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Effect of growing media, nursery beds and containers on seed germination and seedling establishment of *Terminalia bellirica* (Gaertn.) Roxb., a multipurpose tree

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Abstract: *Terminalia bellirica* (Gaertn.) Roxb. (Vern. Behra, family Combretaceae) is found throughout the sub-Himalayan tract and is an important medicinal plant. A study was undertaken to determine the optimum conditions for germination and seedling growth of *T. bellirica* by using four different manures mixed with soil viz. celrich (bio-organic soil enricher), farmyard manure (FYM), goat and poultry manures, three types of nursery beds viz. sunken, flat and raised, three types of containers (having different volumes) and three types of soil viz. silt loam, sandy loam and sandy. Seedlings raised in different treatments in nursery for 12 months were planted in field to assess field growth. Experiments revealed maximum seed germination percent in the FYM and minimum in the poultry manure treatment. Maximum germination percent was recorded in sunken beds as compared to flat and raised nursery beds. Among different types of containers, 4000 ml-plastic pots showed maximum germination whereas the minimum was recorded in 350 ml-root trainers and 1600 ml-polybags. Survival percent was higher for seedlings raised in FYM, sunken beds, silt loam soil and 4000 ml-plastic pots compared to other treatments. The best combination for optimum germination and growth in nursery for *T. bellirica* was silt loam soil + FYM + sunken beds or 4000 ml-plastic pots. After 12 months of growth, height was greater in seedlings raised in soil mixed with FYM, sunken beds, silt loam soil and 4000 ml-plastic pots as compared to other treatments. Compared to other treatments collar diameter was higher in seedlings raised in goat manure, sunken bed, and silt loam soil and root trainer. Survival percent under field conditions was higher in seedlings raised in FYM and Celrich (bio-organic soil enricher) compared to other treatments (goat and poultry manures), whereas maximum height and collar diameter were recorded in seedlings raised in plastic pots.

Resumen: *Terminalia bellirica* Roxb. (Vern. behra, familia Combretaceae) se distribuye en toda la zona sub-Himalaya y es una planta medicinal importante. Se realizó un estudio para determinar las condiciones óptimas de germinación y crecimiento de plántulas de *T. bellirica* mediante el uso de cuatro abonos diferentes mezclados con el suelo,a saber Celrich (enriquecedor bio-orgánico del suelo), estiércol de corral (FYM), estiércol de cabra y gallinaza (estiércol de aves de corral), tres tipos de camas de vivero(hundida, plana y elevada), tres tipos de contenedores (con diferentes volúmenes) y tres tipos de suelo (franco limoso, franco arenoso y arenoso). Las plántulas cultivadas con los diferentes tratamientos en el vivero durante 12 meses fueronplantadas en el campo para evaluar el crecimiento de campo. El mayor porcentaje de germinación de semillas se obtuvo usando FYM y el menorcon el tratamiento de gallinaza. El mayor porcentaje de germinación se registró en las camas hundidas en comparación con las camas planas y las elevadas. Entre los diferentes tipos de contenedores, la germinación más alta se obtuvo en las macetas de plástico de 4000 ml, mientras que lamás baja se registró en las charolas 'entrenadoras de raíz' de 350 ml y las bolsas de plástico de 1600 ml. El máximo

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porcentaje de supervivencia se obtuvo para las plántulas cultivadas en FYM, camas hundidas, suelo franco limoso y macetas de plástico de 4000 ml en comparación con los otros tratamientos. La mejor combinación para la germinación y el crecimiento óptimos de *T. belliricaen* el vivero fuesuelo franco limoso + FYM + camas hundidas o macetas de plástico de 4000 ml. Después de 12 meses de crecimiento, la altura fue mayor en plántulas cultivadas en el suelo mezclado con FYM, camas hundidas, suelo franco limoso y macetas de plástico de 4000 ml en comparación con los otros tratamientos. Asimismo, el mayor diámetro del cuello se obtuvo en plántulas cultivadas en estiércol de cabra, camas hundidas, suelo franco limoso y charolas 'entrenadoras de la raíz'. El porcentaje de supervivencia en campo fue mayor en plántulas cultivadas en FYM y Celrich en comparación con otros tratamientos (estiércol de cabra y gallinaza), mientras que los mayores valores de altura y diámetro del cuello se registraron en plántulas cultivadas en macetas de plástico.

