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Effects of Sawdust, Forest Soil and Cow Dung Mixtures on Growth Characteristics of Blue Gum (*Eucalyptus saligna*) Seedlings in South Kinangop Forest, Nyandarua, Kenya

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Abstract

Forestation programs, in Kenya have been hindered by, among others, high cost of tree seedling production and longtime seedlings stay in the nursery. This has been attributed to poor quality of forest soil and unavailability of alternative growth media. Study was carried out in South Kinangop forest station to evaluate the potential of mixing sawdust and cow dung with forest soil to form a nutrient rich growth media. Using forest soil; sawdust, cow dung and mixture of these components, this study sought to determine growth characteristics of *Eucalyptus saligna* seedlings under different conditions available in the nursery. The experiment was laid out in a Completely Randomized Design (CRD) with six treatments comprising of Saw dust alone (Tr 1), Forest soil alone (Tr 2); Sawdust: Cow dung mixture in the ratio of 1:1 (Tr 3); Forest soil to Sawdust-Cow dung mixture (1:1) in ratio of 1:1 by weight (Tr 4); Forest soil to Sawdust-Cow dung mixture (1:1) in ratio of 1:2 by weight (Tr 5) and Forest soil to Sawdust-Cow dung (1:1) in ratio of 1:3 by weight (Tr 6). Treatments were replicated three times and an experimental unit consisted of 110 seedlings of which 15 were tagged for height and root collar diameter measurement. The remaining 95 were used for biomass determination by destructive sampling. The results showed that Sawdust: Cow dung mixtures (Tr 3) had the highest measurements for height, root collar diameter and biomass at week 20 when compared to the rest of growth mixtures. Height measurements were significantly high (13.81 cm) for the Sawdust: Cow dung mixtures while the variation in root collar diameter and biomass were not significantly different among the treatments. Sawdust alone did not favor seedling growth and recorded the lowest measurements in height, root collar diameter and biomass. Nutrient release from the growth media during the experimental period was equally high for the Saw dust: Cow dung mixture (Tr 3) which was ideal media for raising tree seedlings. The findings of this study illustrate the usability of sawdust and cow dung in enhancing the productivity of tree nurseries and shortening the time taken for raising seedlings in the tree nursery. The findings also propose a safe disposal of saw dust that poses as an environmental waste.

Keywords

CowDung, Forest Soil, Sawdust, Tree Seedling

1. Introduction

Saw dust is one of the byproducts of saw milling, which is a major economic activity practiced in countries with large forests resources (Leconte et al., 2009). It is estimated that between 800,000 m^3 and 1.3 million m^3 of sawdust is produced annually in rural sawmills allover Kenya (Onchieku et al., 2013). Studies done by Chardust Ltd. et al., (2004), revealed that most of the saw dust produced in saw mills in Kenya was burned *in situ*, used to repair roads, used as animal bedding or used as floor covering for bars and restaurants.

Saw dust has also been used as a soil conditioner in general agriculture (Garner, 2014). Saw dust is purely wood material comprising of 50% carbon (Parry, 2007). Its incorporation into the soil enhances a buildup of soil organic carbon pool which is slow to decompose and which can act as agricultural strategy on climate change mitigation that reduces emission of greenhouse gases.

Most of our soils are greatly in need of organic matter because the usual crop rotations and degradation seldom maintain soil humus at desirable levels and thus saw dust can provide these nutrients over a long period if decomposition is managed appropriately. Saw dust is also a largely sterile media that does not harbor microorganisms due to its low nutrient content (Okalebo et al., 2002).

Decomposition is one of the most important processes that accounts for carbon and nutrient recycling on crop land and in the forest systems (Shi, 2013). It is controlled by factors such carbon to nitrogen ratio (Richard & Trautmann, 2014), pH and nutrient balance in the medium, particle size, temperature, moisture content and porosity (Bernal et al., 2009). The slow rate of decomposition of saw dust and temporary depression of nitrogen has been the principal objection to its use in agricultural fields (Garner, 2014). In addition, sawdust is low in readily available plant nutrients when compared to livestock manure which is rich in microbes responsible for rapid decomposition of organic matter and pH of 6.0 - 9.0 which is ideal for microbial activity (Pennington, 2009).

Livestock manure (cow dung) has low carbon to nitrogen ratio of 25 - 30 which is ideal for provision of required energy for microbial activity as well as a high water holding capacity. The high concentration of macro nutrients in cow dung provide initial nutrients required for the decomposition process. These factors make cow dung an ideal component for mixing with sawdust to enhance its decomposition and meet the immediate and long term plant nutrient requirements. Cow dung has been extensively used in crop production in Kenya and is often recommended as a soil nutrient replenishment strategy in low income countries (Okalebo et al., 2006). Forest soils are commonly used to raise seedlings in the nursery. The soils are collected from natural forests. For example in motanne forests in Kenya, forest soils are collected under *Tombeya torrida.* The soils may not contain all essential nutrients either due to leaching or utilization by under growth. Addition of small quantities of inorganic fertilizer is recommended as a supplement for good growth of seedlings in the nursery (Evans, 1983).

