Indian Journal of Science and Technology Vol. 5 No. 7 (July 2012) ISSN: 0974- 6846

Vermicomposting of animal dung and its laboratory evaluation

Hargopal Singh[1], Pritpal Singh[2] and S.S. Hundal[3]
[1, 2]Department of Soil Science, PAU, Ludhiana-141 004; [3]Department of Zoology, PAU, Ludhiana-140 004, India
hargopalsingh@yahoo.co.in, jasppsingh@yahoo.co.in, hundalswarndeep@gmail.com

Abstract

A laboratory studies were conducted on the evaluation of vermicompost obtained from Farm Yard Manure (FYM) and FYM prepared from the same feedstock by only thermophilic processing. Processing of animal dung at a moisture content of around 60% consisted of 6 treatments (T_1) no earthworms, no moisture, no turning, no microbial culture ($E_0M_0T_0C_0$), (T_2) no earthworms, moisture, weekly turning, no microbial culture ($E_0M_1T_1C_0$), (T_3) *Eisenia fetida* earthworms, moisture, weekly turning, no microbial culture ($E_1M_1T_1C_0$), (T_4) *Eisenia fetida* earthworms, moisture, no turning, no microbial culture ($E_1M_1T_0C_0$), (T_5) no earthworms, moisture, weekly turning, microbial culture added ($E_0M_1T_1C_1$), (T_6) *Eisenia fetida* earthworms, moisture, weekly turning, microbial culture added ($E_1M_1T_1C_1$). Laboratory analysis for nutrient composition revealed that there was no appreciable change in nutrient composition in the vermicompost over FYM. Therefore, composting the animal dung by scientific means is as efficient as vermicomposting the animal dung.

Keywords: Animal dung, Earthworms, Nutrient content, Vermicomposting.

Introduction

For centuries, the excreta of animals is being used as manure to supply nutrients to crops. Even today, the animal dung and leftover agro-wastes of organic origin, like fodder are collected and accumulated in manure heaps on a daily basis. This is left in the open for months to facilitate composting and during this period, the waste remains exposed to the vagaries of nature and experiences nutrient losses through volatilization and leaching. Though the State Government of Punjab had allotted a small piece of land to each family in a village for preparing quality manure, but the farmers continued to prepare manure by conventional means that leads to the production of seemingly poor quality manure because we do not take into consideration the environmental conditions (like pH, temperature) in which these decompositions take place. Appropriate disposal involves both maximum cost-effective recovery of recyclable constituents and transformation of non-recoverable material into forms, which do not present environmental hazards (Kale, 2004).

In India, nearly 2000 million tons (MT) of animal waste, 300 MT of crop waste besides huge amount of agro industrial and domestic sewage waste is produced annually and therefore there is a tremendous scope for recycling of this waste using vermitechnology so that quality organic manure can be produced (Ramaswami, 1998; Mishra, 2001); it is becoming increasingly popular due to the emerging trend of organic farming. Vermicomposting is an accelerated biotechnological process of composting of organic wastes that involves interaction between earthworms and micro-organisms. Utilization of earthworms for recycling of organic wastes is an important development in biological sciences and studies have documented vermicomposting as a low-cost technology for the processing or treatment of organic wastes to convert them into value added nutrient rich compost (Hand *et al.,* 1988; Garg *et al.,* 2006; Suthar, 2006, 2008; Singh *et al.,* 2008).

Vermicomposting is a mesophilic process utilizing worms and micro-organisms that are active at temperature range of 10^{O}- 32^{O}C. Micro-organisms are responsible for the biochemical degradation of organic matter; the earthworms after passing the organic matter through their gizzard and gut increased the surface area for the microbial activity on the fragmented organic residues (Ndegwa & Thompson, 2001). As a result of this microbial conversion, both gut associated as well as the cast associated processes, the nutrients forms are much more soluble and available to plants than those in parent compounds.

Vermicompost is considered as an excellent product, since it is homogenous, has desired aesthetics, has reduced levels of contaminants and tends to hold more nutrients over a longer period without impacting the environment (Benitez *et al.,* 2002; Dhiman, 2003; Suthar & Singh, 2008; Singh *et al.,* 2007). Also, vermicompost is considered an inseparable component of sustainable farming because it promises to promote and sustain crop yields (Patil, 1995; Reddy & Ohkura, 2004; Sinha & Herat, 2009) because of increased nutrients content in the earthworm castings (Garg *et al.,* 2006). Dissemination of information on organic farming in the country has enlightened the farmer to engage in and adopt vermitechnology as a part of organic farming practices (Kalra *et al.,* 2008).

