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Vermicomposting of Banana Pseudostem and Maize Fodder (Waste) Using *Eudrilus eugeniae*

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Authors' contributions

This work was carried out in collaboration among all authors. Authors HCP and VBM designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed the analyses of the study. Author SRP managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The experiment was conducted at the Agriculture Research Station, College of Agriculture, Anand Agricultural University, Jabugam during three consecutive seasons of the years 2015-16 and 2016-17. This was to evaluate banana Pseudostem and maize fodder waste with and without cow dung and Anubhav biodegradable bacterial consortium (ABBC) for it bi-product in terms of vermi-composting, time required for degradation and the nutritive quality of vermicompost. The experiment consisted of eight treatments and conducted in RBD with three replications. Results shows that, the treatment Banana pseudostem + 5% Cow dung + Anubhav biodegradable bacterial consortium and the treatment Maize fodder waste + 5% Cow dung + Anubhav biodegradable bacterial consortium were significantly higher for N, P, K content during all the three seasons and in pooled analysis with less number of days to harvest and high recovery. While, microbial count were recorded maximum in banana Pseudostem based vermicompost than maize fodder waste. Overall, vermicompost produced from the banana Pseudostem and maize fodder waste by using ABBC @ 1 lit/t and 5 % cow dung provided the major nutrients in more

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balanced proportion. The main perspectives of this study is to decrease the environmental pollution by making vermicompost from banana pseudostem waste or maize fodder (waste) instead of dumping on road side or burning or left in the field and also reduce the use of chemicals by using vermicompost.

Keywords: Banana pseudostem; maize fodder (waste); vermicompost; Anubhav Biodegradable Bacterial Consortium (ABBC); cow dung.

1. INTRODUCTION

Agricultural by-products, e.g. animal dung, farm yard manure and crop residues are potential sources of plant nutrients. According to a conservation estimation, around 600-700 million tonnes (mt) of agricultural waste are available in India every year, but most of it remains unutilized [1]. Banana is an important food crop of the world. India is one of the leading producers of banana, which are mostly grown in Tamil Nadu, Maharashtra, Gujarat, Karnataka etc. states. After the harvest of the fruits the whole plant (leaves, stem and rhizome) is left in the agricultural field for natural degradation, which takes several months. Earthworms have been used in the vermi-conversion of urban, industrial and agro-industrial wastes to produced bio fertilizers [2]. It is well established that a large number of organic wastes can be ingested by earthworms and egested as peat like materials termed vermicompost [3]. According to Dominquez [4], during vermicomposting earthworms act as mechanical blenders, and by converting the organic matter, they modify its biological, physical and chemical status, gradually reducing its C:N ratio, increasing the surface are exposed to microorganisms, and making it much more favourable for microbial activity and further decomposition. Several epigeics (*Eisenia fetida, Eudrilus eugeniae, Perionyx excavatus*) have been identified as potential candidates to decompose organic waste materials [5,6]. Biological waste treatment technologies such as composting and vermicomposting are widely regarded as a clean and sustainable method to manage organic waste [7]. Traditionally vermicompost has been generated with animal manure as the substrate and has been recognized as a good soil conditioner and fertilizer [8]. Vermicomposting is believed to offer a route by which organic waste can be stabilized to a significant extent, converting it into a finished fertilizer [9]. In recent years, other organic substrates like, pulses straw, tree leaves have also been vermicomposted and the products have been found to be as good as the manure based vermicompost [10]. Therefore, the objective of this study was to test the efficiency of composting of banana waste spiked with organic supplement, i.e., cow dung using an epigeic earthworm *Eudrilus eugeniae*.

In spite of these various use of banana plant, it is seen that huge portion of banana plants are just dumped as waste causing environment hazards and making ecosystem imbalance, currently millions of tones of banana pseudostem are dumped in Asia as waste and most of the farmers are facing huge troubles in disposing the accumulated banana pseudostem [11]. Same in case of maize fodder, in village people fed whole fodder of maize to the animals, so animal fed smooth part of fodder and excluding the hard part of stem, which is generally difficult to handle. So, the farmers dumped the biomass on road sides or burnt or left in to situ causing detrimental impact on environment. The management of solid waste presents a challenge for developing countries as the generation of waste is increasing at a rapid and alarming rate [12].

