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Optimizing the Ratio of Water Hyacinth, Cattle Manure, and Sawdust for the Optimum Physicochemical and Biological Properties of Compost

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ABSTRACT

Utilizing water hyacinth (WH) (*Eichhornia crassipes* L.) offers an opportunity for composting and supports sustainable waste management, despite its invasive nature. Therefore, this study aimed to produce compost using water hyacinth (WH), cattle manure (CM), and Albizia sawdust (AS) as raw materials, and to evaluate its physicochemical and biological properties. Cattle manure and AS were combined in a 1:1 ratio to prepare the initial mixture (M). Then, four compost piles were produced by varying the ratios of WH and M: T0 (1:0), T1 (1:1), T2 (2:1), and T3 (3:1). Colour, odour, moisture content, bulk density, electrical conductivity (EC), organic matter, total nitrogen, total phosphorus, total potassium, total organic carbon, and the C:N ratio were analysed on the 60th, 90th, and 120th days, while sodium, calcium, magnesium, iron, heavy metals, cation exchange capacity (CEC), and germination percentage were evaluated on the 120th day across all treatments. Based on the findings, T0 was rejected due to its high EC (6.01 dS/m), high organic matter content (42.31%), extremely high CEC (90 cmol/kg), all of which reduced its overall quality. T1 had high heavy metal content, and T3 exhibited a high C:N ratio (35.81), and incomplete nitrogen mineralization, making it unsuitable. Among the treatments, T2 was identified as the best compost due to its optimal nutrient composition and superior decomposition indicators, including the lowest C:N ratio (11.46), the highest total nitrogen content (1.395%), and an organic matter content of 27.55%, making it a highly suitable compost based on Sri Lanka Standards (SLS 1635) and United States Environmental Protection Agency (US EPA) standards. There was no significant difference in the germination percentage between T2 and the control. Hence, these findings confirm that T2 (a mixture of water hyacinth at a 2:1 ratio with an equal mixture of cattle manure and Albizia sawdust) is the most nutrient-rich and well-balanced compost among the treatments evaluated in the study.

Keywords: Cattle manure, Compost quality, Sawdust, Water hyacinth

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INTRODUCTION

Water hyacinth (*Eichhornia crassipes*) (WH) proliferates rapidly, doubling its volume within a few weeks (Oladoja *et al*., 2024). Its seeds remain viable for 15-20 years and grow in a wide range of pH values, temperature regimes, and nutrient sources (Gaikwad and Gavande, 2017). It can continue photosynthesis under drought stress and grow in aquatic and terrestrial habitats (Venter *et al*., 2017). These adaptability traits spread WH, destroying ecological balance, reducing dissolved oxygen levels and obstructing sunlight penetration, excluding other aquatic flora (Oladoja *et al*., 2024; Song *et al*., 2024).

Consequently, WH growth decreases water pH, creating intolerable habitats for different plant species (Song *et al*., 2024). Various methods have been employed to limit WH proliferation (Fentie *et al*., 2024). Manual, mechanical, chemical, and biological techniques have been applied to eliminate this plant. However, each method has constraints, necessitating a novel approach to developing sustainable solutions (Pendse and Deshmukh, 2024). Mechanical removal techniques involve filling landfills (Datta *et al*., 2024). Chemical treatments rely on the application of herbicides or algaecides (Xu *et al*., 2024). Biological control methods involve introducing natural predators (Hassan *et al*., 2023; Colombo *et al*., 2024; Righetti *et al*., 2024; Xiang *et al*., 2024; Xu *et al*., 2024). Plant-antagonist interactions diminish the effectiveness of biocontrol agents (Misra *et al*., 2024). Combining a contact herbicide with a systemic herbicide can ensure both rapid action and complete kill, including root structures (Xu *et al*., 2024). Therefore, it is essential to develop locally applicable WH management strategies.

WH is used for diverse purposes such as oil absorption (Phetrungnapha *et al*., 2024), anti-fungal extract production (Ratnani *et al*., 2024), yarn spinning (Chonsakorn *et al*., 2024), hydrogen production (Chee *et al*., 2024), biosynthesis of nanoparticles (Pandey *et al*., 2024), fabric production (Sirisoda, 2024), renewable energy material (Kariim *et al*., 2024), and biochar production (Gezahegn *et al*., 2024), composting and animal feed (Vodounnou *et al*., 2024), substrate for Black Soldier fly (*Hermetia illucens*) larvae, bioenergy production (Karouach *et al*., 2024), and as a source for phytomining (Romanova *et al*., 2016).

Compost production using WH is a low-input, simple technology that can be implemented on a large scale. WH has a remarkable ability to absorb heavy metals from polluted water bodies (Newete *et al*., 2016; Permatasari *et al*., 2023; Guayjarernpanishk and Sampanpanish, 2024; Jamilatun *et al*., 2024). The fibrous root system of WH provides a large surface area for metal adsorption (Ali *et al*., 2019). Hence, WH compost production is tested for heavy metal content (Chen *et al*., 2024). The acceptable ranges for colour, odour, moisture content, bulk density, electrical conductivity (EC), organic matter, total nitrogen, total phosphorus, total potassium, total organic carbon, carbon-to-nitrogen ratio, sodium, calcium, magnesium, iron, heavy metals, cation exchange capacity (CEC), and germination percentage in compost have already been published (Table 1).

On the other hand, WH has a high moisture content, which decreases the decomposition rate and leads to anaerobic conditions (Cherwoo *et al*., 2024). A lack of certain essential nutrients or an imbalanced C: N ratio (Ansari *et al*., 2024) also affects microbial activity and decomposition rates (Noor *et al*., 2024). Compost additives offer a range of benefits: Enhancing the physicochemical properties, accelerating the rate of breaking down of organic matter, boosting microbial activity, and promoting stability (Ibro *et al*., 2024), additives reduce greenhouse gas and ammonia emissions (Wang *et al*., 2017), and retaining nutrients in the compost improves compost maturity (Noor *et al*., 2024).

Sawdust and cattle manure are commonly used compost additives in compost production. Sawdust acts as a bulking agent by enhancing the porosity of the compost and providing a high-carbon material that balances the C:N ratio, thereby increasing compost quality (Wang *et al*., 2024). Since WH is nitrogen-rich, it can benefit from adding sawdust to achieve an optimal C:N ratio (Liu *et al*., 2024a).

Sawdust has excellent moisture-absorbing properties (Seidu and Kutelu, 2014), thus allowing for better airflow and nutrient distribution (Fawole 2015). Sawdust slowly releases nutrients (Oluwafisayo, 2024). Further, cattle manure enhances compost quality (Xu *et al*., 2024) due to its rich nutrient content, including nitrogen, phosphorus, and potassium (Sagala *et al*., 2024). Its organic matter provides a valuable carbon source, achieving an optimal C:N ratio in the compost mixture (Tira and Sutanto, 2024).