Research on vermiculture and vermicomposting is leading towards appreciation of some of the finer and physical aspects of soil entity as well as adding to the other benefits derived from agriculture. The closely related *Eisenia fetida* and *Eisenia andrei* species are most commonly used for the management of organic wastes by vermicomposting and their biology on animal dung or sewage sludge, have been investigated (Hartenstein *et al.,* 1979; Kalpan *et al.,* 1980; Edwards, 1988; Reinecke & Vilijoen, 1990a; Butt, 1993; Elvira *et al.,* 1996; Dominguez & Edwards, 1997; Dominguez *et* *al.,* 1997; Mitchell, 1997; Dominguez *et al*., 2000; Bettiol, 2004).

Agricultural substrates and wastes like farm yard manure (FYM), animal dung, rice straw and plant litter are potential sources of organic nutrients which if converted into vermicompost improve soil and water conservation, sustain crop productivity and enhance crop yields (Hundal & Zinia, 2009).The present study was therefore, planned to evaluate the changes in the nutrient composition of vermicompost from animal dung and compare them with those of FYM.

Materials and methods

Experiment was carried out on the nutrient evaluation of vermicompost from FYM and compared it with farmyard manure (FYM) prepared without adding earthworms into it. Two consecutive vermicomposting cycles *viz.* September-December (C_1) and January-April (C_2) were carried out. Fresh dung was obtained from the dairy farm of Guru Angad Dev Veterinary and Animal Science University (GADVASU), Ludhiana, India. The earthworms (*Eisenia fetida*) were procured from Amritsar Crown Caps Pvt. Ltd., Jandiala Guru, Amritsar, India. Microbial culture consisting of *Trichoderma ressaie* and *Phanerochaeta* used as starter material in a treatment was procured from the Department of Microbiology, PAU, Ludhiana. Fresh dung was added into the raised rectangular pits (3.35 X 1.20 X 0.25 m^3; length x width x height) constructed under galvanized iron sheet shed at a height of 11.5 feet. This provided 4.02 m^2 exposed top surface. The experiment was conducted in an ambient temperature of 25 ± 5^O C. For C_1, dung was filled @ 500 kg pit $^{-1}$ (fresh weight) (146 kg pit $^{-1}$, dry weight), after thermophilic stage of decomposition was over and temperature of the pit came down to 30^O C. Earthworms were introduced @ 1.530 kg pit^{-1} (live weight) corresponding to approximately 4308 individuals on the next day of filling the pits, indicating earthworm stocking density of 1.522 kg-worms m^{-3} and feeding rate of 1.22 kg dung-worm^{-1} day^{-1}, optimal levels for vermicomposting (Ndegwa *et.al.,* 2000) in the respective treatments - this being considered as day 0 of the treatment. At the start of each cycle, the manure was manually mixed using a spade, and optimum moisture content (~60%) was maintained by sprinkling water in all the compost pits. The day-to-day activity and performance of earthworms was monitored. From each compost pit, six samples (each ~500g, fresh weight) were taken using stainless steel tube (0.32 m long, 1.5 inch i.d.), mixed thoroughly, screened through sieve (10 mm) and ~1 kg/ 1000g sub-sample was transferred to the laboratory after 30, 60 and 78 days of composting period. Thus, each sub-sample was a representative of six-grab samples taken from top to the bottom of each compost pit. Throughout the vermicomposting period, the material in the pits was turned at 7th, 21st, 36th , 51st and 81st day of composting to provide aeration and to ensure the homogeneity of the material inside the pit. Throughout the bioconversion period, pit moisture was monitored every 2 to 5 days, depending upon the atmospheric temperature and moisture loss, by adding enough water to obtain optimum moisture content.

For the second cycle of vermicomposting (C_2) during January-April, fresh FYM was filled into same pits @ 500 kg pit^{-1} with same specifications and parameters as for C_1 cycle. The everyday activity and performance of termination of study period were analyzed for chemical parameters similar for C_1 cycle.