2. METHOD USED FOR PREPARATION OF VERMICOMPOST FROM BANANA PSEUDOSTEM OR WASTE MAIZE FODDER FOR 100 KG WEIGHT (SELF DESCRIBED)

Make small pieces (5-10 cm) of banana pseudostem or maize fodder (waste) and dry it under sunlight. Put the dried pieces of banana pseudostem or maize fodder (waste) in plastic bed (size 3.0 m x 1.0 m x 0.6 m LWH). Sprinkle water on banana pseudostem or maize fodder (waste) to get it wetted. After one week, mix the Anubhav Biodegradable Bacterial Consortium (ABBC) 100 ml/ 10 L water & spread on materials kept in the bed. Similarly, spread the slurry prepared by mixing 5 kg cow dung in 10 L of water. After that, release 500 g earthworms (*Eudrilus eugeniae)* in 100 kg pieces of banana pseudostem or maize fodder (waste) in plastic bed. Cover the bed with old gunny bags till the compost is ready by sprinkling the water.

Sprinkling of water is discontinued when compost is ready. Vermicompost is collected after 8-10 days; thereafter sieve the material for use. The vermicompost will be ready within 70 to 75 days.

If, the vermicompost unit is established in the open area then provide a shed/roof over the unit, so that shady conditions could be maintained for the unit and earthworms may be avoided from the direct contact of sun rays and rains.

Plastic beds (size 3.0 m x 1.0 m x 0.6 m LWH) are movable, re usable, easy to handle which avoid leaching and give complete aeration. Beds are prepared locally by demand.

Advantage of this product is to reduce the environment pollution, reuse of the waste, reduction in chemical fertilizer use and increase the soil fertility by using vermicompost. Vermicompost is a good quality manure that contain several essential nutrients needed by the crops such as nitrogen, phosphorus, potassium, calcium, magnesium and micronutrients viz. iron, zinc, copper, manganese in sufficient quantity that increase the productivity and quality of crops [13].

So, there is need to develop waste management system in banana and maize waste which will enhance the fertility as well as reducing the inputs with environment sustainability. Main focus of this study is to recover nutrients from organic waste and returning them to the environment. Keeping this aim in mind an oriented research has been carried out.

3. MATERIALS AND METHODS

An investigation was carried out at Agricultural Research Station, Anand Agricultural University, Jabugam, during three seasons of the years 2015-16 and 2016-17. An experiment was conducted in Randomized Block Design with three replications which included eight treatment combinations with banana pseudostem and maize fodder (waste) comprising of T_1. Banana pseudostem, T_2 : Banana pseudostem + Anubhav Biodegradable Bacterial Consortium (ABBC), T_3 : Banana pseudostem +5% Cow Dung, T_4 : Banana pseudostem + 5% Cow Dung + Anubhav Biodegradable Bacterial Consortium (ABBC), T_5: Maize Fodder (waste), T_6: Maize Fodder (waste) + ABBC, T_7: Maize Fodder (waste) + 5% Cow Dung and T_8 : Maize Fodder (waste) + 5% Cow Dung + ABBC). The small shredded pieces of banana Pseudostem and maize fodder waste were used for the bed filling. Bed filling, application of worms, application of the ABBC and harvesting of the vermicompost during three seasons are as under:

Practices	Season 1	Season 2	Season 3
Bed Filling	21-10-2015	14-06-2016	19-11-2016
Application of worms	28-10-2015	20-06-2016	27-12-2016
Application of ABBC	28-10-2015	20-06-2016	27-12-2016
Harvesting	19-01-2016	13-09-2016	17-02-2017

