

Full Length Research Paper

Effect of turkey litter (*Meleagris gallopavo* L.) vermicompost on growth and yield characteristics of paddy, *Oryza sativa* (ADT-37)

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Accepted 23 September, 2011

Pre-decomposed (15 days), turkey litter was mixed with cow dung (1:1, w/w) and vermicomposted with earthworm, *Perionyx ceylanensis* for 60 days. The vermicompost thus obtained was amended with regular farmers practice in the field soil for the cultivation of paddy (*Oryza sativa*, ADT-37) in six different treatments with and without vermicomposts (RBD). Before application of vermicompost and after the harvesting of paddy, composite soil samples from each plot were taken and subjected to the analyses of pH, organic carbon, available NPK contents and soil microflora. The E.C., total nitrogen, potassium, phosphorus, calcium, manganese, copper, iron and zinc showed increase in vermicomposts than in the worm un-inoculated composts. The organic carbon, C/N and C/P ratio showed reduction in all the vermicomposts over composts. The results on the growth and yield of paddy with the amendment of vermicompost showed notable increase in 40 kg/plot vermicompost amendment with regular farmers practice. All the parameters considered on the growth and yield of paddy for the study were higher in vermicompost amendments in a dose-dependent manner followed by the regular farmer practice and universal control. The average pH range recorded in all the plots before application of vermicomposts and farmers practice showed slight reduction in vermicompost amended plots after harvesting of paddy. The organic carbon and available NPK contents also showed increase in vermicompost applied plots. The results on the status of microbial population in soils amended with various vermicompost treatments and farmers practice after harvesting of paddy (ADT-37) showed an increase over initial and control plots. The final microbial population in plots amended with different treatments was found to be dose-dependent.

Key words: Earthworms, poultry litter, organic carbon, soil nutrients, vermicompost.

INTRODUCTION

Vermitechnology has been proposed globally as potential tool to stabilize the natural and anthropogenic wastes, such as sewage sludge, industrial sludge, plant-derived wastes, agro-industrial solid waste, household waste, animal dung, etc. Vermicomposting is biooxidation and stabilization of organic material involving the joint action

of earthworms and microorganisms. Although, microbes are responsible for the biochemical degradation of the organic matter, earthworms are the important drivers of the process, conditioning the substrate and altering biological activity (Aira et al., 2002). Vermicompost has higher economic value compared with compost derived from traditional methods. Vermicompost are finely divided peat like materials with high porosity, aeration, drainage and water holding capacity. They also contain nutrients in forms that are readily taken up by the plants.

Several epigeic earthworms have been identified as

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detritus feeder which can be reared on large numbers in organic waste resources. The familiar earthworm species, *Eudrilus eugeniae*, *Eisenia fetida*, *Lumbricus rubellus* and *Perionyx excavatus*, are well known for their efficiency in vermicomposting. It is desirable to know about other species of earthworms that may be as efficient or better in their performance over the aforementioned species in a country having rich diversity of fauna for *in situ* and *ex situ* vermiculture. There are more than a dozen of earthworm species that have been reported to be efficient in vermicomposting. Most of the species that are included under genus *Perionyx* show great potential to work on organic matter. Apart from the well-known *P. excavatus*, other *Perionyx* species such as *P. ceylanensis*, *P. bairdii*, *P. nainianus*, and *P. sansibaricus* are recently considered to be the potential vermicomposting earthworms (Karmegam and Daniel, 2009a, b; Suthar, 2009a; John Paul et al., 2011).

Poultry droppings are the excretory products of poultry birds, which contain enormous amount of nutrients. However, they are not suitable for direct application into the field and Scientists have therefore tried to utilize these wastes in different ways. Turan (1999) utilized poultry litter along with natural zeolite as an ingredient during the composting process and concluded that the addition of natural zeolite to poultry litter compost was found to have a beneficial effect on the characteristics of the end product. Whereas, the studies conducted by Guerra-Rodríguez et al. (2000 and 2001) report the utilization of solid poultry manure along with chestnut burr and leaf litter mix, and barley wastes, respectively by the process of co-composting. The co-compost was matured in 103 days from a biological point of view, and the percentage of germination obtained using the co-compost varied with the seeds used. It was 186% for ryegrass seeds, 85.74% for wheat seeds and 103% for barley seeds. Garg and Kaushik (2005) investigated the potential of an epigeic earthworm *E. fetida* to transform textile mill sludge spiked with poultry droppings into value added product- that is vermicompost. Yadav and Garg (2011) also tried vermicomposting of poultry droppings and food industry sludge along with cow dung, employing earthworms (*E. fetida*). These studies clearly show the possible utilization of poultry litter with suitable combination of bulking agents and the method.

Vermicompost has been shown to have higher level of organic matter, organic carbon, total and available NPK and other micronutrients, microbial and enzyme activities, as well as plant growth regulators (Tomati and Galli, 1995; Edwards, 2004; Arancon et al., 2008). They contain nutrients in forms that are taken up by the plants readily, such as nitrates, exchangeable phosphorus and soluble potassium, calcium and magnesium. Hence, vermicompost had been shown to influence the growth and productivity of a variety of plants, cereals and legumes, ornamental flowering plants (Atiyeh et al., 2001; Zaller, 2007). The studies on the effect of vermicomposts on growth and yield characteristics showed encouraging

results (Ansari and Ismail, 2008; Pontillas et al., 2009; Mousavi et al., 2010). However, the studies on vermicomposting of turkey litter and its effect on paddy growth, yield and soil characteristics are unavailable. Hence, the present study was carried out to vermicompost the turkey litter in combination with cow dung. Further, the vermicompost thus produced was also tested for its suitability to be used as manure for paddy (ADT-37) at field level and its influence on soil characteristics.

MATERIALS AND METHODS

The litter produced by poultry birds, *Meleagris gallopavo* L. (commonly called as turkey birds) was undertaken for the study. The raw material, turkey litter was collected from a private poultry farm, Regina Farmstead, R.N. Kandigai village, Uthiramerur Taluk, Kanchipuram district, Tamil Nadu, India and transported to the laboratory. The turkey litter was subjected to initial decomposition in rectangular draining cement tanks of 75 x 60 x 45 cm size by sprinkling water, regular mixing and turning of the substrates for 15 days. The earthworm, *P. ceylanensis* Mich., originally collected from culture bank of the Department of Biology, Gandhigram Rural Institute- Deemed University, Tamil Nadu, India was mass multiplied in cow dung (CD) and used for vermicomposting studies.

Based on the studies reported by Karmegam and Daniel (2009a, b) and Prakash and Karmegam (2010a, b) on vermicomposting of different organic substrates using *P. ceylanensis*, the ratio of organic substrate mix; 1:1 (50:50) proportion on dry weight basis, was used in the present study. Accordingly, the pre-decomposed turkey litter was mixed with CD in 1:1 ratio on dry weight basis, transferred to vermibeds and moistened to hold 60 to 70% moisture content. For each experimental set, a control set was also maintained without earthworms. The vermicomposting studies were carried out for 60 days using *P. ceylanensis* in three replicates twice under controlled conditions. The physico-chemical characteristics of initial vermibed substrates, final control (worm-unworked) and vermicomposts were analysed as per standard procedures given and the results were statistically interpreted that includes students 't' test and ANOVA.