Seedlings height is one of growth parameters used to determine planting stage of seedlings in the field. Lamprecht (1989) recommended a height of 10 - 25 cm as most ideal for planting out *Eucalyptus saligna* in the field for better survival. However, Evans (1983) showed that height is not satisfactory for grading plants and recommended root collar diameter which is highly correlated with survival of the seedlings in the field.

There exists minimal knowledge on how sawdust can be utilized as a growth medium in forest seedlings establishment as well as the appropriate mixing ratios for enhanced decomposition. Thus, this study was aimed at mixing sawdust with cow dung and/or forest soil to form a nutrient rich growth media that can be used to raise quality and fast growing tree seedlings. Specifically, the study sought to find out how the growth media comprising sawdust, forest soil and/or cow dung affects growth characteristics of Blue gum (*Eucalyptus saligna*) seedlings raised in South Kinangop Forest Station of Kenya.

2. Materials and Methods

2.1. Study Area

The study was carried out in South Kinangop forest station in the Aberdare Forest Reserve (**Figure 1**). The station is located on latitude S 00˚43'28.4", longitude E036˚40'51.7" and 2545 m elevation. The forest occupies a total 6660 hectares and forms part of the Aberdare range which is one of the major water towers serving Lake Naivasha to the north and Tana River to the south. The climate at South Kinangop is modified equatorial climate with average temperature of 12.3˚C and annual rainfall of about 1590 mm distributed bi-modally with peaks in late April and late November.

2.2. Research Design, Experimental Layout and Data Collection

The field layout comprised of six treatments (Tr 1 - 6) in a completely randomized design with three (3) replications.

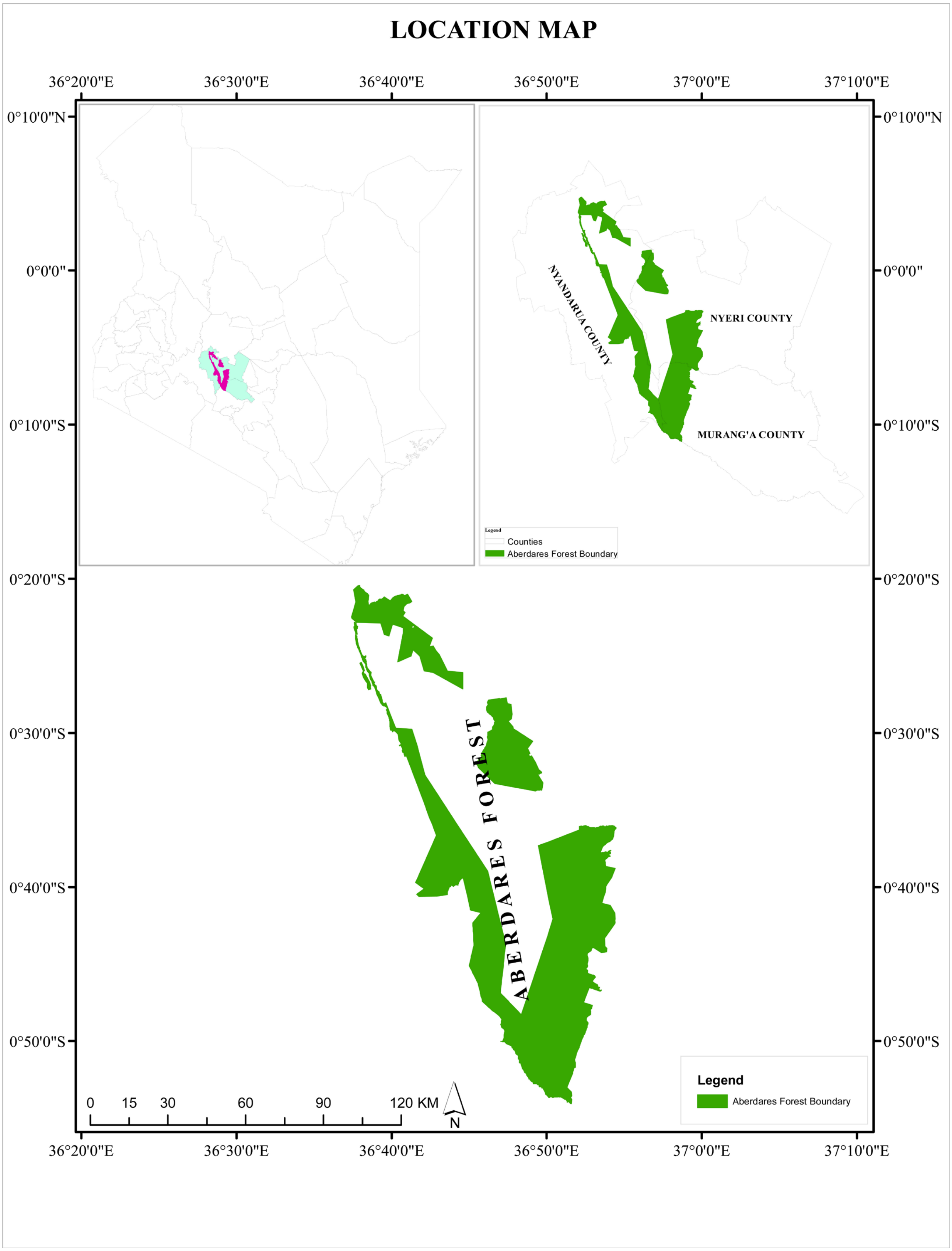


Figure 1. Map of the study area showing the south Kinangop.