The 6 treatments were as follows: (1) no earthworms, no moisture, no turning, no microbial culture ($E_0M_0T_0C_0$),which was considered as control (2) no earthworms, moisture, weekly turning, no microbial culture ($E_0M_1T_1C_0$), (3) *Eisenia fetida* earthworms, moisture, weekly turning, no microbial culture ($E_1M_1T_1C_0$), (4) *Eisenia fetida* earthworms, moisture, no turning, no microbial culture ($E_1M_1T_0C_0$), (5) no earthworms, moisture, weekly turning, microbial culture added ($E_0M_1T_1C_1$), (6) *Eisenia fetida* earthworms, moisture, weekly turning, microbial culture added ($E_1M_1T_1C_1$).

Analytical methods

The compost samples were analyzed for total organic carbon (TOC), total nitrogen (TN), total phosphorus (TP), total potassium (TK), total sulphur (TS), total zinc (T-Zn), total copper (T-Cu), total manganese (T-Mn) and total iron (T-Fe). The TOC was analyzed by dry combustion method at 500^{o}C (Nelson & Sommers, 1982) and TN was determined by digestion with concentrated H_2SO_4 (Bremmer & Mulvaney, 1982). TP was analyzed after digesting the organics in 3:1 mixture of HNO_3: $HClO_4$ followed by calorimetric determination using molybdo-phosphoric acid method on Milton Roy spectrophotometer at 470 nm (Nelson & Sommers, 1982). The same extract was used for the TS and TK analysis of the organics. TS in the extract was determined by developing turbidity with the help of sodium-acetate acetic acid buffer and 30-60 mesh Barium Chloride crystals followed by suspension stabilization with 0.25% gum *Acacia* read at 420nm. Total micro-nutrients (Zn, Cu, Mn & Fe) were determined by means of Atomic Absorption Spectrophotometer (AAS) using specified lamp after digesting the samples HNO_3:$HClO_4$ (2:1).

Statistical analysis

Statistical analysis of major and micronutrients in the vermicompost and FYM was carried out by ANOVA. Mean separation of different treatments was performed using the least significant difference (LSD) test at 0.05 level of probability.

Results and discussion

Vermicomposting is a method to treat faecal matter with water contents up to 85% but little is known about the environmental conditions in which worms treat the material effectively. The results have shown an interaction between different parameters.

Indian Journal of Science and Technology Vol. 5 No. 6 (June 2012) ISSN: 0974- 6846

Table.1. Nutrient composition of organic wastes used for vermicomposting

Parameter	Organic wastes							
	FYM$_1$		FYM$_2$	RSC	RS	LL	FPP	BC
	C$_1$	C$_2$						
Ash (%)	48	52	68	44	93	121	70	40
TOC (%)	40.4	43.3	17.6	30.9	67.4	175	18.6	18.1
TN (%)	1.0	1.2	1.4	1.8	0.6	0.5	0.3	1.2
TP (%)	0.5	0.6	0.6	0.8	0.2	0.1	0.3	1.2
TK (%)	2.2	1.3	1.8	2.1	1.3	0.6	0.5	2.2
TS (%)	0.60	0.53	0.2	0.1	0.1	0.1	0.2	0.5
C:N	40.4	36.1	13.0	18.0	112.3	525	62	11.1
C:P	80.8	72.2	29.3	38.6	337.0	1050	62	15.1
C:S	67.3	81.7	80.0	309.0	518.5	1050	93	36.2
T-Zn ($\mu g\ g^{-1}$)	97	113	88	104	40	46	28	160
T-Cu ($\mu g\ g^{-1}$)	14	14	14	10	2	4	2	20
T-Mn ($\mu g\ g^{-1}$)	96	116	104	216	280	256	84	349
T-Fe ($\mu g\ g^{-1}$)	2723	3143	3336	5238	414	404	312	6438

