven, eight, or nine year cycle, also including an establishment and two coppice rotations.

Based upon our data and assumptions, it appears that costs are minimized with the 5 and 8 year cycles for the dense and less dense stocking levels, respectively. Coppice productivity assumptions do not appear to affect the choice of the optimal rotation. The optimal rotation for either planting density is unaffected by the discount rates examined. After reviewing several other permutations our results indicate a discounted average annual cost per dry tonne of between $20 to

$50. Assuming that there are 19.2 GJ per dry tonne of E. grandis woody biomass then the unprocessed cost of this energy source ranges between $1.04 to $2.60 per GJ.

Pines: Growth

Slash pine is normally grown at densities between 1,000 and 2,000 trees per hectare on 20 to 25 year rotations for pulpwood production. This rotation length has been derived due to the fact that the fiber length of the wood becomes favorable to paper making and because the stand's rate of growth has begun to slow. It has been assumed that by greatly increasing the initial planting density of the stand, the net biomass production function will begin to slow at an earlier age.

Mortality due to over stocking the productive capacity of the site has yet to occur. The rate of survival is above 87 percent with no real dispersion of survival rates by initial planting density. Regression analysis of survival as a function of stand parameters could not produce an equation which explained more than 26 percent of the variability observed. Although the initial density was found to be a significant variable, the use of this parameter in estimating average stand height has a negligible effect on the estimates. This result corresponds to the minor degree of scattering of the height measurements over the first five years of growth.

In equation (7) both initial density and age were found to be significant variables in describing height growth expressed as AHT. Both stand age and existing stand density were significant variables in determining average DBH (ADBH) with equation (8).

$$AHT = -0.64558 - 0.0000011 * DENSITY + 1.259232 * AGE \quad (7)$$

$$ADBH = -1.26546 - 0.00001657 * CUR.DENSITY + 1.589928 * AGE \quad (8)$$

As with the height equations, although the respective density parameters are statistically significant, their impacts on the equation's estimates are minor due to their very small coefficients. It was expected that by increasing the initial stocking from 4,800 to 43,300 trees per hectare, average DBH accumulation rates would vary so that the net basal area by stand would remain fairly stable. Since basal area, which is a parameter describing the productive capacity of the site, is a function of stem DBH and the number of trees per hectare, some reduction in the rate of survival and stem growth would be neccessary if stands of different initial densities are to reach comparable production plateaus. After eight years of growth, the tests have yet to demonstrate this behavior although the DBH statistics indicate that this interplay may be becoming more significant with additional time.

The sand pine study plots indicate that not only is it a slower growing species, but it also has not experienced growth differentiation by initial planting density an equation for estimating stand survival rates over time could not be estimated since mortality has yet to exceed

one percent. The regression equations for average height (AHT) and DBH (ADBH) are (9) and (10), respectively.

$$AHT = 2.161067 * EXP ** (-5.3369238/AGE) \quad (9)$$

$$ADBH = -1.428577 - 0.0000109 * CUR.DENSITY + 0.790764 * AGE \quad (10)$$

The four equations, (7) through (10), explain 97, 95, 95 and 82 percent of the variation in their respective data sets. Since stand survival rates could not be determined to predict future growth and yield, the Coile and Schumacher (1964) slash pine survival equation was used, as was a linear equation for sand pine from Rockwood et al. (1983).

Pine: Economic Evaluation

The equations estimated from the study plots indicate that net growth is still expanding on all plots at all planting densities. Mortality is not significantly reducing stocking and average tree data does not indicate that the productive capacities of the sites have been reached in the first eight years. However, mean annual weight production is declining at the upper stocking levels (ie, over 14,600 trees/hectare) Measurements are also beginning to disperse due to different stocking levels. For the first time, the high density production functions of slash pine can be estimated. The research plots will need to be annually monitored over the next few years since a catastrophic mortality event has yet to occur. Once such a crash occures at the various planting densities, better predictive equations for biomass productivity will be possible.

Figure E-4 demonstrates that the optimal rotation length for SRIC slash pine plantations is affected by both the alternative rate of return for capital used to evaluate the investment, as well as the initial planting density. It appears from the figure that at low alternative rates of capital costs, the less dense plantations on a longer rotation (at least 8 years) would provide for the least cost alternative. But if higher real rates of return are required for investment capital, the higher density plantations will provide the least cost alternative.

The net effect is that stand biomass production functions for intensively managed slash and sand pine plantations still need further estimation. The current spacing and Nelder study plots have the potential for providing these necessary equations, but more time is needed. It is expected that at the higher planting densities, survival and diameter growth should begin to rapidly decline due to the productive capacity of the site being reached. Although the current production functions are incomplete, it is interesting to see what the data indicate as far as the economic attractiveness of slash and sand pine plantations for energetic biomass production. The average cost per dry Mg and per GJ are listed in Table E-8 for both slash and sand pine intensive culture biomass plantations.

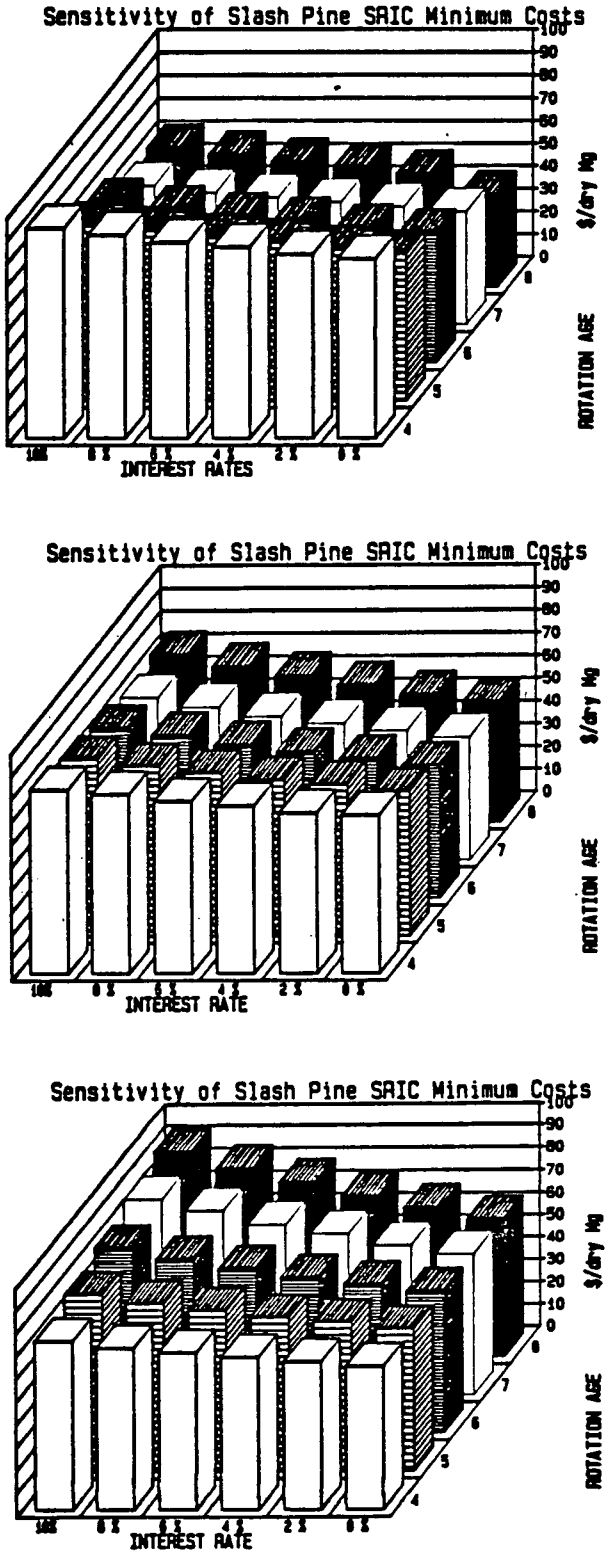

Figure E-4. Sensitivity of slash pine biomass costs to changes in interest rate and rotation age for planting densities of 4,800 (top), 14,600 (middle) and 43,300 (bottom) trees per ha.

Table E-8. Short-rotation intensive culture slash and sand pine biomass plantations: estimated production and average costs.

Species/Density	Age (yrs) 3	4	5	6	7	8
	--------Biomass Production (dry tonnes/ha)--------					
Slash Pine						
4,800	19.2	20.6	31.8	43.2	63.4	73.3
8,400	33.2	36.2	48.4	62.8	85.1	98.2
10,000	38.8	-	54.1	67.1	-	102.6
14,600	58.4	61.4	73.9	88.8	108.5	116.0
25,100	101.1	101.6	111.1	122.1	136.0	139.7
43,300	177.5	172.7	176.0	180.6	181.0	188.6
Sand Pine						
5,000	0.2	0.8	2.1	4.5	8.0	13.0
10,000	0.3	1.6	4.3	8.9	16.0	26.0
	----------Cost Projection (Avg $/DMT)----------					
Slash Pine						
4,800	-	79.16	64.56	57.44	49.78	40.32
10,000	67.76	-	66.35	60.54	-	51.41
14,600	-	69.01	63.54	58.81	54.22	53.71
25,100	-	65.18	62.98	60.72	58.18	58.16
43,300	-	62.52	62.49	62.22	62.74	61.92
Sand Pine						
5,000	-	1853.41	764.52	387.11	236.54	158.51
	----------Cost Projection (Avg $/gj)----------					
Slash Pine						
4,800	-	4.02	3.28	2.92	2.53	2.45
10,000	3.44	-	3.37	3.07	-	2.61
14,600	-	3.50	3.23	2.99	2.75	2.71
25,100	-	3.31	3.20	3.08	2.95	2.95
43,300	-	3.17	3.17	3.16	3.18	3.14
Sand Pine						
5,000	-	93.14	38.42	19.43	11.89	7.97

The data are probably most reliable for rotations of four through eight years of age since the equations are based on data through eight years of age. At planting densities of 4,800 slash pine trees/ha, average cost per dry Mg drops from over $79.16 to under $40.32 by increasing the rotation from four to eight years. The average cost per GJ also drops from $4.02 to 2.45 with the same increase in rotation. If the initial planting rates are increased to 10,000 slash pine trees/ha, the average costs are increased for every rotation considered (Table E-8). Changing the discount factors employed in the analysis will affect the estimated average costs of production, but the estimates are more sensitive to planting densities than to discount factor. Better production functions are more important in determining more reliable

estimates of the attractiveness of slash pine energy plantations than any sensitivity analysis developed at this point in time.

With the current set of equations for sand pine production, the average cost per dry tonne or gigajoule are much greater than the slash pine systems. The average cost of production does not drop below $100 per dry Mg unless a ten year rotation is considered. Such a rotation would provide fuel at an average cost of $4.40 per GJ. Unfortunately this estimate is well beyond the data base on which the equations are based. In general, intensively cultured sand pine plantations do not appear to be very attractive energy biomass production systems.

Energy wood is being increasingly utilized in Florida (Draper et al. 1986). Forest industry used over two million wet Mg of wood for energy production in 1984, and more than 300,000 Mg of wood chips were sold to other wood energy users. While these quantities were almost exclusively derived from commercial forest lands, several applications indicate the potential for short-rotation intensive culture plantations to supply energy wood.

One such application is a wood-fired steam generating facility at Union Correctional Institute in northeast Florida (Shroeder 1985). Using some 20,000 wet Mg annually to produce steam at a cost of approximately $2 per GJ, the Institute saves an estimated $360,000 per year compared to alternative fuels. This annual wood consumption corresponds to the approximate yearly production of 400 ha of E. amplifolia at the growth rate observed in experimental conditions.

Another localized application could be a citrus juice plant, of which there may be as many as 100 in operation in Florida. At the rate of 65 Mj per box of fruit processed (Holladay 1981) and a 1984-85 production of 102 million boxes, the citrus industry is a major energy consumer. Some 90% of the energy consumed by a processing plant, i.e., by the feed mill, evaporators, and boilers, could be derived from wood. Lands in the vicinity of many juice plants are suitable for growing E. camaldulensis and/or E. grandis.

A third potential user of energy wood could be electrical generation plants. Assuming a 10 MW power plant, Draper et al. (1986) estimated that cropping of eucalypts on 2,700 ha in southern Florida would be required to meet the energy demand.

The land base required for woody biomass production depends on the energy facility, time aspects of energy wood demand, species productivity, and rotation length. Assuming that 20% of pasture and rangeland would be available for woody biomass production, some 500,000 ha in Florida could be used for energy wood production Draper et al. 1986. Non-merchantable commercial forest land provides additional potentially available area.

Conclusions

This task estimated of the present net worth of all costs, in ovendry tonnes, necessary to produce and deliver woody biomass to an

energy conversion site. Eucalypt biomass production functions were estimated from study plot data and updated for seedling and coppice rotations as possible. Silvicultural equipment used in all facets of stand management monitored, both from an economic and energetic viewpoint. Strategies for reducing costs while increasing productivity were devised and assessed.

The economics of producing potential energy for the least cost from a Eucalyptus SRIC energy plantation system appear to favor the denser stocking (10,000 vs. 1,600 trees/ha) with a five-year rotation. Actually, the estimated cost/dry Mg is more sensitive to growth and rotation length assumptions than it is to modifications in the assumed production functions (±20%) or real discount rates (0% to 8%). Given the optimal cycle for both planting densities, the optimal planting density is dependent upon the growth function and discount factors assumed.

Associated inputs and costs suggest that short-rotation, close spacing culture can make woody biomass competitive with other feedstocks available for energy generation. Breakeven costs per delivered GJ range from just under $2.00 for E. grandis in 2-year rotations on muck soils and for E. amplifolia in 3-year cycles on agricultural lands to under $4.00/GJ for E. grandis on prairie and E. camaldulensis on sandhills.

The discounted average costs per dry Mg figures presented in this paper only represent cost figures and production functions known to date. Eucalyptus seedling production on a large scale, with its corresponding cost economies of scale, does not currently exist. Harvesting and drying costs are major cost components of the woody biomass SRIC system, but the engineering of efficient equipment still remains in an early testing and design stage.

Ongoing research is evaluating other additional genotypes for properties including faster initial growth and better coppice response in terms of growth rates and harvest success for the time of year and climatic conditions. If coppicing success continues to be limited to certain seasons of the year, the storage methodologies or alternative (off-season) sources of biomass need to be examined. Biomass can be produced at reasonable cost in southern Florida from a SRIC Eucalyptus system. A prototype operation with an electrical generator will be the final determination of its' feasibility for supplying local markets with energy from a renewable resource.

Eucalyptus biomass plantations will be commercially viable in Florida when productivity is assured, harvesting is economical, and markets are established. To date, substantial increases in yields have been achieved through genetic selection and cultural options, harvested and transported biomass is estimated to have very positive economic and energetic ratios, and utilization of woody biomass for energy is increasing.

Based on data through eight years, it would appear that intensively cultured slash pine plantations could serve as the source of biomass for the production of energy at a competitive cost with existing fossil fuel technologies. Better production functions and more detailed analysis

must occur before a more definitive statement can be made. It would also appear that the intensively cultured sand pine plantations are not competitive unless further research determines that these sites are more productive than currently estimated.

If woody biomass is to compete as an energy source, then the delivered cost of the potential energy must be less than that of current fossil fuels. According to Asbury et al. (1983), delivered coal prices are just under $2 per gigajoule in 1982 dollars and they should remain under $3 dollars through the end of this Century. Therefore, since coal has the lowest delivered cost as compared to natural gas or residual oil, the average cost of woody biomass fuels should be targeted to be less than this fuel. This can only serve as a very rough benchmark price since the cost of utilizing the different fuels was ignored. For example, woody biomass can be burned with very little residue or air pollution problems. On the other hand, coal requires special and expensive scrubbers to reduce pollution and much greater quantites of ash must be disposed of after combustion.

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TASK F. BIOMASS CHARACTERIZATION OF EUCALYPTUS.

This task evaluated physical and chemical properties of Eucalyptus biomass, with emphasis on E. grandis, in response to cultural variables.

Methods

Previous Samples: Biomass samples collected before September 1983 were ground and stored for future determination of physicochemical properties.

Biomass Properties: GPOP77-Trees of the 27 E. grandis progenies occurring in ORNL-35 and ORNL-36 were chosen for stemwood sampling in GPOP77. Trees being harvested for the roguing of GPOP77 were marked in February 1986 for collection of stem disks in March. Based on the results of Roeder (1981), tree representative disks were taken at 1.5 m stem height. Trees in the northern half of GPOP77 were 103 months old from seedlings, while trees in the southern half were 90-month-old coppice stems arising from a felling in August 1978. The sampling of the 13-month-old trees cut in 1978 (seven per progeny) was conducted by the U.S. Forest Service using quarter-height stem disks. Routine wood moisture content (MC) and specific gravity (GW) determinations were conducted.

ORNL-35-Destructive sampling of trees in ORNL-35 was conducted in December 1986. Up to three trees per row-plot (the third, sixth, and eighth trees in the row) in a replication were felled for E. grandis, E. robusta, E. amplifolia, and E. dunnii. Each sample tree was separated into stemwood and branches + foliage, and each of these two parts was immediately weighed. A representative branch and a quarter-height stem disk were then taken for the December 1986 trees, bagged, and stored. In the laboratory, these samples were dried at 70°C and weighed to determine green weight-dry weight (DW/GW) ratios and moisture content.

These same 288 trees, plus additional trees felled in March 1987, were utilized to estimate the percentage contribution of stem and crown components on a green weight basis. The additional 44 trees were felled in a fourth replication, partitioned into stem and branches + foliage, and weighed immediately.

Fermentation Analyses: Quarter-height stemwood samples of species in ORNL-7, ORNL-16, DP-1, and SS-1 were provided to the Gas Research Institute (GRI) - funded "Methane From Biomass and Waste" project for determination of fermentability and chemical composition. Analytical procedures were those of Bjorndal and Moore (1986).

Eucalyptus stemwood from ORNL-35 was provided to TVA, Chemical Engineering, at Muscle Shoals, AL, for hydrolysis analysis in March 1987. Stemwood sections were taken from 20-month-old progenies of E. grandis, E. robusta, E. dunnii, and E. amplifolia. Analysis included composition of various sugars, lignin, and ash. Derived results were compared to those of other species.

Pulping Analyses: Stemwood samples from one *Eucalyptus amplifolia*, *E. dunnii*, *E. grandis*, and *E. robusta* in ORNL-35 and one 5.3-year-old ramet of clone 2814 in ORNL-37 were provided to Biodyne Chemicals, Appleton, Wisconsin, in December 1987 for preliminary pulping analysis. These analyses were conducted using procedures for the experimental ester pulping process to estimate tear strength, burst, bulk, breaking length, Kappa number, and yield.

Results

Previous Samples: Ten species and a wide range of conditions are represented by the stored samples (Table F-1). More samples are available for *E. grandis* than any other species, and most of these were obtained in ORNL-7. Several species were sampled in ORNL-16. Management options are best represented by samples from ORNL-7, although numerous samples were taken from young slash pine in several treatments. These dried samples, ground to fit a 40-mesh screen, are suitable for the determination of volatile matter, fixed carbon, ash content, heat of combustion, fatty extractives, and elemental composition.

Table F-1. Biomass samples from ORNL studies in storage for potential physicochemical analysis.

Species	Studies/Factors Represented
Casuarina spp.	ORNL-0; ORNL-16
Melaleuca	ORNL-8; ORNL-16/coppice
E. grandis	ORNL-7/fertilizer, selection, spacing, Nelders; ORNL-16/spacing
E. robusta	ORNL-16/spacing
E. amplifolia	DP-1
T. distichum	ORNL-16
Slash pine	ORNL-10/fertilizer, spacing; ORNL-11/fertilizer, spacing
Sand pine	ORNL-13/spacing

Biomass Properties: GPOP77-The 27 progenies sampled are among the best for biomass production. Several were evaluated in ORNL-7 and/or ORNL-16, and all are established in ORNL-35 and -36. The 27 were highly rated for coppice productivity in GPOP77.

As determined by the U.S. Forest Service when the southern half of GPOP77 was harvested in August 1978, 13-month-old trees of 22 of these 27 *E. grandis* progenies varied in stem wood moisture content and specific gravity (Table F-2). The broad ranges among progeny means must be

moderated by the limited portion of the data reported here. For SG, however, the range is similar to that obtained with larger samples at older ages.

Similar variability in the stemwood properties of older trees and coppice as determined by sampling some eight trees/progeny was evident (Table F-2). Expressed as a percent of the mean, the range among progenies was from 10 to 22% for SG, DW/GW, and MC.

Table F-2. Stemwood specific gravity (SG), dry weight/green weight ratio (DW/GW), and moisture content (MC) of seedlings and coppice of 27 E. grandis progenies in GPOP77.

Characteristic	13-mo.-old Seedlings[1]	103-mo.-old Seedlings[2]	90-mo.-old Coppice[3]
SG (g/cm^3)			
-No. of trees	46	222	222
-Mean	.377	.422	.418
-Progeny range	.341-.418	.396-.464	.374-.449
DW/GW (g/g)			
-No. of trees	-	222	222
-Mean	-	.435	.428
-Progeny range	-	.412-.460	.407-.466
MC (%)			
-No. of trees	45	222	222
-Mean	170	131	135
-Progeny range	146-202	120-144	117-147

1/ 22 progenies (1-4 trees/progeny) in southern half of GPOP77; sampling conducted by U.S. Forest Service in August 1978.
2/ 25 progenies (7-10 trees/progeny) in northern half of GPOP77.
3/ 27 progenies (6-11 trees/progeny) in southern half of GPOP77; 22 and 25 progenies above were common to these 27.

Stem age effects on stemwood SG and MC appeared to be an increase in SG and reduction in MC for seedlings (Table F-2). The 90-month-old coppice stems were similar in SG and MC to the 103-month-old seedlings, though. In general, 13-month-old seedling SG and MC were not correlated with 103-month-old traits on a progeny mean basis, but young seedling SG was related to 90-month-old coppice SG (Table F-3).

Wood properties of seedling-derived stems and coppice-origin stems were under stronger genetic control when examined on an individual stool basis and when compared at similar ages (Table F-3). SG and MC of 90-month-old coppice stems originating from 46 and 45 stools, respectively, were very similar to the SG and MC of the young seedlings that had been felled. Even though the 103-month-old seedlings were sampled over a large area adjacent to the portion of GPOP77 that had been coppiced, correlations for the same trait were high.

Table F-3. Correlations among wood properties of E. grandis of various stem origins and ages in GPOP77.

	Stem Origin							
	13-mo. Seedlings		103-month Seedlings			90-mo.Coppice		
Stem Origin/Property	SG	MC	SG	DW/GW	MC	SG	DW/GW	MC
Individual Stool Basis								
13-mo. Seedlings								
-SG[2]	-	-.723*[1]	-	-	-	.657*	-	-.470*
-MC[1]	-	-	-	-	-	-.433*	-	.589*
Progeny Mean Basis								
13-mo. Seedlings[3]								
-SG	-	-.573*	.142	.114	.040	.596*	.168	-.186
-MC	-	-	.146	.144	.263	-.165	-.419	.236
103-mo. Seedlings[4]								
-SG	-	-	-	.524*	-.512*	.622*	.189	-.206
-DW/GW	-	-	-	-	-.998*	.294	.668*	-.672*
-MC	-	-	-	-	-	-.268	-.653*	.657*
90-mo. Coppice[5]								
-SG	-	-	-	-	-	-	.366	-.403*
-DW/GW	-	-	-	-	-	-	-	-.994*

*Significant at the 5% level.
[1] n=45 stools.
[2] n=46 stools.
[3] n=22 progenies.
[4] n=25 progenies.
[5] n=27 progenies.

