www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; SP-10(12): 590-596

www.thepharmajournal.com
Received: 11-10-2021
Accepted: 14-11-2021

AK Singh
Scientist, Agricultural Science Centre, Jawaharlal Nehru Agricultural University, Jabalpur, Madhya Pradesh, India

AK Tripathi
Scientist, Agricultural Science Centre, Jawaharlal Nehru Agricultural University, Sagar, Madhya Pradesh, India

SRK Singh
Principal Scientist, ICAR-Agricultural Technology Application Research Institute, Zone IX, Adhartal, Jabalpur, Madhya Pradesh, India

Yati Raj Khare
Scientist, Agricultural Science Centre, Jawaharlal Nehru Agricultural University, Jabalpur, Madhya Pradesh, India

Corresponding Author
AK Singh
Scientist, Agricultural Science Centre, Jawaharlal Nehru Agricultural University, Jabalpur, Madhya Pradesh, India

Significance of substrate straw on nutritive quality of vermicompost and growth of vermiworm species *Eisenia fetida*

AK Singh, AK Tripathi, SRK Singh and Yati Raj Khare

Abstract
An experiment was conducted to assess the significance of substrate straw on nutritive quality of vermicompost and growth of earthworm species *Eisenia fetida* during 2015-16 to 2017-18. *Eisenia fetida* vermiworm was used for vermicomposting in all the five treatments *viz*. cow dung alone, soybean straw + cow dung in 3:1 ratio, soybean straw alone, rice straw + cow dung in 3:1 ratio and rice straw alone. The physiochemical parameters, specifically temperature, pH, electrical conductivity, dry matter, organic carbon, C:N ratio, 7 different nutrients, growth of earthworms and economics of vermicomposting was assessed in all the treatments under study. The results revealed higher organic carbon, N, and Zn content in the vermicompost prepared by rice straw alone, however K, Fe and Mn contents were greater in rice straw + cow dung vermicompost. Phosphorus content observed to be high in the vermicompost prepared by soybean straw alone and Cu was maximum in soybean straw + cow dung vermicompost. Earthworm growth and mass was greater in soybean straw + cow dung followed by rice straw + cow dung vermicompost. Economics of vermicomposting indicated highest net income in soybean straw + cow dung vermicompost, however B:C ratio was greater in the vermicompost prepared by soybean straw alone. This study confirms that vermicompost prepared by rice straw alone and rice straw + cow dung has high nutrient value in general followed by soybean straw + cow dung and can be considered a potential method for safely disposing agricultural waste and improving crop production.

Keywords: substrate straw, *Eisenia fetida*, organic carbon, plant nutrients, vermicompost, economics

Introduction

Nation's food production increased manifold by extensive use of agro-chemicals but at the cost of natural resources, environment and society. Organic farming systems involving various biological sources such as farm yard manure and compost may be considered to be accountable for the food safety and environmental security in future. Hence, non-conventional sources of amending organic matter status of soil are acquiring much attention because of their easy availability, prompt response and feasibility in using over large area in less time (Moradi 2014) [37]. This has led the way for using vermicompost, as nutrient rich organic source. Vermicomposting is a green technique that produces vermicompost from various types of organic wastes using definite earthworm species. It helps farmers to reduce the use of chemical fertilizers and primarily the cost of production. Vermicompost is considered an alternative to chemical additives in agricultural crop production that reduces economic costs, while producing healthier organic products for consumers and enriching the environment (Kaplan 2016) [24]. Vermicompost plays a vital role in non-artificial systems such as organic agriculture, sustainable agriculture, or environmentally friendly agriculture, owing to its potential to improve the nutritional value of crops and enhance soil fertility (Varghese and Prabha 2014) [49]. Vermicompost is an essential element in organic agricultural systems, as it contains beneficial and useful properties for plants. It enhances the physical, chemical and biological properties of the soil and increases its organic content (Ansari and Jaikishun 2011; Chauhan and Singh 2013) [2, 9].

Earthworms are considered one of the primary tools for treating solid organic wastes, which consist of domestic, urban and agricultural wastes. *Eisenia fetida* is one of the earthworm species that works efficiently in breaking down and decaying natural remains and turning these wastes into premium organic compost. The behavioral activity of earthworms i.e. feeding, burrowing and casting enhances the physical, chemical and biological properties of organic matter and soil, thereby augmenting the growth of agricultural crops naturally and safely (Kumar *et al*. 2018) [29].