2.3. Growth Media Preparation

Forest soil was dug and collected from the natural forest stands of *Dombeya torrida* within South Kinangop forest. Fine sawdust mainly from pine (*Pinus patula*) trees was collected from nearby sawmill while cow dung was sourced from homesteads near the forest margins. The sawdust, forest soil and cow dung were heaped separately in the nursery and preparations for the growth media carried out during the dry period (August 2015). The treatment mixtures were allowed to decompose for three months under shade so as to improve on aeration, reduce instances of dumping off disease to seedlings, reduce competition of nutrients from weeds, and increase water retention capacity.

2.4. Tree Seedling Establishment and Management

*Eucalyptus saligna s*eeds were acquired from Kenya Forest Research Institute (KEFRI), Muguga Seed Centre and sown in a seed bed of sand, two weeks before the completion of decomposition period of the nursery growth media. After germination the seedlings were allowed to grow for 14 days in the seed bed and on the 15th day after germination, the seedlings were pricked out into polythene tubes at one seedling per tube. In total three hundred and thirty (330) polythene tubes of size 3” by 4” were filled with the growth media for each of the treatment described in Table 1. A total of 1980 tubes were filled for the six treatments. The tubes were arranged in an experimental unit of 110 seedlings per replicate which were then completely randomized and replicated three times. The seedlings were allowed to grow for 6 months under open and uncontrolled climatic conditions. During the experimental period, temperatures ranged from 19.9˚C during the day to 3.2˚C at night with mean temperature being 12.3˚C. Humidity ranged from 100% during early hours of the day to 40% late in the afternoon and an average of 65%. Sunlight was controlled through shading after pricking out from week 1 up to week 2. Afterward the shade was removed to allow for total exposure of seedlings to sunlight.

2.5. Data Collection (Measurement of Height, Root Collar Diameter, Biomass Assessments and Nutrient Analysis)

Data collection involving height, root collar diameter and biomass sampling was

Table 1. Treatment description showing the growth media mixtures used in the study.

Treatment number	Treatment description
Treatment 1 (Tr 1)	Saw dust only
Treatment 2 (Tr 2)	Forest soil only
Treatment 3 (Tr 3)	Sawdust mixed with cow dung in the ratio of 1:1 by weight
Treatment 4 (Tr 4)	Forest soil to sawdust cow dung mixture (1:1) in ratio of 1:1 by weight
Treatment 5 (Tr 5)	Forest soil to sawdust cow dung mixture (1:1) in ratio of 1:2 by weight
Treatment 6 (Tr 6)	Forest soil to sawdust cow dung (1:1) in ratio of 1:3 by weight

carried out at an interval of 4 weeks for a period of 24 weeks. During each sampling period, 45 seedlings were selected randomly from each treatment (15 from each replicate), tagged and measured for height and diameter. The same seedlings were uprooted, washed off soil and foreign material and packaged in clean polythene bags and sent to Kenya Agricultural and Livestock Research Organization (KALRO) laboratory for biomass assessment. Diameter measurement was done at root collar of the seedling using an electronic veneer caliper while height was measured from root collar to the tip of leading shoot using a rule as demonstrated by Mexal et al., (1990). The biomass samples were oven dried at 70˚C for 24 hours and weighed for dry weight determination following the procedures as described by Okalebo et al., (2002).

Soil pH was determined in water using 1:2.5 (soil: water ratio). Organic carbon in the growth media was determined by the sulphuric acid and aqueous potassium dichromate ($K_2Cr_2O_7$) mixture. After complete oxidation from the heat of solution and external heating, the unused or residual $K_2Cr_2O_7$ (in oxidation) is titrated against ferrous ammonium sulphate. The used $K_2Cr_2O_7$, the difference between added and residual $K_2Cr_2O_7$, gives a measure of organic C content of soil. Total nitrogen was measured in a digest obtained by treating soil sample with hydrogen peroxide + sulphuric acid selenium and salicylic acid according to the procedure described by Okalebo et al., (2002).

2.6. Mean Monthly Increment (MMI) and Current Monthly Increment (CMI) of the Tree Height of Seedlings

In this study, growth in height of seedlings raised in different treatments were compared using the model by Evans (1983) to establish if they were making full use of growth potential from the treatments. Measurements done on a four week interval was used to calculate current monthly increment (CMI) which is the increase in height of seedling per unit time (four weeks) and mean monthly increment (MMI) which is the average increase for a given time interval (in weeks).

$$\text{MMI} = \frac{\text{Total growth for the months (cm)}}{\text{No.of months (4 weeks)}}$$

$$\text{CMI} = \text{Current months growth (cm)} - \text{previous months growth (cm)}$$

2.7. Data Analysis

Data were analyzed using Genstat statistical software version 12. Means were separated using Standard Error of the Difference (SED). Significant differences were reported at the $P < 0.05$ level.

