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Original Research

Vermicomposting of water hyacinth [*Eichhornia crassipies* Mart. (Solms)] employing native and exotic earthworm species

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ABSTRACT:

A laboratory experiment on vermicomposting of water hyacinth was carried out in two seasonal trials covering summer and winter period. The indigenous and exotic earthworm species *Perionyx excavatus* and *Eudrilus eugeniae* respectively were employed during the study and a comparative efficacy between the two vermi species was quantified. The experiment was conducted in earthen pots using the mixture of water hyacinth (WH) and cowdung (CD) in the ratio of 5:1. The results revealed that both the earthworm species can efficiently convert the substrate mixture (i.e. WH+CD) into value added material (i.e. vermicompost) although the *Perionyx excavatus* showed better efficiency as compared to the *Eudrilus eugeniae*. The results also revealed that vermicompost of *Perionyx excavatus* showed higher level of nutrient contents (N, P, K, Ca, Mg, Fe, Mn, Zn and Cu) as against *Eudrilus eugeniae.* There also found to be seasonal influence on the overall vermicomposting process and summer was found to be more productive as compared to the winter.

Keywords:

Vermicomposting, Water hyacinth, biomanagement, *Perionyx excavatus, Eudrilus eugeniae.*

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INTRODUCTION

Water hyacinth is one of the most troublesome and invasive aquatic weeds of the world that causes severe damage to the aquatic habitats. It grows profusely in water bodies and multiplies to form large tract of dense stands often pushing water out of sight (Gajalakshmi *et al.,* 2002). It has been reported heavily that this noxious weeds is successfully resisted to the all physical, chemical, biological as well as hybrid methods that have been applied to eradicate it (Abbasi and Ramasami, 1999). Although there are large number of reports for utilization of water hyacinth including use as paper pulp, poultry/veterinary feed, materials for furniture, carry bags, source of medicinals etc., however none of them proved to be economically viable options. The only utilization option of water hyacinth that was found to be economically viable is the treatment of biodegradable waste water (Tchobanoglous and Burton, 1999). However, the quantity of water hyacinth used for this purpose are very low and thus disposal problem of the huge waste biomass of water hyacinth is still remaining unsolved.

Solid waste problem is universal but recycling and utilization of wastes according to local conditions is a difficult task (Govindarajan *et al*., 2011). Vermicomposting is the controlled non-thermophilic decomposition of organic wastes by mutual interaction between earthworms and microbes (Pramanik *et al.,* 2009). It is an ecobiotechnological process of transformation for the conversion of organic waste into stabilized humus like product known as vermicompost (Suthar and Singh, 2008). The use of earthworms for vermiconversion of varieties of waste including urban, industrial and agro-industrial to produce biofertilizer has already been reported (Sangwan *et al.,* 2008; Khwairakpam and Bhargava, 2009a; Suthar, 2007; Adi and Noor, 2009). Even, the technology for bioconversion of water hyacinth into vermicompost has also been already established (Gajalakshmi *et al.,* 2002, 2001). Furthermore, the role of earthworms urine as a foliar spray in *Amaranthus* has also been tested (Olugbemiga *et al*., 2011). Nevertheless, in the present study emphasis has been given for a comparative efficacy of native and exotic earthworm species for vermicomposting of water hyacinth using cowdung as the accelerator during the process.

The vermicomposting efficiency of both exotic *Eudrilus eugeniae* and native *Perionyx excavatus* are well documented in literature. According to (Gajalakshmi *et al.,* 2001) *Eudrilus eugeniae* is a manure worm, used for vermicomposting due to its voracious appetite, high rate of growth and reproductive ability. Various authors suggested *Eudrilus eugeniae* for vermicomposting of different organic material such as animal dung (Dominguez *et al.,* 2001); banana waste (Padmavathiamma *et al.,* 2008); agricultural waste (Suthar, 2008) etc., Similarly, *Perionyx excavatus* was also used frequently in vermiconversion process as it exhibits better growth and reproductive performance (Suthar and Singh, 2008). The potentiality of *P. excavatus* has been already tested to manage agricultural/industrial waste (Khwairakpam and Bhargava, 2009a), water hyacinth (Gajalakshmi *et al.,* 2001), sewage sludge (Khwairakpam and Bhargava, 2009b), etc. In the present study, a comparison between the indigenous *P. excavatus* and exotic *E. eugeniae* was carried out for vermicomposting of water hyacinth

