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THE EFFECTS OF MYCORRHIZAL INOCULATION AND OTHER PRE-CONDITIONING TREATMENTS ON FIELD SURVIVAL AND GROWTH OF BAREROOT PLANTED EUCALYPTUS AND DIPTEROCARPS

REYNALDO E. DE LA CRUZ, Ph.D.
Project Leader

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PROJECT LEADER : Reynaldo E. dela Cruz

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PROJECT STAFF :

Lorna T. Quinita	Research Assistant (July 1986-June 1990)
Nelson M. Pampolina	Research Assistant (July 1986-May 1989)
Victor de Leon	Research Assistant (May 1989-July 1989)
Emmanuel Asinas	Research Assistant (July 1989-Dec. 1991)
Angelito Replan	Research Aide (July 1986-Dec. 1991)
Ramon Sacramento	Research Aide (July 1986-Dec. 1989)
Jose C. Paz	Laborer (July 1986-Dec. 1991)

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ABSTRACT

The effects of mycorrhizal inoculation and silvicultural pre-conditioning treatments on field survival and growth of bareroot planted *Eucalyptus* and Dipterocarps were studied. Ecto- and endomycorrhizal fungi associated with *Eucalyptus* and dipterocarp species were collected, isolated, and identified. Synthesis studies were conducted to verify if isolated fungi were truly mycorrhizal formers. The effectiveness of isolated fungi in promoting growth of host plants were determined. The effects of silvicultural pre-conditioning treatments such as spacing distances and depth of undercutting of roots in combination with mycorrhizal inoculation treatments on field survival and growth of seedlings were studied. Seedlings of *E. deglupta* were grown in nursery beds during which time, the pre-conditioning treatments were imposed. The seedlings were barerooted by removing adhering soil particles. The barerooted seedlings were then placed in different packaging treatments (exposed, covered with mudpuddle, and with mudpuddle and placed in banana leafsheath) before transplanting in the field. The seedlings were planted in a degraded grassland. Survival, height and diameter growth were monitored for 11 months.

Most species of ectomycorrhizal fungi associated with dipterocarps and *Eucalyptus* belongs to the genera *Russula, Lactarius, Scleroderma, Pisolithus, Rhizopogon, Cenococcum*, and *Thelephora*. Species belonging to the genera *Scleroderma, Pisolithus, Rhizopogon* and *Thelephora* can be isolated into pure culture. Species belonging to the genera *Lactarius* and *Russula* are difficult to isolate. Dipterocarps such as *A. thurifera* are associated with ectomycorrhiza and not with endomycorrhiza.

Some endomycorrhizal fungi belonging to the genera *Glomus, Gigaspora, Acaulospora*, and *Scutellospora* were isolated from both *Eucalyptus* and dipterocarps. Species belonging to the genera *Glomus* and *Gigaspora* predominate. While *Eucalyptus* and dipterocarps can form associations with endomycorrhizal fungi, the dominant form of association in these groups of plant is still the ectomycorrhizal form.

Among ectomycorrhizal fungi, *C. geophillum*, 2 *Rhizopogon* species and *P. tinctorius* were most effective in promoting growth of *E. camaldulensis* and *E. deglupta*; while *S. citrinum* was more effective than *S. bovista* in promoting growth of *A. thurifera*.

Among endomycorrhizal fungi, *Gl. macrocarpum* and *Gl. mosseae* were the most effective in promoting height growth of *E. deglupta*; while *S. persica*, an *Acaulospora* species, a *Glomus* species, and *Gl. etunicatum* were more effective than *Gl. macrocarpum* and *Gl. mosseae* in promoting height growth of *A. thurifera*.

Taking into consideration seedling density and growth, the best spacing distances for *E. camaldulensis* are 4 in x 1 in and 3 in x 3 in; 3 in x 2 in for *E. deglupta*; and 4 in x 2 in for *A. thurifera*.

The best depths for undercutting roots of *E. camaldulensis* are 2 inches for seedlings spaced at 3 in x 3 in and 1 inch if spaced at 4 in x 1 in. For *E. deglupta*, the best depth to undercut roots of *E. deglupta* are 2 inches when spaced at 4 in x 3 in and at 1 inch if spaced at 2 in x 3 in.

Bareroot planting of *E. deglupta* in a marginal grassland is feasible if the seedlings are pre-conditioned by proper spacing, by undercutting the roots at a depth of 2 inches, if the seedlings are inoculated with an effective ectomycorrhizal fungi such as *P. tinctorius* and if the barerooted seedlings are covered with mudpuddle enveloped in banana leafsheaths when transported to the field. Survival, height and diameter growth of bareroot planted seedlings were comparable to that from potted controls if the barerooted seedlings were undercut, inoculated with an effective mycorrhizal fungi, and the barerooted seedlings are covered with mudpuddle and transported in banana leafsheaths.

INTRODUCTION

With the unabated depletion of the country's forest resources, the Philippine government is faced with the gigantic task of reforesting millions of hectares of marginal uplands. Painstakingly, the government had embarked on massive reforestation projects to regenerate these marginal areas. However, growth and survival of reforestation species in such areas are very low. Incorporating mycorrhizal technology as a vital component of reforestation may yet prove effective in increasing growth and survival of reforestation species.

In support of the government's reforestation thrust, this project was conceived and started on July 1, 1986 with funding coming from the U.S. Agency for International Development. It's ultimate goal is to determine the feasibility of using mycorrhizal fungi to promote the survival and growth of *Eucalyptus* and Dipterocarps in combination with various silvicultural preconditioning treatments in the development of a bareroot planting technology for the aforementioned reforestation species. Thus, it tried to provide a "fast track" and less expensive approach to the reforestation dilemma by incorporating tested mycorrhizal technologies in the reforestation effort.

OBJECTIVES:

1. To collect, isolate and identify mycorrhizal fungi associated with *Eucalyptus* and Dipterocarp species.

2. To prove that the isolated fungi form mycorrhizal association with *Eucalyptus* and Dipterocarps.

3. To screen for effectiveness among mycorrhizal fungi in promoting growth of *Eucalyptus* and Dipterocarps.

4. To determine the effects of some silvicultural treatments such as spacing, depth of undercutting and time of root pruning on root formation and growth of test plants.

5. To develop a bare-rooting technology for *Eucalyptus* and Dipterocarps incorporating mycorrhizal inoculation and seedling pre-conditioning treatments such as spacing, depth of undercutting and root prunning intensities.

METHODOLOGIES

STUDY 1. Collection, isolation and identification of ectomycorrhizal and endomycorrhizal fungi associated with *Eucalyptus* and Dipterocarps.

Trips were conducted to Carranglan and Pantabangan, Nueva Ecija; Real, Quezon; Bislig, Surigao; and Makiling Forest, Laguna, where natural stands, plantations and/or patches of dipterocarp forests and *Eucalyptus* species exist. Sporocarps of suspected mycorrhizal fungi, mycorrhizal roots and rhizosphere soil were collected under these stands. The associated fungi were isolated and identified.

1.1. ECTOMYCORRHIZA

Close-up pictures of ectomycorrhizal basidiocarps were taken. Important macroscopic features like mushroom's pileus, gills, stipes, puffball's peridium, color and color changes of the fruiting body and exudation of latex (if present) in bruised tissues were recorded in the field. Some of the stipe of cupped sporocarps were cut and placed over a white or black card to obtain spore prints. Color of the mycelial strands attached to the fruiting bodies extending to host's roots were further recorded. Other sporocarps were brought to the laboratory for microscopic examination while some were fixed in FAA (Formalin Acetic Acid) or placed in paper bags, ovendried at 70°C and preserved as herbarium specimen. Basidiospores from puffballs were extracted, placed in plastic bags and stored in a refrigerator to be utilized later as inoculant.

Tissues from the inner stipe, cup and/or gleba were aseptically transferred into test tube slants containing MNM (Melin Norkran Medium) and covered with sterilized cotton plugs layered with aluminum foil (Figure 1). Other isolates were tested in Petri plates and sealed off to prevent the entry of contaminants (Figure 2). Isolated ectomycorrhizal fungi were stored in dark growth cabinets under room temperature. Cultures were monitored daily. Contaminated tissues were discarded while uncontaminated cultures were subcultured in the same media for further purification.

Purified cultures were mass produced in sterilized dextrose bottles containing 100 ml of MNM broth (Figure 3), stored for 2-3 months in an incubator cabinet to allow further multiplication.

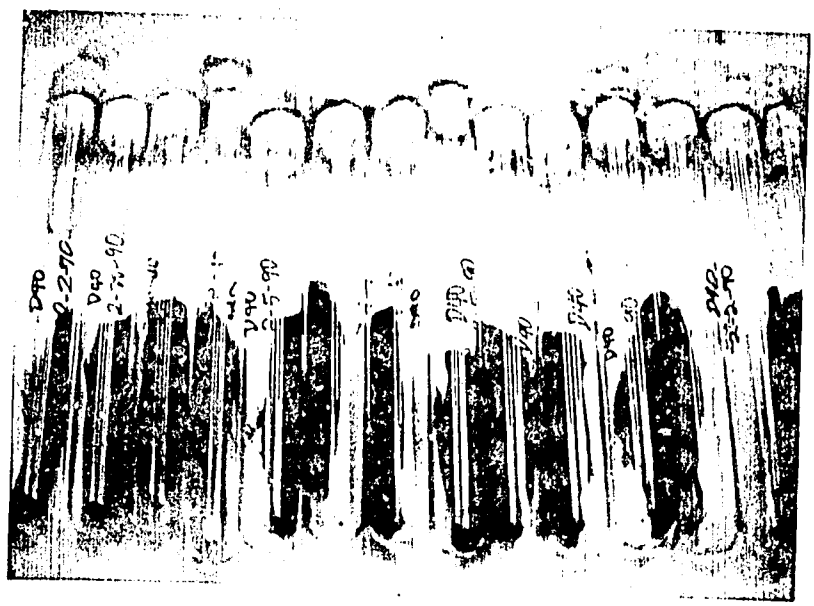

Figure 1. Mass production of ectomycorrhizal fungi in Melin Norkan's Medium (MNM).

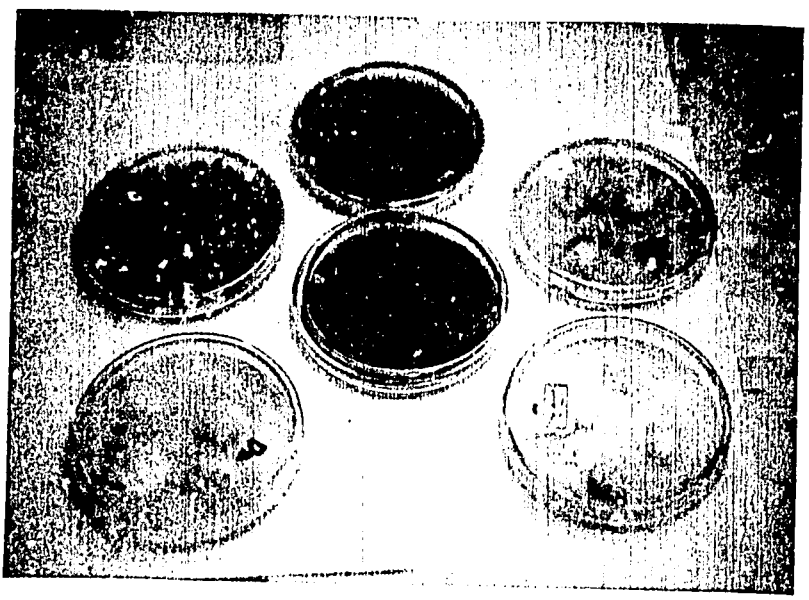

Figure 2 Production of ectomycorrhizal fungi in agar media using Petri plates as culture vessels.

Figure 3. Mass production of ectomycorrhizal fungi in MNM broth using dextrose bottles as culture vessels.

A simple experiment using MNM with agar and sterilized coir dust was performed to determine if the latter inhibits the growth of ectomycorrhizal fungi. The pH of the substrates was adjusted between 4.5 - 5.5 before sterilization.

1.2. ENDOMYCORRHIZA

VAM spores were isolated from soils collected near roots of host plants by wet sieving and decanting techniques through a series of molecular sieves. The VAM fungi were isolated by single spore inoculation to Bahia grass in a green house (Figure 4).

Isolated endomycorrhizal fungi were mass produced singly using different media proportions i.e. fumigated forest soil, quarry sand or lake sand. A separate experiment using complete fertilizer plus 1/2 strength, Hoagland's No. 2 solution was applied to pure medium, i.e. lake sand alone or quarry sand alone.

1.3. SYNTHESIS STUDY

Two mycorrhizal synthesis studies were conducted to determine the mycorrhizal symbionts of certain endomycorrhizal species on *Eucalyptus camaldulensis* and *E. deglupta* seedlings.

Eucalyptus camaldulensis seedlings were used in the first study. Seedlings were transplanted and grown in medium-sized test tubes (20 cm x 2.5 cm) with sterilized perlite and 1/4 strength MNM without a carbohydrate source. Each test tube was inoculated with pure cultures of ecto- and endomycorrhizal fungi. The experiment was conducted in a growth chamber under the following conditions: 30°C, 8 hour light/12 hours dark cycle, with moderate illumination coming from fluorescent and incandescent bulbs.

The second synthesis study used *E. deglupta* seedlings grown in medium-sized cups (9 cm x 7.5 cm) filled with sterile 3:1 mixture of perlite and quarry sand (Figures 5 and 6). Each cup, except for the control, was inoculated with pure cultures of the following endomycorrhizal species: *Gigaspora margarita, Glomus etunicatum, Glomus macrocarpum, Glomus* species 1, *Glomus* species 2, *Glomus* species 3 and an *Acaulospora* species. The seedlings were inoculated with 10 spores each of the endomycorrhizal fungi. Each treatment was replicated 6 times and the plants were grown in a growth chamber with

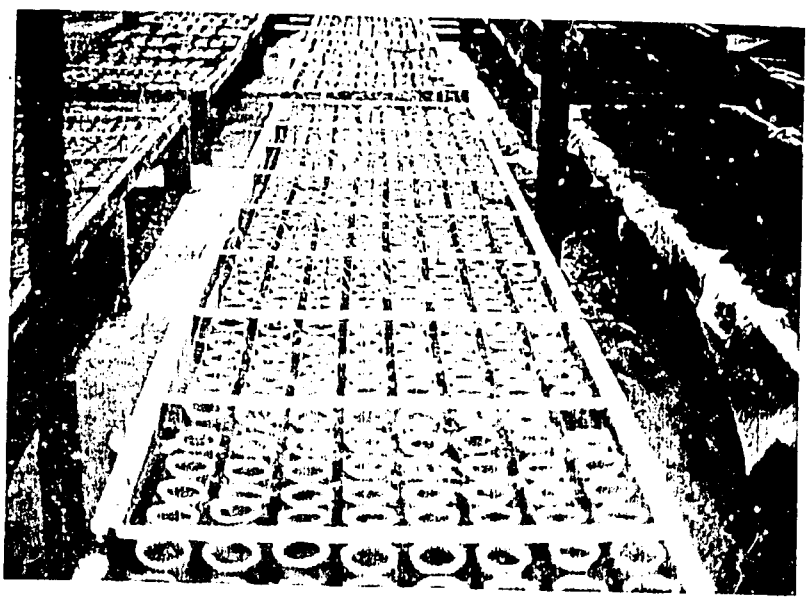

Figure 4. Mass production in cups of endomycorrhizal fungi using Bahia grass as trap plant.

Figure 5. The modified synthesis study for *Eucalyptus deglupta* seedlings using 2 level plastic cups as culture vessel.

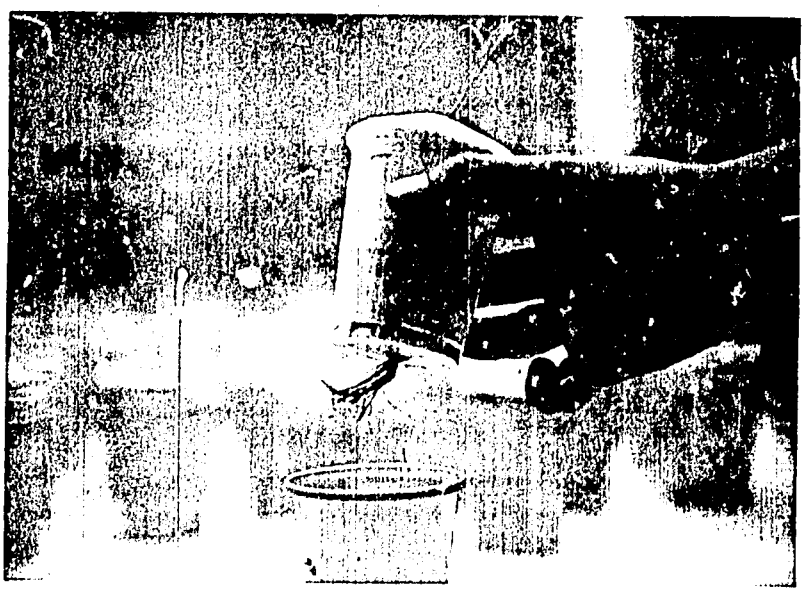

Figure 6. Synthesis study on cups showing abaca twine wick which aids in the absorption of water and nutrients for the growth of *Eucalyptus deglupta* seedlings.

similar conditions as in the first synthesis study above. Three (3) ml of Hoagland's No. 2 solution each, was provided each seedling to provide for the nutrient requirements needed for growth and development.

STUDY 2. Screening for effectiveness among ectomycorrhizal and endomycorrhizal fungi.

2a. Screening for effectiveness using vegetative mycelia of ectomycorrhizal fungi in promoting growth of *Eucalyptus* and *Anisoptera* seedlings.

A mixture of 3:1 Carranglan soil and quarry sand was fumigated with methyl bromide and placed in 4 in x 6 in plastic bags for *Eucalyptus* species and size # 8 clay pots for *A. thurifera*.

Five grams vegetative mycelia of ectomycorrhizal fungi produced in broth cultures were blended and mixed in sterile water and inoculated to the seedlings. Each seedling was given a dosage of 8 ml 1/2 strength Hoagland's No. 2 solution once a week to provide for its initial nutrient requirement.

