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Quality of vermicompost as influenced by earthworm species and legume crop residues

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ABSTRACT

A pot culture experiment was carried out on quality of vermicompost as influenced by earthworm species and legume crop residues during the year 2011-12 at College of Agriculture, Latur. The experiment was laid in factorial compopletely randomized block design (FRBD) with three replications consisting of three levels of earthworm species (Control, *Eisenia foetida* and *Eudrilus eugeniae*) and four levels of legume crop residues (soybean, pigeonpea, groundnut and gram residues). The vermicomposting samples were collected at different stages *viz.,* 35th, 50th, 65th, 80th and 95th days and analyzed for its chemical properties. EC(1.44 dSm^{-1}), total N (1.61 %), P (0.97 %), K(1.04 %), Fe (14.57 ppm), Mn (5.25 ppm), Zn (5.31 ppm) and Cu (1.47 ppm) were found to be increased progressively throughout the vermicomposting of crop residues and also significantly reduced organic carbon (14.39 %), C:N ratio and alkaline pH into neutral with inoculation of earthworms *Eudrilus eugeniae* . C:N ratio of all the treatments decreased significantly and reached to a value below 19 on 95th days of vermicomposting. Moreover, the vermicompost produced by *Eudrilus eugeniae* possessed higher nutrient content than *Eisenia foetida*. Among the different crop residues,vermicompost obtained from pigeonpea residues were rich in total N (1.61 %), P (0.97 %), K(1.04 %), Fe (14.57 ppm), Mn (5.25 ppm), Zn (5.31 ppm) and Cu (1.47 ppm) as compared to all other crop residues. However, the C:N ratio of pigeonpea residues (15.51) was narrower followed by soybean residues (16.11).

Keywords: Earthworm species, legume crop residues, pH, EC, macro and micro nutrients.

INTRODUCTION

Modern agriculture has gone through major changes during the last century. Recycling of organic matter in agriculture brings in the much needed organic matter to the soil. Since most recyclable waste are organic and they directly add organic matter and the plant nutrient content in them and improve soil physical, chemical and biological properties as well as overall soil productivity (Khan *et al.,* 2005). All this organic waste cannot be applied or ploughed directly as such into the soil because of their wider C:N ratio. India produces about 363 million tonnes of wastes annually from all field crops, which is mostly either burnt or land filled. Decomposition of complex organic waste resources into odor free humus like substances through the action of worms is termed as vermicomposting. Although microbes are responsible for biochemical degradation of organic matter, earthworms are the important driver of the process conditioning the substrates and altering the biological activity (Suthar, 2007). Vermicompost contains major and minor nutrients in plant available forms, enzymes, vitamins and plant growth hormones. It has a more beneficial impact on plants than normal compost. Chemical analysis of the casts gives a good indication of changes directly caused by the worms. During composting nitrogen loss or denitrification is an indispensible phenomenon that affects the quality of vermicompost. Vermicompost provides all nutrients in readily available form and also enhance uptake of nutrient by plant. The legume crop includes peas, beans, grams, soybean, black gram, green gram and groundnut. The legume crop residues can provide a wide range of important soil quality benefits due to ability of legumes to fix atmospheric nitrogen in soil. The utilization of vermicompost results in several benefits to farmers, industries, environment and national economy.

MATERIALS AND METHODS

A pot culture experiment was carried out on influence of earthworm species and legume crop residues on quality of vermicompost during the year 2011-12 at College of Agriculture, Latur. The experiment was laid in factorial completely randomized block design (FRBD) with three replications consisting of three levels of earthworm species (Control, *Eisenia foetida and Eudrilus eugeniae*) and four levels of legume crop residues (soybean, pigeonpea, groundnut and gram residues). The vermicomposting samples were collected at different stages *viz.,* 35th, 50th, 65th, 80th and 95th days and analyzed for its qualities.

The legume crop residues i.e., soybean straw and pigeonpea were collected from farm of College of Agriculture, Latur. The groundnut residues and gram straws were collected from Oilseed Research Station, Latur. The material like plastic, stones etc., were separated from crop residues and chopped it in to small pieces and finally dried. Earthen pots of height 35 cm and top diameter 45 cm were used for decomposition of legume crop residues. These pots were filled with legume crop residues along with soil and FYM. Soil and partially decomposed FYM were mixed in 1:3 proportions for pot filling. Pots were filled layer wise *i.e.* first layer of broken bricks and sand were made, then layer of soil + FYM were added. After that, again layer of well chopped crop residue was made. Finally pots were layered with cow dung slurry and at last it was covered with crop residues. These pots were watered regularly and kept for pre-decomposition for 20 days. Moisture in the pot was maintained at field capacity by adding required quantity of water. The content in pot was mixed every week. Filled pots were kept in shade to avoid contact of direct sunlight and protection from birds, rats and ants. Two species of earthworms namely *Eisenia foetida* and *Eudrilus eugineae* were brought from BAIF, Urali Kanchan, Pune used for vermicomposting. These earthworms were inoculated in pots after 20 days of pot filling. Each pot was inoculated with 100 earthworms including juveniles and adults.

