Journal of Experimental Biology and Agricultural Sciences

http://www.jebas.org

ISSN No. 2320 – 8694

COMPARATIVE STUDIES ON COMPOSTING EFFICIENCY OF *Eisenia foetida* (SAVIGNY) AND *Perionyx excavatus* (PERRIER)

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Received – August 22, 2014; Revision – September 10, 2014, Accepted – September 23, 2014
Available Online – October 25, 2014.

KEYWORDS

Agrowaste

Vermicomposting

P. excavatus

E. foetida

Epigeic earthworms

ABSTRACT

The potential of two epigeic earthworms (*Perionyx excavatus* and *Eisenia foetida*) was studied for composting of crop residues (wheat straw and paddy straw) amended with farm yard manure. At the end of vermicomposting significant increase in total nitrogen (71 -150%), phosphorus (49 %–116%) and potassium (26.3–142%), along with decrease in organic carbon was recorded in different experimental vermibeds. Maximum total nitrogen as well as available phosphorous concentration was observed from vermibeds inoculated with *E. foetida*, whereas increased exchangeable potassium and reduction in organic carbon was shown in vermicompost produced by *P. excavatus*. Enhanced hydrolytic enzyme activities of CMCases (1.51 folds), Fpases (2.11 folds) and β-glucosidases (1.38 folds) were recorded in treatments vermicomposted with *P. excavatus*. Microbial activity parameters such as dehydrogenase, FDA hydrolase, alkaline phophatase, were also monitored during decomposition process and gradual increase was recorded in vermibeds up to 90 days of experimentation. The mean individual live weight, growth rate (mg wt. worm^{-1} day^{-1}) of earthworm were higher for *P. excavatus* as compared to *E. foetida*. Overall, *P. excavatus* exhibited better growth and mineralization efficiency, which further support the suitability of the species for large scale vermiculture operations.

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Peer review under responsibility of Journal of Experimental Biology and Agricultural Sciences.

Production and Hosting by Horizon Publisher (www.my-vision.webs.com/horizon.html).

1 Introduction

Each year, anthropogenic activities, produce approximately 38 billion metric tons of organic waste worldwide (Prasad, 2011). Based on crop production data, it is being estimated that around 600 to 700 million tons of agricultural residues are generated in India every year, but most of it remains unutilized (Singh & Nain, 2014). These crop residues are potential source of plant nutrients which must be degraded before recycling to restore soil fertility. Earthworms are considered as suitable organisms for the degradation process since vermicomposting results in reduction of bulk density and reduced phytotoxicity in the composted end products. Several epigeic earthworms, e.g., *Eisenia foetida* (Savigny), *Perionyx excavatus* (Perrier), *Perionyx sansibaricus* (Perrier), and *Eudrilus eugeniae* (Kinberg) had been identified by researchers which may be promising candidate to recycle the organic wastes.

The potential of earthworms, i.e., *Eisenia foetida* (Savigny), and *Perionyx excavatus* (Perrier) to manage organic waste resources is well established. Vermicomposting potential of these earthworms by using a variety of waste materials such as cattle dung (Chaudhuri & Bhattacharjee, 2002), household waste, sewage sludge, industrial waste etc (Edwards, 2004, Suthar, 2006) is already being investigated. However, agricultural crop residues comprising of wheat or paddy straw which are produced annually in huge quantity have not been previously tested as vermicomposting substrates. Therefore the potential of two epigeic and domesticated earthworms namely *E. foetida* and *P. excavatus* for the bioconversion of wheat and paddy straw along with FYM was tested in this study for eco-friendly management of crop residues.

2 Materials and Methods

2.1 Source of Earthworm

Epigeic domesticated species of earthworm i.e. *E. foetida* (Savigny) and *P. excavatus* (Perrier) was obtained from Animal Genetics Division, Indian Veterinary Research Institute, Izzatnagar, Bareilly (India).

2.2 Vermibed formulation and treatment design

Substrates for vermibed/ration formulations; wheat straw (WS), paddy straw (PS) and farm yard manure (FYM) were obtained from biomass utilization facility of IARI, New Delhi. The crop residues were dried at 60^0C in a hot air oven and chopped to a size of 5cm. Two types of vermibed recipes were prepared by mixing paddy straw + farm yard manure (1:1) and wheat straw + farm yard manure (1:1). These substrates were composted in composting pits (1 m^3 dimentions) without and with independent introduction of species of earthworms in triplicate in randomized block design (RBD). The moisture level of vermibeds was maintained at 65–70% throughout the study period by periodic sprinkling of adequate quantity of tap water. Periodic turning of vermibeds were also carried out. The experimental pits were covered with jute bag to prevent the moisture loss. Samples were collected at the start of the experiment and at monthly interval upto 3 months during the course of experiment. These samples were analyzed for chemical parameters (organic carbon, total nitrogen, available phosphorus, and exchangeable potassium) as described in section 2.3.