2a.1. *Eucalyptus* species.

Five species of ectomycorrhizal fungi were screened for their effectiveness in increasing growth of *E. camaldulensis*. The different ectomycorrhizal fungi were: *Pisolithus tinctorius, Cenococcum geophillum*, *Rhizopogon* species 1 and 2 and a *Thelephora* species. The same ectomycorrhizal fungi were inoculated to *E. deglupta* except for *P. tinctorius*. Growth obtained by mycorrhizal inoculated seedlings were compared to that of the non-mycorrhizal control.

2a.2. *Anisoptera thurifera*

Vegetative mycelia of *Scleroderma bovista* and *Scleroderma citrinum* were inoculated to *A. thurifera* seedlings. After seven months, height and diameter growth of inoculated seedlings were compared to uninoculated seedlings.

2b: Screening for effectiveness using basidiospores of ectomycorrhizal fungi in promoting growth of *Eucalyptus* species and *Anisoptera thurifera*.

Seedlings of *E. deglupta* were grown in 4 in x 6 in plastic bags and size # 6 and 8 clay pots for *E. camaldulensis* and *A. thurifera*, respectively under screenhouse conditions. The growth medium was a 3:1 mixture of grassland soil collected from Carranglan, Nueva Ecija and quarry sand. The mixture was fumigated with methyl bromide for 48 hours. The seedlings were inoculated with 0.5 grams of 5 % spore inocula (5 grams basidiospores + 95 grams of soil carrier), placed approximately 3 inches below the soil surface. The seedlings were allowed to respond to treatments for 5 months for *Eucalyptus* species and 7 months for *A. thurifera*. Height, diameter, biomass, mycorrhizal infection and P-uptake were determined.

2c. Screening for effectiveness among endomycorrhizal fungi in promoting growth of *Eucalyptus deglupta* and *Anisoptera thurifera*.

A methyl bromide fumigated 3:1 grassland soil and quarry sand mixture was used as potting medium. About 50 spores per VAM fungus were inoculated per seedling. Inocula were placed 3 inches below the soil surface. Experimental design was CRD and each treatment was replicated 20 times.

STUDY 3. Effects of pre-conditioning silvicultural treatments on seedling growth.

3a. Effects of spacing.

Eucalyptus camaldulensis, E. deglupta and *A. thurifera* were initially raised in seedboxes and seedbeds. The first two hosts were allowed to grow for 2 weeks and 3-4 weeks for *A. thurifera*. Healthy planting stocks were selected based on desirable morphological characteristics.

The seedlings were transplanted in raised 40.5 in wide by 230 inches long seedbeds filled with a mixture of 1:3 forest soil and quarry sand. The seedbeds were sprayed with benlate once a week.

The spacing distance treatments for *E. camaldulensis* and *E. deglupta* are as follows:

3 in x 1 in
3 in x 2 in
3 in x 3 in
4 in x 1 in
4 in x 2 in
4 in x 3 in
5 in x 1 in
5 in x 2 in
5 in x 3 in

The spacing-distance treatments for *A. thurifera* are as follows:

3 in x 2 in
3 in x 3 in
4 in x 2 in
4 in x 3 in
5 in x 2 in
5 in x 3 in
6 in x 2 in
6 in x 3 in

Height, diameter, biomass and root-shoot ratio were obtained.

3b. Effects of depth of undercutting treatments.

This study determined the best depth to undercut roots of *E. camaldulensis* and *E. deglupta*. Seeds of the species were initially sown in seedboxes. After 2-3 weeks, healthy planting stocks were transferred in raised 40.5 inch wide by 230 inch long nursery beds filled with a mixture of 1:3 forest soil and quarry sand. The seed beds were sprayed with benlate fungicide once a week to control damping off. Seedlings were planted based on the spacing distance recommended in sub-study 3a, which were 4 in x 1 in and 3 in x 3 in for *E. camaldulensis* and 2 in x 3 in and 4 in x 3 in for *E. deglupta*.

The depth of undercutting treatments for both *E. camaldulensis* and E. deglupta are:

Control (No undercutting)
1.0 inch
1.5 inches
2.0 inches

Height, diameter and dry matter yield and root-shoot ratio of seedlings were determined at the end of the study.

STUDY 4. Bare root technology for *Eucalyptus* and Dipterocarps.

4a. Effects of mycorrhizal inoculation and silvicultural preconditioning treatments on growth and survival of seedlings.

Seedlings of *E. camaldulensis, E. deglupta*, and *A. thurifera* were used for this experiment.

Eucalyptus camaldulensis seedlings were transplanted in raised nursery beds at a spacing distance of 4 in x 2 in. The seedlings were inoculated with the most effective vegetative mycelia approximately 3 inches below the soil surface. After one month, the seedlings were undercut at a depth of 2 inches. However, no data were gathered for this experiment because of typhoon "Saling" which completely destroyed the nursery and all experimental set-ups.

Seedlings of *E. deglupta* were transplanted and grown on 3 fabricated nursery beds measuring 2 meters long and 1 meter wide, with spacing distance of 4 in x 3 in between seedlings. The nursery bed was filled with methyl bromide-fumigated soil. The seedlings except for those in the control treatment, were inoculated with 4 ml of 5 % inoculum (5 grams vegetative mycelia and 95 ml of distilled water), inoculated approximately 3 inches below the soil surface. Vegetative mycelia of *P. tinctorius* and *C. geophillum* were used for this study. Each treatment was replicated 110 times. The seedlings were allowed to respond to treatments for 4 months. After one month, the tap roots and secondary roots of assigned seedlings were undercut with a fabricated tool, 2 inches below the soil surface (Figure 7). This was the depth of undercutting found best in study 3.

Figure 7. *Eucalyptus deglupta* seedlings being undercut one month after planting.

For *A. thurifera*, 200 seeds were directly seeded on a 8 m x 1 m nursery bed containing a mixture of sterilized 1:3 quarry sand and forest soil. The seedlings were inoculated with *S. bovista* and *S. citrinum* with a dosage of 2.5 ml per seedling about 3 inches below the seeds. The spacing used was 3 in x 2 in and the roots were undercut at a 2 inch depth one month after inoculation. Monthly assessment of height and diameter were made.

4b. Effects of packaging materials and time of bareroot planting using *Eucalyptus* seedlings.

Eucalyptus deglupta seedlings used in sub-study 4a were subjected to the following packaging materials:

1. bareroot not covered or just exposed.
2. bareroot covered with mud puddle.
3. bareroot covered with mud puddle and banana leaf sheath.

These seedlings were transported to Puting Lupa, Calamba, Laguna and outplanted in a degraded grassland. All treatments were repeated 12 times on 3 blocks. The experimental design was split-plot in RCBD with the types of packaging materials serving as the main plots and the different mycorrhizal-silvicultural treatments as subplots.

After 2 months, height, diameter, and survival of outplanted seedlings were measured. Growth parameters were recorded until the end of the experiment. Significant differences in height and diameter growth were assessed by ANOVA while the treatment means were compared using DMRT. Percentage survival of the seedlings was separately measured and computed by determining the number of seedlings which survived with respect to the total number planted.

The treatments are as follows:

Potted	-	Control, Potted
BE	-	Control, bareroot exposed
BMP	-	Control, bareroot with mud puddle
BMP+BLS	-	Control, bareroot with mud puddle and banana leafsheath
PT- U-BE	-	*P. tinctorius,* with undercutting, bareroot exposed
PT- U-BMP	-	*P. tinctorius,* with undercutting, bareroot with mud puddle
PT- U-BMP+BLS	-	*P. tinctorius,* with undercutting, bareroot with mud puddle and banana leafsheath
PT-NU-BE	-	*P. tinctorius*, without undercutting, bareroot exposed
PT-NU-BMP	-	*P. tinctorius*, without undercutting, bareroot with mud puddle
PT-NU-BMP+BLS	-	*P. tinctorius*, without undercutting, bareroot with mud puddle and banana leafsheath
CG- U-BE	-	*C. geophillum,* with undercutting, bareroot exposed
CG- U-BMP	-	*C. geophillum,* with undercutting, bareroot with mud puddle
CG- U-BMP+BLS	-	*C. geophillum,* with undercutting, bareroot with mud puddle and banana leafsheath
CG-NU-BE	-	*C. geophillum*, without undercutting, bareroot exposed
CG-NU-BMP	-	*C. geophillum*, without undercutting, bareroot with mud puddle
CG-NU-BMP+BLS	-	*C. geophillum*, without undercutting, bareroot with mud puddle and banana leafsheath

RESULTS AND DISCUSSION

STUDY 1. Collection, isolation and identification of ecto- and endomycorrhizal fungi associated with *Eucalyptus* and Dipterocarps.

1.1. ECTOMYCORRHIZA

Seven genera of ectomycorrhizal fungi were collected and isolated from the dipterocarp and *Eucalyptus* stands viz; *Russula, Pisolithus, Thelephora, Lactarius, Rhizopogon, Scleroderma* and *Clavaria*. Only species of *Rhizopogon, Scleroderma* and *Thelephora* were successfully isolated and mass produced in MNM solution. Aseptically, synthesized isolates in roots of *A. thurifera* revealed that the latter were ectomycorrhizal formers (Figure 8). Other morphological features observed were swelling of the roots and the absence of root hairs in the primary roots. Almost similar root attributes were exhibited in the synthesis of *E. deglupta*, except for root swelling. Root infection was apparent in the longitudinal view of the root.

1.2. ENDOMYCORRHIZA

Endomycorrhizal fungi collected and isolated from dipterocarps were identified as species belonging to the genera *Glomus, Acaulospora, Gigaspora* and *Sclerocystis*. Species belonging to the genera *Glomus* and *Acaulospora* were found to dominate in most hosts. The former sporulate well during the purification and mass production stages, however, others revealed poor performance. It took five months to obtain sporulation in Bahia grass containing the best potting media, i.e., 1 part forest soil and 3 parts quarry sand.

Purified *Glomus* was synthesized, utilizing both *A. thurifera* and *E. deglupta*. Scanning electron micrograph of the roots of *A. thurifera* showed this species produce ectomycorrhizal association and not endomycorrhiza (Figure 9).

1.3. SYNTHESIS STUDY

After 3 months, the seedlings of *E. camaldulensis* were harvested. The roots were stained and observed under the microscope for mycorrhizal root infection. Fungal hyphae were observed almost

Figure 8. Mycorrhizal roots in *Anisoptera thurifera* formed by inoculation with *Scleroderma citrinum* (note the black fungal rhizomorphs emanating from the surface of the roots).

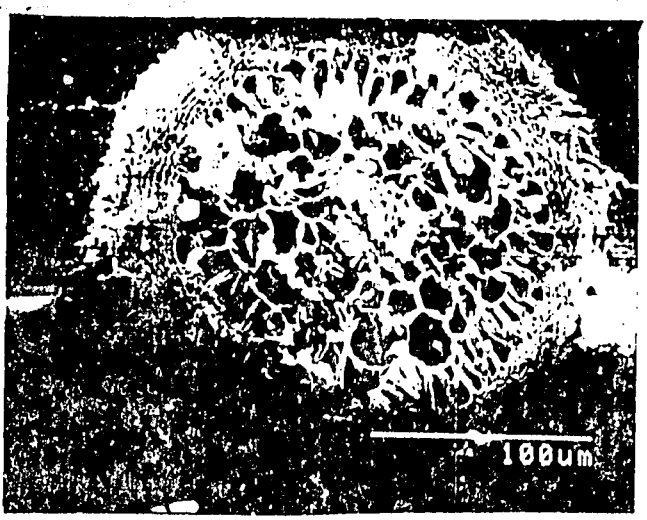

Figure 9. Transverse section in SEM of *Anisoptera thurifera* showing initial development of Hartig net (HN) in few elongated cell walls surrounded by thick multi-layer fungal mantle (FM) (x400).

attached to the epidermal layers of the feeder roots, however, other infection indicators were not seen. One reason may be that the seedlings were not yet in their proper physiological stage for infection when harvested.

STUDY 2. Screening for effectiveness among ecto- and endomycorrhizal fungi.

2a. Screening for effectiveness using vegetative mycelia of ectomycorrhizal fungi in *Eucalyptus* and *Anisoptera thurifera* seedlings.

2a.1. *Eucalyptus camaldulensis*

Four ectomycorrhizal fungi were screened for their effectiveness in increasing growth of *E. camaldulensis, i.e., P. tinctorius, C. geophillum*, and two species of *Rhizopogon* and *Thelephora* (Table 1).

Results during the first month of the experiment revealed a slower height growth response of inoculated seedlings compared with uninoculated ones. However, positive height growth responses of inoculated seedlings were observed during the following months as compared to uninoculated seedlings (Figures 10 and 11).

Among the ectomycorrhizal fungi, *C. geophillum* was the most effective in increasing growth of *E. camaldulensis* by 36 % followed by *Rhizopogon* species 2 (33 %), *Rhizopogon* species 1 (26 %) and *P. tinctorius* (24 %), three months after inoculation. Diameter growth however was best observed in seedlings inoculated with *Rhizopogon* species 1 (69 %), followed by *Rhizopogon* species 2 (65 %) and *P. tinctorius* (60 %) compared with *C. geophillum* (39%) and control. The trend was consistent until the fifth month of the experiment, wherein height and diameter growth were significantly affected by mycorrhizal fungi (Table 2).

In terms of biomass after 5 months, seedlings inoculated with *P. tinctorius* and *Rhizopogon* species 1 were almost equal in root weight - 0.622 g/plant and 0.621 g/plant, respectively (Table 2). However, seedlings inoculated with *Rhizopogon* species 1 was greater in shoot weight with 0.257 g/plant and a total biomass of 0.878 g/plant compared to those inoculated with *P. tinctorius* with shoot weights of 0.243 g/plant and a total biomass of 0.865 g/plant. *Rhizopogon* species 2 gave a greater root weight of 0.574 g/plant and a total biomass of 0.844 g/plant compared to those inoculated with *C. geophillum* which

Table 1. Monthly height and diameter responses of *Eucalyptus camaldulensis* inoculated with vegetative mycelia of different ectomycorrhizal fungi.

TREATMENTS	ONE MONTH				TWO MONTHS				THREE MONTHS			
	Height (cm)	% Inc.	Dia (cm)	% Inc.	Height (cm)	% Inc.	Dia (cm)	% Inc.	Height (cm)	% Inc.	Dia (cm)	% Inc
Uninoculated	4.6 a	--	0.051 bc	--	11.0 b	--	0.141 a	--	11.5 b	--	0.080 b	--
Thelephora sp.	3.7 b	-21	0.062 a	22	10.8 bc	1	0.148 a	5	11.4 b	2	0.091 ab	14
Rhizopogon sp.#1	3.4 b	-26	0.046 c	10	11.5 ab	6	0.146 a	4	14.5 a	26	0.135 a	69
Rhizopogon sp. #2	3.7 b	-20	0.047 c	8	10.8 d	2	0.152 a	8	15.2 a	33	0.132 a	65
Cenococcum geophillum	4.1 ab	-12	0.053 bc	4	12.9 a	18	0.154 a	9	15.7 a	36	0.111 ab	39
Pisolithus tinctorius	4.1 ab	-12	0.058 ab	14	10.8 cd	1	0.144 a	2	14.2 a	24	0.128 a	60

Table 2. Growth responses, mycorrhizal colonization and phosphorus uptake of *Eucalyptus camaldulensis* seedlings inoculated with different ectomycorrhizal fungi using vegetative mycelia after 5 months in the nursery.

TREATMENTS	PARAMETERS						
	HEIGHT (cm)	DIAMETER (cm)	BIOMASS (g/plant)			MYCORRHIZAL COLONIZATION	P-UPTAKE (mg/plant)
			ROOT	SHOOT	TOTAL		
Uninoculated	11.5 bc	0.080 c	0.294 c	0.164 bc	0.458	25	0.688
Thelephora sp.	11.4 c	0.091 bc	0.338 bc	0.137 c	0.475	88	1.858
Rhizopogon sp. # 1	14.5 a	0.135 a	0.621 a	0.257 ab	0.878	100	0.031
Rhizopogon sp. # 2	15.2 a	0.132 ab	0.574 ab	0.270 a	0.844	100	1.266
Cenococcum geophillum	15.6 a	0.111 a	0.493 abc	0.324 a	0.817	100	2.198
Pisolithus tinctorius	14.2 a	0.128 ab	0.622 a	0.243 ab	0.865	100	2.588

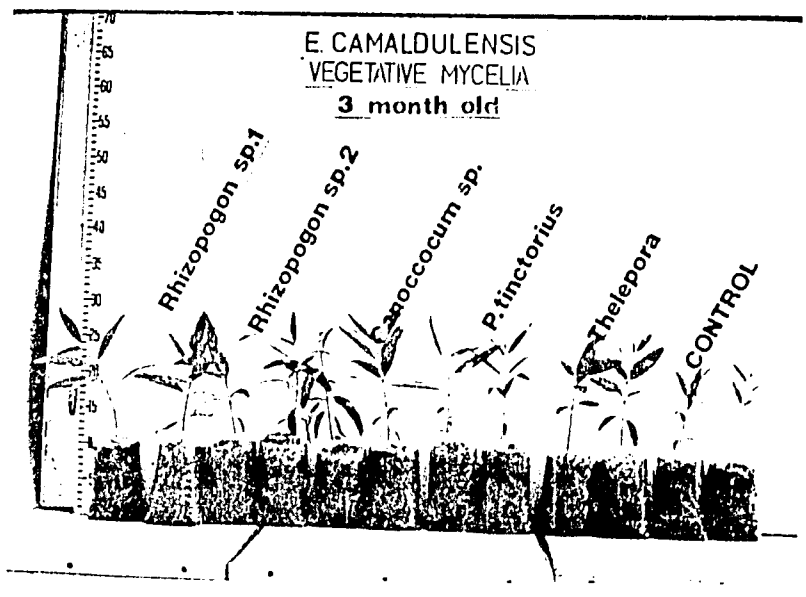

Figure 10. General appearance of 3-month old *Eucalyptus camaldulensis* seedlings after inoculation with different ectomycorrhizal fungi.