3. Results

3.1. Effects of Sawdust-Forest Soil and Cow Dung Mixtures on the Growth of *Eucalyptus saligna* Seedlings

Seedlings height and root collar diameter of *Eucalyptus saligna* seedlings grown in different growth media are presented in Figure 2 and Figure 3. Response of seedling growth to different treatments was highest in the growth media which had Sawdust: Cow dung mixture (Tr 3) which attained a height of 12 centimetres at week 20 and lowest in Sawdust alone (Tr1) Figure 2.

Seedling growth was slow in sawdust alone treatment (Tr 1) throughout the experimental period. Analysis of variance (ANOVA) showed that there were statistical significant differences at $P < 0.05$ in heights of the seedlings under different treatments (Table 2) meaning that seedling height in sawdust differed from all the other treatments.

Seedlings from Tr 2, Tr 3, and Tr 4 had reached transplantable height of 10 cm

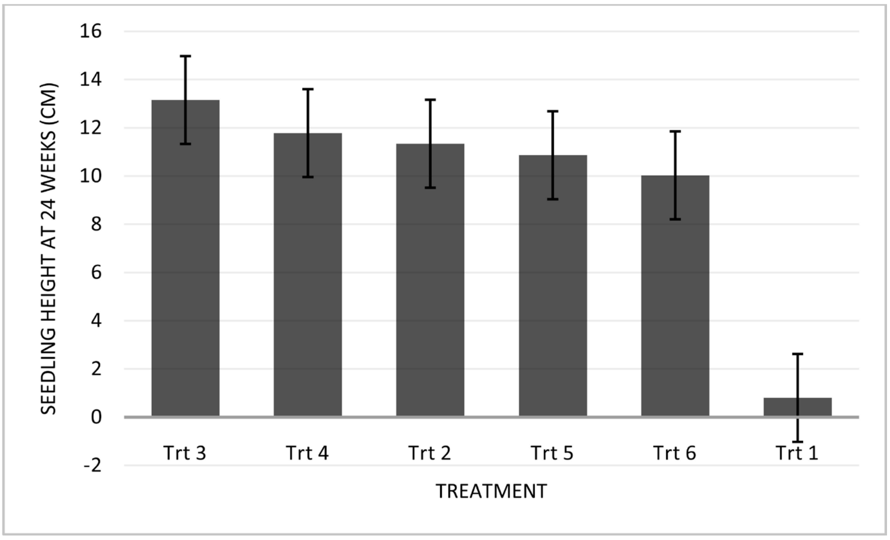


Figure 2. *Eucalyptus saligna* seedling height (cm) at week 24 grown under different growth media.

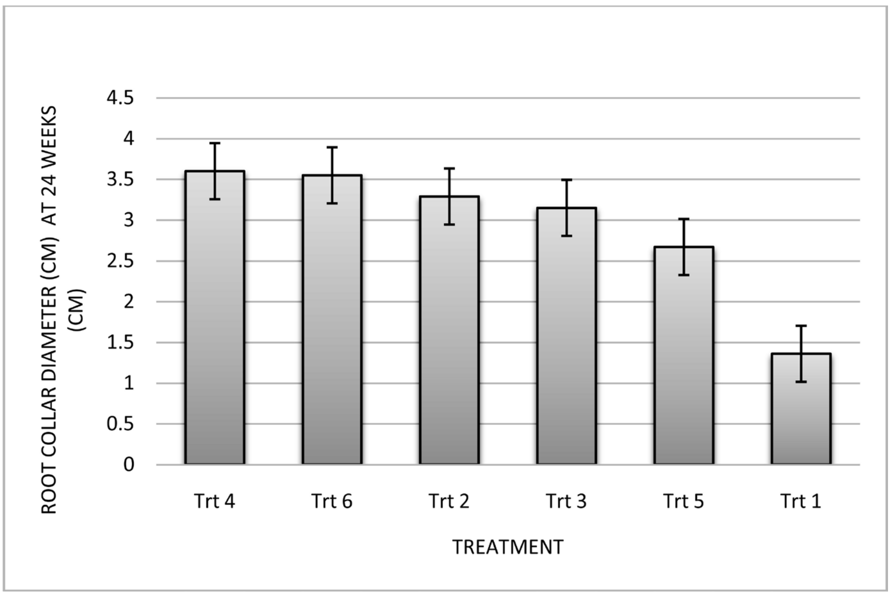


Figure 3. Root collar diameter (mm) of *Eucalyptus saligna* seedlings at week 24 grown in different growth media.

Table 2. Turkey test to determine differences in means of seedling height as affected by treatment.