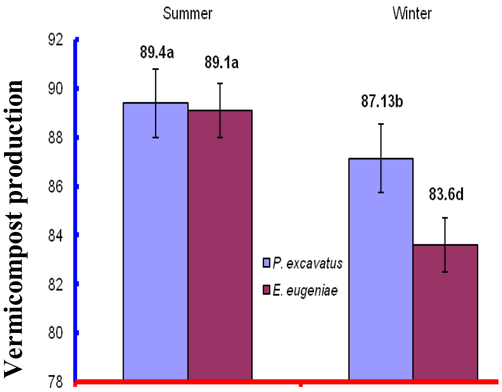

Figure 1 Vermicompost production by *P. excavates* and *E. eugeniae*

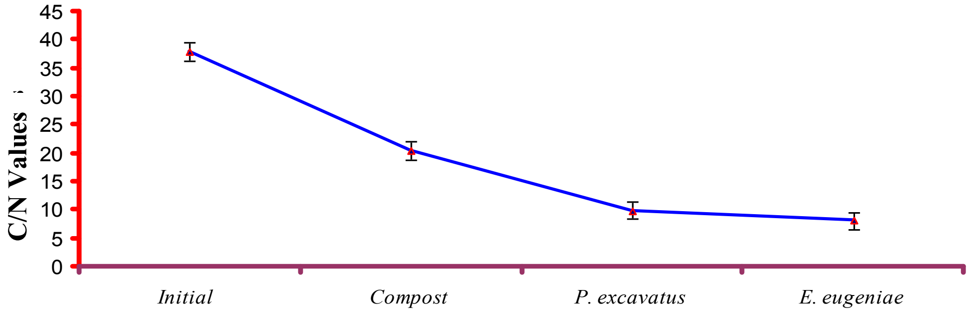

Figure 2 Changes in C/N level during composting and vermi composting process

covering two seasonal trials summer and winter respectively.

METHODS

Earthworms collection and maintenance of cultures

The composting exotic earthworm species *Eudrilus eugeniae* were taken for the experiment and was obtained from vermicomposting unit of Central Silk Board, Boko, Assam (India). Again, the individuals of indigenous *Perionyx excavatus* of different age groups were obtained locally from cowdung dump. The stock cultures of the each earthworm species were maintained separately in earthen pots using partially decomposed biowaste and cowdung as the feeding materials. The taxonomic identification of the collected earthworm species was confirmed at Zoological Survey of India, Solan, India.

Water hyacinth and cowdung

Water hyacinth was harvested from natural wetlands and rinsed thoroughly with tap water in order to remove the mud and other undesirable materials. Fresh urine free cowdung was also collected locally from a livestock farm at Guwahati, Assam, India. The physico-chemical properties of the dry water hyacinth and cowdung are presented in the Table-1.

Experimental setup

The water hyacinth (WH) materials were dried in air, cut into small pieces and mixed with cowdung (CD) on dry weight basis in a ratio of 5:1 for the experiment (Deka *et al.,* 2011a,b). This mixture (i.e. WH + CD) were predecomposed for 15 days so that it becomes palatable for the earthworms (Sangwan *et al.,* 2008). The vermicomposting experiment was conducted by using earthen pots of 2 L capacity (diameter 15 cm, depth 20 cm). The pots were filled with 1.5 cm thick sterilized soil layer at the bottom as soil is considered as an important supporting material for vermicomposting (Deka *et al.,* 2011a,b; Yadav *et al.,* 2010). The experiment was setup by taking 500 g WH + CD mixture (on dry weight basis) in each pot and no extra feeds were provided during the study. For each earthworm species, two similar sets were taken during the experiment and another set was also kept as control without earthworms. Three replications were setup for statistical analysis of

Table 1 The physico-chemical characteristics of WH and CD

Parameters	WH	CD
pH	8.1±0.06	7.01±0.61
Conductivity (mS/ds)	1.5±0.19	0.967±0.14
Ash content (g/kg)	417±3.6	238.7±2.7
TOC (g/kg)	338±2.1	416 ±1.8
TKN (g/kg)	9.5±1.3	8.1 ±0.5
TAP (mg/kg)	5400±2.5	2500 ±3.0
TK (mg/kg)	9700±2.7	3650 ±2.1
TCa (mg/kg)	510±2.8	8978 ±1.7
T Mg (mg/kg)	440±1.9	4669 ±1.6
Fe (mg/kg)	1640±59	1823.4 ±1.8
Cu (mg/kg)	2312±28	251.5 ±1.5
Zn (mg/kg)	640±33	112.6±1.8
C: N ratio	36.0±1.63	51.35 ±1.75

Mean value ± SD
WH = Water hyacinth, CD = Cowdung.