Determination of pH was done by a digital pH meter, electrical conductivity by a conductivity meter (Elico) using 1:10 (w/v) compost-water (double distilled) suspension. The moisture content was determined after drying at 105°C for 24 h. Total organic carbon (TOC) was measured using the method of Walkley and Black (1934). Total Kjeldahl Nitrogen (TKN) was determined after digesting the sample with concentrated H₂SO₄ and HClO₄ (9:1, v/v) (Tandon, 1993). Total phosphorus (TP) was analysed using colorimetric method with molybdenum in sulphuric acid (Tandon, 1993). Total potassium (TK) and total calcium (TCa) were determined after digesting the samples in concentrated HNO₃: HClO₄ (4:1 v/v), by flame photometer (Tandon, 1993). While total Fe and Zn and micronutrients were determined by atomic absorption spectrophotometer after digestion of the sample by the dry ashing method (Tandon, 1993).

Field trials were conducted on paddy (*Oryza sativa*, variety ADT-37) using vermicompost prepared with turkey litter + cow dung. The paddy (ADT-37) seeds procured from M/S. Senthil Seeds, Dharapuram, Tiruppur District, Tamil Nadu, India were used for the study. The study was conducted in a farm land owned by Mr. P. Mani, Arasoor village, Vandavasi Taluk, Thiruvannamalai District, Tamil Nadu, India. The seeds were sown and the seedlings were raised following the traditional practices, then treatments were set-up according to randomized block design (RBD). The details of treatments and replicates are given as follows:

Table 1. Physico-chemical characteristics of turkey litter + cow dung (1:1) composts prepared with and without *P. ceylanensis* (60 days).

Parameter	Compost	Vermicompost	Increase / decrease (%) [§]
pH	7.16 ± 0.05	7.21 ± 0.04	0.70 ^{NS}
Electrical conductivity (dS/m)	1.46 ± 0.04	2.09 ± 0.04	43.15*
Organic carbon (%)	42.18 ± 4.24	31.06 ± 0.04	-26.36*
Nitrogen (%)	1.07 ± 0.03	1.66 ± 0.02	55.14*
Phosphorous (%)	1.09 ± 0.05	1.77 ± 0.02	62.39*
Potassium (%)	0.65 ± 0.03	1.55 ± 0.04	138.46*
Calcium (%)	1.33 ± 0.05	1.85 ± 0.08	39.10*
Sodium (%)	0.27 ± 0.02	0.34 ± 0.02	25.93*
Magnesium (%)	0.51 ± 0.01	0.64 ± 0.03	25.49*
Manganese (ppm)	19.13 ± 0.80	26.54 ± 0.47	38.73*
Sulphur (%)	0.12 ± 0.01	0.18 ± 0.01	50.00*
Iron (ppm)	107.67 ± 2.42	138.67 ± 2.34	28.79*
Copper (ppm)	12.55 ± 1.10	16.67 ± 1.75	32.83*
Zinc (ppm)	46.22 ± 0.73	54.03 ± 0.84	16.90 ^{NS}
C/N	36.57 ± 2.11	18.82 ± 0.43	-48.54*
C/P	35.39 ± 0.54	18.20 ± 0.02	-50.54*

Values are mean of six replicates ± SD; [§] Values without negative and with negative sign are percent increase (+) and percent decrease (-) respectively in vermicompost over compost; * and ^{NS} indicates statistically significant difference at P<0.05 and not significant by 't' test.

Treatments:

- T1: FP + 40 kg VC
- T2: FP + 30 kg VC
- T3: FP + 20 kg VC
- T4: FP + 10 kg VC
- T5: Farmers practice
- T6: Universal control; no amendments

Where, VC is the vermicompost; FP is the farmers practice [farmyard manure (FYM) at 2.0 tonnes acre⁻¹; diammonium phosphate at 50 kg acre⁻¹; potash at 25 kg acre⁻¹]. Treatment details were; Treatments: 6 × 3, replications: 3, Plot size: 4 m × 3 m.

The parameters on paddy growth and yield considered for the study were plant height, root length, shoot length, total tillers, number of productive tillers, weight of panicle, weight of a spikelet, number of grains per panicle, number of grains per spikelet, weight of 1000 grains, number of filled grains per panicle, number of unfilled grains per panicle, grain weight per hill, grain weight per plot, straw weight per hill and straw weight per plot. The initial (before application) and final (after harvesting) soil characteristics such as pH, organic carbon and available NPK. The soil microbial population were analysed by adopting standard procedures (Kannan, 1996).

RESULTS AND DISCUSSION

The physico-chemical characteristics of final composts (control, without earthworms) and vermicomposts of turkey litter in combination with cow dung (1:1) are shown in Table 1. The E.C., total nitrogen, potassium, phosphorus, calcium, manganese, copper, iron and zinc showed increase in vermicomposts than in the composts of respective substrates. The organic carbon, C/N and

C/P ratio showed reduction in the vermicompost over compost (worm unworked). The total nitrogen in turkey litter + cow dung (1:1) vermicompost was 1.66%, which was significantly (P<0.05) higher than the worm unworked compost (1.07%). The total potassium and phosphorus levels were also significantly higher (P<0.05) in vermicompost than in worm unworked compost (K and P: compost- 0.65 and 1.09%; vermicompost – 1.55 and 1.77%). The calcium and zinc contents were higher in the vermicompost than in the respective compost. The copper and iron contents in vermicompost were also showed higher values than that of compost, that is, worm unworked control (Table 1). In addition, the C/N ratio of vermicompost showed decrease (18.82) over compost (36.57) and percent decrease observed was 48.54. The percentage increase of 43.15 for E.C. was recorded. The percentage increase of NPK in vermicompost of turkey litter + cow dung (1:1) was 55.14, 62.39 and 138.46, respectively (Table 1). Also, percentage decrease of organic carbon, C/N and C/P ratios recorded in the vermicompost was 26.36, 48.54 and 50.54 respectively over the control, i.e., worm unworked compost.

The electrical conductivity showed significant increase in the vermicompost over the worm un-worked composts. This shows that during vermicomposting process, the soluble salt level increases due to the mineralization activity of earthworms and microorganisms in the organic substance, as well as in the gut of earthworms. Joshi and Kelkar (1952) have reported a higher electrical conductivity of vermicasts which denotes an increase in the level of soluble salts in the soil. These findings are well

Table 2. Growth and yield of paddy (ADT-37) cultivated in soils amended with vermicompost prepared from turkey litter + cow dung (1:1) using *P. ceylanensis*. The values are mean \pm S.E.