ORNL-35: Between- and within-species variability for DW/GW and MC was assessed for 18-month-old Eucalyptus stems and branches (Table F-4). The stem DW/GW of E. grandis exceeded those of the other species, and due to the inherent correlation between the two traits, the MC of E. grandis stems was among the lowest. The branches + foliage component of E. robusta had a higher DW/GW and lower MC than those of E. grandis, E. dunnii, or E. amplifolia.

These values are similar to stemwood and stembark MCs previously reported for 2.5-year-old E. grandis and E. robusta in ORNL-16 at the same 10,000 trees/ha (Rockwood, et al. 1983). Those 306 and 169% MCs for E. grandis stembark and stemwood, and 313 and 183% MCs for E. robusta stembark and stemwood, respectively, when weighted by their stem volume contributions, give stem MCs approximately the same as observed here for 18-month-old trees. Therefore, E. grandis stems may be expected to contain slightly less water than E. robusta stems at rotation lengths from 18 to 30 months.

In comparison to the previously discussed E. grandis growing on "palmetto prairie" in GPOP77 (Table F-2), certain influences of site may be inferred. Although the comparisons involve stemwood + stembark in

Table F-4. Average and range among progeny/source means for stem and branch dry weight/green weight ratios (DW/GW) and moisture content (MC) of 18-month-old *E. grandis*, *E. robusta*, *E. dunnii*, and *E. amplifolia* in ORNL-35.

	Stem			Branch		
Species/Progeny	No. of Trees	DW/GW	MC	No. of Trees	DW/GW	MC
E. grandis						
-Overall	147	.356a[1/]	184.6b	66	.342b	202.8b
-Progeny Range	7	.390	157.5	1	.427	134.0
	5	.322	215.4	2	.257	292.5
E. robusta						
-Overall	110	.333b	202.5a	53	.378a	166.3a
-Progeny Range	8	.369	176.1	2	.415	141.1
	4	.304	229.3	3	.343	192.6
E. dunnii						
-Overall	12	.336b	177.4b	5	.333b	209.8b
-Progeny Range	4	.391	156.4	1	.399	150.7
	2	.316	218.3	2	.314	218.5
E. amplifolia						
-Overall	19	.333b	202.0a	9	.348b	198.5b
-Progeny Range	1	.360	177.8	1	.395	153.1
	7	.328	205.1	4	.329	221.6

[1/] Species means within a trait sharing a common letter are not different at the 5% level of significance.

ORNL-35 vs. stemwood in GPOP77, the faster-growing *E. grandis* on muck soil appear to have a lower stem DW/GW and a correspondingly higher MC. Based on correlations among progeny means for the 27 progenies common to the two studies, stem DW/GW and MC in ORNL-35 were not related to stemwood DW/GW and MC in GPOP77. While the preliminary conclusion from these correlations would be that genetic control of biomass properties across muck and "palmetto prairie" sites is weak, the limited sample sizes and particularly the different ages and traits involved identify the need for additional investigation. Older trees in ORNL-36 can provide an excellent basis for comparison with the ORNL-35 data.

Variability observed for DW/GW and MC within species in ORNL-35 and GPOP77 suggests that modest genetic gains could be expected on a given site, however. As reported by Wang et al. (1984) for *E. grandis*, changes of 4 to 7% for wood SG and MC, respectively, could be expected from selection. Emphasis on wood density as the selection trait has been suggested as a means of increasing energy yield as well.

Biomass allocation to stem and crown was examined for trees with DBHs from .8 to 9.5 cm (Table F-5). Given the differences among species in tree size, percentage allocations to stem and crown were similar across species, as roughly 75% of total tree biomass was in the stem and 25% was in the branches + foliage. Within species, genetic variability was evident, especially in *E. grandis*. Among well-represented *E. grandis* progenies (6 to 9 trees per progeny), stem vs. crown biomass ranged from

Table F-5. Stem and crown partitioning (green weight basis) for 18- and 20-month-old E. grandis, E. robusta, E. dunnii, and E. amplifolia in ORNL-35.

Species	No. of Trees	Mean DBH (cm)	Mean Ht (m)	Stem (%)	Branches + Foliage (%)
E. grandis	146	5.0	8.2	76.2 (66.8-84.5)[1]	23.8 (15.5-33.2)
E. robusta	110	4.6	7.4	75.5 (68.6-79.0)	24.5 (21.0-31.4)
E. dunnii	12	3.6	6.3	69.3 (64.9-81.8)	30.7 (18.2-35.1)
E. amplifolia	19	4.4	5.9	72.5 (60.9-78.2)	27.5 (21.8-39.1)

[1] Range among progeny/source means.

85%-15% to 67%-33%. Since DBH ranges was similarly sampled, such differences suggest the possibility for selecting trees for efficiency, i.e., trees with high stem production relative to photosynthetic area.

Fermentation Analyses: Fermentability and chemical composition analyses by GRI (Table F-6) identified tentative variability among woody species for the critical factors of cell wall constituents and lignin. Due to their high percentages of these factors, woody species are much less fermentable than other plants (Bjorndal and Moore 1986). Of the woody species assessed, the eucalypts were highest in both cell wall constituents and lignin. The wood of Spathodea campanulata was lowest in these two characteristics.

Compositional analysis of four Eucalyptus species by TVA indicated that these eucalypts have similar compositions (Table F-6). The cellulose (glucose) component ranged from 37.5 to 41.6%, and the hemicellulose constituents (composed mainly of xylose) contributed 6.4 to 8.1%. The lignin compositions, at about 34%, were higher than the GRI estimates for two eucalypt species. Ash content exceeded 1% and was highest for E. dunnii at 1.9%. Compared to Puls (1983) results from eucalypts, the composition of these four samples was some 9% lower in glucose and in xylose, 7% higher in lignin, and 1% higher in ash. In relation to oak, Eucalyptus has higher xylose and lower lignin contents.

Obtained conversion rates for similar feedstocks were applied to the Eucalyptus sugar compositions to estimate ethanol yield (J. Broder, TVA, personal communication). Applying 1) conversion rates of 80% for hemicellulose to xylose and 50% for cellulose to glucose in the dilute sulfuric acid hydrolysis process and 2) fermentation conversion rates of 70% for xylose to ethanol and 95% for glucose to ethanol, one dry ton of Eucalyptus may be expected to yield 115 pounds of xylose and 400 pounds of glucose, or 36 gallons of ethanol. Applying conversion rates for the concentrated sulfuric acid hydrolysis process with sawdust size particles of wood, namely 92% for hemicellulose to xylose and 85% for cellulose to

Table F-6. Fermentation analyses conducted by GRI and TVA on one stem-wood sample from *Eucalyptus grandis* (EG), *E. robusta* (ER), *E. dunnii* (ED), *E. amplifolia* (EA), and other woody species.

Species[1]	GRI Characterization						
	Organic Matter	NDFA[2]	IVOMD[3]	ADF[4]	Lignin[5]	N [6]	P
	(% dry matter basis)						
Acacia auriculiformis	97.1	84.8	11.4	69.3	20.5	0.89	0.05
Acacia mangium	98.4	84.9	15.2	73.6	21.6	0.64	0.05
Albizia falcataria	98.4	87.9	13.6	76.5	21.2	0.58	0.05
Casuarina equisetifolia	98.8	91.6	3.0	75.6	25.8	0.37	0.03
EG	98.6	91.5	5.5	73.7	27.7	0.16	0.13
ER	99.2	95.8	0.0	81.6	30.3	0.21	0.03
Mimosa scabrella	97.3	89.3	20.9	71.1	19.8	0.97	0.05
Plantanus occidentalis	99.2	90.1	6.9	-	-	-	-
Schinus terebinthifolius	98.1	84.8	11.1	69.4	20.5	0.43	0.07
Sapium sebiferum	98.5	85.7	19.1	69.5	20.2	0.49	0.04
Spathodea campanulata	96.7	75.4	18.6	8.0	17.7	0.73	0.14

Progeny/Tree[7]	TVA Composition Analysis						
	Glucose	Xylose	Glactose	Arabinose	Mannose	Lignin	Ash
	(%, dry basis)						
EG 869-8	41.6	7.2	<.2	<.2	<.2	32.9	1.3
ER 2126-8	41.2	6.4	<.2	<.2	<.2	34.7	1.5
ED 2-1-1	37.5	7.1	<.2	<.2	<.2	33.7	1.9
EA 2-8-5	38.7	8.1	<.2	<.2	<.2	34.0	1.5

1/ Samples taken from trees in SS-1 and ORNL-16 at Belle Glade except for *Platanus occidentalis* taken from DP-1.
2/ Neutral detergent fiber ash-free cell wall constituents.
3/ Digestibility by rumen microbes.
4/ Acid detergent fiber = cellulose + lignin.
5/ Potassium permanganate method.
6/ Kjeldahl method.
7/ Samples taken from 20-month-old trees in ORNL-35 at Belle Glade.

glucose, one dry ton would yield 130 pounds of xylose and 675 pounds of glucose, or 55 gallons of ethanol.

The eucalypts are suitable as hydrolysis feedstocks (J. Broder, TVA, personal communication). Neither TVA nor Puls (1983) detected possible inhibitors to hydrolysis and subsequent fermentation to alcohol. While no problems are anticipated in converting *Eucalyptus* to ethanol, actual testing is required to define optimum processing conditions and to verify these estimated sugar and ethanol yields.

Pulping Analyses: *Eucalyptus* pulp is in high demand by many pulp mills in the United States. When blended with other feedstocks, *Eucalyptus* pulp is generally acknowledged to improve the speed and operation of pulp machines (W. Heckrodt, personal communication). For some processes and products, *Eucalyptus* pulp has properties superior to other species (Franklin 1977). For example, *Eucalyptus* pulp is more absorbent than pulps of our native hardwoods.

The properties of the Eucalyptus species that can be grown in Florida appear to be suitable for the ester pulping process (Table F-7). Breaking length was higher than that of species such as aspen. Yield, however, was somewhat low.

Table F-7. Pulping analysis of representative trees of E. amplifolia (EA), E. dunnii (ED), E. grandis (EG), and E. robusta (ER).

Property	Average
Tear	2.2
Burst	2.75
Bulk	1.25
Breaking length (mm)	6.5
Kappa number (ml)	33
Tensile Index	65.0
Yield (% dry wood)	43

1/ 5.3-year-old clone in ORNL-37; all others 2.5-years-old in ORNL-35.

Should further analyses support the use of Florida-grown eucalypts for the ester process, the current constraint of long distance between production site and mill location could be addressed by constructing new mills in central or southern Florida. Presently, southern Florida eucalypt plantations are some 200 miles from the nearest pulp mill. Ester pulp mills, because they have relatively low environmental demands in that they produce few emissions and consume less water, may be compatible with construction regulations in Florida. Ester mills located in areas where eucalypts can be reliably grown would have favorable transportation costs.

Conclusions

This task collected biomass samples for several species representing numerous cultural variables. Recent studies focused on physical and chemical properties of Eucalyptus, particulary of E. grandis. In composite, the significance of genetics, age, and rotation factors on biomass properties was identified.

Modest genetic variability was observed in SG, DW/GW, and MC of E. grandis stem and stemwood of different ages and origins. SG of young trees is less than that of older trees, while MC is higher. A similar comparison may apply to fast-growing trees on muck soils compared to trees growing on "palmetto prairie." Coppice stems and seedling stems of similar ages appear to have similar properties. Genetic control of the SG, DW/GW, and MC across age was observed.

Eucalyptus at rotation-age on muck soil at 10,000 trees/ha have a stem to crown biomass ratio of approximately 3:1. Variability may exist within species for the portion of biomass concentrated in the stem.

The suitability of *Eucalyptus* for fermentation depends on the conversion process and end product. For the production of methane by anaerobic fermentation, *Eucalyptus* is inferior to other woody species, which in turn are generally more unsuitable than herbaceous crops. However, for the production of ethanol by either dilute or concentrated sulfuric acid hydrolysis pretreatment followed by fermentation, *Eucalyptus* appears suitable. *Eucalyptus* species also seem acceptable for the ester pulping process.

Task References

Wang, S., R. C. Littell, and D. L. Rockwood. 1984. Variation in density and moisture content of wood and bark among twenty *Eucalyptus grandis* progenies. Wood Sci. Technol. 18: 97-100.

TASK G. SELECTION OF OTHER SPECIES FOR BIOMASS PRODUCTION.

This task assessed the following species for their potential for woody biomass production under conditions for which eucalypts are not appropriate: slash pine (*Pinus elliottii* var. *elliottii* Engelm.), sand pine (*P. clausa* var. *immuginata* Ward), *Sapium sebiferum*, *Casuarina glauca*, and *Taxodium distichum*.

Methods

Southern Pines: Growth measurements were collected periodically from two slash pine studies (ORNL-10 and ORNL-11) and two sand pine studies (ORNL-13 and ORNL-14) established in 1980. Nelder, fertilizer, selection, and spacing components (Table 7-1) permitted the evaluation of site amendment, spacing, genetic, and genetic x spacing factors on productivity in short-rotation, intensive culture. The three levels of inorganic fertilizers (0, 50-50, 150-50 kg of N and P per ha) were applied as pelleted urea (45-0-0) six months after planting and ground rock phosphate (0-9-0) prior to planting.

Choctawhatchee sand pine (CSP) seedlings representing 40 clones and seedlings from a checklot (seed source ,Eglin Air Base, Fl) were produced in Chipola Forest Nursery during 1979. Nursery techniques appropriate to the production of CSP seedlings were followed (Brendemuehl and Mizell 1978). Dead seedlings in ORNL-13 were replanted in January 1981 in the fertilizer and Nelder tests. Survival, height, and diameter were recorded periodically through age 6 for both studies, and at age 7 for ORNL-13. The number of trees observed varied with the trait age and test. In most of the tests, survival was recorded for all the trees in a plot, while for height and diameter at breast height (DBH) the inner 25 or 36 trees were measured. DBH was mostly recorded at ages 3, 5, and 6 or 7. Data were analyzed using appropriate analysis of variance techniques. Sand pine stem dry weight biomass was calculated using the equation developed by Rockwood et al. (1987)

$$kg = 1.6395 + .008093 \times DBH^2\ (cm) \times \text{Tree Height}\ (m)$$

The stem dry matter accumulation was calculated for ages 4, 5 and 7.

Other Species

Sapium sebiferum: This was one of several species screened at Belle Glade in a GRI-sponsored study SS-1 established in June 1982. Coppicing was monitored through March 1987 after a 17-month seedling rotation. It was also established in a University of Florida - funded species screening study MR-4 in central Florida in June 1983 as progenies of selections throughout the Southeast. Growth was monitored until freeze damage in December 1983 and heavy grass competition terminated the study in 1984. As reported earlier for study DP-1, periodic measurements on its seedling and coppice productivity were also taken on a northern Florida site.

Casuarina glauca: Casuarina glauca planted in ORNL-16 in May 1980, the only one of three Casuarina species in the study to survive the freezes through 1985, was measured periodically in the 1 x 1 m portion of the study. The final measurement was taken in March 1987 on tree size and survival. Ten trees representative of the DBH range in one 100-tree plot were felled and processed in the manner described for ORNL-35 trees in Task F.

Taxodium distichum: Another of the species in ORNL-16 that survived the freezes, T. distichum was evaluated as seedling and coppice in the 1 x 1 m spacing. Seedling and coppice origin trees were last measured in March 1987. Ten trees were destructively sampled as were the C. glauca trees described above. Productivity was estimated for both seedling and coppice rotations.

Results

Southern Pines

Slash pine: Eighth-year response of slash pine to fertilization in ORNL-11 (Table G-1) confirm earlier indications that slash pine responds less to amendments on good sites such as represented by ORNL-11. No differences due to fertilizer level were detected for individual tree traits, although maximum tree size was reached at the N/P levels of 150/50 per ha. In composite, the 150/50 produced the greatest biomass per ha (Figure G-1). Responses to these same levels in ORNL-10 were much greater suggesting that fertilization of slash pine should be matched to nutrient needs of the site. The high level of sewage sludge produced a notable response at all ages.

Table G-1. Mean height, DBH, and survival for 8-year-old slash pine in fertilizer tests in ORNL-10 and ORNL-11.

Treatment[1] (N/P) (kg ha-1)	Height (m)	DBH (cm)	Survival (%)
ORNL-10			
0	5.6c	5.3bc	92.3
50/50	4.7c	4.7c	87.7
150/50	6.5b	5.6b	93.0
175/135S	6.0bc	5.5b	92.7
200/100	6.5b	5.7b	89.7
350/265S	7.8a	7.0a	87.7
ORNL-11			
0	8.4	7.4	93.0
50/50	7.9	7.5	93.4
150/50	9.1	9.0	84.8
200/100	8.5	7.5	89.3

[1] Expressed in elemental units; S=sewage sludge.
[2] Means within a trait/test not sharing the same letter are significantly different at the 5% level.

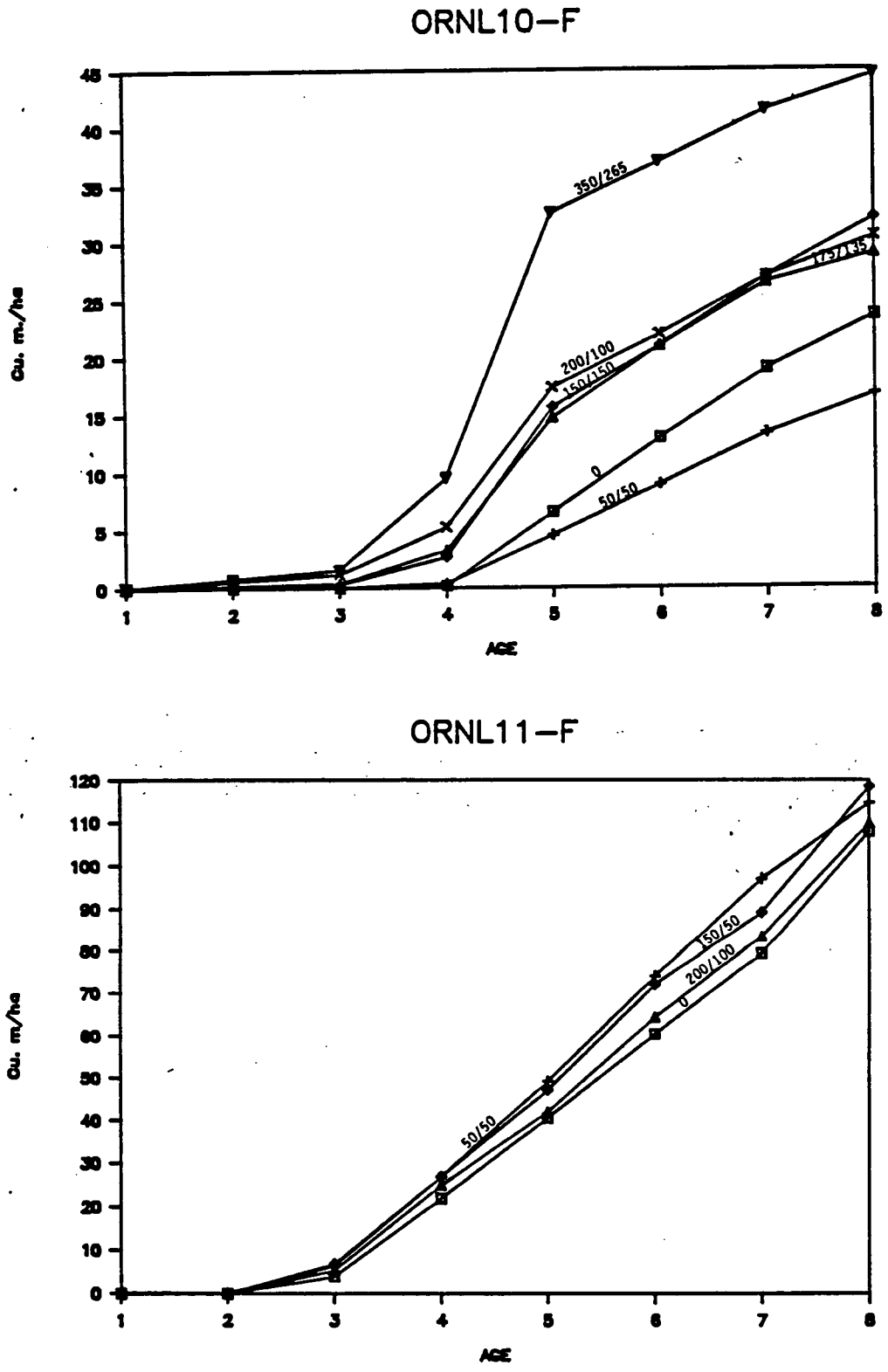

Figure G-1. Productivity (ΣD^2H) through eight years of slash pine in response to fertilization at establishment in ORNL-10 (top) and ORNL-11 (bottom).

Spacing responses were observed through eight years for slash pine. In the wide range of planting densities in the Nelders, slash pine tree size differences were evident, as was a greater yield per ha at the higher densities (Table G-2, Figure G-2). These trends were supported by the 10,000 trees/ha block plots in the ORNL-11 fertilizer and progeny tests.

Table G-2. Mean height, DBH, and survival for 8-year-old slash pine in Nelder's and block plots in ORNL-10 and ORNL-11.

Planting Density (trees/ha)	Height (m)	DBH (cm)	Survival (%)
----------ORNL-10----------			
4,800	6.3	6.7	95.1
8,400	5.8	5.7	96.2
10,000a	-	5.5	94.2
14,600	5.6	4.9	93.6
25,100	5.1	4.2	94.3
43,300	4.8	3.2	89.4
----------ORNL-11----------			
4,800	8.4	9.3	93.0
8,400	8.4	8.0	93.9
10,000a	8.4	7.3	91.2
14,600	7.8	6.5	95.9
25,100	7.3	5.3	91.4
43,300	7.0	4.5	84.9

[a] Average of five progenies in progeny block plots.

Genetic variability among slash pine progenies was significant in ORNL-11 (Table G-3, Figure G-3). Slash pine progeny variation in the closer spacings in the Nelders was greater than in the block plots (10,000 trees/ha).

Sand Pine: Approximately 2.5 to 3 million acres of droughty, infertile land collectively referred to as the sandhills is found in the Panhandle and other parts of northern Florida. Much of this land is poorly stocked with scrub oaks which have little value. However, CSP and longleaf pine (*P. palustris* Mill) have proven to be well adapted to these sites. CSP is the most productive of the two species.

Fertilization has had varying influence on productivity of CSP. Nitrogen and phosphorus have been observed to increase total volume yields up to 71% in 7-year-old CSP (Brendemuehl, 1973). Fertilization had little influence on sand pine growth through 5 years in ORNL-13 and ORNL-14, as only high rates of sewage sludge had an appreciable impact on growth. Hence until meaningful responses are seen fertilizer may not be advocated.