Mean comparison	Difference in means	Standard error SE	Studentized range q.	q 0.05,30,5	Conclusion
Tr 3 vs. Tr 1	2.19 − 0.13 = 2.13	0.16	12.86	4.039	Tr 3 ≠ Tr 1
Tr 4 vs. Tr 1	1.96 − 0.13 = 1.83	0.16	11.44	4.039	Tr 4 ≠ Tr 1
Tr 2 vs. Tr 1	1.89 − 0.13 = 1.76	0.16	11.00	4.039	Tr 2 ≠ Tr 1
Tr 5 vs. Tr 1	1.81 − 0.13 = 1.68	0.16	10.5	4.039	Tr 5 ≠ Tr 1
Tr 6 vs. Tr 1	1.67 − 0.13 = 1.54	0.16	8.38	4.039	Tr 6 ≠ Tr 1

Overall conclusion $\mu_{Tr1} \neq \mu_{Tr2} = \mu_{Tr3} = \mu_{Tr4} = \mu_{Tr5} = \mu_{Tr6}$.

Table 3. Total Seedling biomass in dry weight (g) during the experimental period.

	Treatment					
Sampling time	Tr 1	Tr 2	Tr 3	Tr 4	Tr 5	Tr 6
Baseline at time of pricking	0.004	0.044	0.044	0.044	0.044	0.044
4 weeks	0.061	0.637	0.613	0.165	0.127	0.265
8 weeks	0.706	1.780	1.708	0.364	0.249	0.663
12 weeks	0.777	2.092	2.274	0.937	0.602	1.560
16 weeks	0.850	5.164	4.649	2.402	1.865	3.407
20 weeks	0.935	8.879	9.549	6.635	5.978	6.951
24 weeks	0.987	15.774	15.781	12.867	11.683	13.101

by the end of the experiment period. Lamprecht (1989) recommended planting height of above 10 cm for Eucalyptus seedlings. However, seedlings in Sawdust treatment had severe stunted growth, symptoms associated with deficiency of essential nutrients in the growth media.

Results for root collar diameter of seedlings recorded once every four weeks, after pricking out are presented in **Figure 3**. Treatment four (Tr 4) which comprised of Forest soil to sawdust cow dung mixture (1:1) in ratio of 1:1 by weight showed the greatest root collar diameter of the seedlings (of 3.60 cm) followed by Tr 6 (Forest soil to sawdust cow dung (1:1) in ratio of 1:3 by weight) at with 3.55 cm. Seedlings grown in Sawdust alone (Tr 1) had the lowest root collar diameter at the end of the experiment period (1.36 cm). High root collar diameter media contributes to sturdiness of the seedlings that enhance field survival of the seedlings.

Highest total seedling dry biomass was recorded in Tr 3 (Sawdust mixed with cow dung in the ratio of 1:1) and Tr 2 (Sawdust mixed with cow dung in the ratio of 1:1) at 15.781 g and 15.774 g respectively. Sawdust alone (Tr 1) had the lowest total biomass recorded at the end of the experiment period (0.987 g) (**Table 3**).

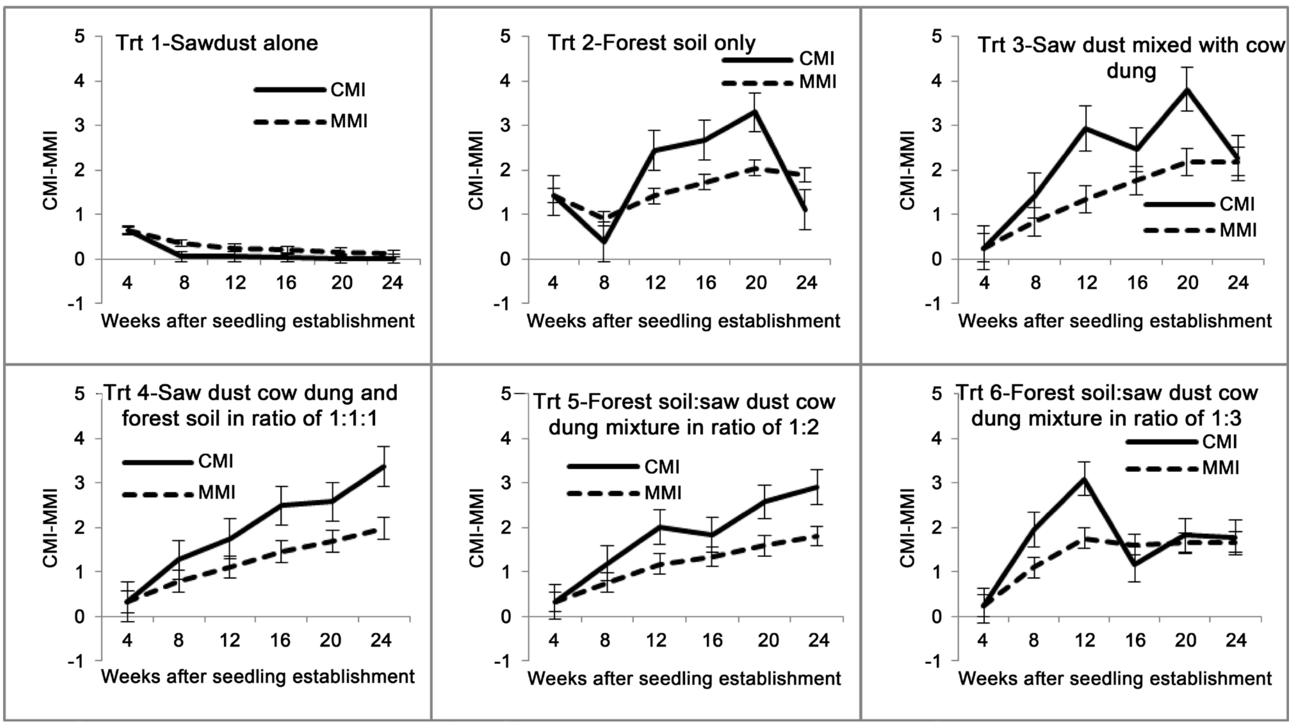
3.2. Mean Monthly Increment (MMI) and Current Monthly Increment (CMI) of the Tree Height of Seedlings

