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Growing tropical tree planting stock in root trainers: Cell volume, seedling density and growing media

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ABSTRACT

The influence of root trainer cell volume and seedling density, and composition of growing media was examined in relation to morphological, biomass and seedling quality parameters of four-month old planting stock of three tropical broadleaved tree species viz., *Acacia catechu*, *Azadiractha indica* and *Pongamia pinnata*. The study revealed that a cell volume of 90 cm^3 was not sufficient for proper seedling growth of *A. catechu* and *A. indica*. However, clear-cut superiority of 300 cm^3 cell volume was evident only in the case of *A. indica*. It appeared that root trainer pots of 150 cm^3 cell volume were suitable for growth of planting stock of *A. catechu* and *P. pinnata* and 300 cm^3 cell volume for *A. indica*. Significant differences in the growth of planting stocks were observed among growing media treatments. Overall the tree species exhibited fast growth and high biomass as well as favorable seeding quality in growing media containing 80% compost with either sand (*A. catechu* and *A. indica*) or soil (*P. pinnata*) than the other treatments having 50%, 60% or 100% compost.

Keywords: biomass, height and root collar diameter, hiko pots, seedling quality

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INTRODUCTION

Most tropical forest nurseries have predominantly used polythene bags for raising planting stock despite the inherent disadvantages of these containers. Research shows that use of these containers result to poor root development and subsequent poor establishment of grown stock in the field (Burden, 1979; Sharma, 1987; Venator *et al.* 1985). However, the popularity of polythene bags in tropical nurseries is more of a function of the apparent hardiness of the seedlings being grown than actual beneficial attributes (Wilson, 1986). In recent years, the use of root trainer pots has increased but species-specific technical packages with experimentally proven prescriptions about cell volume, seedling density and growing media have not been developed for most of the important tropical broadleaved forestry species. Hence, this study was conducted to standardize root-trainer stock production prescriptions for three important tropical broadleaved trees including, *Acacia catechu*, *Azadiractha indica* and *Pongamia pinnata* by investigating the influence of cell volume, seedling density and the composition of growing media.

MATERIALS AND METHODS

Two experiments involving *Acacia catechu* (S_1), *Azadiractha indica* (S_2) and *Pongamia pinnata* (S_3) were carried out during the months of March to June (the usual planting stock growing period in India for planting during the monsoon rains in July- August) at the Model Research Nursery, Tropical Forest Research Institute, Jabalpur (23° 10' N, 79° 59' E). Three different types of root trainers (hiko pots) with varying cell volume and seedling density were used in the first experiment (Table 1). They were filled with a uniform growing medium of compost and sand in a ratio of 4:1 based on earlier study conducted in the same nursery on appropriate growing medium for root trainer seedling production of some tropical trees (Singh *et al*. 2004). In the second experiment five growing media comprised of compost in varying proportions with soil and/or sand were evaluated for seedling growth in root trainer pots (Table 2). In both of these experiments the experimental design was a randomized block design replicated four times with each replication having 40 seedlings. Pre-germinated seeds were placed in root trainer cells. The seedlings were watered regularly (twice a day).

Table 1. Cell volume and seedling density of root trainers (Hiko pots) in experiment 1.

Treatments	Cell volume (cm^3)	Seedling density (seedlings m^{-2})
T_1 (90 cm^3; 575 seedlings m^{-2})	90	575
T_2 (150 cm^3; 225 seedlings m^{-2})	150	225
T_3 (300 cm^3; 144 seedlings m^{-2})	300	144

Table 2. Composition of growing media treatments in experiment 2.

Treatments	Components (%)		
	Compost	Nursery Soil	River Sand
T_1	50	25	25
T_2	60	20	20
T_3	80	0	20
T_4	80	20	0
T_5	100	0	0

Seedling height and root collar diameter were measured during the first week of July by removing all the seedlings of each replicate from the root trainer pots. However, for the study of root system and biomass parameters, ten seedlings per replication were randomly selected. The root plugs were gently washed with water to remove particles of growing medium which had adhered to them. After that shoot and root components were separated and oven dried at 70^{o}C to record biomass (weight in g/seedling). The data on seedling height, root collar diameter and biomass (shoot, root and total) were statistically analyzed employing analysis of variance (ANOVA), '*F*'-test to ascertain significance at $p \leq 0.05$ and least significant difference ($LSD_{0.05}$) values to separate means in different statistical groups (Gomez and Gomez, 1984) using 'SX' (Statix PC DOS version, 1985, 1987; NH Analytical software). Based on the data recorded, secondary parameters were calculated to assess the overall seedling quality. These included a sturdiness quotient (calculated as the height in cm/diameter in mm), a volume index [(Diameter in mm)^2 x height in cm] and a Dickson quality index (total seedling dry weight in g/ sturdiness quotient + shoot/root dry weight ratio; after Dickson *et al.* 1960).

