# Refinement of potting medium ingredients for production of high quality seedlings of sandalwood (*Santalum album* L.)

D. Annapurna[1], T.S. Rathore[1,2] and Geeta Joshi[1]

[1]Tree Improvement and Propagation Division, Institute of Wood Science and Technology, 18th Cross, Malleswaram, Bangalore 560 003, India
[2]Email: tsrathore@iwst.res.in

Revised manuscript received 18 October 2004

## Summary

This study was undertaken in order to refine the potting medium and improve seedling growth of *Santalum album* L. in root trainers. The potting medium ingredients, including sand, soil, compost, cocopeat, burnt rice husk and charcoal, were tested in fourteen combinations in 270 mL block-type root trainers using *Cajanus cajan* as a pot host.

A medium consisting of sand, soil, compost, burnt rice husk (BRH) and charcoal in the ratio of 25:15:50:5:5 favoured overall seedling growth in terms of height, collar diameter, shoot dry weight, root dry weight, total dry weight, root fibrosity and quality index at age 6 mo. The next best medium was a mixture of sand, soil and compost in the ratio 35:15:50. Where rice husk and charcoal are not available, this second medium may be used to produce good quality seedlings.

The best potting medium for sandalwood had up to 60% organic matter mixed with sand and soil. This medium had low bulk density, good aeration and water-holding capacity, encouraged lateral root formation, and ensured good plug formation and easy plug removal. A high proportion of sand, soil or organic matter caused poor seedling growth.

*Keywords:* seedling growth; quality; containers; container grown plants; growing media; ingredients; bulk density; water holding capacity; porosity; *Santalum album*; *Cajanus cajan*

## Introduction

*Santalum album* L. is commonly known as sandalwood or 'Chandan'. The tree is a hemi-root parasite of the family Santalaceae, and is highly prized for its scented wood and oil. Over-exploitation and illicit felling has resulted in genetic erosion and a decline in natural populations. Although demand for sandalwood and oil is increasing, supplies are declining and prices increasing (Shashidhar and Arun Kumar 1999; Ananthapadmanabha 2000; Fox 2000; Padmanabha 2002). Plantations based on high-quality planting material are essential in order to meet the demand and preserve some of the natural *S. album* resource.

In India, sandalwood seedlings have traditionally been raised in 1500 mL polybags to produce plantable seedlings 30 cm high with a dark brown stem (Rai 1990). However, Annapurna *et. al.* (2004) showed that good quality seedlings could be raised in root trainers as small as 270 mL in size. This present study continues to examine the raising of sandalwood seedlings by examining the optimum potting medium.

The potting medium traditionally used in India consists of sand, soil and farmyard manure in a 2:1:1 ratio (Rai 1990). In Timor, the addition of 37% sand to a local soil produced the best seedling growth (Fox *et. al.* 1990). In Western Australia, a mixture of sand, peat and perlite in a 3:2:2 ratio has been used to produce plantable sandalwood seedlings in 5–6 mo using *Alternanthera nana* as the pot host (Radomiljac 1998).

In India, Annapurna (2002) attempted to identify an optimum potting medium by investigating eight different combinations of sand, soil, compost, cocopeat, burnt rice husk and charcoal. A mixture of sand, soil and compost in the ratio 40:10:50 produced the best overall growth, with firm plug formation after 7 mo. A mixture of sand and compost in a 25:75 ratio produced seedlings with better height growth, but with a poorer root:shoot ratio.

The present study was undertaken in order to further refine the potting medium. The objectives were to (i) reduce the bulk density of the medium, (ii) support better seedling growth and plug formation, (iii) reduce the time taken to raise plantable seedlings, and (iv) meet the characteristics of an ideal potting mix as defined by Miller and Jones (1995) and Chakrabarthi *et al.* (1998).

## Materials and methods

Sandalwood seeds were collected in November 1998 from the Clonal Germplasm Bank (Gottipura), Bangalore, India. Seeds were depulped, washed thoroughly in water, dried under shade and stored in airtight containers. Seeds were graded by removing both the very small and very large. Graded seeds were pre-treated with 0.05% gibberellic acid (w/v) for 16 h. Pre-treated seeds were sown in sand trays for germination under shade in the nursery. Sand was kept moist by daily watering. At 35–40 d, seedlings at the two-leaf stage were used for this experiment.