The standard methods were used to analyze the various parameters from vermicompost. pH and Electrical conductivity of vermicompost was determined by using 1:2.5 ratios of compost and water on pH meter and conductivity bridge, respectively as described by Jackson,1973. Organic carbon was estimated by using modified method of Walkley and Black (1934). Total nitrogen in compost was determined by Microkjeldhal's methods (Waranke and Barber, 1974). For this 1 gram of compost sample was digested with 10 ml H_2SO_4, 5 ml H_2O_2 (oxidizing agent), 1 g salt mixture (K_2SO_4 and $CuSO_4$ $.5H_2O$ with 20 : 1 ratio) and then it was distilled with 40 % NaOH. The distillate was collected in boric acid containing mixed indicator. The content was back titrated with *0.1N* H_2SO_4 till pink colour was appeared. Total phosphorous was determined by vanadomolybdate phosphoric acid, yellow colour method using spectrophotometer (Jackson, 1967). Potassium was determined by neutral normal ammonium acetate using flame photometer (Jackson, 1967). Micronutrients from aliquot of compost was estimated on Atomic Absorption Spectrophotometer as the method given by Elwell and Gridley (1967). C: N ratio was calculated by dividing the percentage of organic carbon with the percentage of nitrogen. The data obtained regarding the characters studied was subjected to statistical analysis by following the procedure pertaining to Factorial Completely Randomized Block Design (FRBD) as given by Panse and Sukhatme (1985). The significance of difference was tested by 'F' test. 5 per cent level of significance was used to test the significance of results. The critical differences were calculated when differences among the treatments were found to be significant by 'F' test.

RESULTS AND DISCUSSION

Periodical changes in pH

The result (Table 1) showed that the change in pH of vermicomposting material was non-significant at 35 days of inoculation and significantly decreased from 50 days to 95 days of inoculation of earthworm species. The inoculation with *Eudrilus eugeniae* was significantly superior over control and it was at par with *Eisenia foetida* at 50, 65, 80 and 95th days of vermicomposting. The data further revealed that the pH of vermicomposting material was significantly affected due to different crop residues at all the stages of composting except at 35 and 50 days of vermicomposting. The lower value of pH *viz.,* 7.78, 7.61 and 7.40 was recorded due to composting with pigeonpea residues at 65th, 80th and 95th days of vermicomposting, respectively. The composting with pigeonpea was significantly superior over groundnut residues but it was at par with soybean residues of compost. Further, it was found that pH of vermicomposting material decreased with advance stages of decomposition of legume crop residues from 8.18 to 7.46 irrespective of earthworm species and legume crop residues. Hence, the data observed that pH of vermicompost decreased from alkaline to neutral.

Interaction effects due to earthworm species and crop residues (S x C) was found non-significant on pH of

Table 1. Periodical changes in pH, EC and organic carbon during vermicomposting of legume crop residues

Treatments	Vermicomposting stages (Days)														
	pH					EC (dSm^{-1})					Organic carbon (%)				
Earthwor species (S)	**35**	**50**	**65**	**80**	**95**	**35**	**50**	**65**	**80**	**95**	**35**	**50**	**65**	**80**	**95**
S_1- Control	8.35	8.18	8.09	7.95	7.88	0.36	0.43	0.46	0.67	0.79	45.57	40.48	39.35	34.21	24.87
S_2- *Eisenia foetida*	8.11	7.85	7.73	7.51	7.28	0.41	0.55	0.60	1.16	1.35	41.73	39.03	35.30	30.03	16.57
S_3- *Eudrilus eugeniae*	8.07	7.82	7.71	7.50	7.23	0.46	0.58	0.61	1.21	1.44	38.39	36.98	33.03	27.68	14.39
SE ±	0.08	0.03	0.02	0.01	0.06	0.03	0.04	0.06	0.05	0.06	2.12	1.16	1.78	1.85	0.58
CD at 5%	NS	0.09	0.07	0.04	0.17	NS	NS	NS	0.15	0.18	NS	NS	NS	NS	1.71
Crop residues (C)															
C_1- Soybean residues	8.17	7.95	7.81	7.62	7.41	0.42	0.56	0.67	1.14	1.35	44.66	39.07	35.40	29.99	18.83
C_2- Pigeonpea residues	8.13	7.89	7.78	7.61	7.40	0.47	0.54	0.63	1.03	1.23	40.86	32.70	29.68	25.52	16.04
C_3- Groundnut residues	8.21	7.99	7.90	7.68	7.60	0.35	0.46	0.45	0.93	1.06	36.63	41.69	38.92	32.19	19.55
C_4- Gram residues	8.19	7.97	7.88	7.65	7.46	0.39	0.52	0.47	0.95	1.14	45.42	41.84	39.56	34.86	20.08
SE±	0.09	0.03	0.02	0.02	0.07	0.03	0.05	0.06	0.06	0.07	2.45	1.34	2.06	2.14	0.67
CD at 5%	NS	NS	0.07	0.05	0.18	NS	NS	NS	NS	NS	NS	3.94	6.04	6.28	1.97
Interactions (S X C)															
S.E. ±	0.16	0.06	0.04	0.03	0.12	0.06	0.09	0.11	0.10	0.12	4.24	2.33	3.57	3.70	1.16
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	3.49
General Mean	8.18	7.94	7.84	7.65	7.46	0.41	0.52	0.60	1.01	1.19	41.89	38.83	35.89	30.64	18.60

