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NURSERY MANAGEMENT IN RELATION TO ROOT DEFORMATION, SOWING AND SHADING

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The polybag is widely used for seedling production in the Philippines. Seedlings commonly have root deformation which has adverse effects as they grow and develop into mature trees. This study assessed the influence of potting technique and hardening intensity on the growth performance of seedlings in nursery and field conditions. Seedlings of bagras (*Eucalyptus deglupta*) and mangium (*Acacia mangium*) were grown in hiko trays and 4"x 6" (approximately 10 cm x 15 cm) polybags at the College of Forestry Nursery, Leyte State University (LSU). Kalumpit (*Terminalia microcarpa*) and pellita (*Eucalyptus pellita*) were used for a trial in the Conalum Agroforestry Farmers Association (CAFA) Nursery in Inopacan, Leyte, aimed at validating LSU results and at the same time evaluating farmers' perceptions on the use of hiko trays and polybags in seedling production. It was found that seedlings of bagras, mangium, kalumpit and pellita grown in hiko trays have smaller diameter and height compared with those in polybags at 12 weeks. Root deformation of seedlings was absent in hiko trays but high with seedlings in polybags. As perceived by both farmers and ACIAR researchers, hiko tray seedlings are of high quality exhibiting sturdy shoot, trained roots and homogenous growth.

INTRODUCTION

Smallholder tree farmers have historically used low-quality seedlings in their woodlots, probably due to the type of nursery containers and nursery cultural treatments applied to the planting stock. Overgrown seedlings at planting out, due to the difficulty of matching seedling readiness with time of demand, often leads to low-quality seedlings with root deformation or J-rooting (Mangaoang and Harrison 2003). The usual seedling production technique used in Leyte forestry nurseries involves sowing of seeds in boxes and seedbeds. Germinated seeds are transferred to, and collected wildlings planted in, polyethylene bags. It is commonly observed that this method produces seedlings with a deformed taproot, which can affect the overall root development as the seedlings grow into mature trees. The lack of alternative technique prevents nursery operators from producing high quality seedlings.

A common problem with polybags is that seedling roots tend to grow in spirals once they hit the smooth inner surface, which inevitably lead to plants with restricted growth, poor resistance to stress and wind-throw and even early dieback due to ensnarled root masses or pathogens (Jaenicke 1999). As Josiah and Jones (1992) observed, the most severe disadvantage with polybags is poor root formation which is a possible 'time bomb' with effects sometimes only seen many years after planting. Despite of these reported drawbacks, polybags are commonly used as containers in developing countries because they are locally made and are therefore inexpensive.

A better alternative to polybags as potting containers are root trainers. Root trainers are usually rigid containers with internal vertical ribs which direct roots straight down to prevent sideways growth. The containers are set on frames or beds above the ground to allow air-pruning of roots as they emerge from the containers. The latest developments also encourage lateral air pruning. Seedlings grown in root trainers have more vigorous and rapid root growth than seedlings grown in polybags. Survival rates at outplanting and in the longer long term are much higher. Plants grown in root trainer systems are often ready for planting out when they are still substantially smaller than those in conventional polybags. This helps to reduce requirements for space and potting mix in the nursery and transport costs to the field (Jaenicke 1999)

As part of the ACIAR Project ASEM/2000/088 titled 'Redevelopment of a Timber Industry following Extensive Land Clearing' (locally called the ACIAR Smallholder Forestry Project), nursery and field trial research were conducted to assess the growth of mangium (*Acacia mangium*) and bagras (*Eucalyptus deglupta*) in the nursery and field conditions as affected by sowing techniques, potting containers and varying hardening intensities. Specifically, this research was designed to

(1) compare the growth of seedlings in the conventional polybags and hiko trays as affected by the sowing technique;
(2) determine the effects of hardening intensities on the growth of seedlings;
(3) assess the growth of seedlings when out-planted; and
(4) analyse and compare the economic feasibility of the seedling production techniques.

Because of the broadness of this research, it was divided into two components, namely the seedling component and the tree farm component. This paper presents results from the nursery component addressing the first two objectives of the research.

Current seedling production practices in Leyte and problems associated with nursery practice are first reviewed. The design of the nursery trial is then outlined. Seedling growth (basal diameter and total height) and mortality are reported, and the perception of farmer-cooperators is discussed. Finally, the findings of the analysis are reviewed, and policy implications and suggestions for further research are presented.