The potting medium ingredients were subjected to mechanical, physical and chemical analysis (Table 1). After being sieved through a mesh with 6 x 6 holes in.$^{-2}$, the ingredients were used in 14 different combinations or treatments (Table 2). In all treatments, deoiled neemcake (10 kg m$^{-3}$) and single superphosphate (SSP, 4.5 kg m$^{-3}$) were added for nutritional enrichment. Deoiled neem seed cake is the residue remaining after extraction of oil from the neem seed; its use as manure has been recommended by the

**Table 1.** Physical, mechanical and chemical analysis of potting medium ingredients

| Property | Soil | Sand | Cocopeat | Compost | Neem cake |
|---|---|---|---|---|---|
| *Physical properties* | | | | | |
| Bulk density (g $cc^{-1}$) | 0.90 | 1.40 | 0.08 | 0.22 | – |
| Water holding capacity (%) | 71.06 | 26.23 | 960.66 | 429.40 | – |
| Porosity (%) | 63.84 | 36.83 | 72.99 | 93.41 | – |
| Volume expansion (%) | 2.31 | 3.43 | 0.72 | 9.24 | – |
| *Mechanical properties* | | | | | |
| Fine sand content (%) | 29.95 | 0.55 | 2.20 | 2.00 | – |
| Coarse sand content (%) | 42.55 | 96.95 | – | – | – |
| Silt content (%) | 25.00 | – | 5.00 | 3.50 | – |
| Clay content (%) | 2.50 | 2.50 | – | – | – |
| *Chemical properties* | | | | | |
| Nitrogen (%) | 0.16 | 0.001 | 1.42 | 2.12 | 1.82 |
| Phosphorus (%) | 0.01 | 0.0002 | 0.10 | 0.15 | 0.53 |
| Potassium (%) | 0.18 | 0.0002 | 0.60 | 0.84 | 0.80 |
| Calcium and magnesium (%) | 1.00 | 3.00 | 3.00 | 2.00 | |
| Sulphur (ppm) | 1040 | 4.00 | 932 | 1972 | 1200 |
| pH | 7.50 | 8.3 | 5.50 | 6.20 | 5.20 |
| Electrical conductivity (m mho $cm^{-1}$) | 0.06 | 0.03 | 0.25 | 0.23 | 0.45 |

**Table 2.** The composition of the potting medium in each experimental treatment (%)

| Treatment | Sand | Soil | Compost | Cocopeat | Burnt rice husk (BRH) | Charcoal |
|---|---|---|---|---|---|---|
| T1 | 20 | – | 55 | 15 | 5 | 5 |
| T2 | 25 | – | 50 | 15 | 5 | 5 |
| T3 | 25 | 15 | 50 | – | 5 | 5 |
| T4 | 25 | – | 55 | 10 | 5 | 5 |
| T5 | 25 | 10 | 55 | – | 5 | 5 |
| T6 | 30 | – | 50 | 10 | 5 | 5 |
| T7 | 30 | – | 55 | 10 | 5 | – |
| T8 | 35 | 15 | 50 | – | – | – |
| T9 | 25 | 25 | 50 | – | – | – |
| T10 | 20 | 20 | 60 | – | – | – |
| T11 | 20 | – | 80 | – | – | – |
| T12 | – | 20 | 80 | – | – | – |
| T13 | – | – | 100 | – | – | – |
| T14 | 50 | 25 | 25 | – | – | – |

Indian Standards Institute (Anon. 1990). Neem seed cake not only provides nutrients but also controls soil-borne pathogenic fungi and pests, particularly nematodes, and reduces loss of nitrogen by nitrification (Korah and Shigte 1968; Schmutterer 1995). Fungicide, Indophil M-45™, and nematicide, Phorate™ (0.25 kg $m^{-3}$, each), were used as prophylactic measures against soil-borne pathogenic microbes and pests. The experiment was conducted from May 1999 to October 1999 at the Institute of Wood Science and Technology nursery at Nagaroor, 17 km from Bangalore, India. The experiment was set out in a completely randomized design with 4 replicates and 24 seedlings in each replicate.

Block-type black root trainers were used; each block had 12 cells each of 270 ml volume with 5 ridges. *Cajanus cajan* was used as the primary host; it was planted 7 d after transplanting sandalwood seedlings into root trainers. Host plants were pruned at intervals of 15 d. After 3 mo, nutrient sprays of Nitrophoska™ containing macronutrients (nitrogen, 19%; phosphorus, 19%; potassium, 19%; magnesium, 0.5%; sulphur, 0.3%) and micronutrients (boron, 0.013%; copper, 0.4%; iron, 0.1%; manganese, 0.1%; molybdenum, 0.003%; and zinc, 0.038%) were applied at 0.5 g $L^{-1}$ (w/v in water) at monthly intervals to boost growth of seedlings.