vermicomposting material at all the days of vermicomposting. Vermicompost material also had a lower pH, which might be due to the accumulation of organic acids from microbial metabolism or from production of fulvic acid and humic acid during decomposition. Similar results was also found by Suthar (2010) who reported that the range of pH in vermicomposted material was 8.0 ± 0.05 to 7.4 ± 0.01 at the end. This might be due to the mineralization of the nitrogen and phosphorus into nitrites/nitrates and orthophosphates and bioconversion of the organic material into intermediate species of the organic acids during vermicomposting. In compost preparation earthworm reduced pH as by *Eisenia foetida*, 6.7 to 6.1; *Eudrilus eugeniae* 6.7 to 6.0 and *Megasscolex megasscolex*, 6.7 to 6.4 (Munnoli *et al.,* 2010)

Periodical changes in electrical conductivity (EC)

The result (Table 1) revealed that the electrical conductivity changes due to earthworm species was found non significant at all the stages except at 80th and 95th days of vermicomposting. The maximum electrical conductivity was recorded due to inoculation with *Eudrilus eugeniae* (1.21 and 1.44 dSm^{-1}) over control and it was at par with inoculation of *Eisenia foetida* at 80th and 95th days of vermicomposting. In case of crop residues, non-significant results were recorded at all the stages of composting. The of electrical conductivity increases from 0.41 to 1.19 dSm^{-1} during the period of vermicomposting. The increase of composting material was in trend of C_3>C_4>C_2>C_1 during period of vermicomposting.

The interaction effects between earthworm species and crop residues (SXC) were found non significant at all the stages of vermicomposting. Further, the data indicated that electrical conductivity of vermicomposting material was increased with advance stages of vermicomposting.

Hernandez *et al.* (2012) reported that the increased in electrical conductivity with the period of vermicomposting, which was due to the degradation of organic matter releasing minerals such as exchangeable Ca, Mg, K and P in the available forms, that is, in the forms of cations in the vermicompost.

Periodical changes in per cent organic carbon

The per cent organic carbon (Table 1) was influenced significantly at 95th days of inoculation but non significant at 35th, 50th, 65th and 80th days after inoculation. Inoculation with *Eudrilus eugeniae* resulted in significantly less organic carbon content (14.39 %) over *Eisenia foetida* and control at 95th days of vermicomposting. It was decreased with different stages of composting. In case of crop residues, there was significant and gradual decrease in organic carbon content of all crop residues was observed throughout the vermicomposting period but it was found non significant at 35th days of composting. During vermicomposting, the maximum reduction of organic carbon was observed with pigeon pea residues (16.04 %) and it was at par with soybean residues (18.83 %) and also followed by groundnut residues (19.55 %) and gram residues (20.08 %). Further, the result showed that decreasing trend of per cent organic carbon was also observed with time of composting at different stages. The per cent organic carbon decreased periodically from 41.89 to 18.60 per cent during 35th to 95th days of composting.

The interaction effects between earthworm species and crop residues level (S×C) was significantly influenced on the organic carbon only at 95 days of vermicomposting. The data indicated that the maximum reduction of per cent organic carbon (11.88 %) was observed with the treatment combination of *Eudrilus eugeniae* × pigeonpea residues (S_3C_2) over rest of the treatment combination and it was at par with treatment combination S_3C_1 (*Eudrilus eugeniae* × soybean residues), S_2C_2 (*Eisenia foetida* × pigeonpea residues) and S_2C_1 (*Eisenia foetida* × soybean residues). Organic carbon content decreases at the end of the vermicomposting process because of the organic carbon consumption by earthworm, the transformation in CO_2 by respiratory activity and formation of the humic fraction which gives place to the mature vermicompost, *i.e.* oxidation of carbon to carbon dioxide during decomposition process. The results are in confirmatory with the results of Garg *et al*., (2011) reported that reduction of per cent organic carbon from 17.88 per cent to 9.15 per cent was observed during vermicomposting period.

