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*Full Length Research Paper*

# Effect of small-scale farmers' tree nursery growing medium on agroforestry tree seedlings' quality in Mt. Kenya region

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**Low survival and slow growth rate of multipurpose trees and shrubs as a result of poor quality tree seedlings hamper efforts by small-scale farmers in development of effective agroforestry systems. These may be attributed to the chemical and physical properties of the soil growing media used. With the current high and growing demand for quality agroforestry trees and shrubs, farmers are increasingly raising planting stock on their farms. However, insufficient technical knowledge has often hindered success. Such growing media contribute to physical and chemical conditions that may be inappropriate for quality seedling development. Slow growth and survival rate lead to extra costs in replacement planting as well as delayed benefits. This study assessed the effect of chemical and physical properties of-farm tree nursery growing medium on *Tamarindus indica* seedling quality and growth rate. Compost based growing medium gave higher seed germination percentage as compared to sand and farm medium. Compost based growing medium also gave higher seedlings survival rate and height growth than sand and farm soil. It also gave seedlings with higher sturdiness quotient. The physical and chemical properties of on-farm tree nursery growing media that had the greatest influence on *T. indica* seedling quality were the aeration pore volume, total pore volume, wet bulk density, total nitrogen, organic carbon, magnesium and calcium.**

**Key words:** Growing media, height growth, sturdiness quotient, *Tamarindus indica,* compost, sand, farm soil.

## INTRODUCTION

Low survival and slow growth rate of trees as a result of poor quality tree seedlings often hamper efforts by small-scale farmers in developing successful agroforestry systems. Tree nursery growing media can have sub optimal physical and chemical properties leading to low seedling quality (Wightman, 1999). Currently, there is no standard tree nursery growing medium in use by small-scale farmers. Quite often, the different growing media used affect seedling physical quality and survival in the field (Jaenicke, 1999) and vary from one farmer to another. This may be attributed to different physical and chemical properties of growing medium. Balanced supply of nutrients is needed in tree nurseries for supporting healthy and vigorous seedlings growth while ensuring adequate root development and plant hardiness (Mason and Aldhous, 1994). The basic goal of having quality seedlings is to achieve the best growth possible and have the highest amount of desired output such as timber, food, fodder and fuel (Jones, 1993).

Farmers' tree nurseries indicate their efforts to integrate trees on their farmland and are fundamentally important to long-term development of agroforestry. With increasing demand for high value trees, farmers have attempted to raise them but often with insufficient knowledge for assuring high quality. This is because many of the species that are now popular have grown in the natural population and nobody has raised them in a tree nursery before. This demand therefore has neither been matched with diffusion of knowledge on modern techniques for raising high quality agroforestry trees nor has any effort been made to find out what the farmers do and compare it with seedling development.

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**Table 1.** Classification of growing media and their farm soil, sand and compost percentage.

| Growing media type | UM2 | | | | UM3 | | | |
|---|---|---|---|---|---|---|---|---|
| | Name Nursery | Soil (%) | Compost (%) | Sand (%) | Name Nursery | Soil (%) | Compost (%) | Sand (%) |
| Farm soil | Kiangondu | 100 | 0 | 0 | Majarene | 85 | 0 | 15 |
| | Nyweri | 83 | 16 | 0 | Wendo | 100 | 0 | 0 |
| | Umoja | 100 | 0 | 0 | Njogune | 100 | 0 | 0 |
| Compost | Kierera | 67 | 33 | 0 | Mwiti | 71 | 28 | 0 |
| | Njaina | 75 | 25 | 0 | Njuri | 0 | 100* | 0 |
| | Mwenda | 61 | 30 | 0 | Ntomba | 67 | 22 | 11 |
| Sand | Joyce | 65 | 15 | 20 | Kinoti | 29 | 14 | 57 |
| | Kaburu | 50 | 25 | 25 | Muthee | 67 | 0 | 33 |
| | Karamani | 66 | 0 | 33 | Muungano | 40 | 40 | 20 |

*Forest soil.
UM2, upper midland 2; and UM3, upper midland 3 (Jaetzold and Schmidt, 1983).