Quantitative assays of extracellular enzymes such as Carboxy Methyl Cellulase (CMCases), Filter paper lyase (Fpase), β-Glucosidase and microbial activity parameters [Dehydrogenase, Fluorescein diacetate hydrolyase (FDA), alkaline phosphatase] were also performed at monthly intervals as per procedures listed in section 2.4-2.6. Following treatments have been arranged in triplicate for study.

Paddy Straw + Farm Yard Manure (PS+FYM)
Paddy Straw + Farm Yard Manure + *Eisenia foetida* (PS+FYM+ Ef)
Paddy Straw + Farm Yard Manure + *Perionyx excavatus* (PS+FYM+ Pe)
Wheat Straw + Farm Yard Manure (WS+FYM)
Wheat Straw + Farm Yard Manure + *Eisenia foetida* (WS+FYM + Ef)
Wheat Straw + Farm Yard Manure + *Perionyx excavatus* (WS+FYM+ Pe)

2.3 Physico-chemical analysis

The physico chemical analysis of raw material and vermicompost produced during experiment were analyzed by using the methodology as described by Jackson (1975). Total organic carbon (TOC) was determined by ashing method. Total Kjeldhal nitrogen (TKN) was measured after digesting the sample with digestion mixture and concentrated H_2SO_4. For available phosphorous (AP) determination, 0.5 g of dried sample was taken into a conical flask and 100 ml of sodium bicarbonate (0.5 N) and activated charcoal (1g) was added and the mixture was shaken for 30 min. After this, the solution was filtered through a Whatman no. 42 filter paper and the filtrate was used for the determination of phosphorous as described by Olsen et al. (1954). Exchangeable potassium (EK) was extracted with ammonium acetate and analyzed by flame photometer.

Electrical conductivity (EC) and pH measurement were performed in compost:water suspension (1:5 w/v) by electrometric determination using hand-held digital EC and pH meter (Eutech instruments, Singapore) respectively. Humus was estimated by the method of Kononova (1966) by using alkaline pyrophosphate reagent as extractant.

2.4 Quantification of extracellular enzymes activity

For quantitative enzyme assay, extracellular enzymes were extracted from vermicompost with citrate buffer (0.5M, pH4.8) which was used as crude enzyme (Pandey et al., 2009).

2.5 Activity of hydrolytic enzymes

Fpase and CMCase activities were measured in crude enzyme extracts by the method as described by Ghose (1987). One unit of activity corresponded to 1 µmol of glucose released min^{-1} from filter paper/CMC as substrate. β-Glucosidase assay was performed using *p*-nitrophenyl-β-D-glucopyranoside as substrate (Wood & Bhat, 1988) and the activity was calculated in terms of µmol of *p*-nitrophenol released min^{-1}.

2.6 Estimation of microbial activity parameters

Quantification of microbial activity during the composting process was done by FDA hydrolase, alkaline phosphatases and dehydrogenases. The FDA hydrolyase assay was carried by the method outlined by Schnurer & Roswall (1982). The values were represented as µg Fluorescein released g^{-1} vermicompost h^{-1}. Dehydrogenase activity was assayed using the method of Casida et al. (1964). The values were expressed as µg of Triphenyl Formazon (TPF) g^{-1} vermicompost day^{-1}. Alkaline phophatases activity was assayed in vermicompost by the method of Tabatabai & Bremner (1969) and was expressed as µg p-nitro phenol released g^{-1} vermicompost h^{-1}.

2.7 Vermicomposting coefficient

Vermicomposting coefficient (VC) was calculated by using following formula (Suthar, 2007a)

VC= [Total increase/decrease during vermicomposting (experimental)] / [Total increase/decrease during composting (control)]

2.8 Growth studies

The biomass of earthworms was determined at 30 days interval up to the end of the study in terms of mean individual live weight, maximum individual, net individual weight gained and growth rate (Birundha et al., 2013).

2.9 Statistical analysis

The data of the various parameters of compost maturity and enzyme activities were analyzed in triplicates and subjected to ANOVA (Analysis of variance) in accordance with the experimental design (completely randomized block design) using SPSS-16 statistical package to quantify and evaluate the source of variation. Correlation values were calculated at P level of 0.05. Alphabetical superscripts in table denote ranking in descending value according to Duncan's multiple range test. The treatments denoted by different letters in the each column of tables and figures represent significantly different values among the treatments.

