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ORIGINAL ARTICLE

STANDARDIZATION OF AGROINDUSTRIAL WASTES FOR VERMICULTURE AND VERMICOMPOSTING PRACTICES

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ABSTRACT

India is the largest producer of sugar and during the period of sugar production from the 464 sugar mills and 319 molasses based distilleries large volume of organic waste are produced (pressmud, bagasse, molasses, sugarcane trash and molasses based distillery waste effluent). There are about 10.0 million tones of pressmud per annum, 40 million tones of cane trash and 40.40 x 10^{10} of effluent per annum are produced with more renewable energy sources. These energy resources as wastes are discharged on land or into near by water bodies particularly without any treatment and serve as a major causes of environmental pollution. Disposal and environmental friendly management of these agroindustrial wastes has become a serious global problem. By using vermicomposting technique, efforts have been made to vermicompost the enormously available and unutilized agroindustrial wastes – pressmud (PM), sugarcane trash (ST) and biomethanated distillery effluent (BE) with six different propostions (1000 g PM + 0 g ST + 790 ml BE, 900 g PM + 100 g ST + 740 ml BE, 800 g PM + 200 g ST + 696 ml BE, 700 g PM + 300 g ST + 655 ml BE, 600 g PM + 400 g ST + 625 ml BE and 500 g PM + 500 g ST + 542 ml BE) and during this process the earthworm activity – *Perionyx excavatus* like mortality, biomass, cocoon production, hatchling and vermicompost recovery were studied. The pronounced and better earthworm activity was found in all the treatment proportions, especially more in 800 g PM + 200 g ST + 696 ml BE than other treatments proportions. This seems to be due to rich cellulose, OC, N, P, microbial activity and enhanced water holding capacity. Finally, the agroindustrial wastes-pressmud, sugarcane trash and biomethanated distillery effluent combination to be better vermicomposted by *P. excavatus* and used for vermiculture and vermicomposting practices.

Keywords: Agroindustrial wastes, *Perionyx excavatus*, vermiculture, vermicompost, reproductive performance.

1.INDRODUCTION

Vermicomposting is an effective energy efficient recycling process. It involves earthworms that utilize organic wastes from urban, industrial and agriculture as material for recovery of organic fertilizer. The feasibility of using earthworms for waste management as well as a potential source for protein for animal nutrition depends on a fundamental knowledge of the basic parameters governing the survival, growth and reproduction of earthworm species. The reproductive potential of earthworms were influenced by the quality and availability of food (Neuhauser *et al*, 1979; Edwards *et al*, 1998; Bhattacharjee, 2002). It is also reported that kind and amount of food materials available influence the size of the earthworm population, species diversity, growth and fecundity. Earthworms have been shown to require food rich in nitrogen, cellulose and microorganisms for growth and reproduction (Hartenstein and Bisesi, 1989; Ranganathan and Parthasarathi, 1999).

Many authors have studied the life cycle of the tropical, composting earthworm species - *Perionyx excavatus* (Kale *et al*, 1982; Reinecke and Hallatt, 1989; Hallatt *et al*, 1990; Edwards *et al*, 1998; Biradar *et al*, 1999; Chaudhuri and Bhattacharjee, 2002; Parthasarathi, 2007a). Hallatt *et al* (1990) have studied the growth rate, rate of maturation, cocoon production, the hatching success of cocoons, the incubation period and the number of offsprings per cocoon under controlled laboratory conditions at different moisture and temperature regimes. Biradar *et al.* (1999) studied seasonal variations in growth and reproduction of *P. excavatus* cultured in cow manure, *P. excavatus* seems to be the most promising species for vermicomposting under tropical conditions. It is extremely prolific for use in vermiculture and very easy to handle and to harvest. However in the context of tropical countries, particularly

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India, our knowledge of the right type of food for the right type of earthworm for large scale vermiculture, a prerequisite for vermicomposting, is inadequate. The main objectives of the present study is to determine the best combinations of sugar industrial wastes that would support the maximum growth, production of cocoons, rate of hatchlings and vermicompost recovery in epigeic worms, *Perionyx excavatus*

2.MATERIALS AND METHODS

Collection and preparation of experimental substrates

In the experimental studies, two months old and cured PM free of foul smell and the BE were collected from E.I.D Parry (I) sugar factory at Nellikuppam, Cuddalore district, Tamil Nadu, India at different times of the year. The dried sugarcane trash was collected from sugarcane experimental farm at Madhikulam Madurai district, Tamil Nadu, India. The chemical composition of agroindustrial wastes are given in the table 1.

