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Vermicomposting of Coffee Processing Wastes

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ABSTRACT

In India, nearly 80% of *arabica* and 20% of *robusta* coffee are prepared by wet method. One tonne of coffee pulp is generated for every tonne of clean coffee (coffee beans) processed. Coffee wastes are lignocellulosic enriched residues that can be used as soil fertilizers; however, the direct application of these residues to coffee plants can cause serious environmental problems. Therefore, it is necessary to find a suitable methodological alternative to reduce the environmental problems associated with their management. Considering the significance of the situation and shortage of organic manure in coffee plantations, a case study was conducted in Coorg District of Karnataka in three coffee growers farms to evaluate the efficiency of an exotic (*Eudrilus eugeniae*) and a native earthworm (*Perionyx ceylanensis*) for bioconversion of coffee pulp into valuable vermicompost. The analysis revealed that exotic earthworms were faster in degrading coffee pulp (112 days) as compared to the native worms (165 days). The vermicomposting efficiency (77.9%) and vermicompost yield (389 kg) were found to significantly higher with native worms, while the multiplication rate of earthworms (280%) and worm yield (3.78 kg) recorded significantly higher with the exotic earthworms. The plant nutrients, nitrogen and phosphorus content found to increase significantly in the vermicompost produced using native earthworms. Vermicompost and vermicasts from native earthworms recorded significantly higher functional microbial group's population as compared to the exotic worms. The study reveals that coffee pulp can be very well used as substrate for vermicomposting using exotic (*Eudrilus eugeniae*) and native earthworm (*Perionyx ceylanensis*).

Keywords: coffee pulp, *Eudrilus eugeniae*, *Perionyx ceylanensis*, microflora, nutrients
Abbreviations: **ANOVA**, analysis of variance; **Cfu**, colony forming units; **FYM**, farm yard manure; **PSM**, phosphorus solubilizing microbes

INTRODUCTION

Among the various commercial plantation crops, coffee forms an important export commodity that fetches considerable foreign exchange to the producing countries. In India, coffee is cultivated mainly in Southern states of Karnataka (58% of area and 72% of production), Kerala (25% of area and 20% of production) and Tamil Nadu (9% of area and 7% of production) (Velmourougane *et al.* 2010). In India, nearly 80% of *arabica* and 20% of *robusta* coffee are prepared by wet (parchment coffee: removal of fruit skin followed by fermentation, washing and drying) and dry method (cherry coffee: fruits are directly sun dried) respectively (Velmourougane *et al*. 2011). Coffee is a perennial crop and is mostly confined to hilly tracts of Western Ghats. In general, coffee requires higher nutrients for its growth and productivity compared to other crops. The availability of organic manures particularly the farm yard manure (FYM) is a major problem in coffee plantations because of non-availability of cattle's, but the FYM can be substituted by application of composts if composting is practiced at on-farm level in coffee farms (Muralidhara *et al.* 2006). In the present low price situation, coffee growers are unable to invest on chemical fertilizers for their plants, though reduction of chemical fertilizers seems to be positive in environmental view but the required quantity of nutrients removed should be replenished with alternative source.

In coffee plantations, coffee pulp and cherry husk are the major solid wastes obtained during coffee processing (**Table 1**). About one ton of husks are generated during dry processing, whereas for wet and semi-wet processing this residue amounts to more than 2 tonnes (Aranda and Barois 2000). Coffee pulp and cherry husk are lignocellulose-enriched residues that can be used as soil fertilizers, providing a high content of macro- and micronutrients for crop growth and represent a low-cost alternative to mineral fertilizers, but coffee pulp also contains little amount of caffeine, tannins and polyphenols making them toxic and anti-nutritional resulting in the disposal problem, the direct and inappropriately-timed application of these residues to agricultural fields can cause serious environmental problems, including the release of excessive amounts of tannins and phenols in soils, which could inhibit root growth in coffee (Nagaraja *et al.* 2000). Due to the presence of anti-physiological and anti-nutritional factors, coffee pulp and husk is not considered as an adequate substrate for the bioconversion process. Several authors have worked on detoxification of coffee pulp and husk through various means viz., physical, chemical and microbiological (Muralidhara *et al.*

Table 1 Coffee processing wastes and its composition.