**Expressed on dry weight basis, FYM$_1$ and FYM$_2$ represents FYM used for first and second experiment, respectively*

Nutrient content of animal dung

The TOC content of animal dung used for the experiment was 40.4% and 43.3 % in C$_1$ and C$_2$ composting cycles, respectively (Table 1). Total N was 1.0 and 1.2 %, TP was 0.5 and 0.6 % and TS was 0.60 and 0.53 % that leads to a C: N ratio of 40.4 and 36.1, C: P ratio of 80.8 and 72.2, and C: S ratio of 67.3 and 81.7 used for C$_1$ and C$_2$ cycle of composting, respectively. Total K in the animal dung used for C$_1$ and C$_2$ composting cycles was 2.2 and 1.3 %. Similarly the content of total Zn, Cu, Mn and Fe in the animal dung used for 1st cycle was 97, 14, 96 and 2732 $\mu g\ g^{-1}$ and in 2nd cycle was 113, 14, 116 and 3143 $\mu g\ g^{-1}$, respectively. Gupta (1998) and Hamoda *et al.* (1998) interpreted that various organic materials have been successfully composted with C/N ratio between 17-78, however, a much narrow range of 25 to 35 are desirable indicating optimum initiating parameters.

Nutrient composition of compost

The average nutrient composition of vermicompost and FYM have been shown in Table 2. The content of TOC varied non-significantly ($p \le 0.05$) among different treatments during C$_1$ after 78 days of composting. However, vermicomposting FYM with *Eisenia fetida* resulted in significant ($p \le 0.05$) decrease in TOC from 21.5% in E$_1$M$_1$T$_1$C$_0$ to 17.1% in E$_0$M$_1$T$_1$C$_1$ treatment during C$_2$. During C$_2$, even the traditional composting (E$_0$M$_0$T$_0$C$_0$ and E$_0$M$_1$T$_1$C$_0$) appreciably reduced the TOC content (Table 2). During C$_1$, TN and TP content in compost among different treatments differed non-significantly and TN and TP content remained near to 1.1 and 1.0% respectively. Interestingly, TN and TP content for the two composting cycles was though non-significant; ($p \le 0.05$) in organics undergone traditional composting than from organics vermicomposted using worms. During C$_2$, significantly ($p \le 0.05$) higher TN content in E$_0$M$_1$T$_1$C$_0$ over E$_1$M$_1$T$_1$C$_0$ treatment was observed. Like TN and TP, other major and micro nutrients also differed non-significantly ($p \le 0.05$) among different treatments, for two consecutive composting cycles (Table 2). Intense microbial activity can alter the degradation of soil organic matter, resulting in an accelerated decomposition of indigenous organic matter (Sikora & Yakovchenko, 1996). Results revealed that composting the organics by adopting the scientific methods is equally good as vermicompost as far as nutrient composition of the organics produced by the two different procedures is concerned. Our results found support from the work of other researchers who have reported T-Fe and T-Mn content of most of the composts ranged between 3428-9963 and 264-540 mg kg^{-1}, respectively (Forster *et al.,* 1993; Kadalli *et al.,* 2000; Chastain *et al.,* 2006). Similarly, T-Zn and T-Cu content in most of the composts varied from 200-400 and 60-1200 mg kg^{-1} in the experiments reported by Genevini *et al.,* (1997), Gies (1997) and Vogtman *et al.,* (1993), respectively.

Table 2. Average (3 sampling periods) Nutrient composition (dry weight basis, mean of three samplings) of animal dung manure (FYM$_1$)-vermicompost

Treatment	Major-nutrients					C:N	Micro-nutrients			
	TOC (%)	TN (%)	TP (%)	TK (%)	TS (%)		T-Zn ($\mu g\ g^{-1}$)	T-Cu ($\mu g\ g^{-1}$)	T-Mn ($\mu g\ g^{-1}$)	T-Fe ($\mu g\ g^{-1}$)
September-December Cycle (C$_1$)										
E$_0$M$_0$T$_0$C$_0$	24.4	1.1	2.4	0.6	0.5	22	126	23	190	6373
E$_0$M$_1$T$_1$C$_0$	25.4	1.2	2.5	0.6	0.4	21	114	18	158	6324
E$_1$M$_1$T$_1$C$_0$	23.4	1.0	2.3	0.6	0.5	24	106	20	170	7261
E$_1$M$_1$T$_0$C$_0$	22.6	0.9	2.2	0.5	0.5	23	107	21	165	7146
E$_0$M$_1$T$_1$C$_1$	22.8	1.1	2.1	0.5	0.6	22	103	19	159	7367
E$_1$M$_1$T$_1$C$_1$	24.2	1.1	2.2	0.5	0.5	22	102	19	155	6865
LSD(0.05)	NS	NS	NS	0.2	NS	NS	NS	NS	NS	NS
January-April Cycle (C$_2$)										
E$_0$M$_0$T$_0$C$_0$	19.2	1.5	0.6	1.4	0.6	13	90	15	114	3036
E$_0$M$_1$T$_1$C$_0$	18.0	2.0	0.7	1.5	0.7	9	93	15	119	3466
E$_1$M$_1$T$_1$C$_0$	21.5	1.5	0.7	1.4	0.7	15	94	15	127	3546
E$_1$M$_1$T$_0$C$_0$	20.9	1.6	0.6	1.5	0.6	13	91	13	118	3924
E$_0$M$_1$T$_1$C$_1$	17.1	1.9	0.6	1.5	0.7	9	106	15	107	2706
E$_1$M$_1$T$_1$C$_1$	17.5	1.8	0.7	1.4	0.6	10	86	14	116	3138
LSSD (0.05)	2.4	0.3	NS	NS	NS	3.0	NS	NS	NS	NS

