Growth Performance of Four Acacia Tree Seedlings Raised in
Silt Soil Amended with Compost

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Abstract
The study aimed to examine the growth performance of four acacia tree seedlings (Acacia nilotica, Acacia seyal, Acacia senegal and Acacia tortilis) raised in compost-amended silt soil. It was conducted at the Khartoum University Farm, during December 1999 to January 2002. The compost was prepared from mixtures of forest litter and poultry manure (ratio of 4:1) in a pit; its maturation took three and a half months. Four growing media were prepared by mixing compost with silt soil (volume/volume) as fellows: Silt + zero compost; Silt + 25% compost; Silt + 50% compost and Silt + 75% compost. The blends were packed in polythene bags and transplanted with the acacia seedlings. The compost in comparison with the silt soil was slightly acidic, non-saline and rich in nutrients, and had a high water holding capacity. Compost has negatively affected the germination capacity of the acacia seeds. However, it positively stimulates growth of the acacia seedlings and showed significant difference ($p < 0.05$) from silt medium. Root length growth in the compost media as compared to the silt medium was moderate, due to the relative richness of the silt soil in nutrients. Compost amendments had significantly increased the biomass of the acacia seedlings as compared to silt soil. The results of this study confirm the positive effects of compost as seedling growing medium and fertilizer and showing obvious advantageous merits over the mineral soil alone in the forest tree nurseries.

Key words: Silt soil; compost; acacias; seedlings; nursery.

I. INTRODUCTION
Compost is the product of the deliberate transformation of organic matter into humus through biological and chemical decomposition. The process takes place under controlled conditions in heaps or pits (Müller-Sämann and Kotschi, 1994; Miller and Jones, 1995; Stofella and Kahn, 2001). However, the decomposition process takes place naturally by a mixed population of organisms in a warmed moist environment. Theoretically, any organic matter can be converted into compost (Stofella and Kahn, 2001; Misra et al., 2003). To accelerate the decomposition process, a number of factors should be observed and carefully monitored (Miller and Jones, 1995; Stofella and Kahn, 2001; Misra et al., 2003), including: C/N ratio of the organic input (25 to 35/1); particle size ($~10$ mm); moisture content ($50 – 60\%$); air flow ($0.6 – 1.8$ m$^3$ air per day per kg of matter); temperature ($55 – 60\,^\circ C$ held for $3$ days); heap size ($1.5$ m high and $2.5$ m wide). Compost maturation can generally take few weeks to years, depending on the manipulation and monitoring of the above mentioned factors (Miller and Jones, 1995; Brinton, 2000; Stofella and Kahn, 2001).

Compost attributes as soil ameliorator and crop fertilizer are widely recognized in agricultural and forestry practices. In nursery stock raising of forest and horticultural crops, mature compost is preferably used over other growing media substrate, because it is light, has high cation exchange capacity and nutrients, has high water holding capacity, has favorably low C/N ratio and is weed and pathogen free (Evans, 1982; Landis, 1990; Jaenicke, 1999; Diver and Greer, 2001). Thus, nursery containers filled with compost are easy to handle and permit the production of healthy and strong stock; seedlings grown in organic potting mixtures develop fibrous root systems, effectively bind the media within the container, which is essential to minimize negative effects on plants during transporting or transplanting (Dalzell et al., 1987; Miller and Jones, 1995). Negative effects of compost on seedlings are very rare and if there are any they might come from weeds, disease and pest infestation and harmful polyphenols in case of sensitive crops (Miller and Jones, 1995; Stofella and Kahn, 2001; Gonzalez and Cooperband, 2003).

In the Sudanese nurseries, container seedling substrates usually consists of soil (sand, silt, clay and mixtures) (Waheed Khan, 1989). Use of organic matter in the nursery potting mixtures is limited in the Sudan. Limited and transient experience in this respect was gained from foreign aid organizations, like the Finish International Development Aid (FINNIDA), in the 1980s. It employed peat, brought from abroad, in nursery potting mixtures to raise forest tree seedlings. Recently, it has been observed that a number of nursery owners in the capital and other main towns are beginning to use organic matter in their nursery potting mixtures. However, proper information concerning the form, quality and proportions of organic additions to

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nursery media are extremely lacking in the Sudan in general. Research is needed to find out appropriate standards and specifications of compost that suit nursery production of tree species in the Sudan.