RESULTS

Influence of container volume and seedling density on seedling growth

Significantly superior ($p \leq 0.05$) morphological features as well as shoot and total biomass production were recorded in the seedlings raised in 300 cm^3 hiko pots with a density of 144 seedlings m^{-2} (T_3) in *A. catechu* and *A. indica* (Table 3). All the species exhibited significantly different ($p \leq 0.05$) root biomass in various treatments. In *A. catechu* and *P. pinnata* T_2 (150 cm^3; 225 seedlings m^{-2}) and T_3 recorded statistically similar but higher root biomass production than 90 cm^3 root trainer pots. Container volume of 300 cm^3 was proved the best for root biomass in *A. indica*.

Among quality parameters, the best sturdiness quotient was revealed in 300 cm^3 root trainer pots (144 seedlings m^{-2}) for *A. indica* and *P. pinnata* and T_1 (90 cm^3; 575 seedlings m^{-2}) for *A. catechu* while superior root shoot ratio was recorded in T_3 in *A. indica* (Table 4). The remaining two species leaving *P. pinnata* exhibited maximum values of volume and Dickson quality indices in T_3. In *P. pinnata* the highest value of Dickson quality index was recorded in 150 cm^3 root trainer pots.

Influence of growth media on seedling growth

Among the morphological parameters, height, root collar diameter, shoot biomass, root biomass and total biomass, the growing media treatments significantly influenced ($p \leq 0.05$) seedling height in *A. catechu* (the best- 25 cm in T_3 having 80% compost with 20% sand) and root collar diameter in *A. indica* and *P. pinnata*, with T_3 (5.08 mm) and T_4 i. e. 80% compost with 20% soil (5.34 mm) respectively being the best treatments. *A. indica* also recorded statistically superior ($p \leq 0.05$) shoot biomass and total biomass production in T_3 along with T_5 (100% compost) than other growing media (Table 5).

Three out of four quality parameters, i. e. the sturdiness quotient, volume and the Dickson Quality index showed the superiority of T_3 over other treatments in case of *A. indica*. The values for Dickson quality index were almost similar for all treatments in *A. catechu* and *P. pinnata* but volume

Table 3. Morphological and biomass characteristics of seedling of tree species in different treatments of cell volume and seedling growing density

Treatment	Height (cm)			Root collar diameter(mm)			Shoot biomass (g $seedling^{-1}$)			Root biomass (g $seedling^{-1}$)			Total biomass (g $seedling^{-1}$)		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
T_1	12.41	9.08	19.00	3.22	4.02	5.43	3.78	0.66	1.62	0.89	0.29	1.41	4.37	0.95	3.03
T_2	13.12	9.71	18.50	3.41	4.16	5.32	3.65	0.69	1.71	1.01	0.34	1.52	4.66	1.03	3.23
T_3	15.16	10.13	18.50	4.11	4.26	5.43	4.19	0.75	1.93	1.09	0.39	1.62	5.28	1.14	3.04
$LSD_{0.05}$	1.30	0.30	NS	0.04	0.07	NS	0.05	0.01	NS	0.01	0.05	0.14	0.05	0.01	NS

T_1 - 90 cm^3; 575 seedlings m^{-2}
T_2 - 150 cm^3; 225 seedlings m^{-2}
T_3 - 300 cm^3; 144 seedlings m^{-2}

Table 4. Quality parameters of seedling of tree species in different treatments of cell volume and seedling growing density.

Treatment	Sturdiness quotient			Root Shoot ratio			Volume index			Dickson quality index		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
T_1	3.86	2.26	3.50	0.26	0.44	0.89	128.43	164.40	559.18	1.06	0.21	0.69
T_2	3.85	2.33	3.48	0.28	0.49	0.89	152.19	168.11	523.59	1.13	0.24	0.74
T_3	3.69	2.38	3.41	0.26	0.52	0.90	256.08	183.40	545.59	1.34	0.27	0.71

T_1 - 90 cm^3; 575 seedlings m^{-2}
T_2 - 150 cm^3; 225 seedlings m^{-2}
T_3 - 300 cm^3; 144 seedlings m^{-2}

Table 5. Morphological and biomass characteristics of seedling of tree species in different growing media treatments.

Treatment	Height (cm)			Root collar diameter(mm)			Shoot biomass (g seedling^{-1})			Root biomass (g seedling^{-1})			Total biomass (g seedling^{-1})		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
T_1	11.37	22.50	22.80	3.70	2.66	5.04	0.62	1.48	1.12	0.38	1.33	1.00	1.00	2.82	2.14
T_2	11.92	23.50	22.75	3.70	2.68	4.87	0.61	1.50	1.11	0.39	1.30	1.07	1.01	2.80	2.25
T_3	12.52	25.00	24.75	5.08	2.83	5.04	0.91	1.58	1.17	0.54	1.29	1.08	1.46	2.86	2.24
T_4	12.50	21.75	23.50	3.73	2.66	5.34	0.65	1.40	1.11	0.43	1.28	0.92	1.09	2.68	2.03
T_5	12.95	23.75	23.75	4.02	2.83	5.03	0.94	1.51	1.13	0.52	1.33	1.07	1.46	2.86	2.20
$LSD_{0.05}$	NS	0.14	NS	0.09	NS	0.07	0.09	NS	NS	NS	NS	NS	0.06	NS	NS

Table 6. Quality parameters of seedling of tree species in different growing media treatments.