The PM and chopped ST (>3 cm) were weighed (dry weight) in the above said proportions and mixed well. The substrates (PM and ST) were make it into 65-70% moisture content by sprinkling of BE in each treatments and constantly maintained upto 60 days. For making 65-70% moisture contents of substrates by adding required ml of BE from each per kg of the substrates are given in the table 2. The substrates (PM, ST and BE) (T_1-T_6) were left for 96 hours to stabilize before the experimental animals were inoculated into them. One kg of 96 hours stabilized substrates (T_1-T_6) were taken in a plastic trough (32 cm diameter and 20 cm height) at 31 ± 2°C and 65% relative humidity (Thermo-Hygrometer, Germany). The sides and bottom of the each trough was perforated to facilitate free aeration and to avoid water logging in the trough. The trough were covered with nylon mesh and maintained in the laboratory at aforementioned conditions for 60 days. Experimental bedding were kept in triplicate for each treatment.

Earthworm collection and inoculation

Perionyx excavatus was collected from the stock culture, Department of Zoology, Annamalai University, Chidambaram, Tamil Nadu, India. 15 g of sexually immature preclitellate *P. excavatus* (36 numbers, 15-18 days old) were inocuted into each plastic troughs separately. The worms were not feed with additional substrates in the duration of the experiments (60 days).

Earthworm activity in the vermibeds

The mortality (%) of the worms were absorved on every day morning in each treatments up to 60 days. The growth of the worms (biomass in wet weight) were determining before the animals were inoculated into each of the treatment substrates and at the end of the experiment (60^{th} days) by an electronic balance. The reproductive parameters like number of cocoon production and number of hatchlings were counted on the 60^{th} day by hand sorting method (Parthasarathi, 2007a). The vermicompost was collected on the 60^{th} day by hand sorting method and weighed (Parthasarathi, 2004).

3.RESULTS

The earthworm activity like mortality, growth, cocoon production, hatchling number and recovery of vermicompost by *P.excavatus* reared on different combination of agroindustrial wastes (T_1 – T_6) up to 60 days are given in the table 3. The precomposted T_1 – T_6 agroindustrial waste treatments during vermicomposting process when inoculated with *P. excavatus* it was found that there is no mortality of worms in all the treatments. As summarized in table 3, the rate of growth (biomass), reproduction (cocoon production and hatchlings) and recovery of vermicompost of *P. excavatus* were highest in T_1 followed by T_3 and T_2 treatments and than the values obtained from other treatments (T_4, T_5 and T_6).

Table 1. Chemical composition of agroindustrial wastes

Parameters	PM	ST	BE
pH	7.85	7.68	7.80
Electrical conductivity (dSm^{-1})	0.84	0.76	19.26
Moisture content (%)	12.14	-	94.55
BOD (mg/L)	-	-	5670
COD (mg/L)	-	-	37480
Organic carbon (%)	39.06	38.17	14.15
Nitrogen (%)	2.02	0.98	2.26
Phosphorus (%)	1.99	0.85	0.78
Potassium (%)	0.58	0.29	9.46
Magnesium (%)	0.38	0.27	712*
Calcium (%)	2.44	1.93	1920*
Sodium (%)	0.11	0.08	38*
Zinc (ppm)	60	18	1.66*
Iron (ppm)	1175	824	56.22*
Copper (ppm)	18	14	3.12*
Manganese (ppm)	122	120	5.03*
C:N ratio	19:1	39:1	6:1
C:P ratio	20:1	45:1	18:1
Crude protein (%)	12.6	6.1	14.13
Total microbial population (CFU x 10^6 g^{-1})	520	-	111
Dehydrogenase[a]	7.76	0.96	2.10
Lignin (mg/g)	41	86	-
Cellulose (mg/g)	153	277	-
Hemicellulose (mg/g)	26	32	-
Phenol (mg/100g)	44	56	-
Humic acid (mg/5g)	21.36	0.18	-

Table 2. Description of agro industrial wastes for experiment

Treatment	Description	Substrates PM (g)	ST (g)	BE (ml)
T_1	10:0	1000	0	790
T_2	9:1	900	100	740
T_3	8:2	800	200	696
T_4	7:3	700	300	655
T_5	6:4	600	400	625
T_6	5:5	500	500	542