3 Results and Discussion

3.1 Potential of *E. foetida* and *P. excavatus* in crop residues mineralization

Initial bedding material had C: N ratio of 85:1 (Table 1). Vermicomposting caused drastic changes in nutrient profile of all the substrates by the end of the experiment (Table 2). Organic C content decreased in all the treatments indicating mineralization of organic matter during decomposition. The organic C mineralization rate was rapid up to 60 days, followed by a consistent trend of slow decomposition rate by the end of the experiment (Figure. 1a). Lowest amount of organic carbon (23-24%) was observed in treatments inoculated with *P. excavatus* in both the substrates. But the vermibed of wheat straw inoculated with *P. excavatus* (WS+FYM+ Pe) and *E. foetida* (WS+FYM + Ef) were found to be equally good in organic carbon reduction .The comparison of vermicomposting was also done by using vermicomposting coefficient (VC_{Carbon}) and its highest value was recorded for Paddy straw inoculated with *P. excavatus* (PS+FYM+ Pe) (Table 4). The decrease in the TOC content of vermicompost, was significantly more pronounced in paddy straw inoculated with *P. excavatus* as compared with *E. foetida*. Suthar & Singh (2008) had also reported high rate of organic carbon reduction by *P. excavatus* during vermicomposting of the domestic kitchen waste.

Table 1 Physico-chemical characteristic of bedding material used for experimentation

Parameters	Bedding material	
	WS+FYM	PS+FYM
Organic Carbon (%)	53.31±0.99	56.13±0.98
Total Nitrogen (%)	0.62±0.01	0.71±0.032
Available P (ppm)	51.39±1.6	49.81±2.05
Exchangeable K (ppm)	7.58 ±0.53	9.66 ±0.46
pH	8.56	8.75
EC	4.67	5.32
Carbon to Nitrogen Ratio	85.47 ±3.13	85.73± 9.69

Mean ± SD, n = 3, WS: Wheat straw; PS: Paddy straw; FYM : Farm yard manure

Table 2 Changes in physico-chemical composition of bedding materials during normal composting and vermicomposting after 90 days

Treatments	OC (%)	TKN (%)	C:N	AP (mg kg^{-1})	EK (mg kg^{-1})	Humus (%)	EC (dS m^{-1})	pH
PS +FYM	35.2±1.59^{a}	1.33±0.022^{c}	26.48±1.37^{a}	112.43±0.99^{b}	33.57±1.48^{b}	5.81±0.37^{b}	1.64±0.13^{a}	7.51±0.07^{a}
PS+FYM+Ef	27.57±0.96^{b}	1.79±0.014^{a}	15.36±0.57^{b}	141.16±2.18^{a}	40.3±1.8^{a}	7.49±0.35^{a}	1.15±0.05^{b}	7.16±0.05^{b}
PS+FYM+Pe	23.27±2.69^{c}	1.51±0.024^{b}	15.38±1.56^{b}	127.51±3.27^{c}	37.73±0.32^{a}	8.04±0.13^{a}	1.16±0.07^{b}	7.22±0.06^{b}
WS+FYM	35.06±1.44^{a}	1.32±0.03^{a}	27.98±1.36^{a}	104.64±1.03^{c}	31.1±2.49^{c}	6.37±0.02^{c}	1.5±0.05^{c}	7.2±0.01^{b}
WS+FYM+Ef	24.82±1.54^{b}	1.88±0.02^{a}	13.2±0.98^{b}	112.27±3.08^{b}	33.5±1.5^{b}	8.26±0.06^{b}	0.79±0.03^{b}	7.16±0.05^{b}
WS+FYM+Pe	24.64±0.77^{b}	1.70±0.05^{b}	14.52±0.73^{b}	121.51±3.82^{a}	44.33±0.76^{a}	9.57±0.51^{a}	0.51±0.03^{a}	7.03±0.05^{a}

Mean ± SD, n = 3; WS: Wheat straw; PS: Paddy straw;FYM : Farm yard manure ;Pe: *P. excavatus*; Ef: *E. foetida*

Table 3 Growth of *E. foetida* and *P. excavatus* in different bedding materials after 90 days

Treatments	Mean initial individual weight (mg)	Maximum individual weight achieved (mg)	Net individual weight gained (mg)	Growth rate (mg wt. /worm / day)
PS+FYM+Ef	182±25.05	335.33±21.22^{a}	170.33±29.56^{a}	1.89±0.33^{a}
PS+FYM+Pe	224.66±12.85	466.0±10.19^{b}	241.33±16.01^{b}	2.68±0.18^{b}
WS+FYM+Ef	182±25.05	436.66±4.16^{c}	254.66±28.37^{b}	2.83±0.31^{b}
WS+FYM+Pe	224.66±12.85	559.0±5.56^{d}	334.33±14.01^{c}	3.71±0.15^{c}

Mean ± SD, n= 3, WS: Wheat straw; PS: Paddy straw;FYM : Farm yard manure ;Pe: *P. excavatus*; Ef: *E. foetida*

Table 4 Vermicomposting coefficient of different bedding material for nutrient composition, cellulases production and humus concentration.