Resumo: A Terminalia bellirica Roxb. (Vern. Behra, família Combretaceae) ocorre em toda uma larga extensão sub-Himalaia e é uma importante planta medicinal. Este estudo foi realizado para determinar as condições ótimas para a germinação e crescimento das plântulas de T. bellirica usando quatro adubos diferentes misturados com solo com um enriquecedor bio-orgânico (celrich), estrume da exploração (FYM), estrume de cabra e de aves, três tipos de camas de viveiro como afundado, plana e elevada, três tipos de recipientes (com volumes diferentes) e três tipos de solo: limo-argiloso e areno-argiloso. As plântulas cultivadas sob diferentes tratamentos em viveiro durante 12 meses, foram plantadas no campo para avaliar o seu crescimento. A experimentação revelou que a percentagem de germinação máxima de sementes se verificou sob tratamento de FYM e a mínima com o uso de esterco de galinha. A experimentação mostrou ainda que a percentagem de germinação máxima foi registada em camas de viveiro afundadas em comparação com as camas planas e elevadas. Entre os diferentes tipos de recipientes, os sacos de plástico de 4000 ml vaso, mostraram uma germinação máxima enquanto a mínima foi registada para os recipientes formadores radiculares de 350 ml e sacos de poliéster de 1600 ml. Quanto à percentagem de sobrevivência ela foi maior para plântulas criadas em FYM, camas afundados, em solo limo-argiloso e 4000 ml de sacos de plástico, em comparação com os outros tratamentos. A melhor combinação para a germinação e crescimento ótimo em viveiro para a T. bellirica foi de solo limo-argiloso + FYM + camas afundadas ou sacos de plástico de 4000 ml. Após 12 meses de crescimento, a altura foi maior para as plântulas criadas numa mistura de terra com esterco, cama afundadas, solo limo-argiloso e sacos de plástico de 4000 ml, em comparação com outros tratamentos. Comparado com os outros tratamentos o diâmetro do colo foi maior em plântulas criadas em estrume de cabra, cama afundado, e em solo limo-argiloso e recipientes orientadores do sistema radicular. A percentagem de sobrevivência em condições de campo foi maior em plântulas criadas em FYM e Celrich (enriquecedor bio-orgânico do solo) em comparação com outros tratamentos (estrume de cabra e de aves), enquanto a altura máxima e o diâmetro do colo foram registados em plântulas desenvolvidas em sacos de plástico.

Key words: Collar diameter, farmyard manure, germination, growth, nursery, seedling, soil and survival.

Introduction

Terminalia bellirica (Gaertn.) Roxb. (Vern. Behra, family Combretaceae) known as "Vibhitaki" in Ayurveda, generally occurs throughout the sub-Himalayan tract up to 1200 - 1300 m and is usually common in Sal (*Shorea robusta* Gaertn.) and miscellaneous forests of the sub - tropical zone (Osmaston 1978). It is a large, deciduous tree attaining 40 - 50 m height and 3 - 4 m girth. The species is an important tree from commercial as well as traditional indigenous medicinal point of

view. Seed is edible; exocarp is one of the important components of a medicine commonly known as "Triphala churan" (used in bronchitis, cough problems, indyspepsia, constipation, impurity of blood and stomach problem) (CSIR 1985). Leaves are highly valued as fodder for milk cattle and are fed to tasar silkworm (Bhatia *et al.* 1977), and therefore, are lopped repeatedly (Luna 2005). Poles are used for making the beams of houses, handles of agricultural implements and furniture. Due to its non-durability, wood is not extensively used except for the manufacture of heavy packing cases, tea chests and black boards (CSIR 1985).

T. bellirica can be used for economic upliftment of the local inhabitants as fruits of the tree are sold at high premium in the market for preparing Triphala churan (Annonymous 1997). The species has been over-exploited because it is a resource of multiple use. Moreover, natural regeneration through seeds is poor because insects, cattle and rodents, damage exocarp though the undamaged seeds remain viable for one year (Luna 2005). Moreover, *T. bellirica* has not been included by forest department in any afforestation programme due to the problems associated with its poor germination because of hard seed coat (Negi *et al.* 1995). Owing to high demand for its seedlings in agroforestry plantation work (Luna 2006), we need to know how quality seedlings can be raised in nursery. The objective of this study was to develop suitable nursery techniques for raising seedlings and test the performance of the seedlings in the field. In this communication, we report certain nursery practices for obtaining healthy planting material of *T. bellirica*.

Materials and methods

The experiments were conducted in the nursery of the Department of Forestry, H.N.B. Garhwal University, Srinagar Garhwal, Uttarakhand situated at 30º 13' N latitude, 78º 48' E longitude and 550 m asl.