Farmers often complain about insufficient technical knowledge of nursery practices. They frequently complain about low seedling growth and survival rate. One factor that has been identified for low seedling growth and survival rate in the nursery and on-farms is the sub optimal tree nursery growing media used. Quite often, farmers encounter high seedling mortality. Sometimes seedlings produced on-farm exhibit symptoms of mineral deficiency. Many tree nurseries produce seedlings that have weak stems and lose leaves prematurely.

The ratios of substrate ingredients used by farmers in their nursery growing media contribute to chemical and physical conditions that can be inadequate for optimal seedling development. The effect could be extremely high or extremely low shoot/root ratio and unfavourable above ground versus below ground balance of the seedlings, which may result in low seedling growth rate. Low seedling survival and growth rates in the field lead to extra costs in replacement planting as well as delayed benefits. This study was an attempt to determine the effect of growing media's chemical and physical properties used by small-scale farmers in central Kenya to raise agroforestry tree seedlings on-farm. The study necessitated by the need to determine parameters that make a good tree nursery soil mixture that can be used by farmers on their on-farm tree nurseries for optimal agroforestry seedlings quality.

## MATERIALS AND METHODS

The study was carried out in Meru Central and Meru South districts in Mt. Kenya Region as an on-farm survey and at ICRAF tree nursery in Nairobi as an on-station experiment. Meru South and Meru Central districts (0° 3´ 45´´N-0° 2´ 30´´S; 37º - 38ºE) straddle the equator and lie east of Mt. Kenya. Two agro ecological zones; these areas is bimodal with the long rains occurring from mid March to May and the short rains from October to December. Annual rainfall ranges between 1500 - 2400 mm in UM2 and 1400 – 2200 mm in UM3. Variation in mean annual temperature is low (20.6 - 18.2°C in UM2 and 20.6 - 19.2°C in UM3) because these districts upper midland 2 (UM2) and upper midland 3 (UM3) (Jaetzold and Schmidt, 1983) were the main areas of study. Rainfall pattern in lie on the equator (Jaetzold and Schmidt, 1983). The ICRAF tree nursery in Nairobi is located at 01° 14´ 14´´S and 36° 49´ 02´´E. The mean annual rainfall recorded was 937 mm. Mean monthly temperature was 23.8°C. A reconnaissance survey preceded the study and identified 60 potential farmers out of whom 18 were selected through stratified random sampling method. The on-farm tree nurseries were further classified according to whether the growing medium they used was primarily sand, compost or farm soil. A growing medium was classified as compost when the level of organic component added exceeded 20%, sand when the amount of sand in the medium was more than 20% and farm soil when the level of organic matter used or its sand content was less than 20%. Equal numbers of growing media (3 substrates) in each category and agro ecological zone were chosen and included in the study to enable analyses and comparison.

Table 1 shows the different categories of on-farm tree nurseries (named after the owners or locality). Kaburu and Muungano growing media were classified as sand because of the profound effect of sand on physical properties though they could also be classified as compost-based growing media. Forest soil was classified as compost due to the high amount of organic matter it contains.

The experiment at the ICRAF headquarters tree nursery was a randomized complete block design (RCBD) with six treatments of three replicates each. It compared seedling growth using six different tree nursery growing media. Five of these growing media were sampled from the 18 small-scale on-farm tree nurseries that had been randomly selected while one was an ICRAF standard mixture. The study was carried out between the months of May 2000 and February 2001. Each treatment had 20 seedlings (one seedling per 4×6″ polythene bag of the experimental tree; *Tamarindus indica*. Seedlings were watered in alternate days during the germination period and thereafter every morning. Weeds were removed immediately they were noticed. Seedling selection for measurements was done using systematic random sampling. In each on-farm tree nursery, ten seedlings were selected for measurement while all seedlings on-station nursery were measured. Sampling was done monthly for on-farm tree nurseries and fortnightly for on-station tree nursery. The final measurement was done at 130 days of growth. In addition, stratified random sampling was done after every 6 weeks for the seedlings destructive sampling for root and shoot dry weight measurement. Seedling diameter was measured twice in opposite directions 1 - 2 cm above the growing media surface using vernier callipers (0.1 mm accuracy). Seedling

**Table 2.** Average germination percentage of *T. indica* in different growing media in on-farm tree nurseries.

| Growing medium | Agro ecological zone | | Average germination percentage |
|---|---|---|---|
| | UM2 | UM3 | |
| Compost | 62 | 61 | 61.7 |
| Farm soil | 59 | 43 | 47.2 |
| Sand | 42 | 57 | 49.3 |
| S.E.D | 15.5 | 23.0 | 13.7 |

UM2, upper midland 2; and UM3, upper midland 3 (Jaetzold and Schmidt, 1983).