Treatment	Sturdiness quotient			Root Shoot ratio			Volume index			Dickson quality index		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
T_1	30.71	84.74	45.22	0.60	0.90	0.90	155.82	158.60	579.61	0.27	0.30	0.40
T_2	32.17	87.62	46.71	0.63	0.87	0.96	163.62	169.03	539.55	0.26	0.29	0.40
T_3	24.66	88.43	49.08	0.55	0.82	0.93	322.71	199.79	629.18	0.48	0.30	0.38
T_4	33.53	81.92	44.03	0.65	0.92	0.83	173.63	153.31	669.36	0.27	0.29	0.39
T_5	32.25	83.86	47.19	0.56	0.88	0.94	208.75	190.48	601.37	0.38	0.31	0.39

index indicated T_3 (322.71) being the best for the former and T_4 (669.36) for the latter. T_4 treatment also had the best sturdiness quotient (44.03) in *P. pinnata* (Table 6).

DISCUSSION

Influence of container volume and seedling density on seedling growth

Optimum container size varies according to species, desired size of seedlings, growing density and medium, environmental conditions and length of growing season (Landis, 1990). Increase in container volume (and thus rooting volume) generally results in enhanced rate of growth and increased seedling size (Carlson and Endean, 1976; Alm *et al*. 1982; Liegel and Venator, 1987). However, the benefits of large containers should be weighed with the higher cost per seedling produced. Ideally, the smallest container which gives satisfactory survival and growth for a given species should be used (Evans, 1982).

Results of this investigation indicated that a cell volume of 90 cm^3 is not sufficient for proper growth of seedlings of the tropical broadleaved tree species under study viz., *A. catechu*, *A. indica* and *P. pinnata*. However, the superiority of root trainer pots of 300 cm^3 volume was evident only in the case of *A. indica* for all morphological, biomass and quality parameters. In *P. pinnata*, the effect of cell volume was observed only for root biomass with both 150 and 300 cm^3 cell volume having statistically similar results. The improvement in quality of seedlings from 150 cm^3 to 300 cm^3 root trainer pots was not substantial for *A. indica* as evident from the all four quality parameter values calculated in this study. For example, the increase in volume index in this species is only 9% compared to 68% increment in *A. catechu*. Overall, it may be ascertained that except for *A. indica* which demands a cell volume of 300 cm^3, the other two species can be grown in root trainers of cell volume of 150 cm^3 without comprising seedling quality. Smaller cells with lesser seedling space will also help economize on the cost of seedling production in these species due to low inputs and more seedlings compared to larger trays.

Tree seedlings also require a certain minimum amount of growing space, which varies with species and age (Simpson, 1991, 1994; Singh *et al*. 2005). In general tropical broadleaved species tend to require large containers with their concomitant lower growing density than conifers and eucalypts as their large leaves intercept more water and nutrients and generate more shade. Therefore, spacing of seedlings in root trainer pots is crucial for shoot development, seedling growth and stem form. This seems a plausible cause of superior morphology, shoot and root biomass and quality production of broadleaved species under investigation in larger volume cells with more espacement and thus lower density. In conclusion, root trainers of 150 cm^3 cell volume (providing 225 seedlings m^{-2}) are suitable for growing quality planting stock of *A. catechu* and *P. Pinnata* and 300 cm^3 (providing 144 seedlings m^{-2}) for *A. indica.*

Growing media

Compared to field-grown plants, seedlings raised in containers have access to a very limited amount of growing medium (Swanson, 1989). They have unique functional requirements which must be supplied by the growing medium (Mastalerz, 1977). Milk *et al*. (1989) emphasized that plants growing in small containers often experience growth problems due to poor aeration or low water holding capacity of the growing medium. Therefore, the textural properties of growing medium must be carefully chosen and blended to produce right mixture of porosity that will persist over the growing cycle (Landis, 1990).

Incorporation of organic material such as compost prepared in the nurseries from locally abundant weeds and leaf litter can considerably improve aeration and water holding capacity of the growing medium at minimal cost. The first scientifically standardized horticultural growing medium in England during 1930s contained a loam-based compost (Bunt, 1988). The media containing compost from agricultural wastes have been reported to enhance height, stem diameter and biomass of ornamentals (Chen *et al*. 1988). In some of the experiments, compost-based media have outperformed peat-based media (Lamrana *et al*.

1991; Fitzpatrick, 1994; Pronk *et al.* 1995). However, species-specific variations in root architecture and nutritional requirements deserve to be taken into account before deciding the proportion of compost in a growing medium. In the present investigation, all the tree species exhibited better growth, biomass as well as seedling quality in growing media containing 80% compost with either sand or soil. This is in contrast to traditional prescriptions of growing media being followed by Indian forest nurseries having compost (or farm yard manure) not more than 25 % invariably with both forest soil and sand either 25% or 50%. However, we recommend growing media having 80% compost which seemed to have not only ensured required nutritional input during the growing period but also enhanced porosity and water holding capacity of the medium for raising planting stock of *A. catechu*, *A. indica* and *P. pinnata* in root trainers.

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