PM – Pressmud, ST – Sugarcane trash, BE – Biomethanated distillery effluent

In general, regarding vermicomposting of agroindustrial wastes by using *P.excavatus*, biomass of earthworms had increased significantly ($P<0.05$) in all treatments (T_1-T_6), but the overall rate of biomass production was maximum in the T_1 treatment followed by T_3 and T_2 than other treatments. Like the growth of earthworms, the mean cocoon production also varies in different treatments. Among the 6 treatments, earthworm reared on T_1 treatment, followed by T_3 and T_2 treatments were show significantly ($P<0.05$) increased cocoon production than other treatments. Also, significantly ($P<0.05$) highest rates of hatchling number were observed in the T_1 treatment, followed by T_3 and T_2 treatments than other

Table 3. Earthworm (*P. excavatus*) activity during vermicomposting of agroindustrial wastes (n=6)

Treatments (vermibeds)	Mortality (%)		Biomass (g)		Cocoon production (number)		Hatchling (number)		Recovery rate of vermicompost (g)	
	Initial (0 days)	Final (after 60 day)	Initial (0 days)	Final (after 60 day)	Initial (0 days)	Final (after 60 day)	Initial (0 days)	Final (after 60 day)	Initial (0 days)	Final (after 60 day)
(PM+BE)*	-	-	15.2 [a]	38.6 [c]	0	142 [c]	0	184 [c]	0	692 [c]
(PM+ST+BE)*	-	-	15.5 [a]	35.2 [c]	0	116 [b]	0	172 [b]	0	677 [b]
(PM+ST+BE)*	-	-	15.4 [a]	36.4 [c]	0	131 [c]	0	179 [c]	0	683 [c]
(PM+ST+BE)*	-	-	15.6 [a]	33.1 [b]	0	104 [b]	0	164 [b]	0	612 [b]
(PM+ST+BE)*	-	-	15.0 [a]	30.2 [b]	0	88 [a]	0	148 [a]	0	555 [a]
(PM+ST+BE)*	-	-	15.1 [a]	26.4 [b]	0	67 [a]	0	121 [a]	0	442 [a]

ANOVA (TWO-WAY)

Substrates					
Sum of squares	-	81970.28	34992.00	78085.33	1116910.08
Mean of squares	-	6985.18	615.50	243.50	1901.58
F-value	-	486.87	90.983	283.80	233.68
P-value	-	0.000	0.000	0.000	0.000
Treatments					
Sum of squares	-	1851.94	1923.00	1375.66	23897.41
Mean of squares	-	168.359	384.60	275.13	4779.43
F-value	-	1.000	1.000	1.000	1.000
P-value	-	0.500	0.500	0.500	0.500

PM – Pressmud, ST – Sugarcane Trash, BE – Biomethanated distillery effluent;* For treatment (bedding) composition see in the table 2.
Mean value followed by different letters is statistically different (ANOVA; Duncan multiple - ranged test, $P<0.05$)

treatments. Similar to growth and reproductive performance of *P. excavatus* cultured on the 6 different treatments, recovery of vermicompost was significantly ($P<0.05$) highest in T_1 treatment, followed by T_3 and T_2 treatments, than other treatments.

4.DISCUSSION

Vermicomposting is also considered in terms of production patterns of earthworm biomass, numbers of cocoon, numbers of hatchling and vermicompost. Quality of the organic waste is also one of the factors determining the onset and rate of reproduction (Duminguez *et al*., 2001) and recovery rate of vermicompost (Parthasarathi, 2010). Murchie (1960) proved experimentally the existence of a significant relationship between weight increase and susbtrate type, which may reasonably be attributed to nutritional quality of the susbtrate. Growth and reproduction in earthworms require OC, N and P (Evans and Guild, 1948) which are obtained from litter, grit and microbes (Flack and Hartenstein, 1984; Edwards and Bohlen, 1996; Parthasarathi and Ranganathan, 2000b; Parthasarathi, 2010). Earlier studies of Ranganathan and Parthasarathi (1999) and Parthasarathi and Ranganathan (2000b) have shown the higher nitrogen (1.6%) and phosphorus (2.5%) content of pressmud to support better growth (length and biomass) and bring about earlier maturation, earlier differentiation of the clitellum, lobulation in the ovary and release of cocoons in *L. mauritii* and *E. eugeniae* than worms fed with cowdung or clay loam soil. In the present study, the biomass, number of cocoon production, number of hatchling and recovery rate of vermicompost were highest in T_1, T_3 and T_2 followed by other treatments. *P.excavatus* exhibited highest biomass, more cocoon, hatchling and vermicompost production, very particular in the T_3 treatment.