S/N	Parameter	T1	T2	T3	T4	T5	T6
1	Plant height (cm)	107.0 \pm 2.0	93.0 \pm 1.0	86.0 \pm 1.0	80.3 \pm 1.2	75.3 \pm 1.5	71.7 \pm 1.5
2	Root length (cm)	23.1 \pm 0.6	21.6 \pm 0.5	25.0 \pm 1.0	23.3 \pm 1.5	17.6 \pm 0.4	14.0 \pm 0.4
3	Shoot length (cm)	83.8 \pm 2.6	74.7 \pm 1.5	63.3 \pm 1.5	55.0 \pm 2.7	58.5 \pm 1.9	57.0 \pm 1.1
4	Productive tillers (no.)	24.0 \pm 1.0	18.0 \pm 1.0	16.0 \pm 1.0	9.3 \pm 0.6	7.7 \pm 0.7	5.7 \pm 0.6
5	Wt. of panicle (g)	5.9 \pm 0.2	4.6 \pm 0.5	4.4 \pm 0.3	3.8 \pm 0.1	3.6 \pm 0.1	3.2 \pm 0.1
6	Wt. of a spikelet (g)	0.51 \pm 0.01	0.47 \pm 0.02	0.45 \pm 0.03	0.40 \pm 0.01	0.36 \pm 0.01	0.32 \pm 0.01
7	No. of grains / panicle	143.3 \pm 6.0	105.3 \pm 4.0	70.0 \pm 1.0	52.0 \pm 1.0	42.0 \pm 2.0	24.0 \pm 2.0
8	No. of grains /spikelet	8.3 \pm 0.4	8.0 \pm 1.0	6.0 \pm 0.6	5.3 \pm 0.6	4.7 \pm 0.6	3.8 \pm 0.1
9	Wt. of 1000 grains (g)	32.5 \pm 1.2	29.7 \pm 1.3	27.7 \pm 1.3	25.0 \pm 1.4	22.9 \pm 1.1	21.93 \pm 1.2
10	No. of filled grains / panicle	135.3 \pm 1.5	103.7 \pm 2.1	63.3 \pm 3.5	46.7 \pm 1.2	35.0 \pm 2.0	17.0 \pm 2.0
11	No. of unfilled grains / panicle	3.5 \pm 0.4	4.7 \pm 1.5	5.3 \pm 0.6	5.0 \pm 1.0	6.7 \pm 0.6	6.7 \pm 0.6
12	Grain wt. / hill (g)	89.0 \pm 2.0	85.7 \pm 1.2	83.3 \pm 1.5	77.0 \pm 2.0	63.7 \pm 0.6	55.7 \pm 1.2
13	Straw wt. / hill (g)	993.0 \pm 4.0	928.3 \pm 4.2	863.3 \pm 15.3	717.3 \pm 7.1	639.5 \pm 16.8	604.8 \pm 5.0
14	Straw wt. / plot (kg)	91.6 \pm 1.2	83.7 \pm 1.1	80.5 \pm 1.1	64.4 \pm 1.2	64.1 \pm 1.4	56.9 \pm 1.1

supported by the results of the previous works with different earthworm species during vermicomposting (Karmegam and Daniel, 2009a; Raja Sekar and Karmegam, 2009; Prakash and Karmegam, 2010a, b). The vermicomposts also showed better reduction of organic carbon and C/N ratio than in the composts. Because of the combined action of microorganisms and the earthworms, a large fraction of the organic matter in the initial substrates was lost as CO₂ (20 to 43% as total organic carbon) by the end of the vermicomposting period. Govindan (1998) pointed out that the production of mucus and nitrogenous excrements enhance the level of nitrogen in the vermicompost and this helps in bringing down the ratio of carbon to nitrogen which is most essential in the humification process. Moreover, the lowering of C:N ratio during vermicomposting was achieved by the combustion of carbon substrates during respiration. The nutrient level of vermicompost depends on the nature of the organic material used as food source for earthworms (Chaudhuri and Bhattacharjee, 2002; Garg et al., 2006; Suthar and Singh, 2008).

The higher percentage increase of NPK in vermicomposts in the present study may be attributed to the mineralization process caused by earthworm action along with microorganisms on organic materials. Increased level of P during vermicomposting is due to earthworm gut derived phosphatase activity and also increased microbial activity in the cast (Lee and Foster, 1991). Krishnamoorthy (1990) reported that the rise in the level of P content during vermicomposting is probably due to mineralization and mobilization of P due to bacterial and faecal phosphatase activity of earthworms. The elevated level of Zn and Fe in vermicompost indicates accelerated mineralization with selective feeding by earthworms on materials containing these metals. The increased level of macro and micronutrients in the vermicomposts were in

conformity with the results of earlier works (Parthasarathi and Ranganathan, 1999; Suthar, 2007). The results of the present study showed that the vermicompost of turkey litter + cow dung with *P. ceylanensis* is rich in nutrients suitable to be used as organically rich source of biofertilizers for any crop. Several researchers have used different ratios of organic materials such as leaf litter, pressmud, MSW and vegetable market waste with CD for vermicomposting (Kaviraj and Sharma, 2003; Suthar, 2009a, b; Karmegam and Daniel, 2009b; Prakash and Karmegam, 2010a).

The microbial respiration may lead to rapid carbon loss through CO₂ production and also, digestion of carbohydrates, lignin, cellulose and other polysaccharides from the substrates by inoculated earthworms may cause carbon reduction during the decomposition of organic waste. Some parts may be converted to worm biomass through the assimilation process, which consequently reduces the carbon budget of vermicomposted wastes (Suthar, 2009a, b). The increase in total N content was higher in vermicomposts than composts, where CD increment resulted in increased nutrient contents. Many authors reported that losses in organic carbon might be responsible for N upgrading. Also, the addition of N in the form of mucous, excretory substances which were not initially present in feed substrates has been reported (Sangwan et al., 2008; Karmegam and Daniel, 2009a). The higher percent increase of EC and NPK in vermicompost produced by *P. ceylanensis* than in the compost in this study may be attributed to the mineralization process caused by earthworm action along with microorganisms on organic materials.