Periodical changes in total nitrogen content

Total nitrogen (Table 2) was significantly influenced due to main effect of earthworm species at all the days except at 35th days of composting. The maximum nitrogen content was obtained with treatment S_3 (*Eudrilus eugeniae*) at 50th, 65th, 80th, and 95th days *i.e.,* 1.21, 1.22, 1.66 and 1.85 per cent, respectively over the control. While, the treatment S_3 was at par with the treatment S_2 at all the stages of vermicomposting. Among the organic crop residues, change in nitrogen content was to be observed significant at 65th, 80th and 95th days of vermicomposting and no significant effect was found at 35th and 50th days. The treatment C_3 (groundnut residues) was recorded highest nitrogen at 65th (1.25 %), 80th (1.57 %) and 95th (1.75 %) days of composting and it was at par with treatment C_2 (pigeonpea residues). At 95th days, the treatment C_3 (groundnut residues) was significantly superior over rest of the treatments. Due to composting material, the total nitrogen increased from 0.84 to 1.61 per cent during period of vermicomposting.

The interaction effects of earthworm species and crop residues were also found significant only at 95th days. At 95th days of composting, the higher total nitrogen (2.01 %) was observed with treatment combination S_3C_3 (*Eudrilus eugeniae* × groundnut residues) and it remained at par with S_3S_2 (1.95 %) and S_2S_3 (1.98 %) treatment combinations. However, the treatment combination S_1C_4 showed less nitrogen content (1.14 %). The data further revealed that total nitrogen increased with days of vermicomposting. The increase in the nitrogen value is result of carbon loss and probably because of mineralization of organic matter, so that the mineral N was retained in the nitrate form. Earthworms also add N in the form of mucus, growth stimulating hormones and enzymes during the fragmentation and digestion of organic matter. The highest level of total nitrogen at week 8 and 12 with values of 1.63 ± 0.49 and 1.84 ± 1.41, respectively in RS (rabbit manure + sawdust) treatment. While OS (ovine manure + sawdust) treatment showed the highest level of total nitrogen at weeks 4 and 16 with values of 1.63 ± 1.05 and 2.06 ± 0.62, respectively, because of the mineralization process during vermicomposting (Hernandez *et al*., 2012). Similar results found by Castillo *et al*., (2002).

Periodical changes in C: N ratio

The result (Table 2) showed that C:N ratio of vermicomposting material was influenced significantly due to earthworm species at all the days except at 35th days of vermicomposting. The composting with *Eudrilus eugeniae* (S_3) showed significantly the lowest C:N ratio *viz.,* 22.80, 20.27, 19.60 and 14.38 over rest of the treatment at 50th, 65th, 80th and 95th days of composting but at 80th days *Eudrilus eugeniae* and *Eisenia foetida* remained at par with each other. The C:N ratio of vermicompost was also influenced significantly by various crop residues at all the stages of composting except at 35th and 50th days of composting. The lowest C:N ratio was recorded significantly with pigeonpea residues at 65th (21.82), 80th (19.25) and 95th (15.51) days of vermicomposting than the other treatments. At 65th days, treatment C_2 (pigeonpea residues) was remained at par with treatment C_1 (soybean residues) and C_3 (groundnut residues). At 80th days, treatment C_2 (pigeonpea residues) remained at par with all the treatments. The composting with pigeonpea residues was found significantly superior over groundnut and gram residues but at par with soybean residues at 95th days of vermicomposting. The lowest C:N ratio was recorded with

Table 2. Periodical changes in per cent total nitrogen, phosphorous, potassium and C: N ratio during vermicomposting of crop residues

	Vermicomposting stages (Days)																			
Treatments	**Total nitrogen (%)**					**Total phosphorous (%)**					**Total potassium (%)**					**C: N ratio**				
Earthworm species (S)	**35**	**50**	**65**	**80**	**95**	**35**	**50**	**65**	**80**	**95**	**35**	**50**	**65**	**80**	**95**	**35**	**50**	**65**	**80**	**95**
S$_1$- Control	0.61	0.77	0.98	1.09	1.20	0.24	0.27	0.36	0.48	0.53	0.28	0.33	0.36	0.45	0.64	48.77	39.26	28.06	24.84	21.34
S$_2$- *Eisenia foetida*	0.93	1.17	1.20	1.59	1.79	0.35	0.41	0.57	0.70	0.94	0.42	0.46	0.56	0.73	0.96	37.62	29.19	22.57	20.84	15.83
S$_3$- *Eudrilus eugeniae*	0.99	1.21	1.22	1.66	1.85	0.39	0.43	0.59	0.73	0.97	0.46	0.49	0.59	0.76	1.04	32.33	22.80	20.27	19.60	14.38
SE ±	0.11	0.09	0.04	0.03	0.02	0.02	0.04	0.04	0.03	0.01	0.05	0.02	0.01	0.02	0.01	4.53	2.05	0.63	1.42	0.26
CD at 5%	NS	0.27	0.12	0.09	0.06	NS	NS	0.12	0.09	0.03	NS	NS	0.04	0.06	0.03	NS	6.02	1.85	4.16	0.76
Crop residues (C)																				
C$_1$- Soybean residues	0.77	1.01	1.09	1.45	1.57	0.35	0.38	0.51	0.65	0.84	0.38	0.43	0.52	0.65	0.88	38.40	29.62	22.85	21.42	16.11
C$_2$- Pigeonpea residues	0.89	1.07	1.14	1.52	1.65	0.37	0.42	0.54	0.73	0.86	0.41	0.48	0.55	0.70	0.94	30.60	24.81	21.82	19.25	15.51
C$_3$- Groundnut residues	0.98	1.22	1.25	1.57	1.75	0.32	0.34	0.48	0.58	0.78	0.40	0.42	0.48	0.62	0.85	41.72	35.15	23.86	22.41	18.75
C$_4$- Gram residues	0.74	0.89	1.03	1.24	1.47	0.28	0.32	0.47	0.56	0.77	0.37	0.38	0.45	0.59	0.83	47.93	32.07	24.98	23.95	18.34
SE±	0.13	0.10	0.05	0.03	0.02	0.02	0.05	0.03	0.03	0.01	0.06	0.02	0.02	0.02	0.01	5.24	2.37	0.73	1.65	0.30
CD at 5%	NS	NS	0.15	0.11	0.07	NS	NS	NS	0.10	0.03	NS	NS	0.06	0.06	0.03	NS	NS	2.14	4.83	0.60
Interactions (S X C)																				
S.E. ±	0.22	0.18	0.08	0.07	0.04	0.04	0.09	0.06	0.06	0.02	0.10	0.04	0.03	0.04	0.02	9.07	4.26	1.26	2.85	0.52
C.D. at 5%	NS	NS	NS	NS	1.13	NS	NS	NS	NS	0.81	NS	NS	NS	NS	0.07	NS	NS	NS	NS	1.56
General Mean	0.84	1.05	1.12	1.44	1.61	0.32	0.40	0.50	0.63	0.81	0.38	0.43	0.50	0.64	0.88	39.66	30.41	23.63	21.75	17.18