Height and collar diameter of all seedlings were recorded at the end of the 3rd, 4th, 5th and 6th months. Sturdiness quotient (SQ) was calculated by dividing the seedling height (cm) by collar diameter (mm) (Roller 1977).

At the termination of the experiment, three randomly-selected seedlings from each replicate were carefully uprooted, without disturbing the root system, and washed in running tap water. To remove excess water, they were placed between folds of blotting paper. The seedling stems were cut at the collar region, dried separately at 80°C in a hot air oven in paper bags, and weighed using a top pan electronic balance. The root:shoot dry weight ratio was calculated by dividing the weight of dry root by the weight of dry shoot of each plant, separately. Fibrosity was calculated by dividing the dry weight of first- and second-order lateral roots by the dry weight of primary roots (Hatchel and Muse 1990). Quality index QI was assessed using the formula of Dickson *et al.* (1960), where D is seedling dry weight (g), H is height (cm), CD is collar diameter (mm), SD is shoot dry weight (g), and RD is root dry weight (g):

$$QI = \frac{D}{(H / CD) + (SD / RD)} .$$

## Results

The treatments showed significant differences for collar diameter from the 3rd month, and for height from the 4th month. At 4 mo, the greatest height (17.37 cm) and collar diameter (3.05 mm) were expressed by treatment T10, which consisted of sand, soil and compost in a ratio of 20:20:60. The minimum values for height (14.43 cm) and collar diameter (2.57 mm) were recorded in T4, which consisted of sand, compost, cocopeat, BRH and charcoal in the ratio of 25:55:10:5:5. At 5 mo, T3 (sand:soil:compost: BRH:charcoal = 25:15:50:5:5) showed maximum height and collar diameter of 18.76 cm and 3.10 mm, respectively. At 6 mo, seedlings in T3 were still tallest (19.50 cm), though collar diameters in T14 and T9 were now largest (3.21 mm) (Figs 1 and 2, and Table 3). The five treatments, T3, T8, T9, T10 and T14, in which the compost component was <60% and the soil 15–25%, were better for seedling growth in terms of height and collar diameter. Consistently, T4 seedlings were the shortest (16.24 cm) and had the smallest collar diameter (2.61 mm). There were no significant differences between treatments in the sturdiness quotient.

Maximum shoot dry weight (1.39 g), root dry weight (1.13 g), total dry weight (2.52 g) and quality index (0.325) were recorded in T3, which was significantly superior to all other treatments. This was followed by T5, T8, T10 and T12 (Table 3). The other important features of seedling quality relate to fibrosity, plug formation and removal of seedlings. The treatments T3, T5 and T8, consisting of sand 20–35%, soil 10–20% and compost 50–60%, showed better plug formation. Of the above treatments, fibrosity (lateral root development) was greatest in T3 (0.83), followed by T8 (0.71) and T5 (0.60) (Figs 1 and 2). The proportion of soil was 10–15%, which resulted in easy plug removal. In contrast, treatments T10 and T12, which contained 20% soil, resulted in lower fibrosity (0.49 and 0.53 respectively) and difficulty in removing seedlings.

Media with a high proportion of organic matter, particularly cocopeat (T4 and T6), showed poor seedling growth in terms of height, collar diameter, shoot dry weight, root dry weight and total dry weight. The quality index was lowest in T6 (0.130), and the index was similar in T11, T13, T4, T2, T7, T9 and T1.With the exception of T9, soil was absent in all these treatments.

There were linear correlations between height and total dry weight ($r^2 = 0.567$), height and quality index ($r^2 = 0.602$), and total dry weight and quality index ($r^2 = 0.976$, Fig. 3) within the range of potting media used.

## Discussion

Vigorous root growth, promoting development of haustoria and in turn increasing shoot growth, will be reflected in total dry weight, which may consequently be a good indicator of seedling quality, as concluded by Fox *et al.* (1990).

A combination of organic matter up to 60%, sand and soil in the potting medium produced the best seedling growth. The potting medium consisting of sand, soil, compost, burnt rice husk and charcoal in the ratio of 25:15:50:5:5 (T3) exhibited the best overall seedling growth. This treatment provided favourable conditions for aeration and water holding capacity. Further, it was shown that by using burnt rice husk, charcoal (each 5%)