Additionally, microbial activity within cattle manure accelerates the decomposition process (Olivo *et al.*, 2024). Beneficial microorganisms in cattle manure further enrich the compost with essential nutrients (Liu *et al.*, 2024b).

Phytotoxicity, a concept in compost quality assessment, refers to the potential of compost to harm plant growth and development (Barral and Paradelo, 2011). Additives are added to compost to neutralize toxins (Kulabako *et al.*, 2024). Compost may also contain substances that inhibit seed germination, root elongation, or overall plant vigour (Wang *et al.*, 2022). Therefore, assessing phytotoxicity in compost is important to ensure its suitability for crop production.

The objectives of the present study were to evaluate the physicochemical and biological properties of compost produced from different mixing ratios of water hyacinth, sawdust, and cattle manure, and to formulate an optimal combination for balanced composting. The results of this study will contribute to the sustainable management of water hyacinth and promote eco-friendly crop production through compost use.

Table 1. Acceptable ranges of physical, chemical, and biological parameters in compost

Variable	Acceptable/optimum range	Reference
CL	Brown to black	
OD	No unpleasant odour	(SLS 1635, 2019)
MC (% wb)	50-60%	(SLS 1635, 2019)
BD (g/cm^3 db)	0.2-0.4	(He *et al.*, 2021)
pH	6.5-8.5	(SLS 1635, 2019)
EC (dS/m)	4	(SLS 1635, 2019)
OM% db)	25-65	(Crohn, 2016)
TN% db)	1	(SLS 1635, 2019)
TP% db)	0.5	(SLS 1635, 2019)
TK% db)	1	(SLS 1635, 2019)
TOC% db)	20	(SLS 1635, 2019)
C: N	10-25	(SLS 1635, 2019)
CEC Cmol(+)/Kg)	>60	(Saharinen, 1998)
Na (% db)	1	(Crohn, 2016)
Ca (% db)	0.7	(SLS 1635, 2019)
Ma (% db)	0.5	(SLS 1635, 2019)
Mn (ppm)	431–600	(Abad *et al.*, 2001)
Fe (ppm)	<9300	(Abad *et al.*, 2001)
Cr (ppm)	1000	(SLS 1635, 2019)
Ni (ppm)	100	(SLS 1635, 2019)
Cu (ppm)	400	(SLS 1635, 2019)
Cd (ppm)	10	(SLS 1635, 2019)
Pb (ppm)	250	(SLS 1635, 2019)
As (ppm)	41	(US EPA, 1994)
Zn (ppm)	1000	(SLS 1635, 2019)
GP (%)	50	(Albert *et al.*, 2002)

CL: Colour, OD: odour, MC: moisture content, Bd: Bulk density, EC: electrical conductivity, OM: organic matter, TN: total nitrogen, TP: total phosphorous, TK: total potassium, TOC: total organic carbon, C: N: carbon: nitrogen ratio, CEC: cation exchange capacity, GP: germination percentage

MATERIALS AND METHODS

Experimental Location

The experiment was conducted at the Faculty of Technology, University of Ruhuna, Sri Lanka (6.0833°N latitude and 80.5667°E) from 2021 to 2022. The experimental farm is located about 14.06 m above sea level with a tropical rainforest climate.

Raw Material Collection

Water hyacinth was collected from a water body named *Gamachchi wewa*, Weeraketiya, in the intermediate zone of southern Sri Lanka. Cattle manure and Albezia sawdust were collected from the research farm, Faculty of Agriculture, Mapalana, Sri Lanka, and a nearby sawmill, respectively.

Pile Composition, Preparation, and Composting Process

The compost preparation was carried out on a concrete floor of an open area with good ventilation using the aerobic windrow method (Diaz *et al*., 2002). Windrow composting is a widely used aerobic composting technique where organic materials are piled into long, narrow heaps called windrows. The heaps are regularly turned using mechanical equipment or manually, to maintain aeration and promote uniform decomposition. Three to four days old cattle manure and sawdust were mixed in a 1:1 ratio on a fresh weight basis. Four different types of composts were prepared by amending one-week drained WH with prepared cattle manure and sawdust mixture (M) in the proportions of WH: M in 1:0 (T0), 1:1 (T1), 2:1 (T2) and 3:1 (T3) on a fresh weight basis. These piles were arranged in a completely randomized block design with three replicates. The dimensions of the piles were 0.75 m height × 0.5 m width × 0.75 m length. The piles were subjected to rapid manual turning every day during the first week and once per week until the end of the process. The moisture of the piles was adjusted by adding water to keep the level at approximately 60% using the field method. All piles were covered with perforated plastic material to prevent excessive moisture loss. The composting process was monitored for 120 days until a compost heap size became stable.

Sampling Procedure and Parameter Analysis

Three composite samples (500 g each) representing each pile were collected separately on days 14 (initial stage), 60 (middle stage), and 120 (final stage). The compost pile was divided into eight sections superficially, and randomly selected sampling points were selected from various locations, including the top, middle, bottom, centre, and edges of the pile. The samples were packed in hermetically sealed plastic bags and immediately brought to the laboratory for analysis.

Physicochemical Properties Analysis of Compost

The colour (CL) and odour (OD) of compost mixtures were recorded by observations and smelling, respectively. Bulk density was measured using the cylinder method. Triplicate samples were dried at 105 °C in a hot air oven for 24 h, and the moisture content (MC) was calculated (Singh *et al*., 2012). The air-dried samples were ground to pass through 2 mm sieves and stored at 4 ^{o}C for further analysis. The samples were analysed for pH (pH 700, Eutech Instruments, Singapore) and electrical conductivity (EC) (1:5 w/v waste: water extract) as per the method described by Kalamdhad et *al*. (2009). Total nitrogen (N) was determined by the Kjeldahl method (Bremner and Mulvaney, 1982). The total phosphorus (P) of the compost was measured using the acid digestion spectrophotometry technique (SLS 614, 1983). Total potassium (K) was measured using a flame photometer (Jackson, 1973). Total organic matter (OM) was determined by loss on ignition at 550 °C for six hours (Tiquiaa and Tam, 2000). Furthermore, the C:N ratio was calculated using total organic carbon (TOC) and total nitrogen (TN). Cation exchange capacity (CEC) was determined using the ammonium acetate (NH_4CH_3COO) method (Tan, 2005) and the percentages of sodium (Na), calcium (Ca), and magnesium (Mg) were analysed using a flame photometer (Jackson, 1973) in 120-day matured compost.

Heavy Metal Analysis

The matured compost was analysed for the heavy metals (Mn, Fe, Cr, Ni, Cu, Cd, Pb, As, and Zn) using an inductively coupled plasma optical emission spectrometer (Thermo Scientific, ICAP Spectrometer 7000, UK) as described by Singh and Kalamdhad (2016). For this, the samples were digested with concentrated acids HNO_3 and HCl with a 3:1 ratio and kept in a water bath overnight. The mixtures were filtered using filter papers

(Whatman No. 1), and the filtrates were obtained for analysis.