Treatments	VC_{Carbon}	$VC_{Nitrogen}$	$VC_{Phosphorous}$	$VC_{Potassium}$	$VC_{C\text{-}to\text{-}N}$	$VC_{CMCases}$	VC_{Fpases}	$VC_{\beta\text{-}glucosidases}$	VC_{Humus}
PS+FYM+Ef	1.27	1.34	1.25	1.20	1.72	1.37	1.61	2.77	1.28
PS+FYM+Pe	1.51	1.13	1.13	1.12	1.72	1.05	1.89	3.53	1.38
WS+FYM+Ef	1.41	1.50	1.07	1.08	2.11	1.79	1.33	1.42	1.29
WS+FYM+Pe	1.42	1.35	1.16	1.42	1.92	1.51	2.11	1.38	1.50

n=3, WS: Wheat straw; PS: Paddy straw;FYM : Farm yard manure ;Pe: *P. excavatus*; Ef: *E. foetida*

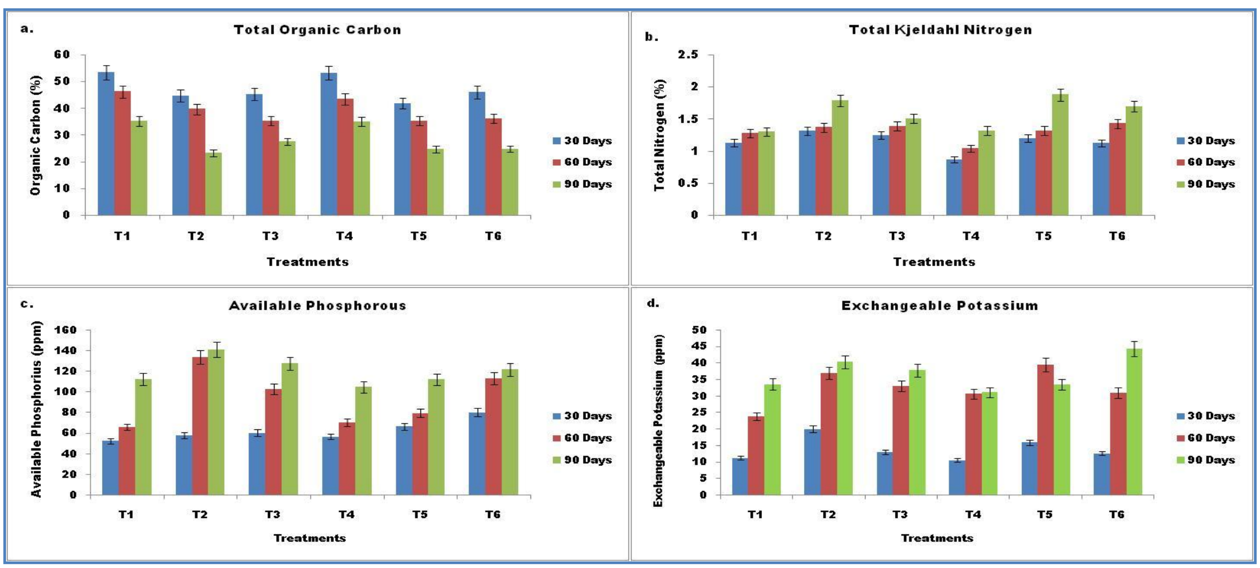

Figure 1 Effects of earthworm inoculation on organic carbon, nitrogen, phosphorous and potassium content in various vermibeds treatments. Each point represents mean ± SD of three observations (T1: Paddy Straw + Farm Yard Manure; T2: Paddy Straw + Farm Yard Manure + *Eisenia foetida;* T3: Paddy Straw + Farm Yard Manure + *Perionyx excavatus;* T4: Wheat Straw + Farm Yard Manure; T5: Wheat Straw + Farm Yard Manure + *E.foetida;* T6: Wheat Straw + Farm Yard Manure + *P.excavatus*).