Furthermore, the growth and yield parameters of paddy (ADT-37) such as plant height, root length, shoot length, number of productive tillers, total number of tillers, weight of panicle, weight of a spikelet, number of grains/panicle,

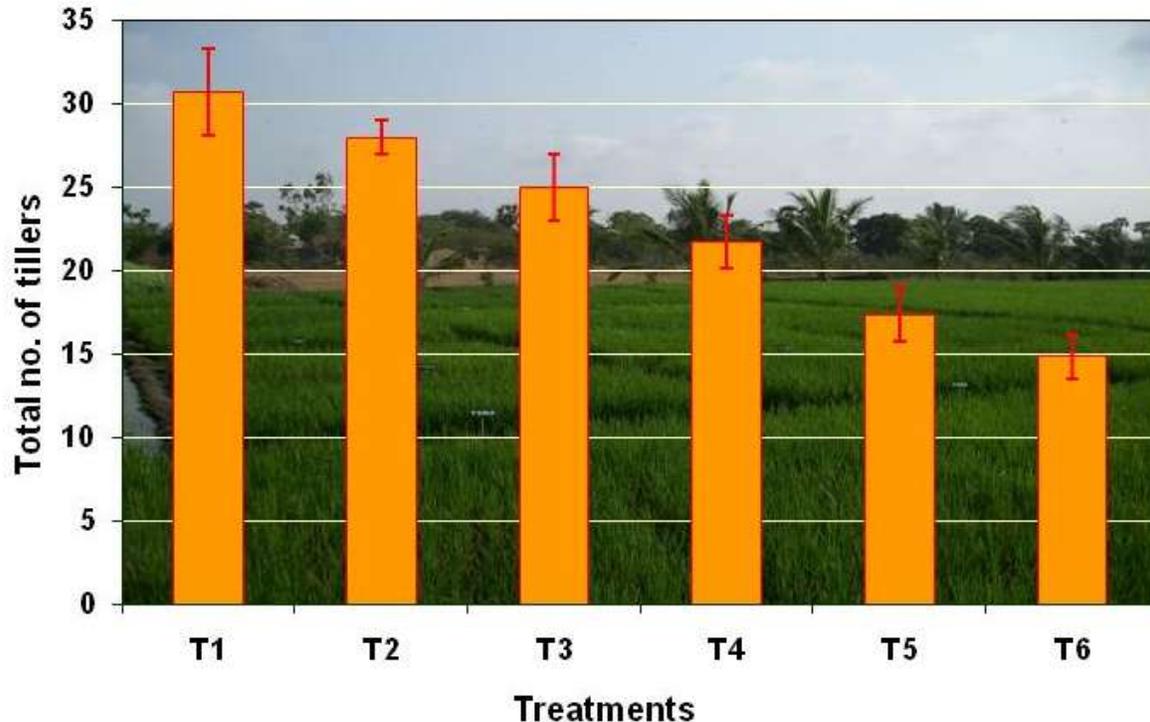


Figure 1. Total number of tillers of paddy (ADT-37) produced in vermicompost (turkey litter +cow dung, 1:1) and non-vermicompost amended soils after harvesting (100 days after sowing). The error bars indicate \pm S.D.

number of grains/spikelet, weight of 1000 grains, number of filled grains/panicle, number of unfilled grains/panicle, grain weight/hill, grain weight/plot, straw weight/hill and straw weight/plot are shown in Table 2 and Figures 1 and 2. All the parameters considered on the growth and yield of paddy (ADT-37) for the study were higher in vermicompost amendments in a dose-dependent manner followed by the regular farmer practice and universal control. The number of productive tillers recorded in different vermicompost amendments was 24.0, 18.0, 16.0, 9.3, 7.7 and 5.7 in T1, T2, T3, T4, T5 and T6, respectively. The number of productive tillers was higher in high dose (40 kg per plot) of vermicompost amendment and the least being the control plot without any inputs or amendments (Table 2). The weight of panicles recorded in vermicompost amendments was 5.9, 4.6, 4.4, 3.8, 3.6 and 3.2 g in T1, T2, T3, T4, T5 and T6, respectively. The weight of panicles was also higher in high dose (40 kg per plot) of vermicompost amendment and the least being the control plot without any inputs or amendments. The total number of tillers in each plot that received vermicompost amendment was 30.7, 28.0, 25.0, 21.67, 17.37 and 14.83 in T1, T2, T3, T4, T5 and T6, respectively (Figure 1). The weight of grains recorded in the treatments with vermicompost was 61.53, 56.0, 54.48, 49.34, 50.79 and 35.4 kg /plot in T1, T2, T3, T4, T5 and T6, respectively (Figure 2). All the other parameters studied were also showed similar results.

The studies conducted by other scientists with paddy

and other crops also showed similar results. Arancon et al. (2004) reported that the vermicompost applications increased strawberry growth and yields significantly, including increases of up to 37% in leaf areas, 37% in plant shoot biomass, 40% in numbers of flowers, 36% in numbers of plant runners and 35% in marketable fruit weights. Prajapati et al. (2008) carried out an experiment to study the growth promotion of rice (*O. sativa*) due to dual inoculation of *Azotobacter chroococcum* and *Piriformospora indica* along with vermicompost. Dual inoculated plants in presence of vermicompost gave better positive effects on both 45th and 90th day, in comparison to single inoculation of *A. chroococcum*, *P. indica* and vermicompost. Ansari and Ismail (2008) also recorded a paddy yield of 4975 kg/ha from plots amended with vermicompost, with 4900 kg/ha from plots amended with chemical fertilizers, as control. Cost benefit ratio was found to be 1:1.5 for cultivation of paddy using vermitech, whereas in case of chemical fertilizers it was 1:1.06, thus suggesting that by the application of vermicompost in paddy, the cost of production could be reduced without compromising on harvest. This report well supports the findings of the present study. Moreover, the efficacy of vermicompost and lignite based *Azospirillum lipoferum* (Az 204), *Bacillus megaterium* (PB2) and *Pseudomonas fluorescens* (Pf1) inoculants on rice variety NLR 145 at 75% N and P levels under field conditions was reported by Gandhi and Sivakumar (2010).