Worms used for vermicomposting was epigeic earthworm *Eudrilus eugeniae.* Cow dung slurry was used for bed filling. The cow dung should be at least 10-15 days old because fresh cow dung produce lot of heat and it can kill the earthworms. Similarly, cow dung should not be too old as it got decomposed and earthworms will not get any food from it. Anubhav Biodegradable Bacterial Consortium (ABBC) is a bacterium which was used for early decomposition of the materials and it was isolated by Dept. of Agril. Microbiology, B. A. College of Agriculture, Anand Agricultural University, Anand [14]. A serial dilution method described by [15] was followed for microbial count and it is represented in CFU (Colony Forming Unit)/g. The chemical parameter of vermicompost such as moisture content was measured gravimetrically. The pH of samples was recorded by a digital pH meter. The OC and OM of the samples was measured by Walkey-Black method [16]; the N was estimated by the Kjeldahl method, and the P and K contents of the samples were analyzed by calorimetric method and flame photometric method, respectively [17]. Statistical analysis was done by Duncan's New Multiple Range Test results method. Recovery % calculated by using the final weight of the product to the initial weight added to the bed.

$$\text{Recovery \%} = \frac{\text{Final weight of vermicompost}}{\text{Initial weight of added material}} \times 100$$

4. RESULTS AND DISCUSSION

The nutrient values of vermicompost as influenced by different treatments obtained in present study are shown in Table 1. From this table, it is evident that the treatment T_4 (Banana Pseudostem + 5% Cow dung + ABBC) (1.246 %) being at par with T_8 (Maize fodder (waste) + 5% Cow dung + ABBC) (1.217 %) and showed significantly higher N content as compared to remaining treatments during all the three seasons and in pooled analysis. The lowest N content in vermicompost was recorded under T_5 (Maize fodder (waste). The increase of N in vermicompost was probably due to the mineralization of the organic matter containing proteins [18,19] and conversion of ammonium-nitrogen into nitrate [20,21]. Earthworms can boost the nitrogen levels of the substrate during digestion in their gut adding their nitrogenous excretory products, mucus, body fluid, enzymes, and even through the decaying dead tissues of worms in vermicomposting subsystem [22].

A significant influence on P content in vermicompost was also observed due to different treatments (Table 1). In pooled analysis, treatments T_4 (Banana Pseudostem + 5% Cow dung + ABBC, 0.426%) and T_8 (Maize fodder (waste) + 5% Cow dung + ABBC, 0.409%) were almost the same and proved better than other treatments in respect to P content in vermicompost. The total P was higher in the vermicompost harvested at the end of the experiment [19,22,23,24]. The enhanced P level in vermicompost suggests phosphorous mineralization during the process. The worms during vermicomposting converted the insoluble P into soluble forms with the help of P-solubilizing microorganisms through phosphatases present in the gut, making it more available to plants [20,25].

The K content (Table 1) in vermicompost was also significantly influenced due to different treatments. Among the different treatments tested, treatment T_4 (Banana Pseudostem + 5% Cow dung + ABBC) proved to be the best by recording the highest value of K content in vermicompost during all the three seasons and in pooled analysis (1.127%). Vermicomposting proved to be an efficient process for recovering higher K from organic waste [20,22,23,24]. The microorganisms present in the worm's gut probably converted insoluble K into the soluble form by producing microbial enzymes [26].

Moisture content (Table 2) at harvest ranged from 40–50%. According to Liang [27], the 50% moisture content was the minimal requirement for rapid rise in microbial activity. Vermicompost samples during the present study showed that treatment T_4 (Banana Pseudostem + 5% Cow dung + ABBC) and T_8 (Maize fodder (waste) + 5% Cow dung + ABBC) were statistically significant and recorded higher moisture content (48.3%) as compared to the rest of the treatments in pooled data, which may be due to their high absorption capacity, and may also be because of assimilation rate by microbial population indicating the higher rate of degradation of waste by earthworms [27].