During the process of vermicomposting, vermiworms are used to transform organic wastes into a high-quality product from degraded organic matter and the dead bodies of vermiworms (Ismail 2005; Devi and Prakash 2015) [20, 11]. This technique of vermicomposting helps to transform various organic wastes (agricultural waste, animal manure and domestic wastes) into nutrient-rich compost for the soil and plants (Bhat *et al.* 2017) [4]. Moreover, because of the humic acids in vermicompost, significant amounts of nutrients such as N, P, K, Ca and Mg accumulate in the shoots, roots and leaves of plants (Tahiri *et al.* 2016) [48]. The concentration of various nutrients in vermicompost depends upon the substrate used for vermicomposting. Variation in nutrient composition of vermicompost prepared from different types of straw wastes has been reported by Kumar *et al.* (2017) [28]. It has also been reported that the digestion of carbohydrates and other polysaccharides from the substrates by inoculated worms may cause carbon reduction during vermicomposting of organic wastes (Suthar 2010) [47]. Vermicompost is a brownish black substance with high porosity, aeration and water retention capacity (Edwards *et al.* 2011) [13]. It is rich in micronutrients and soil beneficial microbes such as nitrogen-fixing and phosphate-solubilizing bacteria and actinomycetes; and it is a sustainable alternative to chemical composts, as well as an excellent growth enhancer and plant crop protector (Chauhan and Singh 2013; Sinha *et al.* 2011) [9, 44]. Keeping in view the above, this study was conducted to assess the physico-chemical characteristics of the vermicompost prepared from locally available substrates using vermiworm species *Eisenia fetida* and its growth.

Materials and Methods

The present study was carried out at vermicomposting unit of Agricultural Science Centre, Sagar, Madhya Pradesh during 2015-16 to 2017-18. Physical and chemical analysis was conducted at the soil and water laboratory of the centre. The experiment was conducted from November 25th till 20th February every year. The farm wastes *viz*. soybean, rice straw and cow dung were used as substrates for vermicomposting. Separate vermicomposting beds were prepared for each treatment with three replicas and the dimension of the bed was kept 10×4×2.5 feet (length ×width ×height).The vermiworm species *Eisenia fetida* was used for preparation of vermicompost in each treatment. In this experiment, there were five treatments *viz*. cow dung alone (T_1), soybean straw + cow dung in 3:1 ratio (T_2), soybean straw alone (T_3), rice straw + cow dung in 3:1 ratio (T_4) and rice straw alone (T_5). The beds having the organic waste mixtures or substrates alone were covered with gunny bags and were watered daily. The earthworms released in the pits after 14 days (after thermogenic stage of microbial decomposition). Healthy earthworms were randomly selected and released in each bed @ 100 earthworms^{-m2}. The experiment was conducted till the maturity of the vermicompost every year. The samples were collected and analyzed for various parameters on 0, 7, 14, 21, 28, 56 days and at maturity stage. Temperature (°C), pH and EC (dSm^{-1}) were recorded on day 7, 28 and at maturity stage. The dry weight of all the five treatments was calculated by oven drying over night at 60°C on day 0, 7, 14, 21 and 28. All the samples were analyzed for organic carbon (at 0, 28, 56 and maturity stage) using the method given by Nelson and Sommers (1982) [38], nitrogen, phosphorus, potassium (at initial and maturity stage) by micro kjeldhal digestion and distillation method (Amma 1989), Koenig and Johnson (1942) [27] and Black (1965) [5] respectively; and micronutrients (Fe, Zn, Cu & Mn) at maturity stage using the method given by Lindsay and Norvell (1978) [31].

Results and Discussion

Physical properties

The data presented in Table 1 dealt with the temperature, pH and electrical conductivity of the pit mixture and matured vermicompost. It is clear from the data that the temperature of the pit mixture on day 7 ranged from 40.5 to 48°C irrespective of the treatments; however the difference between the treatments was non-significant. Maximum temperature was noted in T_1 (cow dung alone) followed by T_2 (soybean straw + cow dung) and T_4 (rice straw + cow dung). Lowest temperature (40.5°C) was noted in T_5 (rice straw alone). High substrate’s temperature of the respective treatments indicated the initialization of bio-waste decomposition which increased the temperature within a week. No definite trend in average temperature was observed after releasing epigeic worm (*Eisenia fetida*) in the pits subsequent to out step the thermogenic stage of microbial decomposition after 14 days in various substrates. The mean temperature on day 28 and at maturity stage ranged from 21.5 to 23.88°C and 21.8 to 23.6°C respectively. The increase in temperature during the vermicomposting process was caused by the heat generated from the respiration and decomposition of sugar, starch and protein by the inhabitants of microorganisms. The rise in temperature is a good sign of microbial activity in the vermibeds, as a higher temperature denotes greater microbial activity (Diaz *et al.* 1993) [12].