Seed collection and processing

Fresh and mature fruits of *T. bellirica* were collected in January 2004 from Dugadda (Tehri Garhwal) at 29º 48' N latitude, 78º 36' E longitude and 670 m asl, a natural sub-tropical habitat for the species in Garhwal Himalaya. Seeds were extracted from fruits by removing the pulp manually. Thereafter, seed were sun dried for period of one week and packed in jute bags for experimentation.

Before sowing, seed viability was checked by floating method. In this method, three replicates of 100 seeds each were soaked in a bucket containing tap water. Non - viable and dead seeds are generally light in weight, therefore, they floated on water and were removed. Other seeds, which settled at the bottom of the bucket, were considered viable. Seed viability varied between 85 and 92 %.

Seeds were given a pretreatment to overcome the problem of hard seed-coat. They were soaked in boiled water for a period of 24 h (water was boiled, seeds were dipped into it and then the vessel was removed from the hot plate and kept at room temperature for 24 h) (Todaria & Negi 1992).

Effect of manure on germination and seedling growth

Four types of manure viz. bio-organic soil enricher (Celrich™), farm yard manure (FYM), poultry manure (chicken manure) and goat manure were used as medium for germination and growth. Celrich™ is a bio-organic soil enricher made from biodegradable organic substances, mainly of plant origin. It is a rich source of plant nutrients. It is a dark brownish powder having earthy smell. It has a pH of 7.5, and contains 1.8 % organic carbon, 1.75 % nitrogen, 1.25 % phosphorus and 1.20 % potash (Khadder *et al.* 2009). FYM is prepared using cow dung, cow urine and crop waste and other dairy wastes and is a rich source of nutrients; it contains 13 % nitrogen, 11 % phosphorus and 11 % potash (Kipkosgei *et al.* 2003). Poultry manure contains 10 % nitrogen, 8 % phosphorus and 5 % potash, and the goat manure contains 1.44 % nitrogen, 1 % phosphorus and 0.22 % potash (Mariakulandai & Minickam 1975). Pretreated seeds were sown in polythene bags containing a mixture of sand, garden soil and the concerned manure in 1:2:1 ratio. A single seed was sown in each polythene bag, and for each type of manure 50 polybags were used. The group of 50 polythene bags for each type of manure was divided into 5 rows, each row containing 10 polythene bags, each row was considered as a replicate. Manual irrigation was applied daily.

Effect of soil texture on germination and seedling growth

Seeds were sown in sandy, sandy loam and silt loam soils. Soil was collected from nearby sites. Soil was placed in polythene bags (soil : FYM, 2:1); 50 pretreated seeds were used for each soil texture treatment with a single seed in each polybag. Thus

each texture treatment contained 50 polythene bags**.** Ten polybags were arranged in each row to make five replicates as described earlier. Manual irrigation was applied daily.

Effect of type of nursery beds on germination and seedling growth

Three types of nursery bed viz. flat, raised and sunken, each 1 x 1 m in size, were used for this study. Each type of nursery bed was replicated thrice. In each bed, pretreated seeds were sown in three replications with 50 seeds each. FYM was used as germinating / planting material as a mixture of sand : garden soil : FYM in the ratio of 1:2:1. Generally, flat beds were laid out at the ground level, they are easily irrigated and drained out. Raised beds were laid out 10 - 15 cm above the ground level, they are easy to use for seedlings transplanting from the nursery. Sunken beds were laid out 30 - 45 cm deep from the ground level, they help in collecting run-off water from adjoining areas and reduce evaporation loss from the sides (Luna 2006). Manual irrigation was applied daily until the completion of germination and thereafter, weekly till commencement of the rainy season. Weeding and hoeing were done manually.

Effect of container volume on germination and seedling growth

Three types of container (different capacity), viz. polybag (1600 ml), plastic pot (4000 ml) and root trainer (350 ml) were used. Seeds were sown in containers having 1:2:1 ratio of sand, garden soil and FYM. Single pretreated seed was sown in each container, 50 replicates were used for each container type. Other details are same as given in the manure treatment.

Seed germination under different treatments as described above was recorded up to 90 days from the date of sowing and plumule emergence was taken as the criterion for successful germination. Survival percentage under different treatments was calculated at the time of recording of seedling height and collar diameter at an interval of 3 months, the data collection continued for one year. Temperature varied from 18.8 ºC to 35.2 ºC and relative humidity from 50 to 90 % during the study period.