Mean monthly increment (MMI) and current monthly increment (CMI) of growth in height for each treatment are shown in **Figure 4**.

In Tr 1 (Sawdust alone) both CMI and MMI declined throughout the growing period. Decrease in both CMI and MMI was due to decline in growth of seedling in sawdust from start of the experiment up to week twenty four. Slow growth could be associated to low nutrients level in the sawdust as reflected in treatment nutrient analysis, table. Sawdust has low growth potential for seedlings.

Treatment two: Current monthly increment (CMI) increased from 1.43 mm to reach a maximum of 3.30 mm at week twenty and started to decline to a minimum of 1.11 mm at week twenty four. Mean Monthly Increment (MMI) increased from 1.43 mm reaching a maximum (2.05 mm) at week twenty and declining to 1.89 mm at week twenty four. CMI intersects MMI at week twenty four when MMI is at its maximum. Greatest growth potential from the media was achieved at twenty fourth week. Further maintenance of seedlings beyond week twenty four will require addition of external nutrients input to the media. Treatment three: Current monthly increment (CMI) increased from 0.25 mm in week 4 attaining a maximum 3.82 mm on week twenty and started to decline at week twenty four. Mean Monthly increment (MMI) increased steadily from 0.25 mm at week four reaching a maximum of 2.51 mm at week twenty four. Media could support maximum growth up to week twenty.

Treatment four: CMI increased from 0.32 mm (week 4), attaining a maximum 3.37 mm at week twenty four and still showing steady growth at the end of the study. MMI was 0.32 mm at week four and had reached 1.97 mm at the end of



(Performances of seedlings in treatments were compared using the model by Evans, 1983)

Figure 4. Current monthly increment (CMI) and mean monthly increment (MMI) of *Eucalyptus saligna* seedlings grown in different growth media.

week twenty four. CMI does not cross MMI which showed the treatment had the potential to support growth of seedlings beyond week twenty four.

Treatment five: CMI and MMI increased from week 4 attaining a maximum of 2.91 mm for CMI and 1.81 mm for MMI at week twenty four. CMI and MMI showed steady growth at the end of study. The treatment had the potential to support growth of seedlings beyond week twenty four.

Treatment six: CMI increased from 0.24 mm to reach a maximum of 3.09 mm at week twelve and dropped to 1.71 mm at week twenty four. MMI increased from 0.24 mm, reaching a maximum of 1.76 mm at week twelve and declining to 1.67 mm at week twenty four. CMI intersects MMI at week twelve when MMI is at its maximum. Greatest growth potential from the media was achieved at week twelve. Further maintenance of seedlings beyond week twelve will require addition of external nutrients to the media.

3.3. Dynamics of Nitrogen and Carbon Mineralization of the Growth Medium over the Study Period

As shown in **Table 4**, percentage Nitrogen content at the start of the experiment was lowest in Tr 1 (sawdust alone) at 0.26% but was near equal across Tr 2 to Tr 6, ranging from 0.53% to 0.56%. At the end of the experiment, Nitrogen content increased in all treatments, ranging from 0.40% in Tr 1 to 1.08% in Tr 6. In terms of Carbon, % content ranged from 17.82 (Tr 4) to 49.56 (Tr 1), decreasing to 12.36% in Tr 4 and 33.43 for Tr 1. The mean carbon content across the five treatments was 26.77% at the start, dropping to 17.37% at the end. As for soil water PH values, there was general progression from Tr 1 towards Tr 6 both at the start (Tr 1 = 4.38 – Tr 6 = 8.05) and end (Tr 1 = 5.12 – Tr 6 = 6.56). ANOVA results indicated that there % Nitrogen and % Carbon did not differ significantly between treatments both at the start and end of the experiment. However, soil water PH differed significantly between treatments ($F = 7.71$; $P = 0.014$; $df = 11$). The Turkey's test indicated that the mean differences occurred between Tr 1 and all other treatments except Tr 2 and between Tr 2 and Tr 4, Tr 5 and Tr 6.

Table 4. Carbon, nitrogen and PH of the growth media at the start and the end of the experimental period.