The average pH of the pit mixture recorded on day 7, 28 and at maturity stage varied from 6.6 to 7.23, 6.75 to 7.09 and 6.91 to 7.27 respectively under various treatments. In all the observations lower pH values were noted in T_4 (rice straw + cow dung) and T_5 (rice straw alone) treatments over the preceding treatments, however the difference was non-significant. The lower pH values of the rice straw alone and with cow dung may perhaps due to activity of lignocelluloses degradation and formation of ethanol, acetic acid, lactic acid, glycerol and many other products. Finally, the pH value varied from 6.91 to 7.27 with the end product in the vermicomposting treatments T_1 to T_5. This indicates a good quality vermicompost and within the suggested range of 6–8.5, as has been reported by several studies (Fogarty and Tuovinen 1991) [14]. Electrical conductivity of the substrates recorded on day 7, 28 and at maturity stage varied from 0.16 to 0.28, 0.22 to 0.34 and 0.25 to 0.31 dSm^{-1} respectively. No distinct trend in average EC was observed at various observation stages, although lower EC values were noted in T_4 and T_5 over preceding treatments in all the observations excluding T_4 at maturity stage, however the difference was non-significant.

Table 1: Physical properties of substrates during vermicomposting and prepared vermicompost

Treatment	Temperature (°C)			pH			EC (dSm^{-1})		
	Day 7	Day 28	Maturity	Day 7	Day 28	Maturity	Day 7	Day 28	Maturity
T_1	48	23.5	22.7	7.13	7.09	7.21	0.22	0.28	0.29
T_2	47.25	21.5	21.8	7.23	7.05	7.15	0.26	0.34	0.31
T_3	42.5	23.13	22.6	7.16	7.07	7.27	0.28	0.30	0.27
T_4	47	22	22.2	6.60	6.75	6.96	0.19	0.25	0.28
T_5	40.5	23.88	23.6	6.73	6.85	6.91	0.16	0.22	0.25
S.Em±	0.21	0.15	0.19	0.03	0.01	0.02	0.01	0.01	0.01
CD(P<0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV%	0.8	1.2	1.1	0.8	0.4	1.0	4.7	4.5	4.7

Dry matter content

The data shown in Table 2 dealt with the dry matter of various bio-wastes used for vermicomposting. It was observed that dry matter of the raw bio-wastes was in range of 84.55 to 92.94% which was significantly high in T_3 and succeeding treatments than that of T_1. The dry matter content recorded on day 7, 14, 21 and 28 varied from 81.5 to 88.5, 62 to 71.9, 50.5 to 63.5 and 42 to 52% respectively. The rate of decomposition was notably high in cow dung alone (T_1) followed by soybean straw alone (T_2) on day 7, in contrast dry matter content was remarkably lower in above treatments, conversely after a week the decomposition rate increased in T_4 (rice straw + cow dung) wherein dry matter content noted 62% on day 14. Observation taken on day 21 and 28 indicated that the dry matter was markedly low in T_1, T_2 and T_4 in comparison to that of T_3 and T_5. These results suggest that microbial degradation remarkably increased after release of vermiworm in either cow dung alone or it mixed with soybean and rice straw which resulted in low dry matter content than that of the substrates decomposed without cow dung.

Table 2: Dry matter in different substrates at initial and subsequent stages of decomposition

Treatment	Dry matter (%)				
	Initial	Day 7	Day 14	Day 21	Day 28
T_1	84.55	81.50	64.50	50.50	42.00
T_2	88.85	84.50	68.75	52.00	43.60
T_3	89.76	87.50	71.90	59.80	51.50
T_4	92.94	84.90	62.00	55.00	45.00
T_5	92.26	88.50	68.50	63.50	52.00
S.Em±	0.81	0.87	0.79	0.80	0.80
CD (*P*< 0.05)	4.37	4.98	4.17	4.29	4.27
CV%	1.6	1.8	2.0	2.5	3.0

Organic carbon and C:N ratio

The chemical and physical properties of the substrate are important for assessing the quality of the nutrients in the final product. Carbon is a major component of the organic molecules in the vermicompost; it is a source of energy and thus a building block for all organisms (Ansari and Jaikishun 2011; Ismail 2005; Ansari and Rajpersaud 2012) [2, 20, 3]. Numerous physical, chemical and the biological reactions take place during vermicomposting process, consequently resulting changes in the organic matter in a definite period of time.

