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ORIGINAL ARTICLE

Use of Invasive Water Hyacinth for Composting of Ordinary Leaf Litter

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Abstract

Many lakes, canals and wetlands in Sri Lanka are infested by water hyacinth (*Eichhornia crassipes* (Mart.) Solms), which is a non-indigenous invasive aquatic weed species. It causes a complete blockage of water resources that makes irrigation and fishing very difficult. Among various eradication methods of water hyacinth, composting has been extensively used in many countries. However, the degree of toxicity and the quality of compost are important for field applications. Therefore, the present study was aimed at transforming ordinary leaf litter into quality compost using water hyacinth and various other amendments, and comparing the compost quality in terms of heavy metals, pH, electrical conductivity (EC) and C: N ratio. The weeds were collected from the *Moragoda* canal, Galle, Sri Lanka. The compost trials were prepared using water hyacinth and different other raw materials and one compost trial was prepared using water hyacinth alone. The mixtures were decomposed aerobically for 12 weeks by windrow method and prepared composts were analysed for pH, EC, organic C %, total N %, Cu, Cd, Pb, Zn, Ni, and As. Finally, the obtained results were compared with the indices given for compost by the Sri Lankan standards. Considering the C: N ratio, pH, EC which obtained 17.84, 7.5, 1.95 dSm^{-1}, respectively and heavy metal content less than permissible limit, it revealed that compost mixture with a composition of water hyacinth and dry leaf litter was the most suitable mixture to recommend for field application.

Keywords: *Compost, Eichhornia crassipes, Eradication, Heavy metals, Weeds*

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1. Introduction

Water hyacinth (*Eichhornia crassipes* (Mart.) Solms) is an invasive aquatic weed in Sri Lanka that created a global threat by making environmental and economic constraints. It shows a prolific growth on the surface of water bodies and acts as a hyper-accumulator of heavy metals (Matindi 2016). Therefore, water hyacinth is among one of the most frequently utilized plants in marshlands for heavy metal and nutrient extraction due to its high up-taking capacity (Rai 2009). A research conducted by Shao and Chang (2004) indicated that water hyacinth was capable of absorbing especially heavy metals such as Pb, Cd, Ni, Zn, and Cu. In Sri Lanka, this weed has invasively spread in almost all wetlands. Quantitatively, it causes complete blockage of canals making all activities very inefficient (Bhattacharya and Kumar 2010). Thus, these reasons have prompted to undertake various measures to control this weed. However, as the growth of the weed is extremely vigorous, eradication is not that easy. It was reported that water hyacinth biomass yield in dry weight basis ranges from 47 to 106 Mg ha^{-1} y^{-1} (Reddy and Sutton 1984). Also, during drought periods, the plant sinks to the bottom of the water body accompanied with the water level and stay behind dormant and thrives back in the next wet season (Ndimele et al. 2011).

The eradication of water hyacinth mechanically is very expensive and would be eradicated for a very short term. It was estimated that the annual cost would be $33.75 per acre to control water hyacinth weed mechanically (Mara 1976). The biological control method is used in South America by *Neochetinaei chhorniae* (Center and Dray 2010). However, biological control methods need a long period to eradicate these weeds (Wainger et al. 2018). Therefore, producing compost is increasingly being opted as a sustainable solution towards the eradication of the weed (Matindi 2016; Gunnarsson and Petersen 2007). The compost production by this weed provides high N (up to 3.2%), P (1.9%) and K (1.35%) nutrients on dry matter basis to the cultivation (Su et al. 2018; Sanni and Adesina, 2012). The most popular compost production method globally is the windrow or heap method (Das and Kalamdhad 2011). Water hyacinth compost may concentrate heavy metals due to the phyto-accumulation ability of live plants, which create problems in its end-use (Mashavira et al. 2015). A study by Singh and Kalamdhad (2013) reported that water hyacinth consists of total heavy metals such as Zn (152 $mgkg^{-1}$, Cu 39.8 $mgkg^{-1}$, Mn 644 $mgkg^{-1}$, Ni 179.8 $mgkg^{-1}$, Cd 43.25 $mgkg^{-1}$, Pb 1140 $mgkg^{-1}$, Cr 301.2 $mgkg^{-1}$) in dry matter basis. Due to this, the metals remain in the compost could pose serious environmental hazards when applied to the field (Singh and Kalamdhad 2015). Excess amounts of heavy metals in soil, due to the use of water hyacinth compost, may get translocate to human and animal food chains as well as declining soil fertility (Iwegbue et al. 2007).