Plant available N in manures ranges from 40 to 70% of their TN content (Pratt *et al.,* 1973) and when the manures are composted N availability decreases by as much as half as a result of immobilization in organic matter, including microbial biomass, transforming the compost into a slowly available N source (Eghball & Power, 1999). Usually initial C: N ratio has been reported as a key factor for controlling N losses through ammonia within a composting process (Sikora & Sowers, 1985; Sikora, 1999). According to Iglesias-Jimenez and Perez-Garcia (1992), a C: N ratio lower than 12 indicates a good degree of maturity. Benito *et al.* (2003) expressed a value around 30 as more adequate for pruning waste.

Manna (2004) reported that TN content of the mature compost should be more than 1.0% and TK between 1.5 to 2.0%. Umrit and Friesen (1994), however, observed P mineralization from organics with C:P ratio of 227, slightly greater than the breakout point suggested by others. Composted organic solid waste contained between 2 to 16% of their TP as rapidly exchangeable inorganic-P, between 40 and 77% of their TP as slowly exchangeable or not exchangeable inorganic P, probably in the form of condensed calcium phosphates and some organic P (Frossard *et. al.,* 2002). Evidences suggest that manure-P may be equally or even more available than fertilizer-P (Gale *et al.,* 2000); therefore these organic wastes have the potential to meet the partial or complete P requirement of crops (Singh, 2004; Singh *et al.,* 2010) on application to the soils.

Compost output and growth rate of earthworms

The compost output varied from 53-76 % during Sep-Dec cycle and from 39-86 % during Jan- Apr cycle with minimum output (53% in Sep-Dec cycle and 39 % in Jan-Apr cycle) from control treatment. On the other hand the maximum output varies from 76-86% in pits where earthworms or earthworms along with microbial culture and moisture were added. The increase in the number and weight of earthworms was respectively 91% and 39 % in the earthworm treatment and 74% and 28 % in the treatment where earthworms along with microbial culture were added. Activity of earthworms started in the 1st week of March with the rise of temperature to optimize earthworms' growth. It was 33 and 45 times in case of earthworm treatment and 43 and 48 times in case of earthworm along with microbial culture treatment

The results put forth the concept that no appreciable change in nutrient composition in the vermicompost over FYM that is produced by only thermophilic microorganisms without adding earthworms under similar conditions. It can be concluded that composting the animal dung by scientific means is as efficient as vermicomposting the animal dung.