Table 2 The physico-chemical properties of the earthworm processed waste material

Treatments	pH	Conductivity (mS/ds)	Ash content (g/kg)	TOC (g/kg)
Initial	8.1 ± 0.6^{a}	1.5 ± 0.19^{a}	417 ± 1.6^{a}	338 ± 2.1^{a}
Compost	5.3 ± 0.8^{b}	0.812 ± 1.0^{b}	481 ± 1.8^{b}	289 ± 2.0^{b}
E.eugeniae	7.23 ± 0.9^{c}	0.597 ± 0.8^{c}	593 ± 1.2^{c}	192.9 ± 1.7^{d}
P. excavatus	7.02 ± 0.4^{c}	0.546 ± 0.6^{d}	612 ± 1.8^{d}	186.1 ± 1.3^{d}

Mean value± SD
Mean values followed by same letters not significant statistically.

the results. In each earthen pot, 15 individuals (average weight of 8.6-9.2 g) of 40 days old earthworms were introduced from the stock cultures. The moisture level in the pots was maintained at 65-70% throughout the study period (Suthar and Singh, 2008). To avoid moisture loss and protect the earthworms from other predators the experimental pots were placed on water filled trays and covered with jute sheets. The water level was also maintained in the trays as and when it was necessary. The experiment was conducted both in summer and winter seasons to study the seasonal impact on vermicompost production. The mean ambient temperature during the experimental period was recorded as 29.5ºC and 20.8ºC in summer and winter, respectively. The average duration of the experiment was of 105 days. The vermicompost was harvested after the appearance of black granular structure on the surface of the composting medium. Watering of the composting medium was discontinued four days before the harvesting. Vermicompost output percentage as against each seasonal period was calculated on dry weight basis taking generated vermicompost and the raw material used in the experiment. Population of earthworm and their biomass as well as cocoons were measured at the end of the experiment as per the method outlined by (Gupta and Garg, 2008).

Physico-chemical analysis

The vermicompost generated in the two seasonal trials were mixed properly for analysis of pH, conductivity, ash content, total organic carbon (TOC), total kjeldhal nitrogen (TKN), available phosphorus (P), total potassium (K), total calcium (Ca), total magnesium (Mg) and heavy metals (Mn, Cu, Fe and Zn). For chemical analysis all the samples i.e. the compost, vermicompost, waste material and cowdung were separately dried in air at room temperature and powdered in stainless steel blender. The pH and conductivity value were measured in 1:5 (w/v) water suspensions using digital pH (Elico Li 127) and conductivity meter (Elico CM 180) respectively. The ash content was measured following the method of (Nelson and Sommer's, 1982). Total Organic Carbon was measured by Walkey and Black titration method described by (Jackson, 1975). Micro Kjeldhal method (Jackson, 1975)

Table 3 Macronutrient composition of the substrate materials and end products

Treatments	TKN	TP	TK	TCa	TMg
Initial	8.9 ± 0.5^{a}	5102 ± 13.9^{a}	9.2 ± 2.1^{a}	502 ± 2.6^{a}	428 ± 2.9^{a}
Compost	14.1 ± 0.4^{b}	6100 ± 18.6^{b}	14.3 ± 0.3^{b}	772 ± 3.8^{b}	480 ± 3.7^{b}
E.eugeniae	19.3 ± 0.7^{c}	9204 ± 104^{c}	20 ± 1.1^{c}	2210 ± 3.9^{c}	502 ± 3.8^{d}
P. excavatus	23.1 ± 0.8^{d}	8000 ± 142^{d}	20.2 ± 2.2^{c}	2304 ± 4.2^{c}	509 ± 4.6^{d}

Mean value± SD (TKN values are in g/kg; others in mg/kg)
Values followed by different letters are statistically different.

was used for measuring nitrogen. The C:N value was calculated from the measured values of total organic carbon and nitrogen. Available phosphorus was determined by using the spectrophotometer (Shimadzu UV 1601) following the stannous chloride method (APHA, 1996). Total sodium and potassium was determined by acid digestion method using flame photometer with standard solution (APHA, 1996). For analysis of Ca, Mg, Mn, Cu, Zn and Fe samples were digested in microwave digester [Milestone, Ethos 900] and then analyzed by Atomic Absorption Spectrophotometer (Shimadzu AA 7000). All the samples were analyzed in triplicate and average results were recorded. The results were reproducible within ±5% error limit.

Statistical analysis

Paired sample t-test was used to analyse the significant differences in vermicompost production, earthworm population and biomass in two seasonal periods. The same test was also used to compare initial bio-waste mixture (WH + CD) as well as compost (without earthworm) and vermicompost generated from this mixture for their different chemical parameters.