Phytotoxicity Evaluation

A seed germination bioassay was performed to evaluate the phytotoxicity of mature compost (day 120). The samples were taken randomly in the four piles of each treatment (T0, T1, T2 and T3) at the end of the process. The biological test using the indicator species radish, tomato, and corn was conducted according to the methodology given by Zucconi *et al*. (1985). The compost extract was prepared by mixing two parts of distilled water with one part of compost on a dry basis in a 150 ml beaker. It was mixed well and allowed to soak for 3 h. The compost extract was then released by compression and filtered through the Whatman No. 40 filter paper. Ten seeds were placed in each Petri dish with filter paper on the bottom. Three replicates of each radish, tomato, and corn seed were maintained. Then, the compost extract was dispensed to saturate the filter paper, applying 3 ml of extract and covering it with a lid. Germination percentage (%) was calculated after 3 days. This germination test was carried out for three species: radish, tomato, and corn. Average gemination percentages of three species were taken for the statistical analysis.

Statistical Analysis

The mean values of reported data were analysed by analysis of variance (ANOVA) using SPSS software 20 version (SPSS Inc. 2012). Significant differences among the main effects were further analyzed using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Physicochemical Properties of Compost

The compost was black in each treatment. There was no foul odour; hence, the digestion was aerobic. T0 recorded a relatively high moisture content on day 14 (56.56%) and day 120 (52.14%). Bulk density increased with time due to compaction in all samples from 14 to 60 days, while it was reduced from day 60 to day 120 in T3. On days 14 and 120, treatments were significantly different ($p<0.05$) from the control sample, while there was no difference with the control sample on day 60. The pH was initially slightly low but increased gradually. However, there was no significant difference ($p>0.05$) between control and treatment groups. Electrical conductivity increased in each sample from day 14 to day 120 due to the accumulation of ions during the decomposition process. A significant difference in EC between T3 and the control was observed only on day 14, while T1 showed a significant difference compared to the control on day 120. Organic matter content decreased drastically, indicating efficient decomposition in the composting process. Total nitrogen gradually decreased due to the nitrogen loss through the mineralization process, which can be mainly volatilization of ammonia (Tiquia and Tam, 2000). When the compost matured, the C:N ratio decreased.

However, EC of the final compost in T_0 was 6.01 dS/m, which is considered excessive for mature compost. High EC can inhibit plant growth (Sonneveld and Voogt, 2009). The bulk density of T0 was 0.45 g/cm^3, which is considered excessive for mature compost and may negatively affect microbial activity and plant root penetration. A high bulk density causes poor porosity and reduced aeration (Ahn *et al.,* 2024). The C:N ratio was 22.62 in T0, which is favourable for mature compost (SLS 1635, 2019). According to SLS 1635 (2019), well-decomposed compost should have a C: N ratio of 10-25. The organic matter content of T0 was 42.31%, which was high due to its incomplete decomposition in T0. The total nitrogen was high in T0; however, due to the high C: N ratio, the amount of available nitrogen in T_0 was lower. Hence, T0 is an immature compost and is not suitable for soil application due to its high electrical conductivity (EC) (6.01 dS/m), high C: N ratio (22.62), high bulk density (0.45 g/cm^3), and high organic matter content (42.31%) (Table 2).The C: N ratio was 17.16 in T1, which is within the recommended limit described in SLS standards (SLS 1635, 2019). In T1, the total nitrogen was 0.86%, which is lower than the favourable range for well-matured compost (SLS 1635, 2019). The bulk density was 0.39 g/cm^3, close to the upper limit of 0.4 g/cm^3 according to SLS standards (SLS 1635, 2019).

A relatively high bulk density in compost is unfavourable for proper aeration and root penetration (Watson and Kelsey, 2006). The EC (2.35 dS/m), pH (7.85), and organic matter content (25.40%) of T1 were within the acceptable range.

Table 2: Means of the analysis of variables measured in the mixtures of compost at the 14^{th}, 60^{th} and 120^{th} days in T0, T1, T2, and T3 obtained from ANOVA and DMRT tests

Day	CL	OD	MC	Bd	pH	EC	OM	TN	TP	TK	TOC	C: N
	-	-	% wb	g/cm^3 db	-	dS/m	%	%	%	%	%	-
14												
T0	Black	No	56.56 ± 0.29^{a}	0.32 ± 0.02^{a}	$6.81+0.10^{a}$	2.36+0.16b	56.05 ± 1.34^{c}	0.630 ± 0.006^{ab}	0.008 ± 0.002^{a}	0.219 ± 0.021^{a}	32.51 ± 0.77^{c}	51.59 ± 1.01^{c}
T1	Brown	No	45.77 ± 0.21^{c}	0.11 ± 0.02^{c}	6.71 ± 0.03^{a}	1.80 ± 0.06^{b}	67.87 ± 1.17^{a}	0.667 ± 0.02^{a}	0.011 ± 0.00^{a}	0.144 ± 0.00^{a}	39.36 ± 0.6^{a}	59.20 ± 2.18^{b}
T2	Brown	No	50.18 ± 1.20^{b}	0.12 ± 0.02^{c}	6.93 ± 0.07^{a}	2.20 ± 0.45^{b}	67.31 ± 1.09^{a}	0.560 ± 0.00^{b}	0.010 ± 0.00^{a}	0.163 ± 0.02^{a}	39.04 ± 0.63^{a}	69.73 ± 1.28^{a}
T3	Brown	No	54.20 ± 1.07^{a}	0.24 ± 0.02^{b}	6.78 ± 0.13^{a}	3.33 ± 0.13^{a}	60.27 ± 1.30^{b}	0.560 ± 0.04^{b}	0.012 ± 0.00^{a}	0.184 ± 0.03^{a}	34.96 ± 0.76^{b}	62.89 ± 3.27^{b}
60												
T0	Black	No	50.90 ± 0.45^{a}	0.37 ± 0.02^{a}	6.46 ± 0.10^{b}	1.53 ± 0.22^{ab}	46.12 ± 0.92^{a}	0.537 ± 0.08^{a}	0.011 ± 0.00^{a}	0.132 ± 0.04^{a}	26.75 ± 0.54^{a}	52.16 ± 7.42^{a}
T1	Brown	No	43.15 ± 0.76^{c}	0.36 ± 0.01^{a}	6.78 ± 0.08^{a}	0.67 ± 0.09^{b}	26.41 ± 1.19^{c}	0.513 ± 0.08^{a}	0.010 ± 0.00^{a}	0.069 ± 0.00^{a}	15.32 ± 0.69^{c}	32.28 ± 7.58^{a}
T2	Black	No	47.57 ± 1.47^{b}	0.40 ± 0.03^{a}	6.82 ± 0.06^{a}	1.24 ± 0.06^{ab}	30.55 ± 1.32^{c}	0.517 ± 0.05^{a}	0.010 ± 0.00^{a}	0.098 ± 0.01^{a}	17.72 ± 0.77^{c}	35.27 ± 4.71^{a}
T3	Black	No	51.80 ± 0.51^{a}	0.34 ± 0.02^{a}	6.73 ± 0.08^{ab}	1.67 ± 0.48^{a}	36.75 ± 1.72^{b}	0.477 ± 0.04^{a}	0.016 ± 0.00^{a}	0.088 ± 0.03^{a}	21.32 ± 0.99^{b}	45.65 ± 5.50^{a}
120												
T0	Black	No	52.14 ± 0.65^{a}	0.45 ± 0.01^{a}	7.85 ± 0.03^{a}	6.01 ± 0.61^{a}	42.31 ± 1.64^{a}	1.084 ± 0.001^{b}	0.020 ± 0.002^{a}	0.140 ± 0.049^{a}	24.88 ± 0.63^{a}	22.62 ± 0.88^{b}
T1	Black	No	40.12 ± 0.21^{d}	0.39 ± 0.01^{b}	7.85 ± 0.07^{a}	2.35 ± 0.91^{b}	25.40 ± 0.47^{b}	0.862 ± 0.046^{c}	0.021 ± 0.001^{a}	0.174 ± 0.023^{a}	14.73 ± 0.27^{b}	17.16 ± 0.62^{c}
T2	Black	No	45.25 ± 1.20^{c}	0.35 ± 0.01^{c}	7.75 ± 0.02^{a}	3.56 ± 0.23^{ab}	27.55 ± 0.62^{b}	1.395 ± 0.021^{a}	0.020 ± 0.001^{a}	0.166 ± 0.025^{a}	15.98 ± 0.36^{b}	11.46 ± 0.38^{d}
T3	Black	No	48.52 ± 1.15^{b}	0.29 ± 0.01^{d}	7.77 ± 0.08^{a}	4.24 ± 1.39^{ab}	17.75 ± 1.58^{c}	0.316 ± 0.001^{d}	0.019 ± 0.001^{a}	0.139 ± 0.005^{a}	11.54 ± 0.03^{c}	35.81 ± 0.75^{a}