Earthworm accelerates the transformation of organic waste material in to more stabilized forms by aeration and bioturvation, by their excreta and quail-quantitative microflora (Vinceslas-Akpa and Loquest, 1997). The utility of epigeic earthworms for successful degration of organic wastes is well documented for different industries such as: paper and pulp (Elvira et al., 1998); dairy (Gratelly et al., 1996); sugar industry (Parthasarathi, 2007b; 2010); winery and distillery (Nogales et al., 2005); wood and wood chips (Maboeta and Van Rensburg, 2003); textile mills (Kaushik and Garg, 2004); oil (Benitez et al., 2002) power (fly ash) (Gupta et al., 2005); guar gum industry (Suthar, 2007) and distillery industry (Suthar and Singh, 2008). During the process of vermicomposting, the stability of the tested substrate mainly depends on fold increase in essential plant nutrients, lowering of toxicants, earthworm biomass as well as reproductive performances, and even less or no mortality in tested earthworm species. In the present study, no mortality of earthworms were found during vermicomposting of agroindustrial wastes (PM-ST-BE) using predominantly available indigenous epigeic earthworm, *P.excavatus* in all the treatments of vermibeds (up to 60 days). This indicates the favourable and acceptable biochemical and micro environment of the vermibeds and absence of any toxic chemicals in the vermibeds. This present result is similar to those by Suthar and Singh (2008) who reported no mortality earthworm during vermicomposting of distillery industry sludge admixed with cowdung using *P. excavatus.*

Organic waste palatability for earthworms is directly related chemical nature of the waste material that consequently affects the earthworm growth, reproductive performances and compost recovery. The growth rate (total biomass) of earthworm varies between different earthworm species and in different organic wastes: *E. eugeniae, P. excavatus* and *E. fetida* cultured on cowdung (for total period of $year^1$) increase at the rate of $12mg/w^{-1}/d^{-1}$, $S.Smg/w^{-1}/d^{-1}$ and $7mg/w^{-1}/d^{-1}$, respectively (Reinecke *et al*, 1992); *E. eugeniae* and *L. mauritii* on pressmud (for total period of $year^1$) increases $15mg/w^{-1}/d^{-1}$ and $4mg/w^{-1}/d^{-1}$, respectively (Ramalingam, 1997); *E. andrei* (for total period of 70 days) on sludges from paper and pulp industries increases 8.4 $mg/w^{-1}/d^{-1}$ (Elvira *et al,* 1998) and *P. excavatus* (for total period of 150 days) on kitchen wastes increases $2.47mg/w^{-1}/d^{-1}$ (Chaudhuri and Bhattacharjee, 2002). Falling in line with these observations in the present study too (restricted to 60 days), it is observed that the higher nutrient content of PM-ST-BE particularly T_3 treatments (micro and macronutrient and microbial population), was found to be supporting higher growth of the earthworms (biomass).

Like the growth of the worm, the mean cocoon production rate varies between different earthworm species and in different organic wastes: *E. eugeniae* (for one year) on cattle manure have been shown to produce 1.3 $cocoons/w^{-1}/d^{-1}$ (Viljoen and Reinecke, 1994), on sludge (for one year) produce 0.1 $cocoons/w^{-1}/d^{-1}$ (Neuhauser *et al.*, 1979), *E.eugeniae* and *L.mauritii* (for one year) on pressmud produces 1.4 and 0.38 $cocoon/w^{-1}/d^{-1}$, respectively (Ramalingam, 1997) and *E. andrei* on sludges from paper and pulp industries (for 70 days) produced 0.22 $cocoon/w^{-1}/d^{-1}$ (Elvira *et al.*, 1998). Edwards *et al*, (1998) reported a weekly rate of mean cocoon production for *P. excavatus* at 30°C to be 2.03 and 0.98 in cattle solids and digested sewage sludge, respectively. In the present study, T_1 and T_3 treatments followed by T_2 treatments were found to be the best for cocoon production than other treatments.

