Recent Research in Science and Technology 2011, 3(9): 62-67
ISSN: 2076-5061
www.scholarjournals.org

www.recent-science.com

RRST-Zoology

Millipede Composting: A Novel Method for Organic Waste Recycling

M. Karthigeyan[1*] and P. Alagesan[2]

[1]*Arumugam Pillai Seethai Ammal College, Tiruppattur, Affiliated to Alagappa University, Karaikudi, Tamilnadu, India*
[2]*PG and Research Department of Zoology, Yadava College, Madurai, Affiliated to Madurai Kamaraj University, Tamilnadu, India*

Article Info

Article History

Received : 27-05-2011
Revised : 25-07-2011
Accepted : 04-08-2011

*Corresponding Author

Tel : +91-8870141559

Email: meenuharshi@gmail.com

Abstract

Millipedes are known to be macro detrivorous terrestrial arthropods which feed on decaying vegetable matter and mineral soils. An attempt was made to assess the ability of millipede *Xenobolus carnifex* in composting the commonly available organic wastes such as leaf litter, sugarcane trash, rice husk and sawdust and the influence of millicompost prepared from different organic wastes on the growth of vegetable plant, *Abelmoschus esculentus*. In addition, biochemical constituents were also estimated in the millicompost by using standard procedures. The millipede compost derived from leaf litter residues possessed better nutritional content than other organic residues. Further plant height, leaf number, leaf length and fruit length and weight were enhanced when leaf litter derived millicompost was applied. Compost derived from different organic wastes could act as effective organic manure to the crop plants and ecofriendly alternative source to minimize the usage of synthetic fertilizers.

Introduction

Millipedes are important members of the soil and litter fauna in temperate and tropical parts of the world, where they and other invertebrates aid in the breakdown of plant organic matter. Millipedes, as primary destructors of plant debris play highly important roles in soil formation as well as enhance the physiochemical properties of the compost.

In present scenario, adverse effects of inorganic fertilizers on soil health has resulted in practice of organic farming for sustainable agriculture, where organic wastes recycling will be of immense importance. Attempts are made to reduce the use of chemical fertilizer through vermicompost and other bio stimulants. Composting is a biological process in which organic biodegradable wastes are converted into hygienic, humus rich product (compost) for use as a soil conditioner and an organic fertilizer [1]. Nowadays, solid waste compost when applied to agricultural soils has shown beneficial effects on crop development and yields as well as improved soil ecosystem.

To our knowledge, only few works have been so far reported about compost derived from millipedes. The main objective of our current study was to evaluate the millipede compost with and conventionally prepared compost and also to assess the growth promoting efficiency on growth and yield of *Abelmoschus esculentus.*

Materials and Methods

Biology of the composting organism

The millipede, *Xenobolus carnifex*(Fabricius) belongs to the class Diplopoda, order Spirobolida and family Pachybolidae. The body segment of *X.carnifex* is black with a broad median band of dark pink color. Adults have exactly fifty segments and an average length of 60mm and mid segment width (MSW) of 5mm.

Collection and maintenance of experimental animals

The adults of *X. carnifex* were collected from thatched organic roof of the huts in Anaiyur village, a settlement at the outskirts of Madurai, India (lat 9° 58' N and long 78° 10' E). They were acclimatized to the laboratory conditions for a period of one month before the onset of the experiment. Commonly available solid waste materials like leaf litter, sugarcane trash, rice husk and sawdust were chosen to feed the millipedes and to convert them into organic manure by composting process.