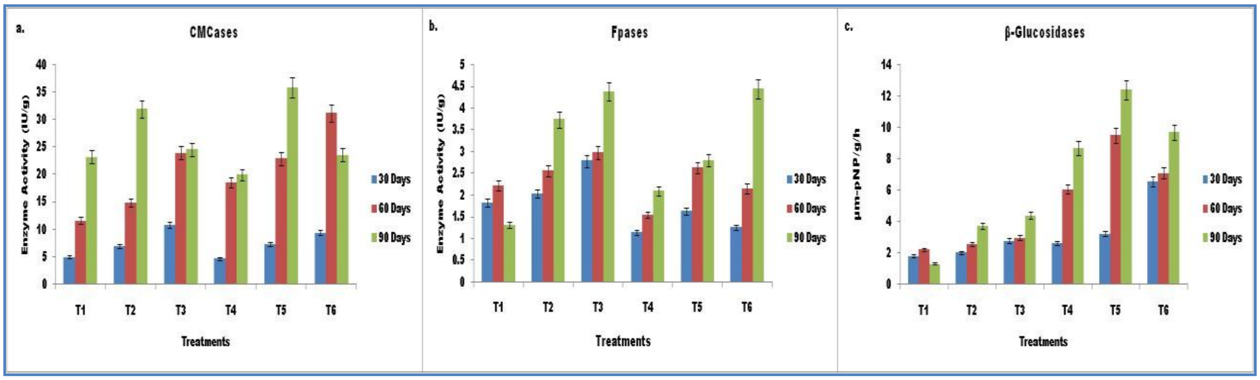

Figure 2 Effects of earthworm inoculation on CMCases, Fpases and β-glucosidase activity in various vermibeds as compared with normal compost. Each point represents mean ± SD of three observations (T1: Paddy Straw + Farm Yard Manure; T2: Paddy Straw + Farm Yard Manure + *Eisenia foetida;* T3: Paddy Straw + Farm Yard Manure + *Perionyx excavatus*; T4: Wheat Straw + Farm Yard Manure; T5: Wheat Straw + Farm Yard Manure + *E. foetida*; T6: Wheat Straw + Farm Yard Manure + *P.excavatus*).

Earthworms metabolize substrates consequently resulting in the carbon loss through mineralization of organic matter. The results observed in this study are comparable with previous work (Kale et al., 1982; Elvira et al., 1998; Suthar, 2007a) that had also reported significant loss in organic C after worm inoculation. Moreover, in this study, there was a significant difference among feed mixtures for organic matter decomposition; possibly due to different rate of enzyme action related to carbon mineralization (Flegel & Schreder, 2000).

Total kjeldahl nitrogen (TKN) was significantly higher in the end products than their initial levels (Table 2, Figure. 1b), by the end of the experiment. Both uninoculated control and vermicomposting showed a valuable increase in TKN but increase was significantly higher in vermicomposted material than that of control. TKN content in vermicompost was highest in *E. foetida* inoculated wheat straw (WS+FYM + Ef - 1.88 %) and paddy straw (PS+FYM+ Ef - 1.79 %). Vermicomposting coefficient for nitrogen ($VC_{Nitrogen}$) was recorded maximum for the same treatments (Table 4). Among the earthworm species *E .foetida* caused 2.64 to 2.88 fold increases in the nitrogen content of the vermicompost as compared to *P. excavatus*. The high nitrogen mineralization rate of *E. foetida* was also reported by Sannigrahi (2005). The enhanced nitrogen levels in the vermicompost was due to carbon loss, addition of excretory products, mucus, body fluid, enzymes and even through decaying tissues of dead worms (Suthar, 2007b). Several researchers reported that increase in TKN by the end of the vermicomposting period, was because of concentration effect mainly due to mineralization of the organic matter (Kale et al., 1982; Elvira et al., 1998; Edwards et al., 1998; Suthar, 2007a).

Vermicomposted material showed more available phosphorous (AP) by the end of the experiment (Table 2, Figure. 1c). In this study different patterns of P mineralization were recorded among the treatments. Maximum available P concentration (141.16 mg kg^{-1}) was observed in *E. foetida* treated paddy straw (PS+FYM+ Ef) but the same worm species fed upon wheat straw (WS+FYM+Ef) showed less available P (112.27 mg kg^{-1}). This observation might be due to type of plant material used as well as feed preference of worm towards the substrate. Treatment PS+FYM+ Ef also showed maximum vermicomposting coefficient ($VC_{Phosphorus}$) (Table 4). Most efficient earthworm species in this parameter was *E. foetida*. The same trend was also reported by Sannigrahi (2005) mainly due to the action of microbial phosphatases of gut microbiota as well as presence of P-solubilizing microorganisms in worm casts (Aira et al., 2005; Le Bayon & Binet, 2006). The concentration of phosphorous increased continuously up to 90 days (Figure. 1c).

Exchangeable potassium (EK) also showed significant increase by the end of the experiment. Comparatively, vermicomposted material showed more potassium mineralization rate than the uninoculated control material (Table 2, Figure. 1d). The vermicomposting caused a significant increase in exchangeable K content and was found to be maximum (44.33 mg kg^{-1}) for treatment WS+FYM+ Pe wheat straw inoculated with *P. excavatus*. Vermicomposting coefficient ($VC_{Potassium}$) was also maximum for the same treatments (Table 4). *P. excavatus* potential for increasing K content in the vermicompost was reported earlier also by Suthar & Singh (2008). The earthworm and its symbiotic gut microflora along with secreted mucus increases their degradation of ingested organic matter as well as accelerates the process of mineralization and subsequently enriches the vermicompost with more available forms of plant nutrients.

Carbon to nitrogen ratio (C:N) of substrate material reflects the mineralization of organic matter due to release of carbon di oxide during process of degradation and metabolism. Due to loss of carbon in the form of CO_2, nitrogen content increases in the vermicompost resulting in decrease in C:N ratio (Gunadi & Edwards, 2003). In this study the maximum reduction in C:N ratio was observed in the treatment WS+FYM + Ef (13.2) where *E. foetida* fed upon wheat straw (Table 2).