Hatchability rates of different species of earthworms cultured on different organic wastes show wide fluctuations: 2.7 in *E.fetida* in cattle manure (cultured for 150 days) (Venter and Reinecke, 1988), 2.2 in *E. eugeniae* (cultured for one year) (Viljoen and Reinecke, 1994) on cattle manure, *E. eugeniae* and *L. mauritii* with 2.63 and 3.15 on pressmud (cultured for one year) (Ramalingam, 1997) and *P. excavatus* with 2.45 on cowdung and *P.excavatus* with 1.37 in kitchen wastes (cultured for 105 days) (Chaudhuri and Bhatacharjee, 2002). Falling in line with these studies, in the present study, among the six different treatments of agroindustrial wastes (during culture period of 60 days) more hatchlings were obtained in the T_1 and T_3 treatments followed by T_2 treatments.

The reasons for the enhanced growth and reproduction in T_1 and T_3 treatments followed by other treatments in the present study seems to be due to : rich cellulose content, microbial population and activity and enhanced water holding capacity (39-41%) which enable the T_3 treatment to maintain good and ideal moisture. The dependency of earthworm on soil moisture for their survival and activity and on organic matter rich in N for growth and reproduction is well known (Edwards and Bohlen, 1996; Parthasarathi, 2010). The physical structure of the T_3 treatment substrate depends on the chemical composition of the constituents particularly organic matter rich in N; it is only in such type of substrate (vermicomposting medium) that earthworm could reproduce. The T_3 treatment provides such ideal physico-chemical conditions suitable for better growth and maximum reproduction. Hence, it may be concluded that through PM-ST-BE are nutritionally inferior and slow degrading, the presence of high cellulose in the T_3 treatment develop better water holding capacity and become more palatable and nutritive (rich OC, N, P and microbial population) supporting better growth, reproduction and more compost recovery. Earlier studies of Ranganathan and Parthasarathi (1999), Parthasarathi and Ranganathan(1999; 2000a) and Parthasarathi (2010) have shown the higher N, P, OC, microbial content of pressmud to support better growth, reproduction and more vermicompost production of *L.mauritii, P.excavatus, Eudrilus eugeniae* and *Eisenia fetida*. This was supported by Kale (1998), Edwards and Bohlen (1996), Suthar (2007a) who reported that the factors relating to the growth, reproduction and compost production of earthworms may also be considered in terms of physico-chemical and nutrient characteristics of waste feed stocks.

Organic waste palatability for earthworms is directly related to the chemical nature of the waste material that consequently affects the earthworm growth, reproduction and compost production. Garg *et al.* (2005), Suthar (2007a) and Parthasarathi(2007b;2010) concluded that growth and reproductive performance of *E.fetida, P. sansibaricus* and *P. excavatus* was directly related to the quality of the feed stock. Edwards *et al*. (1998) and Suthar (2006) concluded that the important difference between the rates of cocoon production in the two organic wastes must be related to the quality of the waste. The variability in the earthworm biomass gain and reproduction rate in different treatments was probably related to the palatability, microbiology as well as the chemistry of the feeding stuff. The difference in cocoon production patterns among different treatment suggest a physiological trade-off (Streans, 1992) related to N-limitations. Recently, Suthar (2007a) and Parthasarathi (2007b; 2010) demonstrated that earthworm growth, reproduction (cocoon production and hatchling) and vermicompost production is related to initial N-content of the substrate. Our present experimental results are confirmatory of above hypothesis. Finally, from our experimental observations it is recommended that the agroindustrial wastes-pressmud, sugarcane trash and biomethanated distillery effluent combination particularly 800 g + 200 g and 696 ml could be better vermicomposted by *P.excavatus* and used for vermiculture and vermicomposting practices. Also further studies are needed for the quali-quantitative nutrient assessment of vermicompost, its production in large scale and its application on soil fertility and crop productivity.

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6.REFERENCES

Benitez, E., H.Saizn, R.Melayar and R.Nogales. 2002. Vermicomposting of a lignocellulosic waste from olive oil industry: A pilot scale study. *Waste Management and Research*, 20: 134-142.

Bhattacharjee, G. 2002. Earthworm resources and waste management through vermicomposting in Tripura, Ph.D Thesis in Zoology Department, Tripura University, Tripura, India.

Biradar, V.A., S.D.Amoji., U.M.Shagoti and P.M.Biradar. 1999. Seasonal variations in growth and reproduction of the earthworm *Perionyx excavatus* (Oligochaeta: Megascolecidae). Biol. Fertil. Soils, 28: 389-392.