RESULTS AND DISCUSSION

Vermicompost production

The vermicompost production efficiency of the two vermi species *P. excavatus* and *E. eugeniae* were found to vary significantly in two seasonal trials i.e. summer and winter respectively. The indigenous species *P. excavatus* was found to be more efficient as against exotic *E. eugeniae* in case of vermicompost generation (Figure 1). Again, considering the seasonal variation the study showed that vermicompost generation was higher in summer than winter. The higher vermicompost production in summer as compared to that in winter season may be due to decreased reproductive and other metabolic activities of the earthworms in winter (Deka *et al.,* 2011a,b). Similarly, the difference in vermicompost generation between the two species may be related to the gut enzymes, microbes, reproductive and metabolic activities which vary species to species although detailed study is much needed to understand the proper science.

Physico-chemical composition (pH, EC, TOC, ash content)

The end products (i.e. vermicompost) of both the vermi species differs significantly from compost and initial substrates (WH + CD mixture) in pH, EC, TOC and ash values (Table 3). There was decrease in pH levels in the vermicompost samples of the two vermi species and compost as compared to the initial substrate materials. The pH value of the initial raw material was 8.1±0.6 which decreased and became near neutral in vermicompost samples of both the earthworm species (7.23±0.9 and 7.02±0.4) whereas in case of compost sample the pH level was acidic (5.3±0.8). The decrease in pH could be due to production of CO_2, ammonia, NO_3^- and organic acids during vermicomposting process (Yadav *et al.,* 2010). However, pH shift during vermicomposting is dynamic and substrate specific as different substrate may produce different intermediate

Table 4 Heavy metal compositions of the substrate materials and end products

Treatments	Fe	Cu	Zn	Mn
Initial	1623±3.4^{a}	306±2.3^{a}	2613 ±2.7^{a}	524.6±2.2^{a}
Compost	1905±4.2^{b}	389±3.9^{b}	2647.3±3.3^{b}	567.7±3.7^{b}
E.eugeniae	2298±4.9^{c}	87±1.8^{c}	201.4±3.6^{c}	1129±3.4^{c}
P. excavatus	2305±4.1^{d}	64.8±1.6^{d}	187.7±2.7^{d}	1321±4.3^{d}

Mean value± SD (All values are in mg/kg)
Values followed by different letters are statistically different.

species of the organic acids (Gupta and Garg, 2008). The electrical conductivity reflects the salinity status of organic products. The electrical conductivity (EC) value of the initial substrate material was 1.5±0.19 mS/ds that were decreased up to 0.546±0.6 mS/ds and 0.597±0.8 mS/ds in the vermicompost of *P. excavatus* and *E. eugeniae* respectively whereas in case of compost it was of 0.812±1.0 mS/ds (Table 2). Similar observation was also made by previous workers who reported decrease in electrical conductivity in the earthworm processed materials. However, the significant variation in EC values in the vermicompost samples could be due to the differences in metabolic activities of the two vermi species that result difference in the release of available mineral salts.

The ash content is an indicative parameter for decomposition and mineralization of composting product including vermicompost (Khwairakpam, and Bhargava, 2009b). The results of the experiment showed that ash value in vermicompost of both the species was higher than compost and initial level of the biowaste mixture (Table 2). Further, ash value was found significantly higher in the vermicompost of *E. eugeniae* in comparison to the *P. excavatus*. The initial level of ash content of the substrate was 417±1.6 g kg^{-1} and it increased up to 612±1.8 g kg^{-1} and 593±1.2 g kg^{-1} in the vermicompost of *P. excavatus* and *E. eugeniae* respectively (Table 2). The enhanced mineralization of biowaste materials due to composting and vermicomposting may be the reason for higher ash value in the final product (Khwairakpam and Bhargava, 2009b). Moreover, the higher ash level in the vermicompost of *E. eugeniae* as compared to *P. excavatus* clearly indicates the faster consumption rate of the waste material.

Total organic carbon (TOC) was lower in the final product (i.e. vermicompost) of both the species and in compost sample than the initial levels of the biowaste. The loss of TOC was 14.5% in compost as against 44.9% and 42.9% in the vermicompost samples of *P. excavatus* and *E. eugeniae* respectively. The present finding reinforce the earlier findings that upto 49% Carbon loss during the vermicomposting process is evident as a result of CO_2 lost due to respiratory activity and consumption of available Carbon by earthworms and microbes (Khwairakpam, and Bhargava, 2009a).