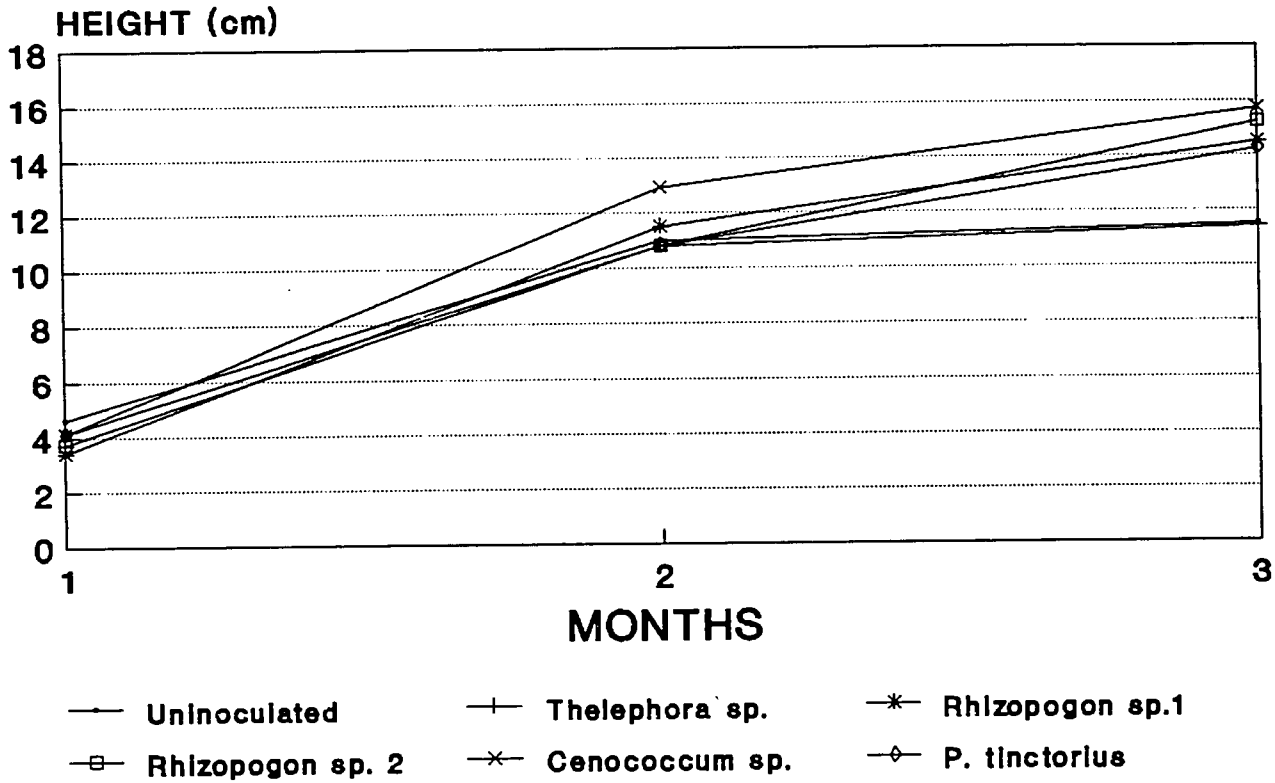

Figure 11. Monthly height growth of *Eucalyptus camaldulensis* as affected by different ectomycorrhizal fungi using vegetative mycelia.

in turn gave a root weight of 0.493 g/plant and total biomass of 0.817 g/plant.

Almost all inoculated seedlings were heavily infected by mycorrhiza (100% infection) except for those inoculated with a *Thelephora* species which developed only 88 % infection (Table 2). Uninoculated control produced 25 % infection due to infection from external sources.

Among the inoculated seedlings, phosphorus uptake was highest in those treated with *P. tinctorius* (2.588 mg P/plant) followed by those inoculated with *C. geophillum* (2.198 mg P/plant) (Table 2). A *Thelephora* species was the least effective among the five ectomycorrhizal species in the absorption of phosphorus (0.031 mg P/plant).

2a.2. *Eucalyptus deglupta*

Growth of *E. deglupta* inoculated with similar species of ectomycorrhiza revealed nearly similar response with that of *E. camaldulensis*. Inoculation with *C. geophillum* for instance favorably increased seedling height by 15.7 % relative to uninoculated seedlings, and diameter by 49.1 % if inoculated with *Rhizopogon* species 1 after 2 months (Table 3). Performance of seedlings inoculated with *P. tinctorius* in terms of height and diameter growth was not significant (Table 3).

The same trend in height growth was observed with the same species, five months after the experiment (Table 4). Height performance of the seedlings treated with *P. tinctorius* was similar with those inoculated with *C. geophillum*, i.e., 6.6 cm. Diameter response however seemed to be unaffected with ectomycorrhizal inoculation considering that control have almost outgrown all other treatments.

In terms of biomass, *P. tinctorius* gave the best results in terms of root (0.339 g/plant), shoot (0.323 g/plant) and total biomass (0.662 g/plant) outperforming other species and the control after 5 months (Table 4).

Mycorrhizal infection was found to be 100 % in all inoculated seedlings. There was some mycorrhizal infection (33%) in the uninoculated control seedlings which favored the increase in diameter of these seedlings (Table 4).

Table 3. Monthly height and diameter growth responses of *Eucalyptus deglupta* inoculated with vegetative mycelia of different ectomycorrhizal fungi.

TREATMENTS	TWO MONTHS				THREE MONTHS				FOUR MONTHS			
	Height (cm)	% Inc.	Diameter (cm)	% Inc.	Height (cm)	% Inc.	Diameter (cm)	% Inc.	Height (cm)	% Inc.	Diameter (cm)	% Inc.
Uninoculated	3.3 a	-	0.053 a	-	5.5 a	-	0.076 a	-	6.2 a	-	0.148 a	-
Rhizopogon sp.1	3.4 a	3.5	0.079 a	49.1	5.0 a	-9.1	0.058 a	23.7	6.2 a	1.1	0.131 ab	-11.5
Rhizopogon sp.2	3.1 a	-6.3	0.049 a	-7.6	5.2 a	-6.6	0.066 a	13.1	6.0 a	2.4	0.130 ab	-12.1
Cenococcum geophillum	3.8 a	15.7	0.049 a	0	5.3 a	-4.1	0.069 a	-9.2	6.6 a	7.6	0.115 b	-22.3
Pisolithus tinctorius	3.2 a	-5.0	0.050 a	2.0	5.4 a	-3.2	0.070 a	-7.9	6.6 a	7.0	0.078 c	-47.3

Table 4. Growth responses. mycorrhizal colonization and phosphorus uptake of *Eucalyptus deglupta* seedlings inoculated with different ectomycorrhizal fungi using vegetative mycelia after 5 months.

TREATMENTS	HEIGHT (cm)	DIAMETER (cm)	BIOMASS (gm/plant)			MYCORRHIZAL INFECTION (%)	P-UPTAKE (mg/plant)
			Root	Shoot	Total		
Uninoculated	6.2 a	0.148 a	0.244 a	0.312 a	0.556	33	0.1004
Rhizopogon sp. 1	6.2 a	0.131 ab	0.279 a	0.246 a	0.525	100	0.1000
Rhizopogon sp. 2	6.0 a	0.130 ab	0.266 a	0.251 a	0.517	100	0.0747
Cenococcum geophillum	6.6 a	0.115 b	0.265 a	0.222 a	0.487	100	0.0336
Pisolithus tinctorius	6.6 a	0.078 c	0.339 a	0.323 a	0.662	100	0.1426

Phosphorus uptake of seedlings treated with *P. tinctorius* was the highest among all mycorrhizal treatments, i.e. 0.143 mg P/plant.

Among the vegetative mycelia, *P. tinctorius* showed effective performance than mycelia from other species in terms of promoting growth and development of *E. deglupta* seedlings. This performance can be attributed to the high mycorrhizal infection in seedlings inoculated with mycelia of *P. tinctorius*.

2a.3. *Anisoptera thurifera*

Height and diameter growth responses of *A. thurifera* due to inoculation with vegetative mycelia from two mycorrhizal fungi, i.e., *S. bovista* and *S. citrinum* are shown in Table 5. The general appearance of seedlings are shown in Figure 12.

Inoculated seedlings exhibited better performance than uninoculated control. Monthly data revealed that *S. citrinum* increased both height and diameter better than *S. bovista* and control (Table 6). An 8 % and 9 % increase in height and diameter respectively were observed after seven months.

Biomass was also significantly affected by inoculation. Root weight increased by 63 % if inoculated with *S. citrinum* (Table 6). But in terms of shoot weight, *S. bovista* increased biomass by 73.4 %, while *S. citrinum* increased biomass by 56% against the uninoculated control. The same trend was observed for total biomass, where inoculation with *S. bovista* and *S. citrinum* significantly increased growth by 63% and 37%, respectively.

Mycorrhizal infection was the same in both ectomycorrhizal species (93%) and some contaminants were observed in the uninoculated control.

Phosphorus uptake was highest in seedlings inoculated with *S. bovista* (1.25 mg P/plant) than those inoculated with *S. citrinum* (0.91 mg P/plant) and the uninoculated control (0.58 mg P/plant) (Table 6).

Both *S. bovista* and *S. citrinum* were considered effective in providing better growth and development of *A. thurifera*, not withstanding differences of the species to infect the host plant.

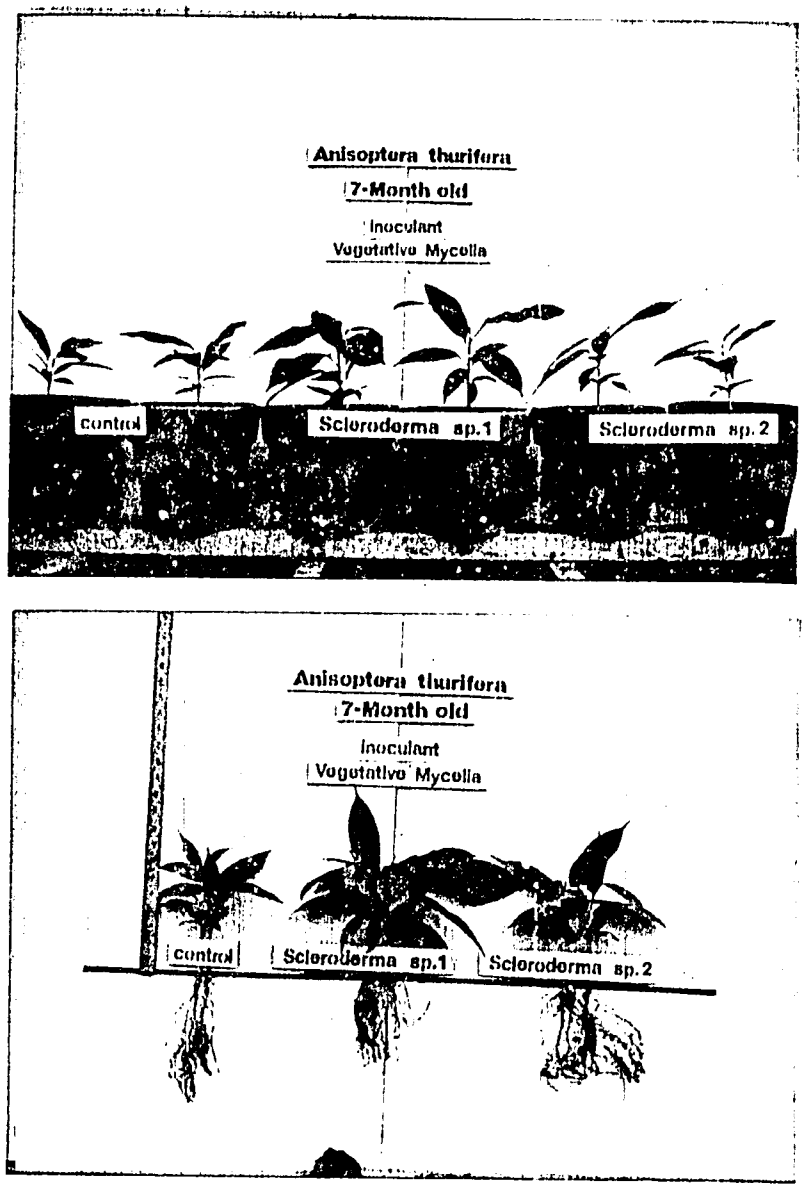

Figure 12. General appearance of *Anisoptera thurifera* in pots (a) and without pots (b), 7 months after inoculation with vegetative mycelia of *Scleroderma bovista* (Sp. 1) and *Scleroderma citrinum* (Sp. 2)

Table 5. Height and diameter growth response of *Anisoptera thurifera* under screenhouse conditions 4, 5, 6 and 7 months after inoculation with vegetative mycelia.

TREATMENTS	FOUR MONTHS		FIVE MONTHS		SIX MONTHS		SEVEN MONTHS		%
	HT	DIA	HT	DIA	HT	DIA	HT	DIA	INC
Uninoculated	6.6 a	0.24 a	8.6 a	0.24 a	10.5 a	0.36 a	12.3 a	0.39 a	-
Scleroderma bovista	7.6 a	0.25 a	9.7 a	0.28 a	11.8 a	0.37 a	14.5 a	0.42 a	8
Scleroderma citrinum	8.2 a	0.23 a	10.1 a	0.26 a	12.2 a	0.33 a	14.7 a	0.43 a	9

Table 6. Biomass, mycorrhizal colonization and phosphorus uptake of *Anisoptera thurifera* seedlings under screenhouse conditions 7 months after inoculation with vegetative mycelia.

TREATMENTS	BIOMASS (gram/plant)						MYCORRHIZAL COLONIZATION	P-UPTAKE (mg/plant)
	Root wt	% INC	Shoot wt	% INC	TOTAL	% INC		
Uninoculated	0.54 b	-	1.39 b	-	1.92 b	-	33	0.58
Scleroderma bovista	0.73 b	36	2.40 a	73	3.13 a	63	93	1.25
Scleroderma citrinum	0.87 a	63	2.16 a	56	3.03 a	37	93	0.91

2b. Screening for effectiveness among ectomycorrhizal fungi using basidiospores.

2b.1. *Eucalyptus camaldulensis*

The response of *E. camaldulensis* seedlings to inoculation with 3 ectomycorrhizal fungi using basidiospores is shown in Figure 13. Table 7 summarizes the effects of inoculation on height, diameter, dry matter and P-uptake on the test plants. Seedlings inoculated with *S. bovista* gave the biggest increase in height growth after 5 months (34.76 cm), which was significantly taller than the uninoculated seedlings (23.24 cm), and those inoculated with *S. citrinum* (22.06 cm) and MYCOGROE-*P. tinctorius* (22.08 cm). *Scleroderma bovista* inoculated seedlings also manifested the highest diameter growth (0.41 cm) among the mycorrhizal treatments after 5 months (Table 8). Conversely, the growth of seedlings inoculated with the *S. citrinum* and MYCOGROE-*P. tinctorius* was not significantly different compared to the uninoculated ones.

For total dry matter yield, seedlings inoculated with *S. bovista* were significantly heavier than those inoculated with *S. citrinum*, MYCOGROE-*P. tinctorius* and uninoculated seedlings (Table 8). Seedlings inoculated with *S. bovista* again exhibited the heaviest roots.

Generally, height, diameter and biomass growth of *E. camaldulensis* can be significantly increased if inoculated with *S. bovista*.

2b.2. *Eucalyptus deglupta*

Height and diameter growth responses of *E. deglupta* to inoculation with various species of ectomycorrhizal fungi are presented in Tables 9 and 10. The general appearance of seedlings are shown in Figure 14 and 15.

Significant growth effects among species were observed in height growth from 2-4 months after inoculation (Table 9). *Pisolithus tinctorius* and *Rhizopogon* species 2 showed consistent good performance exhibiting better height by 18% and 10 % respectively, relative to control (Table 9). No significant difference was found between these two species, although their effects were significantly greater when compared with that from *Scleroderma* and control. This

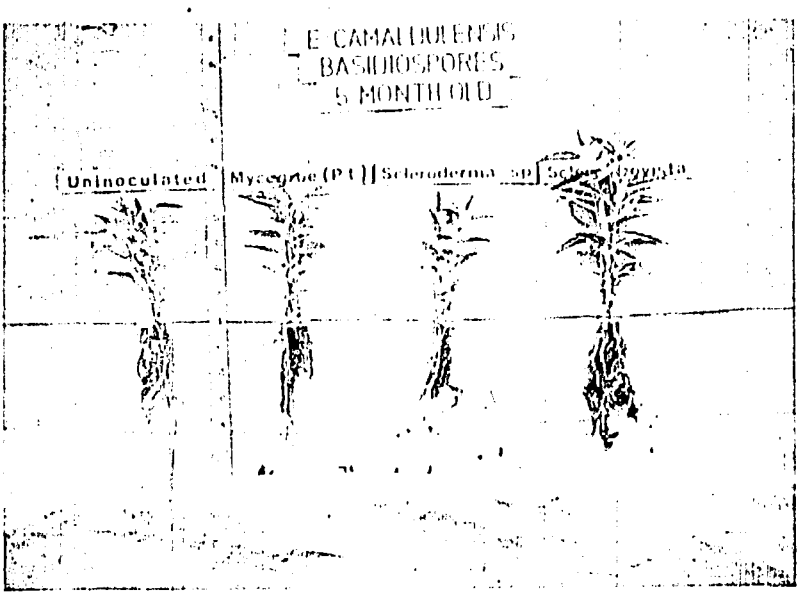

Figure 13. Appearance of *Eucalyptus camaldulensis* inoculated with ectomycorrhizal fungi using basidiospores after 5 months in the nursery.

Table 7. Monthly height and diameter growth of *Eucalyptus camaldulensis* seedlings inoculated with ectomycorrhizal fungi using basidiospores.