Chaudhuri, P.S. and G.Bhattachrgee, 2002. Capacity of various experimental diets to support biomass and reproduction of *Perionyx excavatus*. Bioresource Technology, 82: 147-150.

Duminguez, J., C.A.Edwards and J.Ashby. 2001. The biology and population dynamics of *Eudrilus eugeniae* (Kinberg) (Oligochaeta) in cattle waste solids. *Pedobiologia*, 45: 341-353.

Edwards, C.A. and P.J.Bohlen. 1996. Biology and Ecology of Earthworms, Chapman and Hall, London.

Edwards, C.A., J.Dominguez and E.F. Neuhauser. 1998. Growth and reproduction of *Perionyx excavatus* (Perrier) (Megascolecidae) as factors in organic waste management. *Biol. Fertil. Soils*, 27: 155-161.

Elvira, C., L.Sampedro, E.Beritez and R.Nogales. 1998. Vermicomposting of sludge from paper mill and dairy industries with *Eisenia andrei*: A pilot scale study. *Bioresource Technology*, 63: 211-218.

Evans, A.C and W.J.McL, Guild. 1948. Studies on the relationships between earthworms and soil fertility. IV. On the life-cycles of some British Lumbricidae. *Ann. Appl. Biol.*, 35: 471-484.

Flack, F.M. and R.Hartenstein. 1984. Growth of the earthworms, *Eisenia fetida* on microorganisms and cellulose. *Soil Biol. Biochem*., 16: 491-495.

Garg, V.K., P.Kaushik and N.Dilbaghi. 2005. Vermicomposting of waste water sludge from textile mill mixed with anaerobically digested biogass plant slurry employing *Eisenia fetida*. *Ecotoxic and Environ Safe*., 65: 412-419.

Gratelly, P., E.Benitez., C.Elvira., A.Polo and R.Nogales. 1996. Stabilization of sludge from a diary processing plant using vermicomposting. In: fertilizers and environment, C.Rodriquez-Barrueco (Eds), Netherlands, Kluner. (pp.341-343).

Gupta, S.K., A.Tewari, R.Srivastava, R.C.Murthy and S.Chandra. 2005. Potential of *Eisenia fetida* for sustainable and efficient vermicomposting of fly ash. Water Air Soil. Pollut., 163: 293-302.

Hallatt, L., A.J.Reinecke and S.A.Vilzoen. 1990. Life cycle of the oriental compost worm, *Perionyx excavatus* (Oligochaeta). S. Afri. J. Zool., 25: 41: 45.

Hartenstein, R. and M.S.Bisesi, 1989. Use of earthworm biotechnology for the management of effluents from intensively housed livestock. Outlook Agric., 18: 72-76.

Kale, R.D. 1998. Earthworms: Nature's gift for utilization of organic wastes In: Earthworm Ecology (Eds. C.A.Edwards). Ankeny, Lowast. Lucie Press, New York.

Kale, R.D., K.Bano and R.V.Krishnamoorthy, 1982. Potential of *Perionyx excavatus* for utilization of organic wastes. Pedobiologia, 23: 419-425.

Kaushik, P and V.K.Garg. 2004. Dynamics of biological and chemical parameters during vermicomposting of solid textile mill sludge mixed with cowdung and agricultural residues. Bioresource Technology, 94: 203-209.

Maboeta, M.S and L.Van Rensburg. 2003. Vermicomposting of industrially produced woodchips and sewage sludge utilizing *Eisenia fetida*. Ecotoxicology and Environment Safety., 56: 256-270.

Murchie, W.R. 1960. Biology of Oligochaeta Biomastos Zetekismith and Gittins in northern Michigan. *Am. Midd. Nat*., 64: 194-215.

Neuhauser, E.F. D.L. Kaplan and R.Hartenstein. 1979. Life history of the earthworm, *Eudrilus eugeniae* (Kinberg). Rev. Ecol. Biol. Soil, 16: 524-534.

Nogales, R., C.Cifuentes and E.Benitez. 2005. Vermicomposting of winery wate: a laboratory study. Journal of Environmental Science and Health B, 40: 659-673.

Parthasarathi, K and L.S. Ranganathan. 1999. Longivity of microbial and enzyme activity and their influence on NPK content in pressmud vermicasts. *Eur. J. Soil Biol.*, 35: 107-113.