Table 2 showed the recovery of vermicompost from the different treatments, the maximum 61.8 % vermicompost recovered from treatment T_8 (Banana Pseudostem + 5% Cow dung + ABBC), followed by treatment T_4 (58.8%) (Maize fodder (waste) + 5% Cow dung + ABBC) and the lowest (39.4 % and 41.0 %) recovered from the without FYM and ABBC (Treatments T_1 and T_5). The ABBC treated group had highest microbial count (Table 3) (Treatments T_4 and T_8), hence earthworms gets more food compare to all other treatments therefore this treatment supported the earthworm growth [28]. Cow dung gave extra food for the microbes, hence increase the microbial activity and increasing the composting process. Earthworms feed more on waste and released highest vermicompost. These findings supported by Zaller and Kopke [29] results; they stated that the application of bio-dynamically prepared compost can significantly alter decomposition rates in soils. [30] Madar reported that the organic and biodynamic treatments also showed a greater microbial activity and a greater potential than the conventional treatments (two conventional systems using mineral fertilizer plus farmyard manure and using mineral fertilizer exclusive) to mineralise organic compounds.

The different treatments did not differ significantly in respect of pH of vermicompost in any season or in pooled analysis (Table 2). It was neutral being around 7 and the near-neutral pH of vermicompost may be attributed by the secretion of NH_4^+ ions that reduce the pool of H^+ ions and the activity of calciferous glands in earthworms containing carbonic anhydrase that catalyzes the fixation of CO_2 as $CaCO_3$, thereby preventing the fall in pH [2].

During all the season and in pooled analysis the maximum organic carbon and organic matter content in vermicompost was noted under T_4 (Banana Pseudostem + 5% Cow dung + ABBC) and it was the same with treatment T_8 as compared to rest of the treatments (Table 3). Total organic carbon decreased with the passage of time during vermicomposting. These findings are in consistence with those of earlier authors [31]. The organic carbon is lost as carbon dioxide through microbial respiration and mineralization of organic matter causing increase in total N [2]. Part of the carbon in the decomposing residues

Table 1. N,P and K content (%) in vermi-compost as influenced by different treatments

Treatments	N				P				K			
	S-1	**S-2**	**S-3**	**Pooled**	**S-1**	**S-2**	**S-3**	**Pooled**	**S-1**	**S-2**	**S-3**	**Pooled**
T_1	0.955^{e}	0.963^{c}	0.914^{c}	0.944^{d}	0.275^{cd}	0.231^{d}	0.295^{d}	0.267^{d}	0.883^{e}	0.894^{e}	0.863^{ef}	0.880^{f}
T_2	1.152^{bc}	1.160^{b}	1.127^{b}	1.146^{b}	0.302^{c}	0.312^{c}	0.363^{c}	0.326^{c}	1.002^{c}	1.025^{c}	0.988^{bc}	1.005^{c}
T_3	1.115^{cd}	1.122^{b}	1.089^{b}	1.109^{c}	0.336^{abc}	0.346^{b}	0.397^{b}	0.360^{b}	0.975^{c}	0.997^{c}	0.957^{cd}	0.977^{d}
T_4	1.242^{a}	1.265^{a}	1.231^{a}	1.246^{a}	0.401^{a}	0.407^{a}	0.469^{a}	0.426^{a}	1.130^{a}	1.140^{a}	1.109^{a}	1.127^{a}
T_5	0.853^{f}	0.862^{d}	0.816^{d}	0.844^{e}	0.220^{d}	0.225^{d}	0.289^{d}	0.245^{e}	0.847^{f}	0.860^{f}	0.824^{f}	0.844^{g}
T_6	1.080^{d}	1.123^{b}	1.086^{b}	1.096^{c}	0.299^{c}	0.303^{c}	0.354^{c}	0.319^{c}	0.938^{d}	0.954^{d}	0.899^{de}	0.930^{e}
T_7	1.098^{cd}	1.107^{b}	1.070^{b}	1.091^{c}	0.315^{bc}	0.318^{bc}	0.370^{bc}	0.334^{c}	0.911^{de}	0.928^{d}	0.878^{ef}	0.906^{e}
T_8	1.211^{ab}	1.240^{a}	1.201^{a}	1.217^{a}	0.383^{ab}	0.392^{a}	0.452^{a}	0.409^{a}	1.040^{b}	1.073^{b}	1.039^{b}	1.051^{b}
S.Em.±	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.07	0.01	0.01	0.02	0.08
CD (P=0.05)	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
CV %	2.80	3.13	3.41	3.12	4.16	4.08	2.42	3.55	2.33	1.94	3.86	2.81