**Table 3.** Properties of seedlings of *S. album* grown for 6 mo in 270 mL block-type root trainers filled with experimental media (± std deviation)

| Treatment | Height (cm) | Collar diameter (mm) | Sturdiness quotient (SQ) | Shoot dry weight (g) | Root dry weight (g) | Total dry weight (g) | Root:shoot ratio | Root fibrosity | Quality index | Plug removal* |
|---|---|---|---|---|---|---|---|---|---|---|
| T1 | 17.89± 3.42 | 2.83± 0.64 ab | 6.34± 1.33 | 0.87± 0.23 ab | 0.61± 0.12 ab | 1.48± 0.33 ab | 0.73± 0.14 | 0.47± 0.13 a | 0.189± 0.03 ab | I |
| T2 | 17.71± 3.62 | 2.84± 0.67 b | 6.26± 1.48 | 0.85± 0.16 ab | 0.46± 0.19 a | 1.30± 0.22 ab | 0.55± 0.14 | 0.70± 0.20 b | 0.154± 0.022 ab | I |
| T3 | 19.50± 3.08 | 3.16± 0.50 b | 6.18± 0.92 | 1.39± 0.24 c | 1.13± 0.26 c | 2.52± 0.57 c | 0.81± 0.09 | 0.83± 0.22 b | 0.325± 0.06 c | II |
| T4 | 16.26± 3.84 | 2.61± 0.63 a | 6.34± 2.64 | 0.64±0.15 a | 0.45± 0.04 a | 1.08± 0.20 a | 0.72± 0.11 | 0.62± 0.19 ab | 0.138± 0.03 ab | I |
| T5 | 18.23± 3.99 | 2.89± 0.71 ab | 6.34± 1.63 | 1.01± 0.14 b | 0.79± 0.16 b | 1.79± 0.17 b | 0.80± 0.22 | 0.60± 0.22 ab | 0.231± 0.02 b | II |
| T6 | 17.80± 3.82 | 2.78± 0.71 ab | 6.43± 1.32 | 0.68± 0.08 a | 0.39± 0.09 a | 1.07± 0.15 a | 0.57± 0.10 | 0.71± 0.27 b | 0.130± 0.02 b | II |
| T7 | 17.61± 3.52 | 3.00± 0.75 b | 5.86± 1.10 | 0.66± 0.22 a | 0.53± 0.22 ab | 1.19± 0.44 a | 0.80± 0.11 | 0.56± 0.13 ab | 0.165± 0.06 ab | I |
| T8 | 18.43± 3.68 | 3.19± 0.72 b | 5.79± 1.16 | 1.06± 0.19 b | 0.78± 0.29 b | 1.84± 0.48 b | 0.72± 0.12 | 0.71± 0.22 b | 0.258± 0.08 bc | II |
| T9 | 18.67± 3.58 | 3.21± 0.71 b | 5.85±1.04 | 0.82± 0.11 ab | 0.55± 0.04 ab | 1.37± 0.16 ab | 0.68± 0.04 | 0.59± 0.25 ab | 0.181± 0.02 ab | III |
| T10 | 19.30± 4.73 | 3.16± 0.72 b | 6.12± 0.78 | 1.01± 0.15 b | 0.88± 0.37 b | 1.86± 0.48 b | 0.84± 0.22 | 0.49± 0.19 ab | 0.251± 0.07 b | III |
| T11 | 17.48± 3.73 | 2.73± 0.58 ab | 6.41± 1.39 | 0.67± 0.10 a | 0.42± 0.16 a | 1.08± 0.20 a | 0.63± 0.24 | 0.39± 0.12 a | 0.131± 0.02 a | II |
| T12 | 19.14± 4.21 | 3.07± 0.73 b | 6.25± 1.19 | 1.07± 0.32 b | 0.79± 0.23 b | 1.86± 0.44 b | 0.74± 0.10 | 0.53± 0.23 ab | 0.245± 0.07 b | III |
| T13 | 17.52± 3.16 | 2.75± 0.53 ab | 6.39± 1.06 | 0.67± 0.22 a | 0.45± 0.18 a | 1.12± 0.38 a | 0.67± 0.13 | 0.81± 0.26 b | 0.141± 0.09 ab | I |
| T14 | 19.43± 3.85 | 3.21± 0.72 b | 6.07± 0.97 | 0.82± 0.15 ab | 0.62± 0.07 ab | 1.44± 0.21 ab | 0.77± 0.05 | 0.42± 0.11 a | 0.201± 0.02 b | IV |
| LSD | – | 0.33 | – | 0.28 | 0.27 | 0.49 | – | 0.26 | 0.069 | – |

LSD = least significant difference at $\alpha = 0.05$. Values with the same letter are not significantly different at $\alpha = 0.05$

* Plug removal: I = very easily; II = easily; III = difficult; IV = very difficult