For composting, it is efficient to mix water hyacinth as a compost supporter with ordinary matured/ older leaves than alone. The reason is that the ordinary dry leaves may consist of hemicellulose and cellulose which are easier to decompose than lignin which is the main component of water hyacinth (Su et al. 2018). According to previous studies, the reported C:N ratio of water hyacinth is approximately in between 16 - 20 (Dalzell et al. 1979). However, the water hyacinth is difficult to use to prepare compost alone due to very low dry matter content. In that case, cellulose-rich materials with high C:N ratio such as ordinary dry leaves or carbon-rich bulking materials such as straw or saw dust must be incorporated when composting with green materials such as water hyacinth (Mahimarajah et al. 1994). Further, Mathur et al. (2018) has prepared enriched compost mixtures such as phospho-compost, phosphor-nitro compost using water hyacinth. Therefore, in this study, mixing of water hyacinth with ordinary leaf litter with other amendments such as cattle manure, poultry litter, Eppawala rock phosphate (ERP), wood ash was used to achieve optimum C:N ratio for field application. Further, studies by Hao and Benke (2008) have shown that initial C:N ratio of raw materials affect the N mineralization. Low C:N ratio loses N whereas high C:N ratio slows down the decomposition rate enabling better humification.

The heavy metal accumulation by plants depends on the soil pH and organic matter content (Li et al. 2010). Further, the C:N ratio of finished compost is used to determine the end-use applicability and maturity of compost mixtures (Garcia et al. 1995; Wu and Ma 2002). Accordingly, the water hyacinth compost toxicity by analyzing heavy metals and the C:N ratio of mature compost are important to decide the suitability of compost before field application. Therefore, the objectives of this study were (a) to transform ordinary leaf litter into quality compost using water hyacinth and with the presence of various other amendments, and (b) to compare the

C:N ratio, pH, EC and heavy metals in made compost .

2. Materials and Methods

Pile composting

The pile composting method was used to produce compost by aerobically digesting all the materials. Raw materials were mixed according to the percentages given in the Table 1 to obtain a constant weight of 100 kg heap and replicated three times. The pile was formed with a dimension of 1 m x 0.5 m x 0.5 m.

Feedstock materials

Water hyacinth was collected manually from Moragoda canal (6°1' 60" N and 80°13' 60"), Galle, Sri Lanka. Cattle manure, and dry leaf litter were collected from the farm of the Faculty of Agriculture, University of Ruhuna, Kamburupitiya, Sri Lanka. Eppawala rock phosphate (ERP) was purchased from a fertilizer shop. Wood ash was obtained from a bakery near the university where wood is used to generate heat.

Procedure

A portion of the fresh water hyacinth collected was separated into leaves, stems, and roots, then air-dried, ground and powdered for chemical analysis. The remaining bulk of fresh water hyacinth (400 kg) was chopped into small pieces of about 5 – 10 cm in length to increase the aeration and surface area for microbial action. Subsequently, the compost was prepared by mixing different proportions of water hyacinth, cattle manure, poultry litter, wood ash, ERP and dry leaf litter as shown in Table 1. Day old fallen ordinary leaf litter comprised of Jak leaves, Mahogany leaves, Mango leaves, etc. was used to prepare compost. Eppawala rock phosphate was added as an amendment according to the rate recommended (50 kgt^{-1} raw compost materials) by the Department of Agriculture (Ariyaratne 2000). Ordinary leaf litter was mixed thoroughly with other amendments aerobically decomposed for 12 weeks to produce compost on a concrete top. The top of the heaps were covered with black polythene allowing aeration in the bottom of the heap. The moisture content was determined by field method (squeezing a handful of compost). The water was added until the compost turned in to a stable ball and cracking was visible after squeezing. The heap was manually turned at weekly interval for rapid decomposition.

After 12 weeks decomposition, the triplicate samples of compost were collected from heaps for chemical, metal pollutants and heavy metal analysis. The collected samples were sieved through 2 mm sieve for both analysis.

Table 1. Compost trial composition in wet weight basis.