The objective of this study was to prepare a compost product, a mixture with silt and test its effects on germination and growth of some Sudanese acacia tree species in the nursery viz, Acacia nilotica (L.) Willd. ex Del., Acacia seyal Del. var. fistula (Schweinf.) Oliv., Acacia senegal (L.) Willd. and Acacia tortilis (Forssk.) Hayne subsp. tortilis.

II. MATERIALS AND METHODS

This experiment was conducted in the Khartoum University Farm, located on the eastern bank of the Nile River. The microclimate is strongly influenced by its proximity to the Nile River and human activities (irrigated fruit gardens, vegetables and fodder farms).

Materials used in this experiment included: 1/ Compost which was produced from tree litter and debris (200 kg from Elsunt forest, Khartoum State) and poultry manure (50 kg from a poultry farm adjacent to the study site). It was prepared in a pit according to a procedure described by Miller and Jones (1995) and its maturation took about three and a half months as from 28th December 1999 to 12th March 2000. 2/ A silt soil brought from the Nile River bank 3/ Seeds of acacia trees (A. nilotica, A. seyal, A. senegal and A. tortilis) procured from the National Tree Seed Center (Forest Research Center, Khartoum); 4/ Black polythene bags (20 x 10 cm).

Growing media (treatments) were prepared by mixing the sily soil with the compost in the following proportions by volume: 1/ Silt (100%) + zero compost (SC0); 2/ Silt (75%) + 25% compost (SC25); 3/ Silt (50%) + 50% compost (SC50); 4/ Silt (25%) + 75% compost (SC75). The mixtures were then filled in the polythene bags and well packed to remove air pockets and achieve a uniform bulk density. The bags were arranged in seedbeds in a manner to avoid compost leakage from bags with higher doses to those with lesser doses during irrigation; to achieve this cemented wall were built between the seed beds. Each selected acacia species was replicated four times in each substrate category in three blocks and randomly arranged (192 bags in total). On 28 April 2000, the acacia seeds were sown in the trays filled with sand for procurement of the experimental seedling stock. On 12 May 2000, the seedlings were transplanted into the polythene bags filled with the respective growing media. Watering of the seedlings was done twice daily (in the morning and evening) during the first month and then once daily in the subsequent months. Tap water was sprayed over the seedlings by a container equipped with douche to ensure even and gentle distribution of water and to avoid leaning of the seedlings. Weeding and other tending operations were executed according to routine nursery practices.

Separate seed germination test in the nursery was carried out in the prepared growing media substrates. Three seeds were directly sown in the each respective growing medium and replicated ten times. Seed germination was monitored during a period of two weeks by counting the emerged seedlings each day then the seed germination percentage was calculated.

The parameters measured were: 1/ Shoot heights (cm) from 28 June to 15 December 2000 at 2 weeks interval; 2/ Root lengths (cm) were taken at the end of the experimental period. Roots were cleaned from adhering growing substrate by soaking in water and their lengths were measured at the collar; 3/ Dry biomass of shoots and roots was measured after separating them and drying in an oven at 65 °C for 48 hours.

Laboratory analysis

All the physicochemical determinations were carried out according to the international procedures (Page 1982; Klute 1986; Kalra 1998). Air dry composite-samples of soils and compost (mixture of 3 samples) were used to analyze particle size distribution, bulk density, water holding capacity, pH, electrical conductivity (Ec.), soluble cations (Ca, Mg, Na and K), Nitrogen, Phosphorous and organic carbon.

Statistical analysis

The means of the weekly measurement data were worked out in the spreadsheet and were used to draw temporal variation curves for each growing media and tree species. Seedlings growth parameters were statistically analyzed by a SAS program package (SAS, 2004).

III. RESULTS

Characterization of the soil and the compost used

The particle size distribution of the soil used reveals that it is composed of 50% silt and 32.9% clay fractions (Table 1).