Note: Treatment means with the letter/letters in common are not significantly different by Duncan's New Multiple Range Test at 5% level of significance. S-1, S-2 and S-3 indicate the seasons of vermicomposting

Table 2. Moisture (%), Recovery (%) and pH in vermi-compost as influenced by different treatments

Treatments	Moisture %				Recovery (%)				pH			
	S-1	**S-2**	**S-3**	**Pooled**	**S-1**	**S-2**	**S-3**	**Pooled**	**S-1**	**S-2**	**S-3**	**Pooled**
T_1	42.1^{c}	41.7^{c}	42.5^{b}	42.1^{cd}	39.0^{c}	40.3^{d}	38.9^{d}	39.4^{e}	7.3^{a}	7.3^{a}	7.2^{a}	7.3^{a}
T_2	44.3^{bc}	43.9^{abc}	44.9^{b}	44.4^{b}	52.6^{ab}	51.8^{bc}	50.1^{bc}	51.5^{b}	7.2^{a}	7.2^{a}	7.1^{a}	7.1^{b}
T_3	44.7^{abc}	44.2^{abc}	45.2^{ab}	44.6^{b}	44.6^{bc}	45.4^{cd}	44.4^{cd}	44.8^{cd}	7.1^{a}	7.1^{a}	7.1^{a}	7.1^{b}
T_4	48.7^{a}	47.2^{a}	49.0^{a}	48.3^{a}	58.7^{a}	60.5^{ab}	57.3^{ab}	58.8^{a}	7.2^{a}	7.2^{a}	7.1^{a}	7.1^{b}
T_5	41.9^{c}	40.7^{c}	41.9^{b}	41.5^{d}	41.1^{c}	41.5^{d}	40.5^{d}	41.0^{de}	7.2^{a}	7.2^{a}	7.2^{a}	7.2^{ab}
T_6	43.0^{c}	42.5^{c}	43.0^{b}	42.9^{bcd}	53.1^{ab}	53.9^{abc}	52.3^{abc}	53.1^{b}	7.1^{a}	7.1^{a}	7.1^{a}	7.1^{b}
T_7	43.2^{c}	43.0^{bc}	44.1^{b}	43.4^{bc}	46.0^{bc}	47.4^{cd}	44.5^{cd}	46.0^{c}	7.2^{a}	7.2^{a}	7.2^{a}	7.2^{ab}
T_8	48.6^{ab}	47.1^{ab}	49.2^{a}	48.3^{a}	61.9^{a}	62.7^{a}	60.8^{a}	61.8^{a}	7.2^{a}	7.2^{a}	7.2^{a}	7.2^{ab}
S.Em.±	1.26	1.23	1.21	0.623	3.32	2.66	2.57	1.44	0.06	0.06	0.05	0.03
CD (P=0.05)	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	NS	NS	NS	NS
CV %	4.91	4.85	4.65	4.80	11.59	9.14	9.16	10.03	1.56	1.41	1.30	1.43

Note: Treatment means with the letter/letters in common are not significantly different by Duncan's New Multiple Range Test at 5% level of significance. S-1, S-2 and S-3 indicate the seasons of vermicomposting

Table 3. Organic carbon (%), organic matter (%) and microbial count in vermicompost as influenced by different treatments