RESEARCH METHODOLOGY

Seedling research experiments have been conducted in the College of Forestry (CoF) nursery at Leyte State University, and in a community with the Conlaum Agroforestry Farmers Association (CAFA) as cooperator. The nursery or seedling trial in the College of Forestry Nursery was carried out from November 2001 to January 2002 and the CAFA Nursery trial was carried out from October to December 2003. The experimental set-up in Conalum was in response to the recommendations from the LSU in-house review to validate results from the nursery experiment conducted in the CoF nursery.

The experiment conducted in the CoF nursery had four treatments:

Treatment A – seeds sown directly in hiko trays;
Treatment B – seed sown in plug tray and planted in hiko tray;
Treatment C – seed sown in plug tray planted in polybag; and
Treatment D – seed sown in conventional germination trays and planted in polybags.

The CAFA Nursery set-up had hiko trays and polybags as treatments. Both experiments were laid out in Randomised Complete Block Design (RCBD). The blocking was due to the effect of shade from trees and coconuts, occurring in the CoF nursery and CAFA nurseries respectively.

The species used for the CoF nursery experiment were mangium and bagras while for CAFA nursery were kalumpit and pellita. The container used for both experiments were 4" x 6" black polyethylene bags and V93 hiko trays. V93 hiko trays are made of made of high quality, high density polyethylene, which is durable, recyclable and easy to clean.

Experience has shown that the trays will have a useful life of more than 10 years. All tray cavities have vertical root training ribs and open bottoms which guide roots downward and facilitate natural air-pruning, respectively. The trays have a length of 35.2 cm and a width of 21.6 cm, with 40 cavities or cell per tray and with cavity diameter of 4.1 cm and depth of 8.7 cm. Each cavity has a volume capacity of 93 ml. A single square foot (30 cm x 30 cm) area can accommodate 49 cells, equivalent to 526 seedlings/m^2 (Stuewe and Sons 2003)

There were a total of 1280 seedlings each for mangium and bagras planted for the experiment in the CoF nursery, and a total of 720 seedlings of kalumpit and 420 for pellita. Seedling observations collected for this experiment include basal diameter (mm), total height (cm), number of leaves and survival rate. These data as well as root length (cm), root forms, root and shoot biomass were collected from the CAFA nursery. Means for each plot were used in the multiple comparison of means for diameter, height and number of leaves.

Data were collected weekly from the CoF nursery, from the second week from transplanting through to the 12th week, while data from CAFA community nursery were collected twice a month starting from two weeks after transplanting of seedlings for 12 weeks. In addition to biological data gathered, a survey was conducted of CAFA members to obtain feedback on their perceptions of the quality of seedlings produced from hiko trays and polybags, in which 11 out 16 farmer-cooperators were interviewed.

GROWTH AND SURVIVAL OF SEEDLINGS IN HIKO TRAYS AND POLYBAGS

Analysis of variance (ANOVA) was conducted to test for differences in diameter, height and number of leaves of mangium seedlings between treatments. A multiple comparison of means (Student-Newman-Keuls) test for mangium and bagras seedlings having four weeks shade, found that mean diameter, mean height, and mean number of leaves (NOL) of seedling grown in hiko trays are significantly larger than for seedlings grown in polybags (Tables 1 and 3). Diameter (mm) of mangium seedlings subjected to two weeks shade was significantly different, not only by the treatment ($p = 0.01$) but also with the blocking effect ($p = 0.01$) (Tables 2 and 4). Mean diameter of bagras seedlings with two weeks shade grown in polybags was significantly larger for seedling grown in hiko trays but not for seedlings sown in plug trays and then planted in polybags (Table 4). There was no significant difference on the diameter, height and number of leaves of seedlings between hiko trays and polybags for kalumpit and pellita seedlings.

It was also observed that seedlings in plots established towards the end of the shed (blocks 3 and 4 for mangium, block 1 for pellita and kalumpit) were significantly larger than those established in the middle part of the shed was (Tables 2 and 5). This difference is expected for edge plants due to less competition on plot edges. It was further observed that the survival rate of seedlings in 2 weeks shade was very high compared to seedlings in 4 weeks shade. The high mortality of seedlings in 4 weeks shade is due to the high moisture associated with long exposure to shading. The susceptibility of bagras seedlings to damping off was observed to be an extra factor to the high mortality of bagras in 4 weeks shade (Table 6).