**Table 3.** Average rate of seedling survival (%) from the different growing media and agro-ecological zones in Mount Kenya region.

| Growing media type | UM2 | UM3 | Grand average (%) | Confidence limits (P = 0.05) |
|---|---|---|---|---|
| Compost | 94.3 | 93.6 | 94.0 | 86.5 - 97.3 |
| Farm soil | 62.0 | 25.0 | 43.5 | 21.5 - 68.5* |
| Sand | 81.0 | 86.0 | 83.5 | 62.0 - 95.2 |
| Grand average | 79.1 | 68.2 | 73.6 | |
| Confidence limit (P = 0.05) | 71.5 - 93.3 | 47.4 - 76.5 | | |
| S.E.D | 16.3 | 24.9 | 15.3 | |

UM2, upper midland 2; and UM3, upper midland 3 (Jaetzold and Schmidt, 1983).
*Significantly different from compost and sand.

height was measured from the growing media surface to the highest growing tip using a ruler (1 mm accuracy). The number of leaves and nodes were also counted. Root and shoot dry weights of seedlings were derived through careful root washing followed by separation of the root and the shoot. These were then oven dried at 60°C for 24 h (Duryea, 1985) and their respective weights taken using an electronic weighing balance (0.0001 g accuracy).

## RESULTS AND DISCUSSION

### Effect of growing media on germination percentage

*T. indica* seeds germinated differently in different growing media (Table 2). The highest germination percentage (61.7%) was recorded in compost while sand and farm soil recorded values of 49.3 and 47.2% respectively.

The higher germination percentage recorded in the compost growing medium could be attributed to the fact that compost had lower wet bulk density and more aeration pore volume that could maintain higher oxygen levels as compared to sand and farm soil. Also the compost medium had a higher level of organic matter that is characterized by extended moisture retention and better aeration. These results are in agreement with Ponnammal et al. (1993) who, while working on *Azadrachta indica*, found a mixture of sand, soil and humus in the ration of 1:1:1 exhibiting higher germination percentage than either sand, red soil or black soil. Similarly, while working on *Shorea trapezifolia,* Zoysa and Ashton (1991) found light forest soil with litter to have higher germination percentage than light mineral soil, which tended to compact. They attributed their results to the ability of the litter to retain moisture. However, Otsamo et al. (1996) has reported that some species had higher germination percentage in sand and farm soil than in compost, implying that rate of seed germination in different media could also be dependent on tree species. The low seed germination percentage from one sand based growing medium (Kinoti) could be due to the use of partially decomposed organic manure. Organic acids released during decomposition could have inhibited germination of *T. indica* seedlings.

### Effect of substrate on seedling survival rate

The different growing media had impact on seedlings survival rate in the different agro ecological zones (Table 3). Although compost growing medium had slightly higher survival rate, the differences were not significant from the different agro-ecological zones; UM2 and UM3. The mean overall survival rate was 73.6%. Pair comparison using Students Newmankuels Test showed that farm soil had significantly lower survival rate than compost ($P \leq 0.05$).

Compost growing medium had higher seedlings survival rate than farm soil. The low seedling survival rate recorded in farm soil could be due to their higher levels of

**Table 4.** Effect of different growing media on seedling height (cm) in Mount Kenya region.

| Growing medium | Agro-ecological zone | | Grand average | Confidence limits (p = 0.05) |
|---|---|---|---|---|
| | UM2 | UM3 | | |
| Compost | 17.4 | 12.9 | 13.9 | 12.4- 17.5 |
| Farm soil | 9.2 | 11.3 | 9.6 | 6.4- 12.8* |
| Sand | 10.1 | 13.6 | 12.1 | 9.2- 15.0* |
| Grand average | 11.2 | 12.5 | | |
| Medium S.E.D | 2.82 | 2.48 | 2.20 | |

UM2, upper midland 2; and UM3, upper midland 3 (Jaetzold and Schmidt, 1983).
* Different from compost at p = 0.05