CL: colour, OD: odour, MC: moisture content, Bd: Bulk density, EC: electrical conductivity, OM: organic matter, TN: total nitrogen, TP: total phosphorous, TK: total potassium, TOC: total organic carbon, C: N: carbon: nitrogen ratio, T0: WH only, T1: WH: cattle manure + sawdust mixture (1:1), T2: WH: cattle manure + sawdust mixture (2:1), T3: WH: cattle manure + sawdust mixture (3:1) $p<0.05$
Similar letters in the same column under similar treatment day are not significantly different

However, T1 is not a suitable compost due to its low total nitrogen content (0.862%) (Table 2). T3 had issues with maturity and nutrient content: relatively high C:N ratio (35.81), extremely low total nitrogen (0.32%), high EC (4.24 dS/m) and a little excessive moisture content (48.52%). Nitrogen loss has been identified as a major problem in composting (Qiu *et al*., 2021). It is important to reduce nitrogen loss during the composting process, as plant growth is mainly affected by nitrogen availability (Raviv *et al*., 2004).

T2 was the most favourable compost mixture because it complies with the Sri Lanka Standards (SLS) for compost with C:N ratio (11.46), the highest nitrogen content (1.395%), good organic matter (27.55%), lower bulk density (0.35), and pH in a favourable range (7.75). EC was also acceptable in T2 (3.56 dS/m).

Further analysis of the compost at 120 days revealed several exceptional findings (Table 3): T0 recorded the highest CEC, 90 Cmol (+)/kg, indicating strong nutrient-holding capacity. However, it could mean immature compost. T1 and T3 also exceeded [70.67 Cmol (+)/kg and 78.67 Cmol (+)/kg, respectively] favourable upper limit (60 Cmol (+)/kg) for compost. The CEC is the most important chemical parameter that decides the stability and maturity of compost (Ameen *et al*., 2016). T2 is the only treatment that had accepted CEC [60.07 Cmol (+)/kg] for mature, well-decomposed compost, although it reached the upper limit of 52.67 Cmol(+)/kg (Saharinen, 1998).

Phytotoxicity Evaluation

The germination percentage is a reliable indicator of compost quality, particularly in assessing phytotoxicity, which directly impacts plant growth and contributes to environmental pollution (Luo *et al*., 2018). The germination percentage (GP%) of the control sample was 53.33, while T0, T1, and T2 recorded values of 51.11%, 55.63%, and 42.29%, respectively (Table 3).

Heavy Metal Analysis

All heavy metal concentrations recorded in the study were well below the acceptable or optimum limits, compliance with safety standards. Chromium (Cr) levels ranged from 0.158 to 0.257 ppm, far below the SLS limit of 1000 ppm. Nickel (Ni) concentrations were similarly low, compared to the 100 ppm threshold.

Table 3. Mean CEC, essential plant nutrients, and other elements in the mixtures of compost in different treatments at the 120th day of composting.

Variable	Units	Acceptable/ optimum range	Reference	Final (Day 120)			
				T0	T1	T2	T3
CEC	Cmol(+)/kg	>60	(Saharinen, 1998)	90±3.46 [a]	70.67±4.05 [b]	60.07±2.40 [c]	78.67±1.76 [b]
Na	% db	1	(Crohn, 2016)	0.003±0.00 [c]	0.006±0.00 [b]	0.006±0.00 [b]	0.008±0.00 [a]
Ca	% db	0.7	(SLS 1635, 2019)	0.008±.00 [a]	0.004±.00 [b]	0.004±0.00 [b]	0.004±0.00 [b]
Mg	% db	0.5	(SLS 1635, 2019)	0.002±0.00 [a]	0.002±0.00 [d]	0.002±0.00 [c]	0.002±0.00 [b]
Mn	ppm db	431–600	(Abad *et al*., 2001)	22.56±0.28 [a]	5.68±0.10 [c]	10.39±0.12 [b]	10.56±0.21 [b]
Fe	ppm db	<9300	(Abad *et al*., 2001)	121.11±0.32 [a]	74.53±0.42 [c]	80.61±0.46 [b]	82.14±1.15 [b]
Cr	ppm db	1000	(SLS 1635, 2019)	0.158±0.001 [d]	0.247±0.001 [b]	0.235±0.001 [c]	0.257±0.001 [a]
Ni	ppm db	100	(SLS 1635, 2019)	0.124±0.001 [d]	0.158±0.001 [c]	0.167±0.001 [b]	0.191±0.001 [a]
Cu	ppm db	400	(SLS 1635, 2019)	0.125±0.001 [d]	5.043±0.017 [a]	0.164±0.001 [c]	0.200±0.002 [b]
Cd	ppm db	10	(SLS 1635, 2019)	ND	0.0003±0.00 [a]	0.0001±0.00 [a]	ND
Pb	ppm db	250	(SLS 1635, 2019)	0.046±0.001 [d]	0.095±0.001 [a]	0.080±0.001 [c]	0.085±0.001 [b]
As	ppm db	41	(US EPA 1994)	0.003±0.001 [a]	0.003±0.001 [a]	0.002±0.001 [a]	0.002±0.001 [a]
Zn	ppm db	1000	(SLS 1635, 2019)	0.258±0.001 [d]	2.025±0.001 [a]	0.584±0.001 [b]	0.466±0.001 [c]
GP	%	50	(Albert *et al*., 2002)	53.33±5.09 [a]	51.11±5.88 [a]	55.63±2.18 [a]	42.29±1.14 [a]