Preparation of 'millibed'

The raw materials for this experiment, leaf litter, rice husk, sawdust and sugarcane trash from in and around the outskirts of Madurai. They were dried, ground and powdered. Millibeds were prepared in 8 rectangular culture troughs of equal size i.e., (47 x 32 x16 cm). In all the troughs one kilogram of dried and powdered cow dung was added uniformly. Then the eight troughs were divided into four sets and added with one kg of the powdered wastes viz. leaf litter, sugarcane, rice husk and sawdust respectively. Water was sprinkled over the millibeds to hold moisture content of 60-75% and kept for 2 to 4 days. Then at the end of fourth day, 20 adult millipedes, *Xenobolus carnifex* were introduced in one trough of each set and are named as troughs of "Millicompost". The remaining four troughs without millipedes were also maintained and named as "Compost" (Control). The composting process was extended for a period of 45 days. Throughout the experimental period, appropriate moisture content was maintained. The troughs were covered with wet muslin cloth to prevent the invasion of foreign material and outgoing of millipedes.

Further, the initial and different day intervals of samples were analyzed for biochemical parameters such as organic carbon [2], nitrogen [3], total protein [4], carbohydrates [5], lipid [6], Phosphorous, Potassium and calcium [7].

Preparation of Pot Study

Seeds of *Abelsmoschus esculentus* were purchased from Agriculture College and Research Institute, Madurai. They were surface sterilized with 0.1% mercuric chloride and then sown in earthenware pots (9 cm dia) filled with 15th, 30th and 45th days of composts and millicomposts derived from different substrates (leaf litter, sugarcane trash, rice husk and sawdust). For each treatment, three replicates were maintained. The seed-to-seed distance in pot was maintained as 3-5 cm and pots were watered regularly. After 15th, 30th and 45th days, growth parameters viz., shoot length, root length, total height, total fresh and dry weight, leaf area and moisture content were determined.

Statistical analysis

Wherever required the data were subjected to statistical analysis, like Standard Deviation (S.D), Pearson's product moment Correlation coefficient ('r') and one way ANOVA test.

Results

Millipede composts derived from various organic substances showed significant enhancement in the physiochemical and biochemical constituents. At 15th, 30th and 45th days, organic carbon, nitrogen, carbohydrates, lipid, phosphorous, calcium and potassium were found to be present more in millipede compost when compared to conventionally prepared compost. Similarly, C/N ratio was narrowed in all organic waste residues used (Fig.1). In general, leaf litter millipede compost was found to have more amounts of chemical constituents than rice husk, saw dust and sugarcane trash (Table 1-4).

Table 1: Nutrient composition of millicompost of leaf litter processed by *X. carnifex.*

Parameters	Initial (0 day)	15th day		30th day		45th day	
		Compost	Milli compost	Compost	Milli Compost	Compost	Milli compost
Carbon (%)	20.67 ± 0.826	21.01 ± 0.840	24.11 ± 0.97	21.63 ± 0.865	27.90 ± 1.116	23.63 ± 0.945	32.24 ± 1.28
Nitrogen (%)	0.570 ± 0.022	0.598 ± 0.023	0.723 ± 0.028	0.624 ± 0.024	0.891 ± 0.035	0.703 ± 0.028	1.195 ± 0.047
Protein (mg/gm)	67.17 ± 2.66	76.38 ± 3.05	95.47 ± 3.81	84.52 ± 3.38	142.59 ± 5.70	98.45 ± 3.93	196.82 ± 7.87
Carbohydrate (mg/gm)	11.92 ± 0.95	12.05 ± 0.72	12.60 ± 0.63	12.82 ± 0.76	14.40 ± 0.72	13.10 ± 0.65	18.62 ± 0.74
Lipid (mg/gm)	4.92 ± 0.19	5.19 ± 0.20	6.65 ± 0.26	5.97 ± 0.238	8.88 ± 0.35	7.36 ± 0.29	11.16 ± 0.44
Phosphorus (%)	0.224 ± 0.020	0.241 ± 0.021	0.284 ± 0.025	0.277 ± 0.024	0.316 ± 0.028	0.312 ± 0.028	0.426 ± 0.038
Potassium (%)	0.685 ± 0.027	0.724 ± 0.028	0.817 ± 0.032	0.777 ± 0.031	1.124 ± 0.044	0.123 ± 0.01	1.507 ± 0.06
Calcium (%)	1.416 ± 0.05	1.491 ± 0.059	1.547 ± 0.061	1.514 ± 0.060	1.723 ± 0.068	1.637 ± 0.065	2.124 ± 0.084

Each value represents the mean (X ± S.D) of 3 estimates.