Survival and growth performance of nursery seedlings under field condition

Nursery growth of seedlings can be taken as an indicator of survival and potential growth when planted in field. One year old seedlings raised under different treatments viz. four types of manure, three types of bed, three types of soil, and three types of container were transplanted in an experimental garden in randomized block design in July 2005. Ten healthy seedlings, with three replicates from each treatment (total 30 seedlings) were used for out-planting in the field. Data on growth performance (height and collar diameter) and survival percent of transplanted seedlings were recorded under field condition up to one year at six-month interval.

Data analyses

Data on germination and survival percent, height, collar diameter at nursery stage, and survival percent, plant height and collar diameter of seedlings planted in the field were analysed using one-way ANOVA. The data on germination and survival percentage were analysed after arcsine transformation. The ANOVA was carried out following the method described by Sharma (1998).

Results

Germination and seedling growth in nursery

Effect of manures

Differences in mean percent germination among the different manure types were significant ($F_{3,16}$ = 3.537, $P < 0.05$). Highest germination was recorded for the FYM and lowest for the poultry manure (chicken manure) treatment (Table 1). Survival percent after twelve months of nursery growth also differed significantly ($F_{3,16}$ = 3.87, $P <$ 0.05) among the manure types. Maximum seedling survival was recorded in goat manure and the lowest in poultry manure treatment. There were no significant differences in seedling height and collar diameter after the period of one year in nursery though the highest seedling height was recorded in the FYM and the maximum collar diameter in the goat manure treatment (Table 1).

Effect of bed types

Differences in seed germination among the three nursery bed types were significant ($F_{2,6}$ = 9.811, P = 0.05). The maximum mean seed germination was recorded in sunken beds, followed by flat beds and raised beds (Table 1). Survival of seedlings also differed significantly among the nursery beds with the maximum survival percent for sunken beds followed by flat beds and raised beds. Seedling height also differed significantly ($F_{2,6}$ =

Table 1. Germination, survival and growth of *Terminalia bellirica* seedlings under different treatments (Mean ± SE).

Type of raising medium	Germination (%)	Survival and nursery growth after 12 months of seed sowing		
		Survival (%)	Shoot height (cm)	Collar diameter (mm)
FYM	74.0 ± 16.7	90.2 ± 4.2	40.2 ± 1.4	7.1 ± 0.2
Goat manure	58.0 ± 19.2	92.2 ± 4.8	39.5 ± 2.3	7.4 ± 1.0
Bio-organic soil enricher (Celrich™)	68.0 ± 13.0	91.6 ± 3.6	34.3 ± 1.2	7.0 ± 0.2
Poultry manure	46.0 ± 5.5	73.0 ± 5.8	36.4 ± 1.8	7.3 ± 0.3
F value	3.537*	3.87*	2.60^{Ns}	0.13^{Ns}
Flat bed	45.0 ± 6.4	78.0 ± 1.5	25.4 ± 1.4	5.3 ± 0.2
Raised bed	37.0 ± 3.1	67.7 ± 4.8	21.2 ± 1.0	6.0 ± 0.2
Sunken bed	59.0 ± 8.3	89.7 ± 0.9	35.2 ± 0.9	6.6 ± 0.1
F value	9.811*	14.03**	41.58***	13.59**
Sandy soil	52.0 ± 11.0	66.9 ± 8.3	17.2 ± 0.5	4.3 ± 0.2
Sandy loam soil	54.0 ± 9.0	82.0 ± 5.0	35.3 ± 1.0	6.3 ± 0.2
Silt loam soil	58.0 ± 4.5	83.3 ± 5.3	44.9 ± 1.3	9.0 ± 0.3
F value	0.636^{Ns}	2.06^{Ns}	208.73***	94.44***
Plastic pot (4000 ml)	74.0 ± 20.7	93.0 ± 3.0	42.5 ± 0.5	8.5 ± 0.2
Poly bag (1600 ml)	58.0 ± 13.0	84.1 ± 4.7	36.1 ± 1.4	7.7 ± 0.2
Root trainer (350 ml)	58.0 ± 8.4	66.1 ± 4.0	19.3 ± 0.3	8.6 ± 0.3
F value	0.136^{Ns}	12.16***	201.60***	4.48*

***Significant at $P = 0.001$, **Significant at $P = 0.01$, *Significant at $P = 0.05$, Ns = Not significant.

41.58, $P < 0.01$) among the nursery beds with maximum seedling height recorded in sunken beds and lowest in raised beds. Significant ($F_{2,6} = 13.59$, $P < 0.01$) differences also occurred for collar diameter with the maximum collar diameter observed in seedlings raised in sunken beds followed by raised beds and flat beds (Table 1).

