

## Rapid Composting: A Solution for Elephant Dung Management in Captive Centres

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**Abstract.** We investigated methods for rapid composting of elephant dung to support management of waste generated in establishments holding captive elephants. Elephant dung treated with effective microorganisms (EM) or urea alone, both EM and urea, and untreated dung were composted for 45 days. C:N ratios of treatments were estimated at 10-day intervals. Phytotoxicity and maturity of compost were evaluated after 45 days by a germination bioassay. Addition of urea decreased the C:N ratio more rapidly. EM and urea treatment resulted in an optimum C:N ratio of 22:1 after 20 days. Phytotoxicity was lowest in dung composted with EM and urea. Maturity of compost as indicated by seedling tolerance index was highest in EM and urea treatment. We conclude that EM and urea treatment results in the fastest composting and provides the best compost.

### Introduction

The daily food intake of an elephant is 200–270 kg and 100–130 kg is defecated per day (Sannigrahi 2015). In addition to leafy matter, they consume a considerable amount of bark and woody fragments (Steinheim *et al.* 2005). Therefore, elephant dung contains a significant amount of fibre and complex organic compounds.

The Pinnawala Elephant Orphanage (PEO) in Sri Lanka, where the study was conducted, was established in 1975 and held about 85 Asian elephants (*Elephas maximus*). As feed, elephants at the PEO were provided with leaves of coconut (*Coccus nucifera*), leaves and trunks of jaggery palm (*Careota urenus*), leaves and branches of jack (*Artocarpus heterophyllus*), sacred fig (*Ficus religiosa*), and weeping fig (*Ficus benjamina*). Daily, elephant dung is collected and dumped in an open field without any treatment.

As the decomposition of elephant dung takes a long time, waste management has emerged as a challenge at the PEO. Increasing the efficiency

of composting of elephant dung at establishments like the PEO is useful for management. The slow decomposition of elephant dung is mainly due to the high amount of lignified constituents, and low cellulolytic activity (Meissner *et al.* 1988). Carbon mineralization from dung is extremely rapid during the first 48 h but microbial activity is progressively limited by moisture (Anderson & Coe 1974). Open field disposal of elephant dung leads to drying, decreasing microbial activity (Sannigrahi 2015), and consequently requires a considerable extent of land for dumping.

The decomposition rate of complex organic material can be enhanced by reducing the C:N ratio by adding material high in nitrogen such as urine or nitrogen fertiliser, as they increase the abundance of microbial flora involved in decomposition, leading to rapid composting (Adediran *et al.* 2014). Mixtures of effective microorganisms (EM) available in the market contain a special group of heterotrophic microorganisms commonly found in natural environments and could be used for many purposes (Mupondi *et al.* 2006). This concept was initially developed in Japan with 'nature farming'

using mixed cultures of naturally existing beneficial microorganisms (Yamada & Xu 2000). EM require a carbon, nitrogen and an energy source. Hence, they can be used to convert organic waste into compost. Composting is the microbial aerobic degradation of organic waste through 'bio-oxidation' (Jimenez & Garcia 1989; Gautam *et al.* 2010) and time required for degradation varies with the type of substrate. EM can decompose organic substrates rapidly without any offensive odour (Sangakkara 1999). The objectives of this study were to determine whether elephant dung decomposition could be accelerated by treating with EM and urea and evaluating the applicability of elephant dung compost for improving plant growth.

## Materials and methods

### *Composting of elephant dung*

Elephant dung was collected within 48 h after defecation and brought to the Livestock Field Station of the Department of Animal Science, Faculty of Agriculture, University of Peradeniya. Composting bins 30 x 30 cm and 35 cm high were made with planks. The bottom and sides of the bins were covered with plastic-coated wire mesh (13 mm mesh size) and sides were insulated with white polythene sheets (gauge 1,000) to avoid excessive moisture and heat loss. Composting was done under of four treatments (Table 1) with four replicates each. Bins were randomly assigned to the four treatments. Dung boli were pulverised and mixed manually, 10 kg filled into each composting bin without pressing and treatments applied. A stock solution of EM was obtained from Sarvodaya Sustainable Economic Enterprises Limited. Both EM and urea treatments were applied on day 1. EM treatment was repeated for EM only and, EM and urea on day 16 to maintain microbiota throughout the composting period.