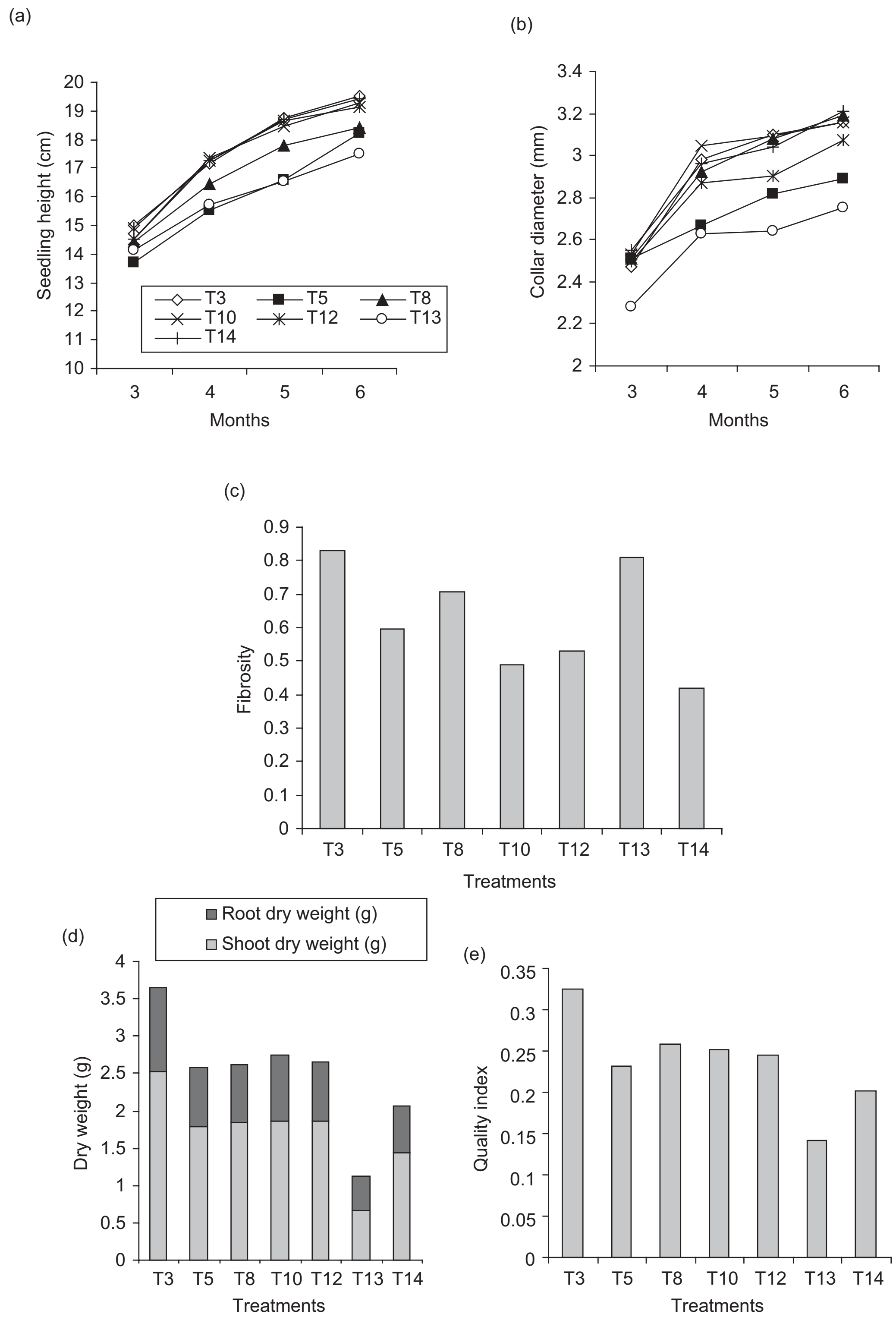


**Figure 1.** Effect of different potting media (T3, T5, T8, T10, T12, T13 and T14) on the height (a), collar diameter (b), fibrosity (c), dry weight (d) and quality index (e) of 6-mo-old seedlings of *S. album* in 270 mL root trainers