TREATMENTS	TWO MONTHS		THREE MONTHS		FOUR MONTHS		FIVE MONTHS	
	Ht	Dia	Ht	Dia	Ht	Dia	Ht	Dia
Uninoculated	2.15 b	0.05 b	7.83 c	0.09 bc	16.57 b	0.13 c	23.24 b	0.29 b
Scleroderma bovista	4.56 a	0.09 a	13.49 a	0.14 a	26.85 a	0.25 a	34.76 a	0.41 a
Scleroderma citrinum	2.46 b	0.05 b	10.31 b	0.10 b	19.08 b	0.17 b	22.06 b	0.29 b
MYCOGROE-*P. tinctorius*	2.16 b	0.07 b	6.36 c	0.08 c	17.89 b	0.13 c	22.08 b	0.30 b

Table 8. Height, diameter and biomass and growth responses of *Eucalyptus camaldulensis* seedlings 5 months after inoculation with basidiospores of ectomycorrhizal fungi.

TREATMENTS	HEIGHT* (cm)	DIAMETER* (cm)	BIOMASS (gm/plant)*		
			Shoot	Root	Total
Uninoculated	23.24 b	0.29 b	1.08 b	0.72 b	1.81 b
Scleroderma bovista	34.76 a	0.41 a	2.17 a	1.42 a	3.58 a
Scleroderma citrinum	22.06 b	0.29 b	0.66 b	1.18 a	1.84 b
MYCOGROE-*P. tinctorius*	22.08 b	0.30 b	0.99 b	0.61 b	1.61 b

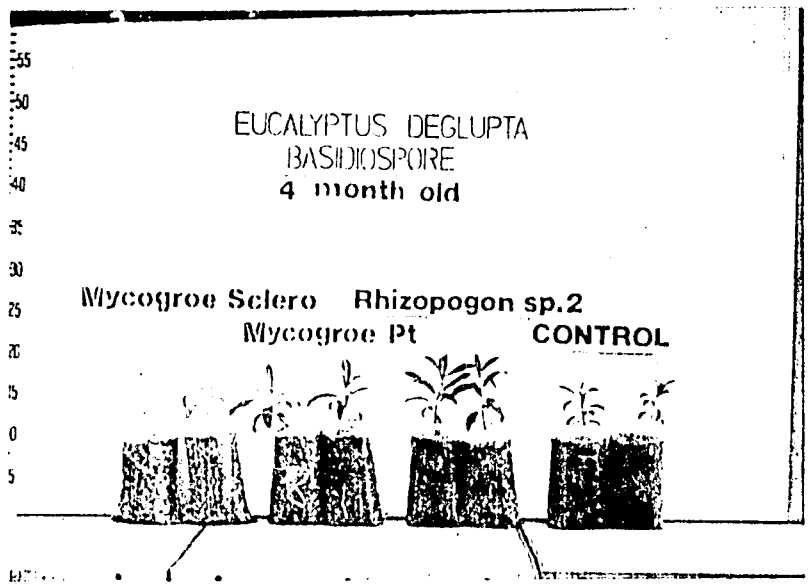

Figure 14. General appearance of *Eucalyptus deglupta* seedlings 4 months after inoculation with basidiospores of different ectomycorrhizal fungi.

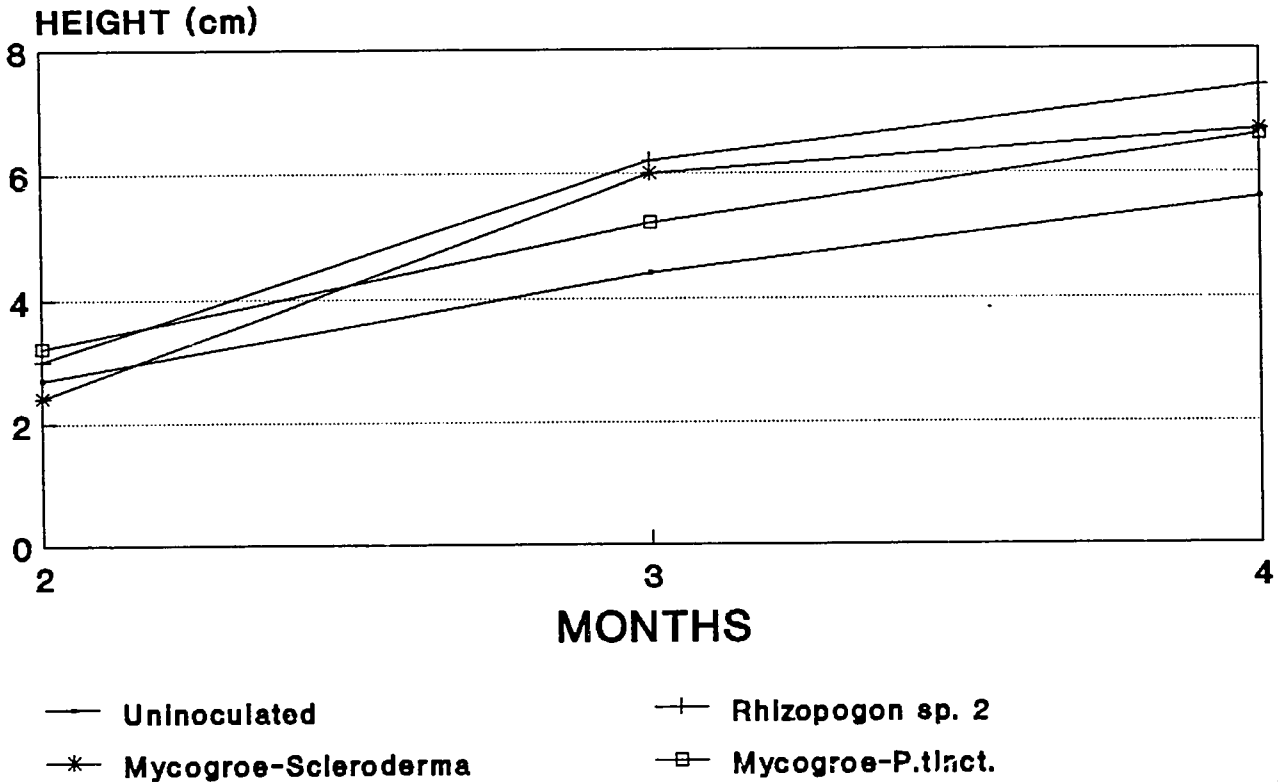

Figure 15. Monthly height growth of *Eucalyptus deglupta* seedlings inoculated with ectomycorrhizal basidiopsores.

Table 9. Height and diameter growth responses of *Eucalyptus deglupta* inoculated with basidiospores of ectomycorrhizal fungi during a period of 4 months.

TREATMENTS	TWO MONTHS				THREE MONTHS				FOUR MONTHS			
	HT* (cm)	% INC	DIA (cm)	% INC	HT* (cm)	% INC	DIA (cm)	% INC	HT* (cm)	% INC	DIA (cm)	% INC
Uninoculated	2.7 bc	-	0.06 a	-	4.4 bc	-	0.06 a	-	5.6 b	-	0.10 a	-
Rhizopogon sp. 2	3.0 a	10	0.05 a	-14	6.2 a	40	0.08 a	27	7.4 a	31	0.12 a	26
MYCOGROE-*Scleroderma*	2.4 c	-13	0.04 a	-31	6.0 a	35	0.08 a	36	6.7 a	18	0.11 a	12
MYCOGROE-*P. tinctorius*	3.2 a	18	0.06 a	0	5.2 c	17	0.06 a	10	6.6 ab	16	0.10 a	3

Table 10. Height, diameter, biomass and phosphorus uptake of *Eucalyptus deglupta* seedlings inoculated with basidiospores of different ectomycorrhizal fungi after 4 months.

TREATMENTS	HEIGHT* (cm)	DIAMETER[ns] (cm)	BIOMASS (gm/plant)			MYCORRHIZAL INFECTION (%)	P-UPTAKE (mg/plant)
			Root*	Shoot*	Total		
Uninoculated	5.6 b	0.10 a	0.24 b	0.20 b	0.44	27	0.12
Rhizopogon sp. 2	7.4 a	0.12 a	0.37 a	0.29 a	0.66	100	0.12
MYCOGROE-*Scleroderma*	6.7 a	0.11 a	0.39 a	0.24 ab	0.62	94	0.12
MYCOGROE-*P. tinctorius*	6.6 ab	0.10 a	0.24 b	0.27 ab	0.51	94	0.09

trend was maintained until the fourth month. Height of seedlings increased by 31 % using *Rhizopogon* when compared with control. *Pisolithus tinctorius* however was observed to be outperformed by *Scleroderma*. An 18 % increase in height was observed using the latter and only 16 % for the former.

There was no significant response in terms of diameter growth but *Rhizopogon* still remained the best among the species giving a 26 % increase in diameter growth relative to uninoculated control (Table 9).

Roots, shoots and total biomass of harvested seedlings further supported best performance by *Rhizopogon* species 2 (Table 10). This fungus provided a total weight of 0.66 g/plant compared to only 0.44 g/plant for uninoculated seedlings.

Mycorrhizal infection was also highest in *Rhizopogon* treated seedlings (100%) while contaminants were again observed in control (Table 10).

2.b.3. *Anisoptera thurifera*

Monthly height and diameter growth of *A. thurifera* seedlings inoculated with basidiospores of ectomycorrhizal fungi are summarized in Table 11. Height growth was not significantly affected by inoculation treatments during the six month period. Seedlings inoculated with *S. bovista* did not perform better than the uninoculated seedlings (Figure 16).

Height, diameter, biomass, mycorrhizal infection and P-uptake of *A. thurifera* seedlings 7 months after inoculation with basidiospores are presented in Table 12. In general, all these parameters are not significantly different from the uninoculated control.

Mycorrhizal roots were observed even in uninoculated control and this may attribute to the insignificant effects of inoculation on growth. However, P-uptake of seedlings inoculated with *S. bovista* (5.92 mg P/plant) and *S. citrinum* (2.03 mg P/plant) were much higher than the amount of phosphorus taken up by the uninoculated seedlings (0.86 mg P/plant) (Table 12). This maybe an indication that *S. bovista* and *S. citrinum* were more effective in absorbing phosphorus than the native mycorrhizal fungi which infected the uninoculated seedlings.

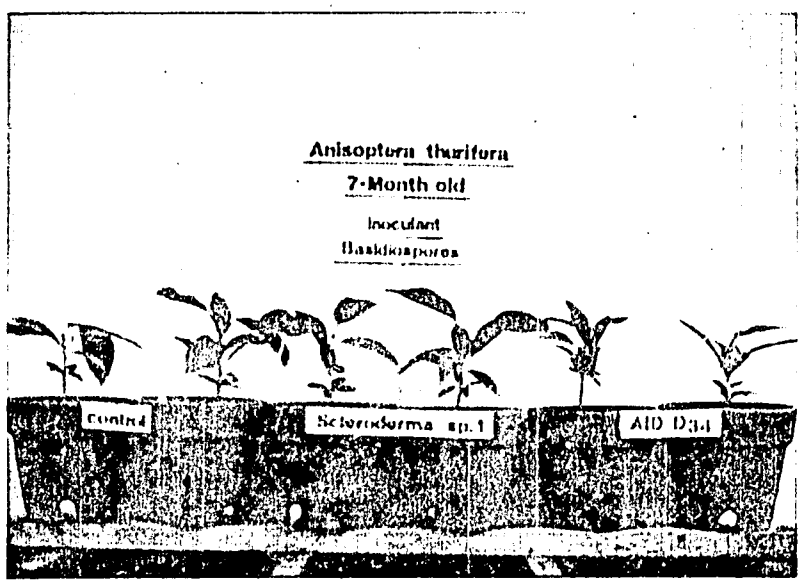

Figure 16. General appearance of 7-month old *Anisoptera thurifera* seedlings inoculated with *Scleroderma bovista* (Sp. 1) and *Scleroderma citrinum* (AID-D34).

Table 11. Height and diameter growth of *Anisoptera thurifera* seedlings at 4, 5 and 6 months after inoculation with basidiospores of ectomycorrhizal fungi.

TREATMENTS	FOUR MONTHS		FIVE MONTHS		SIX MONTHS	
	HEIGHT^{ns} (cm)	DIA^{ns} (cm)	HEIGHT^{ns} (cm)	DIA^{ns} (cm)	HEIGHT^{ns} (cm)	DIA^{ns} (cm)
Uninoculated	9.0 a	0.26 a	10.4 a	0.29 a	10.7 a	0.37 a
Scleroderma bovista	7.9 a	0.25 a	10.3 a	0.26 a	11.6 a	0.36 a
Scleroderma citrinum	7.8 a	0.26 a	9.6 a	0.25 a	11.4 a	0.32 a

Table 12. Height, diameter, biomass, mycorrhizal colonization and phosphorus uptake of *Anisoptera thurifera* seedlings 7 months after inoculation with basidiospores of ectomycorrhizal fungi.

TRERATMENTS	HEIGHT^{ns} (cm)	DIAMETER ^{ns}	BIOMASS (gm/plant)			MYCORRHIZAL COLONIZATION	P-UPTAKE (mg/plant)
			Root^{ns}	Shoot ^{ns}	Total ^{ns}		
Uninoculated	12.5 a	0.38 a	0.65 a	1.61 a	2.26 a	53	0.86
Scleroderma bovista	13.6 a	0.40 a	0.72 a	2.14 a	2.86 a	75	5.92
Scleroderma citrinum	13.4 a	0.38 a	0.68 a	1.78 a	2.46 a	94	2.03

2c. Screening for effectiveness among endomycorrhizal fungi in *Eucalyptus deglupta* and *Anisoptera thurifera*.

2c.1. *Eucalyptus deglupta*

Height and diameter growth of *E. deglupta* seedlings 5 months after inoculation with endomycorrhizal fungi are summarized in Table 13 and Figure 17. Height was significantly affected by inoculation as early as the third month (Table 14). At this stage *Gl. macrocarpum* and *Gl. mosseae* were the most effective in increasing height of *E. deglupta*. Their effectiveness was consistent until harvest time.

Height and diameter growth, biomass and phosphorus uptake of seedlings 5 months after inoculation with the various endomycorrhizal fungi are presented in Table 13. In terms of total biomass, heaviest seedlings were those inoculated with *Gl. mosseae* (1.21 g), *G. margarita* (1.26 g), *Gl. macrocarpum* (1.10 g), *Acaulospora* sp. (1.06 g), *Gl. etunicatum* (0.99 g.) and a *Glomus* species (0.99 g), respectively followed by those inoculated with *S. persica* (0.87 g). Uninoculated seedlings performed poorly (0.70 g.). Phosphorus uptake values were consistently higher for seedlings inoculated with the effective endomycorrhizal fungi.

2c.2. *Anisoptera thurifera*

Height and diameter growth of *A. thurifera* seedlings seven months after inoculation with various endomycorrhizal fungi are summarized in Table 15 and Figure 18. Height growth responses of seedlings inoculated with *S. persica* (13.3 cm), *Acaulospora* sp. (12 cm), *Glomus* sp. (11.9 cm) and *Gl. etunicatum* (11.8 cm) were significantly better than those inoculated with *Gl. macrocarpum* (11.1 cm), *Gl. mosseae* (10.1 cm), and *G. margarita* (11.2 cm) after six months (Table 16).

After 7 months, height growth of seedlings inoculated with *S. persica* (16.6 cm) were significantly better than those inoculated with *Gl. mosseae* (12.4 cm) and *G. margarita* (13.7 cm). Height of seedlings inoculated with *Gl. macrocarpum* (14.8 cm), *Gl. etunicatum* (14.9 cm), *Glomus* sp. (15.2 cm), and *Acaulospora* sp. (15.4 cm) were significantly better than those inoculated with *Gl. mosseae* (12.4 cm)(Table 15).

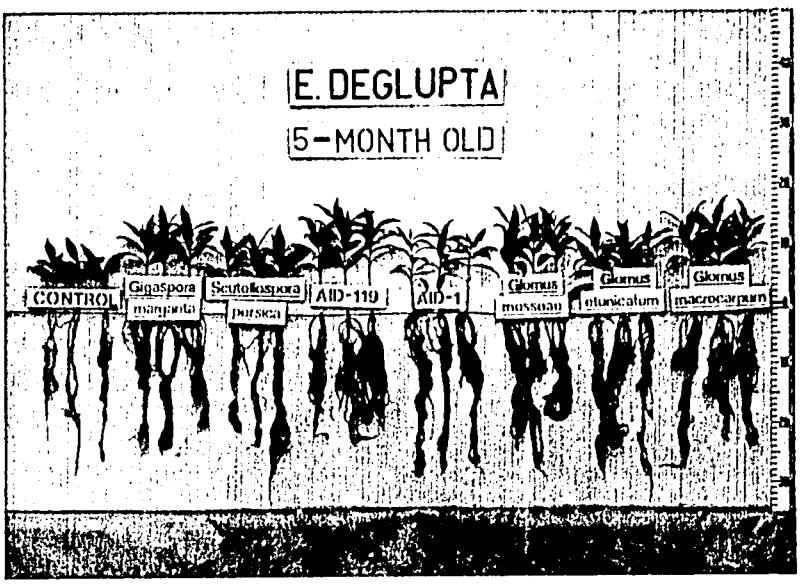

Figure 17. General appearance of 5-month old *Eucalyptus deglupta* seedlings inoculated with different species of endomycorrhizal fungi.

Table 13. Height, diameter, biomass and phosphorous uptake of *Eucalyptus deglupta* seedlings 5 months after inoculation with endomycorrhizal fungi.

TREATMENTS	HEIGHT** (cm)	DIAMETER** (cm)	BIOMASS (gram/plant)			P-UPTAKE (gm/plant)
			Root**	Shoot**	Total**	
Uninoculated	8.1 e	0.16 d	0.34 c	0.39 c	0.70 c	0.34
Glomus macrocarpum	14.5 a	0.22 bc	0.58 ab	0.52 ac	1.10 ab	2.42
Glomus etunicatum	12.3 bc	0.22 bc	0.51 ab	0.49 ac	0.99 ab	2.81
Glomus mossseae	14.0 a	0.26 a	0.58 ab	0.62 a	1.21 a	4.24
Glomus sp.	11.7 c	0.23 ac	0.47 bc	0.53 ac	0.99 ab	1.55
Acaulospora sp.	13.4 ab	0.24 ac	0.51 ab	0.55 ab	1.06 ab	1.17
Scutellospora persica	10.1 d	0.21 c	0.42 bc	0.45 bc	0.87 bc	1.65
Gigaspora margarita	13.4 ab	0.25 a	0.65 a	0.60 ab	1.26 a	1.83

Table 14. Monthly height and diameter growth of *Eucalyptus deglupta* seedlings inoculated with endomycorrhizal fungi.