TOC: total organic carbon, C:N: carbon: nitrogen ratio, CEC: cation exchange capacity, Na: Na content, Ca: Ca content, Mg: Mg content, Mn: Mn content, Fe: Fe content, Cr: Cr content, Ni: Ni content, Cu: Cu content, Cd: Cd content, Pb: Pb content, As: As content, Zn: Zn content, GP: germination percentage, T0: WH only, T1: WH: cattle manure + sawdust mixture (1:1), T2: WH: cattle manure + sawdust mixture (2:1), T3: WH: cattle manure + sawdust mixture (3:1). $p<0.05$
Similar letters in the same column under similar treatment day are not significantly different

The data discussed in Tables 2 and 3 support the exceptional results shown in Table 4

Table 4: Interpretation of key findings in different compost mixtures produced using treatments

Variable	Treatment with Exception	Issue	Remarks
EC (dS/m)	T0 (6.01)	Very high	Risk of salt accumulation
CEC (cmol/kg)	T0 (90)	Extremely high	Immature compost
Bd (g/cm^3)	T0 (0.45)	Very dense	Poor aeration
TN (%)	T1 (0.862)	Very low	Less nutritive
TN (%)	T1 (0.316)	Very low	Less nutritive
C: N Ratio	T3 (35.81)	Extremely high	Immature compost
TOC (%)	T3 (11.54)	Very low	Excessive carbon loss

EC: electrical conductivity, C:N: carbon: nitrogen ratio, TN: total nitrogen, OM: organic matter, TOC: total organic carbon, Bd: Bulk density, MC: moisture content, CEC: cation exchange capacity

Cadmium (Cd) was either not detected or found in trace amounts (≤0.0003 ppm). Lead (Pb) values were low across treatments, with the highest (0.095 ppm) recorded in T1, while arsenic (As) remained consistent at 0.002–0.003 ppm in all treatments. Zinc (Zn), though elevated in T1 (2.025 ppm), remained far below the maximum permissible level of 1000 ppm. These findings confirm that heavy metal levels across all treatments pose no environmental or health hazards.

In brief, T0 exhibited excessively high electrical conductivity. Its cation exchange capacity was extremely high, and bulk density was excessively high, leading to poor aeration and restricted microbial activity. T1 was also unsuitable as it had a very low total nitrogen content and very low moisture content. T3 was considered unfavourable due to its high C:N ratio and low total organic carbon. Due to these limitations, T0, T1, and T3 are not suitable composts, as they failed to meet the necessary nutrient balance

Among the combinations tested, the T2 is the best compost mixture that maintained all parameters in favourable ranges, indicating its potential for effective use in sustainable cultivation practices.

CONCLUSION

Based on compost quality at day 120, T0 was found to be unsuitable due to its high electrical conductivity (6.01 dS/m) and extremely high cation exchange capacity (90 cmol/kg). Furthermore, T0 recorded the highest bulk density (0.45 g/cm^3), indicating that the compost remained immature. T1 and T3 were also rejected due to various deficiencies: T1 recorded the lowest moisture content (40.12%) and total nitrogen (0.862). T3 had an extremely high C: N ratio (35.81), indicating incomplete nitrogen mineralization and immaturity, and it also showed a substantial loss of total organic carbon (11.54%). These characteristics make T1 and T3 unsuitable as high-quality compost. T2 was identified as the best compost among the treatments due to its balanced nutrient composition and optimal indicators. It reported the lowest C: N ratio (11.46) and the highest total nitrogen content (1.395%), making it the most nutrient-rich compost. Furthermore, T2 had a 3.56 dS/m electrical conductivity (EC), ensuring that salt accumulation is within acceptable limits. The organic matter content of T2 (27.55%) was also effective, and its bulk density (0.35 g/cm^3) was well-optimized. Hence, T2 (WH 2: an equally mixed cattle manure and Albizia-sawdust mixture) had all key compost quality parameters, making it the best compost among the combinations tested in this study.

REFERENCES

Abad, M., Noguera, P. and Burés, S. (2001). National inventory of organic wastes for use as growing media for ornamental potted plant production: Case study in Spain. *Bioresource Technology*, 77: 197–200. DOI: https://doi.org/10.1016/S0960-8524(00)00152-8

Ahn, C. H., Lee, S. and Park, Y. (2024). Particle and bulk media characteristics of food waste compost-based biomedia by dynamic high-temperature aerobic composting process. *Environmental Technology and Innovation*, 35: 103711. DOI: https://doi.org/10.1016/j.eti.2024.103711

Albert, M.J., Iriondo, J.M. and Pérez-García F. (2002). Effects of temperature and pretreatments on seed germination of nine semiarid species from ne spain. *Israel Journal of Plant Sciences*. 50: 103–112. DOI: https://doi.org/10.1560/3HT7-P4UB-GA7N-PB3F

Ali, F., Jilani, G., Fahim, R., Bai, L., Wang, C., Tian, L. and Jiang, H. (2019). Functional and structural roles of wiry and sturdy rooted emerged macrophytes root functional traits in the abatement of nutrients and metals. *Journal of environmental management*, 249: 109-330. DOI: https://doi.org/10.1016/j.jenvman.2019.109330

Ameen, A., Ahmad, J. and Raza, S. (2016). Determination of CEC to evaluate the quality and maturity of compost prepared by using municipal solid waste. *International Journal of Scientific Research and Publications*, 6: 42-44.

Ansari, A.A., Naraine, D. and Jaikishun, S. (2024). Biochemical alterations of vermicompost produced from Eichhornia crassipes (water hyacinth) and cattle dung. *In Earthworm Technology in Organic Waste Management*. 115-134.: DOI: https://doi.org/10.1016/B978-0-443-16050-9.00019-0

Barral, M.T. and Paradelo, R. (2011). A review on the use of phytotoxicity as a compost quality indicator. *Dynamic Soil, Dynamic Plant*, 5(2), 36-44.