Effect of soil texture

Soil texture did not affect seed germination. Seedling survival also was not significantly affected by the soil texture. However, significant ($F_{2,12} = 208.73$, $P < 0.001$) variation was recorded in the seedling height after one year growth in the nursery with the maximum value for silt loam and the lowest for sandy soil. Collar diameter also differed significantly ($F_{2,12} = 94.44$, $P < 0.001$) among different soil texture treatments. Maximum collar diameter of 1 yr old seedlings was recorded in silt loam soil and the lowest in sandy soil (Table 1).

Effect of container volume

Seed germination was not significantly affected by the container volume, but seedling survival ($F_{2,12} = 12.16$, $P < 0.001$), seedling height ($F_{2,12} = 201.60$, $P < 0.001$) and collar diameter ($F_{2,12} = 4.48$, $P < 0.05$) were significantly affected by the container volume (Table 1). Maximum survival, seedling height and collar diameter were recorded for 4000 ml plastic pots (Table 1).

Survival and seedling growth performance under field conditions

During field growth, high mortality was observed in seedlings raised in nursery beds. Seedling survival in the field was significantly different for seedlings raised in different bed types ($F_{2,6} = 17.50$, $P < 0.01$) and soil texture ($F_{2,6} = 10.50$, $P < 0.05$) whereas there were no significant differences in the survival of seedlings raised in different manures and container types. Maximum seedling survival was recorded for celrich™ (bio-organic manure), sunken beds and root trainer - raised seedlings (Table 2). Significant differences ($F_{2,6} = 206.23$, $P < 0.001$) were also recorded in plant height and collar diameter after one year of field growth with the maximum average plant height and maximum average collar diameter for

Table 2. Survival and growth performance of *Terminalia bellirica* seedlings after 12 months of transplanting in field (Mean ± SE).

Seedlings developed from different raising media / treatments	Survival (%)	Shoot height (cm)	Collar diameter (mm)
FYM	83.3 ± 3.3	124.8 ±11.3	20.3 ± 0.2
Goat manure	76.7 ± 3.3	96.3 ± 1.7	27.8 ± 0.5
Bio-organic soil enricher (Celrich™)	90.0 ± 0.0	124.8 ± 5.1	25.7 ± 1.5
Poultry manure	83.3 ± 3.3	86.4 ± 3.2	19.1 ± 0.2
F value	3.56^{Ns}	9.39**	28.43***
Flat bed	56.7 ± 6.7	66.3 ± 2.3	19.8 ± 0.8
Raised bed	40.0 ± 5.8	66.9 ± 2.5	20.0 ± 0.3
Sunken bed	90.0 ± 5.8	98.6 ± 2.8	25.7 ± 0.4
F value	17.50**	52.73***	38.82***
Sandy soil	50.0 ± 5.8	92.0 ± 1.5	20.2 ± 1.0
Sandy loam soil	80.0 ± 0.0	122.4 ± 8.5	27.3 ± 0.4
Silt loam soil	60.0 ± 5.8	127.6 ± 4.9	30.6 ± 1.1
F value	10.50*	11.31**	36.68***
Plastic pot (4000 ml)	86.7 ± 8.8	205.93± 8.2	42.8 ± 2.0
Poly bag (1600 ml)	66.7 ± 6.7	83.1 ± 1.4	24.5 ± 1.3
Root trainer (350 ml)	90.0 ± 5.8	91.4 ± 0.1	27.2 ± 0.4
F value	1.50^{Ns}	206.23***	49.11***

***Significant at $P = 0.001$, **Significant at $P = 0.01$, * Significant at $P = 0.05$, Ns = Not significant.

seedling raised in 4000 ml-plastic pots (Table 2).

Discussion

Substrate plays a significant role in seedling emergence, because seeds have characteristic requirements for moisture and oxygen for germination. A substrate needs to be non- toxic, free of moulds with adequate aeration and moisture for germinating seeds (Justice 1972). Farmyard manure gave highest germination percent while minimum days to complete germination were recorded in the case of goat manure. Higher germination in FYM may be due to the fact that compost is non-toxic, rich in NPK and has adequate aeration and moisture for germination of seeds (Justice 1972). In a similar investigation, germination of *Albizia lebbek* Benth. was found best in FYM followed by sand, sand + soil and sand + soil + FYM (Thakur *et al.* 2000). FYM was the richest in NPK.