The inoculation of all the three vermicompost carrier

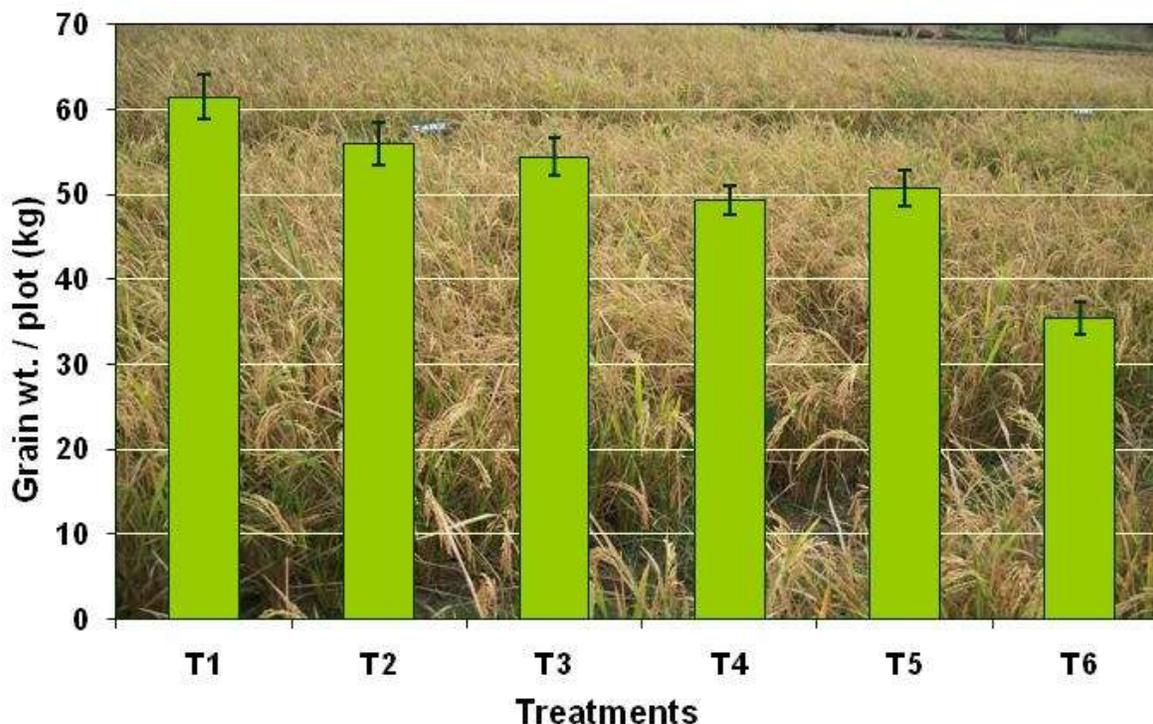


Figure 2. Grain weight of paddy (ADT-37) per plot produced in vermicompost (turkey litter +cow dung, 1:1) and non-vermicompost amended soils after harvesting (100 days after sowing). The error bars indicate \pm S.D.

inoculants as combined form recorded significant results in enhancing the plant height, leaf area, total tillers, dry matter production and reducing the number of days to 50% flowering and maturity. The combined form of vermicompost carrier based inoculants application also significantly influenced the number of tillers, panicle length, total number of grains per panicles, the number of filled grains per panicle, thousand grains weight, grain yield and straw yield. This study reinforces the same as that of the results recorded in the present work.

pH, organic carbon, available NPK contents, functional microbial groups in soils amended with various combinations of vermicomposts and farmers practice, before application of different amendments (initial) and after cultivation of paddy (ADT-37) are given in Figures 3 and 4. The average pH range recorded in all the plots before application of vermicomposts and farmers practice was 8.6 which showed reduction up to 7.1, after harvesting of paddy (ADT-37) from vermicompost amended plots. The organic carbon content showed increase with the rate of application of vermicomposts. The initial average pH of the plots selected for the treatment with vermicompost was 8.66, which showed reduction in pH of 8.03, 7.74, 8.22, 7.69, 7.17 and 7.31 in T1, T2, T3, T4, T5 and T6 plots, respectively after harvesting. The initial average organic carbon content of soils in the plots selected for the treatment with vermicompost was 0.52%, whereas the organic carbon content in T1, T2, T3, T4, T5 and T6 was 1.26, 0.71, 0.63, 0.61, 0.65 and 0.63%, respectively

(Figure 3). The initial NPK contents in the soil were 332, 162 and 132 mg/kg, which showed an increase of 447, 770 and 390 mg/kg of soil respectively in T1 after harvesting. In other treatments, N and P showed variation in increase of different vermicompost amendments (Figure 4).

The results on the status of microbial population in soils amended with various vermicompost treatments and farmers practice before application (initial) and after harvesting of paddy (ADT-37) are shown in Table 3. The total bacterial, fungal, actinomycetes, fluorescent pseudomonads and phosphate solubilizing bacterial population in the soil was higher in T1 than in initial and other treatments. The final microbial population in plots amended with different treatments was found to be dose dependent, that is, higher amendment of vermicompost showed higher microbial populations. However, the plots which received chemical fertilizer + FYM (farmers practice) and universal control (no amendments) showed least colonization of microorganisms.

Ghosh et al. (1999) observed that integration of vermicompost with inorganic fertilization tended to increase the yield of potato, rape seed, mulberry and marigold over that with traditional compost prepared from the same material. Bhattacharjee et al. (2001) reported that the increased yield was due to uptake of nutrients in paddy and the application of vermicompost reduced the dosage of NPK. Increased yield owing to the application of vermicompost along with chemical fertilizer might be

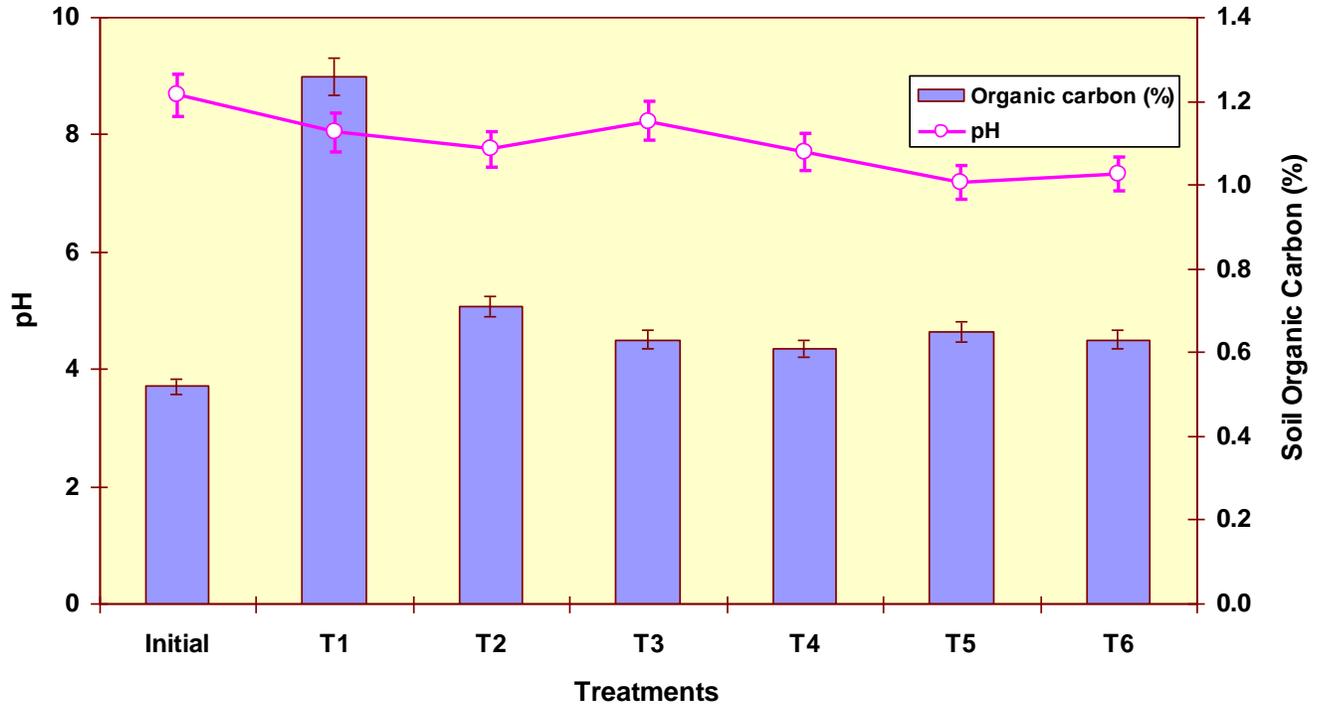


Figure 3. pH and organic carbon content in soils amended with various combinations of vermicompost (turkey litter +cow dung, 1:1) and farmers practice, before and after cultivation of paddy (ADT-37). The error bars indicate \pm S.D.