Processing methods	Weight (kg)
Wet processing (for 100 kg of coffee cherries)	
Beans with mucilage	60-62
Pulp/fruit skin	38-42
Wet parchment	43-46
Mucilage	17-20
Dry processing (for 100 kg of dry cherries)	
Cherry husk	46-48
Constituents (coffee pulp)	% by weight
Moisture content	12.7
Ash	8.30
Crude protein	9.30
Ether extracts	11.7
Soluble carbohydrates	56.0

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2006). The vermicomposting process is one of the best-known processes for the biological stabilization of solid organic wastes by transforming them into a safer and more stabilized material that can be used as a source of nutrients and soil conditioner in agricultural applications (Lavelle *et al*. 2006).

Earthworms are a major soil fauna, constituting 80% of the soil invertebrate population in many ecosystems. There are about 3920 named species of earthworm so far reported worldwide. In India, so far, 509 species, referable to 67 genera and 10 families, have been reported (Kale *et al*. 1992). Vermicomposting is an accelerated process of bio-oxidation and stabilization of the organic matter that involves complex interactions between earthworms and micro-organisms (Senapati 1999). Microorganisms are responsible for the biochemical decomposition of organic matter, but earthworms are crucial drivers of the process as they aerate, condition and fragment the substrate, thereby drastically altering the microbial activity (Lavelle *et al*. 2006). Efforts to recycle coffee pulp include activities such as composting (Orozco 1996), feeding animals, the production of organic fertilizers, single-cell protein and biogas (Adams and Dougan 1981; Rolz *et al*. 1982). Application of vermicompost prepared using many organic wastes, has been shown to enhance microbial and enzymatic activities in soils (Lavelle and Martin 1992). But the use of coffee pulp as substrate for vermicomposting has not been well studied in India due less attention given for soil waste management in coffee plantations. But, recent stringent measures taken by Pollution Control authorities, made it obligatory to treat all the solid and liquid waste emanating from the coffee farms. Hence, vermicomposting surely will come in way for management of coffee pulp in coffee farms for better pollution control and enhancing soil fertility.

In India, there are no studies related to vermicomposting of coffee pulp using earthworms and information of nutrient and microbial dynamics during coffee waste vermicomposting is also lacking. Considering the urgency of the situation and scarcity of organic manure in coffee plantations, a case study was taken up in the farmers field on bioconversion of coffee waste to vermicompost using exotic (*Eudrilus eugeniae*) and native earthworm species (*Perionyx ceylanensis*). Under the study, we also evaluated the chemical and microbiological changes occurring during vermicomposting of coffee pulp.

MATERIALS AND METHODS

Coffee pulp

The coffee pulp for experimentation were obtained from the pulper house of Coffee Research Sub Station, Chettalli, Kodagu, Karnataka (Farm-1) and another two coffee plantations in Kodagu (Farm-2 and Farm-3).

Collection of earthworms

The exotic African earthworms (*Eudrilus eugeniae*) were obtained from University of Madras, Tamil Nadu, India, and the native earthworms (*Perionyx ceylanensis*) were isolated from the coffee waste compost pit near pulper house of Coffee Research Sub Station, Chettalli, Kodagu, Karnataka.