TREATMENTS	THREE MONTHS		FOUR MONTHS		FIVE MONTHS	
	HT**	DIA**	HT**	DIA**	HT**	DIA**
Uninoculated	4.9 e	0.08 a	6.8 c	0.17 e	8.1 e	0.16 d
Glomus macrocarpum	7.9 a	0.11 a	11.4 a	0.24 ab	14.5 a	0.22 bc
Glomus etunicatum	6.4 bc	0.08 a	9.7 ab	0.21 cd	12.3 bc	0.22 bc
Glomus mosseae	8.0 a	0.12 a	11.1 a	0.25 a	14.0 a	0.26 a
Glomus sp.	5.6 cd	0.08 a	9.0 b	0.22 bd	11.7 c	0.23 ac
Acaulospora sp.	5.6 cd	0.08 a	9.2 b	0.21 bd	13.4 ab	0.24 ac
Scutelospora persica	4.3 e	0.07 a	7.2 c	0.19 de	10.1 d	0.21 c
Gigaspora margarita	7.8 ab	0.11 a	10.4 ab	0.24 ac	13.4 ab	0.25 ab

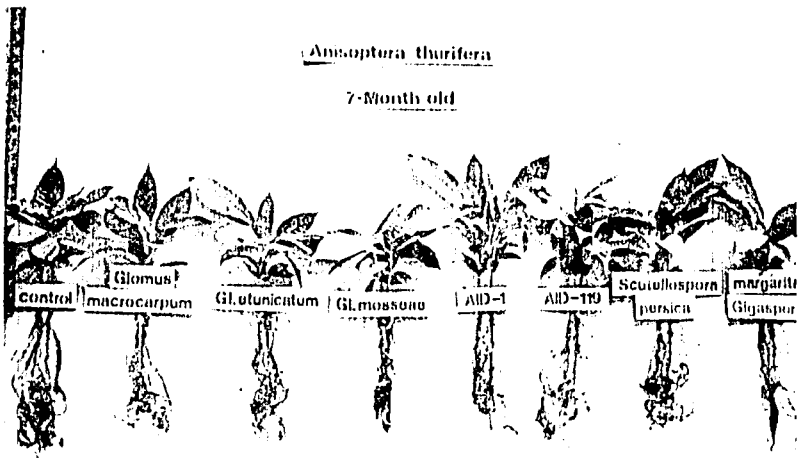

Figure 18. General appearance of *Anisoptera thurifera* seedlings inoculated with various endomycorrhizal fungi.

Table 15. Height, diameter, biomass and phosphorous uptake of *Anisoptera thurifera* seedlings 7 months after inoculation with endomycorrhizal fungi.

TREATMENTS	HEIGHT* (cm)	DIAMETER[ns] (cm)	BIOMASS (gram/plant)			P-UPTAKE (mg/plant)
			Root[ns]	Shoot[ns]	Total[ns]	
Uninoculated	14.70 ab	0.44 a	0.80 a	2.35 a	3.15 a	1.25
Glomus macrocarpum	14.80 ab	0.46 a	0.93 a	2.13 a	3.06 a	0.63
Glomus etunicatum	14.90 ab	0.44 a	1.11 a	1.97 a	3.08 a	0.61
Glomus mosseae	12.40 c	0.39 a	0.96 a	1.78 a	2.74 a	0.92
Glomus sp.	15.20 ab	0.44 a	0.97 a	2.22 a	3.19 a	1.09
Acaulospora sp.	15.40 ab	0.46 a	0.98 a	2.13 a	3.10 a	0.62
Scuttelospora persica	16.60 a	0.49 a	1.29 a	2.70 a	3.99 a	1.20
Gigaspora margarita	13.70 bc	0.42 a	0.74 a	1.80 a	2.53 a	0.51

Table 16. Height and diameter growth of *Anisoptera thurifera* seedlings at 4, 5, 6 and 7 months after inoculation with endomycorrhizal fungi.

TREATMENTS	FOUR MONTHS		FIVE MONTHS		SIX MONTHS		SEVEN MONTHS	
	HT^{ns} (cm)	DIA** (cm)	HT* (cm)	DIA** (cm)	HT** (cm)	DIA^{ns} (cm)	HT** (cm)	DIA^{ns} (cm)
Uninoculated	9.5	0.28 b	11.9 a	0.36 a	13.8 a	0.34	14.7 ab	0.44
G. macrocarpum	8.1	0.27 ab	9.8 bc	0.33 abc	11.1 b	0.35	14.8 ab	0.46
G. etunicatum	8.5	0.28 ab	10.6 abc	0.35 a	11.8 ab	0.37	14.9 ab	0.44
G. mosseae	8.1	0.26 abc	9.1 c	0.32 bc	10.1 b	0.32	12.4 c	0.39
Glomus sp.	8.6	0.26 bc	10.3 abc	0.35 ab	11.9 ab	0.37	15.2 ab	0.44
Acaulospora sp.	9.3	0.28 ab	10.3 abc	0.33 abc	12.0 ab	0.36	15.4 ab	0.46
Scutellospora persica	9.0	0.29 a	11.3 abc	0.37 a	13.3 a	0.37	16.6 a	0.49
Gigaspora margarita	8.1	0.24 c	10.3 abc	0.31 c	11.2 b	0.33	13.7 bc	0.42

Diameter growth and biomass production were not significantly affected by inoculation treatments (Table 15). However, both diameter and biomass of seedlings inoculated with *S. persica* were larger than all other treatments. Phosphorus uptake values also reflected the degree of effectiveness of the mycorrhizal fungi.

STUDY 3. Effects of pre-conditioning silvicultural treatments on seedling growth.

3a. Effects of spacing.

3a.1. *Eucalyptus camaldulensis*

Height growth of *E. camaldulensis* is best performed in 5 in x 3 in spacing (33.3 cm). However, height growth obtained from this spacing was not significantly different with that obtained in 5 in x 2 in (31.7 cm), 3 in x 3 in (32.4 cm) and 4 in x 3 in (31.7 cm) spacings (Tables 17 and 18).

Highest diameter growth was obtained in spacings 3 in x 1 in (0.52 cm), 5 in x 1 in (0.43 cm) and 4 in x 2 in (0.48 cm) which were not significantly different from each other but are significantly higher compared with those obtained from other spacing distances (Table 18).

Total dry matter yield is best expressed when a spacing of 5 in x 3 in (1.31 gm/plant) is used (Table 18).

The highest root-shoot ratio (0.84 g) obtained is in 3 in x 3 in spacing (Table 18).

The best spacing distances for *E. camaldulensis* taking into consideration seedling density and growth are 4 in x 1 in and 3 in x 3 in.

3a.2. *Eucalyptus deglupta*

Among the parameters analyzed, only diameter growth did not respond significantly to spacing treatments (Tables 19 and 20). Response of *E. deglupta* seedlings to a spacing distance of 3 in x 2 in depicted a highest mean growth (20.50 cm) albeit, it is not significantly

Table 17. Monthly height growth of *Eucalyptus camaldulensis* seedlings in nursery beds in response to various spacing treatments.

SPACING (in x in)	ONE MONTH (cm)	TWO MONTHS (cm)	THREE MONTHS (cm)	FOUR MONTHS (cm)
3 x 1	3.7	6.6	16.7	19.5
4 x 1	3.5	6.7	20.9	23.6
5 x 1	3.2	5.2	10.0	15.4
3 x 2	3.5	6.7	19.6	19.6
4 x 2	4.9	11.3	27.4	28.2
5 x 2	3.6	10.8	30.6	31.7
3 x 3	5.0	12.3	28.9	32.4
4 x 3	4.1	10.6	28.2	31.7
5 x 3	3.9	8.6	31.2	33.2

Table 18. Height, diameter, dry matter yield, root shoot ratio and density of 3 month old *Eucalyptus camaldulensis* in response to various spacing treatments.

SPACING (in x in)	HEIGHT** (cm)	DIAMETER** (cm)	DRY MATTER YIELD (gm/plant)			ROOT/SHOOT RATIO**	DENSITY*/
			Root**	Shoot**	Total**		
3 x 1	16.7 cd	0.52 a	0.08 d	0.22 c	0.31 c	0.69 d	273
4 x 1	25.6 bc	0.44 c	0.09 d	0.38 c	0.46 c	0.78 abc	210
5 x 1	15.4 d	0.43 a	0.07 d	0.25 c	0.33 c	0.74 bcd	168
3 x 2	19.6 cd	0.13 c	0.11 cd	0.34 c	0.49 c	0.75 bcd	143
4 x 2	28.2 ab	0.48 a	0.17 bc	0.80 ab	0.97 b	0.80 ab	110
5 x 2	31.7 a	0.27 b	0.21 b	0.68 b	0.90 b	0.72 cd	85
3 x 3	32.4 a	0.21 b	0.16 bc	0.84 ab	1.00 b	0.84 a	104
4 x 3	31.7 a	0.26 b	0.21 b	0.85 ab	1.05 ab	0.78 abc	80
5 x 3	33.2 a	0.25 b	0.30 a	1.01 a	1.31 a	0.75 bcd	64

*/ number of seedlings per 891 in^2 (size of plot)

Table 19. Monthly height growth of *Eucalyptus deglupta* seedlings planted in nurserybed in response to various spacing treatments.

SPACING (in x in)	ONE MONTH (cm)	TWO MONTHS (cm)	THREE MONTHS (cm)	FOUR MONTHS (cm)
3 x 1	2.0	3.3	7.2	19.2
4 x 1	2.1	3.1	8.7	11.0
5 x 1	2.0	3.2	8.8	14.8
3 x 2	2.2	4.0	12.3	20.5
4 x 2	1.8	2.6	5.6	8.5
5 x 2	1.9	2.7	7.3	11.9
3 x 3	2.0	3.2	8.0	12.8
4 x 3	1.9	2.9	10.4	17.9
5 x 3	1.9	2.7	11.0	12.0

Table 20. Height, diameter, dry matter yield, root shoot ratio and density of 3 month old *Eucalyptus deglupta* seedlings in response to various spacing treatments.

SPACING (in x in)	HEIGHT** (cm)	DIAMETER^ns (cm)	DRY MATTER YIELD (gm/plant)			ROOT/SHOOT RATIO**	DENSITY^a/
			Root**	Shoot **	Total**		
3 x 1	19.20 a	0.14 a	0.11 bcd	21.60 f	0.58 de	0.29 b	273
4 x 1	11.00 cd	0.17 a	0.06 bd	46.30 df	0.28 f	0.51 b	210
5 x 1	14.30 a	0.20 a	0.19 a	101.00 ab	120.00 a	0.25 b	168
3 x 2	20.50 a	0.18 a	0.14 abc	82.00 bc	96.00 bc	0.20 b	143
4 x 2	8.50 d	0.15 a	0.08 d	29.70 ef	38.00 ef	0.39 b	110
5 x 2	11.90 bc	0.17 a	0.09 cd	49.30 de	60.00 de	0.29 b	88
3 x 3	12.80 bc	0.15 a	0.16 ab	58.50 cd	75.00 cd	0.35 b	104
4 x 3	17.90 a	0.18 a	0.18 a	116.90 a	135.00 a	0.26 b	80
5 x 3	14.30 b	0.13 a	0.17 ab	442.00 ef	161.00 de	0.93 a	64

different with the responses of seedlings planted at spacing distances of 3 in x 1 in (19.20 cm) and 4 in x 3 in (17.90 cm)(Tables 19 and 20).

Highest root-shoot ratio of 0.93 was obtained at a spacing distance of 5 in x 3 in which was significantly greater with that from other spacing distances (Table 20).

Taking into consideration seedling density and growth, the best spacing distance selected for *E. deglupta* is 3 in x 2 in.

3a.3. *Anisoptera thurifera*

Height, diameter, biomass production, root-shoot ratio of *A. thurifera* seedlings in response to spacing distances are summarized in Table 21. Height growth was not significantly affected by spacing treatments (Table 21, Figure 19). However, a spacing distance of 4 in x 2 in significantly promoted diameter (0.28 cm), total biomass production (1.35 gm/plant), and root-shoot ratio (0.38 g) as compared to other planting distances. A planting distance of 4 in x 2 in will provide a planting density of 24 seedlings per 891 square inch plot.

3b. Effects of depth of undercutting treatments.

3b.1. *Eucalyptus camaldulensis*

Conditioning of seedlings by undercutting of roots can cause physical changes in seedlings such as significant reduction in height and diameter growth (Table 22; Figure 20).

Monthly height and diameter growth of *E. camaldulensis* subject to different depths of undercutting are summarized in Table 22. During the third and fourth months, it was at depth of 2.0 inches that the height and diameter growth were tallest at 3 in x 3 in planting distance. However, at harvest time (5 months), there was no significant effect of undercutting on seedling's growth observed, although seedlings that served as control attained the tallest height. Monthly height growth of *E. camaldulensis* in response to depth of undercutting and spacing distances of 3 in x 3 in and 4 in x 1 in are summarozed in Table 21 1nd 22, respectively.

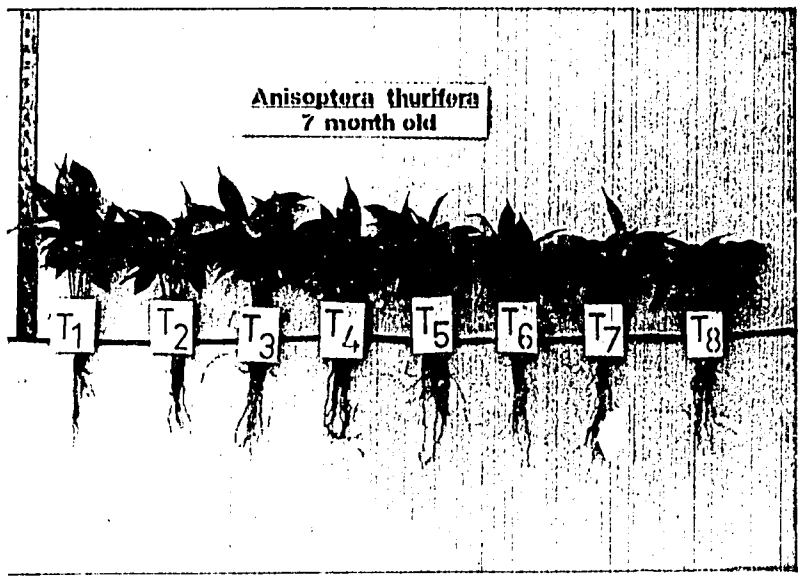

Figure 19. General appearance of seven-month old *Anisoptera thurifera* seedlings in response to different spacing distances.

T_1 = 3 in x 2 in	T_5 = 5 in x 2 in
T_2 = 3 in x 3 in	T_6 = 5 in x 3 in
T_3 = 4 in x 2 in	T_7 = 6 in x 2 in
T_4 = 4 in x 3 in	T_8 = 6 in x 3 in

Table 21. Height, diameter, biomass, root shoot ratio and density of *Anisoptera thurifera* planted in nursery bed in response to various spacing treatments.

SPACING (in x in)	DENSITY	HEIGHT** (cm)	DIA** (cm)	BIOMASS (gm/plant)			ROOT/SHOOT**
				Root**	Shoot**	Total**	
3 x 2	54	10.60 a	0.24 c	0.19 c	0.64 b	0.83 c	0.32 ab
3 x 3	36	10.50 a	0.25 bc	0.20 c	0.72 b	0.92 bc	0.28 b
4 x 2	24	12.30 a	0.28 a	0.36 a	0.99 a	1.35 a	0.38 a
4 x 3	21	11.00 a	0.27 abc	0.25 bc	0.71 b	0.96 bc	0.36 a
5 x 2	24	10.70 a	0.26 abc	0.25 bc	0.80 ab	1.05 bc	0.31 ab
5 x 3	18	12.20 a	0.28 ab	0.30 ab	0.86 ab	1.17 ab	0.36 a
6 x 2	12	11.10 a	0.27 ab	0.25 bc	0.81 ab	1.06 bc	0.33 ab
6 x 3	9	11.40 a	0.27 ab	0.26 bc	0.82 ab	1.08 bc	0.31 ab

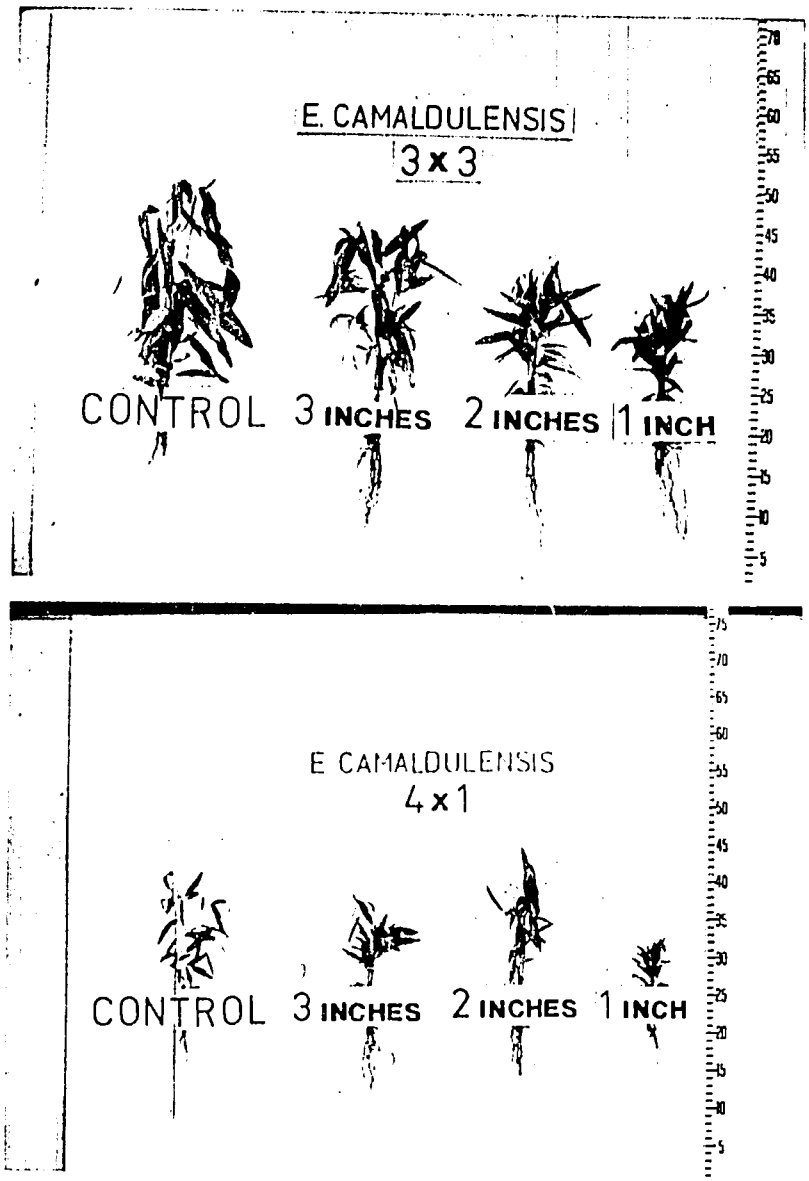

Figure 20. Five-month old *Eucalyptus camaldulensis* seedlings in response to various depths of undercutting and spacing distance of (a) 3 in x 3 in and (b) 4 in x 1 in.