Macronutrient composition

The macronutrient composition of the biowaste material, compost and vermicompost are presented in the Table-3. All the macronutrients significantly enriched in compost and vermicompost samples of both the species as against the initial biowaste material. The vermicompost samples showed higher levels of all the macronutrients than the control (i.e. compost). Further, the vermicompost produced by the indigenous *P. excavatus* contain higher level of macronutrients over *E. eugeniae* available P. There was 2.6 fold increases in TKN level in the vermicomposted material of *P. excavatus* whereas it was 2.2 fold in the end product of *E. eugeniae*. The compost sample showed 1.5 fold increase in TKN level as compared to the initial value of the biowaste material. The enhanced levels of nitrogen is already reported in literature which may be due to loss of organic carbon and mineralization of organic matter during bioconversion process (Yadav and Garg, 2011a; Garg and Gupta, 2011). Similarly, compost recorded 1.2 fold increase in available P whereas in case of vermicompost samples it was 1.7 fold (*P. excavatus*) and 1.8 fold (*E. eugeniae*) respectively. The present findings are similar with the earlier workers (Fernandez-Gomez *et al.,* 2010) that reports increase in available P due to mineralization of phosphorus in biowaste material. The release of phosphorus in available form is contributed partly by earthworm gut phosphatase, and further release of P through P-solubilizing microorganisms present in worm casts (Suthar, 2009a). The total K increase was 2.2 fold in vermicompost samples as against 1.5 fold of compost sample. The present findings is an agreement with the earlier work of (Raphael and Velmourougane,

2010) who reported seven fold increase in TK content in the vermicompost. It has been suggested that earthworm processed material contains higher concentration of TK due to higher mineralization rate as a result of enhanced microbial and enzyme activities in the guts of earthworms (Tripathi and Bhardwaj, 2004). Similarly for vermicompost samples Ca level increase was in the range of 4.4-4.5 fold whereas in case of Mg it was 2.2 fold for the end products of both the earthworm species. The compost recorded 1.5 fold increases in Ca level as against 1.1 fold increase of Mg value. It has been suggested that activity of earthworms drives the mineralization process efficiently and transforms a large proportion of Ca and Mg from bind to free form that may enhance the composition of the elements in the final product (Suthar, 2009b).

Heavy metals (Fe, Cu, Zn and Mn)

Heavy metals are important trace elements for well being of plants, animals and humans, but their excess is known to have toxic effects (Kizilkaya, 2005). The compost as well as vermicomposted materials of *P. excavatus* and *E. eugeniae* showed significant variation in heavy metal concentrations in relation to the initial levels of the bio-waste (Table 4). There was a significant enhancement in the concentration of Fe and Mn in control (compost) and vermicompost samples of both the earthworm species although Zn and Cu concentration decreased in the end products of both the species. The higher concentration of heavy metals in the vermicompost as compared to compost may be due to mineralization of partially digested worm faecal by detritus communities for example bacteria and fungi (Suthar, 2010a). Earthworm fragments and modifies the physical structure of ingested wastes through muscular action of foregut thereby increasing the surface area for microbial action and such biological action may enhance the metal concentrations in vermicompost (Suthar, 2010b). Again, decreased level of Cu and Zn in the vermicompost samples may be due to selective absorption of these metals by the earthworm's body tissue.

C/N ratio

The C/N ratio is a reliable indicator to measure the maturity of the compost. The C/N values of the biowaste mixture along with compost and vermicompost samples of both the species are graphically presented in the Figure-2. . The result reveals a significant decrease in the values after 105 days of composting and vermicomposting. The C/N value of the raw materials was 37.9 which decreased upto 20.4, 9.9 and 8.05 in compost, vermicompost samples of *E. eugeniae* and *P. excavatus* respectively. . The declines in C/N values are obvious as there was decrease in TOC level and increase in N value in the compost and vermicompost samples. Further, the greater decrease in the C/N values in the *P. excavatus* processed material as against *E. eugeniae* may be due to the differences in microbial community and physiological profiles as well as carbon mineralization rate of the two earthworm species (Suthar and Singh, 2008). The C/N ratio less than 25 is considered as an indication of compost maturity (Subramanian *et al.,* 2010). The present findings corroborated with the previous worker (Yadav and Garg, 2011b) who reported decrease level of C/N value during vermicomposting of *Parthenium* weed.

CONCLUSION

The mixture of water hyacinth and cowdung can be converted into vermicompost by employing the earthworm species *P. excavatus* and *E. eugeniae*. The end products i.e. so called vermicompost of both the species were found to be more homogeneous, nutrient rich and stabilized than the initial biowaste mixture as well as traditional compost. Nevertheless, the indigenous earthworm species showed better efficiency in terms of vermicast generation in both the seasonal trial summer and winter.

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