Turning of compost piles were carried out at 4-day intervals to facilitate aeration by dumping the contents of each bin onto a polythene sheet, mixing by hand and placing back in the bin. A hand-squeeze test was conducted to monitor moisture content of compost piles by taking a handful of sample and squeezing tightly. If wa-

ter flowed out freely, it was considered too wet. A damp and sponge like consistency was considered as the ideal moisture content, assumed to correspond to about 50–60%. If it was dry and crumbly it was considered too dry. Piles considered too wet were allowed to dry and if too dry, they were watered. Composting was continued for 45 days.

A representative sample of about 50 g was taken from each bin, at 10-day intervals and stored in polythene bags. Samples were oven-dried at 60°C for up to 48 h and weighed at 1-hour intervals till constant in weight. Afterward, samples were ground using a laboratory-milling machine (ZM 200, Retsch, Germany) and passed through a 1 mm sieve.

Loss on ignition method was used to estimate the total organic matter percentage of samples. From the prepared samples, 2 g were oven-dried again at 100°C for 24 h and dried weight (DW) determined. Afterward, samples were transferred into a Muffle furnace (CSF 1200, Carbolite, UK) and completely burnt at 525°C for 4 h, and ash weight (AW) was determined. The equation below was used to estimate the total organic matter percentage (TOM%). A conversion factor (1.25) was used to estimate total carbon percentage from total organic matter percentage of treatments (Jimenez & Garcia 1989).

$$\text{TOM}\% = (\text{DW} - \text{AW}) / \text{DW} \times 100$$

The total nitrogen percentage was determined using the micro-Kjeldahl method (AOAC 2005).

### *Germination bioassay*

A seed germination test was conducted to evaluate the phytotoxicity of compost. After 45 days

**Table 1.** Composition of compost treatments.

Treatment #	Composition
1	ED + Water (1:1000)
2	ED + Urea (1:1000)
3	ED + EM (1:1000)
4	ED + EM (1:1000) + Urea (1:1000)

the compost in each bin was mixed, a 500 g sample taken and combined to create a composite sample of 2 kg for each treatment, from which a sub-sample of 2.5 g was taken for testing. A compost-water extract was prepared by mixing 2.5 g of the compost with 25 ml of de-ionised water, mixed using a vortex mixer at 24,000 rpm for 2 min and filtered using Whatman no. 1 filter papers. Maize seeds (variety: Thai-Hybrid) were rinsed three times in de-ionised water and five seeds were placed on a petri dish lined with Whatman no.1 filter paper. Two replicates were set up per sample and 5 ml of compost extracts were added to each test sample and 5 ml of de-ionised water to the control. The petri dishes were incubated at a room temperature of  $30 \pm 2^\circ\text{C}$  for 4 days in the dark.

At the end of the incubation period, radicle length, coleoptile length, and root length of each germinated seed were measured. If both radicle and coleoptile length was above 5 mm, a seed was considered to have germinated. Following equations (Asmare 2013) were applied to calculate the germination percentage (G%), relative seed germination (RSG), relative radicle growth (RRG), and germination index (GI). The method proposed by Chou & Lin (1976) was used for measuring root length of seedlings for calculating the seedling tolerance index (STI).

$$G\% = \# \text{ germinated seeds} / \# \text{ total seeds} \times 100$$

$$RSG = \# \text{ germinated seeds (sample)} / \# \text{ germinated seeds (control)} \times 100$$

$$RRG = \text{total radicle length of germinated seeds (sample)} / \text{total radicle length of germinated seeds (control)} \times 100$$

$$GI = RSG \times RRG \times 100$$

$$STI = \text{mean root length in compost extract} / \text{mean root length in deionised water} \times 100$$

#### *Plant growth bioassay*

A plant growth bioassay was conducted to evaluate the effect of compost on plant growth using composite samples of each treatment. Compost and river sand were mixed in a ratio of 1:1 by volume and river sand alone was used as a con-

trol. Five grams of controlled-release fertiliser OSMOCOTE (14-14-14; N: P: K) were added to each treatment at 1:800 ratio, and placed in 4 L black plastic pots. Each treatment including the control was duplicated. All of the pots were kept under uniform conditions with day/night temperatures of  $28 \pm 3^\circ\text{C}$  and 12 h light per day. The pots were kept moist by regular watering. Maize seeds (variety: Thai-Hybrid) were soaked in de-ionised water overnight, and 5 seeds placed in each pot. After 7 days, 3 seedlings were removed to facilitate the growth of the remaining two seedlings. Stem height from the base to the junction of the two full upper leaves of plants was measured at 10-day intervals for 40 days, and a single maize plant was considered as a unit.