	At the start of the experiment			At week 24		
Treatment No.	PH (water)	Nitrogen (%)	Carbon (g/kg)	PH (water)	Nitrogen (%)	Carbon (g/kg)
Tr 1	4.38	0.26	49.56	5.12	0.40	33.43
Tr 2	4.93	0.55	18.09	5.16	0.73	10.39
Tr 3	6.03	0.53	36.80	6.07	0.85	9.83
Tr 4	6.30	0.56	17.82	6.30	0.85	12.36
Tr 5	6.75	0.54	20.20	6.48	0.83	13.20
Tr 6	8.05	0.54	18.15	6.56	1.08	25.00

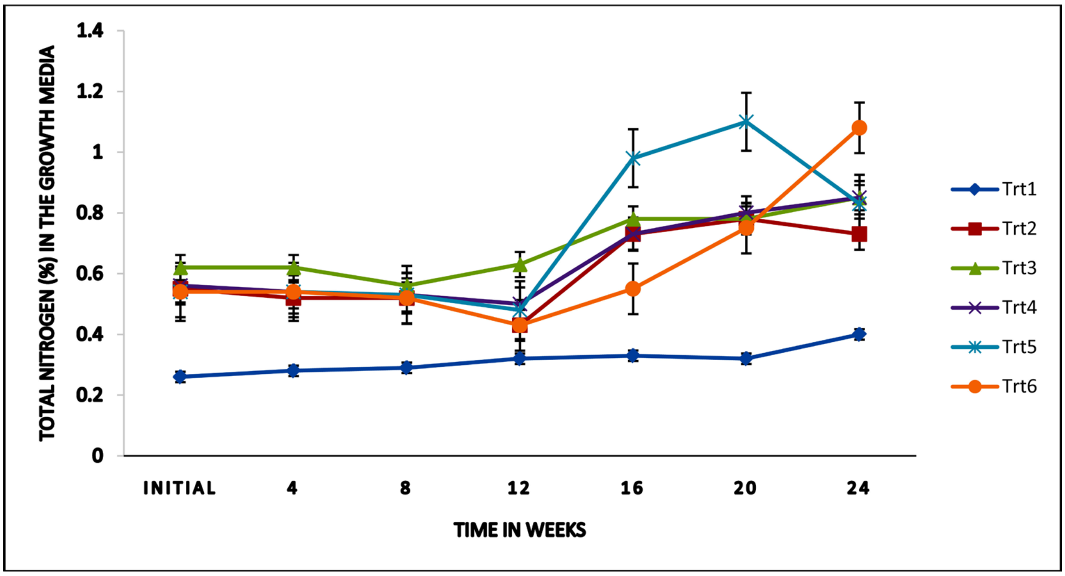


Figure 5. Nitrogen concentration of the growth media during the experimental period.

There was a general increase in the contents of total nitrogen in growth media during the study period with exception of week 8 to 12 (**Figure 5**). Treatments with cow dung had high levels of nitrogen compared to those with forest soil.

Low levels of nitrogen in the treatments at the start of the experiment to week 12 could be associated to decomposing microbes utilizing available nitrogen in protein synthesis and volatilization of part of it into gaseous form (Brady & Weil, 2002). Thus the lag phase of mineralization was up to 8 - 12 weeks. Increase in nitrogen in the media from week 12 to 24 could be associated with an increase in mineralizable nitrogen after the onset of decomposition.

Low levels of nitrogen in the sawdust alone treatment (Tr 1) could be associated with the fact that saw dust has high levels of cellulose and lignin and the chemicals are resistant to decomposition by microbes.

There was a general decline in organic carbon content in the treatments from the start of the experiment (week 0 to week 24) (**Figure 6**). Treatment 1 (Sawdust alone) had the highest level of organic carbon (49.56 g/kg) followed by Tr 3 (Sawdust mixed with cow dung in the ratio of 1:1) (36.80 g/kg) at the start of the experiment (**Table 4**).

The pH of the growth media was assessed throughout the study period and the results are shown in **Table 4**. The Ph of the media ranged between 4.38 (strong acid) to 8.05 (weak base) in the Sawdust alone (Tr 1) and Forest soil to sawdust cow dung (1:1) in ratio (Tr 6) respectively). At the end of the study period (24 weeks) the PH ranged between 5.16 and 6.8. Mixing of cow dung saw dust had the effect of increasing pH value of up to levels that make most nutrients available for plant uptake.

4. Discussion

Rapid growth of seedlings in treatments with Sawdust-forest soil-cow dung mixtures