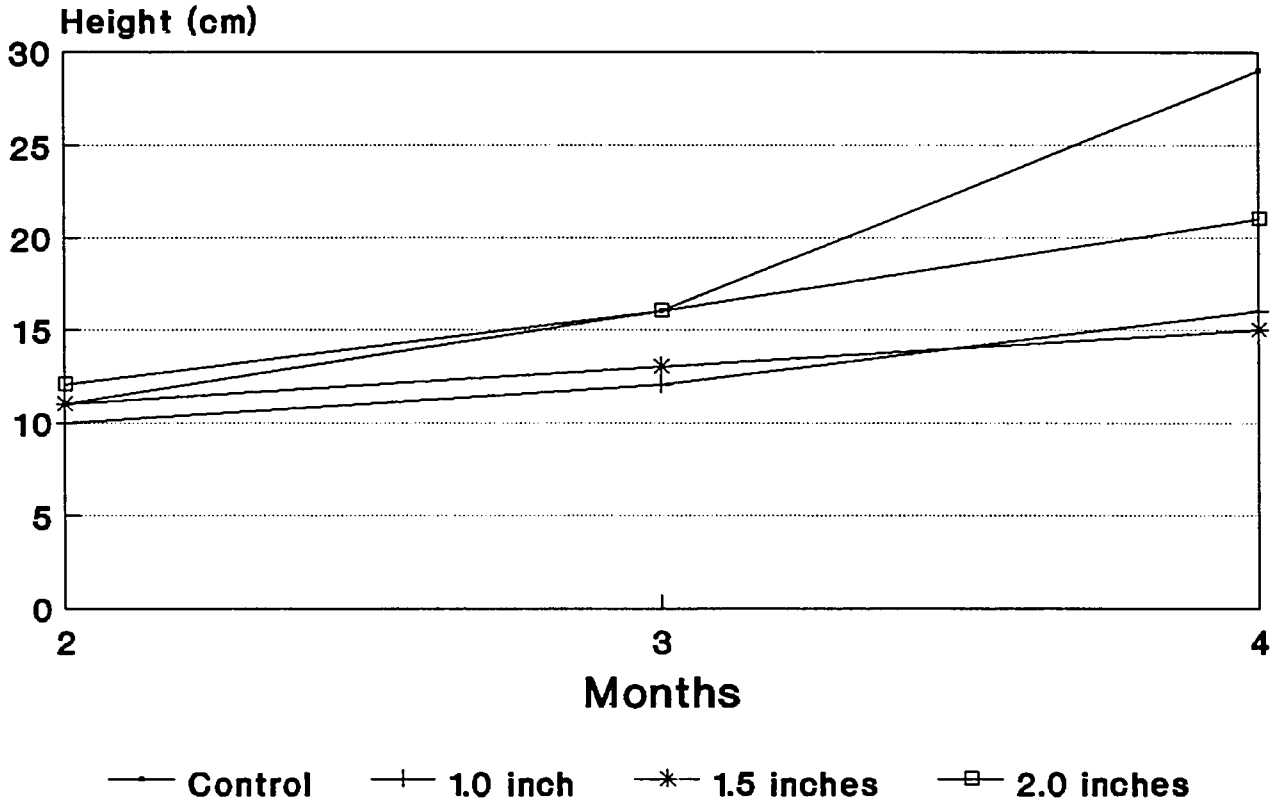

Figure 21. Height growth of *Eucalyptus camaldulensis* in response to different depth of undercutting treatments (3 in x 3 in planting distance).

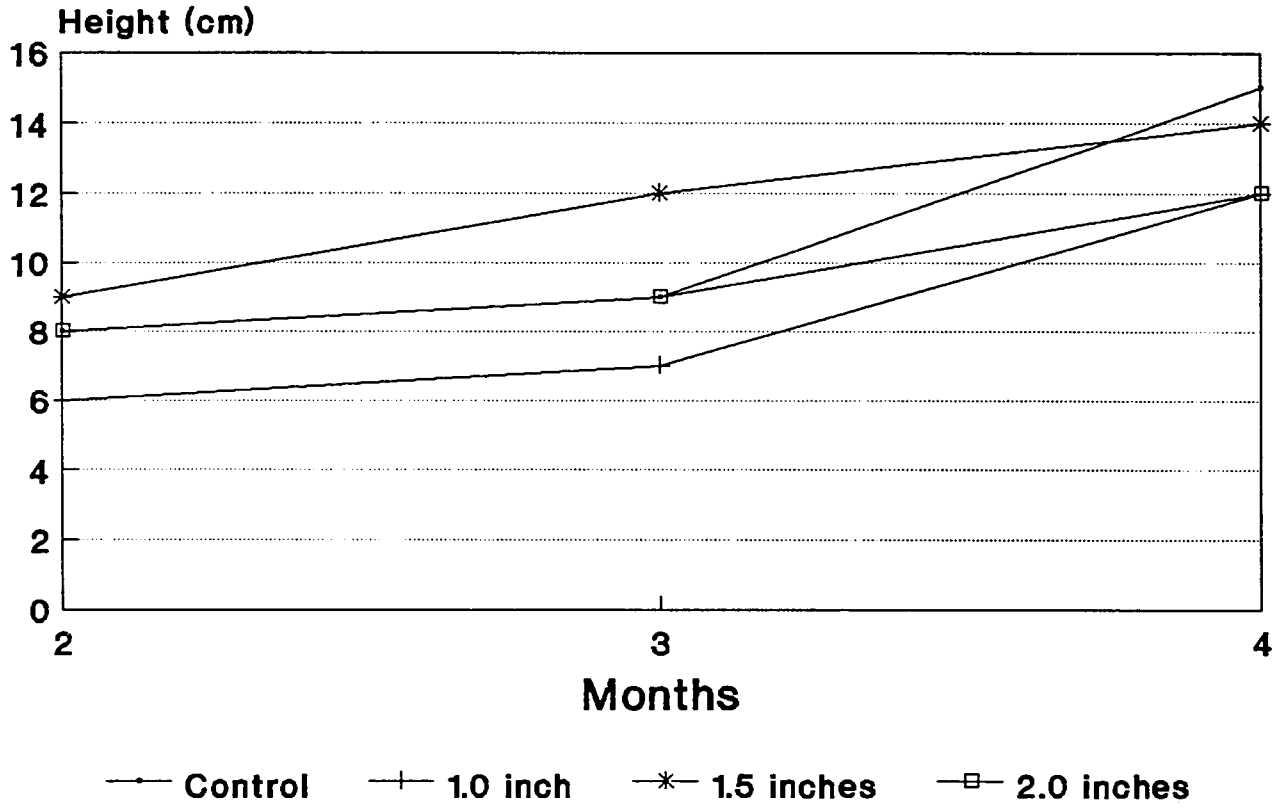

Figure 22. Height growth of *Eucalyptus camaldulensis* seedlings in resposne to different depth of undercutting treatments (4 in x in planting distance).

Table 22. Monthly height and diameter growth of *Eucalyptus camaldulensis* seedlings in response to various spacing and depth of undercutting treatments after 3, 4 and 5 months.

SPACING (in x in)	DEPTH OF UNDERCUTTING	THREE MONTHS		FOUR MONTHS		FIVE MONTHS	
		HEIGHT (cm)	DIAMETER (cm)	HEIGHT (cm)	DIAMETER (cm)	HEIGHT (cm)	DIAMETER (cm)
3 x 3	CONTROL	11 ab	0.055 cd	16 a	0.111 bc	29 a	0.135 a
	1.0 inch	10 b	0.064 bc	12 b	0.104 bcd	16 a	0.128 a
	1.5 inches	11 b	0.074 ab	13 b	0.114 ab	15 a	0.099 a
	2.0 inches	12 a	0.075 ab	16 a	0.149 a	21 a	0.112 a
	MEAN	**11**	**0.067**	**14**	**0.120**	**20**	**0.119**
4 x 1	CONTROL	8 d	0.077 ab	9 c	0.064 c	15 a	0.119 a
	1.0 inch	6 e	0.070 b	7 d	0.062 d	12 d	0.122 a
	1.5 inches	9 c	0.086 a	12 b	0.085 bcd	14 a	0.114 a
	2.0 inches	8 d	0.044 d	9 c	0.075 bcd	12 a	0.110 a
	MEAN	**8**	**0.069**	**9**	**0.072**	**13**	**0.116**

Table 23. Height, diameter, dry matter yield and root shoot ratio of *Eucalyptus camaldulensis* seedlings in response to various spacing and depth of undercutting treatments.

SPACING (in x in)	DEPTH OF UNDERCUTTING	HEIGHT (cm)	DIAMETER (cm)	DRY MATTER YIELD (gm/plant)			ROOT/SHOOT RATIO
				Root	Shoot	Total	
3 x 3	Control	29 a	0.135 a	0.165 a	0.65[illegible]	0.822	0.251
	1.0 inch	16 a	0.128 a	---	---	---	---
	1.5 inches	15 a	0.099 a	0.133 ab	0.450	0.583	0.296
	2.0 inches	21 a	0.112 a	0.172 a	0.650	0.822	0.265
	Mean	20	0.119	0.157	0.586	0.742	0.271
4 x 1	Control	15 a	0.119 a	0.060 a	0.293	0.353	0.205
	1.0 inch	35 a	0.122 a	0.050 a	0.146	0.196	0.342
	1.5 inches	14 a	0.114 a	0.103 bc	0.337	0.440	0.306
	2.0 inches	12 a	0.110 a	0.080 bc	0.259	0.339	0.309
	Mean	19	0.116	0.073	0.259	0.174	0.291

Aside from physical changes that may occur in the seedling after undercutting, physiological differences can be observed too (Table 23), such as a significant increase in the root-shoot dry weight ratio (0.342 g) because of the reduced shoot size which was attained by seedlings undercut to 1.0 inch depth (0.146 cm) using 4 in x 1 in spacing distance. Furthermore, a significant increase in the dry weight of the fibrous roots, especially the finer tertiary roots was obtained by seedlings undercut to 2.0 inches depth (0.172 gm/plant) in 3 in x 3 in planting distance.

Recommended depth of undercutting for *E. camaldulensis* are 2.0 inches for seedlings spaced at 3 in x 3 in and 1.0 inch if spaced at 4 in x 1 in.

3b.2. *Eucalyptus deglupta*

Tables 24 and 25 summarize the height, diameter, and dry matter yield of *E. deglupta* seedlings in response to spacing distance and depth of undercutting treatments. The general appearance of the seedlings in response to different depth of undercutting and spacing distances are shown in Figure 23. The monthly height growth of seedlings in response to depth of undercutting treatments and spaced at 2 in x 3 in and 4 in x 3 in are shown in Figures 24 and 25 respectively. Height after 5 months was significant in seedlings that served as control (7.0 cm), while the smallest was found in seedlings undercut at 2.0 inches depth (4.60 cm) both using 2 in x 3 in spacing distance. Diameter was observed to be bigger at a planting distance of 4 in x 3 in and undercut at 2.0 inches depth (0.082 cm).

Among the undercut seedlings, the significant increase in the dry weight of the fibrous roots were given by seedlings undercut at 1.5 inches depth (0.040 g) using 2 in x 3 in spacing distance and those undercut at 2.0 inches depth and spaced at 4 in x 3 in distance (0.053 g.). The latter also gave significant increase in the root-shoot dry weight ratio with 0.898 grams and 0.625 grams for seedlings undercut with 1.0 inch using 2 in x 3 in spacing distance.

Recommended depths of undercutting for *E. deglupta* are 1.0 inch depth for a spacing of 2 in x 3 in and 2.0 inches depth when spaced at 4 in x 3 in.

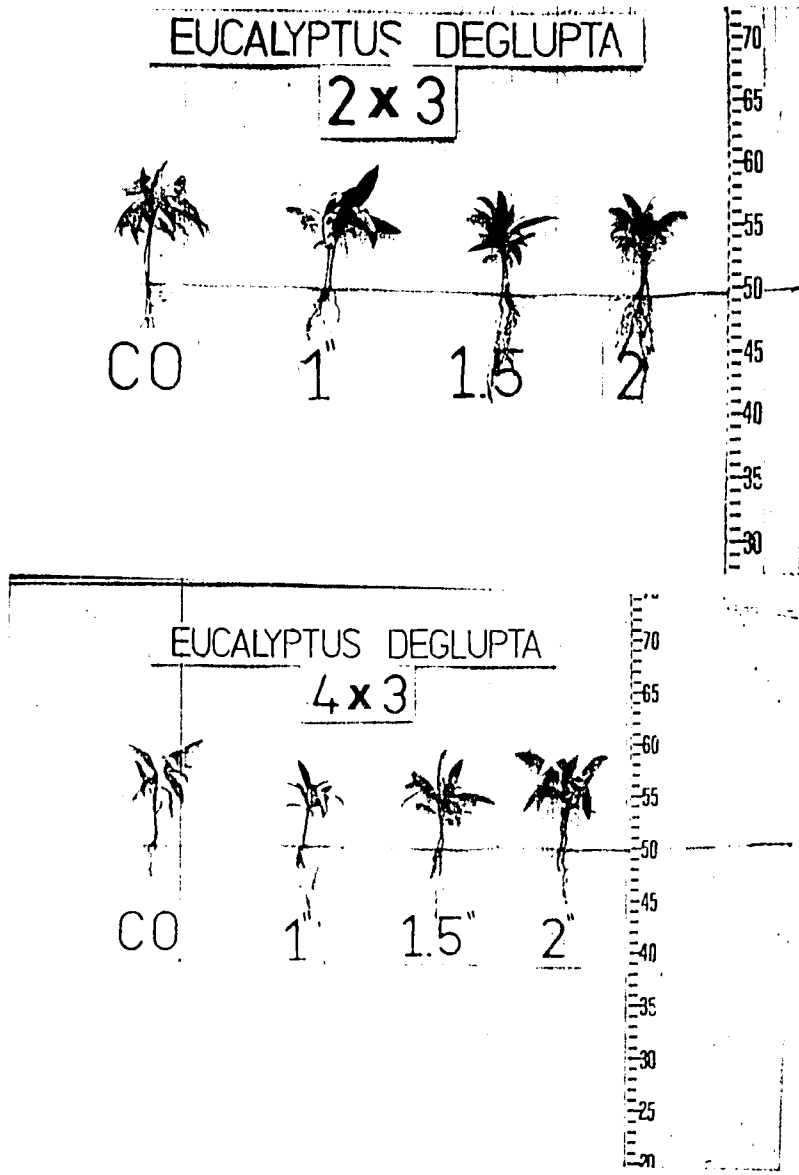

Figure 23. Five-month old *Eucalyptus deglupta* seedlings in response to various depths of undercutting treatments and spacing distance of (a) 2 in x 3 in and (b) 4 in x 3 in.

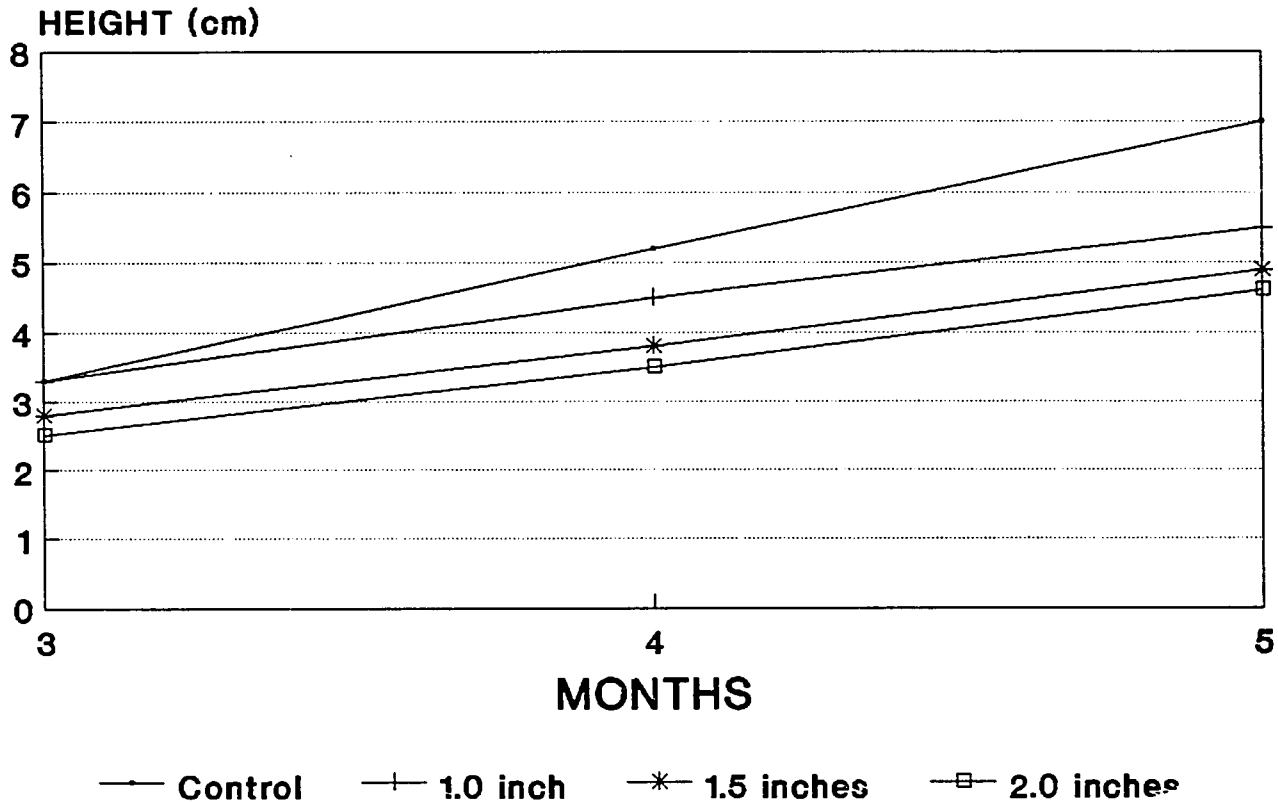

Figure 24. Height growth of *Eucalyptus deglupta* seedlings in response to different depth of undercutting treatments (2 in x 3 in planting distance).