Experimental setup/vermicomposting

Experiments were performed in brick tanks measuring 1 m × 1 m × 0.75 m (length × breadth × depth) with a capacity to hold 500 kg of waste, with a hole at the bottom and overhead shade (**Figs. 1, 2**). Partially dried coffee pulp (10-day-old) was used as raw material along with cow dung slurry and FYM as starter. Initially the tanks were smeared with cow dung slurry and filled with a layer of dried coffee husk (15 cm) over which cow dung slurry was sprinkled and weed biomass (10 cm) was spread. Partially composted coffee pulp was used as next two layers and sprinkled with cow dung slurry. Third and fourth layer is of partially composted coffee pulp mixed with partially composted weeds. 75% composted coffee pulp with dry FYM was used as fifth layer. Exotic (*Eudrilus eugeniae*) and native (*Perionyx ceylanensis*) earthworms were inoculated separately on the top of the heap at one kg worms per tank. The tanks were covered with gunny bags and the moisture was maintained by periodical sprinkling of water. For subsequent vermicomposting of the pre-decomposed waste, the earthworms *E. eugeniae* and native earthworms were cultured in cow dung employing the windrow method. There were 3 tanks (3 replicates) each for native and exotic earthworms; a treatment without earthworm inoculation was also included as control. Sampling has been done at initial and at the end of vermicomposting process. The completion of vermicomposting process was judged by visual observation and physical measurement (Sieving) under farmers field. The composting efficiency was calculated based the quantum of un-degraded material left in the tank by sieving method.

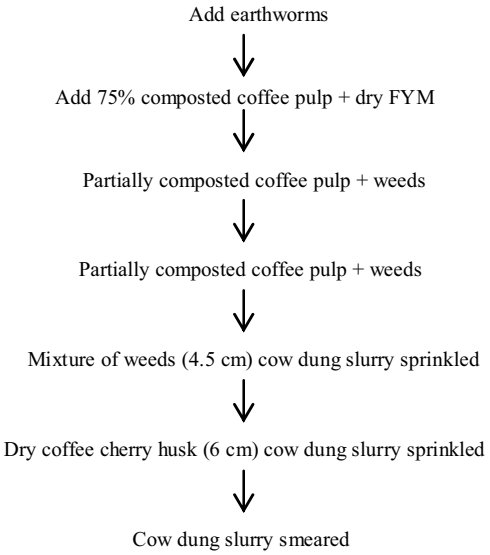

Fig. 1 Vermicomposting bed preparation. Brick tank size = 1 m × 1 m × 0.75 m (l × b × h). Capacity = 500 Kg.

Chemical analysis

Vermicompost samples for chemical analysis were drawn at the end of vermicomposting process. The earthworms were removed manually at the end of the experiment and the worm yield and compost yield per tank were quantified separately. Determination of pH was done by a digital pH meter (ELICO- L11 62, Elico Pvt. Ltd, New Delhi, India). Total organic carbon and total Kjeldhal nitrogen were estimated by Walkley and Black rapid titration method (Walkley and Black 1934) and microKjeldhal method, respectively (Singh and Pradhan 1981). Available phosphorus and total potassium were estimated by Bray and Krutz method (1945) and by Flame emission technique (AOAC 1990), respectively. Exchangeable calcium and magnesium were estimated by method as outlined by Jackson (1973). All the determinations were carried out in triplicate.

Microbiological analysis

Samples of 10 g (fresh weight) of vermicompost and vermicasts at the end of vermicomposting process from tanks inoculated with exotic and native worms were serially diluted in 90 ml Ringers solution (Hi Media) up to 10^{-4} dilution and 1 ml of aliquot was poured plated in selective media (Nutrient agar (Hi Media) for bacteria (Allen 1959), Martin's rose Bengal agar (Hi Media for fungi (Martin 1950), Kenknights and Munaier's agar (Hi Media) (Allen 1959) for actinomycetes and buffered yeast agar (Hi Media) for yeast and the plates were incubated at 25 ± 1°C in triplicates. The functional groups from the soil samples were enumerated using Pikovskaya agar (Pikovskaya 1948) for phosphorus solubilizing microbes (PSM), Waksmann No. 77 media (Hi Media) for *Azotobacter*, Beckings media for *Beijerinckia* (Becking 1959) and Kings-B for fluorescent pseudomonads (King *et al*. 1954). The other physiological groups viz., cellulolytic, pectinolytic, starch