Mixture Trials	WH*	DLL*	CM*	ERP*	WA*	SPL*
Trial 1	50%	25%	25%	-	-	-
Trial 2	50%	45%	-	-	5%	-
Trial 3	50%	45%	-	5%	-	-
Trial 4	50%	50%	-	-	-	-
Trial 5	50%	25%	-	5%	5%	15%
Trial 6	50%	25%	15%	5%	5%	-
Trial 7	100%	-	-	-	-	-

*WH- water hyacinth, CM- cattle manure, DLL -Dry leaf litter, ERP-Eppawala rock phosphate, WA- wood ash, SPL- Spent poultry litter

Samples were analyzed for pH (1:2.5 w/v compost: water extract) and electrical conductivity (EC) (1:5 w/v compost: water extract). Further, organic C was analyzed using loss on ignition method (Tiquia and Tam 2002). According to Bremner and Mulvancy (1982), total N% was determined by Kjeldahl method (Velp UDK 139, Italy). The heavy metals (Cu, Cd, Pb, Zn, Ni) and a metaloid pollutant (As) was analyzed using inductively coupled plasma optical emission spectrometer (Thermo scientific, ICAP Spectrometer 7000, UK). For this, the samples were digested by conc. HNO_3 and conc. HCl with 3:1 ratio and kept in a water bath and kept overnight. Then, the mixture was filtered by Whatmann No. 42 filter paper and the filtrate was taken for analysis. The same procedure was followed for the water hyacinth leaf, stem and root samples to analyze heavy metals.

The trials were arranged according to the mixtures given in Table 1 in complete randomized design with three replicates. The LSD values at $p \leq 0.05$ were used to determine the significant differences between compost mixtures using ANOVA in SAS statistical package.

3. Results and Discussion

The total heavy metal and metal pollutant contents in water hyacinth plant parts are given in Table 2.

High concentration of Cu and As in roots, Pb in leaves and Zn in stems were reported in the water hyacinth collected from the canal (Table 2). The normal range of heavy metals in plants (Opaluwa et al. 2012, Heikens 2006) and the permissible limits for heavy metals in compost given by Sri Lanka standard institution (SLS 1246:2003) are shown in Table 3.

The Cu concentrations in stems and roots of water hyacinth plants were higher than the normal range of plants.

Table 2. Heavy metal and metal pollutant contents in water hyacinth plants.

(ppm)	**Cu**	**Cd**	**Pb**	**Zn**	**Ni**	**As**
Leaf	2.49±0.64†	ND*	0.88±0.08	13.88±0.61	ND	0.148±0.021
Stem	2.56±0.74	ND	ND	18.21±3.49	ND	0.088±0.002
Root	9.83±0.21	ND	0.08±0.02	10.22±1.07	ND	0.702±0.022

† Standard deviation

*ND-Not detected

Table 3. Normal total values for heavy metals in plants and SL standards (1246:2003) for heavy metals in compost.

Heavy metal	Normal value (ppm) in plants	SLS for compost (ppm)
Cu	2.5	400.0
Cd	<2.4	10.0
Pb	0.5 – 30.0	250.0
Zn	20.0 – 100.0	1000.0
Ni	0.02 – 50.0	100.0
As	0.03 – 4.0*	10.0

* For rice plants (Heikens 2006)

The reason may be the phyto - accumulation effects of these weeds. According to Zayed et al. (1998), it was reported that Cd, Cr, Cu, Ni, and As were highly accumulated in plant roots than in shoots. However, all the other heavy metals concentrations in roots and shoots were within the permissible limits.

According to the characterization of raw materials, water hyacinth, spent poultry litter, fallen mature ordinary leaf litter, cattle manure, and wood ash had a total N of 3.80%, 2.48%, 1.35%, 1.56%, and 0.23%, respectively. Further, water hyacinth, spent poultry litter, fallen mature ordinary leaf litter, cattle manure and wood ash (<2 mm) showed 43.56%, 25.02%, 38.67% 14.32%, 45.29% organic carbon, respectively. Accordingly, the C:N ratio of water hyacinth, spent poultry litter, fallen mature ordinary leaf litter, cattle manure and wood ash were 11.46, 10.08, 21.24, 9.18, 196.91, respectively.

The pH, EC, heavy metal concentration, organic C %, total N%, and the C:N ratio of the different compost trials are given in Table 4.

Although the Cu concentration in water hyacinth plants was high, the amount of Cu in compost trials (Table 4) were not beyond the permissible level for compost (Table 3). Similarly, Pb, Ni, As, Cd and Zn concentrations were not exceeded the limits of compost trials (Table 4).

Table 4. Characteristics of different compost trials after 12 weeks of composting.