**Table 5.** Correlation (r2) value showing the effect of growing media physical properties on seedling height at different growth periods in on-farm tree nurseries.

| No of days of growth | Wet bulk density | Water holding capacity | Total pore volume | Aeration pore volume |
|---|---|---|---|---|
| 30 | -0.04 | -0.23 | 0.01 | 0.17 |
| 60 | -0.01 | -0.14 | 0.01 | 0.06 |
| 90 | -0.04 | -0.13 | 0.01 | 0.06 |
| 130 | -0.02 | -0.01 | 0.07 | 0.02 |

water holding capacity that could have led to water logging. Water logging is known to hamper gaseous exchange which inhibits growth and ultimately leads to seedling mortality. The seedling survival rate in compost and sand did not differ significantly.

## Farm nursery growing media and seedling height growth

Seedlings from the different growing media in the two agro-ecological zones (UM1 and UM2) had height growths that were significantly different (Table 4). However, there were no significant differences ($P \leq 0.05$) observed in seedling heights in UM3 between the growing media types and agro-ecological zones. Significant differences in seedling height in UM2 from the different growing media could be due to the low nutrient status of sand and farm soil as compared to compost. Overall, paired comparison showed that farm soil and sand produced seedlings with significantly lower heights ($P \leq 0.05$) than compost. This could be attributed to the better combination of chemical and physical properties of the compost than farm soil and sand. The superior performance of compost growing media could be due to ameliorated medium physical properties and ease of nutrient uptake by seedlings. Similar observations were made by Oluwole and Okusanya (1992) and Okusanya et al. (1991) who found out that humus significantly enhanced growth of *Tetracarpidium conophorum* and *Treculia africana* seedlings. Compost growing medium performed better than sand and farm soil due to its lower average wet bulk density and higher water holding capacity as well as higher concentration of nitrogen and organic carbon. The levelling of the farm soil curves in the second half of the experiment period resulting in low seedling growth could be due to exhaustion of one or more of the plant nutrients (Figure 1). Such seedlings would result in slow growth later in the life of the tree as observed by Bana et al. (1995) that tall seed-lings survive better and continue with superior growth when established in the field as compared to short seedlings.

The effects of growing media physical properties on seedling height were larger at initial period of growth and decreased with increasing nursery period (Table 5). Seedling height was inversely related with wet bulk density and water holding capacity, and directly related to aeration pore volume and total pore volume in most cases. These findings are in agreement with Bukhari's (1998) finding that high growing media bulk density and low moisture content reduced growth of *Acacia seyal* seedlings. In UM2 and UM3 agro-ecological zones, nitrogen had the greatest correlation followed by organic carbon (Table 6). Similar findings were made by Oluwole and Okusanya (1992) who observed higher reduced seedling growth following absence of nitrogen as compared to absence of other nutrients (phosphorus and potassium). Nitrogen is used in chlorophyll and its deficiency leads to reduced photosynthesis and seedling growth (Anoop et al., 1998).

## Effect of substrate on tree seedling sturdiness quotient

In this study, the observed range of sturdiness quotients

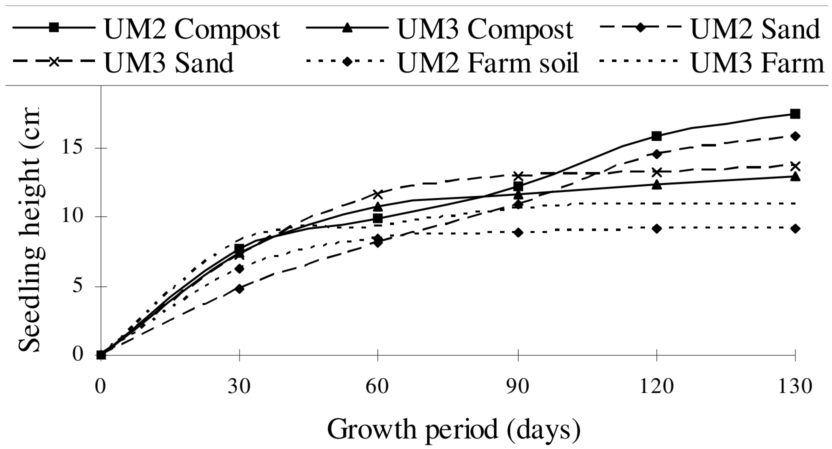


**Figure 1.** Seedling growth curves for farm soil, sand and compost in Mount Kenya region in UM2 and UM3 agro-ecological zones. UM2, upper midland 2; and UM3, upper midland 3 (Jaetzold and Schmidt, 1983).