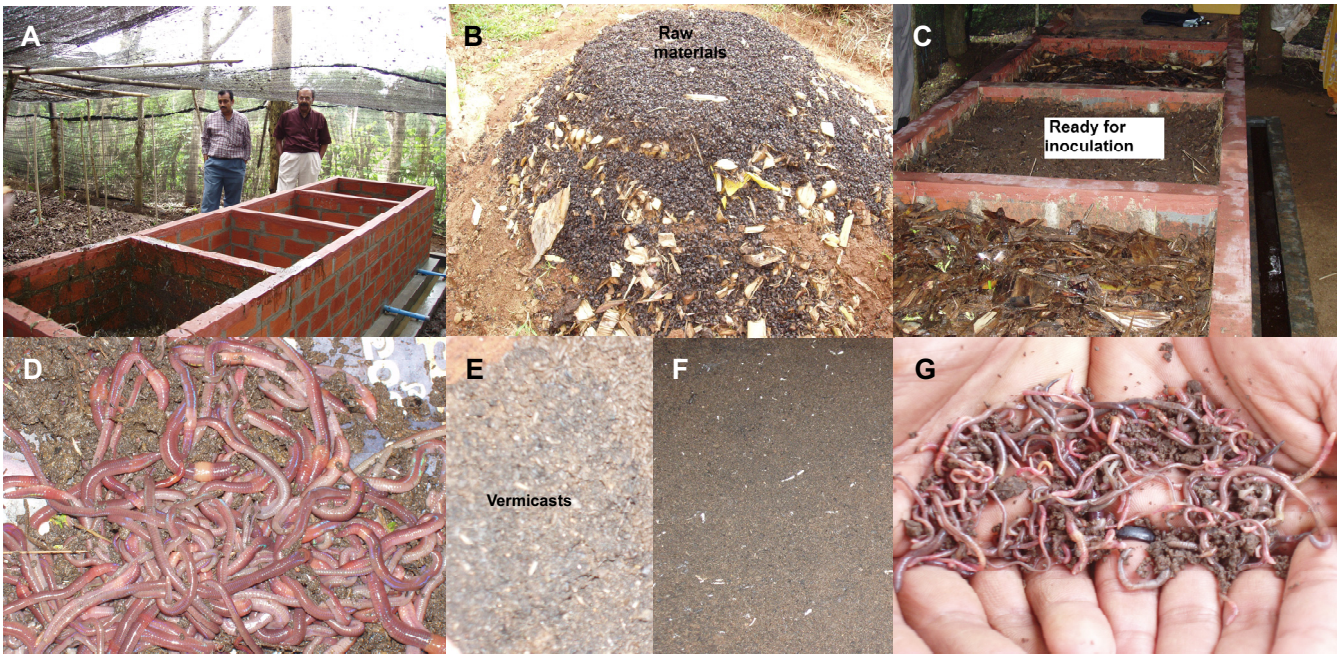

Fig. 2 Vermicompost preparation from coffee pulp. (**A**) Vermicomposting pit – farmer's field. (**B**) Coffee pulp. (**C**) Vermicomposting pit with raw material. (**D**) Earthworms for inoculation. (**E**) Vermicasts from vermicompost. (**F**) Vermicompost from coffee pulp. (**G**) Harvested earthworms from compost.

hydrolytic, proteolytic and chitinolytic microbes were enumerated by following standard microbiological methods (Wollum 1982).

The microbial colonies appearing after the stipulated time period of incubation were counted as colony-forming units (cfu)/g fresh weight of the sample. The colony characteristics were observed and representative single colonies were isolated and subcultured on respective media.

Statistical analysis

The results of the analysis were subjected to analyses of variance (ANOVA) at $P < 0.01$. All statistical analyses were carried out using the SAS program, Version 8.02 (SAS System 1999).