Bremner, J. M. and Mulvaney, C. S. (1982). Nitrogen-Total. In Methods of Soil Analysis, Part 2, Chemical and Microbial Properties, edited by A. L. Page, R. H. Miller, and D. R. Keeney, Agronomy Society of America, Agronomy Monography 9, 595-624. DOI: https://doi.org/10.2134/agronmonogr9.2.2ed.c31

Chee, A.L.K., Chin, B.L.F., Sulaiman, S.A., Chai, Y.H., Saptoro, A., Umar, H.A., Lock, S.S.M. and Yiin, C.L. (2024). Syngas-Enriched hydrogen production via catalytic gasification of water hyacinth using renewable palm kernel shell hydrochar. *Fuel*, 362: 130811. DOI: https://doi.org/10.1016/j.fuel.2023.130811

Chen, X., Fu, X., Li, G., Zhang, J., Li, H. and Xie, F. (2024). Source-specific probabilistic health risk assessment of heavy metals in surface water of the Yangtze River Basin. *Science of The Total Environment*, 926:.171923. DOI: https://doi.org/10.1016/j.scitotenv.2024.171923

Cherwoo, L., Berwal, B., Kumar, S., Datta, A., Prabhu, G.N., Oo, H.N. and Bhondekar, A.P. (2024). Water hyacinth biomass valorization: fostering biodiversity and sustainable development in the bioeconomy. In Biodiversity and Bioeconomy. 445-474. DOI:

https://doi.org/10.1016/B978-0-323-95482-2.00020-1

Chonsakorn, S., Mongkholrattanasit, R., Rungruangkitkrai, N., Ruangnarong, C., Panyathikun, N. and Srivorradatphisan, S. (2024). Physical properties of water hyacinth, polyester, and cotton blended spun Yarn: A Blend Ratio Study. *Journal of Natural Fibers*, 21(1): 2311299. DOI: https://doi.org/10.1080/15440478.2024.2311299

Colombo, P., Bressa, M.J. and Remis, M.I. (2024). C-banding characterization of centric fusion and heterochromatin polymorphisms in the water-hyacinth grasshopper, Cornops aquaticum (Orthoptera: Acrididae). *Annals of the Entomological Society of America*, 117(1): 27-35. DOI: https://doi.org/10.1093/aesa/saad031

Crohn, D.M. (2016). Assessing Compost Quality for Agriculture. Agriculture and Natural Resources, University of California, Agriculture and Natural Resources, ANR Publication 2-12. https://doi.org/10.3733/ucanr.8514

Datta, A., Cherwoo, L., Oo, H. N., Prabhu, N., Kumar, S., Sharma, A., and Bhondekar, A. P. (2024). Aquatic Weed Mining Using Artificial Intelligence. In Artificial Intelligence and Society 5.0. 246-266. Chapman and Hall/CRC.

Diaz, M.J., Madejon, E., Lopez, R. and Cabrera, F. (2002). Composting of vinasse and cotton gin wastes by using two different systems. *Resource, Conservations and Recycling*, 34: 235-248. DOI: https://doi.org/10.1016/S0921-3449(01)00109-4

Fawole, F.O. (2015). Main and residual effects of broiler droppings on some soil's physical and chemical properties and on the growth and marketable yield of leaf amaranth (*Amaranthus cruentus* (hybridus) L) Amaranthaceae. *International Journal of Agricultural Research*. 2: 23-30.

Fentie, D., Mihretie, F. A., Kohira, Y., Legesse, S. A., Abune, B. B. and Sato, S. (2024). Locally Produced Biochar Derived from Water Hyacinth Impacts on Soil Nutrients and Bread Wheat Production in Ethiopia. *Journal of Earth and Environmental Sciences:* JEES-124. DOI: https://doi.org/10.47991/2835-7868/JEES-124

Gaikwad, R. P., and Gavande, S. (2017). Major factors contributing growth of water hyacinth in natural water bodies. *International Journal of Engineering Research*, 6(6): 304-306. DOI: http://dx.doi.org/10.5958/2319-6890.2017.00024.1

Gezahegn, A., G Selassie, Y., Agegnehu, G., Addisu, S., Asargew, M., F., Kohira, Y. and Sato, S. (2024). Pyrolysis temperature changes the physicochemical characteristics of water hyacinth-based biochar as a potential soil amendment. *Biomass Conversion and Biorefinery*, 1-16.

Guayjarernpanishk, W. and Sampanpanish, P. (2024). Efficiency of sodium phytate in the remediation of As, Mn, and Cu contamination in acid mine drainage using water hyacinth. *Heliyon*: 10(4): e26590. DOI: https://doi.org/10.1016/j.heliyon.2024.e26590

Hassan, M.H., Latifah, O., Ahmed, O. H., Feng, N.J., Perumal, M. and Roslim, M.H.M. (2023). Black soldier fly larvae frass production for managing water hyacinth encroachment. *International Journal of Agriculture, Forestry and Plantation*, 75–81.

He, Z., Yang, X., Kahn, B., Stoffella, P., Calvert, D. (2001). Plant Nutrition Benefits of Phosphorus, Potassium, Calcium, Magnesium, and Micronutrients from Compost Utilization. CRC Press, Boca Raton, FL, USA.

Ibro, M. K., Ancha, V.R., Lemma, D.B. and Mekbib Pohl, M. (2024). Enhancing Biodegradability of Coffee Husk and Water Hyacinth using Food Waste: Synergistic and Kinetic Evaluation under Co-digestion. *International Journal of Scientific Research and Publications, 17:* 1953–1970. DOI: https://doi.org/10.21203/rs.3.rs-3880494/v1

Jackson, M.L. (1973). Soil Chemical Analysis. Advanced Course Ed. 2. A Manual of Methods Useful for Instruction and Research in Soil Chemistry, Physical Chemistry of Soils, Soil Fertility and Genesis Revised from Original Edition of 1965.

Jamilatun, S., Rahayu, A., Hakika, D.C., Muthadin, A.S. and Taufiqurahman, M.A. (2024). Heavy Metal Phytoremediation: Plant Hyperaccumulators and Clean Strategies for the Environment. *Indonesian Journal of Chemical Engineering*, 2(1): 9-21.