#### *Statistical analyses*

The C:N ratio data were subjected to analysis of variance (ANOVA) for each time point and throughout the time series. Germination bioassay and plant growth bioassay were subjected to ANOVA under CRD experimental design using SAS 9.0, and means were separated by Tukey's test at  $P < 0.05$ .

## **Results**

#### *Total nitrogen percentage*

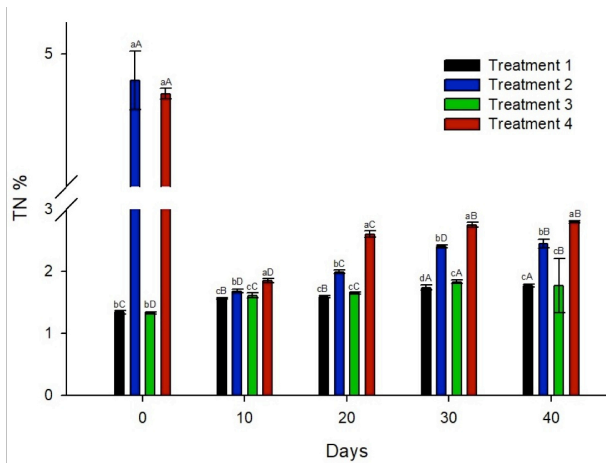
Treatments with urea (2 and 4) had a higher total nitrogen percentage than those without urea (1 and 3) at the start, which declined by the 10th day (Fig. 1). Treatments 1 and 3 did not differ except on 30th day. Treatment 4 had the highest total nitrogen percentage among treatments, on 40th day.

#### *Total carbon percentage*

All treatments had similar total carbon percentages at the start (Fig. 2). Subsequently, treatment 4 had a lower total carbon percentage except on 30th day.

#### *C:N ratio*

At the start of the experiment the C:N ratios of treatments 2 and 4 were 13:1 and in treatments 1 and 3, 50:1 (Fig. 3). The C:N ratio of treat-

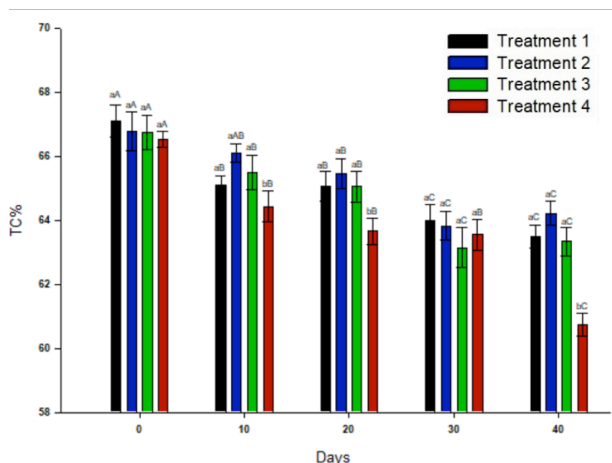


**Figure 1.** Changes in total nitrogen percentage (TN%). Lowercase letters on top of bars denote comparison of different treatments within days and uppercase letters the same treatment between days, with the same letter signifying no difference in means (Tukey's test at  $P < 0.05$ ).

ments 2 and 4 increased to 39:1 and 35:1 respectively on day 10 then decreased gradually to 34:1 and 22:1 respectively by day 40. The C:N ratios of treatments 1 and 3 gradually decreased from the start to end (from 50:1 to 36:1). Treatment 2 reached a C:N ratio of 27:1 by day 30 and Treatment 4 reached a ratio of 25:1 by day 20.

#### Germination bioassay for different treatments

The germination results are shown in Table 2 and Figure 4.



**Figure 2.** Changes in total carbon percentage (TC%). Lowercase letters on top of bars denote comparisons of different treatments within days and uppercase letters the same treatment between days, with the same letter signifying no difference in means (Tukey's test at  $P < 0.05$ ).