RESULTS AND DISCUSSION

Chemical and nutrient status of vermicompost

The chemical and microbiological characteristics of coffee pulp used in the experimentation are presented in the **Table 2** and the data on nutrient status of coffee pulp vermicompost prepared using exotic and native earthworms are summarized in **Table 3**. In general, the pH of the vermicomposting material found to fall from its initial value in both the trials with exotic and native worms. The vermicompost which was prepared using native and exotic earthworm recorded a mean pH value of 7.33 and 7.21, respectively as compared to control treatment (7.18). The lower pH recorded in the final vermicompost might have been due to the production of CO_2 and organic acids by microbial metabolism during decomposition of different substrates in the feed mixtures (Albanell *et al*. 1988; Elvira *et al*. 1998). Similar results on vermicomposting of cattle manure, fruit and vegetable wastes have been reported by Mitchell (1997) and Gunadi and Edwards (2003). The pH-shift towards acidic conditions is believed to occur because of the resulting higher mineralization of the nitrogen and phosphorus into nitrites/nitrates and the orthophosphates, respectively. This pH shift could also be attributed to the bioconversion of the organic material into other various intermediate species of organic acids (Ndegwa *et al*. 2000).

Organic carbon found to reduce significantly from the initial value and the decline was more pronounced with the native earthworm as compared to exotic. The C:N ratio of the coffee pulp after vermicomposting found to reduce significantly with both the worms to the extent of 75% as compared to control (10.2: 1) (**Table 4**). Various studies have shown that earthworms utilize microorganisms in their substrates as a food source and can digest them selectively (Edwards 1988; Edwards and Bohlen 1996). The increase in earthworms growth may also be attributed to a low C: N ratio (Ndegwa and Thompson 2000). The lower C/N ratio is due to the reduction of organic carbon due to the respiratory activity of earthworms and microorganisms, and mineralization of organic materials (Karmegam and Daniel 2009a; Sangwan *et al*. 2010). Loss of organic carbon (20–43%) as CO_2 was also observed during vermicomposting of paper mill and dairy sludges (Elvira *et al*. 1998).

The major nutrients, nitrogen (80.6%), phosphorus (292%) and potassium (550%) content found to increase significantly in the vermicompost produced using native earthworms as compared to the initial values, while the calcium (85.7%) and magnesium (210%) content found to increase significantly in vermicompost prepared using exotic earthworm. Kaushik and Garg (2004) observed increase in total nitrogen by vermicomposting of textile mill sludge along with cow dung and agricultural residues. Prakash and Karmegam (2010) recorded an increase of NPK in vermicompost over worm-free compost to the tune of 36.94%, 28.56%, and 20.82%, respectively using *Perionyx ceylanensis* Mich. Decrease in pH (10-7.59) may be an important

Table 2 Chemical and microbiological characteristics of coffee pulp.

Chemical parameters	
pH	7.6
Organic carbon %	53.5
C:N ratio	35.5:1
Nitrogen %	1.03
Phosphorus %	0.13
Potassium %	0.12
Calcium %	0.28
Magnesium %	0.10
Microbiological parameters (cfu[a] × 10^4/g)	
Bacteria	42.0
Fungi	14.0
Yeast	37.5
Actinomycetes	12.0

[a] cfu, colony-forming units

Table 3 Nutrient status of coffee pulp vermicompost prepared using exotic and native earthworms.[a]

	pH [b]	Organic carbon	C:N Ratio	N	P_2O_5	K_2O	Ca	Mg
Exotic earthworms								
Farm-1	7.23	20.40	9.35	2.35	0.27	0.64	0.53	0.34
Farm-2	7.37	10.47	8.41	1.18	0.47	0.69	0.50	0.30
Farm-3	7.03	13.15	8.42	1.43	0.50	0.78	0.53	0.29
Mean	7.21	14.67	8.73	1.66	0.41	0.70	0.52	0.31
Native earthworms								
Farm-1	7.37	24.96	8.66	2.99	0.65	0.67	0.49	0.23
Farm-2	7.20	10.85	8.41	1.25	0.31	0.89	0.50	0.30
Farm-3	7.43	14.54	9.04	1.33	0.56	0.77	0.53	0.34
Mean	7.33	16.78	8.71	1.86	0.51	0.78	0.51	0.29
Control	7.18	11.24	10.2	1.26	0.32	0.64	0.42	0.25
***P* > 0.01**	0.461* [c]	0.941*	0.979*	0.993*	0.794*	0.585*	0.997*	0.954*