In the present investigation, organic carbon decreased in all the treatments during vermicomposting over the initial concentration (Table 3). It was found highest in T_5 (rice straw alone) specifically 38.81, 34.28, 26.14 and 21.08% at 0, 28, 56 and maturity (82 days) respectively followed by T_4 (rice straw + cow dung) and T_2 (soybean straw + cow dung). Minimum organic carbon content was recorded in T_1 (cow dung) which was 26.12, 21.08, 15.68 and 8.94% at 0, 28, 56 and maturity (78 days) respectively. Organic carbon was significantly high in T_4 and T_5 than that of T_1 at all the observation stages; however at maturity stage it was considerably high as well in T_2 over T_1. Kumar *et al.* (2017) [28] observed reduction in organic carbon content in all the substrates used for vermicomposting. Some part of organic carbon may be converted to worm biomass through the assimilation process, which therefore reduces the carbon budget of waste substrate in the treatments. A part of the carbon in the decomposing residues evolved as CO_2 and a part was assimilated by the microbial biomass (Cabrera *et al.* 2005). Subsequent to inoculation of worms, the digestion of carbohydrates and other polysaccharides from the substrates may cause carbon reduction during vermicomposting of organic wastes (Suthar 2010) [47]. The reduction in carbon concentration during the composting process was also reported by Chhotu and Fulekar (2008) [10].

Normally plant roots cannot absorb the mineral nitrogen unless the C:N (carbon: nitrogen) ratio is more or less 20:1. In the current study, C:N ratio of the substrates reduced with time consequently due to microbial degradation during vermicomposting (Table 3). It was found highest in T_5 (rice straw + cow dung) which was 61.03, 46.32, 27.82 and 21.95 at initial, day 28, 56 and 82 (maturity) followed by T_4 (rice straw alone) and lowest in T_2 (soybean straw + cow dung) specifically 34.62, 21.53 and 11.73 at respective intervals till day 56, however at maturity stage it was lowest in T_1 (cow dung alone). The C:N ratio in T_3 (soybean straw alone) was noted 34.68, 24.76, 15.64 and 11.14 at initial, day 28, 56 and 77 (maturity) respectively. Rice straw is a material that consists of high C:N ratio and carbon content. Appreciably high C:N ratio was observed in rice straw + cow dung and rice straw alone at all the observation stages. Diaz *et al.* (1993) [12] reported that during composting, C is a source of energy for microorganisms to build up cells. Almost the entire carbon is absorbed by the microorganisms and transformed to CO_2 during the metabolism process of the cells. The left over carbon will be changed into membrane and protoplasm form. Throughout the composting process this organic matter is decomposed by microorganisms through which the organic carbon will be oxidized in aerobic condition to CO_2 gas to the atmosphere and thus lower the C/N ratio. Kaushik and Garg (2003) [25] reported that the reduction in carbon and lowering of C:N ratio in the vermicomposting could be achieved either by the respiratory activity of the earthworms and microorganisms or by an increase in the nitrogen by microbial mineralization of organic matter and also by the addition of the worm's nitrogenous wastes through their excretion. Analogous reduction in the C:N ratio during composting process was reported by Garg and Kaushik (2005) [15]. The vermicomposting resulted in faster reduction of C:N ratio as compared to composts without earthworms (Chhotu and

Fulekar 2008) [10]. According to Levi-Minzi *et al.* (1986) [30] the C:N ratio of the farmyard manure decreased after storing it for a period of three months.

Table 3: Organic carbon and C:N ratio in different substrates at initial and subsequent stages of vermicomposting

Treatment	Organic carbon (%)				C:N ratio			
	Initial	Day 28	Day 56	Maturity	Initial	Day 28	Day 56	Maturity
T_1	26.12	21.08	15.68	8.94	34.85	23.38	13.68	6.78
T_2	28.63	24.21	18.72	14.25	34.62	21.53	11.73	7.92
T_3	28.47	23.94	17.97	12.68	34.68	24.76	15.64	11.14
T_4	38.92	33.79	25.23	20.11	60.92	42.05	25.61	20.86
T_5	38.81	34.28	26.14	21.08	61.03	46.32	27.82	21.95
S.Em±	0.97	0.92	0.79	0.83	0.84	0.89	0.84	0.77
CD (P<0.05)	6.23	5.6	4.11	4.56	4.67	5.26	4.65	3.97
CV%	5.2	5.8	6.6	9.3	3.2	4.9	7.5	9.7