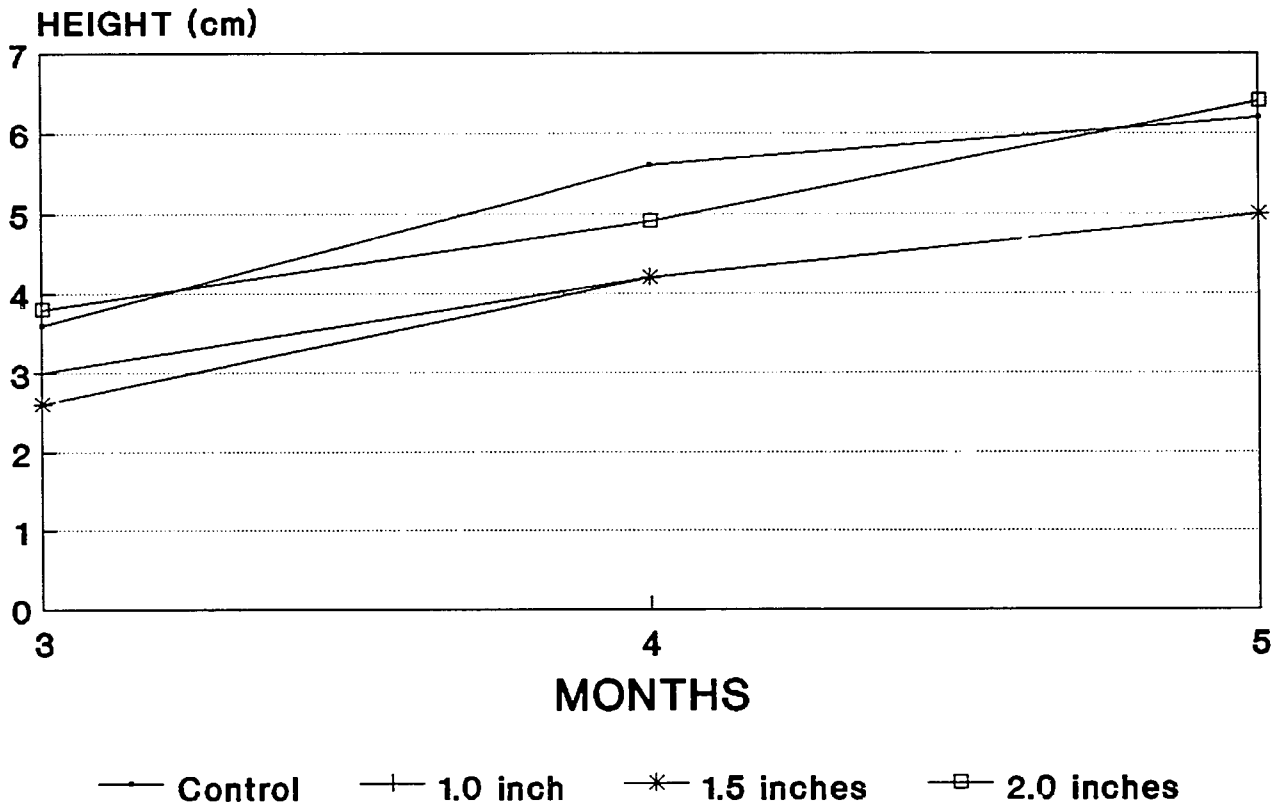

Figure 25. Height growth of *Eucalyptus deglupta* seedlings in response to different depth of undercutting treatments (4 in x 3 in planting distance)

Table 24. Monthly height and diameter growth of *Eucalyptus deglupta* in response to various spacing and depth of undercutting treatments.

SPACING (in x in)	DEPTH OF UNDERCUTTING	THREE MONTHS		FOUR MONTHS		FIVE MONTHS	
		HEIGHT (cm)	DIA (cm)	HEIGHT (cm)	DIA (cm)	HEIGHT (cm)	DIA (cm)
2 x 3	CONTROL	3.30 ab	0.026 d	5.20 ab	0.043 b	7.00 a	0.078 ab
	1.0 inch	3.30 ab	0.030 bcd	4.50 bc	0.044 b	5.50 bcd	0.072 abc
	1.5 inches	2.80 bc	0.039 a	3.80 cd	0.057 a	4.90 d	0.062 cd
	2.0 inches	2.50 c	0.037 ab	3.50 d	0.030 cd	4.60 a	0.047 d
	MEAN	**2.99**	**0.033**	**4.25**	**0.044**	**5.50**	**0.065**
4 x 3	CONTROL	3.60 a	0.036 abc	5.60 a	0.038 bc	6.20 abc	0.067 abc
	1.0 inch	3.00 bc	0.034 abcd	4.20 cd	0.026 d	5.00 cd	0.064 bc
	1.5 inches	2.60 c	0.029 cd	4.20 cd	0.026 d	5.00 cd	0.064 bc
	2.0 inches	3.80 a	0.028 cd	4.90 abc	0.046 b	6.40ab	0.082 b
	MEAN	**3.22**	**0.032**	**4.73**	**0.034**	**5.68**	**0.069**

Table 25. Height, diameter, dry matter yield and root shoot ratio of *Eucalyptus deglupta* in response to various spacing and depth of undercutting treatments.

SPACING (in x in)	DEPTH OF UNDERCUTTING	HEIGHT (cm)	DIAMETER (cm)	DRY MATTER YIELD (gr/plant)			ROOT/SHOOT RATIO
				Root	Shoot	Total	
2 X 3	Control	7.00 a	0. 078 ab	0.063 a	0.100	0.163	0.630
	1.0 inch	5.50 bcd	0.072 abc	0.035 b	0.056	0.091	0.625
	1.5 inches	4.90 d	0.062 cd	0.040 b	0.071	0.111	0.563
	2.0 inches	4.60 d	0.047 d	0.038 b	0.024	0.062	0.158
	Mean	**5.42**	**0.065**	**0.044**	**0.063**	**0.107**	**0.850**
4 X 3	Control	6.20 abc	0.067 abc	0.069 a	0.101	0.170	0.683
	1.0 inch	5.00 cd	0.064 bc	0.038 c	0.114	0.152	0.333
	1.5 inches	5.10 cd	0.064 bc	0.036 c	0.069	0.105	0.522
	2.0 inches	6.40 ab	0.082 a	0.053 abc	0.059	0.112	0.898
	Mean	**5.68**	**0.069**	**0.049**	**0.086**	**0.135**	**0.609**

Study 4. Bareroot technology for *Eucalyptus* and Dipterocarps.

4a. Effects of mycorrhizal inoculation and silvicultural preconditioning treatments on growth and survival of seedlings.

4a.1. *Eucalyptus camaldulensis*

No data were gathered because of typhoon "SALING" which completely destroyed the nursery and all experimental set-ups. The nursery was consequently reconstructed.

4a.2. *Eucalyptus deglupta*

One month and two months after undercutting, height and diameter growth of seedlings inoculated with *P. tinctorius* with or without undercutting and *C. geophillum* with undercutting gave highly significant response in comparison with the two control set-ups (Table 26). On the other hand, seedlings inoculated with *C. geophillum* without undercutting were not considerably different with the control ones.

Both *P. tinctorius* and *C. geophillum* inoculated seedlings without undercutting showed greater significant responses than their counterparts with undercutting (Table 26). This is attributable to the fact, that after undercutting the seedlings are not expected to have higher growth, vertically or horizontally, relative to those without undercutting. Undercutting enhances the development of more lateral roots to enable plants to have greater survival and adaptation in the field.

Table 26 also showed that undercut *P. tinctorius* inoculated seedlings have significantly higher growth responses than either undercut *C. geophillum* inoculated seedlings or the control ones.

From the above data, it can be observed that using the same undercutting treatment, *P. tinctorius* inoculated seedlings will perform better in terms of growth increments than *C. geophillum* seedlings. Undercutting slow height growth of seedlings but tends to produce more secondary absorbing roots.

Table 26. Height and diameter growth of *Eucalyptus deglupta* seedlings in the nursery in response to inoculation with ectomycorrhizal fungi in combination with undercutting treatment.

TREATMENTS	ONE MONTH		TWO MONTHS	
	HEIGHT** (cm)	DIAMETER** (cm)	HEIGHT** (cm)	DIAMETER** (cm)
Control 1 (Potted)	16.39 c	0.11 c	27.99 d	0.19 d
Control 2 (Bare)	14.93 c	0.14 b	32.96 c	0.23 bc
Pisolithus tinctorius with undercutting	19.84 b	0.18 a	37.13 b	0.25 ab
Pisolithus tinctorius w/o undercutting	22.79 a	0.17 a	40.10 a	0.26 a
Cenococcum geophillum with undercutting	16.13 c	0.13 b	29.13 d	0.21 cd
Cenococcum geophillum w/o undercutting	21.96 a	0.169 a	38.44 ab	0.25 ab

Conclusively, *P. tinctorius* significantly increased growth of *E. deglupta* seedlings much more than *C. geophillum* even with undercutting treatments.

4a.3. *Anisoptera thurifera*

After eight months in the nursery, seedlings inoculated with *S. citrinum* gave the biggest height (11.62 cm) compared to seedlings inoculated with *S. bovista* (10.33 cm) and uninoculated control (10.46 cm)(Table 27). In terms of diameter, there was no significant effect of mycorrhizal inoculation in combination with best spacing and depth of undercutting obtained in the previous studies. On the other hand, the highest shoot weight was obtained by seedlings inoculated with *S. bovista* (0.658 g) followed by control (0.549 g) and the least was recorded in seedlings inoculated with *S. citrinum* (0.529 g). The control seedlings gave the highest root weight (0.297 g) because their roots were not undercut all throughout the experiment. There was no significant differences when seedlings were inoculated with *S. bovista* and *S. citrinum*.

4b. Effects of packaging materials on ectomycorrhizal inoculated and silviculturally pre-conditioned *Eucalyptus deglupta* seedlings.

Table 28 summarizes the monthly performance of the treated seedlings in the field in terms of height, diameter, and survival ratings.

Monthly measurement shows that, PT-U-BMP treated seedlings produced the greatest mean height of 38.85 cm (2 months), 46.58 cm (3 months) and 52.88 cm (4 months). This was followed by the potted seedlings with 35.12 cm (2 months), 41.20 cm (3 months) and 44.28 cm (4 months). CG-NU-BMP gave a high mean height of 38.37 cm during the first 2 months but after the third and fourth months period, its height performance declined considerably. PT-NU-BE gave the lowest mean height of 14.25 cm, 20.50 cm and 18.00 cm monthly.

In terms of diameter, PT-U-BMP+BLS again showed the highest mean (0.30 cm) compared with the other treated seedlings. The same treatment (PT-U-BMP+BLS) promoted higher diameter growth during the third month (0.39 cm) and fourth month (0.47 cm). However, during the second month, the potted control seedlings performed equally well with PT-U-BMP+BLS.

Table 27. Height, diameter and biomass growth responses of *Anisoptera thurifera* seedlings 8 months after inoculation with ectomycorrhizal fungi in combination with various silvicultural treatments.

TREATMENTS	HEIGHT (cm)	DIAMETER (cm)	BIOMASS (gm/plant)		
			Root	Shoot	Total
Control	10.46 b	0.321 a	0.297 a	0.549 b	0.846 b
Scleroderma bovista	10.33 b	0.314 a	0.263 b	0.658 a	0.921 b
Scleroderma citrinum	11.62 a	0.315 a	0.237 b	0.529 b	0.766 b

Table 28. Height, diameter and percent survival of *Eucalyptus deglupta* seedlings in the field in response to inoculations with different ectomycorrhizal fungi in combination with undercutting and transport packaging techniques.

TREATMENTS	TWO MONTHS			THREE MONTHS			FOUR MONTHS		
	HEIGHT* (cm)	DIA* (cm)	% SURV	HEIGHT* (cm)	DIA* (cm)	% SURV	HEIGHT*	DIA*	% SURV
Potted	35.12 ab	0.31 a	94	41.20 ab	0.36 abc	89	44.28 ab	0.43 ab	89
BE	24.90 bc	0.20 bcde	17	27.00 bcd	0.21 def	17	27.40 bc	0.25 c	17
BMP	28.32 ab	0.29 abc	31	28.40 bcd	0.27 abcdef	25	28.44 bc	0.30 bc	25
BMP+BLS	34.22 ab	0.28 abc	81	35.11 abcd	0.32 abcd	67	38.86 ab	0.37 abc	64
PT-V-BE	30.07 ab	0.24 abcde	64	33.38 abcd	0.26 abcdef	64	36.22 abc	0.32 bc	67
PT-U-BMP	35.06 ab	0.26 abcd	86	38.92 abc	0.30 abcd	81	39.99 ab	0.36 abc	75
PT-U-BMP+BLS	38.85 a	0.30 ab	97	46.58 a	0.39 a	94	52.88 a	0.47 a	97
PT-NU-BE	14.25 c	0.23 abcde	6	20.50 d	0.15 f	6	18.00 c	0.24 c	6
PT-NU-BMP	29.55 ab	0.19 cde	11	33.17 abcd	0.20 def	11	33.89 abc	0.24 c	14
PT-BU-BMP+BLS	33.98 ab	0.28 abc	56	34.72 abcd	0.37 ab	50	33.45 bc	0.33 abc	53
CG-U-BE	25.00 bc	0.15 e	8	32.00 abcd	0.16 ef	8	31.50 bc	0.26 c	6
CG-U-BMP	28.42 ab	0.17 de	33	22.92 cd	0.25 bcdef	33	30.24 bc	0.25 c	31
CGU-U-BMP+BLS	26.26 b	0.20 bcde	75	29.02 bcd	0.24 cdef	69	31.38 bc	0.29 c	69
CG-NU-BE	24.72 bc	0.22 abcde	22	28.33 bcd	0.19 def	17	28.17 bc	0.24 c	17
CG-NU-BMP	38.37 a	0.28 abc	64	34.09 abcd	0.29 abcd	33	37.50 ab	0.32 bc	31
CG-NU-BMP+BLS	35.02 ab	0.26 abcd	64	37.10 abcd	0.28 abcde	58	40.41 ab	0.34 abc	56

Seedlings treated with PT-NU-BE and CG-NU-BE on the other hand, showed the lowest mean diameter, overall.

Furthermore, the highest survival ratings were achieved by PT-U-BMP+BLS with 97 %, 94 % and 97 % after the second, third and fourth months, respectively. The increase in survival rating of the seedlings from the third months to the fourth months period can be explained by the capacity of PT-U-BMP+BLS treated seedlings to recover even at extreme conditions. Pre-potted seedlings followed second with survival ratings of 94 % (second month) and 89 % (third and fourth months). Meanwhile, PT-NU-BE and CG-U-BE yielded the lowest survival ratings of 6 % during the fourth month. The two treatments also produced the lowest survival ratings at 2 months and 3 months.

In general, the greatest survival, height and diameter growth increments were observed in seedlings with bareroots packaged in mudpuddle and banana leafsheath, followed by the potted (control) seedlings. In terms of survival, abovementioned seedlings produced very significant differences compared to the other differently packaged seedlings. This only proves that growth and survival performance of *E. deglupta* seedlings are greatly enhanced when their bareroots are packaged in mudpuddle with banana leafsheath covering. Survival and growth of seedlings were further enhanced if inoculated with *P. tinctorius* and their roots were undercut. This result is evident among PT-U-BMP+BLS treated seedlings (Table 28).

The same trends in survival, height and diameter growth after 8 and 11 months are in a grassland were observed (Table 29). The survival, height and diameter growth after 11 months are graphically presented in Figures 26, 27 and 28, respectively.

Table 29. Height, diameter and percent survival of *Eucalyptus deglupta* seedlings as affected by inoculation with ectomycorrhizal fungi, undercutting and transport packaging technique after 8 and 11 months in the field.