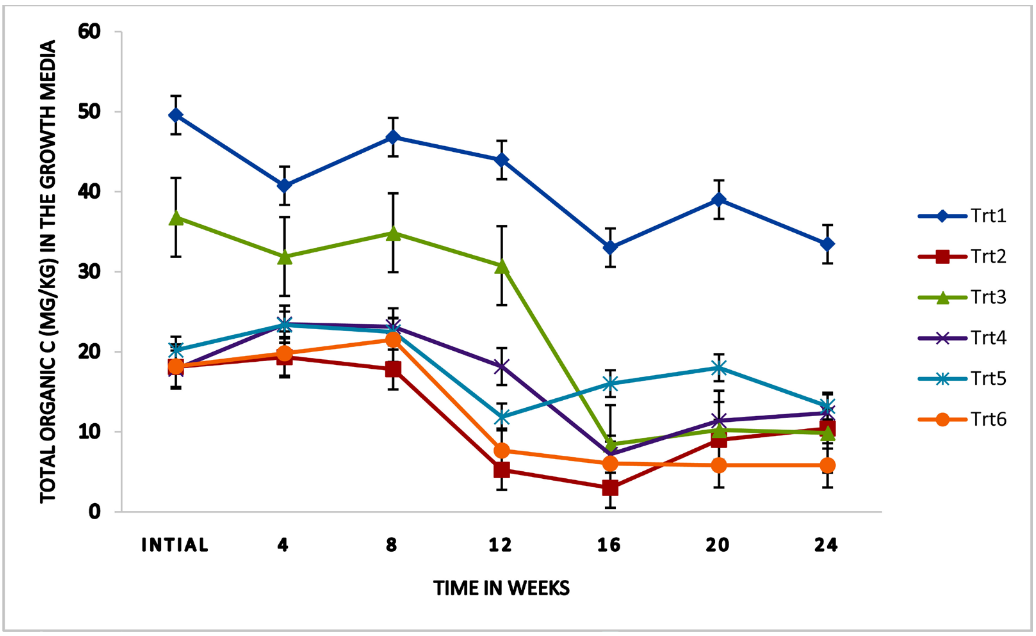


Figure 6. Organic carbon content of the growth media during the experimental period.

was realized in this study implying the potential of sawdust as a growth media when mixed with other materials.

Sawdust/cow dung mixture 1:1 supported growth of seedlings to an average height of 10.89 cm within a period of 20 weeks. The time was shortened by two month which seedlings of Eucalyptus take in most nurseries to reach transplant height (MENR, Forest Department Technical Orders, 1996). Lamprecht (1989), recommends transplanting of *Eucalyptus saligna* seedlings at a height of 10 cm and above. Studies by Garner (2014), reported sawdust as stale media for plant growth and low nutrient content could be reason for poor growth of seedlings raised in the medium.

Use of growth model as illustrated by Evans (1983) to determine growth potential of media by comparing monthly mean increment (MMI) and current monthly increment (CMI), showed that addition of sawdust cow dung mixture to forest soil enhanced growth potential of the media to sustain seedlings growth for a longer time as compared to sawdust only, that showed a decline in growth potential. Seedlings raised in sawdust-cow dung mixture had root collar diameter range between 2.69 - 3.55 mm, and according to Mexal et al., (1990), such seedling have a chance of over 70% survival when transplanted in the field. Seedling raised in sawdust only had root collar diameter less than 1.36 mm that would have a lower survival count in field. Root collar diameter is used as a utility in performance prediction and survival in the field (Evans, 1983). The findings of this study concur with those done by Ossom et al, (2010) on raising seedling using pine sawdust where the seedling raised in sawdust only had stunted growth with a root collar diameter less than 1.36 mm. High biomass gain of 15.77 g was realized in forest soil, followed by sawdust-cow dung mixtures. Saw dust had the lowest biomass gain of 1.03 g at the end of experiment period.

High biomass gain obtained using forest soil and cow dung indicates the two media have growth potential to support seedlings growth as compared to sawdust only that is a poor growth media. Mixing cow dung, sawdust and forest soil gave average gain in biomass; an indication of moderate growth potential of the media which can enhance survival of seedlings in the field as observed by Mexal et al. (1990).

A decline in organic carbon content during the experimental period was observed for all treatments could be associated with mineralization of the growth media due to favorable decomposition environment. Their decline, reflect the dynamic changes occurring as of mixing the growth media of sawdust, forest soil and cow dung.

According to Myrold (1998), soils with C: N of >30 will have a net immobilization of NH_4^+ and NO_3^- as was observed in our study in most treatments.

It has been reported that soils with less than 0.07% total N will have limited N mineralization potential, while soils with >0.15% total N would be expected to mineralize significant amount nitrogen during the following crop cycle (Kamiri et al., 2013; Cassman et al., 1996; Becker et al., 1994).

5. Conclusion

Growth characteristics of *Eucalyptus saligna* seedlings differed according to the growth media in the study. Sawdust-Cow dung mixture in ratio of 1:1 resulted to faster growth of seedlings which reached transplantable height of 10.89 cm at week 20; an indication that the media could be recommended for raising seedlings. Thus, addition of cow dung to saw dust offered options of developing a cheap media that was used to raise *Eucalyptus* seedlings within a short period of time and solve problems associated with saw dust as an environmental waste.

6. Recommendation

Sawdust/cow dung mixture in ratio of 1:1 by weight, gave excellent results in raising seedlings in the nursery. The mixture is recommended for fast growing seedlings that take shorter time to reach transplantable height. Higher ratio of sawdust/cowdung with forest soil is ideal for seedlings that take much longer time in the nursery. Application of artificial fertilizers rich in Nitrogen and Potassium may be required for seedlings that will stay in nursery for more than twenty weeks. The research findings provide safe disposal of sawdust heaps from sawmills and their environs into forest ecosystems where it will continue to decompose and form part of soil organic matter. The findings are relevant for formulation of policies on afforestation program and disposal of sawdust.

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