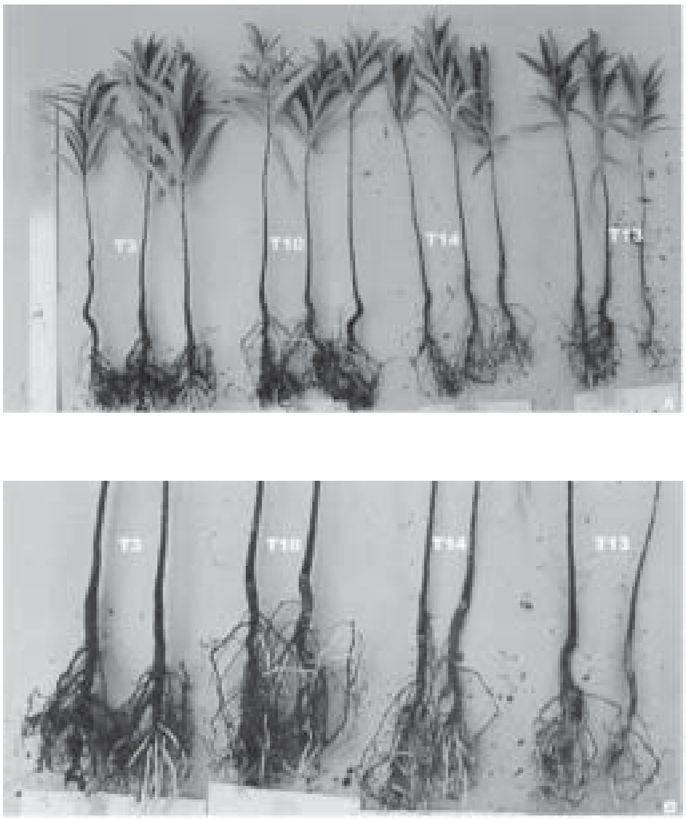


**Figure 2.** Effect of different potting medium ingredients and their ratios (T3 = sand, soil, compost, burnt rice husk and charcoal in the ratio 25:15:50:5:5; T10 = sand, soil and compost in the ratio 20:20:60; T14 = sand, soil and compost in the ratio 50:25:25; T13 = compost 100%) on the overall growth (top) and root system (bottom) of *S. album* seedlings at 6 mo in 270 mL block-type root trainers

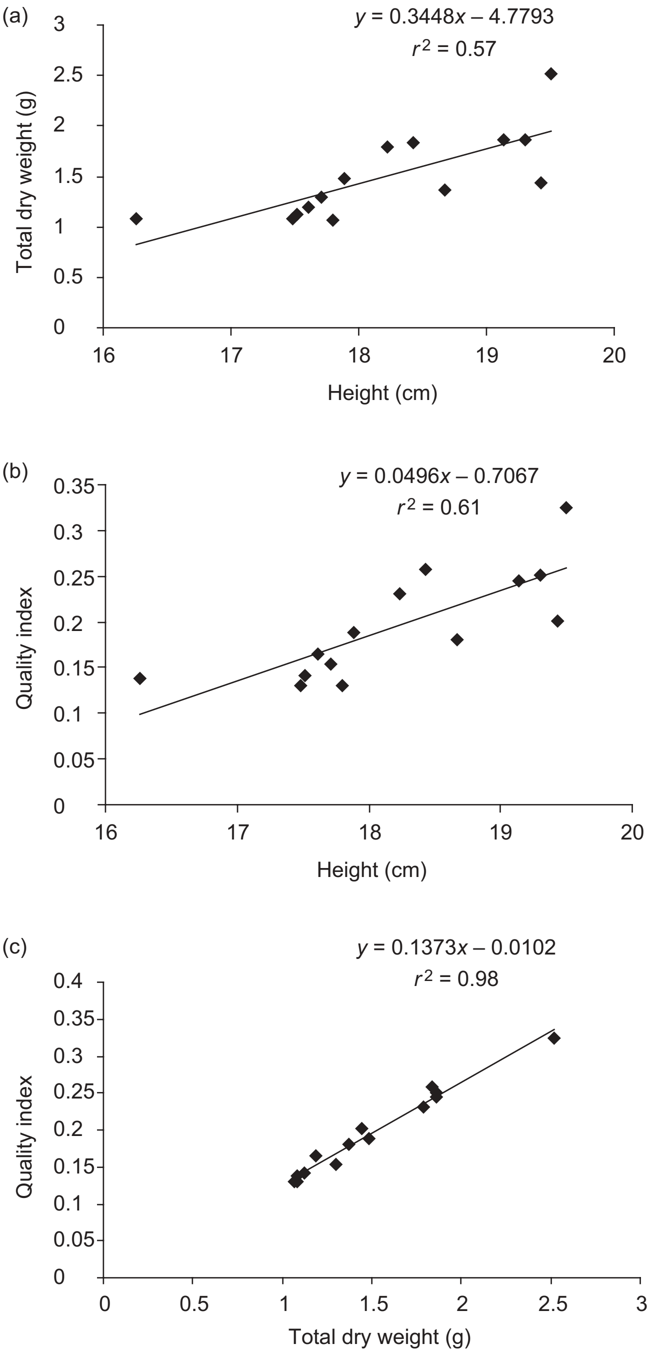


**Figure 3.** Inter-relationship between seedling height/dry weight (a), seedling height/quality index (b) and total dry weight/quality index (c)