[a] All the values are average of three replicates
[b] All the values are given in percentage except pH and C:N ratio
[c] * Significant at 1%

Table 4 Vermicomposting on nutrient status and microbiological properties of coffee pulp.[a]

	Chemical parameters								Microbes (cfu × 10^4/g)			
	pH [b]	OC	C:N ratio	N	P_2O_5	K_2O	Ca	Mg	Bacteria	Fungi	Yeast	Actino-mycetes
Coffee pulp (before composting)	7.60	53.5	35.5:1	1.03	0.13	0.12	0.28	0.10	42.0	14.0	37.5	12.0
After composting (exotic worms)	7.21	14.67	8.73:1	1.66	0.41	0.70	0.52	0.31	75.4	21.1	56.2	25.1
After composting (native worms)	7.33	16.78	8.71:1	1.86	0.51	0.78	0.51	0.29	76.4	17.4	64.3	27.0
Control	7.18	11.24	10.2:1	1.26	0.32	0.64	0.42	0.25	51.0	15.2	42.0	16.2
P > 0.01	0.894* [c]	0.999*	0.993*	0.984*	0.986*	0.980*	0.981*	0.305*	0.919*	0.636*	0.916*	0.692*

[a] All the values are average of three replicates
[b] All the values are given in percentage except pH and C:N ratio
[c] * Significant at 1%

Table 5 Vermicomposting efficiency and yield.[a]

	Days for composting	Compost yield (Kg)	Composting efficiency (%)	Earthworm yield (Kg)	Worm multiplication (%)
Exotic earthworms					
Farm-1	114.00	356.67	71.24	3.74	274.0
Farm-2	110.67	362.33	72.09	3.47	247.6
Farm-3	111.67	349.33	69.62	4.12	317.0
Native earthworms					
Farm-1	157.00	401.67	80.61	2.46	150.6
Farm-2	165.33	393.33	78.72	2.11	116.3
Farm-3	173.33	371.67	74.64	2.31	135.3
Control	205.00	270.33	54.06	-	-
***P* > 0.01**	0.998* [b]	0.994*	0.980*	0.958*	0.999*

[a] All the values are average of three replicates
[b] * Significant at 1%

factor in nitrogen retention as this element is lost as volatile ammonia at higher pH (Hartenstein and Hartenstein 1981). Increase in nitrogen content in the final product in the form of mucus, nitrogenous excretory substances, growth stimulating hormones and enzymes from earthworms have also been reported (Tripathi and Bhardwaj 2004). According to Viel *et al*. (1987) loss in organic carbon might be responsible for nitrogen enhancement. Earthworms are also reported to have a greater impact on nitrogen transformations in manure, by enhancing nitrogen mineralization, so that mineral nitrogen may be retained in the nitrate form (Atiyeh *et al*. 2000). However, in general the final nitrogen content of compost is dependent on the initial nitrogen present in the waste and the extent of decomposition (Gaur and Singh 1995). Mansell *et al.* (1981) observed that plant litter was found to contain more available phosphorus after ingestion by earthworms, which may be due to the physical breakdown of the plant material by worms. Satchell and Martin (1984) also found a 25% increase in phosphorus in paper waste sludge, after earthworm activity. They attributed this increase in phosphorus to direct action of worm gut enzymes and indirectly by stimulation of the microflora. The vermicompost has more available nutrients per kg weight than the organic substrate from which it is produced (Buchanan *et al*. 1988). The biological activity of earthworms provides nutrient-rich vermicompost for plant growth thus facilitating the transfer of nutrients to plants (Ismail 2000).