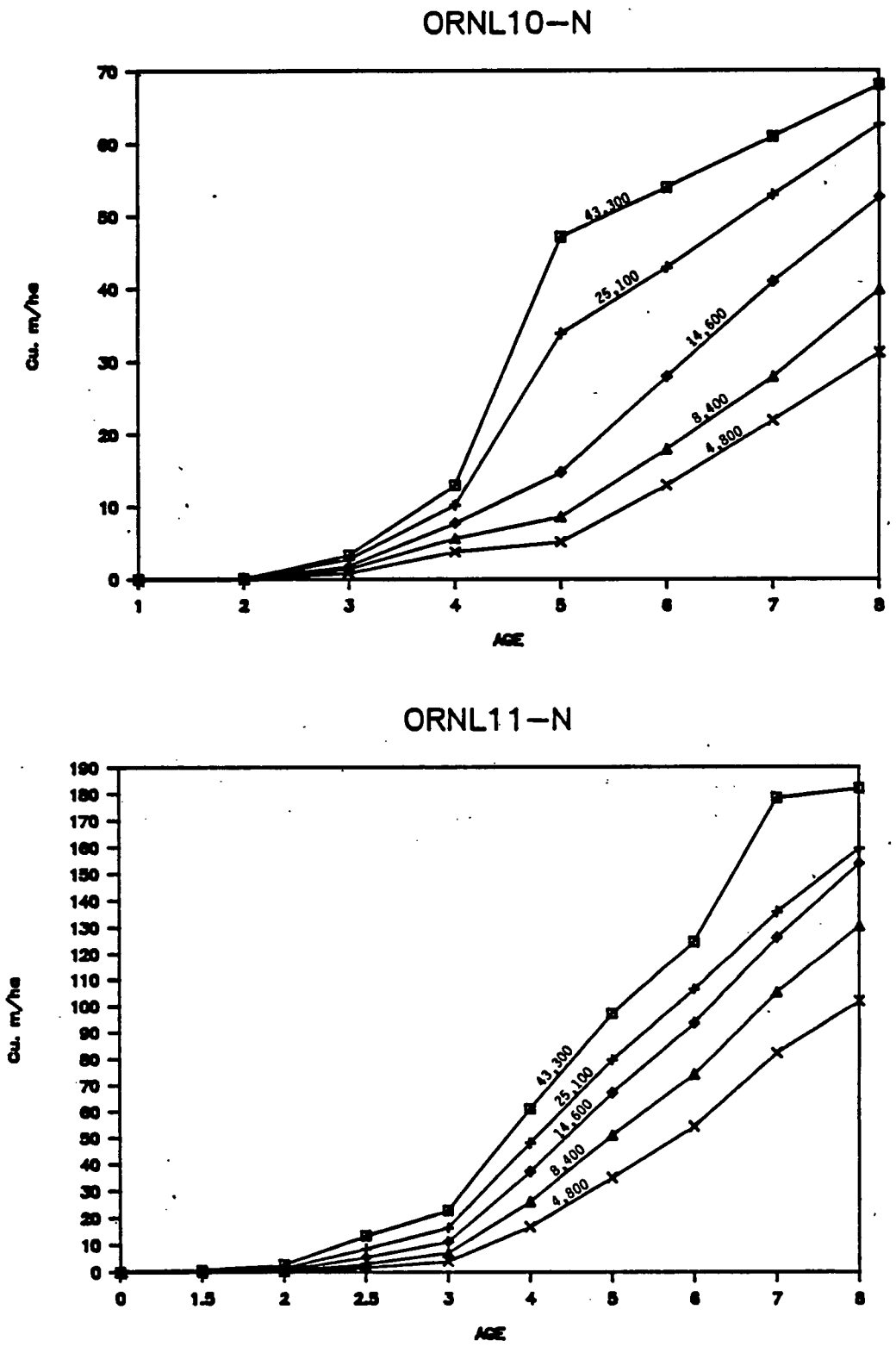

Figure G-2. Productivity (ΣD^2H) through eight years of slash pine in response to five planting densities in ORNL-10 (top) and ORNL-11 (bottom).

Table G-3. Variability among 8-year-old slash pine progenies in ORNL-10 and ORNL-11 for height, DBH, and survival in block plots and Nelder plots.

	ORNL-10				ORNL-11			
	No. of Progenies	Height (m)	DBH (cm)	Survival (%)	No. of Progenies	Height (m)	DBH (cm)	Survival (%)
Block Plots								
	22				17			
Mean		-	5.5	93		8.7	7.4	91.3
Low		-	5.1	83		7.2	6.7	86.7
High		-	6.1	99		10.0	8.1	94.7
Nelders Plots								
	33				25			
Mean		5.5	5.0	94		6.4	5.9	88
Low		4.8	4.4	85		5.5	4.7	73
High		6.1	5.6	100		6.9	6.5	97

Tree height in ORNL-13 at measurement ages 1 thru 5 varied significantly due to fertilizer (Table G-4). Application of 20 tons sewage sludge produced the tallest trees. Similar response was seen for DBH at age 5, but at age 7 there was no significant difference either in height or DBH. In earlier studies, fertilizer also had little influence on sand pine growth through five years. The stem biomass accumulation rate at age 5 and 7 decreased from age 5 to 7 in all treatments but 20 tons sludge, in which it increased. This suggests that nutrients might have started becoming limiting and larger differences could be expected during the subsequent years.

In ORNL-14, sand pine did not respond to fertilization (Table G-4) as in ORNL-13. Though the height varied significantly at age 3, the difference was not sizable, as the minimum was .9 m and the maximum was 1.03 m. Survival at age 6 was significantly lower in 150/50 when compared to other rates. DBH and stem dry matter accumulation at age 6 did not vary much. It appears that for the present level and rate of growth of sand pine growth, nutrients have not yet begun to become limiting.

Overall, sand pine did not respond to fertilizers until age 6 to 7. Twenty tons sewage sludge appeared to show better growth probably indicating its advantage of slow release. This was also evident from the earlier studies where split application was superior to single application as sandhills do not have much nutrient storage capacity. Applied nutrients, particularly N, may leach especially because sand pine grows slowly during the initial one to two years with little demand for nutrients, and the inherent nutrient content of the sandhills may be enough for the growth of sand pine at that stage. Sewage sludge also contains other nutrients in addition to N and P. It appears that the nutrients have not yet become limiting. Meaningful responses may occur

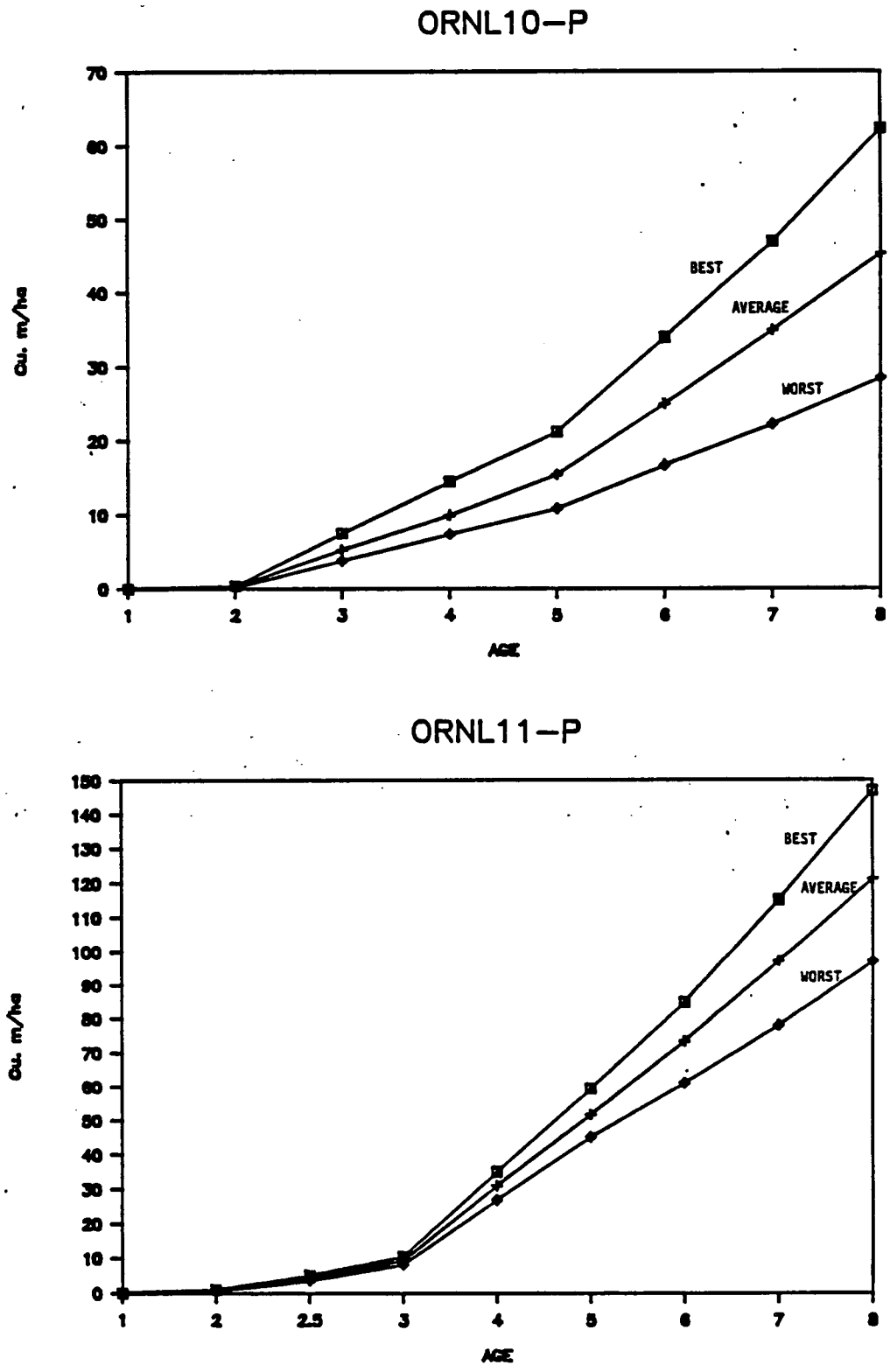

Figure G-3. Productivity (ΣD^2H) through eight years of slash pine progenies (top 5, average, bottom 5) in ORNL-10 (top) and ORNL-11 (bottom).

Table G-4. Mean height, DBH, and survival for sand pine in fertilizer studies in ORNL-13 and ORNL-14 at 7 and 6 years of age, respectively.

Treatment (N/P) (kg/ha)	Height (m)	DBH (cm)	Survival (%)
ORNL-13			
0[1]	5.0	4.6	100.0
50/50	5.2	4.7	99.0
150/50	5.1	4.7	99.5
175/135S	5.0	4.5	99.8
350/265S	5.3	5.0	99.5
ORNL-14			
0	4.1	3.8	87.7
50/50	4.2	4.1	88.0
150/50	4.0	3.8	82.3

[1] Expressed in elemental units; S=sewage sludge.
[2] Means within a trait/test not sharing the same letter are significantly different at the 5% level.

during subsequent years. Earlier studies indicate a marked response to N after P deficiency is corrected. Also, better response to split application than single dose and a slow release fertilizer is suggested. Alternatively a slow release source like sewage may be better suited.

The Nelder's in ORNL-13 had high survival that was not influenced by spacing from ages 1 thru 7 (Table G-5). Spacings did influence the height of trees especially at age 7 where the trees at 43,300 trees/ha were .8 m shorter than the trees at 4,800 trees/ha. DBH varied significantly with spacing at ages 4, 5 and 7; at age 7 it was quite distinct with the widest having almost double the DBH of the closest spacing.

At age 4, 18 dry Mg/ha/yr was recorded in the closest spacing while 2 Mg/ha/yr was recorded with the widest spacing (Figure G-2). Though DBH increased considerably in wider spacings, it did not compensate for the larger number of trees in the closer spacing.

The height of sand pine varied significantly due to spacings at age 6 in ORNL-14 (Table G-5). The widest spacing produced the tallest trees as observed in ORNL-13. The response to DBH was similar to study 13 where the widest spacing produced significantly higher DBH at age 6. The stem dry matter accumulation at age 6 was similar to the Chipola site, closest spacing produced 11.3 DTE versus 1.6 in the widest spacing. The survival at age 6 varied significantly as the wider spacings had higher survival than closer spacings, indicating spacing may become critical as the trees grow.

Table G-5. Mean height, DBH, survival, and dry weight for sand pine in Nelder's and spacing plots in ORNL-13 and ORNL-14 at 7 and 6 years of age, respectively.

Planting Density (trees/ha)	Height (m)	DBH (cm)	Survival (%)	Stem Dry Weight Per Hectare Per Year (Mg)
ORNL-13				
4,800	4.8	5.1	99.2	1.64
8,400	4.6	4.5	98.9	2.70
14,600	4.4	3.6	100.0	4.37
25,100	4.2	3.1	98.9	6.83
43,300	4.0	2.7	97.8	10.84
ORNL-14				
4,800	3.81	4.5	90.7	1.80
6,667a	3.76	4.16	65.3	1.54
8,400	3.81	3.9	91.9	2.86
10,000a	3.83	3.63	77.9	2.66
14,600	3.66	3.4	91.0	4.38
20,000a	3.71	3.27	77.9	5.09
25,100	3.32	2.8	88.3	6.95
43,300	3.31	2.4	83.5	11.31

a/Block plot densities in Spacing plots; otherwise densities for concentric circles in Nelder's plots.

The three spacings tested in block plots did not affect height significantly in ORNL-13 until age 5. Survival varied significantly at ages 3 and 5 (Table G-5). Both at age 3 and 5 ,the 1 x 1.5 m had significantly lower survival than the other two spacings. DBH at age 5 did not vary significantly due to spacings. Age 5 may be too early to expect any differences due to spacing on height or DBH.

Varying spacing from 1 x 1.5 m did not significantly affect the growth of sand pine in ORNL-14 through age 6 (Table G-5). However, the DBH at age 6 varied significantly, as the widest spacing had higher DBH. Stem biomass yield at age 6 was highest (5.1 Dry Mg/yr) in closest spacing and lowest (1.54 Dry Mg/ha/yr) in widest spacing (Figure G-4). The higher number of trees per unit area in the former case was the reason for this. The dry matter production in ORNL-13 was higher that in ORNL-14 (Figure G-4) which was due to the higher survival in the former case (Table G-5). Among the five progenies tested 121 was significantly taller at all measurement ages, as observed in other studies, and larger in DBH, but significantly lower in survival at age 6.

Among the three spacings in ORNL-14, 20,000 trees/ha performed better till age 5 to 6 in terms of stem dry matter accumulation without much drop in survival and DBH. Previously, a plant density of 14,800 or more trees per hectare was best for higher production. However, DBH decreased significantly at age 6 with closer spacings. In ORNL-13 at age 5, the spacing response in terms of height and DBH had no definite trend.

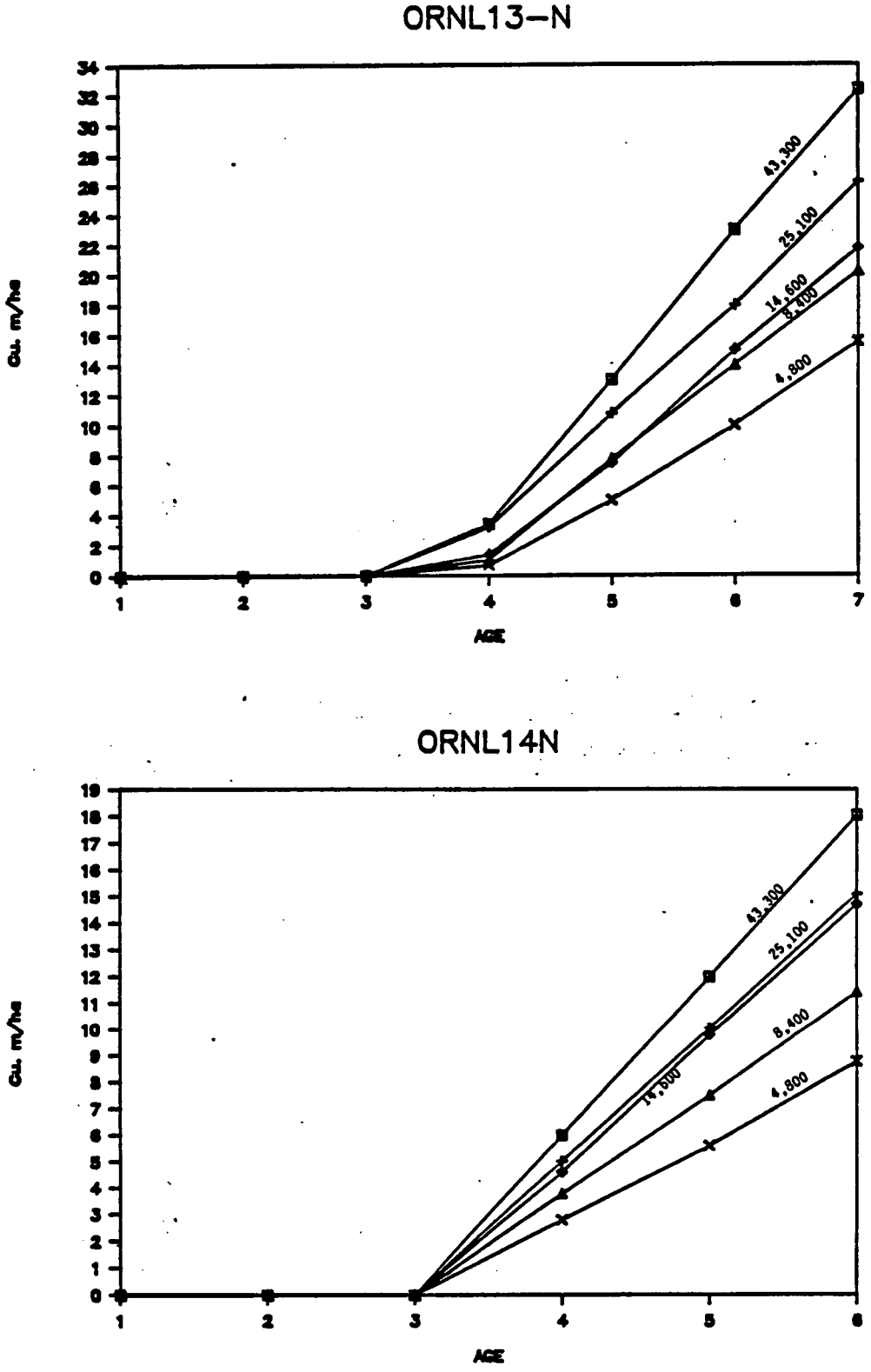

Figure G-4. Productivity (ΣD^2H) of Choctawhatchee sand pine in response to planting density in ORNL-13 (top) and ORNL-14 (bottom).

From the spacing studies, it is clear that through ages 7 the highest density of 43,300 trees/ha is still performing better in terms of stem dry matter accumulation without appreciable reduction in survival. Of course, the DBH decreased significantly which affects the quality of the trees. Among the various progenies tested, 121 and 124 have shown very good performance across locations and across studies as well. The poor performers.were 163 and 164.

The height and DBH of the various progenies tested varied significantly at all the ages (Table G-6). The top performers were 121, 142, and 162 both for height and DBH, and the poor performers were C6 and SC7. At age 7, height varied significantly from 3.7 to 5 m, and DBH varied from 2.8 to 4.8 cm. As observed in the case of spacing, the progenies did not vary significantly for survival through 7 years.

The five progenies in spacing plots in ORNL-13, varied significantly for their height through age 5. Progeny 121 was the best performer and 104 was the poor performer. In DBH at age 5, the performance of progenies was similar to height. Survival through five years did not vary significantly due to progenies.

The progenies tested in ORNL-14 varied significantly in height at age 1 thru 6 and for DBH at age 6 (Table G-6). As observed in ORNL-13, progenies 121 and 142 were best, and 163 was poor. The survival of the progenies did not vary significantly through age 6.

The 14 progenies tested in progeny block plots in ORNL-13 did not vary significantly in height, DBH, or survival through 5 years (Table G-6). Only at age 1 the height varied significantly where 103 and 121 ranked top and C and C1 was poor. At age 5 though no significant difference existed among the progenies, 121 showed higher height, DBH and stem dry matter accumulation. At age 5 the height varied from 2.4 to 3m, DBH from 1.6 to 2.4 cm, and survival from 96 to 100 per cent. The average stem dry matter accumulation at age 5 was 3.44 DTE/ha/yr.

The height of the progenies in progeny block plots in ORNL-14 varied significantly at age 1 and 3 (Table G-6). Progeny 121 ranked top as observed in the other studies. The survival at ages 1 thru 6 did not vary significantly and so was the case with DBH at age 6. The stem biomass accumulation at age 6 varied from 2.81 to 3.36 dry Mg/ha/yr, with an average of 3.19. The progenies tested did not differ until age 6. However, progenies 121, 124 and 118 showed better growth as observed in the other studies.

Across the sand pine studies, it is evident that a dry matter production of 3-3.5 dry Mg/ha/yr can be expected at age of 6-7 years with a planting density of 10,000 trees/ha. However, rotation age also depends on the commercial feasibility with respect to machines and also utilization of the bio- mass. Stands must be carried for longer rotations than Eucalyptus or slash pine in order to maximize productivity. Mortality due to high competition levels appears to be minor. At close spacing, rotations longer than 10 years may be necessary to maximize productivity.

Table G-6. Variability among sand pine progenies in ORNL-13 and ORNL-14 for height, DBH, survival, and dry weight in block plots and Nelder plots.

	ORNL-13			ORNL-14		
	No. of Progenies	7 Years Height (m)	DBH (cm)	Survival (%)	No. of Progenies	6 Years Height (m)	DBH (cm)	Survival (%)
Block Plots								
	14	(5th-Year)			14			
Mean		2.7	2.0	99.1		4.3	3.9	88.7
Low		2.4	1.6	97.3		3.6	3.1	84.0
High		3.1	2.4	100.0		4.6	5.7	96.0
Nelders Plots								
	40				37			
Mean		4.4	3.8	98.9		3.6	3.4	88.6
Low		3.7	2.8	95.2		3.1	2.5	76.8
High		5.0	4.7	100.0		4.1	4.2	96.8

Other Species

Sapium sebiferum: Sapium sebiferum did not grow as rapidly as several tropical species in the seedling rotation at Belle Glade, but its acceptable size of 3.2 m at 17-months and particularly survival after the December 1983 freeze indicated potential on the drained organic muck soils in southern Florida. Subsequent coppice survival and growth (Figure G-5, Tables C-1 and G-7) have demonstrated the species' potential. Its productivity on the muck soils is below that of the eucalypts, but as on more northern sites, its frost resistance provides security against crop mortality.

In a study (MR-4) on a previously farmed flatwoods site in central Florida, S. sebiferum had excellent early survival through 10 months (Table G-7). The low average height of less than .4 m reflects the heavy grass competition that developed due to uneven disking during site preparation. However, the best of the progenies had 100% survival and was .7 m in height, in contrast to the poorest progenies which had 80% survival and .2 m in height. Nevertheless, all progenies faired poorly in subsequent competition, and the additional impact of the December 1985 freeze, resulted in only a few survivors of about .7 m height after 40 months.

A nearby planting of S. sebiferum on a phosphate mine settling pond, a wet, heavy clay site with abundant cogon grass competition, showed that the species is more competitive than other woody species under such conditions. After nine months, S. sebiferum averaged 22% survival and .5 m tall.