<table>
<thead>
<tr>
<th>Property</th>
<th>Silt</th>
<th>Compost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand (%)</td>
<td>17.1</td>
<td>-</td>
</tr>
<tr>
<td>Silt (%)</td>
<td>50</td>
<td>1.0</td>
</tr>
<tr>
<td>Clay (%)</td>
<td>32.9</td>
<td>5.0</td>
</tr>
<tr>
<td>Bulk density (g/cm³)</td>
<td>1.07</td>
<td>0.76</td>
</tr>
<tr>
<td>Water holding capacity (%)</td>
<td>55.7</td>
<td>85.5</td>
</tr>
<tr>
<td>pH</td>
<td>7.4</td>
<td>6.8</td>
</tr>
<tr>
<td>EC (dS/m)</td>
<td>0.8</td>
<td>1.3</td>
</tr>
<tr>
<td>Bulk density (g/cm³)</td>
<td>1.07</td>
<td>0.76</td>
</tr>
<tr>
<td>Ca²⁺ (meq/l)</td>
<td>2.4</td>
<td>37</td>
</tr>
<tr>
<td>Mg²⁺ (meq/l)</td>
<td>1.5</td>
<td>16</td>
</tr>
<tr>
<td>K⁺ (meq/l)</td>
<td>0.05</td>
<td>0.24</td>
</tr>
<tr>
<td>Na⁺ (meq/l)</td>
<td>0.21</td>
<td>3.41</td>
</tr>
<tr>
<td>Total N (%)</td>
<td>0.03</td>
<td>0.58</td>
</tr>
<tr>
<td>Organic carbon (%)</td>
<td>1.12</td>
<td>21</td>
</tr>
<tr>
<td>C/N ratio</td>
<td>37</td>
<td>36</td>
</tr>
<tr>
<td>Available P (ppm)</td>
<td>1.06</td>
<td>6.04</td>
</tr>
</tbody>
</table>

| Property values were obtained from analysis of compost samples (mixtures of 3 samples before analysis). | Soluble concentrations |

Its bulk density is of medium magnitude and the soil has a neutral pH reaction and is non-saline, 7.4 and 1.0 dS/m.
It is amply garnished with nutrients particularly Calcium, Magnesium and Phosphorus. The Carbon and Nitrogen contents are of moderate magnitudes and hence, it has a relatively higher C/N ratio (37); and the water holding capacity of the soil is about 55.7%. The prepared compost has a very low bulk density (0.76 g/cm³) denoting that it is almost entirely composed of organic matter (21% organic carbon). Its reaction is slightly acidic and non-saline, with a pH value of 6.8, each of the 1.3 days/m (Table 1) and the water holding capacity is 85.5%.

**Seed germination**

Seed germination results showed that, A. nilotica gave the highest germination percentage in the SC75 medium and significantly different (P < 0.05) from the other media; while the lowest was in SC25 medium (Table 2). Seed germination in silt medium was significantly different from that in compost media. A. seyal seed germination rate was high (63%) in the silt and low (21%) in compost-amended medium and were significantly different. Meanwhile, A. senegal seed germination rates in all the media were the highest as compared to other species. The highest germination rate (85%) in silt medium was significantly different from the higher compost doses SC50 and SC75 but not from the low dose SC0. A. tortilis seed germination rate was highest in SC0 and lowest in SC75, and showed significant differences between all the media.

<table>
<thead>
<tr>
<th>Table 2: Seed germination (%) of four acacia species in the different soil–compost mixtures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growing media †</td>
</tr>
<tr>
<td>SC0</td>
</tr>
<tr>
<td>SC25</td>
</tr>
<tr>
<td>SC50</td>
</tr>
<tr>
<td>SC75</td>
</tr>
</tbody>
</table>

* †SC0: silt without compost; SC25: silt with compost 25%; SC50: silt with compost 50%; SC75: silt with compost 75%. Values in the column with different letters are significant at P < 0.05.

**The temporal growth rate of the seedlings shoots height**

A. nilotica seedlings growth rate in all the media showed similar pattern all along the experimental period (Figure 1A). Growth rates occurred in very close parallel lines, whereby seedlings in the silt grew at a lower level and in the medium compost dose (SC50) at a higher level. There was strong seedling growth up to the 10th week; then followed by a second rise at the 18th week.

A. seyal seedlings growth rate was very similar to that described for A. nilotica, except that seedlings growth in the SC25 and SC50 compost media occurred at the higher and lower parallel levels, respectively (Figure 1B). The control (silt) and the highest compost dose (SC75) induced identical seedlings’ growth rates.

A. Senegal seedlings showed a strong growth rate in all the media up to the 10th week and without a distinct pattern between the compost substrates (Figure 1C). Thereafter, the growth rate slowed down to the 14th week; whereas from the 16th week seedlings’ growth rate increased and revealed a distinct pattern between the treatments. Seedling growth in the highest composts dose SC75 exceeded that in the other media and proceeded at higher parallel level, followed by SC25 and other treatments at the lowest levels.