Table 5 Pearson's correlation coefficient between composting period and chemical parameters

	PS+FYM+ Ef	PS+FYM+ Pe	WS+FYM + Ef	WS+FYM+ Pe
Composting period, OC	-0.997	-0.997	-0.913	-0.939
Composting period, TKN	0.958	0.929	0.975	0.995
Composting period, AP	0.933	0.978	0.978	0.976
Composting period, EK	0.973	0.956	0.869	0.970
Composting period, C:N	-0.907	-0.916	-0.938	-0.926

Mean ± SD, n = 3; WS: Wheat straw; PS: Paddy straw;FYM : Farm yard manure ;Pe: *P. excavatus*; Ef: *E. foetida*

Table 6 Pearson's correlation coefficient between composting period and biological parameters.

	PS+FYM+ Ef	PS+FYM+ Pe	WS+FYM + Ef	WS+FYM+ Pe
Composting period, CMCase	0.974	0.991	0.954	0.853
Composting period, FPase	0.972	0.945	0.939	0.980
Composting period, β-glucosidase	0.961	0.989	0.939	0.927
Composting period, Dehydrogemase	0.984	0.976	0.977	0.977
Composting period, FDA hydrolase	0.934	0.959	0.914	0.943
Composting period, Alkaline Phosphatase	0.945	0.950	0.950	0.951

Mean ± SD, n = 3; WS: Wheat straw; PS: Paddy straw;FYM : Farm yard manure ;Pe: *P. excavatus*; Ef: *E. Foetida*

Vermicomposting coefficient for C:N ratio was also calculated and found to be maximum in WS+FYM + Ef (Table 4). Both the earthworm species used in the present study caused significant reduction in C:N ratio and variations in the results indicates that composition of the plant materials used in the study and earthworm species has a substantial effect on C:N ratio of the end products.

Electrical conductivity (EC) indicates the level of total dissolved salts in a compost sample at particular stage of degradation and the most desired value should be < 3.0 dS m^{-1} (WERL, 2000). In all the treatments, the EC was found to be < 3.0 dS m^{-1} but appreciable decrease in the EC was observed in all the vermicompost treatments (Table 2). Similar trends in EC reduction during vermicomposting by *E. foetida* and *P. excvatus* were previously reported by Pattnaik & Vikram (2010). During vermicomposting the minor production of ammonium (NH_4^+), as well as loss of the dissolved salts in the environment may lead to lower EC values (Mitchell, 1997).

The pH value decreased from 8.75 to 7.2 during the vermicomposting period (Table 2). Among all the treatments, maximum reduction was for treatment WS+FYM+ Pe wheat straw based verminbed fed upon by *P. excavatus*. The drop in pH during vermicomposting may be due to development of anaerobic conditions and accumulation of organic acids resulting due to action of acidogenic microbes in the earthworm gut (Elvira et al., 1998).. Humus concentration was found to be in the range of 5.8-9.57 % (Table 2). *P. excavatus* resulted in maximum humus percent in both treatments comprising of wheat straw WS+FYM+ Pe (9.57 %) as well as paddy straw PS+FYM+ Pe (8.04 %).The vermicomposting coefficient (VC_{Humus}) was maximum for WS+FYM+ Pe (Table 4).

Vermicomposting process caused significant change ($p< 0.05$) in chemical composition of all the vermibeds. Composting duration showed significant positive correlation with total N, phosphorus and potassium while significant negative correlation was recorded with organic C, C:N ratio in the vermibeds (Table 5).

3.2 Estimation of hydrolytic enzymes

Various hydrolytic enzymes are believed to control the rate at which various substrates are degraded. Enzymes are the main mediators of various degradation processes (Tiquia, 2002). So the changes in the activities of three important enzymes CMCase, Fpases and β-Glucosidase which are responsible for hydrolysis of cellulose were studied to understand the degradation of various organic wastes.

Carboxymethyl cellulase activity showed significant increase by the end of the experiment (Figure. 2a). Both uninoculated treatment and vermicomposting treatments showed increase in CMCases activity; but increase was more pronounced in vermicomposted material. Among the treatments, highest activity (35.82 IU g^{-1}) was recorded in WS+FYM + Ef, where *E. foetida* was inoculated in the vermibed.. CMCase activity increased slowly up to 60 days; thereafter a rapid increase was observed up to the end of the experiments (Figure. 2a). Vermicomposting coefficient ($VC_{CMCases}$) was also highest for *E. foetida* inoculated in the vermibed comprising of paddy straw. Activity of FPase also increased till the end of the experiment (Figure. 2b). Maximum activity (4.44 IU g^{-1}) was observed in wheat straw vermibeds fed upon by *P. excavatus* (WS+FYM+ Pe).