As outlined in Task B, S. sebiferum performed well in Study DP-1 on an agricultural site in northern Florida. It was frost-hardy in the 1983 and 1985 freezes, grew well in the seedling rotation, and was second to E. amplifolia in coppice yield. In its second coppice rotation, it also

Figure G-5. Two-year-old Sapium sebiferum coppice in SS-1.

Table G-7. Productivity of Sapium sebiferum, Casuarina glauca, and Taxodium distichum as short-rotation woody crops.

Species/Study	Age (mo)	Trait	Yield
Sapium sebiferum			
-SS-1	24	Coppice weight	24.4 dry Mg/ha/yr
-MR-4	10	Seedling survival	95%
	10	Seedling height	.38m
-DP-1	10	Coppice weight	8.3 dry Mg/ha/yr
Casuarina glauca			
-ORNL-16	82	Seedling weight	16.4 dry Mg/ha/yr
Taxodium distichum			
-ORNL-16	82	Seedling weight	9.8 dry Mg/ha/yr

had high survival with coppice stems over 2 m tall after nine months. Favorable performance of S. sebiferum in Texas (Cowles and Scheld, 1987) further suggests the potential of the species in short-rotation culture in Florida.

Casuarina glauca: Casuarina glauca grew fairly well through seven years in ORNL-16 on the organic soils at Belle Glade. Survival at the 10,000 trees/ha planting density was over 70% after 82 months, and trees averaged over 8 m tall and 8 cm in DBH. Individual trees were up to 15 m in height. Dry weight yields at some 16 dry Mg/ha/yr were less than those of E. grandis and E. robusta on the site. Coppicing following a March 1987 harvest, 1%, was even lower than the worst eucalypts in ORNL-35.

Taxodium distichum: Taxodium distichum also grew reasonably well through seven years at Belle Glade, and exhibited good coppice growth. Survival in the seedling rotation varied considerably from plot to plot, averaging 48% after 82 months. Consequently, although the trees were only slightly smaller than the Casuarina glauca, productivity was low. Good coppice survival and growth, however, after two harvests (Table C-1) were observed.

Conclusions

This task assessed potential of several species for woody biomass production under conditions for which eucalypts are not appropriate. Of these, slash pine, sand pine, Casuarina glauca, Sapium sebiferum, and Taxodium distichum appear promising but need further study. Preliminary yield models for slash and sand pines require verification by additional data, very likely through 10 years for slash pine and 15 years or longer for sand pine.

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SUMMARY

Guided by results from research initiated in 1978, woody biomass production research in Florida from 1983-88 was directed toward genetic improvement of Eucalyptus species; coppice productivity of eucalypts; clonal propagation and testing; economics of various biomass production strategies; biomass properties of E. grandis; and assessment of other promising species for short rotation intensive culture.

A fourth-generation E. grandis seedling seed orchard with 1720 trees on 17 ha has the potential to produce over 100 million seedlings annually. Seed collected from the 50 best trees could more than double the productivity of the average tree in the preceding genetic base population. Exceptional trees in the orchard are candidates for clonal testing and can also serve as parent trees of offspring that have high probability of being successful clones.

The E. grandis genetic base population could be broadened with sources appropriate for Florida conditions. Introductions from northern New South Wales and southern Queensland in Australia appear to perform best here. After field testing, superior trees in these sources may be infused into the ongoing E. grandis breeding population to maintain a broad genetic base.

Eucalyptus tereticornis performed well on a range of sites. Several E. tereticornis sources were vigorous and frost-hardy on a sandhills site in central Florida. One E. tereticornis source also grew well on a "palmetto prairie" site through four years.

Similarly, E. camaldulensis may provide frost-resistance and good growth in central and southern Florida. Only sources of E. camaldulensis survived a hard freeze and grew acceptably in a test with other species on "palmetto prairie." Some E. camaldulensis clones did well in tests located in south-central Florida sandhills.

For northern Florida, E. amplifolia has good frost-resilience; new accessions may provide necessary cold-hardiness to constitute a first-generation base population. Coppicing of E. amplifolia may be more reliable than that of any other Eucalyptus species in Florida.

Preliminary estimates of E. amplifolia coppice productivity were as high as 23 Mg/ha/yr, and the species remained vigorous in a fourth coppice rotation. Coppice yields of other eucalypts, notably E. grandis, are very dependent on climatic factors at and following harvest. Consequently, harvesting schedules of E. grandis should be restricted to the winter months. However, even during the winter, coppicing of E. grandis on muck soils in southern Florida cannot be assured. Under ideal conditions, coppice regrowth of E. grandis can exceed seedling growth. Coppicing of Sapium sebiferum was also excellent, with high survival and vigorous regrowth.

Some 350 E. grandis cloning candidates were selected and evaluated. Of an original 100 candidates, three of 55 clones were frost-resilient and rapid-growing in an initial test. These three demonstrated further

superior propagation characteristics in a second clonal test. Over 250 additional clonal candidates were selected in commercial plantations and entered into this test by rooting of cuttings. Up to 1,000 more candidates could be located in over 5,000 ha of plantations and studies in the Palmdale area.

Rooted cuttings can be mass produced in less than seven months for outplanting during the same year. Propagation by rooted cuttings may be enhanced by regulator treatments and appears to have a genetic component. Grafting success likewise was initially influenced by cultural treatment and scion and rootstock components, but eventual incompatibility showed that grafting is unreliable.

The three proven E. grandis clones are being commercially propagated by tissue culture for outplanting in 1988. These clones adapted readily to tissue culture when juvenile tissues were used. In fact, one clone's exceptional multiplication rate and characteristics suggested the potential for somatic embryogenesis. This micropropagation option has the potential to reduce the cost of vegetative propagation dramatically.

Biomass properties of Eucalyptus species varied with age, site, and genetics. Younger trees and rapidly growing trees had lower wood densities and moisture contents. Specific gravity and moisture content of E. grandis stemwood were similar for coppice and seedling origin stems of comparable age and varied across progenies. Rotation age Eucalyptus were estimated to have a stem to crown biomass ratio of 3:1, but this partitioning may be amenable to selection. Preliminary fermentation and pulping analyses suggest that Eucalyptus species are suitable feedstocks for these processes.

Several other species performed well in our studies. Slash pine, which continued to respond to spacing, cultural, and genetic factors, and sand pine, may be species to consider for northern and central Florida. Casuarina glauca and Taxodium distichum produced adequately on muck soils for seven years. Sapium sebiferum coppiced well on several sites and has wide adaptability across the state.

To estimate the feasibility of short-rotation culture in Florida, earlier economic models for woody biomass production systems were updated with rotation-length data for Eucalyptus and results through eight years with the pines. The earlier growth model for E. grandis appeared valid and lead to an estimated break-even cost of under $2.00 per GJ for 2-year rotations on muck soils. A similar cost estimate was obtained for E. amplifolia in 3-year rotations on agricultural lands, while break-even costs for E. grandis on "palmetto prairie" and Eucalyptus on sandhills were about $4.00 per GJ. Short rotation culture appears feasible for slash pine under certain fertilization, spacing, and genetic options but cannot yet be advised for sand pine. All cost estimates were more sensitive to growth and rotation length assumptions than to real discount rates.

9. FUTURE RESEARCH

As discussed previously in the report, results acquired in the 1983-1988 phase of this project greatly strengthened many of the earlier conclusions. At the same time, the results and activities since 1983 have established an excellent base for, and indicated necessary directions of, future research. The following are some initiatives possible in the near-term.

To insure the quality of E. grandis seedling planting stock, the trees in GORCH77 should be progeny tested. Open-pollinated seed from as many of the 1720 trees as possible should be collected for future testing. A series of three tests per parent, established across the range of sites available for E. grandis in southern Florida, could provide comparative data within three years. These data would be the basis for large-scale seed collections necessary for mass seedling propagation.

Such progeny testing could also serve as a source for additional cloning candidates. In fact, intensive selection, propagation, and testing of progenies from trees in GORCH77, such as was initiated in GORCH73 for the seedlings used in PT1 (the source of the new cloning candidates in ORNL-40), is the second most immediate option for expanding the pool of cloning candidates. The quickest option is searching commercial plantations established from seedlings derived from elite trees in GORCH73.

A similar opportunity for simultaneously progeny testing and developing cloning candidates exists with the established E. camaldulensis/E. tereticornis orchard (CT74). CT74 trees need to be progeny tested, ideally in central Florida, to order to obtain frost-resilient, vigorous seedlings. Because of CT74's proximity to GORCH73 and GORCH77, some natural crossing may occur, resulting in a relative abundance of desirable hybrids. Interplanting E. grandis ramets in CT74 would increase the likelihood of obtaining hybrid seed.

Verification of the current E. grandis cloning candidates must continue. Field testing for growth and ideally for frost-resilience can be completed within three years. As demonstrated by the ORNL-37 results, however, securing frost-resilient clones is dependent on sufficient frost exposure. Artificial frost-screening techniques would be useful to avoid the unreliability of natural screening.

Evaluation of field-proven clones should also include ease of propagation, with consideration both of rooted cuttings and tissue culture. Ideally, larger scale tissue culture propagation through a callus phase of rejuvenated material would be done for the most valuable clones.

Comparison of field performance of different types of propagules is needed. Tissue culture material should be extensively tested against both seedling and rooted cutting material of the same clonal souce to determine the comparative benefits and costs for each method in capturing genetic gain.

In the longer term, development of somatic embryogenesis for large scale micropropagation would be ideal for limiting the inherent additional costs of tissue culture as compared to rooting of cuttings. This would allow for testing the development of artificial "seed" consisting of such embryos and examining them for their comparative merits against normal seedlings and rooted cuttings. The callus/somatic embryo micropropagation procedure could also be utilized for the ultimate purpose of selecting somaclonal variants and the possible introduction of genetic engineering techniques to Eucalyptus spp.

Further testing is needed of the promising sources of E. camaldulensis, E. tereticornis, and E. amplifolia for vigor and frost resilience, especially across a range of sites. Existing tests can be searched for cloning candidates to determine the prospects for vegetative propagation. Additional sources or expanded representation of proven sources need to be introduced and tested.

Those Eucalyptus species that have coppiced adequately must be evaluated further to determine coppice management options. Coppice schedules reflecting site, climate, and other relevant variables should be developed. Coppice productivity estimates are needed to set management guidelines.

Economic analyses should be updated with rotation length production data. In the case of E. grandis, this necessitates monitoring growth in response to management options on "palmetto prairie" sites up to an age of about five years. Measurement of slash pine studies should be continued until mortality becomes appreciable, presumably to age 10. Sand pine measurement may have to continue until age 15. As part of these continuing observations, biomass sampling and whole plot weighing should be conducted to confirm productivity estimates. Very importantly, the cost savings due to changes in operational activites such as establishment, harvest, and transportation should be explored

Intensive biomass characterization may be justified to confirm the suitability of short-rotation grown species for various uses. Differences primarily at the species level, and less so within species, could be important to the utilization of Eucalyptus and other "new" species for emerging processes.

For those conditions where neither the eucalypts or pines are acceptable species, evaluation of other species for short-rotation culture should be continued. Sapium sebiferum, which appears to have frost-tolerance, vigor, and coppicing ability, is one that warrants more study.

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13. APPENDICES

Table 7-1. Detailed description of various components of field studies contributing to the final report.

Component	Study			
	DP-1	PT-1	MR-4	ORNL-7
Species	*E. amplifolia*, et al.	*E. grandis*	*S. sebiferum*, et al.	*E. grandis*
Location	Gainesville, FL	Palmdale, FL	Bowling Green, FL	LaBelle, FL
Latitude (N)	29 37	26 46	27 40	26 45
Longitude (W)	82 22	81 26	81 50	81 26
Altitude (m)	29	10	20	10
Date Planted	4/1981	7/1982	6/1983	7/1979
Soil Type	Sand/Clay	Sand/Clay	Sand/Clay	Sand/Clay
Site Preparation	Rotavating	Burning, Doublechopped, Bedding	Disking	Rotavating, Bedding
Fertilizer[1]				
Treatments	None	0/50	None	8:0, 100/0, 300/0, 0/50, 100/50, 300/50, 400/175S, 800/350S
# Reps/Design				3/RCB
Planting Stock				5 Progeny Mix
Spacing[2]				
# Reps/Design	None	2/CRD		3/RCB
Planting Stock		10 Progenies		5 Progenies
Nelders[3]				
# Reps/Design				8/RCB
# of Progenies				33
Progeny[4]				
# Reps/Design				3/RCB
# of Progenies	11 Species	17	3 Species	20

[1] 1 x 1 m spacing, 10 x 10 m plot size for all treatments, 10 m distance between plots; _/_ = N/P application rates (kg/ha).

[2] 5 x 5 plot configuration with 1 m distance between rows with three densities derived from within-row spacings of 1.5, 1.0, and .5 m (6,667, 10,000, and 20,000 trees/ha, respectively).

[3] Densities of 4,800, 8,400, 14,600, 25,100, and 43,300 trees/ha corresponding to planting positions along radii.

[4] 1 x 1 m spacing, typically 5 x 5 plot configuration for progeny plots.

Table 7-1. (Continued).

Component	Study			
	ORNL-10	ORNL-11	ORNL13	ORNL-14
Species	Slash Pine	Slash Pine	Sand Pine	Sand Pine
Location	Gainesville, FL	Trenton, FL	Clarksville, FL	Perry, FL
Latitude (N)	29 46	29 47	30 26	30 01
Longitude (W)	82 13	82 47	85 12	83 34
Altitude (m)	29	26	58	8
Date Planted	1/1980	1/1980	1/1980	1/1980
Soil Type	Sand/Clay	Sand/Clay	Deep Sand (Kershaw series)	Deep Sand
Site Preparation	Burning, Doublechopped, Windrowed	Burning, Doublechopped	Double Chopped, Burned	Double Chopped, Windrowed,
Fertilizer[1]				
Treatments	5:0, 50/50, 150/50, sludge at 175/135 and 340/265	3:0, 50/50, and 150/50	5:0, 50/50, 150/50, sludge at 175/135 and 340/265	3:0, 50/50, and 150/50
# Reps/Design	3/CRD	4/CRD	4/RCB	3/RCB
Planting Stock	5 Progeny Mix	5 Progeny Mix	5 progeny Mix	5 Progeny Mix
Spacing[2]				
# Reps/Design	3/RCB	3/RCB	3/RCB	3/RCB
Planting Stock	3 Progenies	3 Progenies	5 Progenies	5 Progenies
Nelders[3]				
# Reps/Design	8/RCB	8/RCB	9/RCB	9/RCB
# of Progenies	33	25	40	37
Progeny[4]				
# Reps/Design	3/RCB	3/RCB	3/RCB	3/RCB
# of Progenies	22	17	14	37

Table 7-1. (Continued).

Component	Study			
	ORNL-16	ORNL-33	ORNL-34	ORNL-35
Species	*E. grandis*, *E. robusta*, et al.	*E. grandis*	*E. grandis*, *E. robusta*, hybrids	*E. amplifolia*, *E. dunnii*, *E. grandis*, *E. robusta*
Location	Belle Glade, FL	LaBelle, FL	Palmdale, FL	Belle Glade, FL
Latitude (N)	26 41	26 51	26 50	26 41
Longitude (W)	80 39	81 26	81 26	80 39
Altitude (m)	4	10	10	4
Date Planted	5/1980	7/1977	1979/1980	7/1985
Soil Type	Muck/Rock	Sand/Clay	Sand/Clay	Muck/Rock
Site Preparation	Disked	Burning, Doublechopped, Bedded	Double Chopped, Burned, Bedded	Disked
Fertilizer[1]/				
Treatments		0/50	0/50	
# Reps/Design				
Planting Stock				
Spacing[2]/				
# Reps/Design	5/RCB			6/RCB
Planting Stock	6 Progenies			5 Progenies
Nelders[3]/				
# Reps/Design				
# of Progenies				
Progeny[4]/				
# Reps/Design	5/RCB	3/RCB	3/RCB	3/RCB
# of Progenies	22	17	14	37

Table 7-1. (Continued).

Component	Study			
	ORNL-36	ORNL-37	ORNL-38	ORNL-39
Species	*E. amplifolia*, *E. dunnii*, *E. grandis*, *E. robusta*	*E. grandis*	*E. camaldulensis* *E. tereticornis*	*E. amplifolia*
Location	LaBelle, FL	Palmdale, FL	Lake Placid, FL	Gainesville, FL
Latitude (N)	26 46	26 57	27 12	29 37
Longitude (W)	81 26	81 17	81 19	82 22
Altitude (m)	10	10	50	29
Date Planted	7/1986	8/1982	7/1986	9/1986
Soil Type	Sand/Clay	Sand/Clay	Deep Sand	Sand/Clay
Site Preparation	Rotavating Bedding	Burning, Doublechopped Bedding	Double Chopped, Burned, Disked	Disked
Fertilizer[1]/				
Treatments	0/50	0/50		
# Reps/Design				
Planting Stock				
Spacing[2]/				
# Reps/Design	4/RCB		3/RCB	
Planting Stock	5 Progenies		3 Sources	
Nelders[3]/				
# Reps/Design				
# of Progenies				
Progeny[4]/				
# Reps/Design	3/RCB	4/CRD	3/RCB	3/RCB
# of Progenies	5-27/species	55 clones	20-75/species	69

Table 7-1. (Continued).

Component	Study			
	ORNL-40	SS-1	SS-2	SS-3
Species	E. grandis	S. sebiferum et al.	E. camaldulensis E. tereticornis et al.	E. camaldulensis E. tereticornis et al.
Location	LaBelle, FL	Belle Glade, FL	Lake Placid, FL	Palmdale, FL
Latitude (N)	26 46	26 41	27 15	26 57
Longitude (W)	81 26	80 39	81 20	81 17
Altitude (m)	10	4	50	10
Date Planted	8/1987	6/1982	7/1983	6/1983
Soil Type	Sand/Clay	Muck/Rock	Deep Sand	Sand/Clay
Site Preparation	Double Chopped, Burned, Bedded	Disking,	Double Chopped, Burned, Disked	Double Chopped, Burned, Bedded
Fertilizer[1]				
Treatments	0/50			0/50
# Reps/Design				
Planting Stock				
Spacing[2]				
# Reps/Design				
Planting Stock				
Nelders[3]				
# Reps/Design				
# of Progenies				
Progeny[4]				
# Reps/Design	3/RCB	3/RCB	3/RCB	3/RCB
# of Progenies	30 progenies, 248 clones			

Table 7-1. (Continued).

Component	Study		
	SS-8	SS-9	SS-11
Species	*E. grandis*, *E. tereticornis*, *E. camaldulensis*, *E. dunnii*, *E. robusta*	*E. amplifolia*	*E. amplifolia*
Location	LaBelle, FL	Gainesville, FL	Gainesville, FL
Latitude (N)	26 45	29 37	29 37
Longitude (W)	81 26	82 22	82 22
Altitude (m)	10	29	29
Date Planted	7/1984	9/1984	7/1985
Soil Type	Sand/Clay	Sand/Clay	Sand/Clay
Site Preparation	Rotavated, Bedded	Disking	Disked
Fertilizer[1/]			
Treatments	0/50		
# Reps/Design			
Planting Stock			
Spacing[2/]			
# Reps/Design			
Planting Stock			
Nelders[3/]			
# Reps/Design			
# of Progenies			
Progeny[4/]			
# Reps/Design	3/RCB	2/CRD	3/RCB
# of Progenies	1-32 sources		

Table 7-2. Location (Row and Column), mother tree (FAM), generation (GN), and pedigree of seed trees (ID) in *Eucalyptus grandis* seed orchard GORCH77 near LaBelle, Florida.