Destructive samples of kalumpit and pellita seedlings revealed that there was a high incidence of root coiling in polybags (Table 8). High incidence of J-rooting for both tree species may not be due to the potting container but rather to the poor transplanting skills of farmers, because kinking occurs near or close to the root collar just beneath the surface of the potting substrate but rather to the poor transplanting skills of farmers.

Perceptions of farmer-cooperators about the quality of seedlings grown in hiko trays and polybags show that 64% of the farmers interviewed perceived that hiko tray seedlings were of high quality while only 36% judged that seedlings grown in polybags were of high quality

(Table 9). Their perceptions of quality in seedlings grown in hiko trays arose due to limited root growth, straight and firm stem and small seedling size.

Table 1. Mean diameter (mm), mean height (cm) and mean number of leaves (NOL) of three month old mangium seedling at 4 weeks shade in COF Nursery, LSU, Baybay, Leyte

Treatment	Number of observation	Mean diameter (mm)	Mean height (cm)	Mean number of leaves (NOL)
A. Direct-hiko tray	4	1.73b	18.83b	20.74b
B. Plug tray-hiko tray	4	1.84b	19.60b	21.89b
C. Plug tray-polybag	4	2.49a	26.03a	25.23a
D. Conventional tray-polybag	4	2.45a	27.28a	25.24a

Means followed with a common letter in a column are not significantly different at alpha = 0.05.

Table 2. Mean diameter (mm), mean height (cm) and mean number of leaves (NOL) of 3-month old mangium seedling at 2 weeks shade in COF Nursery, LSU, Baybay, Leyte

Treatment	Number of observation	Mean diameter (mm)	Mean height (cm)	Mean number of leaves (NOL)
Direct-hiko tray	4	2.17b	22.93b	22.26a
Plug tray-hiko tray	4	2.02c	23.31b	21.66a
Plug tray-polybag	4	3.21a	34.21a	26.22a
Conventional tray-polybag	4	3.14a	34.63a	27.25a
Block		Mean diameter (mm)		
1	4	2.53b		
2	4	2.60ab		
3	4	2.68a		
4	4	2.72a		

Means followed with a common letter in a column are not significantly different at alpha = 0.05.

Table 3. Mean diameter (mm), mean height (cm) and mean number of leaves (NOL) of 3-month old bagras seedling at 2 weeks shade in COF Nursery, LSU, Baybay, Leyte

Treatment	Number of observation	Mean diameter (mm)	Mean height (cm)	Mean number of leaves (NOL)
Direct-hiko tray	4	1.57b	16.56b	15.89b
Plug tray-hiko tray	4	1.68b	18.37b	16.15b
Plug tray-polybag	4	2.40a	27.40a	28.49a
Conventional tray-polybag	4	2.42a	28.30a	28.86a

Means followed with a common letter in a column are not significantly different at alpha = 0.05

Table 4. Mean diameter (mm), mean height (cm) and mean number of leaves (NOL) of 3 months old bagras seedling at 4 weeks shade in COF Nursery, LSU, Baybay, Leyte

Treatment	Number of observation	Mean diameter (mm)	Mean height (cm)	Mean number of leaves (NOL)
Direct-hiko tray	4	1.30b	9.86c	14.36b
Plug tray-hiko tray	4	1.30b	12.48bc	15.52b
Plug tray-polybag	4	1.53ab	14.69b	21.28a
Conventional tray-polybag	4	1.74a	19.30a	23.81a

Means followed with a common letter in a column are not significantly different at alpha = 0.05

Table 5. Report for means on diameter (mm), height (cm) and number of leaves by blocks for 3 months old Kalumpit and pellita seedlings from CAFA Nursery, Conalum, Inopacan, Leyte

Block	Kalumpit			Pellita		
	Diameter (mm)	Height (cm)	Number of leaves	Diameter (mm)	Height (cm)	Number of leaves
1	2.53 a	17.78 b	14.60 a	2.11 a	34.96 a	12.06 a
2	2.53 a	18.85 ab	14.23 a	1.67 b	24.76 b	9.82 a
3	2.65 a	20.71 a	14.77 a	1.52 b	20.91 b	16.10 a

Means followed with a common letter in a column are not significantly different at alpha = 0.05