Therefore the vermicomposting coeffiecient (VC_{Fpases}) was also highest for the same treatments (Table 4). β-glucosidases activity also increased with the time and at the end of experimental period the activity was found to be maximum for vermicompost as compared to control (Figure. 2c). *E. foetida* worked vermibed of wheat straw (WS+FYM + Ef) showed elevated β-glucosidases (12.37 IU g^{-1}) activity. Vermicomposting coefficient ($VC_{\beta\text{-glucosidases}}$) was maximum for *P. excavatus* fed vermicompost (PS+FYM+ Pe) obtained from paddy straw (Table 4). Although microbiota is the main agent responsible for cellulose decomposition, earthworms also play an important role by contributing in through their digestive processes. Zhang et al. (2000) reported high cellulase activity in the gut content of *E. foetida* Further, Moody et al. (1995) reported that different earthworm species (*Lumbricus terrestris, Allolobophora longa,* and *A. chlorotica*) eject lignin-decomposing fungi into the substrate during composting and may indirectly enrich the bedding materials with the lignocellulolytic degradative microflora.

In all the vermibeds there was significant increase in activity of all the cellulolytic enzymes upto 90 days of vermicomposting with high degree of positive correlation (Table 6, $p<0.05$) between composting period and vermibeds treatments.

3.3 Estimation of microbial activity parameters

Dehydrogenase activity represents the microbial activity of mostly intracellular enzymes in living microbial cells which participate in the respiratory process. There was a significant increase in dehydrogenase activity up to 90 days of vermicomposting period (Figure. 3a). Maximum activity of dehydrogenase (198 µg TPF g^{-1} day^{-1}) was observed in PS+FYM+ Pe treatment; paddy straw inoculated with *P. excavatus* (Figure. 3a). High dehydrogenase activity during vermicomposting may be because of proliferation of gut microbes (Barrena et al., 2008).

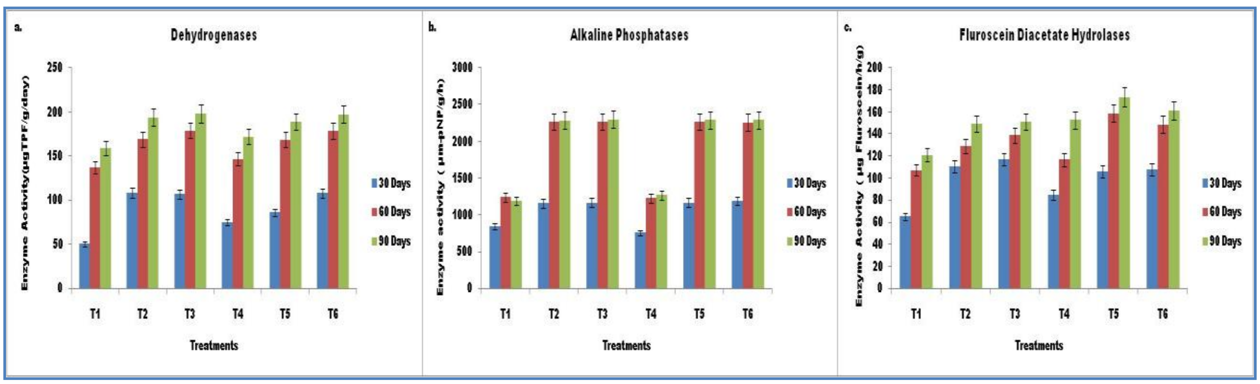

Figure 3 Effects of earthworm inoculation on dehydrogenases, alkaline phophatases and fluroscein diacetate hydrolase activity in various vermibeds as compared with normal compost. Each point represents mean ± SD of three observations (T1: Paddy Straw + Farm Yard Manure; T2: Paddy Straw + Farm Yard Manure + *Eisenia foetida*; T3: Paddy Straw + Farm Yard Manure + *Perionyx excavatus*; T4: Wheat Straw + Farm Yard Manure; T5: Wheat Straw + Farm Yard Manure + *E. foetida*; T6: Wheat Straw + Farm Yard Manure + *P. excavatus*).