Macronutrients

The data presented in Table 4 dealt with major and micronutrients content in vermicompost prepared by various substrates. The total nitrogen content showed remarkable increase in the vermicompost prepared by various substrates over the initial value of the respective treatments. Maximum N content in vermicompost was noted in T_5 (rice straw alone) followed by T_4 (rice straw + cow dung) and T_2 (soybean straw + cow dung), however minimum in T_1 (cow dung alone). Similar results were reported in previous studies, where N content increased after vermicomposting prepared by agro-wastes (Jaybhaye and Satish 2016; Maheswari and Priya 2018; Manyuchi *et al.* 2017; Oluseyi *et al.* 2016; Ramnarain *et al*. 2019 and Singh 2009) [22, 32, 34, 39, 42, 43]. Broz *et al*. (2016) [6] mentioned that the microbial content of organic compost and vermicompost is responsible for changing the dynamics of N in the soil. Suthar (2007) [45] suggested that earthworms increase the levels of N in the vermicompost through their excretory products, mucus and body fluids and through the decaying tissues of dead worms in the vermicomposting system. The N levels in the vermicompost could be related to the quality of the substrate used to feed the worms (Suthar 2009) [46] or due to the mineralization of organic matter (Garg and Kaushik 2005) [15]. Hand *et al.* (1988) [19] reported that nitrogen mineralization would be greater in the presence of earthworms and this mineral nitrogen was retained in nitrate form.

The total P content in vermicompost prepared by various substrates was markedly high which was in range of 0.71 to 1.14% over the initial value of the substrates used for vermicomposting. Highest TP content was noted in soybean straw followed by T_2 (soybean straw + cow dung) and T_4 (rice straw + cow dung), whereas lowest in T_1 (cow dung alone). The TP values of vermicompost prepared by various substrates were also greater compared with the values recorded by Jaybhaye and Satish 2016 [22] (0.30%), Manyuchi *et al*. 2017 [34] (796.3-838.1 ppm), Ramnarain *et al*. 2019 [42] (0.58%) and Singh 2009 [43] (0.137 mg g^{-1}), which may be attributed to the differences in the bio-wastes used to feed the worms or the different vermicomposting protocols such as decomposition time. Marlin and Rajeshkumar (2012) [33] also recorded a high percentage of TP (2.68-3.61%) in vermicompost obtained from different waste products, such as sawdust, city waste, sugarcane, weeds, pressed mud and slaughter house waste. The release of P during vermicomposting is attributed partly to the activity of phosphatases in the earthworm gut and partly to the P-solubilizing microorganisms present in the worm casts, which convert P into a form more readily available to the plants (Goswami *et al.* 2013; Suthar 2009) [18, 46].

The total K in the vermicompost showed remarkable increase in all the treatments and it ranged from 1.12 to 1.7 over their initial values irrespective of treatments. Maximum TK content was noted in T_4 (rice straw + cow dung) followed by T_5 (rice straw alone) and T_3 (soybean straw + cow dung), whereas minimum in T_1 (cow dung alone). It was noticed that the TK content was considerably greater in the substrates containing rice straw. These values were similar to the K values of 0.54-1.72% reported in earlier studies (Chaudhuri *et al.* 2000; Giraddi 2007; Giraddi 2011; Kale 1998; Kitturmath *et al.* 2007; Meenatchi 2008 and Waseem *et al.* 2013) [8, 16, 17, 23, 26, 35, 50] but much higher than those reported by Jaybhaye and Satish 2016 [22] (0.56%), Maheswari and Priya 2018 [32] (0.15-0.73%), Manyuchi *et al*. 2017 [34] (1915.8-2384.7 ppm), Ramnarain *et al*. 2019 [42] (0.56%) and Singh 2009 [43] (0.176 mg g^{-1}). Vermicompost contains high concentrations of exchangeable K due to the enhanced microbial activity during decomposition, which also enhances the rate of mineralization (Suthar 2007) [45]. The use of rice straw as a medium that can absorb moisture and maintain its structural integrity and porosity, might avoid the loss of K in compost (Iyengar and Bhave 2005) [21].

Micronutrients

It is evident from table - 4 that the Fe content in the vermicompost ranged from 1146 to 1218 mg kg^{-1} irrespective of the treatments. The highest Fe content was observed in T_4 (rice straw + cow dung) followed by T_5 (rice straw alone) and lowest in T_1 (cow dung alone). It was quite low in substrates containing soybean straws alone or with cow dung. Significant difference in Fe content was noticed between all the treatments of vermicomposting. Similar trend of Fe content in vermicompost was observed by Oluseyi *et al*. (2016) [39]; Maheswari and Priya (2018) [32]; Ramnarain *et al*. (2019) [42]; Punjab State council for science and technology (2010) [41] and Singh (2009) [43].