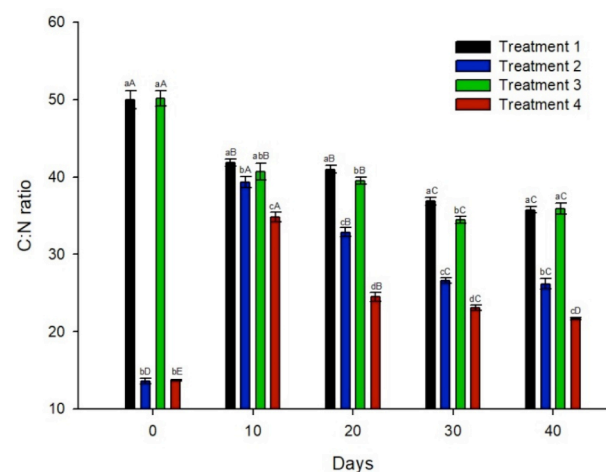
#### Plant growth bioassay of different treatments

Maize plants in all treatments showed rapid growth (Fig. 5). Plant height of treatment 1 was the lowest ( $P < 0.05$ ), and urea added treatments (2 and 4) the highest ( $P < 0.05$ ) in the last 20 days of the bioassay. When comparing the plant heights of treatments 1 and 3 against the control, plant height of both treatments was lower ( $P < 0.05$ ) than the control in the last 20 days. Figure 6 shows the plants grown for 40 days.

#### Discussion

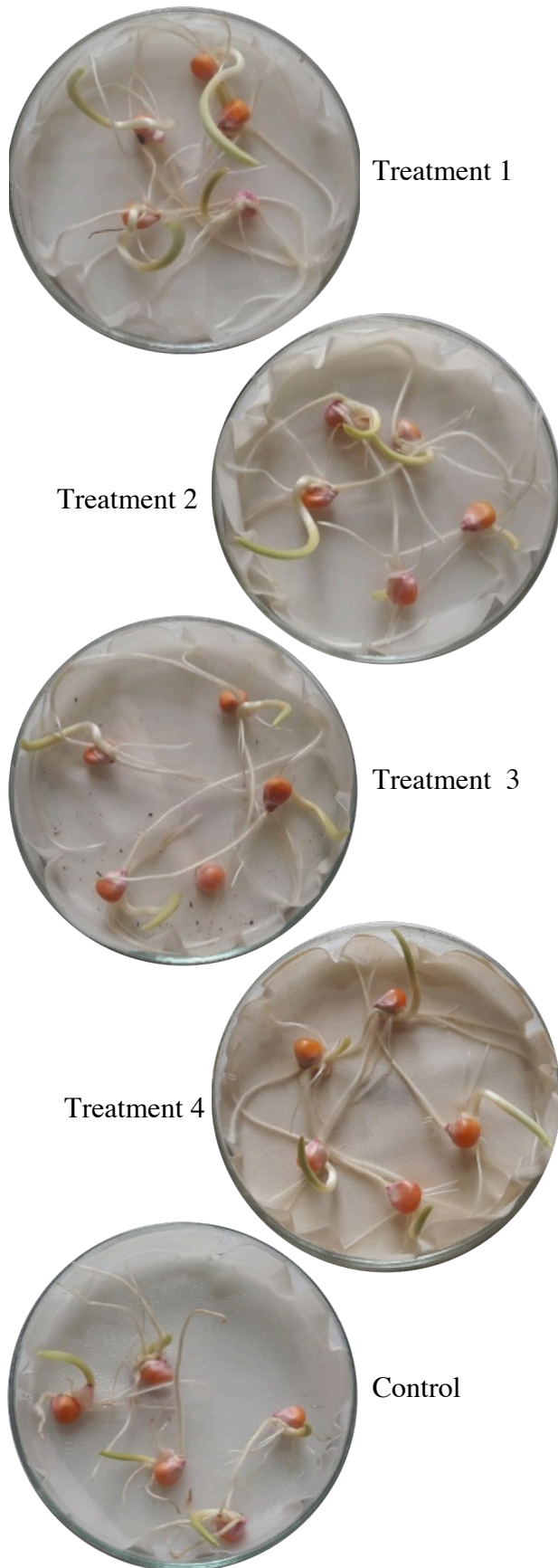
##### Time to decomposition

Traditional composting takes several months to produce compost (Liu *et al.* 2011). Therefore, rapid composting methods are required for dealing with large volumes of raw waste. In this study, we measured the C:N ratio of four treatments to evaluate the rapidity of composting of elephant dung with different treatments. The C:N ratio is an indicator of the decomposition rate. In composting, microorganisms utilise substrate carbon for cellular growth and energy. Consequently, carbon and therefore the C:N ratio decreases. The magnitude of change in the C:N ratio reflects the intensity of microbial activity (Mupondi *et al.* 2006). We found a rapid decrease of the C:N ratio when urea was added to dung. The fastest decrease in the C:N ratio was in treatment 4 which reached a low



**Figure 3.** Changes in C:N ratios. Treatments followed by the same uppercase letter along the days and the same lowercase letter within a particular day do not differ significantly according to Tukey's test at  $P < 0.05$ .

level by day 20, indicating that decomposition was faster when elephant dung was treated with both EM and urea.