Kalamdhad, A.S., Singh, Y.K., Ali, M., Khwairakpam, M., Kazmi, A.A. (2009). Rotary drum composting of vegetable waste and tree leaves. *Bioresource Technology*. 100: 6442–6450. DOI: https://doi.org/10.1016/j.biortech.2009.07.030

Kariim, I., Bakari, R., Waidi, Y.O., Kazmi, W.W., Malla, S.K., Park, J.Y., Syed, M.W., Bhatti, A.H., Omer, A., Swai, H. and Lee, I.G. (2024). Optimization of solvothermal liquefaction of water hyacinth over PTFE-acid mediated kaolin catalyst for enhanced biocrude production. *Journal of Analytical and Applied Pyrolysis*, 178: 106416. DOI: https://doi.org/10.1016/j.jaap.2024.106416

Karouach, F., Bakrim, W.B., Ezzariai, A., Mnaouer, I., Ibourki, M., Kibret, M., Sobeh, M., Hafidi, M. and Kouisni, L. (2024). Valorization of water hyacinth to biomethane and biofertilizer through anaerobic digestion technology. *Fuel*, 358, p.130008. DOI: https://doi.org/10.1016/j.fuel.2023.130008

Liu, S., Zeng, J.L., Cheng, Z.W., He, J.L., Pang, Y.L., Liao, X.D. and Xing, S.C. (2024a). Evaluation of compost quality and the environmental effects of semipermeable membrane composting with poultry manure using sawdust or mushroom residue as the bulking agent. *Journal of Environmental Management*, 353, p.120162. DOI: https://doi.org/10.1016/j.jenvman.2024.120162

Liu, S., Zhao, J., Feng, W.L., Zhang, Z.J., Gu, Y.F. and Wang, Y.P. (2024b). Microbial community succession of cow manure and tobacco straw composting. *Frontiers in Microbiomes*, 3: 1301156. DOI: https://doi.org/10.3389/frmbi.2024.1301156

Luo, Y., Liang, J., Zeng, G., Chen, M., Mo, D., Li, G. and Zhang, D. (2018). Seed germination test for toxicity evaluation of compost: Its roles, problems and prospects. *Waste Management*, 71: 109-114. DOI: https://doi.org/10.1016/j.wasman.2017.09.023

Misra, D., Dutta, W., Prieto, J. G. and Ray, P. (2024). (in press). Impact of Biocontrol Agents on Biochemical Changes of Aquatic Weed Water Hyacinth, *Pontederia crassipes* (Mart.) Solms-Laubach. *Plant Ecology*. DOI: https://doi.org/10.21203/rs.3.rs-4160435/v1

Newete, S.W., Erasmus, B.F., Weiersbye, I.M. and Byrne, M.J. (2016). Sequestration of precious and pollutant metals in biomass of cultured water hyacinth (*Eichhornia crassipes*). *Environmental Science and Pollution Research*, 23: 20805-20818.

Noor, R.S., Shah, A.N., Tahir, M.B., Umair, M., Nawaz, M., Ali, A., Ercisli, S., Abdelsalam, N.R., Ali, H.M., Yang, S.H. and Ullah, S. (2024). Recent Trends and Advances in Additive-Mediated Composting Technology for Agricultural Waste Resources: A Comprehensive Review. *ACS omega*. 9(8), 8632-8653. DOI: https://doi: 10.1021/acsomega.3c06516.

Oladoja, N.A., Bulu, Y.I., Akinyeye, J.O., Ahmed, R.O., Ololade, I.A. and Ogunniyi, J.A. (2024). Mitigating the exchange flux of sedimented phosphorus in invasive water Hyacinth (*Pontederia crassipes*) bloom system using a biogenic waste material. *Ecohydrology and Hydrobiology*. 21 (1): 54-73. DOI: https://doi.org/10.1016/j.ecohyd.2024.01.004

Olivo, A.J., Henning, E., Schott, L. and Schmidt, A.M. (2024). Carbon and nitrogen dynamics in agricultural soil after application of cattle manure and eastern redcedar wood chips, 53(1): 35-46. DOI: https://doi.org/10.1002/jeq2.20524

Oluwafisayo, A.F. (2024). Improving Worowo [Senecio biafrae (Oliv. and Hiern.) S. Moore] Production with Cattle Dung/Sawdust Compost Enriched with Neam Leaf Meal. Asian Science Bulletin, 2(3): 192-199. DOI: https://doi.org/10.3923/asb.2024.192.199

Pandey, S., Chaudhary, J., Sharma, H., Pundir, S., Rustagi, S., Malik, S. and Choudhary, P. (2024). Biosynthesis of zirconia nanoparticles (ZrO_2) by water hyacinth: characterization and its photocatalytic dye degradation activity. *Biomass Conversion and Biorefinery*, 14: 31817 - 31825.

Permatasari, N.V., Abidin, F., Azmi, M.U., Novitasari, Y. and Hapid, A. 2023. Phytoremediation of Hexavalent Chromium Using Aquatic Plants in Nickel Mine Waste. EKSPLORIUM: Buletin Pusat Pengembangan Bahan Galian Nuklir, 44(2): 81-92. DOI: https://doi.org/10.55981/eksplorium.2023.44.2.6927

Pendse, D.S. and Deshmukh, M.P. (2024). (In press).

A comprehensive study on an integrated approach for water hyacinth management to conserve natural water resources in India. *Materials Today: Proceedings*. DOI: https://doi.org/10.1016/j.matpr.2023.12.047

Phetrungnapha, A., Wiengnak, N. and Maikrang, K. (2024). A low-cost water hyacinth-based adsorbent for free fatty acids removal from waste cooking oil: kinetic, isotherm, and thermodynamic studies. *Brazilian Journal of Chemical Engineering*. 42: 727-740. DOI: https://doi.org/10.1007/s43153-024-00449-9

Qiu, Z., Li, M., Song, L., Wang, C., Yang, S., Yan, Z. and Wang, Y. (2021). Study on nitrogen-retaining microbial agent to reduce nitrogen loss during chicken manure composting and nitrogen transformation mechanism. *Journal of Cleaner Production,* 285: 124813. DOI: https://doi.org/10.1016/j.jclepro.2020.124813

Ratnani, R.D., Arianti, F.D. and Sasongko, N.A. (2024). Exploring the potential of water hyacinth weed (*Pontederia crassipes*) as an environmentally friendly antifungal to realize sustainable development in lakes: A review. *Case Studies in Chemical and Environmental Engineering,* 9(7): 100702. DOI: https://doi.org/10.1016/j.cscee.2024.100702

Raviv, M., Medina, S., Krasnovsky, A. and Ziadna, H. 2004. Organic matter and nitrogen conservation in manure compost for organic agriculture. Compost Science and Utilization, 12(1): 6-10. DOI: https://doi.org/10.1080/1065657X.2004.10702151

Righetti, T., de la Fuente, D., Paper, M. K., Brentassi, M. E., Hill, M. P., Coetzee, J. A., Salinas, N.A., Bruzzone, O. A., and Sosa, A. J. (2024). Effects of elevated CO_2 on the water hyacinth-biocontrol agent *Megamelus scutellaris* (Hemiptera: Delphacidae) and its yeast-like symbiotes. *Biological Control*, 188: 105433. DOI: https://doi.org/10.1016/j.biocontrol.2023.105433

Romanova, T.E., Shuvaeva, O.V. and Belchenko, L.A. (2016). Phytoextraction of trace elements by water hyacinth in contaminated area of gold mine tailing. *International Journal of Phytoremediation*, 18(2), 190-194. DOI: https://doi.org/10.1080/15226514.2015.1073674

Sagala, D., Juwinten, J., Prihanani, P., Mulatsih, S., Suzanna, E. and Dermawan, R. (2024). Growth and Yield of Three Soybean Cultivars on a Combination of Cow Manure and NPK Fertilizers on Sandy Land. *In BIO Web of Conferences*, 96, 06007. DOI: https://doi.org/10.1051/bioconf/20249606007

Saharinen M.H. (1998). Evaluation of changes in CEC during composting. *Compost Science and Utilization*. 6: 29–37. DOI: https://doi.org/10.1080/1065657X.1998.10701938

Seidu, S.O. and Kutelu, B.J. (2014). Effects of additives on some selected properties of base sand. *Journal of Minerals and Materials characterization and Engineering*, 2(5): 507.