References

1. Benitez E, Nogales R, Masiciandro G and Ceccanti B (2002) Isolation of isoelectric focusing of humic-urease complexes from earthworm (*Eisenia fetida*) Processed sewage sludges. *Biol. Fert. Soils.* 31. 489-493.
2. Benito MA, Masaguer A, Moliner Arrigo N and Palma (2003) Chemical and microbiological parameters for the characterization of the stability and maturity of pruning waste compost. *Biol. Fertil. Soils.* 37, 184-189.
3. Bettiol W (2004) Effect of sewage sludge on the incidence of corn stalk rot caused by *Fusarium' Summa Phytopathol*. 30, 16-22.
4. Bremmer JM and Mulvaney CS (1982) Nitrogen-total: *(In) Methods of Soil Analysis, Part-2. Chemical and Microbial Properties.* Page A L (ed), Agronomy Monograph No.9 (2nd ed.) ASA, SSA, Madison, WI, USA. pp: 595-624.
5. Butt KR (1993) Utilization of solid paper mill sludge and spent brewery yeast as a feed for soil-dwelling earthworms. *Biores. Technol.* 44, 105-107.
6. Chastain JP, Frase CC and Moore KP (2006) Composition of animal manure compost and utilization implications. ASABE paper No. 064054. St. Joseph, Mich.: ASABE. Available at: asabe.org.
7. Dhiman N (2003) Ecotaxonomy and biology of terrestrial earthworms of North Indian States. (Unpublished) *Ph.D., Thesis., Punjab Agri. Univ.*, Ludhiana.
8. Dominguez J and Edwards CA and Webster M (2000) Vermicomposting of sewage sludge: Effect of bulking materials on the growth and reproduction the earthworm *Eisenia andrei*. *Pedobiologia.* 44, 1-13.
9. Edwards CA (1988) Breakdown of animal, vegetable and industrial organic wastes by earthworms. In: *Earthworms in Waste and in Environment*. *SPB Acad. Publi.,* The Hague, The Netherlands. pp: 21-31.
10. Eghball B and Power JF (1999) Phosphorus-and nitrogen-based manure and compost based applications: Crop production and soil phosphorus. *Soil Sci. Soc. American J.* 63, 895-901.
11. Elvira CA, Dominguez J and Neuhauser EF (1996) The potential use of *Perionyx excavatus* (Perr.) (Megascolecidae) in organic waste management. *Biol. Fertil. Soils.* 27, 155-161.
12. Forster JC, Wolfgang Z and Wurdinger E (1993) Comparison of chemical and microbiological methods for the characterization of the maturity of composts from contrasting sources. *Bio. Fertil. Soils.* 16, 93-99.
13. Frossard E, Skrabal P, Sinaj S, Bangerter F and Traore O (2002) Form and exchangeability of inorganic phosphate in composted solid organic wastes. *Nutrient Cycling in Agroecosystem.* 62, 103-113.
14. Gale PM, Mullen MD, Cierlik C, Tyler DD, Dcuk BN, Kirchner M and Mc Clure (2000) Phosphorus distribution and availability in response to dairy manure application. *Commun. Soil Sci. Plant Anal.* 31, 553-565.
15. Garg P, Gupta A and Satya S (2006) Vermicomposting of different types of wastes using