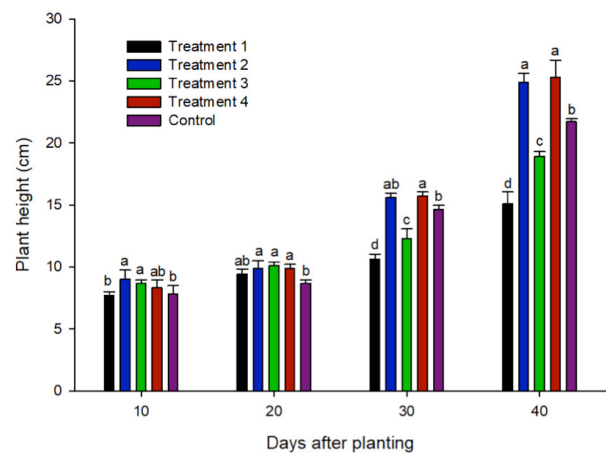
**Figure 4.** Germination of maize seedlings in the germination bioassay.

High C:N ratios in composting material indicate late maturity (Adediran *et al.* 2014) hence longer time to decomposition. A cause of high C:N ratios is lignocellulosic materials, which hinder the composting process due to their recalcitrance to enzymatic attack by microorganisms (Sanches *et al.* 2017). Elephant dung has a high level of lignocellulosic material as it is high in fibre. We found that elephant dung alone and treatment with EM only had high initial C:N ratios, indicating that they would have decomposed at a slow rate, whereas adding urea decreased the C:N ratio.

The C:N ratio is also an indicator of the quality of organic matter, with the preferred C:N ratio for compost ranging between 15:1 to 30:1 (Haug 1993). We found, treatments 2 and 4 reached the preferred C:N ratios by the 40th day of composting indicating maturity. Thus, treating elephant dung with urea or urea and EM enabled reaching maturity earlier than when composting elephant dung alone or treating with only EM.

#### Germination bioassay

Phytotoxicity is a major criterion for evaluating the suitability and maturity of composts. Compounds such as phenolic acids are able to induce inhibiting effects on seed germination and plant growth (Rejila *et al.* 2012).



**Figure 5.** Plant height of maize grown in different treatments. Treatments followed by the same letter within a particular day do not differ significantly according to Tukey's test at  $P < 0.05$ .

**Table 2.** Results of maize seed germination bioassay with different treatments. Treatments with the same letter within a line do not differ significantly according to Tukey's test at  $P < 0.05$ .

Parameter	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Control*
Germination [%]	90.00	100.00	80.00	90.00	100.00
Relative seed germination	90.00	100.00	80.00	90.00	-
Radicle length [cm]	4.52 <sup>C</sup>	6.51 <sup>AB</sup>	7.06 <sup>A</sup>	7.63 <sup>A</sup>	4.69 <sup>BC</sup>
Relative radicle growth	96.38 <sup>C</sup>	138.81 <sup>AB</sup>	120.47 <sup>B</sup>	145.20 <sup>A</sup>	-
Germination index	86.44 <sup>A</sup>	138.81 <sup>A</sup>	96.37 <sup>A</sup>	131.18 <sup>A</sup>	-
Seed tolerance index	148.41 <sup>C</sup>	121.42 <sup>D</sup>	179.55 <sup>A</sup>	163.98 <sup>B</sup>	-

\* no dung

### Germination percentage (G%)

We found that germination was inhibited in EM added treatments and with dung only, while there was no inhibition in the urea only treatment and the control. Seed germination inhibition can occur due to high levels of dissolved solids, which are absorbed by seeds before germination (Sujatha *et al.* 2017). Adding EMs could increase dissolved solids, causing inhibition of seed germination.

Germination is less sensitive than seedling growth to phytotoxic substances (Verma *et al.* 2012). Therefore, relative radicle growth (RRG) and germination index (GI) are more sensitive indicators of phytotoxicity of composts.