and a soil proportion up to 15%, without change in the compost level (50%), bulk density can be reduced, and further improvement in overall seedling quality can be achieved, particularly in respect to root fibrosity, plug formation and easy removal of seedlings from the root trainers. In general, a low proportion of soil and greater lateral root growth leads to better plug formation and easy removal of seedlings. The T3 medium fulfilled many characteristics of the ideal potting mixture as described by Miller and Jones (1995) and Chakrabarti *et al.* (1998).

Further, where burnt rice husk and charcoal are not available, the sand proportion can be increased from 25% to 35% without compromising seedling quality (T8, consisting of sand, soil and compost in the ratio 35:15:50). Fox *et al.* (1990) recommended that the addition of sand up to 37.5% improved seedling growth in sandalwood.

This experiment confirmed that particle size within the potting medium has an indirect influence on seedling growth. In both the above treatments (T3 and T8), even though the sand proportion was reduced from 40% in the earlier experiment (to 25% and 35%), seedling growth was better. This might be due to increased size of particles, which improved aeration and porosity.

Use of soil up to 15% helps to bind the potting medium, and is a source of nutrients for both the host and sandalwood. Sandalwood prefers red loamy soils for its better performance in natural habitats (Rangaswamy *et al.* 1986). However, a soil proportion above 15% in the medium proved unsuitable because of compaction of the medium, and it had an adverse effect on root fibrosity/biomass. A good root environment with adequate aeration and low resistance to root penetration favours high root mass (Warkentin 1984).

A high level (>60%) of organic matter, particularly cocopeat, improved shoot biomass, but adversely affected root fibrosity, which is one of the most important parameters of seedling quality. Improved growth of seedlings using coconut husk (decomposed coir pith or cocopeat) as an organic potting medium ingredient has been reported in a number of species including *Pterocarpus macrocarpus* (Kijkar 1991), *Eucalyptus tereticornis* (Kumar and Marimuthu 1997) and *Swietenia macrophylla* (Woods *et al*. 1998). In the present study, however, incorporation of cocopeat in the medium did not improve overall growth of seedlings of *S. album*. This may be because it was used along with compost, resulting in high water holding capacity and poor aeration, and hence poor root growth.

The optimum proportion of the organic ingredient (compost) in the potting medium varies with species. In *Acacia nilotica* (Ginwal *et al.* 2001) and *Dalbergia sissoo* (Ginwal *et al.* 2002) a high proportion of organic matter — 80% compost — resulted in the best growth, whereas *Eucalyptus tereticornis* required only 40% (Srivastava *et al.* 1998).

## Conclusion

The potting media ingredients sand, soil, compost, burnt rice husk and charcoal sieved through 6 x 6 holes in.$^{-2}$ in the ratio of 25:15:50:5:5 produced the best seedling growth and fulfilled many characteristics of an ideal potting mix, including low bulk density, good lateral root formation, rapid plug formation and easy plug removal. Particle size has an indirect effect on seedling growth by influencing aeration porosity; particle size in the medium can be changed by changing the proportion of sand used.

## Acknowledgements

Dr K.S. Rao, Director, and Mr K.S. Reddy, Group Co-ordinator (Research and World Bank FREE Project), IWST, Bangalore have provided facilities and constant encouragement to carry out the present work. Chemistry of Non-Wood Products Division provided facilities for physical and chemical analysis. Financial support was provided by the World Bank under ICFRE, Forestry Research Education and Extension Project, Research on Sandal.

## References

Ananthapadmanabha, H.S. (2000) Sandalwood and its marketing trend. *My Forest* **36,** 147–151.

Annapurna, D. (2002) Investigations on seed variability, germination and modern nursery practices for mass production of quality seedlings of sandalwood, *Santalum album* L. PhD thesis, FRI Deemed University, Dehra Dun, India.

Annapurna, D., Rathore, T.S. and Geeta Joshi (2004) Effect of container type and size on the growth and quality of seedlings of Indian sandalwood (*Santalum album* L.). *Australian Forestry* **67,** 82–87.

Anon. (1990) Requirement of neem cake for manuring. Indian Standards Institute Specification No. 8558. In: Puri, H.S. *Neem — The Divine Tree* Azadirachta indica. Hardwood Academic Publishers, India, pp.129–131.

Chakrabarti, K., Zaidi, A. and Barari, S. (1998) Compost for container nursery — a West Bengal experience. *Indian Forester* **124,** 17–30.