Table 2: Nutrient composition of millicompost from rice husk processed by *X. carnifex.*

Parameters	Initial (0 day)	15th day		30th day		45th day	
		Compost	Milli compost	Compost	Milli compost	Compost	Milli compost
Carbon (%)	18.47 ± 0.738	18.86 ± 0.951	21.26 ± 0.850	19.83 ± 0.991	24.74 ± 0.989	22.01 ± 0.880	27.68 ± 1.107
Nitrogen (%)	0.384 ± 0.034	0.396 ± 0.031	0.455 ± 0.022	0.422 ± 0.029	0.573 ± 0.028	0.497 ± 0.039	0.696 ± 0.041
Protein (mg/gm)	44.38 ± 1.77	52.42 ± 2.09	59.72 ± 2.38	64.32 ± 2.57	79.96 ± 3.19	76.51 ± 3.06	98.66 ± 3.94
Carbohydrate (mg/gm)	15.39 ± 0.923	15.86 ± 0.634	16.72 ± 0.634	16.56 ± 0.826	19.91 ± 0.79	17.16 ± 0.85	26.54 ± 1.06
Lipid (mg/gm)	3.24 ± 0.194	3.50 ± 0.315	3.94 ± 0.197	4.12 ± 0.160	5.76 ± 0.403	5.61 ± 0.412	7.98± 0.798
Phosphorus (%)	0.172 ± 0.015	0.178 ± 0.016	0.183 ± 0.016	0.187 ± 0.015	0.201 ± 0.014	0.196 ± 0.017	0.224 ± 0.017
Potassium (%)	0.421 ± 0.0378	0.478 ± 0.033	0.508 ± 0.030	0.545 ± 0.049	0.597 ± 0.035	0.588 ± 0.052	0.716 ± 0.028
Calcium (%)	0.985 ± 0.039	0.997 ± 0.039	1.063 ± 0.042	1.022 ± 0.040	1.174 ± 0.046	1.156 ± 0.046	1.281 ± 0.051

Each value represents the mean (X ± S.D) of 3 estimates.

Table 3: Nutrient composition of millicompost from sugarcane trash processed by *X. carnifex.*

Parameters	Initial (0 day)	15th day		30th day		45th day	
		Compost	Milli compost	Compost	Milli compost	Compost	Milli compost
Carbon (%)	10.20 ± 0.714	10.73 ± 0.085	11.88 ± 0.926	12.36 ± 0.865	14.76 ± 0.738	13.79 ± 0.827	15.18 ± 0.671
Nitrogen (%)	0.156 ± 0.015	0.167 ± 0.009	0.188 ± 0.013	0.195 ± 0.009	0.245 ± 0.019	0.224 ± 0.020	0.297 ± 0.020
Protein (mg/gm)	26.30 ± 1.05	29.55 ± 1.18	32.63 ± 1.30	33.71 ± 1.34	37.64 ± 1.49	39.48 ± 1.57	46.79 ± 1.87
Carbohydrate (mg/gm)	16.76 ± 0.836	17.25 ± 0.862	18.52 ± 0.92	17.94 ± 0.71	21.58 ± 0.86	20.51 ± 0.82	32.42 ± 1.29
Lipid (mg/gm)	2.20 ± 0.198	2.41 ± 0.216	2.88 ± 0.144	3.01 ± 0.210	3.94 ± 0.315	3.77 ± 0.263	5.26 ± 0.473
Phosphorus (%)	0.094 ± 0.003	0.095 ± 0.008	0.099 ± 0.009	0.099 ± 0.007	0.108 ± 0.007	0.104 ± 0.006	0.126 ± 0.011
Potassium (%)	0.124 ± 0.011	0.126 ± 0.011	0.128 ± 0.011	0.13 ± 0.013	0.135 ± 0.012	0.134 ± 0.012	0.141 ± 0.012
Calcium (%)	0.923 ± 0.083	0.929 ± 0.065	0.945 ± 0.056	0.936 ± 0.084	0.976 ± 0.039	0.951 ± 0.038	1.025 ± 0.041

Each value represents the mean (X ± S.D) of 3 estimates.