ID	ROW	COL	FAM	GN	PEDIGREE
0	16	180	946	3	G73)BPP)COFFS HRBR N
0	25	65	881	3	G73)SLP)URUNGA N
0	50	197	1022	4	G73)SLP)IMOK)GYMPIE Q
2123	13	35	997	4	G73)SLP)IMOK)GYMPIE Q
3000	1	5	1517	2	G73)RSA
3001	1	23	853	3	G73)FFF)URUNGA N
3003	1	45	1024	4	G73)SLP)IMOK)GYMPIE Q
3005	1	60	960	3	G73)SFDP)COFFS HRBR N
3006	1	66	1010	4	G73)SLP)IMOK)GYMPIE Q
3007	2	87	905	3	G73)SLP)COFFS HRBR N
3008	2	94	856	3	G73)FFF)URUNGA N
3009	1	104	988	4	G73)SLP)IMOK)GYMPIE Q
3010	1	133	958	3	G73)SFDP)COFFS HRBR N
3011	1	149	909	3	G73)SLP)COFFS HRBR N
3012	2	155	978	4	G73)F69)BIG)COFFS HRBR N
3013	1	171	1697	1	DANBULLA Q
3014	1	182	889	3	G73)SLP)URUNGA N
3015	2	215	1513	2	G73)RSA
3016	1	219	1024	4	G73)SLP)IMOK)GYMPIE Q
3017	4	225	1002	4	G73)SLP)IMOK)GYMPIE Q
3018	4	213	1526	2	G73)RSA
3019	4	203	1052	2	G73)MULBERRY
3020	4	199	586	1	OSCEOLA CO
3021	3	198	966	3	G73)SFSP)COFFS HRBR N
3022	3	195	1004	4	G73)SLP)IMOK)GYMPIE Q
3023	3	176	1005	4	G73)SLP)IMOK)GYMPIE Q
3024	4	167	1067	2	G73)TICE
3025	4	156	587	1	OSCEOLA CO
3026	3	142	1022	4	G73)SLP)IMOK)GYMPIE Q
3027	4	136	941	3	G73)BPP)COFFS HRBR N
3028	3	131	844	3	G73)FFF)URUNGA N
3029	3	111	1009	4	G73)SLP)IMOK)GYMPIE Q
3030	4	79	1493	0	UNKNOWN
3031	4	72	1068	2	G73)TICE
3032	3	64	968	3	G73)SFSP)COFFS HRBR N
3033	3	53	1026	4	G73)SLP)IMOK)GYMPIE Q
3034	4	49	1177	2	G73)POMONA Q
3035	3	38	1194	3	G73)RSA
3036	4	34	884	3	G73)SLP)URUNGA N
3037	4	17	926	3	G73)SLP)COFFS HRBR N
3038	3	11	1158	2	G73)GYMPIE Q
3039	4	8	1038	3	G73)SLP)NORTH COAST N
3040	7	4	859	3	G73)FFF)URUNGA N
3041	7	7	931	3	G73)SLP)COFFS HRBR N
3042	6	16	1001	4	G73)SLP)IMOK)GYMPIE Q
3043	5	23	1039	3	G73)SLP)NORTH COAST N
3045	8	30	879	3	G73)SLP)URUNGA N
3046	7	45	1552	2	G73)RSA
3047	7	49	101	3	SLP)IMOK)GYMPIE Q
3048	6	52	1000	4	G73)SLP)IMOK)GYMPIE Q
3049	7	59	1127	2	G73)CONGLOMERATE N
3050	8	66	884	3	G73)SLP)URUNGA N
3051	8	74	905	3	G73)SLP)COFFS HRBR N
3052	6	78	1026	4	G73)SLP)IMOK)GYMPIE Q
3053	6	88	74	2	FFF)URUNGA N
3054	8	91	844	3	G73)FFF)URUNGA N
3055	8	95	1023	4	G73)SLP)IMOK)GYMPIE Q
3056	7	96	1026	4	G73)SLP)IMOK)GYMPIE Q
3057	5	100	962	3	G73)SFDP)COFFS HRBR N
3058	6	104	996	4	G73)SLP)IMOK)GYMPIE Q
3059	6	108	854	3	G73)FFF)URUNGA N
3060	5	109	1173	2	G73)POMONA Q
3061	5	119	888	3	G73)SLP)URUNGA N
3062	6	123	1166	2	G73)POMONA Q
3063	8	127	897	3	G73)BIG)COFFS HRBR N
3064	5	127	1003	4	G73)SLP)IMOK)GYMPIE Q
3065	8	137	1113	2	G73)NEWRY N
3066	5	141	987	4	G73)SLP)IMOK)GYMPIE Q
3067	8	160	1166	2	G73)POMONA Q
3068	5	161	867	3	G73)FFF)URUNGA N
3069	8	163	1057	2	G73)CABBAGE VAT
3070	6	167	966	3	G73)SFSP)COFFS HRBR N
3071	8	180	1162	2	G73)BELLTHORPE Q
3072	8	188	1109	2	G73)NEWRY N
3073	5	189	1011	4	G73)SLP)IMOK)GYMPIE Q
3075	7	197	1553	2	G73)RSA
3076	7	204	1562	2	G73)HYBRID COMPOSITE
3077	8	220	961	3	G73)SFDP)COFFS HRBR N
3078	10	223	876	3	G73)SLP)URUNGA N
3079	12	216	1147	2	G73)WOONDUM Q
3080	9	211	1481	2	G73)RSA
3081	12	206	991	4	G73)SLP)IMOK)GYMPIE Q
3082	9	206	963	3	G73)SFSP)COFFS HRBR N
3083	12	201	1526	2	G73)RSA
3084	10	199	1038	3	G73)SLP)NORTH COAST N
3085	11	191	1725	3	F69)BIG)COFFS HRBR N
3086	10	186	1018	4	G73)SLP)IMOK)GYMPIE Q
3087	12	181	1170	2	G73)POMONA Q
3088	11	176	1068	2	G73)TICE
3089	12	173	927	3	G73)SLP)COFFS HRBR N
3090	9	171	1551	2	G73)RSA
3091	10	162	850	3	G73)FFF)URUNGA N
3092	11	157	991	4	G73)SLP)IMOK)GYMPIE Q
3093	11	153	1009	4	G73)SLP)IMOK)GYMPIE Q
3094	9	146	1100	2	G73)PINE CREEK N
3095	10	143	870	3	G73)FFF)URUNGA N
3096	10	137	985	4	G73)F69)BIG)COFFS HRBR N
3097	11	134	1080	2	G73)PINE CREEK N
3098	10	111	992	4	G73)SLP)IMOK)GYMPIE Q
3099	10	103	1111	2	G73)NEWRY N
3102	12	80	1478	2	G73)RSA
3103	12	71	90	3	SLP)IMOK)GYMPIE Q
3104	10	69	1160	2	G73)KENILWORTH Q
3105	11	64	1093	2	G73)PINE CREEK N
3106	10	52	961	3	G73)SFDP)COFFS HRBR N
3107	10	41	1166	2	G73)POMONA Q
3108	9	38	908	3	G73)SLP)COFFS HRBR N
3111	10	22	965	3	G73)SFSP)COFFS HRBR N
3112	11	14	997	4	G73)SLP)IMOK)GYMPIE Q
3113	9	14	1499	2	G73)RSA
3114	10	9	1558	2	G73)HYBRID COMPOSITE
3115	9	8	1142	2	G73)WOONDUM Q
3116	11	4	923	3	G73)SLP)COFFS HRBR N
3117	16	4	1509	2	G73)RSA
3118	15	10	931	3	G73)SLP)COFFS HRBR N
3122	17	29	1142	2	G73)WOONDUM Q
3125	16	36	1169	2	G73)POMONA Q
3126	14	43	844	3	G73)FFF)URUNGA N
3127	15	49	1031	3	G73)SLP)GYMPIE Q
3128	13	48	991	4	G73)SLP)IMOK)GYMPIE Q
3130	16	58	1492	2	G73)RSA
3131	13	60	998	4	G73)SLP)IMOK)GYMPIE Q
3133	17	68	1046	3	G73)SLP)ARGENTINA
3134	15	73	1038	3	G73)SLP)NORTH COAST N
3136	13	83	908	3	G73)SLP)COFFS HRBR N
3137	15	85	879	3	G73)SLP)URUNGA N
3138	15	89	905	3	G73)SLP)COFFS HRBR N
3139	18	91	921	3	G73)SLP)COFFS HRBR N

Table 7-2. (Continued).

ID	ROW	COL	FAM	GN	PEDIGREE
3140	15	91	926	3	G73)SLP)COFFS HRBR N
3141	18	95	864	3	G73)FFF)URUNGA N
3142	14	97	1117	2	G73)BOAMBEE N
3143	13	99	586	1	OSCEOLA CO
3144	15	103	1150	2	G73)WOONDUM Q
3145	13	106	1082	2	G73)PINE CREEK N
3146	15	110	874	3	G73)FFF)URUNGA N
3147	13	115	1523	2	G73)RSA
3148	15	115	1078	2	G73)ITALY
3149	14	119	1022	4	G73)SLP)IMOK)GYMPIE Q
3150	16	122	1030	3	G73)SLP)GYMPIE Q
3151	13	121	1006	4	G73)SLP)IMOK)GYMPIE Q
3152	15	127	587	1	OSCEOLA CO
3153	13	129	935	3	G73)BPP)COFFS HRBR N
3154	14	136	1486	2	G73)RSA
3155	13	138	1039	3	G73)SLP)NORTH COAST N
3156	16	145	1694	1	COMO Q
3157	13	145	1033	2	G73)GYMPIE Q
3158	18	150	1479	2	G73)RSA
3159	13	150	1006	4	G73)SLP)IMOK)GYMPIE Q
3160	17	153	953	3	G73)SFDP)COFFS HRBR N
3161	14	158	946	3	G73)BPP)COFFS HRBR N
3163	13	166	1007	4	G73)SLP)IMOK)GYMPIE Q
3164	15	170	1196	2	G73)RSA
3165	15	173	919	3	G73)SLP)COFFS HRBR N
3166	14	174	1003	4	G73)SLP)IMOK)GYMPIE Q
3167	14	176	842	3	G73)FFF)URUNGA N
3168	14	183	934	3	G73)BPP)COFFS HRBR N
3169	16	186	1495	2	G73)RSA
3170	13	187	1695	1	COMO Q
3171	14	192	1054	2	G73)PALMDALE
3172	15	197	1049	2	G73)ORLANDO
3173	16	202	853	3	G73)FFF)URUNGA N
3174	18	204	1139	2	G73)CONGLOMERATE N
3175	16	206	1091	2	G73)PINE CREEK N
3176	18	211	917	3	G73)SLP)COFFS HRBR N
3177	13	214	1723	3	F69)BIG)COFFS HRBR N
3178	15	214	893	2	G73)PINE CREEK N
3179	17	217	915	3	G73)SLP)COFFS HRBR N
3180	18	219	101	3	SLP)IMOK)GYMPIE Q
3181	15	225	1515	2	G73)RSA
3182	18	224	1049	2	G73)ORLANDO
3183	23	225	899	3	G73)BIG)COFFS HRBR N
3184	23	218	1478	2	G73)RSA
3185	19	214	887	3	G73)SLP)URUNGA N
3186	21	206	921	3	G73)SLP)COFFS HRBR N
3187	22	202	1019	4	G73)SLP)IMOK)GYMPIE Q
3188	21	199	1070	2	G73)TICE
3189	20	194	1057	2	G73)CABBAGE VAT
3190	22	192	1026	4	G73)SLP)IMOK)GYMPIE Q
3191	24	191	1046	3	G73)SLP)ARGENTINA
3192	19	188	1526	2	G73)RSA
3193	20	185	1549	2	G73)RSA
3194	24	180	1488	2	G73)RSA
3195	19	178	921	3	G73)SLP)COFFS HRBR N
3196	20	173	1057	2	G73)CABBAGE VAT
3197	24	171	1038	3	G73)SLP)NORTH COAST N
3198	22	170	1040	2	G73)NORTH COAST N
3199	19	170	1163	2	G73)POMONA Q
3200	21	164	916	3	G73)SLP)COFFS HRBR N
3201	24	158	865	3	G73)FFF)URUNGA N
3202	21	158	998	4	G73)SLP)IMOK)GYMPIE Q
3203	24	152	868	3	G73)FFF)URUNGA N
3204	20	145	845	3	G73)FFF)URUNGA N
3205	23	147	897	3	G73)BIG)COFFS HRBR N
3206	19	141	1171	2	G73)POMONA Q
3207	20	140	1171	2	G73)POMONA Q
3208	22	140	946	3	G73)BPP)COFFS HRBR N
3209	20	132	976	4	G73)F69)BIG)COFFS HRBR N
3210	22	132	1550	2	G73)RSA
3211	22	129	1536	2	G73)RSA
3212	19	128	892	3	G73)SLP)URUNGA N
3213	20	125	1021	4	G73)SLP)IMOK)GYMPIE Q
3214	20	120	1705	1	MT MEE Q
3216	20	111	1001	4	G73)SLP)IMOK)GYMPIE Q
3217	24	111	1009	4	G73)SLP)IMOK)GYMPIE Q
3218	19	106	857	3	G73)FFF)URUNGA N
3219	19	103	908	3	G73)SLP)COFFS HRBR N
3220	23	101	1552	2	G73)RSA
3221	24	99	986	4	G73)SLP)IMOK)GYMPIE Q
3222	20	96	1007	4	G73)SLP)IMOK)GYMPIE Q
3224	21	90	1176	2	G73)POMONA Q
3225	22	84	1005	4	G73)SLP)IMOK)GYMPIE Q
3226	19	87	1478	2	G73)RSA
3227	19	82	1544	2	G73)RSA
3234	24	71	846	3	G73)FFF)URUNGA N
3235	21	70	864	3	G73)FFF)URUNGA N
3237	19	65	1010	4	G73)SLP)IMOK)GYMPIE Q
3240	20	58	1539	2	G73)RSA
3241	23	57	1175	2	G73)POMONA Q
3242	21	51	1065	2	G73)TICE
3243	24	53	1163	2	G73)POMONA Q
3244	19	52	1120	2	G73)CONGLOMERATE N
3245	20	48	883	3	G73)SLP)URUNGA N
3246	23	48	1118	2	G73)BOAMBEE N
3247	21	47	1764	1	CHOMA ZAMBIA
3248	24	45	921	3	G73)SLP)COFFS HRBR N
3249	21	41	972	3	G73)SLHQ)COFFS HRBR N
3250	19	37	1753	1	RSA
3251	21	34	1544	2	G73)RSA
3253	21	26	1083	2	G73)PINE CREEK N
3254	23	26	890	3	G73)SLP)URUNGA N
3255	19	22	1093	2	G73)PINE CREEK N
3256	24	22	1016	4	G73)SLP)IMOK)GYMPIE Q
3257	22	19	1491	2	G73)RSA
3258	20	17	1153	2	G73)WOONDUM Q
3262	19	4	921	3	G73)SLP)COFFS HRBR N
3263	24	3	983	4	G73)F69)BIG)COFFS HRBR N
3264	28	3	1529	2	G73)RSA
3265	29	6	1056	2	G73)CABBAGE VAT
3266	25	11	905	3	G73)SLP)COFFS HRBR N
3268	26	18	97	2	SLP)URUNGA N
3269	27	23	1124	2	G73)CONGLOMERATE N
3271	27	31	1515	2	G73)RSA
3273	28	45	911	3	G73)SLP)COFFS HRBR N
3274	27	50	1083	2	G73)PINE CREEK N
3275	26	52	842	3	G73)FFF)URUNGA N
3276	29	60	864	3	G73)FFF)URUNGA N
3277	28	71	955	3	G73)SFDP)COFFS HRBR N
3278	27	75	908	3	G73)SLP)COFFS HRBR N
3279	27	78	955	3	G73)SFDP)COFFS HRBR N
3280	26	81	1003	4	G73)SLP)IMOK)GYMPIE Q
3281	25	87	991	4	G73)SLP)IMOK)GYMPIE Q
3282	26	88	888	3	G73)SLP)URUNGA N
3283	27	92	1035	3	G73)SLP)NORTH COAST N
3284	28	100	1118	2	G73)BOAMBEE N
3285	28	103	1117	2	G73)BOAMBEE N
3286	29	107	1002	4	G73)SLP)IMOK)GYMPIE Q

Table 7-2. (Continued).

ID	ROW	COL	FAM	GN	PEDIGREE
3287	25	108	997	4	G73)SLP)IMOK)GYMPIE Q
3288	26	108	1133	2	G73)CONGLOMERATE N
3289	27	112	948	3	G73)BPP)COFFS HRBR N
3290	29	118	1077	2	G73)ITALY
3291	29	123	918	3	G73)SLP)COFFS HRBR N
3292	25	124	982	4	G73)F69)BIG)COFFS HRBR N
3293	26	127	1058	2	G73)CABBAGE VAT
3294	26	135	1117	2	G73)BOAMBEE N
3295	29	138	967	3	G73)SFSP)COFFS HRBR N
3296	26	145	1142	2	G73)WOONDUM Q
3297	29	147	1482	2	G73)RSA
3298	27	155	998	4	G73)SLP)IMOK)GYMPIE Q
3299	28	156	1544	2	G73)RSA
3300	28	162	1170	2	G73)POMONA Q
3301	25	164	1149	2	G73)WOONDUM Q
3302	27	172	979	4	G73)F69)BIG)COFFS HRBR N
3303	26	180	931	3	G73)SLP)COFFS HRBR N
3304	25	183	1767	1	RHODESIA
3305	27	184	1010	4	G73)SLP)IMOK)GYMPIE Q
3306	25	186	1053	2	G73)MULBERRY
3307	27	190	853	3	G73)FFF)URUNGA N
3308	29	191	1492	2	G73)RSA
3309	26	196	101	3	SLP)IMOK)GYMPIE Q
3310	25	199	1497	2	G73)RSA
3311	29	200	858	3	G73)FFF)URUNGA N
3312	27	205	997	4	G73)SLP)IMOK)GYMPIE Q
3313	26	209	74	2	FFF)URUNGA N
3314	29	211	988	4	G73)SLP)IMOK)GYMPIE Q
3316	28	218	991	4	G73)SLP)IMOK)GYMPIE Q
3317	26	221	1104	2	G73)PINE CREEK N
3318	29	224	1496	2	G73)RSA
3319	32	221	938	3	G73)BPP)COFFS HRBR N
3320	31	217	1515	2	G73)RSA
3321	31	215	1003	4	G73)SLP)IMOK)GYMPIE Q
3322	33	208	859	3	G73)FFF)URUNGA N
3323	33	199	988	4	G73)SLP)IMOK)GYMPIE Q
3324	32	195	1696	1	DANBULLA Q
3325	33	190	1056	2	G73)CABBAGE VAT
3326	31	182	1012	4	G73)SLP)IMOK)GYMPIE Q
3327	30	178	1141	2	G73)CONGLOMERATE N
3328	30	173	1533	2	G73)RSA
3329	31	169	1160	2	G73)KENILWORTH Q
3330	32	163	1082	2	G73)PINE CREEK N
3331	33	163	1111	2	G73)NEWRY N
3332	31	160	907	3	G73)SLP)COFFS HRBR N
3333	30	154	1526	2	G73)RSA
3334	31	148	1052	2	G73)MULBERRY
3335	30	144	857	3	G73)FFF)URUNGA N
3336	32	137	1175	2	G73)POMONA Q
3337	30	135	1007	4	G73)SLP)IMOK)GYMPIE Q
3338	30	128	965	3	G73)SFSP)COFFS HRBR N
3339	31	125	1517	2	G73)RSA
3340	33	120	845	3	G73)FFF)URUNGA N
3341	32	112	981	4	G73)F69)BIG)COFFS HRBR N
3343	32	103	909	3	G73)SLP)COFFS HRBR N
3344	31	102	1528	2	G73)RSA
3345	30	98	900	3	G73)BIG)COFFS HRBR N
3346	33	92	900	3	G73)BIG)COFFS HRBR N
3347	30	88	861	3	G73)FFF)URUNGA N
3348	30	85	9999	0	IDENTITY LOST
3349	33	81	848	3	G73)FFF)URUNGA N
3350	30	80	864	3	G73)FFF)URUNGA N
3351	33	75	846	3	G73)FFF)URUNGA N
3352	30	75	997	4	G73)SLP)IMOK)GYMPIE Q
3353	30	70	921	3	G73)SLP)COFFS HRBR N
3354	31	67	1020	4	G73)SLP)IMOK)GYMPIE Q
3355	30	64	871	3	G73)FFF)URUNGA N
3356	31	58	1082	2	G73)PINE CREEK N
3357	33	53	933	3	G73)BPP)COFFS HRBR N
3359	32	48	847	3	G73)FFF)URUNGA N
3360	30	43	1070	2	G73)TICE
3361	33	36	1068	2	G73)TICE
3362	32	35	844	3	G73)FFF)URUNGA N
3364	33	27	997	4	G73)SLP)IMOK)GYMPIE Q
3365	32	22	917	3	G73)SLP)COFFS HRBR N
3366	32	10	943	3	G73)BPP)COFFS HRBR N
3367	32	8	1764	1	CHOMA ZAMBIA
3368	33	3	1010	4	G73)SLP)IMOK)GYMPIE Q
3369	35	12	909	3	G73)SLP)COFFS HRBR N
3370	37	13	1650	1	CONONDALE Q
3371	36	30	1009	4	G73)SLP)IMOK)GYMPIE Q
3372	35	38	1199	2	G73)RSA
3373	35	42	846	3	G73)FFF)URUNGA N
3374	34	56	125	2	BPP)COFFS HRBR N
3375	36	59	1127	2	G73)CONGLOMERATE N
3376	37	62	1155	2	G73)GYMPIE Q
3377	35	66	908	3	G73)SLP)COFFS HRBR N
3378	35	73	1010	4	G73)SLP)IMOK)GYMPIE Q
3379	37	80	1022	4	G73)SLP)IMOK)GYMPIE Q
3380	34	90	998	4	G73)SLP)IMOK)GYMPIE Q
3381	36	95	1093	2	G73)PINE CREEK N
3382	35	97	88	3	SLP)IMOK)GYMPIE Q
3383	35	105	1024	4	G73)SLP)IMOK)GYMPIE Q
3384	37	108	1018	4	G73)SLP)IMOK)GYMPIE Q
3385	37	110	874	3	G73)FFF)URUNGA N
3386	35	112	1723	3	F69)BIG)COFFS HRBR N
3387	34	121	1009	4	G73)SLP)IMOK)GYMPIE Q
3388	37	124	887	3	G73)SLP)URUNGA N
3389	35	132	997	4	G73)SLP)IMOK)GYMPIE Q
3390	35	139	871	3	G73)FFF)URUNGA N
3391	34	142	965	3	G73)SFSP)COFFS HRBR N
3392	37	146	1172	2	G73)POMONA Q
3393	35	154	101	3	SLP)IMOK)GYMPIE Q
3394	36	158	1495	2	G73)RSA
3395	35	162	877	3	G73)SLP)URUNGA N
3397	34	166	1764	1	CHOMA ZAMBIA
3398	35	171	1526	2	G73)RSA
3399	35	174	1091	2	G73)PINE CREEK N
3400	37	180	923	3	G73)SLP)COFFS HRBR N
3401	36	184	675	1	TAMPA
3402	34	186	962	3	G73)SFDP)COFFS HRBR N
3403	34	193	955	3	G73)SFDP)COFFS HRBR N
3404	37	196	997	4	G73)SLP)IMOK)GYMPIE Q
3405	34	203	924	3	G73)SLP)COFFS HRBR N
3406	36	206	982	4	G73)F69)BIG)COFFS HRBR N
3407	36	209	1686	1	COMO Q
3408	35	214	921	3	G73)SLP)COFFS HRBR N
3409	34	220	1156	2	G73)GYMPIE Q
3410	35	224	987	4	G73)SLP)IMOK)GYMPIE Q
3411	38	221	1124	2	G73)CONGLOMERATE N
3412	40	219	947	3	G73)BPP)COFFS HRBR N
3413	40	215	869	3	G73)FFF)URUNGA N
3414	41	208	1194	2	G73)RSA
3415	41	194	984	4	G73)F69)BIG)COFFS HRBR N
3416	40	188	1046	3	G73)SLP)ARGENTINA
3417	39	183	884	3	G73)SLP)URUNGA N
3418	40	180	1192	2	G73)RSA
3419	40	174	1138	2	G73)CONGLOMERATE N

Table 7-2. (Continued).