The Zn content in vermicompost prepared by various substrates varied from 38.35 to 47.18 mg kg^{-1} (Table 4). It was significantly greater in T_3 and succeeding treatments over T_1. Maximum and minimum Zn content was noted in rice straw alone and cow dung alone respectively. These results are in line with the vermicomposting studies conducted by Maheswari and Priya (2018) [32]; Oluseyi *et al.* (2016) [39]; Punjab State council for science and technology (2010) [41] and Ramnarain *et al.* (2019) [42]. Pare *et al.* (1999) [40] concluded that the stability of bio solid compost can be correlated with the accumulation of heavy metals and nutrients, and, thus extractability and exchangeability of heavy metals.

Cu content in the vermicompost ranged from 16.71 to 18.56

mg kg^{-1} in the various substrates used for vermicomposting. It was highest in soybean straw + cow dung followed by rice straw + cow dung and lowest in cow dung alone. The accumulation of heavy metals *viz*. Zn and Fe increases during composting, except for Cu whereas the values decrease proportional to the time. The decrease in Cu values in this study is similar to the result reported by Md Sabiani (2004) [36].

It is evident from the table that the Mn content in the vermicompost was in range of 76.32 to 80.61 mg kg^{-1} in all the treatments. Maximum Mn content was recorded in the vermicompost prepared by rice straw + cow dung which was significantly high over the minimum content containing vermicompost prepared by cow dung alone (T_1). It was considerably high in the vermicompost prepared by soybean straw + cow dung in comparison to that of T_1 but the difference was non-significant. These findings are similar to those reported by Maheswari and Priya (2018) [32], Punjab State council for science and technology (2010) [41] and Singh (2009) [43].

Table 4: Major and micronutrients in raw material and vermicompost prepared by different substrates

Treatment	Macronutrients (%)						Micronutrients (mg kg^{-1}) at maturity stage			
	N		P		K		Fe	Zn	Cu	Mn
	Initial	Maturity	Initial	Maturity	Initial	Maturity				
T_1	0.48	0.92	0.28	0.71	0.59	1.12	1146	38.35	16.71	76.32
T_2	0.76	1.35	0.47	1.10	0.78	1.39	1191	40.65	18.58	79.46
T_3	0.72	1.28	0.51	1.14	0.65	1.28	1184	43.26	17.67	77.54
T_4	0.91	1.51	0.50	1.02	0.88	1.70	1218	45.42	18.56	80.61
T_5	0.88	1.62	0.46	0.97	0.83	1.58	1206	47.18	16.75	78.48
S.Em±	0.01	0.02	0.01	0.02	0.02	0.02	0.90	0.80	0.64	0.79
CD (P< 0.05)	NS	NS	NS	NS	NS	NS	5.43	4.29	NS	4.16
CV%	2.7	2.7	4.2	3.3	5.8	2.9	0.10	3.2	6.3	1.7

Growth of earthworms and vermicompost production

The data presented in table-5 dealt with vermicompost maturity (days), number of worms^{-m2}, weight of worms and vermicompost production in each treatments. It was observed that the vermicompost prepared using soybean straw + cow dung matured in minimum duration (74 days), however maximum duration was noted in the rice straw used for vermicomposting. The average numbers of worms were found maximum (1497^{-m2}) in T_2 (soybean straw + cow dung) followed by T_4 (rice straw + cow dung) and T_3 (soybean straw alone) whereas minimum (1117.5^{-m2}) in T_1 cow dung alone. Similarly 3.4 kg worms were harvested in T_2 followed by T_4 and T_3 (3.34 and 3.16 kg respectively), whereas minimum in T_5 (2.77 kg). Highest vermicompost production was recorded in T_2 (1545 kg) followed by T_4 and T_3 (1400 and 1353 kg respectively), however lowest in T_1 (1179.5 kg). This attributed to the fact that the agro-waste provided a source of food for the earthworms during vermicomposting however the growth and mass of vermiworm was remarkably less in rice straw probably due to lignin being the single most limiting component which affected the microbial decomposition and worm's activity.

Table 5: Worm and vermicompost production in different substrates

Treatment	Vermicompost maturity (days)	No. of worms^{-m2} at maturity	Worm's weight (kg pit^{-1})	Vermicompost production (kg pit^{-1})
T_1	78	1117.5	2.83	1179.5
T_2	74	1497	3.40	1545
T_3	77	1261.5	3.16	1353
T_4	79	1446	3.34	1400
T_5	82	1137.5	2.77	1277
S.Em±	0.89	1.51	0.03	1.60
CD (P< 0.05)	5.32	15.19	NS	17.07
CV%	2.0	0.2	1.6	0.2

Vermicomposting economics

The economics of vermicompost production shown in Table 6 indicated that the net income was distinguished to be highest in T_2 (Rs.4935 pit^{-1}) followed by T_3 (Rs.4765 pit^{-1}) and lowest in T_1 (Rs.3528 pit^{-1}), however the reverse trend was noticed in B:C ratio which was greater in T_3 (3.38) followed by T_5 (3.19) but lowest in T_1 (2.49). The lower values of BCR in T_2 and T_4 were mainly attributed to the gross cost which increased due to additional cost incurred in cow dung.