	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7
pH	8.50±0.14	9.25±0.07	7.30±0.07	7.50±0.14	9.35±0.21	7.15±0.35	7.60±0.21
EC (dSm^{-1})	4.78±0.06	2.91±0.06	1.59±0.12	1.95±0.07	3.71±0.19	3.49±0.02	5.28±0.09
Organic C%	10.32±0.03	14.78±0.02	20.04±0.14	21.50±0.04	11.38±0.04	18.51±0.05	32.58±0.27
Total N%	1.14±0.03	2.71±0.14	2.26±0.33	1.20±0.02	1.45±0.04	2.12±0.02	3.07±0.06
C:N ratio	9.08±0.28	5.44±0.29	8.96±1.41	17.84±0.31	7.85±0.23	8.70±0.08	10.29±1.22
Heavy metals and metal pollutants ($mgkg^{-1}$)							
Cu	18.50±0.14	13.83±0.18	8.28±0.08	6.44±0.14	5.71±0.08	17.240.38±	14.6±0.
Cd	ND*	ND	ND	ND	ND	ND	ND
Pb	19.59±0.93	6.74±0.26	10.58±0.30	5.7875±0.51	5.10±048	18.34±0.13	ND
Zn	25.16±0.16	31.43±0.70	5.77±0.02	15.97±0.25	26.51±0.32	21.93±0.19	32.47±0.29
Ni	ND	ND	ND	ND	ND	ND	ND
As	1.24±0.03	0.28±0.01	1.00±0.05	0.28±0.02	0.21±0.03	1.35±0.04	0.79±0.01

* Not detected

The pH values of all the compost trials ranged between 7.15 –9.35 (Table 4). The highest pH value was observed in trial 5 followed by 2,1,7,4,3, and 6. pH of compost trials were within the pH quality standard range of 6.5 – 8.5 given by SLS (SLS 1246:2003), except trial 2 and 5. All the compost trials from 1 to 6 were significantly different (p<0.05) in pH compared to the trial 7. The reason to obtain high pH in trial 2 and 5 may be due to incorporation of wood ash which contained alkaline cations in considerable quantities.

Further, the high pH of the mixtures causes higher N reduction by NH_3 volatilization. Moreover, CO_2 and humic substances originated in the composting process decrease pH. However, this acidic level is partially neutralized due to NH_3 volatilization (Estévez-Schwarz et al. 2012). Hence, pH in compost showed direct relationships with nitrification (Sanchez-Monedero 2001). The high total nitrogen observed in trial 2 may be related with high pH showing higher microbial activities although there was no amendment with higher N content in trial 2.

The EC of the compost trials varied between 1.59 dSm^{-1} – 5.28 dSm^{-1} (Table 4). All the trials from 1 to 6 were significantly different (p<0.05) in EC compared to the trial 7. Soluble salt levels of compost typically should be less than 4 dSm^{-1} (SLS 1246:2003). All the trials showed an acceptable level of EC for field application except for trial 1, which showed a slight salinity. However, the acceptable levels of EC are determined based on the intended use of the compost. The EC values were in an order of trial 3 < trial 4 < trial 2 < trial 6 < trial 5 < trial 1 < trial 7. The highest EC observed in compost trial 7 may be due to less ammonium volatilization and the availability of mineral salts in the composed heap.

The C:N ratio of different compost trials are shown in Table 4 and varied from 5.44 to 17.84. The quality, stability and maturity for the end–use of compost is measured mostly by C:N ratio (Goyal et al. 2005; Kaboré et al. 2010). Further, the stabilized optimum C:N ratio can create less competition between plants and microorganisms for consuming specially N ,P and S to a certain extent. Compared to trial 7, the C:N ratio of all the other trials were significantly low except in trial 4. The different C:N ratios of final compost trials may be due to the mixing of raw materials having different C and N percentages (Charert et al. 2004). The C:N ratios were in an order of trial 2 < trial 5 < trail 6 < trial 3 < trial 1 < trail 7 < trial 4. Trials prepared using raw materials with a high amount of total N has lessened the C:N ratios of the final compost. It was reported (Goyal et al. 2005) that N content is directly related to the C:N ratio of compost mixtures. Among the compost trials, the C:N ratio was above 15 only in trial 4 with 1:1 water hyacinth and dry leaf litter . Incorporating materials such as dry leaf litter with high C:N ratio may reduce the ammonia loss. The SLS indicated that the C:N ratio of end compost should not be less than 20 (SLS 1246:2003), which was not achieved by any of the trials. However, trial 4 has the optimum C:N ratio between 15 – 20 compared to other trials which was recommended by Golueke 1977.

4. Conclusions

According to the results of the present study, the concentrations of heavy metals and metal pollutants in all the compost trails were lower than the recommended level. pH of compost trials remained within the acceptable level except in trial 2 and 5. EC in trial 1 and 7 showed slight salinity conditions. Considering the C:N ratio, pH, EC and heavy metal concentrations of the final compost mixtures, trial 4 with 1:1 water hyacinth and dry leaf litter found to be a better option for field application. Further, the degradation of carbonaceous materials such as leaf litter can be optimized by incorporating water hyacinth. Further studies by using field trials are needed to recommend these compost trials prior to the plant applications.

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