ID	ROW	COL	FAM	GN	PEDIGREE
3420	39	169	856	3	G73)FFF)URUNGA N
3421	41	164	842	3	G73)FFF)URUNGA N
3422	39	159	1052	2	G73)MULBERRY
3423	41	155	961	3	G73)SFDP)COFFS HRBR N
3424	39	145	1544	2	G73)RSA
3425	38	140	1022	4	G73)SLP)IMOK)GYMPIE Q
3426	39	131	1021	4	G73)SLP)IMOK)GYMPIE Q
3427	41	121	1528	2	G73)RSA
3428	38	118	1485	2	G73)RSA
3429	39	115	845	3	G73)FFF)URUNGA N
3430	39	108	844	3	G73)FFF)URUNGA N
3431	38	97	1500	2	G73)RSA
3432	41	95	1109	2	G73)NEWRY N
3433	39	91	864	3	G73)FFF)URUNGA N
3434	38	87	880	3	G73)SLP)URUNGA N
3435	40	77	881	3	G73)SLP)URUNGA N
3436	41	72	990	4	G73)SLP)IMOK)GYMPIE Q
3437	40	69	949	3	G73)BPP)COFFS HRBR N
3438	38	62	1012	4	G73)SLP)IMOK)GYMPIE Q
3439	41	59	1002	4	G73)SLP)IMOK)GYMPIE Q
3440	41	52	972	3	G73)SLHQ)COFFS HRBR N
3441	38	49	994	4	G73)SLP)IMOK)GYMPIE Q
3442	39	42	1024	4	G73)SLP)IMOK)GYMPIE Q
3443	41	38	1020	4	G73)SLP)IMOK)GYMPIE Q
3444	39	34	998	4	G73)SLP)IMOK)GYMPIE Q
3445	40	30	1141	2	G73)CONGLOMERATE N
3446	41	24	1023	4	G73)SLP)IMOK)GYMPIE Q
3447	38	24	898	3	G73)BIG)COFFS HRBR N
3448	38	16	1021	4	G73)SLP)IMOK)GYMPIE Q
3449	40	14	974	4	G73)F69)BIG)COFFS HRBR N
3450	39	3	88	3	SLP)IMOK)GYMPIE Q
3451	42	5	1166	2	G73)POMONA Q
3452	49	4	1165	2	G73)POMONA Q
3453	46	6	1160	2	G73)KENILWORTH Q
3455	43	19	1134	2	G73)CONGLOMERATE N
3456	49	17	1035	3	G73)SLP)NORTH COAST N
3457	47	23	953	3	G73)SFDP)COFFS HRBR N
3458	44	28	871	3	G73)FFF)URUNGA N
3459	46	30	1088	2	G73)PINE CREEK N
3460	46	33	898	3	G73)BIG)COFFS HRBR N
3461	45	33	919	3	G73)SLP)COFFS HRBR N
3462	45	37	1194	2	G73)RSA
3463	44	39	845	3	G73)FFF)URUNGA N
3464	48	40	1047	2	G73)ORLANDO
3465	45	44	1012	4	G73)SLP)IMOK)GYMPIE Q
3466	45	47	1534	2	G73)RSA
3467	49	50	968	3	G73)SFSP)COFFS HRBR N
3468	43	52	1508	2	G73)RSA
3469	44	54	915	3	G73)SLP)COFFS HRBR N
3470	44	58	1083	2	G73)PINE CREEK N
3471	48	58	88	3	SLP)IMOK)GYMPIE Q
3472	44	63	892	3	G73)SLP)URUNGA N
3473	49	64	1721	3	F69)BIG)COFFS HRBR N
3474	45	71	1511	2	G73)RSA
3475	49	72	9999	0	IDENTITY LOST
3476	45	80	88	3	SLP)IMOK)GYMPIE Q
3477	49	80	1715	1	BELLTHORPE Q
3478	43	82	901	3	G73)BIG)COFFS HRBR N
3479	48	83	186	2	SLP)URUNGA N
3480	47	86	1020	4	G73)SLP)IMOK)GYMPIE Q
3481	44	88	921	3	G73)SLP)COFFS HRBR N
3482	47	92	868	3	G73)FFF)URUNGA N
3483	44	95	938	3	G73)BPP)COFFS HRBR N
3484	47	95	847	3	G73)FFF)URUNGA N
3485	42	97	1025	4	G73)SLP)IMOK)GYMPIE Q
3486	49	96	1086	2	G73)PINE CREEK N
3487	44	102	1049	2	G73)ORLANDO
3488	49	102	896	3	G73)BIG)COFFS HRBR N
3489	42	106	1534	2	G73)RSA
3490	49	107	1114	2	G73)NEWRY N
3491	47	113	1479	2	G73)RSA
3492	42	114	867	3	G73)FFF)URUNGA N
3493	44	114	864	3	G73)FFF)URUNGA N
3494	49	122	1536	2	G73)RSA
3495	44	128	997	4	G73)SLP)IMOK)GYMPIE Q
3496	44	133	1010	4	G73)SLP)IMOK)GYMPIE Q
3497	46	133	1052	2	G73)MULBERRY
3498	42	137	1065	2	G73)TICE
3499	46	139	1520	2	G73)RSA
3501	44	150	911	3	G73)SLP)COFFS HRBR N
3502	47	154	884	3	G73)SLP)URUNGA N
3503	45	155	976	4	G73)F69)BIG)COFFS HRBR N
3504	43	157	1173	2	G73)POMONA Q
3505	46	158	890	3	G73)SLP)URUNGA N
3507	48	162	1538	2	G73)RSA
3508	45	169	867	3	G73)FFF)URUNGA N
3509	48	169	847	3	G73)FFF)URUNGA N
3510	42	173	1495	2	G73)RSA
3511	49	174	9999	0	IDENTITY LOST
3512	46	179	926	3	G73)SLP)COFFS HRBR N
3513	45	180	1083	2	G73)PINE CREEK N
3514	45	184	845	3	G73)FFF)URUNGA N
3515	48	184	1488	2	G73)RSA
3516	42	190	88	3	SLP)IMOK)GYMPIE Q
3517	49	192	1007	4	G73)SLP)IMOK)GYMPIE Q
3518	43	193	1142	2	G73)WOONDUM Q
3519	49	196	892	3	G73)SLP)URUNGA N
3520	42	198	1507	2	G73)RSA
3521	45	204	953	3	G73)SFDP)COFFS HRBR N
3522	49	204	1026	4	G73)SLP)IMOK)GYMPIE Q
3523	49	206	1626	1	BRASIL
3524	45	207	917	3	G73)SLP)COFFS HRBR N
3525	44	211	97	2	SLP)URUNGA N
3526	49	214	867	3	G73)FFF)URUNGA N
3527	46	219	1150	2	G73)WOONDUM Q
3528	43	225	1149	2	G73)WOONDUM Q
3529	47	225	1052	2	G73)MULBERRY
3530	52	222	1628	1	GLADFIELD Q
3531	55	222	1154	2	G73)WOONDUM Q
3532	56	217	1173	2	G73)POMONA Q
3533	52	216	1024	4	G73)SLP)IMOK)GYMPIE Q
3534	54	213	857	3	G73)FFF)URUNGA N
3535	51	213	1038	3	G73)SLP)NORTH COAST N
3536	53	210	875	3	G73)FFF)URUNGA N
3537	56	208	1003	4	G73)SLP)IMOK)GYMPIE Q
3539	56	197	977	4	G73)F69)BIG)COFFS HRBR N
3540	52	194	960	3	G73)SFDP)COFFS HRBR N
3541	55	193	1513	2	G73)RSA
3542	51	184	90	3	SLP)IMOK)GYMPIE Q
3543	57	182	1562	1	BRASIL
3544	53	179	926	3	G73)SLP)COFFS HRBR N
3545	57	175	956	3	G73)SFDP)COFFS HRBR N
3546	51	174	926	3	G73)SLP)COFFS HRBR N
3547	54	170	1002	4	G73)SLP)IMOK)GYMPIE Q
3548	51	168	1537	2	G73)RSA
3549	52	163	991	4	G73)SLP)IMOK)GYMPIE Q
3550	55	157	962	3	G73)SFDP)COFFS HRBR N
3551	52	156	975	4	G73)F69)BIG)COFFS HRBR N

Table 7-2. (Continued).

ID	ROW	COL	FAM	GN	PEDIGREE
3552	54	155	1007	4	G73)SLP)IMOK)GYMPIE Q
3553	52	154	1063	2	G73)CABBAGE VAT
3554	52	146	1021	4	G73)SLP)IMOK)GYMPIE Q
3555	57	144	1488	2	G73)RSA
3556	50	141	1026	4	G73)SLP)IMOK)GYMPIE Q
3557	57	138	1508	2	G73)RSA
3558	50	137	912	3	G73)SLP)COFFS HRBR N
3559	54	135	1540	2	G73)RSA
3560	49	130	845	3	G73)FFF)URUNGA N
3561	53	127	874	3	G73)FFF)URUNGA N
3562	54	125	996	4	G73)SLP)IMOK)GYMPIE Q
3563	50	125	1020	4	G73)SLP)IMOK)GYMPIE Q
3564	53	120	1175	2	G73)POMONA Q
3565	56	116	1198	2	G73)RSA
3566	53	113	873	3	G73)FFF)URUNGA N
3567	54	112	931	3	G73)SLP)COFFS HRBR N
3568	56	108	1068	2	G73)TICE
3569	51	104	1010	4	G73)SLP)IMOK)GYMPIE Q
3570	50	99	1025	4	G73)SLP)IMOK)GYMPIE Q
3571	56	97	978	4	G73)F69)BIG)COFFS HRBR N
3572	54	95	885	3	G73)SLP)URUNGA N
3573	50	88	965	3	G73)SFSP)COFFS HRBR N
3574	55	86	1118	2	G73)BOAMBEE N
3575	55	85	1038	3	G73)SLP)NORTH COAST N
3576	51	82	1016	4	G73)SLP)IMOK)GYMPIE Q
3577	51	80	1170	2	G73)POMONA Q
3578	56	80	923	3	G73)SLP)COFFS HRBR N
3579	55	78	1021	4	G73)SLP)IMOK)GYMPIE Q
3580	57	76	1150	2	G73)WOONDUM Q
3581	57	75	856	3	G73)FFF)URUNGA N
3582	52	74	1000	4	G73)SLP)IMOK)GYMPIE Q
3583	55	70	892	3	G73)SLP)URUNGA N
3584	50	67	1023	4	G73)SLP)IMOK)GYMPIE Q
3585	57	62	884	3	G73)SLP)URUNGA N
3586	50	62	887	3	G73)SLP)URUNGA N
3587	54	58	1012	4	G73)SLP)IMOK)GYMPIE Q
3588	52	54	1119	2	G73)CONGLOMERATE N
3589	55	53	845	3	G73)FFF)URUNGA N
3590	56	51	997	4	G73)SLP)IMOK)GYMPIE Q
3591	52	49	1082	2	G73)PINE CREEK N
3592	56	49	1170	2	G73)POMONA Q
3593	53	44	1543	2	G73)RSA
3594	57	42	873	3	G73)FFF)URUNGA N
3595	50	40	998	4	G73)SLP)IMOK)GYMPIE Q
3596	52	39	1010	4	G73)SLP)IMOK)GYMPIE Q
3597	54	38	1007	4	G73)SLP)IMOK)GYMPIE Q
3598	53	35	1499	2	G73)RSA
3599	54	33	1023	4	G73)SLP)IMOK)GYMPIE Q
3600	52	30	990	4	G73)SLP)IMOK)GYMPIE Q
3601	56	27	1049	2	G73)ORLANDO
3602	50	23	889	3	G73)SLP)URUNGA N
3604	53	18	1027	4	G73)SLP)IMOK)GYMPIE Q
3605	55	18	1539	2	G73)RSA
3606	50	15	991	4	G73)SLP)IMOK)GYMPIE Q
3607	56	14	1172	2	G73)POMONA Q
3608	53	13	1199	2	G73)RSA
3609	57	9	1031	4	G73)SLP)IMOK)GYMPIE Q
3610	50	8	1112	2	G73)NEWRY N
3611	54	8	1019	4	G73)SLP)IMOK)GYMPIE Q
3612	57	5	1528	2	G73)RSA
3613	52	2	101	3	SLP)IMOK)GYMPIE Q
3614	60	1	884	3	G73)SLP)URUNGA N
3615	62	2	1112	2	G73)NEWRY N
3616	64	7	1502	2	G73)RSA
3618	59	15	908	3	G73)SLP)COFFS HRBR N
3619	63	15	868	3	G73)FFF)URUNGA N
3620	58	17	876	3	G73)SLP)URUNGA N
3621	64	17	1551	2	G73)RSA
3622	59	19	1666	1	COOLOOLABIN Q
3623	65	22	991	4	G73)SLP)IMOK)GYMPIE Q
3624	59	24	971	3	G73)SLHQ)COFFS HRBR N
3625	61	26	904	3	G73)SLP)COFFS HRBR N
3626	63	30	186	2	SLP)URUNGA N
3627	61	31	867	3	G73)FFF)URUNGA N
3628	63	36	1134	2	G73)CONGLOMERATE N
3629	61	40	1026	4	G73)SLP)IMOK)GYMPIE Q
3630	65	43	871	3	G73)FFF)URUNGA N
3631	60	44	1142	2	G73)WOONDUM Q
3632	65	47	921	3	G73)SLP)COFFS HRBR N
3633	59	48	1007	4	G73)SLP)IMOK)GYMPIE Q
3634	63	48	983	4	G73)F69)BIG)COFFS HRBR N
3635	61	55	892	3	G73)SLP)URUNGA N
3636	65	55	1010	4	G73)SLP)IMOK)GYMPIE Q
3637	65	57	1016	4	G73)SLP)IMOK)GYMPIE Q
3638	60	59	1022	4	G73)SLP)IMOK)GYMPIE Q
3639	64	64	884	3	G73)SLP)URUNGA N
3640	59	69	1001	4	G73)SLP)IMOK)GYMPIE Q
3641	65	69	1020	4	G73)SLP)IMOK)GYMPIE Q
3642	62	74	1035	3	G73)SLP)NORTH COAST N
3643	59	78	918	3	G73)SLP)COFFS HRBR N
3644	60	81	1155	2	G73)GYMPIE Q
3645	58	86	965	3	G73)SFSP)COFFS HRBR N
3646	62	87	1018	4	G73)SLP)IMOK)GYMPIE Q
3647	65	87	908	3	G73)SLP)COFFS HRBR N
3648	65	93	1025	4	G73)SLP)IMOK)GYMPIE Q
3649	59	99	998	4	G73)SLP)IMOK)GYMPIE Q
3650	61	101	88	3	SLP)IMOK)GYMPIE Q
3651	65	103	1083	2	G73)PINE CREEK N
3652	62	107	1197	2	G73)RSA
3653	61	108	998	4	G73)SLP)IMOK)GYMPIE Q
3654	58	112	1124	2	G73)CONGLOMERATE N
3655	65	112	913	3	G73)SLP)COFFS HRBR N
3656	62	118	90	3	SLP)IMOK)GYMPIE Q
3657	60	121	88	3	SLP)IMOK)GYMPIE Q
3658	65	123	1509	2	G73)RSA
3659	62	127	1520	2	G73)RSA
3660	61	128	991	4	G73)SLP)IMOK)GYMPIE Q
3661	61	131	921	3	G73)SLP)COFFS HRBR N
3662	63	134	910	3	G73)SLP)COFFS HRBR N
3663	58	136	1199	2	G73)RSA
3664	65	136	1007	4	G73)SLP)IMOK)GYMPIE Q
3665	58	142	1149	2	G73)WOONDUM Q
3666	64	146	883	3	G73)SLP)URUNGA N
3667	60	148	88	3	SLP)IMOK)GYMPIE Q
3668	60	151	1498	2	G73)RSA
3669	64	151	1542	2	G73)RSA
3670	60	156	1503	2	G73)RSA
3671	65	158	1134	2	G73)CONGLOMERATE N
3672	62	162	953	3	G73)SFDP)COFFS HRBR N
3673	60	164	1109	2	G73)NEWRY N
3674	61	169	1764	1	CHOMA ZAMBIA
3675	62	173	1720	1	HWY 31 CHARLOTTE CO
3676	59	175	931	3	G73)SLP)COFFS HRBR N
3677	62	177	1505	2	G73)RSA
3678	58	179	1530	2	G73)RSA
3679	61	184	1154	2	G73)WOONDUM Q
3680	64	184	1161	2	G73)BELLTHORPE Q
3681	58	188	1007	4	G73)SLP)IMOK)GYMPIE Q

Table 7-2. (Continued).

ID	ROW	COL	FAM	GN	PEDIGREE
3682	64	188	1499	2	G73)RSA
3683	65	192	983	4	G73)F69)BIG)COFFS HRBR N
3684	61	194	1166	2	G73)POMONA Q
3685	58	198	586	1	OSCEOLA CO
3686	64	200	898	3	G73)BIG)COFFS HRBR N
3688	59	205	867	3	G73)FFF)URUNGA N
3689	65	209	1043	3	G73)SLP)ARGENTINA
3690	60	211	1057	2	G73)CABBAGE VAT
3691	63	212	1011	4	G73)SLP)IMOK)GYMPIE Q
3692	59	219	937	3	G73)BPP)COFFS HRBR N
3693	65	219	847	3	G73)FFF)URUNGA N
3694	61	221	1002	4	G73)SLP)IMOK)GYMPIE Q
3695	64	221	1029	3	G73)SLP)GYMPIE Q
3696	58	223	1528	2	G73)RSA
3697	70	225	859	3	G73)FFF)URUNGA N
3698	66	221	1124	2	G73)CONGLOMERATE N
3699	67	218	1022	4	G73)SLP)IMOK)GYMPIE Q
3700	71	218	88	3	SLP)IMOK)GYMPIE Q
3701	68	214	1022	4	G73)SLP)IMOK)GYMPIE Q
3702	72	214	1034	2	G73)GYMPIE Q
3703	70	210	1027	4	G73)SLP)IMOK)GYMPIE Q
3704	68	206	1005	4	G73)SLP)IMOK)GYMPIE Q
3705	73	203	969	3	G73)SFSP)COFFS HRBR N
3706	66	202	955	3	G73)SFDP)COFFS HRBR N
3707	67	199	1169	2	G73)POMONA Q
3708	70	199	90	3	SLP)IMOK)GYMPIE Q
3709	70	195	1173	2	G73)POMONA Q
3710	67	191	898	3	G73)BIG)COFFS HRBR N
3711	70	189	1022	4	G73)SLP)IMOK)GYMPIE Q
3712	73	188	834	1	BAINBRIDGE GA
3713	67	186	842	3	G73)FFF)URUNGA N
3714	73	185	881	3	G73)SLP)URUNGA N
3715	68	182	1534	2	G73)RSA
3716	73	180	1480	2	G73)RSA
3717	67	172	1053	2	G73)MULBERRY
3718	70	172	1002	4	G73)SLP)IMOK)GYMPIE Q
3719	67	170	1764	1	CHOMA ZAMBIA
3720	70	168	1512	2	G73)RSA
3721	68	165	883	3	G73)SLP)URUNGA N
3722	73	165	1519	2	G73)RSA
3723	73	158	1052	2	G73)MULBERRY
3724	67	157	985	4	G73)F69)BIG)COFFS HRBR N
3725	71	155	1137	2	G73)CONGLOMERATE N
3726	66	151	1087	2	G73)PINE CREEK N
3727	73	150	847	3	G73)FFF)URUNGA N
3728	67	146	883	3	G73)SLP)URUNGA N
3729	71	144	1022	4	G73)SLP)IMOK)GYMPIE Q
3730	66	142	1702	1	MT MEE Q
3731	73	138	186	2	SLP)URUNGA N
3732	69	137	958	3	G73)SFDP)COFFS HRBR N
3733	66	135	1713	1	BELLTHORPE Q
3734	71	133	1541	2	G73)RSA
3735	70	129	961	3	G73)SFDP)COFFS HRBR N
3736	68	127	921	3	G73)SLP)COFFS HRBR N
3737	67	122	1060	2	G73)CABBAGE VAT
3738	70	122	1539	2	G73)RSA
3739	66	120	845	3	G73)FFF)URUNGA N
3740	73	114	901	3	G73)BIG)COFFS HRBR N
3741	67	111	983	4	G73)F69)BIG)COFFS HRBR N
3743	73	105	884	3	G73)SLP)URUNGA N
3744	72	100	946	3	G73)BPP)COFFS HRBR N
3745	67	96	1479	2	G73)RSA
3746	68	94	1484	2	G73)RSA
3747	70	91	849	3	G73)FFF)URUNGA N
3748	69	90	992	4	G73)SLP)IMOK)GYMPIE Q
3749	70	86	1136	2	G73)CONGLOMERATE N
3750	69	83	1145	2	G73)WOONDUM Q
3751	67	76	988	4	G73)SLP)IMOK)GYMPIE Q
3752	72	76	1026	4	G73)SLP)IMOK)GYMPIE Q
3753	73	72	846	3	G73)FFF)URUNGA N
3754	67	70	1111	2	G73)NEWRY N
3755	72	68	947	3	G73)BPP)COFFS HRBR N
3756	68	67	958	3	G73)SFDP)COFFS HRBR N
3757	69	65	1001	4	G73)SLP)IMOK)GYMPIE Q
3758	73	63	987	4	G73)SLP)IMOK)GYMPIE Q
3759	73	58	1177	2	G73)POMONA Q
3760	71	53	1018	4	G73)SLP)IMOK)GYMPIE Q
3761	66	52	846	3	G73)FFF)URUNGA N
3762	67	50	977	4	G73)F69)BIG)COFFS HRBR N
3763	71	48	1045	3	G73)SLP)ARGENTINA
3764	68	44	907	3	G73)SLP)COFFS HRBR N
3765	71	41	959	3	G73)SFDP)COFFS HRBR N
3766	73	39	988	4	G73)SLP)IMOK)GYMPIE Q
3767	67	32	986	4	G73)SLP)IMOK)GYMPIE Q
3768	70	32	1063	2	G73)CABBAGE VAT
3769	67	28	1027	4	G73)SLP)IMOK)GYMPIE Q
3770	72	26	990	4	G73)SLP)IMOK)GYMPIE Q
3771	68	22	1499	2	G73)RSA
3772	71	22	1098	2	G73)PINE CREEK N
3773	67	16	880	3	G73)SLP)URUNGA N
3774	70	16	1040	2	G73)NORTH COAST N
3775	73	13	635	1	INDIAN RIVER CO
3776	69	11	867	3	G73)FFF)URUNGA N
3777	73	7	1009	4	G73)SLP)IMOK)GYMPIE Q
3778	69	6	1026	4	G73)SLP)IMOK)GYMPIE Q
3779	67	5	1528	2	G73)RSA
3780	68	4	1686	1	COMO Q
3781	70	4	991	4	G73)SLP)IMOK)GYMPIE Q
3782	75	1	868	3	G73)FFF)URUNGA N
3783	77	4	1155	2	G73)GYMPIE Q
3784	80	5	1545	2	G73)RSA
3785	75	8	943	3	G73)BPP)COFFS HRBR N
3786	81	10	987	4	G73)SLP)IMOK)GYMPIE Q
3788	75	13	1688	1	COMO Q
3789	74	15	1020	4	G73)SLP)IMOK)GYMPIE Q
3790	76	17	9999	0	IDENTITY LOST
3791	78	19	1021	4	G73)SLP)IMOK)GYMPIE Q
3792	78	21	1067	2	G73)TICE
3793	75	22	883	3	G73)SLP)URUNGA N
3794	77	28	880	3	G73)SLP)URUNGA N
3795	78	30	867	3	G73)FFF)URUNGA N
3796	80	31	977	4	G73)F69)BIG)COFFS HRBR N
3797	76	33	1022	4	G73)SLP)IMOK)GYMPIE Q
3798	76	36	858	3	G73)FFF)URUNGA N
3799	78	38	1007	4	G73)SLP)IMOK)GYMPIE Q
3800	76	40	1145	2	G73)WOONDUM Q
3801	77	44	885	3	G73)SLP)URUNGA N
3802	81	45	125	2	BPP)COFFS HRBR N
3803	79	46	1046	3	G73)SLP)ARGENTINA
3804	74	48	1171	2	G73)POMONA Q
3805	76	51	988	4	G73)SLP)IMOK)GYMPIE Q
3806	77	55	1160	2	G73)KENILWORTH Q
3807	74	56	899	3	G73)BIG)COFFS HRBR N
3809	74	60	1505	2	G73)RSA
3810	77	61	1726	3	F69)BIG)COFFS HRBR N
3811	74	67	1083	2	G73)PINE CREEK N
3812	77	67	1012	4	G73)SLP)IMOK)GYMPIE Q
3813	79	70	846	3	G73)FFF)URUNGA N

Table 7-2. (Continued).