Eisenia fetida: A comparative study. *Biores. Technol.* 97, 391-395.
16. Genevini PL, Adani F, Borio D and Tambone F (1997) Heavy metal content in selected european commercial compost. *Compost Sci. Uti.* 5, 31-39.
17. Gies G (1997) Developing compost standards in Europe. *Biocycle.* 38, 82-83.
18. Hand P, Hayes WA, Frankland JC and Satchell JE (1988) The vermicomposting of cow slurry. *Pedobiologia.* 31, 199-209.
19. Hartenstein R, Neuhauser EF and Kaplan DL (1979) Reproductive potential of the earthworm *Eisenia fetida*. *Oecologia.* 43, 329-340.
20. Hundal SS and Dhingra Z (2009) Growth and reproduction of *Eudrilus eugeniae* in Agricultural wastes. *GEOBIOS* 36, 9-12.
21. Iglesias-Jimenez E and Perez-Garcia V (1992) Determination of maturity indices for city refuse compost. *Agri. Ecosys. Environ*. 38, 331-343.
22. Kadalli GG, Suseeladevi L, Siddaramappa R and Patil CR (2000) Quality and efficiency of value added coir dust based compost. *J. Ind. Soc. Soil Sci.* 48, 141-144.
23. Kale RD (2004) The use of earthworms: Nature's gift for utilization of organic wastes in Asia. In: C. A. Edwards (ed.). *Earthworm Ecol.* (2nd ed.) CRC Press LLC USA.
24. Kalra RK, Zinia and Hundal SS (2008) Adoption of Vermiculture as a segment of Organic farming: A Case Study. *Ind. J. Ecol.* 35(2), 143-145.
25. Kaplan DL, Hartenstein R, Neuhauser EF and Malechi MR (1980) Physiochemical requirements in the environment of the earthworm *Eisenia fetida. Soil Biol. Biochem.* 12, 347-352.
26. Manna MC (2004) Evaluation of compost maturity, stability and quality. Short course on assessment of compost quality for agriculture crop production. Division of Soil Biology. *Indian Instit. Soil Sci.,* Bhopal (India) pp: 20-25.
27. Mitchell A (1997) Production of *Eisenia fetida* and vermicompost from feed-lot cattle manure. *Soil Bio. Biochem.* 29, 763-766.
28. Mishra B (2001) Organic waste recycling in aqua farming. *Yojana*, Nov. pp: 419-425.
29. Ndegwa PM and Thompson SA (2001) Integrating composting and vermicomposting in treatment and bioconversion of biosolids. *Biores. Technol.* 76, 107-112.
30. Ndegwa PM, Thompson SA and Das KC (2000) Effect of stocking density and feeding rate on vermicomposting of biosolids. *Biores. Technol.* 71, 5-12.
31. Nelson DN and Sommers LE (1982) Total C, organic C and organic matter. In: Page AL, Muller RH and Keeney DR (eds) Methods of soil analysis. *American Soc. Agronomy, Madison, Wisconsin, USA*. pp: 539-579.
32. Patil MP (1995) Integrated nutrient management in commercial vegetable. *M.Sc. Agri. Thesis, Univ. Agric. Sci.* Dharwad (India).
33. Pratt PS, Broadbent SP and Martin JP (1973) Using organic waste as N-fertilizer. *Calif. Agric*. 27, 10-13.
34. Ramaswami PP (1998) Recycling of wastes as manure – potentials and prospects. In: *Summer School on Integrated Soil Productivity Managt. Sustainable Agricul.* ICAR, New Delhi. pp: 83-91.
35. Reddy MV and Ohkura K (2004) Vermicomposting of rice straw and its effects on sorghum yield. *Trop. Ecol.* 45, 27-31.
36. Reinecke AJ and Vijioen SA (1990) The influence of worm density on growth and cocoon production of the compost worm *Eisenia fetida* (Oligochaeta). *Revue d' Ecologie et Biologie du Sol.* 27, 221- 230.
37. Singh H, Hundal SS and Singh P (2008) Vermicomposting of rice straw compost and farm yard manure with two epigeic earthworm species*, J. Res. (PAU).* 43(182), 51-55 PAU.
38. Singh H, Hundal SS and Singh P (2010) Vermicomposting potential of *Eisenia fetida* for different agro-organic wastes. *Indian. J. Ecol.* 37(1), 60-64.
39. Singh P (2004) Phosphorus availability in recent floodplain soils as influenced by their physical and chemical parameters and application of pressmud. M.Sc. Thesis (Unpublished) Punjab Agricultural University, Ludhiana, Punjab.
40. Singh R, Sharma RR and Tyagi SK (2007) Pre-harvest foliar application of calcium and boron influences physiology disorders, fruit yield and quality of strawberry (*Fragaria x ananassa Duch*.). *Scientia Horticult.* 112, 215-220.
41. Sinha RK and Herat S (2009) Vermiculture and sustainable agriculture. *Americ. Eurasian J. Agric. Environ. Sci.* 5(S), 01-55.
42. Sikora LJ (1999) MSW compost reduces nitrogen volatilization during dairy manure composting. *Compost Sci. Uti.* 7, 34-41.
43. Suthar S (2006, Nutrient changes and biodynamics of epigeic earthworm, Perionyx excavatus (Perrier) during recycling of some agricultural wastes. *Bioresource Tech doi. 10 1016/j.biotech).*
44. Suthar S (2008) Bioconversion of post harvest crop residues and cattle shed manure into value added products using earthworm *Eudrilus eugeniae* (Kinberg). *Ecol. Eng.* 32, 206-314.
45. Suthar S and Singh S (2008) Feasibility of vermicomposting in bio-stabilization sludge from a distillery industry. *Sci. Total Environ.* 393, 327- 343.
46. Umrit G and Friesen DK (1994) The effect of C:P ratio of plant residues added to soils of contrasting phosphate sorption capacities on P uptake by *Panicum maximum* (Jacq.) *Plant Soil.* 158, 275-285.
47. Vogtman H, Fricke K and Turk T (1993) Quality, physical characteristics, nutrient content, heavy metals and organic chemicals in Biogenic waste compost. *Compost Sci. Uti.* 1, 69-87.