Table 4: Nutrient composition of millicompost from saw dust processed by *X. carnifex.*

Parameters	Initial (0 day)	15th day		30th day		45th day	
		Compost	Milli compost	Compost	Milli Compost	Compost	Milli compost
Carbon (%)	29.41 ± 1.176	29.62 ± 1.481	30.55 ± 1.22	29.81 ± 1.192	33.24 ± 1.329	31.33 ± 1.253	35.22 ± 1.408
Nitrogen (%)	0.322 ± 0.032	0.325 ± 0.029	0.339 ± 0.027	0.331 ± 0.029	0.375 ± 0.026	0.353 ± 0.021	0.428 ± 0.038
Protein (mg/gm)	56.32 ± 2.25	62.35 ± 2.49	66.82 ± 2.67	71.39 ± 2.85	84.78 ± 3.39	82.55 ± 3.30	107.53 ± 4.30
Carbohydrate (mg/gm)	18.54 ± 0.92	19.25 ± 0.77	20.96 ± 0.83	22.36 ± 0.89	26.09 ± 1.04	24.21 ± 0.96	32.42 ± 1.29
Lipid (mg/gm)	5.48 ± 0.328	5.96 ± 0.417	6.43 ± 0.514	6.10 ± 0.240	7.21 ± 0.360	6.88 ± 0.619	8.56 ± 0.599
Phosphorus (%)	0.215 ± 0.012	0.217 ± 0.019	0.220 ± 0.017	0.220 ± 0.020	0.231 ± 0.018	0.228 ± 0.015	0.245 ± 0.022
Potassium (%)	0.508 ± 0.030	0.522 ± 0.041	0.527 ± 0.047	0.559 ± 0.039	0.612 ± 0.036	0.610 ± 0.054	0.687 ± 0.048
Calcium (%)	0.942 ± 0.056	0.946 ± 0.075	0.956 ± 0.085	0.952 ± 0.084	0.972 ± 0.097	0.964 ± 0.077	0.998 ± 0.059

Each value represents the mean (X ± S.D) of 3 estimates.

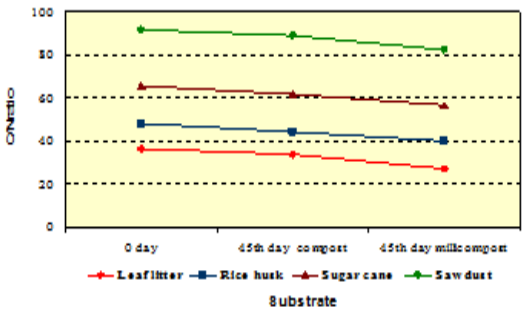

Fig. 1. C/N ratio of the compost and millicompost of different samples processed by *X.carnifex*

Organic carbon was steadily increased in leaf litter wastes from 20.67 to 32.24% at the end of 45th day. Similarly, the carbon content was significantly increased in compost prepared from rice husk, saw dust and sugarcane trash with millipedes. Among the four organic substrates, millipede compost derived from leaf litter was found to contain more amount of organic carbon. Compost and millicompost prepared from leaf litter showed maximum nitrogen content (0.703 and

1.195%) when compared to rice husk (0.384 and 0.696%) and saw dust (0.322and 0.428%). Minimum amount of nitrogen (0.224 and 0.297%) was noticed in the compost and millicompost obtained from sugarcane trash. Once again, Phosphorous content was found to be rich in leaf litter derived millipede compost (0.426%) than the compost (0.316%) at the end of the 45th day of composting. Similarly, potassium (0.685%) and calcium (2.216%) was found to be higher in leaf litter (0.685%) derived millipede compost than any other organic substrates.