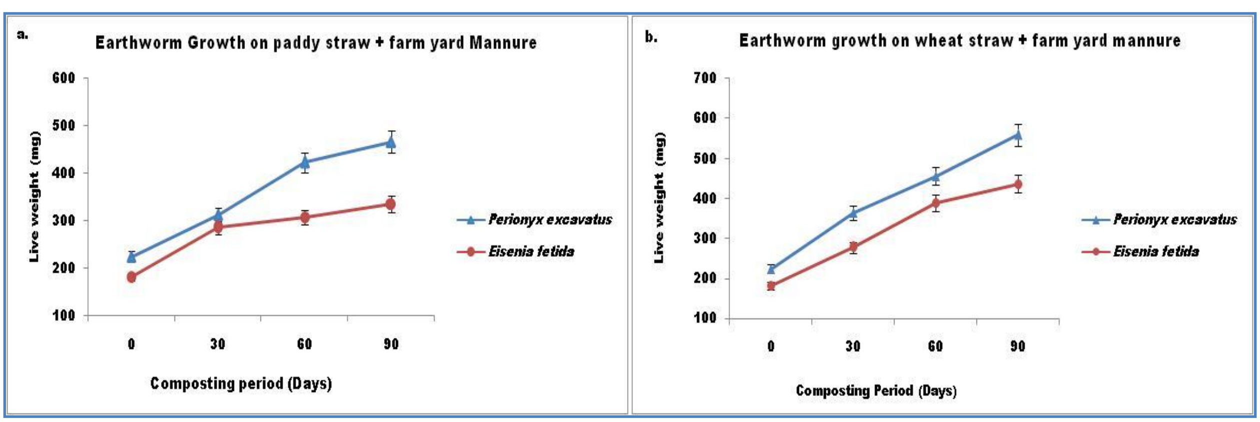

Figure 4 Effects of vermibeds on earthworms biomass. Each point represents mean ± SD of three observations.

Phosphatase activity reflects the mineralization of organic phosphorous (Nannipieri et al., 1979). In accordance with the above report, alkaline phosphatase activity in all treatments increased throughout the study. Values of alkaline phosphatase were much higher in all the vermicomposted treatment, and maximum activity (2298.87 µg-pNP g^{-1} h^{-1}) was recorded in the treatment paddy straw inoculated with *P. excavatus* (PS+FYM+ Pe) (Figure. 3b). Phosphatase activity followed a similar trend to that reported by Benitez et al. (1999) as obtained during vermicomposting of sewage sludge and olive waste respectively.

FDA is a non-fluorescent substrate that is hydrolyzed by various extracellular enzymes produced by the microbes resulting in production of fluorescein which is quantified spectrophotometrically (Schnurer & Roswall, 1982). The highest FDA hydrolase was recorded in the treatments of vermicompost as compared to control (Figure. 3c). Elevated FDA hydrolytic activity (173.67 µg Fluroscein h^{-1} g^{-1}) was obtained from *E. foetida* inoculated wheat straw (WS+FYM + Ef). The result was in accordance with Domínguez et al. (2010), who reported that *E. foetida* and *P. excavatus* inoculation caused enhancement of the microbial activity in the cast which resulted in increased FDA hydrolase activity.

There was high degree of positive correlation between vermicomposting period and microbial activity parameters during the experiment, which demonstrated rapid mineralization of the crop residues (Table 6).

3.4 Growth performance by earthworms in different vermibeds

The composting earthworm showed a different pattern of biomass increase among the different treatments. Some biological parameters such as mean initial individual weight, maximum individual weight achieved, net individual weight gained and growth rate were found to be significantly different among the treatments (Table 3). The maximum individual live weight by inoculated earthworms was achieved after 90 days in all the treatments (Figure. 4).

P. excavatus showed maximum individual weight gain (559.0±5.56 mg) when feed upon wheat straw, (T6) whereas maximum individual weight gain for *E. foetida* (436.66±4.16 mg) was also obtained when it was also fed upon wheat straw, WS+FYM + Ef (Table 3, Figure. 4a, b). The maximum growth rate for *P. excavatus* (3.71±0.15 mg wt. $worm^{-1}$ day^{-1}) and *E. foetida* (2.83±0.31 mg wt. $worm^{-1}$ day^{-1}) was observed in wheat straw based vermibed. The difference among these treatments for the maximum growth rate could be related to the quality of the feedstuff used in the vermicomposting trials. Suthar (2007a) concluded that the crop residues have different palatability, particle size, protein and crude fiber contents, polyphenols, and related substances that directly or indirectly influence the decomposing potential of earthworms in vermibeds.

Conclusions

Experiments were performed to determine the composting potential of a non-native (*E. foetida*) and a local species (*P. excavatus*) over a period of 90 days under laboratory conditions using paddy straw, wheat straw amended with farm yard manure as bedding material. Results of the study showed more carbon mineralization by *P. excavatus* than *E. foetida*. In terms of nutrient availability of P and K, more potassium was observed in vermicompost prepared by *P. excavatus*, whereas available phosphorous was maximum in vermicompost prepared by *E. foetida*. Surge in hydrolytic enzyme activity as well as microbial activity was observed in the vermicompost produced by *P. excavatus.* In all the vermifeed combinations inoculation of *P. excavatus* showed high mean individual live weight, maximum individual growth rate (mg wt. $worm^{-1}$ day^{-1}). This concludes that *P. excavatus* may be used as a local composting species for faster degradation of crop residue.

Acknowledgements

Authors are thankful to Post Graduate School and Director, Indian Agricultural Research Institute (New Delhi) for providing fellowship to carry out doctoral research of first author.

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