A. tortilis seedlings in all media showed very strong growth rates (Figure 1D). The growth patterns were in very close parallel lines superimposed all the treatments except that for the SC50 treatment that occurred at a slightly lower parallel level. A general trend in the growth of these species seedlings is that in the compost-amended substrates the shoot heights exceed that in the silt with time especially the high compost dose treatments.
Final assessment of the seedlings’ growth parameters of the tested tree species

A. Acacia nilotica: Shoot height values of A. nilotica seedlings in the compost-amended media, after seven months from sowing date, were more than 6.8 to 15 cm tall than in silt medium, and were all significantly different (P < 0.05) from that in the silt medium (Table 3). The root length growth tended to be longer in the middle compost doses even though it was shorter in the higher compost dose than in the silt. The shoot/root length ratio values (Table 3) were all above 1 unit and inclined to be slightly greater in the high compost-amended medium. The average shoot biomasses in the compost-amended treatments (SC50 and SC75) increased proportionally to the amounts of amendments and were significantly different from that in the silt. Among the compost media significant differences were confined between the lowest and the highest doses. Likewise, the root biomass in compost treatments exceeded that in the silt but without significant differences. The shoot/root biomass ratios in all treatments were close to each other and showed no significant differences.

B. Acacia seyal: A. seyal seedlings’ shoot heights in compost-amended media were higher (> 10 cm) than in silt medium and were all significantly different at P < 0.05, (Table 3). Similarly, seedlings root lengths were longer in the compost media, especially the middle doses, but were not significantly different. Shoot/root length ratios were more than 1 unit, very close in magnitude and showed no significant differences. The shoot biomass in compost-amended treatments grew to 1.2 and 1.6 folds as compared to silt medium and revealed significant differences at P < 0.05, except for the lower compost doses. No significant differences were detected between the root biomass in silt and lower compost-amended treatments. Similarly, the shoot/root biomass ratios were not significantly different among all the treatments.

C. Acacia senegal: A. senegal seedlings’ shoot heights were taller in the greatest compost-amended media than in the silt medium, and revealed significant differences (Table 3). Likewise, root lengths were higher in the compost treatments than in the silt but significant differences were found between silt and higher compost dose treatments. Shoot/root length ratios in all the media gave above 1 unit with no significant differences. Shoot biomass in the compost treatments were greater than in the silt alone, with magnitude factors ranging from 1.8 to 2.2 folds and were significantly different. Root biomass rates were similar to that outlined for the shoot biomass, and the significant differences existed between silt and the highest compost dose treatments. The shoot/root biomass ratio of the seedlings raised in the silt medium was less than 1 unit, while in the compost treatments, all were above 1 unit, significant differences.

D. Acacia tortilis: A. tortilis seedlings raised in the compost-amended media induced greater shoot height growth than in the silt; and value magnitude gaps ranged between 6.8 and 13.5 cm, however, without being significantly different (Table 3). Average root lengths in all the compost treated media were higher than in the silt medium, even though significant differences were restricted between the highest compost dose and the silt treatments. Shoot/root length ratio values in all the treatments were very close to each other and > 1 unit. The shoot and root biomass varied little between the treatments and were not significantly different. The shoot/root biomass ratios in all the treatments gave similar values, > 1 unit and were not significantly different.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Shoot height (cm)</th>
<th>Root length (cm)</th>
<th>Shoot/root length ratio</th>
<th>Shoot biomass (g)</th>
<th>Root biomass (g)</th>
<th>Shoot/root biomass ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. nilotica</td>
<td>SC0: 77a 28.5ab 2.8ab 8.0a 1.6a 5.2a</td>
<td>SC25: 83.8b 31.3ab 2.7b 10.4ab 1.8a 6.0a</td>
<td>SC50: 89.3b 35.3a 2.9ab 13.2bc 2.8a 5.3a</td>
<td>SC75: 92b 23.5b 3.9a 14.0c 2.7a 5.4a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. seyal</td>
<td>SC0: 63.8a 34.8a 1.9a 4.9a 4.6a 1.4a</td>
<td>SC25: 74.7b 30.8a 1.9a 6.5ab 4.8a 1.4a</td>
<td>SC50: 76.0b 44.3a 1.7a 5.5a 4.5a 1.5a</td>
<td>SC75: 77.3b 35.6a 2.2a 7.6b 5.8a 1.4a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. senegal</td>
<td>SC0: 45.3a 21.5a 2.1a 2.6a 2.8a 0.9a</td>
<td>SC25: 47.5ab 21.8ab 2.2a 4.6b 5.8ab 1.3a</td>
<td>SC50: 49.5b 24.3ab 2.1a 4.9b 4.4ab 1.1a</td>
<td>SC75: 53.8c 24.8b 2.2a 5.7b 4.9b 1.2a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A. tortilis</td>
<td>SC0: 67.5a 26.3a 2.6a 3.5a 2.1a 2.9a</td>
<td>SC25: 74.3a 29.3ab 2.6a 3.6a 2.5a 2.4a</td>
<td>SC50: 75.5a 31.8ab 2.4a 3.7a 2.6a 2.2a</td>
<td>SC75: 81.0a 35.8b 2.3a 7.4a 2.9a 2.5a</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SC0: silt without compost; SC25: silt with compost 25%; SC50: silt with compost 50%; SC75: silt with compost 75%. Values in the column for each species with different letters are significant at P < 0.05.