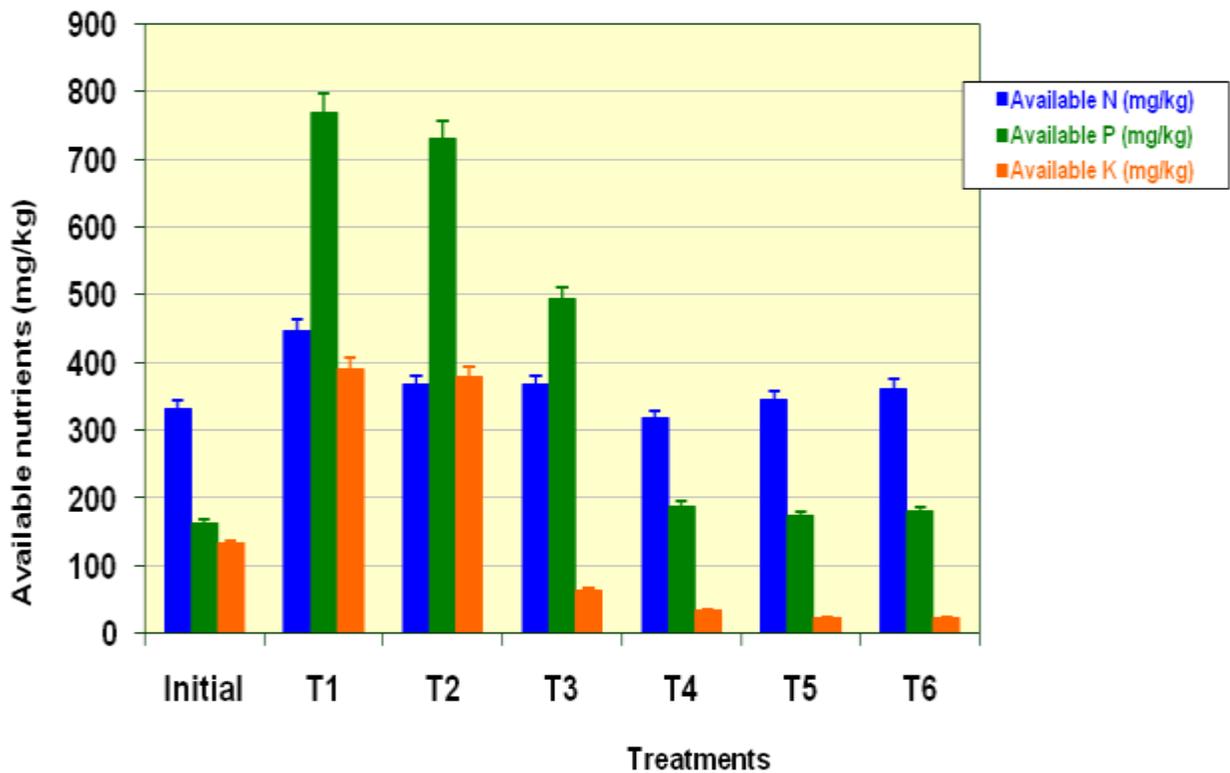


Figure 4. Available NPK contents in soils amended with various combinations of vermicompost (turkey litter +cow dung, 1:1) and farmers practice, before and after cultivation of paddy (ADT-37). The error bars indicate \pm S.D.

Table 3. Different microbial groups in soils amended with vermicompost (turkey litter +cow dung, 1:1) and farmers practice, before and after cultivation of paddy (ADT-37).

Treatment	Total bacterial count ($\times 10^6$ CFU)	Total fungal count ($\times 10^3$ CFU)	Total actinomycetes count ($\times 10^3$ CFU)	Fluorescent Pseudomonads ($\times 10^6$ CFU)	Phosphate solubilizing bacteria ($\times 10^6$ CFU)
Initial	70×10^5	14	10	13×10^5	4
T1	115	57	35	118	13
T2	65	35	30	91	9
T3	67	27	28	78	6
T4	60	23	17	36	5
T5	21	14	12	24	4
T6	12	10	10	20	4

due to increased uptake of nutrients. This may indicate that vermicompost reduces the loss of nutrients through leeching from the soil by changing the physico-chemical properties of the soil. Other factors, such as the presence of beneficial microorganisms or biologically active plant growth influencing substances or phytohormones released by beneficial microorganisms including humates in the vermicompost might be also involved (Krishnamoorthy and Vajranabhaiah 1986; Tomati and Galli, 1995; Atiyeh et al., 2002). Nitrogen encourages the vegetative growth and is a regulator that governs to a considerable degree of the uptake of phosphorus and potassium, which are important for seed production. Muscolo et al. (1999) reported that the effects of these substances on plant growth have been shown to be very similar to the effects of soil-applied plant growth regulators or hormones. Vermicompost contains most nutrients in forms that are available for plants such as nitrates, phosphates and exchangeable calcium and soluble potassium. Usually, the vermicompost contains most of the essential minerals. They are rich in microbial populations and diversity, particularly fungi, bacteria and actinomycetes (Edwards, 1998).

The field trial carried out by Karmegam and Daniel (2008) with a vegetable crop, *Lablab purpureus* for 180 days showed that the vermicompost either alone or in combination with 50% of the recommended dose of chemical fertilizer is able to produce results constantly equal to exclusive application of chemical fertilizer as observed through certain growth parameters. The nutrient uptake (NPK) by plants and fruit yield was higher with vermicompost application and equivalent to chemical fertilizer application. The nutrient uptake (NPK) by plants and fruit yield was higher with vermicompost application and equivalent to chemical fertilizer application. Similar results for *Arachis hypogea* and *Vigna mungo* were reported by Parthasarathi and Ranganathan (2001). Fernández-Luqueño et al. (2010) reported that the yields of common bean (*Phaseolus vulgaris* L.) plants cultivated in unamended soil or soil amended with urea were lower than those cultivated in wastewater sludge-amended soil. Application of vermicompost further improved plant

development and increased yield compared with beans cultivated in wastewater amended soil. It was found that application of organic waste products improved growth and yield of bean plants compared to those amended with inorganic fertilizer. These studies form a good support of the findings of the present study results on the growth and yield of paddy (ADT-37) and the improved soil available nutrients. There are also many reports confirming the increment of microbial activity and population in vermicasts and in vermicomposts because of the activity of earthworms and organic nature of the vermicompost. Rajani et al. (2001) have related the microbial density and enzyme activity as a measure to assess the effectiveness of process of vermicomposting. It is essential to make an in-depth study to understand the mutualistic association between microflora and earthworms in the mechanism of decomposition of organic matter.