Vermicomposting efficiency and yield

Data pertaining to vermicomposting efficiency and vermicompost yield are presented in **Table 5**. There found to be significant differences between vermicomposting efficiency of exotic and native earthworms on coffee pulp as compared to control treatment without earthworms. Exotic earthworms found to degrade the coffee pulp faster (112 days) as compared to the native worms (165 days). The control treatment without earthworm inoculation took 205 days for complete degradation of coffee pulp. Native worms took 53 days more to that of exotic earthworms to complete the vermicomposting process. However the vermicompost yield was found to be significantly higher in case of native earthworms. The multiplication rate and earthworm yield recorded significantly higher with the exotic earthworms and it was almost double the population as compared to native earthworms. Uses of vermicomposting technology in coffee waste management have been reported by many workers in coffee producing countries (Aranda and Barois 2000). Suthar (2007) have reported production of vermifertilizer from guar gum industrial wastes by using composting earthworm *Perionyx sansibaricus* (Perrier), while Benitez *et al*. (2002) reported production of vermicompost from olive oil industry waste. Karmegam and Daniel (2009a, 2009b) reported that *Perionyx ceylanensis* is more suitable species for vermicomposting since it is a native species with vermi-

composting potential and short life cycle.

Microbiological attributes

Data on general and functional microflora of coffee pulp vermicompost prepared using exotic and native earthworms are presented in **Table 6**. In general microflora, except fungi, found to be significantly higher in vermicompost prepared using native earthworms as compared to exotic species. Similar is the case with functional microbial groups, vermicompost prepared using native earthworms recorded significantly higher microbial counts as compared to the exotic earthworms. Kristufek *et al*. (1992) have reported that the number of bacteria, microfungi, and micromycetes increased in the guts of *Lumbricus rubellus* while Edwards and Burrows (1998) have reported that vermicompost was richer in fungi, bacteria, and actinomycetes compared to the soil. This could be attributed to the fact, as reported by Pedersen and Hendriksen (1993) that in the guts, there could have been an increase in the number of vegetative cells as well as germination of the spores of this bacterial community due to an increase in nutrient availability by the release of nutrients from ingested material. Prakash and Karmegam (2010) observed an increase in the population of bacteria, actinomycetes and fungi in the vermicompost prepared using *Perionyx ceylanensis* Mich.

Microbiological properties of vermicasts from exotic and native earthworms are summarized in **Table 7**. Bacteria,

Table 6 Microbiology of vermicompost prepared from coffee pulp.[a]

	General microflora (cfu[b] × 10^4/g)							
	Bacteria		**Fungi**		**Yeast**		**Actinomycetes**	
Exotic worms								
Farm-1	83.0		23.7		61.3		26.0	
Farm-2	75.3		24.0		53.0		25.7	
Farm-3	68.0		15.7		54.3		23.7	
Native worms								
Farm-1	67.0		18.3		62.0		23.7	
Farm-2	80.7		17.0		69.3		27.0	
Farm-3	81.7		17.0		61.7		30.3	
Control	51.0		15.2		42.0		16.2	
***P* > 0.01**	0.425* [b]		0.452*		0.144*		0.924*	
	Functional/physiological groups (cfu × 10^3/g)							
	N_2 fixers	**P-Solubilisers**	**Fluorescent pseudomonads**	**Cellulolytic**	**Pectinolytic**	**Starch hydrolytic**	**Proteolytic**	**Chitinolytic**
Exotic worms								
Farm-1	11.7	7.3	12.0	7.0	15.7	8.0	3.0	1.7
Farm-2	8.3	5.0	12.7	8.3	19.7	10.7	5.0	1.7
Farm-3	6.0	5.3	14.3	9.7	19.0	11.3	5.3	2.3
Native worms								
Farm-1	8.7	4.7	14.3	9.7	21.3	15.7	8.0	2.7
Farm-2	12.0	7.0	19.0	10.7	20.3	12.0	6.7	2.7
Farm-3	10.7	7.3	21.3	9.3	19.7	8.7	9.0	4.0
Control	3.9	3.0	9.40	5.4	14.0	5.5	2.8	1.6
***P* > 0.01**	0.178*	0.523*	0.865*	0.05*	0.09*	0.698*	0.977*	0.232*