At the final stage (after 45 days), it was found to be 26.98, 39.77, 56.51 and 82.28 in leaf litter, rice husk, and sugarcane and saw dust millicomposts respectively. Leaf litter wastes considerably decreased the C/N ratio, thus rendering the soil for plant growth.

Biochemical constituents were also enhanced in millipede compost when compared to compost. Protein and lipid was found to be more in leaf litter derived millipede compost than other substrates. Moreover, millipede compost recorded 11.16mg/gm of lipid content in final days of composting derived from leaf litter wastes. Similarly, protein and lipid content in conventionally derived compost was found to be minimum when compared to millipede compost. But, in case of carbohydrate, the content was found to be more in saw dust millicompost (32.42mg/gm) when compared to rice husk (26.54 mg/gm), sugarcane (24.87mg/gm) and leaf litter (18.62mg/gm).

Pot experiment:

Influence of millipede compost obtained from different organic wastes on growth and yield of *Abelmoschus esculentus* was also assessed. The results revealed that the plants grown on leaf litter compost and millicompost attained a maximum height (20.3 and 28.4cm) when compared to rice husk (18.2 and 21.8cm), sugarcane (17.4 and 21.3cm) and saw dust (16.2 and 20.5cm). Increased number of leaves and leaf length was observed in leaf litter millicompost (9.0/plant;15.2cm) when compared to rice husk (8.0/ plant; 14.6cm), sugarcane (7.0/plant; 13.7cm) and saw dust (5.0/plant; 13.2cm) millicomposts (Table. 9). Similarly, the length and weight of the fruit was also found maximum (14.3cm; 15.6gm) in leaf litter when compared to saw dust millicompost (12.2cm; 13.1gm) treated plants.

Table 5. Effect of millicompost of different samples on the growth and yield of *Abelmoschus esculentus*.

Organic waste	Height	Leaf number	Leaf length	Fruit length	Fruit weight
Leaf litter	28.4 ± 2.27	9.0 ± 0.48	15.2 ± 0.51	14.3 ± 0.43	15.6 ± 0.87
Rice husk	21.8 ± 1.26	8.3 ± 0.40	14.6 ± 0.71	13.2 ± 0.76	14.7 ± 0.77
Sugar cane	21.3 ± 1.71	6.7 ± 0.44	13.7 ± 0.8	12.7 ± 0.63	13.8 ± 0.76
Saw dust	20.5 ± 1.85	5.3 ± 0.42	13.2 ± 0.72	12.2 ± 0.72	13.1± 0.64

Each value represents the mean (X ± S.D) of 3 estimates.

Discussion

The results obtained from our present investigation revealed that millicompost prepared from different organic wastes processed by the millipede, *Xenobolus carnifex* was highly potential than the compost produced by conventional methods, in terms of nutritional quality and also their effect on growth of the vegetable plant, *Abelmoschus esculentus*.

The quality of millicompost produced from different organic wastes depends very much on the material that has been used [8]. In our study, the millicompost prepared from the leaf litter waste with *X. carnifex* showed the richest nutrient content when compared to other millicomposts. Our results were in line with the previous observations made by various workers [9, 10, 11, 12]. Similarly, Leaf litter compost supplies heavy inoculum of microorganisms [13] and moulds, which are known to shift the compost pH from acidic towards neutral [14]. Fragments of leaf litter in the faeces have a greater surface area for microbial colonization, which enhances the rate of decomposition [15, 16].

In the our present investigations, the magnitude of increase of carbon in the millicomposts over the composts are 1.65, 1.56, 1.50 and 1.20 times in sugarcane trash, leaf litter, rice husk and saw dust respectively. Maximum and minimum level of nitrogen acceleration was observed in leaf litter (2.10 times) and saw dust (1.33 times) with advancing days of composting. The increase in organic nutrients may be due to the presence of gut microflora of the millipede [17]. The increased level of nitrogen in the millicompost may be due to the excretory products of the millipedes and by the increased rate of mineralization of organic nitrogen by the micro organism in the millipede feces [18]. High degree of decomposition and mineralization increase high nitrogen content of soil which may fix atmospheric nitrogen in significant quantities and also act as vital source of nitrogen for the plant growth [19]. The narrow C/N ratio in treated samples indicates the enhancement of respiration, influenced by the activities of *A. magna* [11]. Our results were in accordance with the earlier studies made by Bano and Krishanmurthy, [9], Ashwini and Sridhar, [10], Prabhas et. al. [12].