Vermicomposting is considered a potential method of composting for disposing of the rual, urban and agricultural wastes. It contains higher amount of exchangeable plant nutrients than other organic manures such as farm yard manure or compost. Vermicomposting is quite helpful in the management of domestic, agricultural and animal wastes. These are changed into compost which can be applied to boost the crop production and of harmless and nutrient rich produce. Thus, this is the commendable approach in reducing the ecological nuisance and on the other hand it enriches the soil. The findings of this study will certainly help in safe disposal of organic resources and production of nutrient rich vermicompost which would be mile stone for sustainable agriculture that will not only improve soil physicochemical properties but plant growth and finally resilient food security.

Table 6: Economics of vermicompost preparation in different substrates

Treatment	Gross cost* (Rs pit^{-1})	Gross Income (Rs pit^{-1})	Net Income (Rs pit^{-1})	B:C ratio
T_1	2370	5898	3528	2.49
T_2	2790	7725	4935	2.77
T_3	2000	6765	4765	3.38
T_4	2790	7000	4210	2.51
T_5	2000	6385	4385	3.19

*includes cow dung and bio-waste cost only

References

1. Amma MK. Plant and soil analysis. Rubber Research Institute, Rubber Board, Kottayam, Kerala, 1989.
2. Ansari AA, Jaikishun S. Vermicomposting of sugarcane bagasse and rice straw and its impact on the cultivation of *Phaseolus vulgaris* L. in Guyana, South America. J Agric. Technol. 2011;7:225-34.
3. Ansari AA, Rajpersaud J. Physicochemical changes during vermicomposting of water hyacinth (*Eichhornia crassipes*) and Grass clippings. ISRN Soil Sci. 2012. 10.5402/2012/984783.
4. Bhat S, Singh J, Vig A. Instrumental characterization of organic wastes for evaluation of vermicompost maturity. J Anal. Sci. Technol. 2017, 8(1). 10.1186/s40543-017-0112-2.
5. Black CA. Methods of soil analysis. Part1. Am. Soc. Agron. Inc. Publi. Madison Wisconsin USA, 1965.
6. Broz AP, Verma P, Appel C. Nitrogen dynamics of vermicompost use in sustainable agriculture. J Soil. Sci. Environ. Manage. 2016;7:173-83.
7. Cabrera ML, Kissel DE, Vigil MF. Nitrogen mineralization from organic residues: Research opportunities. J Environ. Qual. 2005;34:75-79.
8. Chaudhuri PS, Pal TK, Bhattacharjee G, Dey SK. Chemical changes during vermicomposting (*Perionyx excavates*) of kitchen waste. Trop. Ecol. 2000;41:107-10.
9. Chauhan HK, Singh K. Effect of tertiary combinations of animal dung with agro wastes on the growth and development of earthworm *Eisenia fetida* during organic waste management. Int. J Recycl. Org. Waste Agric. 2013;2:10. 1186/2251-7715-2-11.
10. Chhotu Jadia D, Fulekar MH. Vermicomposting of vegetable waste: A bio physicochemical process based on hydro-operating bioreactor. African J Biotechnol. 2008;7:3723-30.
11. Devi J, Prakash M. Microbial population dynamics during vermicomposting of three different substrates amended with cowdung. Int. J Curr. Microbiol. Applied Sci. 2015;4:1086-92.
12. Diaz LF, Savage GM, Eggerth LL, Golueke CG. Composting and recycling municipal solid waste. United State of America: Lewis Publishers, 1993.
13. Edwards CA, Subler S, Arancon N. Quality Criteria for Vermicomposts. Vermiculture Technology: Earthworms, Organic Waste and Environmental Management, Edwards, C.A., N.Q. Arancon and R.L. Sherman (Eds.). CRC Press, Boca Raton, USA. 2011, 287-301. ISBN: 9781439809877.
14. Fogarty A, Tuovinen O. Microbiological degradation of pesticides in yard waste composting. Microbiol Rev. 1991;55:225-33.
15. Garg VK, Kaushik P. Verm stabilization of textile mill sludge spiked with poultry droppings by an epigeic earthworm Eisenia foetida. Bioresource Technol. 2005;96:1063-71.
16. Giraddi RS. Verm technologies. University of Agricultural Sciences, Dharwad, India, (In Kannada). 2007.