treatment C$_4$ (gram residues) at all the stages of vermicomposting. The mean value of C:N ratio decreased from 39.66 to 17.18 during the period of vermicomposting.

The interaction between Eudrilus *eugeniae* × pigeon pea residues (S$_3$C$_2$) recorded lowest C:N ratio (10.80) over rest of the treatment combinations and it was at par with the treatment combination *Eudrilus eugeniae* × soybean residues (S$_3$ C$_1$). The loss of carbon as carbon dioxide through microbial respiration and simultaneous addition of nitrogen by worms in the form of mucus and nitrogenous excretory material, hence lowered the C:N ratio of the substrate. Another way this might be due to enhanced microbial activity, as carbon is utilized by micro-organisms for their energy requirement and cause transformation of soluble nitrogen to microbial protein thereby preventing nitrogen loss. Higher C:N ratio indicates slow degradation of substrate and the lower C:N ratio indicated the higher efficiency level of mineralization by the species. This finding is in agreement with finding of Pattnaik and Reddy (2011) that lower C:N ratio in vermicompost produced by *Eudrilus eugeniae* implies that this species enhanced the organic matter mineralization more efficiently than *Eisenia foetida* and *Perionyx excavates.* Sensi (1989) found declined C:N ratio to less than 20 which indicates an advanced degree of organic wastes.

Periodical changes in total phosphorous content

Effect of earthworm species on total phosphorous was found significant at 60th, 80th and 95th days but it was non significant at 35th and 50th days of inoculation. It is evident from the results (Table 2) that inoculation with *Eudrilus eugeniae* recorded highest total phosphorous at 60th, 80th and 95th days *i.e.,* 0.59, 0.73 and 0.97 % of vermicomposting, respectively and it was at par with *Eisenia foetida*. Among the crop residues, phosphorous content of vermicompost was influenced significantly at 80th and 95th days but no any significant result was obtained at 35th, 50th and 65th days of composting. The composting with pigeon pea residues was found significantly higher P content (0.73 % and 0.97 %) than groundnut and gram residues and it was at par with soybean residues at 80th and 95th days of composting. The lower phosphorous content (0.56 and 0.77 per cent) was observed

Table 3. Periodical changes in total iron, total manganese, total zinc and total cupper during vermicomposting of crop residues