ID	ROW	COL	FAM	GN	PEDIGREE
3814	75	73	1109	2	G73)NEWRY N
3815	77	80	1022	4	G73)SLP)IMOK)GYMPIE Q
3816	74	81	9999	0	IDENTITY LOST
3817	78	83	1012	4	G73)SLP)IMOK)GYMPIE Q
3819	80	87	1024	4	G73)SLP)IMOK)GYMPIE Q
3820	80	90	88	3	G73)IMOK)GYMPIE Q
3821	76	92	904	3	G73)SLP)COFFS HRBR N
3822	78	95	846	3	G73)FFF)URUNGA N
3823	74	96	1109	2	G73)NEWRY N
3824	76	97	1092	2	G73)PINE CREEK N
3825	80	97	991	4	G73)SLP)IMOK)GYMPIE Q
3826	79	103	1028	4	G73)SLP)IMOK)GYMPIE Q
3827	75	105	913	3	G73)SLP)COFFS HRBR N
3828	81	109	9999	0	IDENTITY LOST
3829	75	113	958	3	G73)SFDP)COFFS HRBR N
3830	79	113	1133	2	G73)CONGLOMERATE N
3831	80	119	1526	2	G73)RSA
3832	76	124	88	3	SLP)IMOK)GYMPIE Q
3833	78	126	88	3	SLP)IMOK)GYMPIE Q
3834	74	128	1158	2	G73)GYMPIE Q
3835	75	131	965	3	G73)SFSP)COFFS HRBR N
3836	81	131	1022	4	G73)SLP)IMOK)GYMPIE Q
3837	77	134	1487	2	G73)RSA
3838	80	137	938	3	G73)BPP)COFFS HRBR N
3839	77	139	874	3	G73)FFF)URUNGA N
3840	80	141	1163	2	G73)POMONA Q
3841	74	142	1646	1	CONONDALE Q
3842	77	146	956	3	G73)SFDP)COFFS HRBR N
3843	80	148	990	4	G73)SLP)IMOK)GYMPIE Q
3844	76	153	1196	2	G73)RSA
3845	80	154	923	3	G73)SLP)COFFS HRBR N
3846	77	157	998	4	G73)SLP)IMOK)GYMPIE Q
3847	80	162	916	3	G73)SLP)COFFS HRBR N
3848	77	165	1010	4	G73)SLP)IMOK)GYMPIE Q
3849	74	169	1507	2	G73)RSA
3850	79	170	847	3	G73)FFF)URUNGA N
3851	81	173	1165	2	G73)POMONA Q
3852	77	174	9999	0	UNPLANTED SPOT
3853	78	179	1020	4	G73)SLP)IMOK)GYMPIE Q
3854	76	180	1003	4	G73)SLP)IMOK)GYMPIE Q
3855	74	181	938	3	G73)BPP)COFFS HRBR N
3856	80	181	1101	2	G73)PINE CREEK N
3857	81	187	1003	4	G73)SLP)IMOK)GYMPIE Q
3858	76	190	1087	2	G73)PINE CREEK N
3859	75	192	1012	4	G73)SLP)IMOK)GYMPIE Q
3860	79	192	1040	2	G73)NORTH COAST N
3861	75	196	1484	2	G73)RSA
3862	78	196	869	3	G73)FFF)URUNGA N
3863	74	200	991	4	G73)SLP)IMOK)GYMPIE Q
3864	76	201	1056	2	G73)CABBAGE VAT
3865	74	208	1016	4	G73)SLP)IMOK)GYMPIE Q
3866	78	211	859	3	G73)FFF)URUNGA N
3867	74	215	955	3	G73)SFDP)COFFS HRBR N
3868	74	219	1686	1	COMO Q
3869	78	219	1043	3	G73)SLP)ARGENTINA
3870	80	219	998	4	G73)SLP)IMOK)GYMPIE Q
3871	78	223	1043	3	G73)SLP)ARGENTINA
3872	74	224	1168	2	G73)POMONA Q
3873	82	225	1019	4	G73)SLP)IMOK)GYMPIE Q
3874	88	222	1482	2	G73)RSA
3875	87	217	884	3	G73)SLP)URUNGA N
3876	84	216	1747	1	RSA
3877	86	214	1011	4	G73)SLP)IMOK)GYMPIE Q
3878	83	212	1020	4	G73)SLP)IMOK)GYMPIE Q
3879	87	210	1046	3	G73)SLP)ARGENTINA
3880	82	209	873	3	G73)FFF)URUNGA N
3881	88	203	9999	0	IDENTITY LOST
3882	83	201	1000	4	G73)SLP)IMOK)GYMPIE Q
3883	87	196	950	3	G73)BPP)COFFS HRBR N
3884	84	193	870	3	G73)FFF)URUNGA N
3885	87	192	1118	2	G73)BOAMBEE N
3886	83	190	9999	0	IDENTITY LOST
3887	89	189	1723	3	F69)BIG)COFFS HRBR N
3888	82	185	874	3	G73)FFF)URUNGA N
3889	85	183	991	4	G73)SLP)IMOK)GYMPIE Q
3890	89	182	1086	2	G73)PINE CREEK N
3891	83	178	1517	2	G73)RSA
3892	87	177	1537	2	G73)RSA
3893	85	174	1147	2	G73)WOONDUM Q
3894	87	174	850	3	G73)FFF)URUNGA N
3895	83	170	1171	2	G73)POMONA Q
3896	88	168	1103	2	G73)PINE CREEK N
3897	83	165	1007	4	G73)SLP)IMOK)GYMPIE Q
3898	89	161	1147	2	G73)WOONDUM Q
3899	83	159	908	3	G73)SLP)COFFS HRBR N
3900	85	155	1024	4	G73)SLP)IMOK)GYMPIE Q
3901	87	153	834	1	BAINBRIDGE GA
3902	86	148	1104	2	G73)PINE CREEK N
3903	83	147	1194	2	G73)RSA
3904	84	142	1198	2	G73)RSA
3905	88	140	876	3	G73)SLP)URUNGA N
3906	83	136	1491	2	G73)RSA
3908	83	126	1052	2	G73)MULBERRY
3909	88	122	1127	2	G73)CONGLOMERATE N
3910	83	119	1537	2	G73)RSA
3911	87	119	1083	2	G73)PINE CREEK N
3912	83	115	1144	2	G73)WOONDUM Q
3913	89	112	1485	2	G73)RSA
3914	82	110	1086	2	G73)PINE CREEK N
3915	82	104	998	4	G73)SLP)IMOK)GYMPIE Q
3916	85	103	991	4	G73)SLP)IMOK)GYMPIE Q
3917	86	100	88	3	SLP)IMOK)GYMPIE Q
3918	83	93	910	3	G73)SLP)COFFS HRBR N
3920	85	90	1010	4	G73)SLP)IMOK)GYMPIE Q
3921	87	86	586	1	OSCEOLA CO
3922	88	81	1175	2	G73)POMONA Q
3923	84	79	998	4	G73)SLP)IMOK)GYMPIE Q
3924	89	78	921	3	G73)SLP)COFFS HRBR N
3925	83	74	926	3	G73)SLP)COFFS HRBR N
3926	89	72	1016	4	G73)SLP)IMOK)GYMPIE Q
3927	82	70	1012	4	G73)SLP)IMOK)GYMPIE Q
3928	86	69	97	2	SLP)URUNGA N
3929	87	67	1541	2	G73)RSA
3930	83	58	1527	2	G73)RSA
3931	88	58	909	3	G73)SLP)COFFS HRBR N
3932	84	53	877	3	G73)SLP)URUNGA N
3933	87	50	1481	2	G73)RSA
3934	89	48	982	4	G73)F69)BIG)COFFS HRBR N
3935	88	45	895	2	G73)URUNGA N
3936	82	43	1009	4	G73)SLP)IMOK)GYMPIE Q
3937	84	41	864	3	G73)FFF)URUNGA N
3938	83	37	1040	2	G73)NORTH COAST N
3939	89	35	880	3	G73)SLP)URUNGA N
3940	85	33	1026	4	G73)SLP)IMOK)GYMPIE Q
3941	84	32	1010	4	G73)SLP)IMOK)GYMPIE Q
3942	86	29	1759	1	RSA
3943	88	27	879	3	G73)SLP)URUNGA N
3944	85	26	1026	4	G73)SLP)IMOK)GYMPIE Q

Table 7-2. (Continued).

ID	ROW	COL	FAM	GN	PEDIGREE
3945	89	25	920	3	G73)SLP)COFFS HRBR N
3946	88	22	874	3	G73)FFF)URUNGA N
3947	82	19	1035	3	G73)SLP)NORTH COAST N
3948	82	17	1003	4	G73)SLP)IMOK)GYMPIE Q
3949	85	15	1021	4	G73)SLP)IMOK)GYMPIE Q
3950	86	15	1160	2	G73)KENILWORTH Q
3951	88	13	873	3	G73)FFF)URUNGA N
3952	89	11	1024	4	G73)SLP)IMOK)GYMPIE Q
3953	82	9	1759	1	RSA
3954	86	8	1080	2	G73)PINE CREEK N
3955	85	7	908	3	G73)SLP)COFFS HRBR N
3956	87	5	1509	2	G73)RSA
3957	84	3	1516	2	G73)RSA
3958	83	1	847	3	G73)FFF)URUNGA N
3959	91	1	1145	2	G73)WOONDUM Q
3960	96	1	1130	2	G73)CONGLOMERATE N
3961	94	2	1026	4	G73)SLP)IMOK)GYMPIE Q
3962	96	4	1155	2	G73)GYMPIE Q
3964	92	10	1112	2	G73)NEWRY N
3965	95	11	1087	2	G73)PINE CREEK N
3966	97	12	1705	1	MT MEE Q
3967	90	14	1034	2	G73)GYMPIE Q
3968	95	14	1080	2	G73)PINE CREEK N
3969	91	19	1040	2	G73)NORTH COAST N
3970	92	23	1000	4	G73)SLP)IMOK)GYMPIE Q
3971	90	27	1535	2	G73)RSA
3972	95	29	1009	4	G73)SLP)IMOK)GYMPIE Q
3973	96	29	847	3	G73)FFF)URUNGA N
3974	97	37	1103	2	G73)PINE CREEK N
3975	94	41	1022	4	G73)SLP)IMOK)GYMPIE Q
3976	93	42	998	4	G73)SLP)IMOK)GYMPIE Q
3977	96	44	876	3	G73)SLP)URUNGA N
3978	90	52	1049	2	G73)ORLANDO
3979	95	54	988	4	G73)SLP)IMOK)GYMPIE Q
3980	93	56	846	3	G73)FFF)URUNGA N
3981	97	61	900	3	G73)BIG)COFFS HRBR N
3982	90	63	1491	2	G73)RSA
3984	93	72	960	3	G73)SFDP)COFFS HRBR N
3985	97	78	1142	2	G73)WOONDUM Q
3986	91	79	1020	4	G73)SLP)IMOK)GYMPIE Q
3987	94	82	1199	2	G73)RSA
3988	90	84	1497	2	G73)RSA
3989	95	91	974	4	G73)F69)BIG)COFFS HRBR N
3990	90	93	989	4	G73)SLP)IMOK)GYMPIE Q
3991	96	99	1127	2	G73)CONGLOMERATE N
3992	91	104	913	3	G73)SLP)COFFS HRBR N
3993	91	108	871	3	G73)FFF)URUNGA N
3995	91	118	892	3	G73)SLP)URUNGA N
3996	95	120	905	3	G73)SLP)COFFS HRBR N
3997	92	121	1127	2	G73)CONGLOMERATE N
3998	95	123	1018	4	G73)SLP)IMOK)GYMPIE Q
3999	96	126	873	3	G73)FFF)URUNGA N
4000	91	130	1171	2	G73)POMONA Q
4001	91	134	844	3	G73)FFF)URUNGA N
4002	95	139	1141	2	G73)CONGLOMERATE N
4003	90	142	884	3	G73)SLP)URUNGA N
4004	95	142	1511	2	G73)RSA
4005	93	146	1166	2	G73)POMONA Q
4006	96	147	941	3	G73)BPP)COFFS HRBR N
4007	94	151	850	3	G73)FFF)URUNGA N
4008	91	152	938	3	G73)BPP)COFFS HRBR N
4009	95	157	1196	2	G73)RSA
4010	91	158	998	4	G73)SLP)IMOK)GYMPIE Q
4011	91	162	868	3	G73)FFF)URUNGA N
4012	95	164	992	4	G73)SLP)IMOK)GYMPIE Q
4013	91	166	883	3	G73)SLP)URUNGA N
4014	95	169	846	3	G73)FFF)URUNGA N
4015	91	171	923	3	G73)SLP)COFFS HRBR N
4016	95	174	842	3	G73)FFF)URUNGA N
4017	94	178	1118	2	G73)BOAMBEE N
4018	94	181	884	3	G73)SLP)URUNGA N
4019	90	185	1006	4	G73)SLP)IMOK)GYMPIE Q
4020	94	186	1128	2	G73)CONGLOMERATE N
4021	90	190	1553	2	G73)RSA
4022	96	191	1151	2	G73)WOONDUM Q
4023	93	193	1493	2	G73)RSA
4024	94	196	1497	2	G73)RSA
4025	91	203	877	3	G73)SLP)URUNGA N
4026	95	203	1163	2	G73)POMONA Q
4027	91	210	1526	2	G73)RSA
4028	94	216	905	3	G73)SLP)COFFS HRBR N
4029	90	218	1119	2	G73)CONGLOMERATE N
4030	97	220	97	2	SLP)URUNGA N
4031	92	223	935	3	G73)BPP)COFFS HRBR N
4032	95	223	1105	2	G73)PINE CREEK N
4033	104	225	896	3	G73)BIG)COFFS HRBR N
4034	98	224	928	3	G73)SLP)COFFS HRBR N
4035	105	224	1023	4	G73)SLP)IMOK)GYMPIE Q
4036	98	212	1494	2	G73)RSA
4037	98	209	1751	1	RSA
4038	99	208	845	3	G73)FFF)URUNGA N
4039	103	203	1764	1	CHOMA ZAMBIA
4040	98	202	954	3	G73)SFDP)COFFS HRBR N
4041	100	202	1021	4	G73)SLP)IMOK)GYMPIE Q
4042	101	199	90	3	SLP)IMOK)GYMPIE Q
4043	104	199	997	4	G73)SLP)IMOK)GYMPIE Q
4044	101	196	1026	4	G73)SLP)IMOK)GYMPIE Q
4045	105	195	845	3	G73)FFF)URUNGA N
4046	99	193	1083	2	G73)PINE CREEK N
4047	101	188	1532	2	G73)RSA
4048	105	187	1153	2	G73)WOONDUM Q
4049	101	183	1146	2	G73)WOONDUM Q
4050	105	181	1136	2	G73)CONGLOMERATE N
4051	101	180	1012	4	G73)SLP)IMOK)GYMPIE Q
4052	100	173	919	3	G73)SLP)COFFS HRBR N
4053	101	170	1194	2	G73)RSA
4054	104	170	1024	4	G73)SLP)IMOK)GYMPIE Q
4055	98	163	1038	3	G73)SLP)NORTH COAST N
4056	105	163	1081	2	G73)PINE CREEK N
4057	102	160	186	2	SLP)URUNGA N
4058	101	159	1199	2	G73)RSA
4059	100	152	1029	3	G73)SLP)GYMPIE Q
4060	105	152	1019	4	G73)SLP)IMOK)GYMPIE Q
4061	102	148	1726	3	F69)BIG)COFFS HRBR N
4062	98	146	1493	2	G73)RSA
4063	105	144	924	3	G73)SLP)COFFS HRBR N
4064	103	137	1003	4	G73)SLP)IMOK)GYMPIE Q
4065	102	134	1022	4	G73)SLP)IMOK)GYMPIE Q
4066	100	131	1134	2	G73)CONGLOMERATE N
4067	99	130	1505	2	G73)RSA
4068	102	126	993	4	G73)SLP)IMOK)GYMPIE Q
4069	102	123	1088	2	G73)PINE CREEK N
4070	100	122	1545	2	G73)RSA
4072	100	115	1498	2	G73)RSA
4073	102	113	1003	4	G73)SLP)IMOK)GYMPIE Q
4074	104	101	877	3	G73)SLP)URUNGA N
4076	100	87	1532	2	G73)RSA
4078	98	82	884	3	G73)SLP)URUNGA N

Table 7-2. (Continued).

ID	ROW	COL	FAM	GN	PEDIGREE
4079	99	77	1199	2	G73)RSA
4080	103	75	1130	2	G73)CONGLOMERATE N
4081	100	72	1198	2	G73)RSA
4082	102	64	998	4	G73)SLP)IMOK)GYMPIE Q
4083	104	60	1002	4	G73)SLP)IMOK)GYMPIE Q
4084	98	54	885	3	G73)SLP)URUNGA N
4086	103	51	1480	2	G73)RSA
4087	105	47	1550	2	G73)RSA
4088	103	43	1175	2	G73)POMONA Q
4089	101	36	9999	0	IDENTITY LOST
4090	99	27	1019	4	G73)SLP)IMOK)GYMPIE Q
4091	98	23	90	3	SLP)IMOK)GYMPIE Q
4092	103	18	1045	3	G73)SLP)ARGENTINA
4093	100	13	1534	2	G73)RSA
4094	100	9	9999	0	IDENTITY LOST
4095	101	6	955	3	G73)SFDP)COFFS HRBR N
4096	100	2	965	3	G73)SFSP)COFFS HRBR N
4097	102	1	1022	4	G73)SLP)IMOK)GYMPIE Q
4098	108	1	1112	2	G73)NEWRY N
4099	110	1	888	3	G73)SLP)URUNGA N
4100	112	2	905	3	G73)SLP)COFFS HRBR N
4101	110	8	1038	3	G73)SLP)NORTH COAST N
4102	107	11	1636	1	GLADFIELD Q
4103	112	11	961	3	G73)SFDP)COFFS HRBR N
4104	106	18	994	4	G73)SLP)IMOK)GYMPIE Q
4105	110	18	1480	2	G73)RSA
4106	113	29	900	3	G73)BIG)COFFS HRBR N
4107	113	35	1002	4	G73)SLP)IMOK)GYMPIE Q
4108	111	39	1562	2	G73)HYBRID COMPOSITE
4109	106	44	1011	4	G73)SLP)IMOK)GYMPIE Q
4110	109	64	1480	2	G73)RSA
4111	111	72	1488	2	G73)RSA
4112	112	76	948	3	G73)BPP)COFFS HRBR N
4113	107	79	867	3	G73)FFF)URUNGA N
4114	108	84	1024	4	G73)SLP)IMOK)GYMPIE Q
4115	110	86	986	4	G73)SLP)IMOK)GYMPIE Q
4116	108	87	979	4	G73)F69)BIG)COFFS HRBR N
4117	107	92	1158	2	G73)GYMPIE Q
4118	113	92	1113	2	G73)NEWRY N
4119	107	94	1693	1	COMO Q
4122	113	102	1554	2	G73)RSA
4123	112	107	946	3	G73)BPP)COFFS HRBR N
4124	107	119	9999	0	IDENTITY LOST
4125	109	121	101	3	SLP)IMOK)GYMPIE Q
4126	113	124	1031	3	G73)SLP)GYMPIE Q
4127	109	129	1046	3	G73)SLP)ARGENTINA
4128	110	130	1196	2	G73)RSA
4129	108	132	946	3	G73)BPP)COFFS HRBR N
4130	109	137	1532	2	G73)RSA
4131	113	138	1030	3	G73)SLP)GYMPIE Q
4132	109	142	1078	2	G73)ITALY
4133	111	143	1488	2	G73)RSA
4134	108	148	1068	2	G73)TICE
4135	108	153	1677	1	WEST COOROY Q
4136	112	155	1500	2	G73)RSA
4137	107	157	1532	2	G73)RSA
4138	109	163	1199	2	G73)RSA
4139	113	165	1036	3	G73)SLP)NORTH COAST N
4140	106	167	921	3	G73)SLP)COFFS HRBR N
4141	113	168	861	3	G73)FFF)URUNGA N
4142	106	171	1550	2	G73)RSA
4143	110	171	1020	4	G73)SLP)IMOK)GYMPIE Q
4144	112	178	1023	4	G73)SLP)IMOK)GYMPIE Q
4145	109	179	946	3	G73)BPP)COFFS HRBR N
4147	111	183	848	3	G73)FFF)URUNGA N
4148	109	187	1091	2	G73)PINE CREEK N
4149	113	189	844	3	G73)FFF)URUNGA N
4150	111	191	1505	2	G73)RSA
4151	107	195	884	3	G73)SLP)URUNGA N
4152	113	196	1065	2	G73)TICE
4153	111	201	1020	4	G73)SLP)IMOK)GYMPIE Q
4154	107	204	9999	0	IDENTITY LOST
4155	108	212	1049	2	G73)ORLANDO
4156	107	217	938	3	G73)BPP)COFFS HRBR N
4157	108	221	1010	4	G73)SLP)IMOK)GYMPIE Q
4158	110	222	857	3	G73)FFF)URUNGA N
4159	112	222	1020	4	G73)SLP)IMOK)GYMPIE Q
4160	115	224	987	4	G73)SLP)IMOK)GYMPIE Q
4161	118	224	873	3	G73)FFF)URUNGA N
4162	119	223	1764	1	RHODESIA
4163	116	218	847	3	G73)FFF)URUNGA N
4164	121	216	987	4	G73)SLP)IMOK)GYMPIE Q
4165	115	212	988	4	G73)SLP)IMOK)GYMPIE Q
4166	116	207	1541	2	G73)RSA
4167	115	205	90	3	SLP)IMOK)GYMPIE Q
4169	114	200	1003	4	G73)SLP)IMOK)GYMPIE Q
4170	120	199	1111	2	G73)NEWRY N
4171	116	198	1134	2	G73)CONGLOMERATE N
4172	116	193	931	3	G73)SLP)COFFS HRBR N
4173	119	192	880	3	G73)SLP)URUNGA N
4174	121	192	1011	4	G73)SLP)IMOK)GYMPIE Q
4175	115	189	846	3	G73)FFF)URUNGA N
4176	119	185	898	3	G73)BIG)COFFS HRBR N
4177	115	185	978	4	G73)F69)BIG)COFFS HRBR N
4178	120	181	1016	4	G73)SLP)IMOK)GYMPIE Q
4179	117	177	1175	2	G73)POMONA Q
4180	120	173	1010	4	G73)SLP)IMOK)GYMPIE Q
4181	115	160	1161	2	G73)BELLTHORPE Q
4182	115	157	898	3	G73)BIG)COFFS HRBR N
4183	120	157	877	3	G73)SLP)URUNGA N
4184	116	154	1096	2	G73)PINE CREEK N
4185	120	152	997	4	G73)SLP)IMOK)GYMPIE Q
4186	118	148	1543	2	G73)RSA
4187	114	146	1500	2	G73)RSA
4188	120	144	1674	1	WEST COOROY Q
4189	116	143	1497	2	G73)RSA
4190	120	140	924	3	G73)SLP)COFFS HRBR N
4191	114	137	1509	2	G73)RSA
4192	120	137	1734	1	BELLE GLADE
4193	114	132	88	3	SLP)IMOK)GYMPIE Q
4194	120	130	986	4	G73)SLP)IMOK)GYMPIE Q
4195	117	129	1156	2	G73)GYMPIE Q
4196	115	125	1028	4	G73)SLP)IMOK)GYMPIE Q
4197	121	125	1177	2	G73)POMONA Q
4198	116	120	1160	2	G73)KENILWORTH Q
4199	119	119	1011	4	G73)SLP)IMOK)GYMPIE Q
4200	115	116	1114	2	G73)NEWRY N
4201	120	115	1111	2	G73)NEWRY N
4203	117	109	1027	4	G73)SLP)IMOK)GYMPIE Q
4204	120	97	933	3	G73)BPP)COFFS HRBR N
4205	121	93	842	3	G73)FFF)URUNGA N
4206	120	87	1005	4	G73)SLP)IMOK)GYMPIE Q
4207	117	82	1053	2	G73)MULBERRY
4208	120	81	1173	2	G73)POMONA Q
4209	117	76	898	3	G73)BIG)COFFS HRBR N
4210	121	76	911	3	G73)SLP)COFFS HRBR N
4211	116	71	1163	2	G73)POMONA Q
4212	117	61	1099	2	G73)PINE CREEK N

Table 7-2. (Continued).