Kulabako, R.N, Semiyaga, S., Tumwesige, R.S., Irumba, C., Opio, M.I., Manga, M., Tumwesige, V., Quintana-Najera, J. and Ross, A.B. (2024). Enhanced biogas production from water hyacinth and cow dung with wood and faecal sludge biochar. *Energy Nexus* 17, 100342 DOI: https://doi.org/10.1016/j.nexus.2024.100342

Singh J. and Kalamdhad A.S. (2012). Concentration and speciation of heavy metals during water hyacinth composting. *Bioresource Technology*. 124: 169–179. DOI: https://doi.org/10.1016/j.biortech.2012.08.043

Singh, J. and Kalamdhad, A.S. (2016). Effect of lime on speciation of heavy metals during composting of water hyacinth. *Frontiers of Environmental Science and Engineering.* 10(1), 93–102. DOI: https://doi.org/10.1007/s11783-014-0704-7

Sirisoda, T. (2024). Thailand's traditional art of water hyacinth weaving: reviving a craft for modern sustainability. *ArtsEduca*, 38, 95-111.

Sonneveld, C. and Voogt, W. (2009). Plant nutrition in future greenhouse production. In: *Plant nutrition of greenhouse crops*. 393–403. DOI: https://doi.org/10.1007/978-90-481-2532-2_17

Song, U., Oh, S.H., Kim, B.W., Jeong, S. and Rim, H. (2024). Pontederia crassipes invasiveness on Jeju Island is linked to a decline in water pH and climate change-driven overwintering. *Aquatic Invasions*, 19(1), 35-49. DOI: https://doi.org/10.3391/ai.2024.19.1.117155

SPSS Inc. (2012). IBM SPSS Software for Windows, Version 20.0

Sri Lanka Standards Institution. (1983). Sri Lanka Standards for drinking water guidelines SLS 614, 1983 Part I-5, Physical and Chemical Requirements. Sri Lanka Standards Institute. Colombo, Sri Lanka

Sri Lanka Standards Institution. (2019). Specification for Compost Made from Raw Materials of Agricultural Origin Sri Lanka (Sri Lanka Standard 1635: 2019 Udc 628.477.3). 11–26.

Tan K. (2005). Soil Sampling, Preparation, and Analysis, 2nd ed. CRC Press, Boca Raton, FL, USA. https://doi.org/10.1201/9781482274769

Tiquiaa, S.M. and Tam, N. (2000). Fate of nitrogen during composting of chicken litter. *Environmental Pollution* 110 (3): 535–541. DOI: https://doi.org/10.1016/S0269-7491(99)00319-X

Tira, H. and Sutanto, R. (2024). Production of Biogas from a Mixture of Chicken Litter and Cow Manure and Its Effect on the Resulting Volume and C/N Ratio. *Jurnal Pijar Matematika dan Ilmu Pengetahuan Alam*, 19(1): 107-112. DOI: https://doi.org/10.29303/jpm.v19i1.4942

US EPA. (1994). A Plain English Guide to the EPA Part 503, 175. Biosolids Rule. Epa-832/R-93/003.

Venter, N., Cowie, B. W., Witkowski, E. T., Snow, G. C. and Byrne, M. J. (2017). The amphibious invader: Rooted water hyacinth's morphological and physiological strategy to survive stranding and drought events. *Aquatic Botany*, 143: 41-48. DOI: https://doi.org/10.1016/j.aquabot.2017.09.004

Vodounnou, J.V., Dossa, V., Djissou, C., Kpogue, D., Agadjihouede, H., Fiogbe, E.D. and Micha, J.C. (2024). Feeding Optimization of Water Hyacinth (*Eichhornia crassipes*) Leaves as Rearing Substrate for the Production of Black Soldier Fly (*Hermetia illucens*) Larvae. *Waste and Biomass Valorization*, 1-10.

Wang, F., Wang, J., He, Y., Yan, Y., Fu, D., Rene, E.R. and Singh, R.P. (2024). Effect of different bulking agents on fed-batch composting and microbial community profile. *Environmental Research*, p.118449. DOI: https://doi.org/10.1016/j.envres.2024.118449

Wang, G., Yang, Y., Kong, Y., Ma, R., Yuan, J. and Li, G. (2022). Key factors affecting seed germination in phytotoxicity tests during sheep manure composting with carbon additives. *Journal of Hazardous Materials*, 421, 126809. DOI: https://doi.org/10.1016/j.jhazmat.2021.126809

Wang, M., Awasthi, M.K., Wang, Q., Chen, H., Ren, X., Zhao, J., Li, R. and Zhang, Z. (2017). Comparison of additives amendment for mitigation of greenhouse gases and ammonia emission during sewage sludge co-composting based on correlation analysis. Bioresource technology, 243: 520-527.
DOI: https://doi.org/10.1016/j.biortech.2017.06.158

Watson, G.W. and Kelsey, P. (2006). The impact of soil compaction on soil aeration and fine root density of Quercus palustris. *Urban Forestry and Urban Greening*, 4(2): 69-74. DOI: DOI: https://doi.org/10.1016/j.ufug.2005.08.001

Xiang, Y., Zhao, K., Guo, W. and Li, X. (2024). Soil fertility as a mediator of interactions between an introduced specialist beetle and a native generalist nematode on an exotic invasive plant and its native congener. *Journal of Applied Ecology.* 61(5): 963-974. DOI: https://doi.org/10.1111/1365-2664.14621

Xu, Z., Li, R., Liu, J., Xu, X., Wang, S., Gao, F., Yang, G., Yao, Y., Zhang, Z., Zhang, X. and Zhang, Y. (2024). The impact of ammonifying microorganisms on the stabilization and carbon conversion of cow manure and wheat husk co-composting. *Chemical Engineering Journal*, 490, 151626. DOI: https://doi.org/10.1016/j.cej.2024.151626

Zucconi F, Monaco A, Forte M, De Bertoldi M. (1985). Phytotoxins during the stabilization of organic matter. In: Gasser, J.K.R. (Ed.), Composting of Agricultural and Other Wastes. Elsevier Applied Science Publishers, London, 73–86.