TREATMENTS	8 MONTHS			11 MONTHS		
	HEIGHT (cm)	DIAMETER (cm)	SURVIVAL (%)	HEIGHT (cm)	DIAMETER (cm)	SURVIVAL (%)
Potted	63.2 abc	0.588 ab	83 a	74.0 ab	0.662 a	75 a
BE	36.0 bcd	0.477 ab	17 fg	38.0 bcd	0.280 a	3 ef
BMP	32.7 cd	0.461 ab	25 ef	49.2abc	0.366 a	14 ef
BMP+BLS	53.9 a-d	0.470 ab	62 bc	62.2 abc	0.548 a	44 b
PT-U-BE	46.9 a-d	0.409 bc	50 cd	56.3 abc	0.563 a	39 bc
PT-U-BMP	68.9 ab	0.525 ab	38 de	61.6 abc	0.473 a	28 bcd
PT-U-BMP+BLS	76.1 a	0.699 a	92 a	84.6 a	0.715 a	92 a
PT-NU-BE	24.6 d	0.444 b	4 g	22.0 cd	0.340 a	3 bc
PT-NU-BMP	48.7 a-d	0.448 b	8 g	69.8 ab	0.548 a	6 ef
PT-NU-BMP+BLS	57.4 a-d	0.431 ab	42 d	62.3 abc	0.460 a	22 cde
CG-U-BE	39.4 bcd	0.389 b	3 g	---	---	0 f
CG-U-BMP	34.0 cd	0.360 ab	17 fg	52.5 abc	0.402 a	6 ef
CG-U-BMP+BLS	43.4 a-d	0.446 ab	67 b	51.6 abc	0.622 a	44 b
CG-NU-BE	28.1 d	0.282 b	14 fg	34.0 bcd	0.340 a	6 ef
CG-NU-BMP	63.8 abc	0.437 ab	22 ef	81.0 a	0.528 a	14 def
CG-NU-BMP+BLS	47.6 a-d	0.347 b	54 bcd	56.2 abc	0.580 a	36 bc

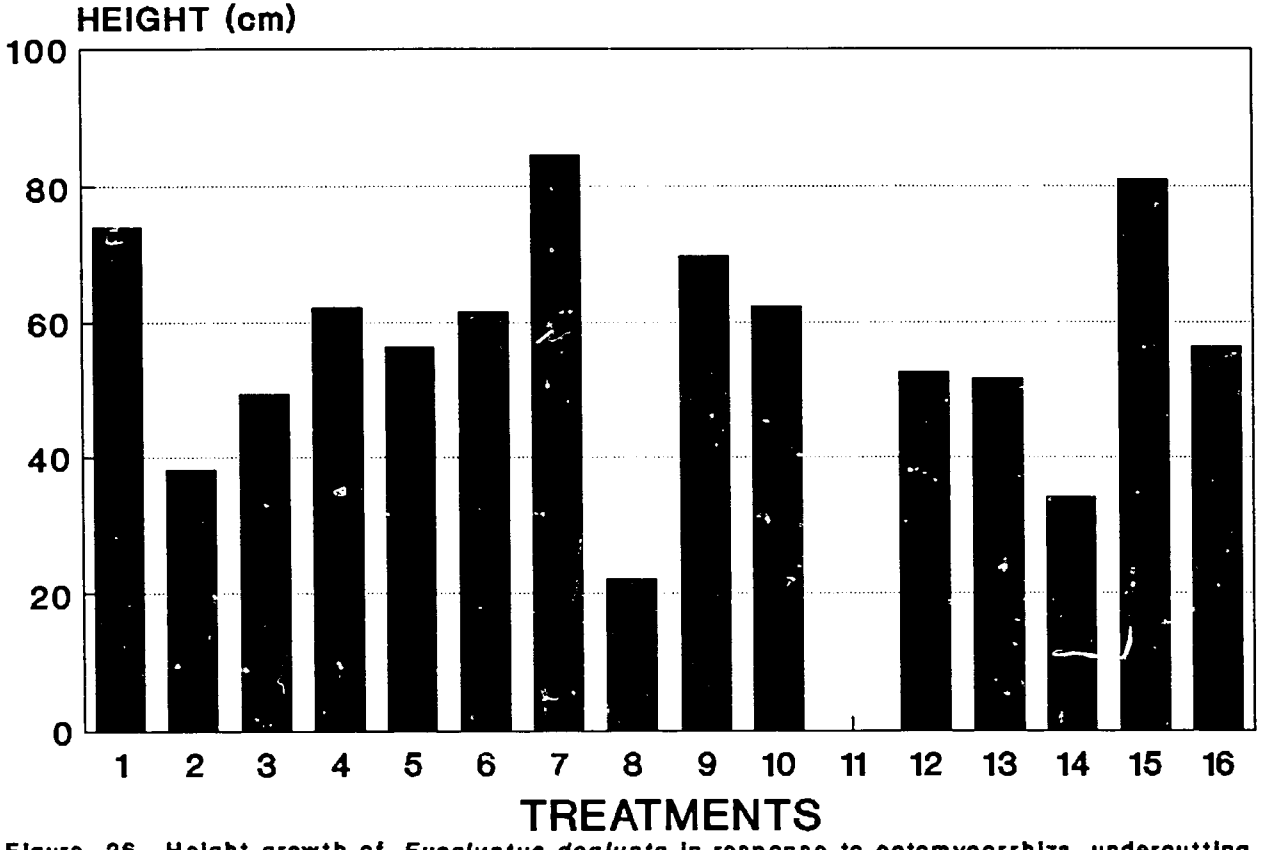

Figure 26. Height growth of *Eucalyptus deglupta* in response to ectomycorrhiza, undercutting and packaging treatments 11 months after outplanting.

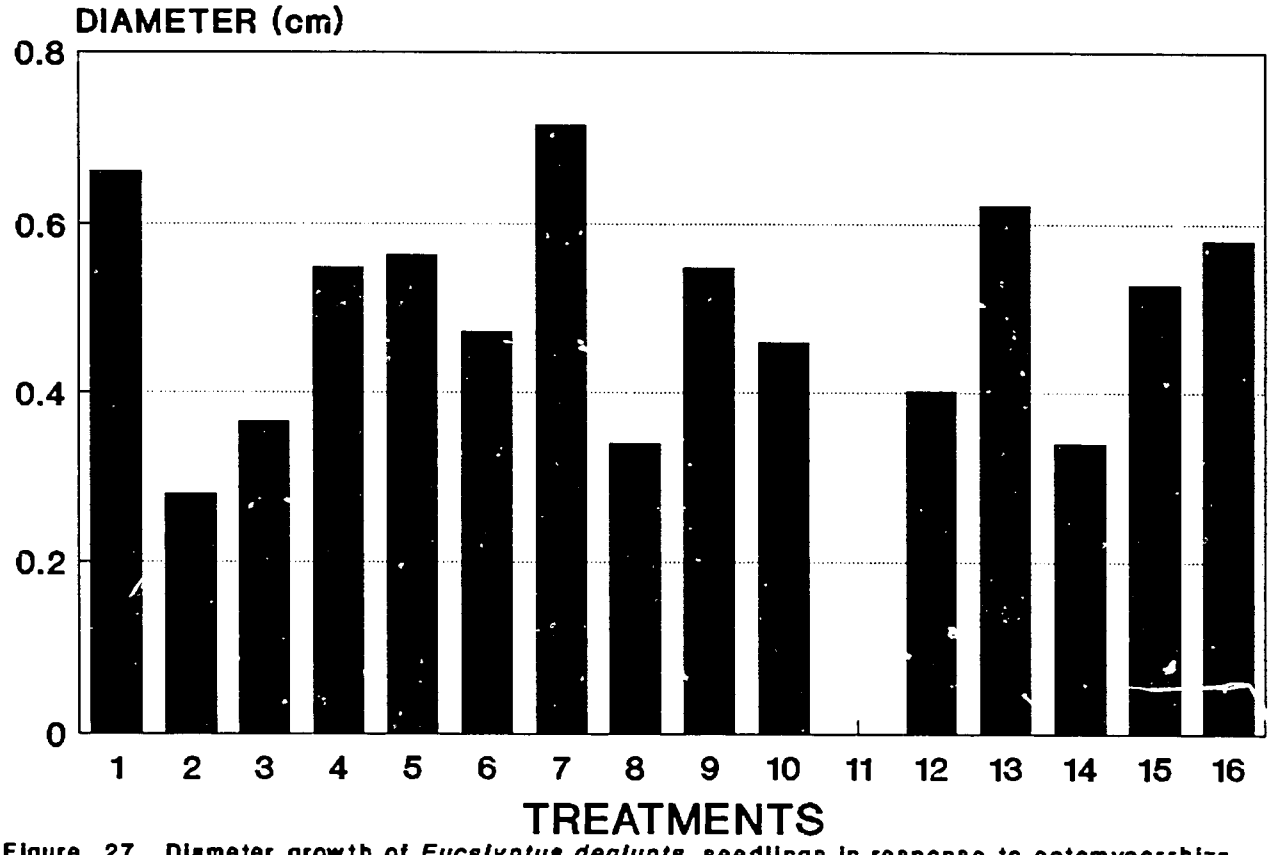

Figure 27. Diameter growth of *Eucalyptus deglupta* seedlings in response to ectomycorrhiza, undercutting and packaging treatments 11 months after outplanting.

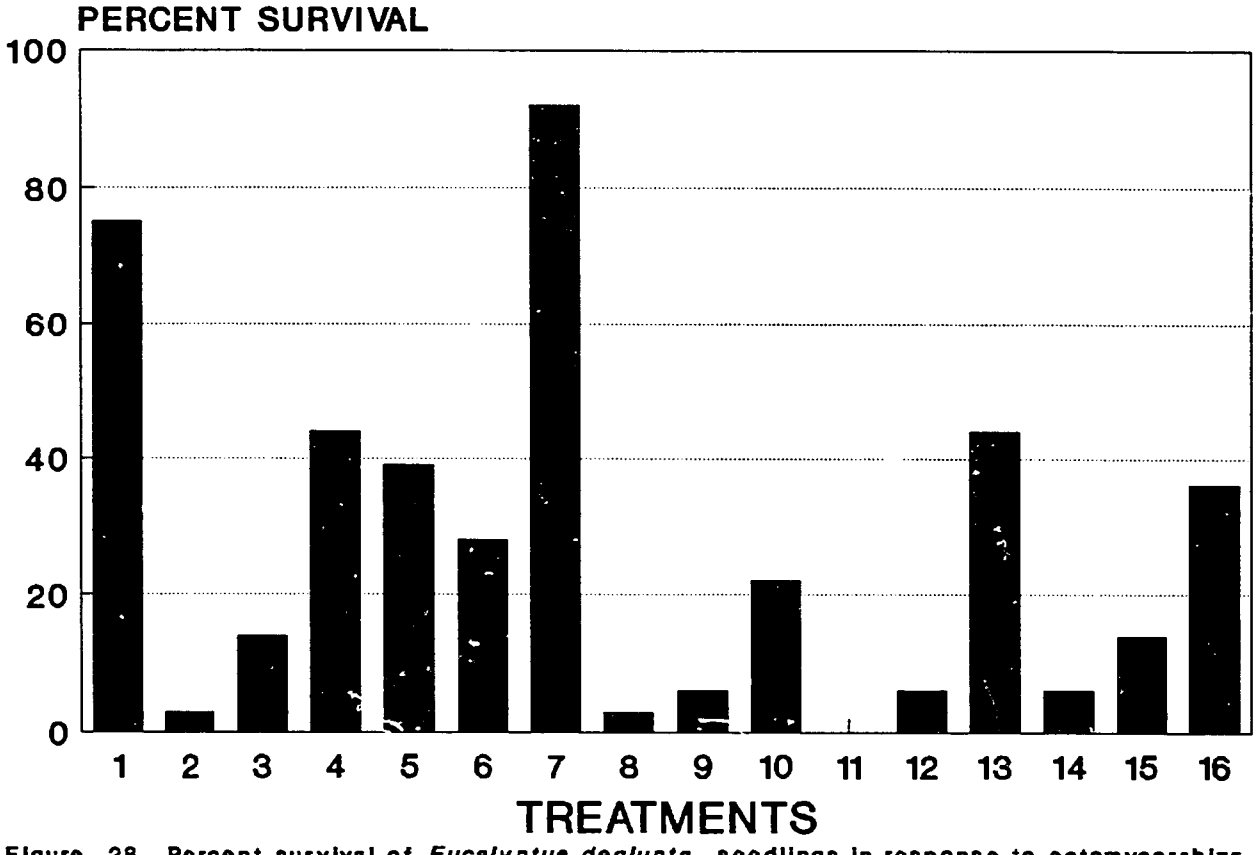

Figure 28. Percent survival of *Eucalyptus deglupta* seedlings in response to ectomycorrhiza, undercutting and packaging treatments 11 months after outplanting.

SUMMARY AND CONCLUSIONS

The effects of mycorrhizal inoculation and silvicultural treatments on field survival and growth of bareroot planted *E. camaldulensis, E. deglupta* and *A. thurifera* were studied. Ecto- and endomycorrhizal fungi associated with the above host plants were collected, isolated, and identified. Synthesis studies were conducted to verify if isolated fungi were truly mycorrhizal formers. The effectiveness of isolated fungi in promoting growth of host plants were determined. The effects of silvicultural pre-conditioning treatments such as spacing distances and depth of undercutting of roots in combination with mycorrhizal inoculation treatments on field survival and growth of seedlings were also studied. Seedlings of *E. deglupta* were grown in nursery beds during which time, pre-conditioning treatments were imposed. The barerooted seedlings were then placed in different packaging treatments before transplanting in the field. The seedlings were planted in a degraded grassland. Survival, height and diameter growth were monitored for 11 months.

Results of this project are summarized as follows:

1. Most species of ectomycorrhizal fungi associated with dipterocarps and *Eucalyptus* species belong to the genera *Russula, Lactarius, Scleroderma, Pisolithus, Rhizopogon, Cenococcum*, and *Thelephora*. Species belonging to the genera *Scleroderma, Pisolithus, Rhizopogon* and *Thelephora* can be isolated into pure culture. Species belonging to the genera *Lactarius* and *Russula* are difficult to isolate. Dipterocarps such as *A. thurifera* are associated with ectomycorrhiza and not with endomycorrhiza.

2. Some endomycorrhizal fungi belonging to the genera *Glomus, Gigaspora, Acaulospora*, and *Scutellospora* were isolated from both *Eucalyptus* and dipterocarps. Species belonging to the genera *Glomus* and *Gigaspora* predominate. *Eucalyptus* and dipterocarps can form associations with endomycorrhizal fungi, but the dominant form of association in these groups of plant is still the ectomycorrhizal form.

3. Among the ectomycorrhizal fungi, *C. geophillum*, 2 *Rhizopogon* species and *P. tinctorius* were most effective in promoting growth of *E. camaldulensis* and *E. deglupta* while *S. citrinum* was more effective than *S. bovista* in promoting growth of *A. thurifera*.

4. Among the endomycorrhizal fungi, *Gl. macrocarpum* and *Gl. mosseae* were the most effective in promoting height growth of *E. deglupta*; while *S. persica*, an *Acaulospora* species, a *Glomus* species, and *Gl. etunicatum* were more effective than *Gl. macrocarpum* and *Gl. mosseae* in promoting height growth of *A. thurifera*.

5. The best spacing distances for the growth of *E. camaldulensis* are 4 in x 1 in and 3 in x 3 in; 3 in x 3 in for *E. deglupta*; and 4 in x 2 in for *A. thurifera*.

6. The best depths for undercutting roots of *E. camaldulensis* are 2 inches for seedlings spaced at 3 in x 3 in and 1 inch if spaced at 4 in x 1 in. For *E. deglupta*, the best depth to undercut roots of *E. deglupta* are 2 inches when spaced at 4 in x 3 in and at 1 inch if spaced at 2 in x 3 in.

7. Survival and growth of bareroot planted *E. deglupta* in the field is significantly increased if the seedlings are planted at a distance of 4 in x 3 in, the roots undercut at a depth of 2 inches, inoculated with an effective ectomycorrhizal fungus such as P. tinctorius, barerooted seedlings covered with mud puddle. and the seedlings placed in banana leafsheath prior to transport to the field. Survival and growth of such seedlings are comparable to that observed by the traditional potted controls.

It is therefore concluded that barerooting is an efficient alternative to the traditional potted seedling technology for reforestation, provided that the barerooted seedlings are pre-conditioned silviculturally by proper spacing distances, that the roots are undercut at specified depths to promote the production of more secondary/absorbing roots, that the roots are inoculated with an efficient mycorrhizal fungi, and that the barerooted seedlings are covered with mud puddle and placed in a banana leafsheath prior to transplanting in the field. Bareroot planting is equally efficient in promoting survival and growth of seedlings in the field than the potted seedling method, but the former is less expensive than the latter. More seedlings can also be transported to the field by the barerooting technique as compared to potted seedlings.

OTHER ACCOMPLISHMENTS

1. A screenhouse was expanded to accommodate experimental set-ups.

2. An airconditioned room for the growth chamber was constructed in the screenhouse.

3. USAID through WINROCK International invited Dr. dela Cruz to attend a workshops on Multipurpose Tree Species (MPTS), first, in Bangkok, Thailand (September 22-28, 1986) and second in Kuala Lumpur, Malaysia (December 14-18, 1986). During the workshop, mycorrhiza was given emphasis as a major priority in MPTS establishment in Asia-Pacific countries. Dr. dela Cruz was selected as member of the Research Committee.

4. Dr. R.E. dela Cruz had undergone a training on Endomycorrhiza Taxonomy last August, 1986 at the University of Florida. He also attended a Taxonomy Workshop in Florida (April-May, 1987) and the 7th North American Conference on Mycorrhiza in Florida (May 3-8, 1987).

5. Starter VAM cultures were obtained from the International Culture Collection of VA Mycorrhizal Fungi (INVAM) through Dr. Norman Schenck.

6. Mass production of Ectomycorrhizal cultures through the use of Fermentor.

7. A training course on "The Production and Development of Mycorrhizal Inoculants" sponsored by UNESCO was organized by Dr. dela Cruz. It was held at BIOTECH, UPLB, College, Laguna on October 16-29, 1988.

8. Dr. Francis Sanders, an expert on the field of mycorrhizal research from U.K., gave some exotic mycorrhizal cultures.

9. Dr. John Dodd, another mycorrhizal expert from U.K., assisted the group in the laboratory of VA mycorrhiza.

PROBLEMS ENCOUNTERED

1. Availability of both *Eucalyptus* and Dipterocarps seeds most especially *A. thurifera* and *Dipterocarpus grandiflorus* that hindered the activities of the project.

2. Collection of fruiting bodies of ectomycorrhizal fungi which is seasonal.

3. Breakdown of University's computer during the early part of the project which hampered the statistical analysis of the results of many studies.

4. Occurrence of natural calamities i.e., typhoons and earthquake which destroyed many nursery and field trials.