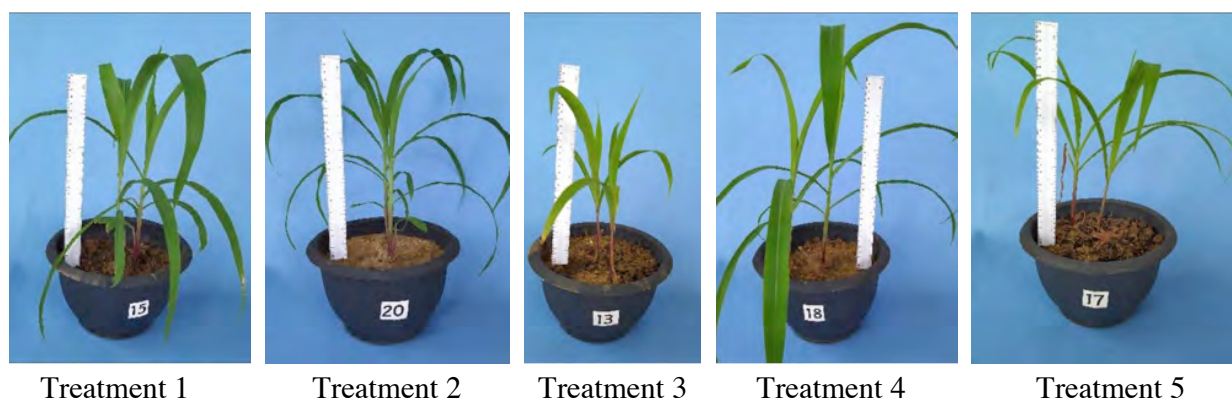
### Relative radicle growth (RRG)

The radicle of a germinating seed emerges first, coming into contact with any phytotoxic compounds in the substrate. Thus, radicle length is very sensitive to extracts (Verma *et al.* 2012). The lowest RRG was observed in the treatment with elephant dung only, which could be due to the slow breakdown of existing phytotoxic

compounds in dung composted without additions. Adding urea or EM showed greater RRG and adding both, the highest RRG, indicating the least phytotoxicity was achieved by adding both urea and EM to elephant dung.

### Germination index (GI)

GI is a common and sensitive biological indicator for assessing phytotoxicity and maturity (Bougnom *et al.* 2020). We observed, higher GI values in treatments with urea than without, which suggests that adding urea overcomes phytotoxicity and promotes the maturity of compost. Dung without additions had the lowest GI value, even though it had a higher germination percentage than when only EM was added. This suggests that root growth was restricted due to inhibitory substances that remained at the end of the 45-day period, when elephant dung was composted without additions. Germination index values greater than 80% indicate maturity and the lack of toxic effects of compost (Bougnom *et al.* 2020). Based on an 80% cut-off value, all of the treatments showed maturity and lack of phytotoxic compounds by 45 days.



**Figure 6.** Plant growth bioassay after 40 days growth.

### *Seedling tolerance index (STI)*

Soluble salts affect root growth of seedlings (Sujatha *et al.* 2017), therefore root length could be influenced by the salinity of the growth medium. The lowest seed tolerance index (STI) was recorded in urea only treatment and the highest in EM only treatment, with a mid level value observed when both urea and EM were added. This suggests a negative impact of urea and a positive impact of EM on root growth.

### *Plant growth bioassay of different treatments*

Growth rates between treatments were similar during the first 20 days. This is possibly due to initial shoot and root growth being dependant on seed reserves (Nadeem *et al.* 2011). Plant heights of treatments differed in the last 20 days, which may be due to effects of phytotoxic substances in compost. Plant height was lowest at 40 days, with dung composted without additions, and those with added urea the highest. This also suggests the slower decomposition of elephant dung alone. Also, application of unstable composts can cause low plant growth and damage crops by competing for oxygen (Mupondi *et al.* 2006). On the other hand, compost with EM only had higher plant height than only dung and the compost with urea the highest. Therefore, EM and particularly urea treatment of elephant dung, has a positive impact on plant growth.

In conclusion, this study shows the possibility of rapid composting of elephant dung by treating with EM and urea in around 40 days as opposed to composting without treating which would take longer. The highest decomposition rate and the lowest level of phytotoxicity occurred in elephant dung treated with both urea and EM, hence it is the best suited for rapid composting of elephant dung.