	Vermicomposting stages (Days)																			
Treatments	**Total iron (ppm)**					**Total manganese (ppm)**					**Total zinc (ppm)**					**Total cupper (ppm)**				
Earthworm species (S)	**35**	**50**	**65**	**80**	**95**	**35**	**50**	**65**	**80**	**95**	**35**	**50**	**65**	**80**	**95**	**35**	**50**	**65**	**80**	**95**
S_1- Control	0.58	1.02	2.09	2.85	3.03	1.38	1.50	1.75	2.22	3.62	0.16	0.25	0.53	0.81	2.17	0.38	0.45	0.58	0.63	0.76
S_2- *Eisenia foetida*	4.48	7.22	8.09	9.42	12.52	1.53	1.71	2.53	3.85	5.17	0.35	0.54	1.32	2.65	5.28	0.51	0.63	0.83	0.96	1.42
S_3- *Eudrilus eugeniae*	5.63	8.19	9.81	10.5	14.57	1.59	1.74	2.60	4.02	5.25	0.42	0.59	1.43	2.93	5.31	0.54	0.65	0.87	1.00	1.47
SE±	0.16	0.26	0.27	0.32	0.60	0.05	0.06	0.07	0.07	0.08	0.01	0.04	0.04	0.07	0.12	0.04	0.06	0.04	0.02	0.03
CD at 5%	0.49	0.76	0.80	0.95	1.74	NS	NS	0.21	0.21	0.24	NS	NS	0.13	0.20	0.38	NS	NS	0.12	0.08	0.09
Crop residues (C)																				
C_1- Soybean residues	3.70	5.91	7.42	8.16	10.54	1.65	1.74	2.46	3.49	4.80	0.32	0.46	1.12	2.21	4.35	0.54	0.64	0.83	0.95	1.30
C_2- Pigeonpea residues	4.23	6.21	7.65	9.14	13.35	1.55	1.70	2.38	3.45	4.75	0.34	0.53	1.21	2.33	4.84	0.47	0.59	0.80	0.88	1.25
C_3- Groundnut residues	3.28	4.90	5.86	6.59	8.64	1.42	1.63	2.23	3.27	4.67	0.27	0.41	0.99	2.01	4.01	0.45	0.56	0.73	0.83	1.18
C_4- Gram residues	3.03	4.87	5.70	6.50	7.74	1.39	1.54	2.12	3.22	4.50	0.29	0.42	1.03	1.96	3.81	0.43	0.50	0.68	0.77	1.12
SE±	0.19	0.30	0.31	0.37	0.68	0.06	0.08	0.08	0.08	0.06	0.01	0.04	0.05	0.08	0.14	0.05	0.07	0.05	0.03	0.03
CD at 5%	0.56	0.88	0.92	1.10	2.01	NS	NS	0.23	0.24	0.19	NS	NS	0.15	0.24	0.42	NS	NS	NS	0.10	0.09
Interactions (S X C)																				
S.E. ±	0.33	0.52	0.54	0.65	1.18	0.11	0.15	0.14	0.14	0.11	0.03	0.08	0.09	0.14	0.25	0.08	0.12	0.08	0.06	0.06
C.D. at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.76	NS	NS	NS	NS	NS
General Mean	3.56	5.47	6.66	7.60	10.07	1.49	1.65	2.29	3.36	4.29	0.31	0.46	1.09	2.13	4.25	0.48	0.58	0.76	0.86	1.21

in gram residues at 80th and 95th days of composting. The total phosphorous was significantly influenced by interaction effect of earthworm species and legume crop residues (S×C) at harvesting stage of composting (Table 3). The higher phosphorous content (1.00 %) was recorded with treatment combination S_3C_2 (*Eudrilus eugeniae* × pigeon pea residues) as compare to rest of the treatment combinations. However, it was at par with S_3C_1 (*Eudrilus eugeniae* × soybean residues), S_2C_1 (*Eisenia foetida* × soybean residues), S_3C_3 (*Eudrilus eugeniae* × groundnut residues) and S_2C_2 (*Eisenia foetida* × soybean residues) treatment combinations. The per cent total phosphorous was increased with increasing period of vermicomposting up to harvest. Similar observations were found by Venkatesh and Evera (2007) that normally P was found in unavailable form like calcium phosphate and potassium phosphate, the study reveals that worms have the ability to convert insoluble P into soluble forms. According to Sannigrahi (2005) the total P increased in compost prepared by *Perionyx excavates* from 0.54 ± 0.06 to 0.90 ±0.12 and by *Eisenia foetida* from 0.69 ± 0.05 to 1.09 ± 0.20 during the period of vermicomposting. It was probably due to increased activity of micro-organisms related to P mineralization or ageing of casts enhanced the mineralization process.

Periodical changes in total potassium content

The concentration of total potassium (Table 2) of vermicompost was significantly affected due to earthworm species at 65th, 80th and 95th days but it was found non significant at 35th and 50th days of composting. The inoculation with *Eudrilus eugeniae* recorded significantly higher potassium content at 65th (0.59 %), 80th (0.76 %), and 95th (1.04 %) days of vermicomposting than the other treatments. At 65th and 80th days of vermicomposting, the treatment *Eudrilus eugeniae* and *Eisenia foetida* were remained at par with each other While, the lower potassium content was obtained with control. Total potassium was significantly influenced at 65th, 80th and 95th days but it was not reach to significant level at 35th and 50th days of composting due to different crop residues. The composting with pigeonpea residues (C_2) recorded maximum total potassium at 65th, 80th and 95th days *viz.,* 0.55, 0.70 and 0.94 per cent, respectively over rest of the treatments. At 95th days of composting, the pigeonpea residues (C_2) was significantly superior (0.94 %) over rest of the crop residues *i.e.,* soybean, groundnut and gram residues but it was at par with soybean residues (C_1) at 65th (0.52 %) and 80th (0.65 %) days of composting. The lowest total potassium was recorded in gram residues (C_4) at all the stages of composting. Hence, the total potassium was significantly increased in the order of $C_2 > C_1 > C_3 > C_4$.