In order to maximize survival and growth, it is essential to raise seedlings in nurseries with proper care. Watering, weeding around the out-planted seedling and the protection against big herbivores enhance seedling growth (Bognounou *et al.* 2010). In the nursery, raised beds are used in areas with high water tables, sunken ones are used in semi-arid and arid areas while flat beds are used in intermediate areas (Anonymous 1996). Nature of the bed affects the conditions for germination, sunken beds in our study yielded the highest germination percent. The large seeds (as in *Terminalia bellirica*) need higher moisture and deeper soil for proper germination than small seeds. The texture or particle size distribution of nursery soils and that of potting medium for containerized planting stock is an important soil physical property influencing root and shoot growth (Dickson *et al.* 1960). The three textural types in the present study did not differ significantly in their impact on seed germination. ISTA (1993) has suggested sand as a suitable medium for seed germination in *Acacia* spp.. In *Acacia nilotica* (L.) Wild. ex Del. the maximum germination (97 %) was observed in the sand medium as compared to other soil media (Venkatesh *et al.* 2000). Maithani *et al.* (1988) recorded significant differences in seed germination in *Dalbergia sissoo* Roxb. under 1:2:1 (sand:soil:FYM) and 1:1:1 (sand:soil:FYM). In *Picea smithiana* (Wall.) Boiss. maximum seed germination was

recorded in humus medium (Lavania *et al*. 2007). Sand as a germination substratum is preferred for tree species having large seeds (Magini 1962) because aeration in sand medium is best. However, *T. bellirica* did not behave similarly. It may be due to hard seed coat, which may need constant moisture conditions to soften it, which is not possible in sand.

Seedlings grown in containers have many advantages such as better survival rate, easier to plant, immediate growth response benefits, cheaper to produce and plant than bare-root seedlings (Landis *et al*. 1990). However, we found no significant effect of container volume on germination percent of *T. bellirica*. Derby & Hinesley (2005) reported that germination percent of *Chamaecyparis thyoides* (L.) Britton, Sterns & Poggenb. (atlantic white cedar) was affected by container volume with the maximum germination percent in Hiko Trays (V - 530 model, 15 cells / tray, volume = 530 cm^3).

In our study, the maximum survival percent after one year was recorded for seedlings raised in goat manure followed by those raised in bio-organic manure. The possible cause of differential growth performance could be due to differences in the organic components in different manures, this aspect however, needs further study. Ginwal *et al*. (2002) found that sand and compost combination (20 % sand + 80 % compost) gave best result in *Dalbergia sissoo* Roxb.. We did not find significant effect of manure type on seedling growth. On the other hand, Thakur *et al*. (2000) found sand + soil + FYM as the best potting medium for development of healthy seedlings with nodulated roots and better growth in *Albizia lebbeck* Benth.. Nandeshwar & Patra (2004) also suggested that soil, sand and compost in the ratio of 1:1:2 is the best for growth and survival of *Acacia catechu* Willd. seedlings.

In our study, the overall survival and growth performance was higher in silt loam soil and sandy loam soils as compared to sandy soil. Soil texture had no significant effect although sandy loam soil tended to favour *Alnus nepalensis* Don., *Quercus griffithii* Hook & Thom. and *Schima khasiana* Dyer in J. D. Hooker (Khan & Tripathi 1989).

Container size is a consideration in the production of seedlings. Studies carried out by Annapurna *et al*. (2004) to determine the effects of container type and size on the growth and quality of seedlings of Indian sandalwood (*Santalum album* L.) revealed that survival and overall growth of 6 month old sandalwood seedlings, in terms of height, collar diameter, seedling biomass and root-shoot ratio, were best in root trainers (600 ml) and next best in plastic containers (1500 ml). In *Dendrocalamus strictus* Nees. and *Bambusa bambos* (L.) Voss. raised in root trainers and polythene bags of different sizes, significant variations were observed in almost all seedling morphological parameters (Gera *et al*. 2007). Large container seedlings tend to maintain their size advantage over time as compared to smaller container seedlings (Kope *et al*. 1996; Simpson 1994; Sutherland & Day 1988) while the absolute growth of large stock may be one year ahead of smaller stock (Simpson 1994).

Based on our findings the following combinations are proposed for optimum germination and growth in nursery for *T. bellirica*: silt loam soil + FYM in sunken beds or 4000 ml-plastic pots. Further research to develop suitable techniques for breaking the seed coat dormancy easily is recommended.

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