Table 6. Mortality rate (%) of bagras and mangium at the COF Nursery, LSU

Shading	Treatment	Mangium		Bagras	
		N	Mortality (%)	N	Mortality (%)
2 weeks	1	160	5.00	160	18.75
	2	160	0	160	8.13
	3	160	0	160	4.38
	4	160	0	160	2.50
4 weeks	1	160	1.88	160	39.38
	2	160	1.25	160	27.50
	3	160	5.00	160	8.75
	4	160	1.25	160	25.63

Table 7. Mortality of kalumpit and *E. pellita* seedlings in CAFA Conalum Inopacan, Nursery

Species	Treatment	Block	Number of seedlings	Mortality rate (%)
Kalumpit	Hiko trays	1	120	6.67
		2	120	8.33
		3	120	5.00
	Ploybags	1	120	5.00
		2	120	8.33
		3	120	7.50
E. pellita	Hiko trays	1	80	15.00
		2	80	7.5
		3	80	18.75
	Ploybags	1	80	16.25
		2	80	11.25
		3	80	10.00

Table 8. Frequency of root deformity of 3 months old *E. pellita* and kalumpit

Root deformity	Pellita (n = 53)		Kalumpit	
	Hiko (n = 26)	Polybag (n = 27)	Hiko (n = 45	Polybag (n = 45)
J-rooting	22	25	44	43
Root coiling	0	27	0	45

Table 9. Perceptions of farmers of the quality of seedlings grown in hiko trays and polybags

Perceived quality of seedlings	Hiko trays		Polybags	
	Frequency	Relative frequency (%)	Frequency	Relative frequency (%)
Low	4	36	7	64
High	7	64	4	36

DISCUSSION

In most cases, farmers view large seedlings as high quality seedlings. However, the size of the seedling in the nursery does not necessarily correlate closely with survival rate after out-planting. What is important is the proportional balance of the shoot and root systems. The nursery trial results indicate that seedlings grown in hiko trays, although having significantly smaller diameter, height and number of leaves, can be considered as high quality seedlings. Large seedlings can become stunted when planted in the field. The relatively small size of seedlings in hiko trays is attributed to the size of the container. The volume of the potting mix needed for one cell in a hiko tray is only about one third of that in a polybag. This means a smaller quantity of potting mix required. In addition, the soil volume in the potting container dictates the maximum age of seedlings it can support, and that the shorter the time required for the plant to become plantable, the lower the cost it will involve. The smaller size of the hiko trays is disadvantageous in that more frequent watering of seedlings is required because of the small quantity of substrate. The regular spacing of the cells in each tray also has some advantage in producing a more or less uniform diameter and height of seedlings. This characteristic of seedlings in hiko trays has an advantage in field performance because with a relatively homogenous size of seedlings in the nursery, a more or less homogenous stand can be expected in the future.

This poor root formation of seedlings grown in polybags is due to the bag structure that allows spiraling of roots once they hit the smooth inner surface. Unlike polybags, the structure of hiko trays has been important in controlling root deformities. The vertical ribs in each cell in the hiko trays train roots downward thus avoiding root spiraling. The hole in the bottom of the cell facilitates natural air-pruning and drainage of excess water. This structure of the hiko trays helps the seedlings to remain firm against windthrow when planted in the field.

Shading the seedlings for 4 weeks has been found to slow the growth of seedlings. Seedlings grown with 4 weeks shading were found to have slower growth compared to seedlings under shade for only two weeks. The argument here is not about the size of the seedling but rather on the ability of the seedlings to withstand field conditions – known as the hardening process. Seedlings are required to have not only good root-shot balance and freedom from root deformities, but also be well hardened so that survival in the field is more or less secured.

CONCLUSION

Seedlings grown in hiko trays were found to be generally smaller than those grown in polybags (due to the difference in container size) but the quality of the former can be considered high because the occurrence of root coiling is minimised. The occurrence of J-rooting can be reduced by trying other possible sowing methods, apart from sowing in conventional germination trays and transplanting to pots. Shading for only two weeks is enough before seedlings are hardened. Farmers who have had hands-on experience in using hiko trays and polybags as potting containers for seedling production perceived seedlings grown in hiko trays to be of high quality because, having limited root growth, they grow straight with a firm stem and small size. As perceived by both farmers and ACIAR researchers, hiko tray-grown seedlings are of high quality exhibiting sturdy shoot, trained roots and homogenous growth – a new definition of a quality seedling.

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