The interaction effects between earthworm species and crop residues (SxC) was significantly influenced on total potassium at harvesting stage of vermicomposting. A treatment combination S_3C_2 (*Eudrilus eugeniae* x pigeonpea residues) was found significantly superior (1.16 %) as compared to rest of the treatment combinations. The significantly the lowest value (0.63 %) was recorded with S_1C_3 treatment combination. The treatment combination of control with crop residues showed lower potassium content over the treatment combinations of S_3 (*Eudrilus eugeniae*) and S_2 (*Eisenia foetida*) with crop residues. According to Singh and Sharma (2002), the chemical analysis of the material with different treatments showed a significant increase in K concentration at the end of the vermicomposting period with values from 0.52 $\pm$ 0.02 to 0.55 $\pm$ 0.04 per cent, possibly because of mineralization of organic matter.

Periodical changes in total iron content

The concentration of iron (Table 3) was significantly higher due to inoculation with *Eudrilus eugeniae i.e.,* 5.63, 8.19, 9.81, 10.54 and 14.57 ppm at 35, 50, 65 80 and 95th days of composting. However, the lower concentration of total iron content was observed with control at all the stages of vermicomposting. Among the crop residues, the iron concentration was found significant at all the stages of vermicomposting. Iron content was maximum with the pigeonpea residues which was significantly superior (13.35 ppm) over all other legume crop residues at 95th days of vermicomposting. However, it was at par with soybean residues at 35th, 50th, 65th and 80th days of composting. Lower iron content was found with gram residues at all the stages of composting. The general mean of iron concentration was increased from 3.56 to 10.07 ppm during period of vermicomposting.

Interaction effects between earthworm species and crop residues on iron content was not reached to the significant level. The concentration of iron increases with values from 2.0 to 9.5 mg L^{-1} during the period of vermicomposting (Garg *et al.*, 2011)

Periodical changes in total manganese content

The data (Table 3) revealed that there was a significant variation in manganese concentration due to inoculation of earthworm species was observed at 65th, 80th and 95th days, respectively except 35th and 50th days of composting. The manganese concentration was recorded higher *i.e.,* 2.60, 4.02, and 5.25 ppm with *Eudrilus eugeniae* treatment over rest of the treatment. But it was at par with *Eisenia foetida* treatment at 65th, 80th and 95th days of composting. However, the lower manganese concentration was recorded with control. Among crop residues, the concentration of manganese increased significantly at 65th, 80th and 95th days but found non significant at 35th and 50th days of composting. The maximum concentration of manganese was observed with the composting of pigeonpea residues *viz.,* 2.38 ppm, 3.45 ppm and 4.67 ppm at 65th, 80th and 95th days, respectively of composing but it was at par with composting of soybean residues. The lower Mn content was found with gram residues at all the stages of composting.

The interaction effect of earthworm species and crop residues on total manganese content was observed statistically non-significant at all the stages of vermicomposting. Similar result was found by Loncaric *et al*. (2005) that the concentration of manganese was 354 mg kg^{-1} at the end of vermicomposting.

Periodical changes in total zinc content

Zinc content of vermicompost (Table 3) was not significantly influenced due to earthworm species at 35 and 50th days but it was significantly influenced at 65, 80 and 95 days of composting. The treatment S_3 (*Eudrilus eugeniae*) recorded maximum zinc concentration *i.e.,* 1.43, 2.93 and 5.31 ppm at 65, 80 and 95th days of vermicomposting, respectively,as compared to other treatments, but it was at par with S_2 (*Eisenia foetida*) treatment at 65th and 95th days of composting. In case of crop residues, zinc content of vermicompost was significantly affected at 65, 80 and 95th days, respectively and remained non significant at 35 and 50th days of composting. The composting with pigeonpea residues recorded significantly higher (4.84 ppm) zinc content over rest of the treatment at 95th days, but it was at par with soybean residues at 60 and 80th days of vermicomposting. The lower concentration of zinc was obtained with gram residues. The mean of zinc concentration increased from 0.31 to 4.25 ppm during period of vermicomposting.

An interaction effect between earthworm species and crop residues (S×C) on zinc concentration was found to be significant at 95th days of composting. The data indicated that total zinc content of vermicompost was the highest (6.23 ppm) due to S_3C_2 (*Eudrilus eugeniae* × pigeonpea residues) than other treatment combinations and it was at par with S_2C_2 (*Eisenia foetida* × pigeonpea residues) treatment combination. The lower zinc concentration was recorded with treatment combination S_1C_4 (Control × gram residues). Similar finding recorded by Sharma *et al*. (2005) on the content of the zinc in lantana and carrot vermicompost was 15.0 ppm and 11.3 ppm, respectively.

Periodical changes in total copper content

The copper content of vermicompost (Table 3) was significantly influenced by earthworm species at 65, 80 and 95th days except 35 and 50th days of vermicomposting. The inoculation with *Eudrilus eugeniae* showed higher concentration of copper *viz.,* 0.87, 1.00 and 1.47 ppm and it was remained at par with inoculation of *Eisenia foetida* at 65, 80 and 95th days of vermicomposting, respectively.