Biochemical constituents viz. protein, carbohydrate and lipid in millicomposts were found to be enhanced along with the duration of composting. Increase in the protein content may

be due to the fact that the millipedes can convert 20- 40 % of their assimilated energy in to high quality protein, rich in most of the essential amino acids [20]. Enhancement in carbohydrate content may be due to the action of cellulases, xylanases and lignases of the gut microbes present in *X. carnifex* [18, 21]. Similarly, the rise in lipid content of the organic wastes processed by millipede may be also due to the synthesis of fatty acids by the microbial population present in the gut of the millipede [17].

However, concentrations of nitrogen and phosphorus increased due to digestion and faecal pellet formation in pill millipedes (*Glomeris marginata*) [22]. Higher concentration of elements was found in compost derived from millipedes than in control [23]. Nicholson et al. [24] and Webb, [25] observed that the ash and phosphorus were found to be high in faecal pellets of millipedes. Similarly, Mcbrayer, [26] reported that faecal pellets of millipedes increased pH, moisture and bacterial count; decreased fungal count and carbon than undigested leaf litter [26].

In addition, leaf litter millicompost contained all the essential nutrients at the optimum level to enhance the growth and yield of the vegetable plant, *Abelmoschus esculentus* more effectively than others organic residual wastes. Pill millipede compost had a positive effect on plant growth as well as dry matter yield with or without FYM black gram (*Phaseolus mungo*) and finger millet (*Eleusine coracana*) [11].

Conclusions:

The millipedes are known to have a considerable role in the disintegration and decomposition of organic material when added to the soil. Similarly, the millipede compost has known to alter pH towards neutral, elevation of macro and micronutrients and tapering C/N ratio. This indicates that millipede compost could play a vital role in soil enrichment in terms of nutrition and soil microflora. However, further studies on production of compost by millipedes on agricultural residues, soil enrichment and their influence on crop growth and yield. Similarly, application of millipede compost in appropriate proportions with farmyard manure or any other organic manure could play a pivotal role in organic farming as well as eco-friendly approach towards sustainable agriculture. Investigations are necessary to understand the rate of millipede compost amendment to increase the growth, dry matter and yields in different plant species.

References

[1] Popkin, R. 1995. Good news for waste watchers: recycling, composting show results for the future. *Environ. Prot. Agency J.*, 21: 188–90.

[2] Jackson M.L. 1962. Soil chemical analysis. Constable and Co. Ltd. London, pp 183-192.

[3] Umbreit, W.W., R.N. Burris and J. F. Stauffer, 1974. Method for nitrogen estimation. In: Manometric and Biochemical Techniques. Minneasota: Burgess Publishing company . 358p.

[4] Lowry, O.I., N.J. Rosebrough, A.L. Farr and R.J. Randall, 1951. Protein measurement with Folin phenol reagent. *J. Biol. Chem.* 193: 265- 275.

[5] Seifter, S., S. Dayton, B.Novic and K. Muntwyler, 1950. The estimation of glycogen with the anthrone reagent. *Archi. Biochem. and Biophy.* 2: 191- 200.

[6] Bragdon, J. H. 1951. Colorimetric determination of blood lipids. *Biol.Chem.*190: 513.

[7] Humpshires, E.C. 1956. Mineral components and ash analysis. In: Modern methods of Plant analysis. Ed. Rach K and M.V Tracer. Springer-Valeg. Berlin.

[8] Albanel, E., J. Plaixats and T.Cabrero. 1988. Chemical changes during Vermicomposting (*E.fetida*) of sheep manure mixed with cotton industrial waste. *Biol.Fertl.Soils*,6: 266-269.