**Table 6.** Correlation of seedling height with nutrient levels in agro-ecological zones UM2 and UM3 in central Kenya.

| AEZ | pH | Ca | Mg | K | P | C | Cu | Fe | Mn | Zn | N |
|---|---|---|---|---|---|---|---|---|---|---|---|
| UM2 | 0.03 | 0 | 0.06 | 0.07 | 0.06 | 0.13 | -0.01 | 0 | -0.02 | 0.13 | 0.43 |
| UM3 | 0.12 | 0.1 | 0.15 | 0.07 | -0.00 | 0.18 | -0.02 | -0.04 | -0.04 | -0.08 | 0.35 |

UM2, upper midland 2; and UM3, upper midland 3 (Jaetzold and Schmidt, 1983).

**Table 7.** Effect of growing media and agro-ecological zone on tree seedling sturdiness quotient in Mount Kenya region.

| Growing medium | UM2 | UM3 | Average |
|---|---|---|---|
| Compost | 5.3 | 4.8 | 5.03 |
| Farm soil | 3.7* | 3.7 | 3.70* |
| Sand | 3.4* | 4.4 | 3.92* |
| Average | 4.16 | 4.28 | |
| S.E.D | 0.43 | 0.57 | 0.38 |

UM2, upper midland 2; and UM3, upper midland 3 (Jaetzold and Schmidt, 1983).
*Significantly different from compost medium (p = 0.05)

{seedling height (cm)/root collar diameter (mm)} in seedlings from on-farm tree nurseries was between 3.2 and 6.0. All tree nursery growing media used in this study produced seedling sturdiness quotient within the acceptable range. A sturdiness quotient greater than 6 has been reported as an indication of physiological imbalance resulting in tall spindly seedlings while an extremely small sturdiness quotient implies difficulty in seedling establishment (Jaenicke, 1999).

There were significant overall differences ($P \leq 0.05$) in seedling sturdiness quotients in UM2 but not in UM3 (Table 7). There was also a significant overall difference ($P \leq 0.05$) between the three growing media types. Compost medium produced seedlings with significantly higher sturdiness quotient compared to both farm soil and sand. This could be due to the effect of organic carbon and nitrogen in the compost growing medium. As with seedling heights, farm soil and sand produced seedlings with significantly lower ($P \leq 0.05$) sturdiness quotients in UM2. This could be due to the low nutrient status of sand and farm soil in UM2. Pricking-out time and watering regime did not affect sturdiness quotient significantly in both UM2 and UM3.

## Conclusion and Recommendation

This study aimed at determining the effect of growing medium on seedling growth. The physical and chemical properties of the different growing media were found to affect seed germination, height growth and seedling sturdyness quotient. Compost based medium gave the highest seed germination percentage of 61.7% as compared to farm soil which gave the lowest seed germination percentage of 47.2%. Compost based growing medium gave the highest seedlings height growth as compared to sand and farm soil. The most important growing media physical properties that were found to have effect on growth rate were total pore volume, aeration pore volume and wet bulk density. All these properties affected seedling height and diameter growth. They had also effect on seedlings sturdiness quotient. Seedings in compost based growing medium had significantly higher sturdiness quotient as compared to those growing in farm soil and sand based growing medium.

The results of these experiments show that growing media chemical and physical properties affect seedling growth in various ways. Compost-based growing media produced higher germination percentage as compared to sand and farm soil-based growing media. Higher percentage of organic matter in germination media could have provided better germination environment such as moisture and aeration. It is recommended that farmers should incorporate organic matter in their growing media to improve the nutrient content. This could results to higher germination percentage, better seedling survival rates, higher height growth and better sturdiness quotient. Farm soil based growing medium, has little organic matter content and it is therefore inappropriate for good seedling production. These results suggest that the use of organic matter in substrates can produce seedlings that grow significantly faster than seedlings raised from either sand or farm soil medium.

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