Treatments	OC (%)				OM (%)				Microbial count			
	S-1	**S-2**	**S-1**	**S-1**	**S-1**	**S-1**	**S-3**	**Pooled**	**S-1**	**S-2**	**S-3**	**Mean**
T_1	10.63^{c}	10.94^{bc}	10.17^{b}	10.58^{d}	18.33^{c}	18.87^{bc}	17.53^{b}	18.24^{d}	$1.7 X 10^{9}$	$2.7 x 10^{9}$	$1.5 x 10^{9}$	$1.97 x 10^{9}$
T_2	11.50^{ab}	11.97^{ab}	11.10^{a}	11.52^{bc}	19.83^{ab}	20.63^{ab}	19.14^{a}	19.87^{bc}	$2.2 X 10^{10}$	$2.4 x 10^{10}$	$1.4 x 10^{10}$	$2.0 x 10^{10}$
T_3	11.53^{ab}	12.00^{ab}	11.19^{a}	11.57^{bc}	19.88^{ab}	20.68^{ab}	19.30^{a}	19.95^{bc}	$2.1 X 10^{10}$	$1.3 x 10^{10}$	$1.5 x 10^{10}$	$1.6 x 10^{10}$
T_4	12.13^{a}	12.44^{a}	11.82^{a}	12.13^{a}	20.91^{a}	21.44^{a}	20.38^{a}	20.91^{a}	$1.4 X 10^{11}$	$1.2 x 10^{11}$	$8.1 x 10^{10}$	$1.4 x 10^{11}$
T_5	09.97^{d}	10.33^{c}	09.24^{c}	09.84^{e}	17.18^{c}	17.80^{c}	15.93^{c}	16.97^{e}	$1.3 X 10^{8}$	$2.1 x 10^{8}$	$1.4 x 10^{9}$	$5.8 x 10^{8}$
T_6	11.36^{b}	11.88^{ab}	11.03^{ab}	11.43^{c}	19.59^{b}	20.49^{ab}	19.02^{ab}	19.70^{c}	$3.9 X 10^{9}$	$4.0 x 10^{9}$	$4.4 x 10^{8}$	$2.8 x 10^{9}$
T_7	11.39^{ab}	11.91^{ab}	10.99^{ab}	11.43^{c}	19.63^{ab}	20.53^{ab}	18.95^{ab}	19.70^{c}	$1.4 X 10^{9}$	$1.0 x 10^{9}$	$1.9 x 10^{9}$	$1.4 x 10^{9}$
T_8	11.94^{ab}	12.30^{a}	11.58^{a}	11.94^{ab}	20.58^{ab}	21.21^{a}	19.96^{a}	20.58^{ab}	$1.1 X 10^{9}$	$1.7 x 10^{9}$	$1.9 x 10^{9}$	$3.6 x 10^{9}$
S.Em.±	0.22	0.33	0.28	0.14	0.38	0.57	0.48	0.25	-	-	-	-
CD (P=0.05)	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	-	-	-	-
CV %	3.37	4.90	4.43	4.30	3.37	4.90	4.43	4.30	-	-	-	-

Note: Treatment means with the letter/letters in common are not significantly different by Duncan's New Multiple Range Test at 5% level of significance. S-1, S-2 and S-3 indicate the seasons of vermicomposting.