IV. DISCUSSION

The compost material produced and used in this study is of high quality (Table 1) and is rated as one of the richest categories compared with products described in literature (Stofella and Kahn, 2001; Szmidt et al., 2003); and it is richer than the silty soil used here. Generally, compost has induced significant repressive effects on acacia seed germination. The most affected species were A. tortilis, A. seyal and A. nilotica. This might be attributed to the organic matter effects by either creating water logged conditions in the containers and thereby reducing the oxygen supply or releasing deleterious acids that damage the seed viability (Hall et al., 1982; Shiralipour et al., 1992; Sanker and Rai, 1993; Fenner and Thompson, 2005). It is worth to mention that, organic matter in the natural habitats of these acacias
(except *A. nilotica*) is very scanty and their seeds do not encode any signs of conditions created in the containers and hence engendering the poor germination capacities.

Qualitatively, seedlings of acacias in all the growing media developed densely green foliage and numerous lateral shoots. Acacia seedlings shoot heights in all the media, including the pure silt, grew at similar patterns and with very close lengths along the monitoring period. Towards the end of the monitoring period, seedlings shoot heights growth in the silt medium slowed down and deflected from the parallels of compost media. Root lengths growth developed in the same pattern as described for the shoot height, although at lower magnitude values. Shoot heights for most of the species were more than double the root lengths except for *A. seyal*, which generally gave identical lengths. This indicates that seedlings did not expend much energy on root development, because the substrates in which they grew were rich in nutrients (*Marschner, 1986; Kraske and Fernandez, 1990*). On the other hand, seedlings biomass were invariably higher in the compost media and proportionate to the amount of doses added. The shoot/root biomass ratios revealed that *A. nilotica* and to some extend *A. tortilis* shoots responded to compost application better than the roots, with these ratios figuring to more than five and two folds respectively.

The results from this study confirm the numerous assertions cited in literature about the positive effects of composts on the growing media characteristics, in terms of ameliorating physical (bulk density, porosity, water holding capacity), and chemical (reactivity, conductivity, CEC, nutrient content, C/N) conditions (*Moxal and Fisher, 1987; Fitzpatrick, 2001; Stofella and Kahn, 2001*). Hence, the good growth performance of the acacia seedlings recorded here is directly linked to the improvements of the growing media induced by the application of the compost product. However, the relative richness of the silt medium will support the seedlings growth for a certain time alongside the growth rates in the compost. Even though, at long times the compost will continue to release nutrients (*Alexander, 2001; Chaney et al., 2001; He et al., 2001; Sikora and Szmidt 2001*) when their stocks in the silt medium had been depleted or used up by the seedlings.

In conclusion, silt medium will support acacia seedlings growth for a while before its nutrient capacity is exhausted. However, compost media will continue to support seedlings growth for a long period due to release of nutrient from its decomposition and this will lead to produce sturdier and healthier seedlings. Seed germination suffers a little in the compost media due to noxious solutes released by this material. Even though, compost merits as a growing medium and fertilizer, in addition to its light mass definitely outweigh any benefits attained from the mineral soil as growing substrate.

V. REFERENCES