Dickson, A., Leaf, A.L. and Hosner, J.F. (1960) Quality appraisal of white spruce and white pine seedling stock in nurseries. *Forestry Chronicle* **36,** 10–13.

Fox, J.E.D. (2000) Sandalwood: the royal tree. *The Biologist* **47,** 31–34.

Fox, J.E.D., Surata, I.K. and Suriamidhardja, S. (1990) Nursery potting mixture for *Santalum album* L. in Timor. *Mulga Research Centre Journal* **10,** 38–44.

Ginwal, H.S., Rawat, P.S., Bhandari, A.S., Krishnan, C. and Shukla, P.K. (2001) Selection of proper potting mixtures for raising *Acacia nilotica* seedlings under root trainer seedling production system. *Indian Forester* **127**(11)**,** 1239–1249.

Ginwal, H.S., Rawat, P.S., Bhandari, A.S., Krishnan, C. and Shukla, P.K. (2002) Evaluation of potting mixtures for raising *Dalbergia sissoo* seedlings under root trainer system. *Indian Forester* **128,** 523–532.

Hatchel, G.E. and Muse, D.H. (1990) Nursery cultural practices and morphological attributes of long leaf pine bare rootstock as indicators of early yield performance. *Southern Forest Experiment Station, USDA Forest Service Research Paper* No. SE 277, 34 pp.

Kijkar, S. (1991) *Handbook: Coconut Husk as a Potting Medium.* ASEAN-Canada Forest Tree Seed Centre Project, Muak-Lek, Saraburi, Thailand, 14 pp.

Korah, P.A. and Shingte, A.K. (1968) On the effect of non-edible oil cakes on the respiratory activity of soil. *Agricultural Research Journal of Kerala (India)* **6,** 95–97.

Kumar, A. and Marimuthu, T. (1997) Decomposed coconut coir pith — a good nursery media mix for *Eucalyptus* spp. *Indian Forester* **122,** 769–772.

Miller, J.H. and Jones, N. (1995) *Organic and Compost-Based Growing Media for Tree Seedling Nurseries*. World Bank Technical Paper No. 264, Forestry Series. The World Bank, Washington DC, 75 pp.

Padmanabha, H.S. (2002) Commercial sandalwood cultivation. *Fafai Journal* **4**(2)**,** 53–59.

Radomiljac, A.M. (1998) The influence of pot host species, seedling age and supplementary nursery nutrition on *Santalum album* Linn. (Indian sandalwood) plantation establishment within the Ord River irrigation area, Western Australia. *Forest Ecology and Management* **102,** 193–201.

Rai, S.N. (1990) Status and cultivation of sandalwood in India. In: Hamilton, L. and Conrad, C.E. (eds) *Proceedings of the Symposium on Sandalwood in the Pacific*. 9–11 April 1990. Honolulu, Hawaii. US Forest Service General Technical Paper PSW–122, pp. 66–71.

Rangaswamy, C.R., Ananthapadmanabha, H.S., Jain, S.H. and Nagaveni, H.C. (1986) Nutrient uptake and host requirement of sandal. *Van Vignan* **24,** 75–79.

Roller, K.J. (1977) *Suggested Minimum Standards for Containerised Seedlings in Nova Scotia.* Canadian Forestry Service, Department of the Environment, Information Report M-X, 69 pp.

Schmutterer, H. (1995) The neem tree, *Azardirachta indica* A. Juss., and other meliaceous plants: sources of unique natural products for integrated pest management, medicine, industry and other purposes. VCH Verlagsgesellschaft mhB, D-6951, Weinheim, Germany, pp. 367–477.

Shashidhar, K.S. and Arun Kumar, A.N. (1999) Trade in sandal (*Santalum album* L.). *Fafai Journal* **1**(4)**,** 51–56.

Srivastava, R., Nanhorya, R. and Upadhyaya, J.K. (1998) Selection of proper potting medium for root trainers of 'Eucalyptus Hybrid'. *Indian Forester* **124,** 502–510.

Warkentin, B.P. (1984). Physical properties of forest nursery soils: relation to seedling growth. In: Duryea, M.L. and Landis, D.T. (eds) *Forest Nursery Manual: Production of Bareroot Seedlings.* Martinus Nijhoff/Dr W. Junk Publishers, Boston, pp. 53–61.

Woods, P.V., Peseta, O. and Webb, M.J. (1998) Effectiveness of organic potting media for raising mahogany (*Swietenia macrophylla*) seedlings in western Samoa. *Journal of Tropical Forest Science* **10,** 555–560.