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### **References**

- Adediran JA, Taiwo LB & Sobulo RA (2014) Effect of organic wastes and method of composting on compost maturity, nutrient composition of compost and yields of two vegetable crops. *Journal of Agriculture* **22**: 95-109.
- Anderson JM & Coe MJ (1974) Decomposition of elephant dung in an arid, tropical environment. *Oecologia* **14**: 111-125.
- AOAC (2005) *Official Methods of Analysis of the Association of Official Analytical Chemists International. 18th Edition.* Maryland, USA.
- Asmare HA (2013) Impact of salinity on tolerance, vigor, and seedling relative water content of haricot bean (*Phaseolus vulgaris* L.) cultivars. *Journal of Plant Sciences* **1(3)**: 22-27.
- Bougnom BP, Dieudonne O & Sontsa-Donhoung AM (2020) Evaluation of wood ash as additive for cow manure composting. *International Annals of Science* **9**: 100-110.
- Chou CH & Lin HJ (1976) Autotoxication mechanism of *Oryza sativa* I. Phytotoxic effects of decomposing rice residues in soil. *Journal of Chemical Ecology* **2**: 353-367.
- Gautam SP, Bundela PS, Pandey AK, Awasthi MK & Sarsaiya S (2010) Composting of municipal solid waste of Jabalpur City. *Global Journal of Environmental Research* **4**: 43-46.
- Haug RT (1993) *The Practical Handbook of Compost Engineering.* Lewis Publishers, Boca Raton, USA.
- Jimenez EI & Garcia VP (1989) Evaluation of city refuse compost maturity: A review. *Biological Wastes* **27**: 115-142.
- Sangakkara R (1999) *Kyusei Nature Farming and the Technology of Effective Microorganisms.* INFCR, Atami, Japan and APNAN, Bangkok, Thailand.
- Liu D, Zhang R, Wu H, Xu D, Tang Z, Yu G, Xu Z & Shen Q (2011) Changes in biochemical

and microbiological parameters during the period of rapid composting of dairy manure with rice chaff. *Bioresource Technology* **102**: 9040-9049.

Meissner HH, Spreeth EB, de Villiers PA, Pietersen EW, Hugo TA & Terblanché TF (1988) Quality of food and voluntary intake by elephant as measured by lignin index. *South African Journal of Wildlife Resources* **20**: 104-110.

Mupondi LT, Mnkeni PNS & Brutsch MO (2006) The effects of goat manure, sewage sludge and effective microorganisms on the composting of pine bark. *Compost Science and Utilization* **14**: 201-210.

Nadeem M, Mollier A & Pellerinis S (2011) Relative contribution of seed phosphorus reserves and exogenous phosphorus uptake to maize (*Zea mays* L.) nutrition during early growth stages. *Plant and Soil* **346**: 231-244.

Rejila S, Vijayakumar N & Jayakumar M (2012) Chromatographic determination of allelochemicals (phenolic acids) in *Jatropha curcas* by HPTLC. *Asian Journal of Plant Science and Research* **2**: 123-128.

Sanchez OJ, Ospina DA & Montoya S (2017) Compost supplementation with nutrients and

microorganisms in composting process. *Waste Management* **69(26)**: 136–153.

Sannigrahi AK (2015) Beneficial utilization of elephant dung through vermicomposting. *International Journal of Recent Scientific Research* **6**: 4814-4817.

Steinheim G, Wegge P, Fjellstad JI, Jnawali SR and Weladji RB (2005) Dry season diets and habitat use of sympatric Asian elephants (*Elephas maximus*) and greater one-horned rhinoceros (*Rhinoceros unicornis*) in Nepal. *Journal of Zoology* **265**: 377-385.

Sujatha D, Rose C, Mani U & Elumalai A (2017) Phytotoxic effect of tannery effluents on seed germination and seedling growth of cowpea (*Vigna unguiculata* L.) walp. *Indian Journal of Plant Science* **6(3)**: 13-20.

Verma SK, Kumar S, Pandey V, Verma RK & Patra DD (2012) Phytotoxic effects of sweet basil (*Ocimum basilicum* L.) extracts on germination and seedling growth of commercial crop plants. *European Journal of Experimental Biology* **2**: 2310-2316.

Yamada K & Xu HL (2000) Properties and applications of an organic fertilizer inoculated with effective microorganisms. *Journal of Crop Production* **3**: 255-268.



Elephants at the PEO.