The vermicasts of *P. ceylanensis* showed 14 different fungal species belonging to the genera, *Aspergillus*, *Chaetomium*, *Cladosporium*, *Cunninghamella*, *Fusarium*, *Mucor*, *Penicillium* and *Rhizopus*. Total nitrogen, phosphorus, potassium, calcium, copper, iron and zinc were higher in vermicasts than in control (substrate without earthworms). The incubation of vermicasts (45 days) showed significant correlation with that of the increase in fungal population ($r = 0.720$; $p < 0.05$) (Prakash et al., 2008). The total microbial population, viz., bacteria, fungi and actinomycetes were found to be many-fold higher in worm casts than in the initial vermicompost substrate and in substrate without earthworms (control). The initial count of bacteria, fungi and actinomycetes in the control was $123.42 \text{ CFU} \times 10^7 \text{ g}^{-1}$, $159.64 \text{ CFU} \times 10^3 \text{ g}^{-1}$ and $86.90 \text{ CFU} \times 10^4 \text{ g}^{-1}$, whereas in castings (vermicompost) of *P. ceylanensis* the reported microbial populations were 268.62, 223.39 and 141.09 (Jayakumar et al., 2009). The vermicasts are therefore able to increase the longevity of biofertilizer microorganisms when used as carrier materials. The increase of vermicast proportion in carrier materials also showed increase in the survival rate (Raja Sekar and Karmegam 2010). These observations clearly indicate the importance of microorganisms associated

with earthworms in creating suitable environment for the standing crops as well as for vermicomposting of different organic wastes.

Conclusion

As observed from the present study, the vermicomposting potential of *P. ceylanensis* over the organic substrate, turkey litter in combination with cow dung (1:1, w/w), could result in the production of nutrient-rich vermicompost. Also, the vermicompost obtained from turkey litter + cow dung yielded a vermicompost with superior quality. The data regarding the analyses of nutrients obtained in the present study reveals that the action of earthworms enhanced the nutrients which were higher in vermicompost than recorded in the compost (control, worm un-worked). The field trials conducted with vermicompost application on paddy (ADT-37) clearly also showed that the growth and yield were higher in the treatments which received high proportion of vermicompost amendment along with regular farmer practice. In addition, the soil nutrients and microbial population showed increase in the plots which received vermicompost, insisting that the growth of beneficial microorganisms in the soil are enhanced along with sustainable nutrient release.

REFERENCES

- Aira M, Monroy F, Dominguez J, Mato S (2002). How earthworm density affects microbial biomass and activity in pig manure. *Eur. J. Soil Biol.* 38: 7-10.
- Ansari AA, Ismail SA (2008). Paddy cultivation in sodic soil through vermitech. *Int. J. Sustain. Crop Productn.* 3(5): 1-4.
- Arancon NQ, Edwards CA, Babenko A, Cannon J, Galvis P, Metzger JD (2008). Influences of vermicomposts, produced by earthworms and microorganisms from cattle manure, food waste and paper waste, on the germination, growth and flowering of petunias in the greenhouse. *Appl. Soil Ecol.* 39: 91-99.
- Arancon NQ, Edwards CA, Bierman P, Welch C, Metzger JD (2004). Influences of Vermicomposts on field strawberries: I. Effects on growth and yields. *Bioresour. Technol.* 93: 145-153.
- Atiyeh RM, Arancon NQ, Edwards CA, Metzger JD (2001). The influence of earthworm processed pig manure on the growth and productivity of marigolds. *Bioresour. Technol.* 81: 103-108.
- Atiyeh RM, Lee S, Edwards CA, Arancon NQ, Metzger JD (2002). The influence of humic acids derived from earthworm-processed organic wastes on plant growth. *Bioresour. Technol.* 84: 7-14.
- Bhattacharjee G, Chaudhuri PS, Datta M (2001). Response of paddy (var. TRC-87-251) crop on amendment of the field with different levels of vermicompost. *Asian J. Microbiol. Biotechnol. Environ. Sci.* 3: 191-196.
- Chaudhuri PS, Bhattacharjee G (2002). Capacity of various experimental diets to support biomass and reproduction of *Perionyx excavatus*. *Bioresour. Technol.* 82: 147-150.
- Edwards CA (1998). The use of earthworms in the breakdown and management of organic waste. In: *Earthworm Ecology*, (Ed.: Edwards CA), St. Lucie Press, Boca Raton, pp. 327-354.
- Edwards CA, Arancon NQ (2004). The use of earthworms in the breakdown of organic wastes to produce vermicomposts and animal feed protein. In: *Earthworm Ecology*, (Ed.: Edwards CA), Second Ed., CRC Press, Boca Raton, pp. 345-438.
- Fernández-Luqueño F, Reyes-Varela V, Martínez-Suárez C, Salomón-Hernández G, Yáñez-Meneses J, Ceballos-Ramírez JM, Dendooven L (2010). Effect of different nitrogen sources on plant characteristics and yield of common bean (*Phaseolus vulgaris* L.). *Bioresour. Technol.* 101: 396-403.
- Gandhi A, Sivakumar K (2010). Impact of vermicompost carrier based bioinoculants on the growth, yield and quality of rice (*Oryza sativa* L.) C. V. NLR 145. *The Ecoscan*, 4 (1): 83-88.
- Garg P, Gupta A, Satya S (2006). Vermicomposting of different types of waste using *Eisenia foetida*: A comparative study. *Bioresour. Technol.* 97: 391-395.
- Garg VK, Kaushik P (2005). Vermistabilization of textile mill sludge spiked with poultry droppings by an epigeic earthworm *Eisenia foetida*. *Bioresour. Technol.* 96: 1063-1071.
- Ghosh M, Chattopadhyay GN, Baral K (1999). Transformation of phosphorus during vermicomposting. *Bioresour. Technol.*, 69: 149-154.
- Govindan VS (1998). Vermiculture and vermicomposting. In: Trivedy RK, Arvind Kumar (Eds.), *Ecotechnology for pollution control and environmental management*, Enviro Media, Karad, India. pp. 49-57.
- Guerra-Rodríguez E, Diaz-Ravina M, Vazquez M (2001). Co-composting of chestnut burr and leaf litter with solid poultry manure. *Bioresour. Technol.* 78: 107-109.
- Guerra-Rodríguez E, Vazquez M, Diaz-Ravina M (2000). Co-composting of barley wastes and solid poultry manure. *Bioresour. Technol.* 75: 223-225.
- Jayakumar M, Karthikeyan V, Karmegam N (2009). Comparative studies on physico-chemical, microbiological and enzymatic activities of vermicasts of the earthworms, *Eudrilus eugeniae*, *Lampito mauritii* and *Perionyx ceylanensis* cultured in press mud. *Int. J. Appl. Agric. Res.* 4(1): 75-85.
- John Paul JA, Karmegam N, Daniel T (2011). Municipal solid waste (MSW) vermicomposting with an epigeic earthworm, *Perionyx ceylanensis* Mich. *Bioresour. Technol.* 102: 6769-6773.
- Joshi NV, Kelkar BV (1952). Role of earthworms in soil fertility. *Indian J. Agric. Sci.*, 22: 189-196.
- Karmegam N, Daniel T (2008). Effect of vermicompost and chemical fertilizer on growth and yield of hyacinth bean, *Lablab purpureus* (L.) Sweet. *Dyn. Soil, Dyn. Plant*, 2: 77-81.
- Karmegam N, Daniel T (2009a). Investigating efficiency of *Lampito mauritii* (Kinberg) and *Perionyx ceylanensis* Michaelsen for vermicomposting of different types of organic substrates. *Environmentalist*, 29(3): 287-300.
- Karmegam N, Daniel T (2009b). Growth, reproductive biology and life cycle of the vermicomposting earthworm, *Perionyx ceylanensis* Mich. (Oligochaeta: Megascolecidae). *Bioresour. Technol.* 100(20): 4790-4796.
- Kaviraj, Sharma S (2003). Municipal solid waste management through vermicomposting employing exotic and local species of earthworms. *Bioresour. Technol.* 90: 169-173.
- Krishnamoorthy RV (1990). Mineralization of phosphorus by faecal phosphatases of some earthworms of Indian tropics. *Proc. Indian Acad. Sci. (Ani. Sci.)*, 99: 509-518.
- Krishnamoorthy RV, Vajranabhaiah SN (1986). Biological activity of earthworm casts: an assessment of plant growth promoter levels in the casts. *Proc. Indian Acad. Sci. (Anim. Sci.)*, 95: 341-351.
- Lee KE, Foster RC (1991). Soil fauna and soil structure. *Aust. J. Soil Res.* 29: 745-776.
- Mousavi SM, Bahmanyar MA, Pirdashti H, Gilani SS (2010). Trace metals distribution and uptake in soil and rice grown on a 3-year vermicompost amended soil. *Afr. J. Biotechnol.* 9(25): 3780-3785.
- Muscolo A, Bovolenta F, Gionfriddo F, Nardi S (1999). Earthworm humic matter produces auxin-like effects on *Daucus carota* cell growth and nitrate metabolism. *Soil Biol. Biochem.* 31: 1303-1311.
- Parthasarathi K, Ranganathan LS (1999). Longevity of microbial and enzyme activities and their influence on NPK content in pressmud vermicasts. *Eur. J. Soil Biol.* 35: 107-113.
- Parthasarathi K, Ranganathan LS (2001). Supplementation of pressmud vermicasts with NPK enhances growth and yield in leguminous crops (*Vigna mungo* and *Arachis hypogaea*). *J. Curr. Sci.* 2: 35-41.
- Pontillas L, Lugo E, Malate R, Lanioso A (2009). Efficacy evaluation of vermicompost and inorganic fertilizer applied in lowland rice.