Among the crop residues, the copper content of vermicomposting was increased significantly at 80 and 95th days but remained non significant at 35, 50 and 65th days of composting. The composting material such as soybean residues was recorded maximum copper content (0.95 and 1.30 ppm) over rest of the treatments but it was at par with pigeonpea residues treatment at 80 and 95th days of composting. The lower concentration was found with gram residues during all the stages of vermicomposting. General mean of copper concentration changes during period of vermicomposting from 0.48 to 1.21 ppm.

The interaction effects between earthworm species and crop residues on copper concentration was found non significant. Similar findings are reported by Garg *et al*. (2011) that the concentration of copper ranges from 2.0 to 9.5 mg L^{-1} at the end of vermicomposting.

CONCLUSIONS

Periodical changes in chemical properties of vermicompost indicated that there were a progressive increase in EC, total N, P, K and micronutrients (Fe, Mn, Zn and Cu) and also significantly reduces organic carbon, C:N ratio and alkaline pH into neutral with inoculation of earthworms *Eudrilus eugeniae* followed by *Eisenia foetida*.

REFERENCES

Castillo AE, Quarin SH, Iglesias MC (2002). Vermicompost, chemical and physical characterization from raw and mixed organic wastes. J*. Agric. Technol.* **60** (1): 74-79.

Elwell ET, Gridley P (1967). Atomic Absorption Spectrophotometry. Pergamon Press Ltd. London. Pp 221.

Garg P, Gupta A, Satya S (2011). Vermicomposting of different types of waste using *Eisenia foetida,* a comparative study. *J. Biores. Tech*nol. **97** (3): 391 - 395.

Hernandez- Rodriguez OA, Lopez-Diaz JC, Arras- Vota AM, Quezada and Ojeda- Barrios (2012). Qualities of vermicompost obtain from residues of forestry and livestock. *J. Biores. Technol.* **1** (1).

Jackson ML (1967). *Soil Chemical Analysis*, Prentis Hall of India Pvt.Ltd. New Dehli,pp- 498.

Jackson ML (1973). *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd. New Delhi. Pp- 481. Khan SP, Duley FL, McCalla TM (2005). Effect of stubble mulching on number and activity of earthworms. *Nebraska Agricultural Experiment Station Research Bulletin*, **165**:20.

Loncaric Z, Engler M, Karalic K, Bukvic G, Loncaric R, Kralik D (2005). Evaluation of vermicomposted cattle manure. *Agricultural Scientific and Professional Review,* **11** (1): 57 - 63.

Munnoli PM, Silva JA, Bhosle S (2010). Dynamics of the soil earthworm plant relationship. *Global Science Book*: 1 - 21.

Panse VG, Sukhatme PV (1985). Statistical Methods for Agricultural Workers, *ICAR. Publ. Ist Impression in 1954*.

Pattnaik S, Reddy VM (2011). Nutrient status of vermicompost of urban green waste processed by three earthworm species *Eisenia Foetida*, *Eudrilus eugeniae* and *Perionyx excavates*. *Applied Environtal Soil Science*, 13.

Pramanik P, Ghosh GK, Ghosal PK, Banik K (2007). Changes in oraganic carbon, N, P and K and enzyme activity in vermicompost of biodegradable organic waste under liming and microbial inoculants. *J. Biores. Tech*nol. **98**: 2485-2494.

Sannigrahi AK (2005). Efficiency of *Perionyx excavates* in vermicomposting of thatch grass in comparison to *Eisenia foetida* in Asam. *J. Indian Society of Soil Sci.* **53** (2): 237 – 239.

Sensi N (1989). Composted materials as organic fertilizers. *Environmental Science,* **5** (81/82): 521 – 524.

Sharma S, Pradhan K, Satya S, Vasudevan P (2005). Potentiality of earthworms for waste management. *J. Am. Sci.* **1** (1). 140 – 143.

Singh and Sharma (2002). Composting of crop residues through treatment with microorganisms and subsequent vermicomposting. *Elsevier Science,* **12** (3): 42-45.

Suthar S (2007). Bioconversion of post harvest crop residues and cattle shed manure into value added products using earthworm *Eudrilus eugeniae* (king berg). *Ecology Engineering ,* **32** (3): 206-214.

Suthar S (2010). Potential of domestic biogas digested slurry in vermitechnology. *J. Bioresearch. Tech*nol. **10** (1): 5419 - 5425.

Venkatesh RM, Evera T (2007). Mass reduction and recovery of nutrients through vermicomposting of fly ash. *Appl. Ecol. Environ. Res.* **6** (1): 77-84.

Waranke DD, Barber SP (1974). Root development and nutrient uptake by corn grown in solution culture. *Agron. J.* **66**: 544.

Walkely AJ, Black IA (1934). An examination of the method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science,37:29-3

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