ID	ROW	COL	FAM	GN	PEDIGREE
4213	116	51	1687	1	COMO Q
4214	117	45	1532	2	G73)RSA
4215	118	41	1522	2	G73)RSA
4216	119	35	1558	2	G73)HYBRID COMPOSITE
4217	117	22	847	3	G73)FFF)URUNGA N
4218	121	14	880	3	G73)SLP)URUNGA N
4219	117	13	931	3	G73)SLP)COFFS HRBR N
4222	122	1	925	3	G73)SLP)COFFS HRBR N
4223	128	1	90	3	SLP)IMOK)GYMPIE Q
4225	126	7	921	3	G73)SLP)COFFS HRBR N
4226	125	21	1532	2	G73)RSA
4227	122	22	1117	2	G73)BOAMBEE N
4228	122	24	1035	3	G73)SLP)NORTH COAST N
4229	123	32	1036	3	G73)SLP)NORTH COAST N
4230	127	40	931	3	G73)SLP)COFFS HRBR N
4231	124	48	1535	2	G73)RSA
4232	126	54	1010	4	G73)SLP)IMOK)GYMPIE Q
4233	125	70	1134	2	G73)CONGLOMERATE N
4234	128	75	1020	4	G73)SLP)IMOK)GYMPIE Q
4235	129	77	916	3	G73)SLP)COFFS HRBR N
4236	125	79	1175	2	G73)POMONA Q
4237	123	80	1742	1	RSA
4238	124	85	1097	2	G73)PINE CREEK N
4239	128	99	1147	2	G73)WOODNUM Q
4240	122	105	1105	2	G73)PINE CREEK N
4241	129	105	1047	2	G73)WOODNUM Q
4242	127	106	873	3	G73)FFF)URUNGA N
4243	123	108	1194	2	G73)RSA
4244	125	113	90	3	SLP)IMOK)GYMPIE Q
4245	125	117	1520	2	G73)RSA
4246	128	120	1507	2	G73)RSA
4247	123	122	1004	4	G73)SLP)IMOK)GYMPIE Q
4249	129	129	1199	2	G73)RSA
4250	122	133	1155	2	G73)GYMPIE Q
4251	122	140	1145	2	G73)WOONDUM Q
4252	129	136	1673	1	WEST COOROY Q
4253	122	143	842	3	G73)FFF)URUNGA N
4254	127	145	847	3	G73)FFF)URUNGA N
4255	128	150	1722	3	F69)BIG)COFFS HRBR N
4256	123	152	1127	2	G73)CONGLOMERATE N
4257	127	153	1043	3	G73)SLP)ARGENTINA
4258	129	157	1115	2	G73)NEWRY N
4259	122	159	897	3	G73)BIG)COFFS HRBR N
4260	122	162	1023	4	G73)SLP)IMOK)GYMPIE Q
4261	129	162	987	4	G73)SLP)IMOK)GYMPIE Q
4262	124	166	965	3	G73)SFSP)COFFS HRBR N
4263	127	167	1125	2	G73)CONGLOMERATE N
4264	129	200	1547	2	G73)RSA
4265	127	174	931	3	G73)SLP)COFFS HRBR N
4266	122	177	1025	4	G73)SLP)IMOK)GYMPIE Q
4267	127	177	1036	3	G73)SLP)NORTH COAST N
4268	126	182	857	3	G73)FFF)URUNGA N
4270	128	188	963	3	G73)SFSP)COFFS HRBR N
4271	125	192	1504	2	G73)RSA
4272	128	192	1004	4	G73)SLP)IMOK)GYMPIE Q
4273	125	198	858	3	G73)FFF)URUNGA N
4274	129	200	1011	4	G73)SLP)IMOK)GYMPIE Q
4275	126	203	1002	4	G73)SLP)IMOK)GYMPIE Q
4276	123	207	847	3	G73)FFF)URUNGA N
4277	126	207	861	3	G73)FFF)URUNGA N
4278	127	211	859	3	G73)FFF)URUNGA N
4279	123	213	1538	2	G73)RSA
4280	126	215	1478	2	G73)RSA
4281	127	218	1538	2	G73)RSA
4282	124	221	1005	4	G73)SLP)IMOK)GYMPIE Q
4283	130	1	101	3	SLP)IMOK)GYMPIE Q
4284	131	222	1067	2	G73)TICE
4285	134	222	1143	2	G73)WOONDUM Q
4286	137	217	1150	2	G73)WOONDUM Q
4287	131	213	1552	2	G73)RSA
4288	131	208	849	3	G73)FFF)URUNGA N
4289	135	206	1519	2	G73)RSA
4290	135	204	903	3	G73)BIG)COFFS HRBR N
4291	132	198	1484	2	G73)RSA
4292	135	197	1547	2	G73)RSA
4293	136	195	954	3	G73)SFDP)COFFS HRBR N
4294	132	194	880	3	G73)SLP)URUNGA N
4295	131	189	847	3	G73)FFF)URUNGA N
4296	136	188	1175	2	G73)POMONA Q
4297	134	186	1545	2	G73)RSA
4298	132	184	1169	2	G73)POMONA Q
4299	131	181	1004	4	G73)SLP)IMOK)GYMPIE Q
4300	131	175	876	3	G73)SLP)URUNGA N
4301	132	173	988	4	G73)SLP)IMOK)GYMPIE Q
4302	137	172	123	2	BPP)COFFS HRBR N
4303	134	169	1532	2	G73)RSA
4304	131	166	881	3	G73)SLP)URUNGA N
4305	136	165	1052	2	G73)MULBERRY
4306	134	159	101	3	SLP)IMOK)GYMPIE Q
4307	137	157	1500	2	G73)RSA
4308	131	46	1026	4	G73)SLP)IMOK)GYMPIE Q
4309	136	153	1516	2	G73)RSA
4310	133	149	1480	2	G73)RSA
4311	131	144	1503	2	G73)RSA
4312	134	144	1532	2	G73)RSA
4313	135	137	911	3	G73)SLP)COFFS HRBR N
4314	136	132	847	3	G73)FFF)URUNGA N
4315	132	131	1560	2	G73)HYBRID COMPOSITE
4316	135	128	1038	3	G73)SLP)NORTH COAST N
4317	131	126	1526	2	G73)RSA
4318	133	123	1547	2	G73)RSA
4319	134	121	884	3	G73)SLP)URUNGA N
4320	134	119	1078	2	G73)ITALY
4322	131	112	991	4	G73)SLP)IMOK)GYMPIE Q
4323	131	110	981	4	G73)F69)BIG)COFFS HRBR N
4324	137	109	962	3	G73)SFDP)COFFS HRBR N
4325	131	101	1002	4	G73)SLP)IMOK)GYMPIE Q
4326	135	99	873	3	G73)FFF)URUNGA N
4327	133	95	1098	2	G73)PINE CREEK N
4328	137	95	925	3	G73)SLP)COFFS HRBR N
4329	134	89	1678	1	WEST COOROY Q
4330	137	84	1729	1	ORANGE CO
4331	137	73	587	1	OSCEOLA CO
4332	135	67	1080	2	G73)PINE CREEK N
4333	133	63	1118	2	G73)BOAMBEE N
4335	133	58	1537	2	G73)RSA
4338	133	37	1132	2	G73)CONGLOMERATE N
4339	134	31	1478	2	G73)RSA
4340	134	28	1012	4	G73)SLP)IMOK)GYMPIE Q
4341	136	11	847	3	G73)FFF)URUNGA N
4342	135	3	1193	2	G73)RSA
4343	130	156	1006	4	G73)SLP)IMOK)GYMPIE Q
4344	140	9	101	3	SLP)IMOK)GYMPIE Q
4345	141	15	847	3	G73)FFF)URUNGA N
4346	141	39	1530	2	G73)RSA
4347	139	43	1117	2	G73)BOAMBEE N
4348	140	52	587	1	OSCEOLA CO

Table 7-2. (Continued).

ID	ROW	COL	FAM	GN	PEDIGREE
4349	140	65	981	4	G73)F69)BIG)COFFS HRBR N
4350	141	77	925	3	G73)SLP)COFFS HRBR N
4351	139	85	1142	2	G73)WOODNUM Q
4352	141	86	1499	2	G73)RSA
4353	140	88	913	3	G73)SLP)COFFS HRBR N
4354	141	98	1142	2	G73)WOONDUM Q
4355	141	101	1764	1	RSA
4356	140	105	1103	2	G73)PINE CREEK N
4357	140	107	848	3	G73)FFF)URUNGA N
4359	140	120	1081	2	G73)PINE CREEK N
4360	139	121	1012	4	G73)SLP)IMOK)GYMPIE Q
4361	141	124	1161	2	G73)BELLTHORPE Q
4362	139	127	987	4	G73)SLP)IMOK)GYMPIE Q
4363	140	134	1020	4	G73)SLP)IMOK)GYMPIE Q
4364	141	138	1028	4	G73)SLP)IMOK)GYMPIE Q
4365	141	145	1099	2	G73)PINE CREEK N
4366	138	151	1507	2	G73)RSA
4367	139	155	911	3	G73)SLP)COFFS HRBR N
4368	141	159	868	3	G73)FFF)URUNGA N
4369	139	162	1022	4	G73)SLP)IMOK)GYMPIE Q
4370	141	168	1110	2	G73)NEWRY N
4371	141	173	1528	2	G73)RSA
4372	141	190	1039	3	G73)SLP)NORTH COAST N
4373	138	191	1144	2	G73)WOONDUM Q
4374	140	195	1200	2	G73)RSA
4375	140	206	997	4	G73)SLP)IMOK)GYMPIE Q
4376	140	215	916	3	G73)SLP)COFFS HRBR N
4377	141	219	1158	2	G73)GYMPIE Q
4378	138	223	1046	3	G73)SLP)ARGENTINA
4379	2	30	1018	4	G73)SLP)IMOK)GYMPIE Q

Table 7-3. Tabulation of Eucalyptus accessions and slash pine progenies evaluated from 1983-1988 in Florida.

Eucalyptus amplifolia

Progeny/ Source	Study							Progeny/ Source	Study
84								601	39
191								602	39
192				39	SS-8			701	39
193	DP-1			39		SS-9	SS-11	801	39
201				39		SS-9	SS-11	802	39
202		35	36			SS-9	SS-11	803	39
203		35	36	39		SS-9	SS-11	804	39
204					SS-8	SS-9	SS-11	805	39
205		35	36		SS-8	SS-9	SS-11	806	39
206						SS-9	SS-11	807	39
207		35	36			SS-9	SS-11	808	39
208		35	36		SS-8	SS-9	SS-11	901	39
209		35	36			SS-9	SS-11	902	39
210						SS-9		903	39
211						SS-9		1001	39
301				39				1002	
302				39				1003	39
303				39				1004	39
304				39				1005	39
305				39				1006	39
306				39				1007	39
307				39				1008	39
308				39				1009	39
309				39				1101	39
310				39				1102	39
401				39				1103	39
402				39				1104	39
403				39				1105	39
404				39				1106	39
405				39				1201	
406				39				1202	
501				39				1203	39
502				39				1204	39
503				39				1205	39
504				39				1206	39
505				39				1207	39
506				39				1208	39
507				39				1301	39
508				39				1302	39
509				39				1303	39
510				39				1304	39
511				39					
512				39					

Eucalyptus camaldulensis

Source	Study	Source	Study	Source	Study	Source	Study	Clone	Study	
101	SS-8	205	38 SS-8	213	38 SS-8	221	38	171	SS-2	SS-3
102		206	38 SS-8	214	38	222	38	172	SS-2	
103		207	38 SS-8	215	38 SS-8	223	38	174	SS-2	SS-3
104	SS-8	208	38 SS-8	216	38 SS-8	224	38	178	SS-2	
201	SS-8	209	38	217	38 SS-8			BH	SS-2	SS-3
202	SS-8	210	38 SS-8	218	38 SS-8					
203	SS-8	211	38 SS-8	219	38 SS-8					
204		212	SS-8	220	38					

Table 7-3. (Continued).

Eucalyptus grandis

Progeny	Study						Source	Study	Progeny	Study
88	7		33	35	36		202	SS-8	3336	40
90	7		33	35	36		203	SS-8	3424	40
847	7	16	33	35	36	40	204	SS-8	3516	40
849	7		33	35	36		205	SS-8	3517	40
867	7		33	35	36		206	SS-8	3521	40
869	7		33	35	36		207	SS-8	3641	40
888	7		33	35	36		208	SS-8	3674	40
898	7		33				209	SS-8	3698	40
910	7		33				210	SS-8	3706	40
965	7		33	35	36		211	SS-8	4050	40
987	7		33	35	36		213	SS-8	4157	40
988	7		33				215	SS-8	4160	40
993	7		33				220	SS-8	4161	40
997	7		33	35	36		221	SS-8	4249	40
998	7		33	35	36		222	SS-8	4268	40
1000	7		33	35	36		223		4292	40
1001	7		33	35	36		227	SS-8	4304	40
1002	7	16	33	35	36		229	SS-8	4305	40
1003	7	16	33	35	36		230	SS-8	4310	40
1010	7		33	35	36	40	232	SS-8	4360	40
1011	7		33	35	36		233	SS-8	4361	40
1012	7	16	33	35	36	SS-8	234	SS-8		
1035	7		33				235	SS-8		
1038	7		33	35	36	40	236	SS-8		
1067		16	33				238	SS-8		
1070		16	33	35	36	40	239	SS-8		
1146	7		33	35	36		241	SS-8		
1176	7		33	35	36		242	SS-8		
1499	7		33	35	36		243	SS-8		
1501	7		33	35	36		244	SS-8		
1510	7		33				245	SS-8		
1516	7		33	35	36		301	SS-8		
1517	7		33	35	36					
1529	7		33	35	36					
1535	7		33							

Eucalyptus robusta

Progeny	Study			
101				
106				
201				SS-8
416	16			
437	16			
458	16			
1876	16	35	36	
1879		35	36	
1941		35	36	
1942		35	36	
1948		35	36	
2066		35	36	
2070		35	36	
2072		35	36	
2102		35	36	
2110		35	36	
2113		35	36	
2114		35	36	
2125	16	35	36	
2126		35	36	
2246	16	35	36	
2275		35	36	

Eucalyptus dunnii

Source	Study		
101	35		36
106	35		36
107	35		36
108			
109		SS-8	
110	35		36
111		SS-8	
201	35	SS-8	36

Table 7-3. (Continued).

Eucalyptus grandis Clones																	
Clone	Study		Clone	Study	Clone	Study	Clone	Study	Clone	Study	Clone	Study	Clone	Study	Clone	Study	
101	37		31	40	522	40	664	40	891	40	1296	40					
990	37		37	40	523	40	665	40	892	40	1301	40					
1005	37		41	40	524	40	681	40	901	40	1302	40					
1016	37		44	40	525	40	691	40	902	40	1331	40					
1721	37		45	40	526	40	692	40	903	40	1341	40					
2531	37		67	40	531	40	694	40	904	40	1342	40					
2532	37		68	40	541	40	701	40	905	40	1381	40					
2534	37		84	40	542	40	711	40	906	40	1382	40					
2535	37		91	40	543	40	721	40	907	40	1391	40					
2564	37		109	40	544	40	722	40	908	40	1441	40					
2565	37		117	40	545	40	723	40	931	40	1532	40					
2566	37		191	40	546	40	724	40	951	40	6010	40					
2567	37		211	40	551	40	742	40	961	40	6011	40					
2568	37		261	40	552	40	743	40	967	40	9010	40					
2569	37		271	40	553	40	744	40	981	40	9011	40					
2571	37		272	40	554	40	745	40	991	40							
2696	37		301	40	555	40	751	40	992	40							
2697	37		302	40	561	40	752	40	1021	40							
2770	37		312	40	562	40	753	40	1022	40							
2771	37		361	40	563	40	761	40	1023	40							
2775	37		362	40	564	40	771	40	1031	40							
2776	37	40	371	40	571	40	772	40	1032	40							
2777	37		372	40	572	40	781	40	1041	40							
2779	37		381	40	574	40	783	40	1042	40							
2783	37		401	40	575	40	784	40	1043	40							
2784	37		402	40	576	40	800	40	1051	40							
2785	37		403	40	577	40	801	40	1052	40							
2786	37	40	410	40	578	40	802	40	1061	40							
2787	37		421	40	579	40	803	40	1081	40							
2788	37	40	422	40	581	40	805	40	1091	40							
2789	37		423	40	582	40	806	40	1101	40							
2790	37		425	40	583	40	807	40	1102	40							
2791	37		426	40	584	40	811	40	1111	40							
2793	37		427	40	591	40	812	40	1112	40							
2794	37		431	40	592	40	813	40	1113	40							
2795	37		441	40	601	40	831	40	1114	40							
2797	37		451	40	602	40	841	40	1115	40							
2798	37	40	452	40	603	40	842	40	1131	40							
2801	37		455	40	604	40	843	40	1161	40							
2802	37		461	40	607	40	844	40	1162	40							
2805	37	40	463	40	608	40	846	40	1171	40							
2806	37		464	40	609	40	851	40	1181	40							
2807	37		465	40	611	40	852	40	1214	40							
2809	37		481	40	612	40	853	40	1221	40							
2811	37		482	40	621	40	861	40	1231	40							
2813	37		484	40	631	40	862	40	1232	40							
2814	37	40	511	40	640	40	863	40	1233	40							
2817	37	40	512	40	641	40	872	40	1271	40							
2819	37		513	40	651	40	874	40	1272	40							
2824	37		514	40	660	40	875	40	1274	40							
2831	37		515	40	661	40	876	40	1291	40							
2832	37		516	40	662	40	877	40	1292	40							
2833	37		517	40	663	40	881	40	1293	40							
2834	37		521	40	664	40	882	40	1295	40							

Table 7-3. (Continued).

Eucalyptus tereticornis

Source	Study	Source	Study	Source	Study	Source	Study
95		128	38	152	38	183	36
191		129	38	157	38	184	36
102	38	130	38	158	38	185	36
103	38	131	38	159	38	186	36
104	38	132	38	160	38	187	36
105	38	133	38	161	38	188	36
106	38	134	38	162	38	189	36
107	38	135	38	163	38	190	38
108	38	136	38	164	38	192	38
109	38	137	38	165	38	194	38
110	38	138	38	166	38	195	38
114	38	139	38	167	38	196	38
115	38	140	38	169	38		
116	38	141	38	170	38		
117	38	142	38	171	38		
118	38	143	38	172	38		
119	38	144	38	173	38		
120	38	145	38	174	38		
121	38	146	38	175	38		
122	38	147	38	176	38		
123	38	148	38	177	38		
124	38	149	38	180	38		
125	38	150	38	181	38		
126	38	151	38	182	38		

Sand Pine

Progeny	Study		Progeny	Study	
102-71	13	14	134-71	13	14
103-71	13	14	135-71	13	14
104-71	13	14	136-71	13	14
105-71	13	14	139-71	13	14
106-71	13	14	142-71	13	14
107-71	13	14	143-71	13	14
108-71	13	14	155-71	13	14
109-71	13	14	156-71	13	14
111-71	13	14	158-71	13	14
112-71	13	14	159-71	13	14
117-71	13	14	162-71	13	14
118-71	13	14	163-71	13	14
120-71	13	14	164-71	13	14
121-71	13	14	173-71	13	14
122-71	13	14	178-71	13	14
124-71	13	14	204-71	13	14
128-71	13	14	C-1	13	14
129-71	13	14	C-61	13	14
130-71	13	14	SC-7	13	
132-71	13		SC-18	13	14

Slash Pine

Progeny	Study			Progeny	Study		
167-55	10	11		257-56		11	
244-55	10			261-56	10	11	12
264-55	10	11		271-56	10	11	
285-55	10	11		286-56	10		
293-55		11		298-56	10		
297-55	10			303-56	10	11	
1-56	10	11		310-56	10	11	
6-56	10	11		315-56	10	11	
7-56		11	12	26-57	10		
54-56	10			71-57	10	11	
56-56	10	11		152-57	10	11	12
64-56	10	11		172-57	10	11	12
70-56	10	11		173-57	10	11	
89-56		11		14-58	10		
91-56	10	11		18-58	10	11	
92-56	10			95-58		11	
106-56	10	11		158-58	10		
230-56	10	11		183-58	10	11	
246-56	10	11		39-62	10	11	

Table 7-4. Standardized GORCH73 E. grandis parental tree evaluations[1] from progeny tests.

	ORNL Study							
PROG	7N[2] 18MTV	7S[3] 18MTV	16N[4] 12MTV	16W[5] 12MTV	35[6] 18MTV	36[7] 13MHGT	33[8] 5.2YMTV	Overall[9]
88	-0.423				1.178	-1.340	-0.238	-0.084
90	-0.470	-0.602			0.176	-0.396	0.155	-0.227
847	-0.069	-0.183	0.044	0.044	-0.100	-0.020	0.064	-0.031
849	-0.054			0.265	-1.151	-0.696		-0.409
867	0.017	0.116			0.129	-0.019	-0.811	-0.115
869	-0.208	-0.203			0.744	-0.774	-0.823	-0.253
888	0.048	0.042			0.068	-0.774	-0.727	-0.269
965	0.454	-0.201			-0.041	1.113	-0.355	0.194
987	-0.185				0.531	-0.019	-0.434	-0.027
988	-0.323	-0.169						-0.246
993	-0.255	0.026						-0.115
997	0.124	0.514			0.301	-1.075	0.176	0.008
998	0.012				-0.034	-1.264	0.181	-0.276
1000	-0.085				-0.370	-0.925	-0.598	-0.494
1001	0.200				-0.302	-0.660	-0.371	-0.283
1002	-0.229	-0.175	-0.044	-0.044	-0.352	-0.060	-0.138	-0.149
1003	0.297	0.155	0.132	0.219	0.369	0.094	0.120	0.198
1010	0.305				-0.711	-0.019	0.261	-0.041
1011	0.043	-0.458			1.217	-0.396	-0.500	-0.019
1012	0.001	0.205	-0.132	-0.219	0.084	-0.019	-0.046	-0.018
1035	-0.881	-0.369						-0.625
1038	0.402				-0.203	-0.019	-0.368	-0.047
1067			-0.132	0.132				0.000
1070			0.044	0.044	-0.048	-1.340	-0.921	-0.444
1146	0.044	0.470			0.019	0.358	-0.322	0.114
1176	-0.075				-0.165	-0.773	-0.548	-0.353
1499	0.357				-0.247	-0.170	-0.832	-0.223
1501	-0.048				-0.019	-0.208	-0.899	-0.293
1510	-0.372	-0.508						-0.440
1516	-0.295	-0.196			-0.184	-1.377	-0.942	-0.599
1517	-0.215	-0.307			-0.264		-0.609	-0.349
1529	-0.299				-0.136			-0.217

[1] Evaluation = (Progeny Mean - Check Mean)/√ Error MS where Checks are progenies 847, 1002, 1003, 1012.
[2] Based on 18-mo. tree volume in ORNL-7 Nelders.
[3] Based on 18-mo. tree volume in ORNL-7 Spacing plots.
[4] Based on 12-mo. tree volume in ORNL-16 Narrow Spacing plots.
[5] Based on 12-mo. tree volume in ORNL-16 Wide Spacing plots.
[6] Based on 18-mo. tree volume in ORNL-35 Row plots.
[7] Based on 13-mo. tree height in ORNL-36 Row plots.
[8] Based on 64-mo coppice tree volume in GPOP-77 Southern half.
[9] Average evaluation across tests.

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