- Threshold, 4: 66-75.
- Prajapati KK, Yami KD, Singh A (2008). Plant growth promotional effect of *Azotobacter chroococcum*, *Piriformospora indica* and vermicompost on rice plant. Nepal J. Sci. Technol. 9: 85-90.
- Prakash M, Jayakumar M, Karmegam N (2008). Physico-chemical characteristics and fungal flora in the casts of the earthworm, *Perionyx ceylanensis* Mich. reared in *Polyalthia longifolia* leaf litter. J. Appl. Sci. Res. 4(1): 53-57.
- Prakash M, Karmegam N (2010a). Dynamics of nutrients and microflora during vermicomposting of mango leaf litter (*Mangifera indica*) using *Perionyx ceylanensis*. Int. J. Global Environ. Issues, 10(3-4): 339-353.
- Prakash M, Karmegam N (2010b). Vermistabilization of pressmud using *Perionyx ceylanensis* Mich. Bioresour. Technol. 101: 8464-8468.
- Raja Sekar K, Karmegam N (2009). Efficiency of the earthworm, *Eisenia fetida* (Sav.) in vermistabilization of silkworm litter mixed with leaf litter. Int. J. Appl. Environ. Sci. 4(4): 481-486.
- Raja Sekar K, Karmegam N (2010). Earthworm casts as an alternate carrier material for biofertilizers: Assessment of endurance and viability of *Azotobacter chroococcum*, *Bacillus megaterium* and *Rhizobium leguminosarum*. Sci. Horticul. 124: 286-289.
- Rajani BS, Radhakrishna D, Ramakrishnaparama VR, Kale RD, Balakrishna AN (2001). Influence of vermicomposting of urban solid wastes on microbial density and enzyme activities, in Session 4, Soil Biota as Bioindicators of Soil Health. Bagyaraj DJ (Ed.). VII Nat. Symp. Soil Biol. Ecol. Ab. p. 69.
- Sangwan P, Kaushik CP, Garg VK (2008). Feasibility of utilization of horse dung spiked filtercake in vermicomposters using exotic earthworm *Eisenia fetida*. Bioresour. Technol. 99: 2442-2448.
- Suthar S (2007). Vermicomposting potential of *Perionyx sansibaricus* (Perrier) in different waste materials. Bioresour. Technol. 97: 2474-2477.
- Suthar S (2009a). Growth and fecundity of earthworms: *Perionyx excavatus* and *Perionyx sansibaricus* in cattle waste solids. Environmentalist, 29(1): 78-84.
- Suthar S (2009b). Vermicomposting of vegetable-market solid waste using *Eisenia fetida*: Impact of bulking material on earthworm growth and decomposition rate. Ecol. Eng. 35: 914-920.
- Suthar S, Singh S (2008). Vermicomposting of domestic waste by using two epigeic earthworms (*Perionyx excavatus* and *Perionyx sansibaricus*). Int. J. Environ. Sci. Technol. 5 (1): 99-106.
- Tandon HZ (1993). Methods of analysis of soils, plant, water and fertilizers. Fertilizer Development and Consultation Organization, New Delhi., pp. 1-148.
- Tomati U, Galli E (1995). Earthworms, soil fertility and plant productivity. Proc. Int. Colloq. Soil Zool. Acta Zool. Fennica, 196: 11-14.
- Turan NG (1999). The effects of natural zeolite on salinity level of poultry litter compost. Bioresour. Technol. 99: 2097-2101.
- Walkley A, Black IA (1934). An examination of the Degjareff method for determining soil organic matter and prepared modification of the chronic acid titration method. Soil Sci. 34:29-38.
- Yadav A, Garg VK (2011). Recycling of organic wastes by employing *Eisenia fetida*. Bioresour. Technol. 102: 2874-2880.
- Zaller JG (2007). Vermicompost as a substitute for peat in potting media: Effects on germination, biomass allocation, yields and fruit quality of three tomato varieties. Sci. Horticul. 112: 191-199.