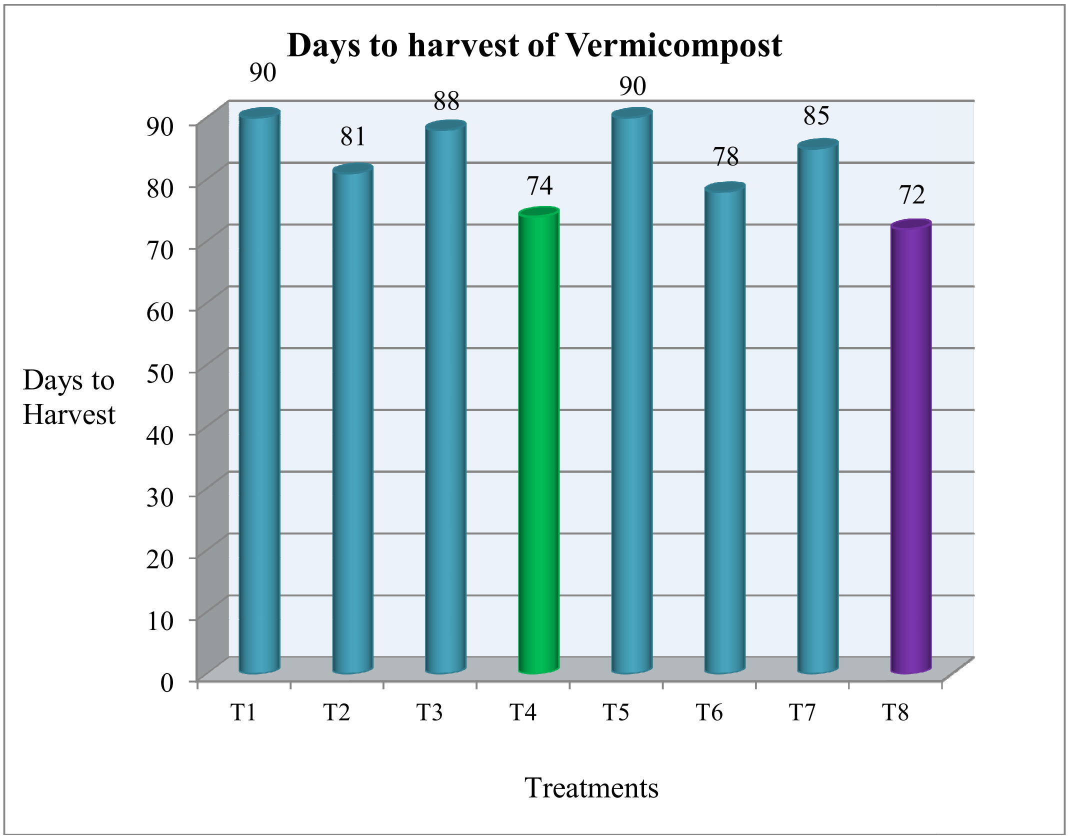

Fig. 1. Days to harvest of vermicompost in different treatments (mean of the three seasons)

released as CO_2 and a part was assimilated by the microbial biomass [2] microorganisms used the carbon as a source of energy decomposing the organic matter. The reduction was higher in vermicomposting compared to the ordinary composting process, which may be due to the fact that earthworms have higher assimilating capacity [2].

Microbial count (Table 3) also observed maximum in ABBC treated treatments. It is due to ABBC create favourable condition for growth of micro organism by rapid degradation of waste, and thus more number of microbial count was observed compared to other treatments [29]. The different treatments showed marked influence on days to harvest (Fig. 1). Among the different treatments studied, T_4 (74 days) and T_8 (72 days) took minimum time for preparation of vermicompost. It was due to the higher microbial activity and rapid decomposition of waste by the added biodegradable bacterial consortium and thus earthworm gets more food than other treatments and ultimately took less number of days to harvest than other treatments [29].

5. CONCLUSIONS

From the above results, it can be concluded that the vermicompost produced from the banana Pseudostem and maize fodder waste by using Anubhav Biodegradable Bacterial Consortium @ 1 lit/t and 5% cow dung provided the major nutrients in more balanced proportion compared to that prepared without Anubhav Biodegradable Bacterial Consortium @ 1 lit/t and 5% cow dung. Cow dung gave extra food for the microbes; hence increase the microbial activity and increasing the composting process resulting good quality. The higher microbial population, moisture and recovery of vermicompost were also observed under the treatments received both 5% cow dung and ABBC as compared to treatment receiving individual or no application of Anubhav Biodegradable Bacterial Consortium or cow dung and control. The lowest time for preparation of vermicompost was also noted under treatment received both Anubhav Biodegradable Bacterial Consortium @ 1 lit/t and 5% cow dung. Between the two sources of farm waste, there was no marked difference in respect of quality in terms of nutrient content or quantity in terms of recovery or time required for preparation of vermicompost. The main perspectives of this study is to decrease the environmental pollution by making vermicompost from banana pseudostem waste or maize fodder (waste) instead of dumping on road side or burning or left in the field and also reduce the use of chemicals by using vermicompost.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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