[9] Bano, K and R. V. Krishnamoorthy. 1981. Consumatory responses of the millipede *Jonespeltis splendidus* in relation to soil organic matter- *Proc. Indian Acad. Sci., (Anim. Sci.)* 90: 631- 640.

[10] Ashwini, K.M. and K.R. Sridhar. 2002. Towards organic farming with millipede *Arthrosphaera magna*. Curr. Sci. 82: 20-22.

[11] Ashwini, K.M and Sridhar K.R. 2006. Breakdown of plantation residues by pill millipedes (*Arthrosphaera magna*) and assessment of compost quality. *Curr. Sci.* 90 (7), 954-959.

[12] Prabhas C.T., P.Apurva and K.S. Shailendra. 2011. Comparative study of characteristics of biocompost produced by millipedes and earthworms. *Adv. Appl. Sci. Res., 2011, 2 (3):94-98*

[13] Eberhardt, D. L and W. O. Pipes.1974. The fungus flora of composts *Trans. Br. Mycol. Soc*., 35, 215–220.

[14] Guar, A. C. and K. V. Sadasivam. 1993. Theory and practical considerations of composting organic wastes. In *Organics in Soil Health and Crop Production* (ed. Thampan, P. K.), Peekay Tree Crops Development Foundation, Cochin, pp. 1–21.

[15] Jenson V., 1974. Decomposition of angiosperm tree leaf litter. In *Biology of Plant Litter Decomposition* (ed. Dickinson, C. H. and Pugh, G. J. F.), Academic Press, London, pp. 69–104.

[16] Hopkin, S. P and H. J. Read. 1992. *The Biology of Millipedes*, Oxford University Press, Oxford.

[17] Bano, K., D.J. Bagyaraj and R.V. Krishnamoorthy. 1976. Feeding activity of the millipede, *Jonespeltis splendidus*. *Proc. Indian Acad. sci*., 83: pp 1- 11.

[18] Alagesan, P., B.Ashokkumar, J. Muthukrishnan and P.Gunaskaran, 2003. Isolation and characterization of gut bacteria of the millipede, *Xenobolus carnifex* (Fabricius) . *Indian J. Microbiol.* 43 (2): 111-113.

[19] Hari, T. K., K. Thankamani, and P.K. Sushama, 2004. Value addition of compost to enrich the soil.3: *Agrobios*, 18- 20.

[20] Bano, K. and R.V. Krishnamoorthy, 1977. Changes in the composition of soils due to Defaecation by the Millipede *Jonespeltis splendidus* (Verhoef) *Mysore J.Agri.Sci.* 11: 561-566.

[21] Gajalakshmi. and S.A. Abbasi. 2004. Earthworms and vermicomposting. *Indian J. Biotech.* 3: 486- 494.

[22] Maraun, M. and Scheu, S, 1996. Changes in microbial biomass respiration and nutrient status of beech (*Fagus sylvatica*) leaf litter processed by millipedes (*Glomeris marginata*). *Oecologia*, 107, 131–140.

[23] Smit, A.M. and van Aarde, R. J, 2001. The influence of millipedes on selected soil elements: a microcosm study

on three species occurring on coastal sand dunes. *Funct. Ecol*., 15, 51–59.

[24] Nicholson, P. B., Bocock, K. L. and , O. W, Heath. 1966. Studies on the decomposition of the faecal pellets of a millipede (*Glomeris marginata* Villers). *J. Ecol*., 54, 755–766.

[25] Webb, D. P. 1977. Regulation of deciduous forest litter decomposition by soil arthropod faeces. In *The Role of Arthropods in Forest Ecosystem* (ed. Mattson, W. J.), Springer-Verlag, Heidelberg, pp. 57–69.

[26] McBrayer, J. F. 1973. Exploitation of deciduous leaf litter by *Apheleria montana* (Diplopoda: Eurydesmidae). *Pedobiologia*, 13, 90– 98.