Parthasarathi, K and L.S. Ranganathan. 2000a. Aging effect on enzyme activities in pressmud vermicasts of *Lampito mauritii* (Kinberg) and *Eudrilus eugeniae* (Kinbger). *Biol. Fertil. Soils*, 30: 347-350.

Parthasarathi, K and L.S.Ranganathan, 2015. Pressmud: A rich source of organic manure. Vermeco (in press).

Parthasarathi, K. 2004. Vermicompost produced by four species of earthworms from sugar mill wastes (pressmud). *National Journal of Life Sciences*, 1(1): 41-46.

Parthasarathi, K. 2007a. Influence of moisture on the activity of *Perionyx excavatus* (Perrier) and microbial – nutrient dynamics of pressmud vermicompost. Iran. *J. Environ. Health. Sci. Eng.* 4(3): 147-156.

Parthasarathi, K. 2007b. Life cycle of *Lampito mauritii* (Kinberg) in comparison with *Eudrilus eugenia* (Kinberg) cultured on different substrates. *J. Environ. Biol.,* 28(4): 803-812.

Parthasarathi, K. 2010. Earthworms – Life cycle, Compost and Therapy. Lap Lambert Academic Publishing AG & Co. KG. Germany.

Parthasarathi, K. and L.S.Ranganathan. 2000b. Influence of pressmud on the development of ovary, oogenesis and the neurosecretory cells of the earthworm, *Eudrilus eugeniae* (Kinberg). *African Zoology*, 35(2): 281-286.

Ramalingam, R. 1997. Studies on the life cycle, growth and population dynamics of *Lampito mauritii* (Kinberg) and *Eudrilus eugeniae* (Kinberg) cultured in different organic wastes and analysis of nutrients and microbes of vermicompost. Ph.D Thesis, Annamalai University, India.

Ranganathan, L.S. and K.Parthasarathi. 1999. Precocious development of *Lampito mauritii* (Kinberg) and *Eudrilus eugeniae* (Kinberg) reared in pressmud. *Pedobiologia*, 43: 904-908.

Reinecke, A.J. and L. Hallatt, 1989. Growth and cocoon production of *Perionyx excavatus* (Oligochaeta). Biol. Fertil. Soils, 8: 303-306.

Reinecke, A.J., S.A.Vilzoen and R.K.Saayman, 1992. The suitability of *Eudrilus eugeniae*, *Perionyx excavatus* and *Eisenia fetida* (Oligochaeta) for vermicomposting in

Southern Africa in terms of their temperature requirements. Soil. Biol. Biochem., 24: 1295-1307.

Streans, S.C. 1992. The Evolution of Life History. Oxford University Press, New York, USA.

Suthar, S. 2006. Potential utilization of guar gum industrial waste in vermicompost production. *Bioresource Technology*, 97(18): 2474-2477.

Suthar, S. 2007. Production of vermifertilizer from guar gum industrial wastes by using composting earthworm, *Perionyx sansibaricus* (Perrier). *Environmentalist*. 27: 329-335.

Suthar, S. 2007a. Nutrient changes and biodynamics of epigeic earthworm *Perionyx excavatus* (Perrier) during recycling of some agriculture wastes. *Bioresource Technology*, 98: 1608-1614.

Suthar, S. and S.Singh. 2008. Feasibility of vermicomposting in biostabilization of sludge from a distillery industry. Science of the Total Environment, 394: 237-243.

Venter, J.M. and A.J. Reinecke. 1988. The life cycle of the compost worm, *Eisenia fetida* (Oligochaeta). S. Afr. J. Zool., 23: 161-165.

Viljoen, S.A. and A.J. Reinecke. 1994. The life cycle and reproduction of *Eudrilus eugeniae* under controlled environmental conditions. Mitt Hamb. Zool. Mus. Inst., 89: 149-157.

Vinceslas – Akpa, M and M. Loquest. 1997. Organic matter transformation in lignocellulosic waste products composted or vermicomposted (*Eisenia fetida andrei):* Chemical analysis and C^{13} CPMAS, NMR Spectroscopy. *Soil Biol. Biochem.* 29: 751-758.

Yadav, S. and R.Chandra. 2013. Delection of persistent organic compounds from biomethanated distillery spent wash (BMDS) and their degradation by manganese peroxidase and laccase producing bacterial stains. J. Environ. Biol., 34: 755-764.

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