[a] All the values are average of three replicates
[b] * Significant at 1%
[c] cfu, colony forming units

Table 7 General and functional microflora of coffee pulp vermicasts.[a]

	General microflora (cfu[b] × 10^4/g)							
	Bacteria		**Fungi**		**Yeast**		**Actinomycetes**	
Exotic worms								
Farm-1	165.3		31.3		127.7		38.0	
Farm-2	148.3		34.0		123.3		42.0	
Farm-3	134.7		39.7		118.0		33.0	
Native worms								
Farm-1	185.7		25.7		132.3		23.7	
Farm-2	181.7		31.3		152.7		43.3	
Farm-3	164.0		48.7		132.3		37.0	
Control	120.6		16.3		98.60		16.4	
***P* > 0.01**	0.795* [c]		0.963*		0.997*		0.676*	
	Functional/physiological groups (cfu × 10^3/g)							
	N_2 fixers	**P-Solubilisers**	**Fluorescent pseudomonads**	**Cellulolytic**	**Pectinolytic**	**Starch hydrolytic**	**Proteolytic**	**Chitinolytic**
Exotic worms								
Farm-1	14.7	11.0	22.7	16.0	38.3	18.0	7.3	4.7
Farm-2	13.7	12.0	17.3	12.7	34.0	27.3	9.7	6.3
Farm-3	8.30	12.0	20.0	13.7	32.3	17.7	7.0	4.7
Native worms								
Farm-1	14.3	8.0	28.3	12.0	43.3	25.3	5.0	5.3
Farm-2	16.0	16.0	28.3	18.7	36.0	34.3	7.3	4.7
Farm-3	20.0	15.0	34.7	18.3	32.7	33.3	12.3	4.0
Control	5.80	5.50	14.4	8.0	21.2	12.5	3.6	2.4
***P* > 0.01**	0.739*	0.619*	0.215*	0.219*	0.215*	0.989*	0.835*	0.382*

[a] All the values are average of three replicates
[b] cfu, colony forming units
[c] * Significant at 1%

fungi and yeast population found to significantly higher in the vermicasts from the native earthworms as compared to exotic earthworms, while the actinomycetes population found to significantly higher with the vermicasts of exotic earthworms. Vermicasts are reported as rich sources of macro and micronutrients, vitamins, enzymes, antibiotics, growth hormones and immobilized microflora (Kale *et al*. 1987). The nutrients present in vermicasts are readily absorbed by the plants as it is highly soluble in water (Bhawalkar and Bhawalkar 1993). Syers and Springett (1984) reported an increase in the number of bacteria and actinomycetes with enhanced phosphatase activity in earthworm casts. Earthworm gut is having many beneficial microbes including polymer degraders, phosphorus solubilizers, and nitrogen fixers. In functional microbial groups, except chitinolytic microbes all other microbes found to significantly higher with the vermicasts of native worm. Gopal *et al*. (2009) has reported similar results on the occurrence of beneficial microflora in vermicompost prepared from coconut leaves. Vermicompost not only increase the soil fertility through the addition of plant growth hormones and increased levels of soil enzymes (Chaoui *et al*. 2003); they are also reported to be responsible for the dissemination of beneficial microorganisms as they are rich in microbial diversity, population, and activity (Kale *et al*. 1992).

CONCLUSION

The present study clearly demonstrated that coffee pulp can be very well used as a substrate for vermicomposting using native and exotic earthworm species. The data from this study provides a sound foundation that vermicomposting is a suitable technology for onfarm bioconversion of coffee pulp into value-added vermicompost and reduction of solid waste pollution in coffee growing regions of India. Analysis of chemical and microbiological properties of vermicompost obtained from coffee pulp clearly indicates the enhancement in nutrient value and microbiological quality of vermicompost and its utility as a good source for plant nutrients and soil health enhancement in coffee plantations.

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