17. Giraddi RS. Research priorities in Verm technologies. Final Report Submitted to NABARD, Mumbai, India, 2011.
18. Goswami L, Patel AK, Dutta G, Bhattacharyya P, Gogoi N, Bhattacharya SS. Hazard remediation and recycling of tea industry and paper mill bottom ash through Verm conversion. Chemosphere. 2013;92:708-13.
19. Hand P, Hayes WA, Satchell JE, Frankland JC. The vermicomposting of cow slurry, 'Earthworms in waste and environmental management' edited by Edwards, C. A. and Neuhauser, E. F. SPB Academic Publishing, Netherlands. 1988, 90. ISBN: 5103-0177.
20. Ismail SA. The Earthworm Book. Other India Press, Apusa, Goa. 2005, 101.
21. Iyengar SR, Bhave PP. In-vessel composting of household wastes. Waste Management. 2005;26:1070-80.
22. Jaybhaye M, Satish AB. Vermicomposting: A new trend towards management of agricultural waste (Paddy straw). Int. J Curr. Res. Aca. Rev. 2016;4:61-67.
23. Kale RD. Earthworm: Cinderella of Organic Farming. Prism Books Pvt. Ltd., Bangalore, India, 1998. ISBN-10:8172861001.
24. Kaplan M. The national master plan for agricultural development in Suriname. Final report. Kaplan Planners Ltd. Regional and Environmental Planning, 2016. https://www. share4dev.info/kb/documents/5426.pdf
25. Kaushik P, Garg VK. Vermicomposting of mixed solid textile mill sludge and cow dung with the epigemic earthworm *Eisenia foetida*. Bioresource Technology. 2003;90:311-16.
26. Kitturmath MS, Giraddi RS, Basavaraj B. Nutrient changes during earthworm, *Eudrilus eugeniae* (Kinberg) mediated vermicomposting of agro-industrial wastes. Karnataka J Agric. Sci. 2007;20:653-54.
27. Koenig RA, Johnson CR. Colorometric determination of phosphorus in biological materials. Indian Engg. Chem. Anal. 1942;14:155-56.
28. Kumar A, Gupta RK, Kumar S. Variation in organic carbon content and carbon nitrogen ratio in vermicompost as affected by substrate straw. Forage Res. 2017;43(1):46-49.
29. Kumar A, Prakash CHB, Brar NS, Kumar B. Potential of vermicompost for sustainable crop production and soil health improvement in different cropping systems. Int. J Curr. Microbiol. Applied Sci. 2018;7:1042-55.
30. Levi-Minzi R, Riffaldi R, Saviozzi A. Organic matter and nutrients in fresh and mature farm yard manure. Agric. Wastes. 1986;16:225-36.
31. Lindsay WL, Norvell WA. Development of DTPA soil test for zinc, manganese and copper. Soil Sci. Soc. Am. J. 1978;42:421-28.
32. Maheswari UN, Priya M. Vermicompost., a backbone for sustainable agriculture-review article. Eur. J Biomed. Pharm. Sci. 2018;5:835-46.
33. Marlin CJ, Rajeshkumar KT. A study on sustainable utility of sugar mill effluent to vermicompost. Adv. Applied Sci. Res. 2012;3:1092-97.
34. Manyuchi MM, Mbohwa C, Muzenda E. Vermicomposting of soybean and maize straw residues as an agro waste management initiative. Proceedings of the 6th International Conference on Sustainability, Technology and Education, Sydney, Australia. 2017 Dec 11-13, 11-18.
35. Meenatchi R. Molecular characterization of earthworms, nutrient assessment and use of Verm technologies in pest management. Ph.D. Thesis, Dharwad (Karnataka), India. 2008.
36. Md Sabiani NH, Asaari F. Kajian perbandingan kualiti kompos daripada sisa tanaman menggunakan pelbagai kaedah pengkomposan. Pulau Pinang: Universiti Sains

Malaysia. 2004.
37. Moradi H. Effect of vermicompost on plant growth and its relationship with soil properties. Int. J Fisheries and Aquatic Studies. 2014;3:333-38.
38. Nelson DW, Sommers LE. Total carbon and organic carbon. In: Methods of Soil Analysis, Part 2. 1982, 539-79. A.L., Miller, R.H., Keeney, D. R. (eds.). Agronomy 9. Amer. Soc. Agron. Inc. Madison, W. I.
39. Oluseyi EE, Ewemoje TA, Adedeji AA. Comparative analysis of pit composting and vermicomposting in a tropical environment. Int. J Agric. Biol. Eng. 2016;10:184-87.
40. Paré T, Dinel H, Schnitzer M. Extractability of trace metals during composting of biosolids and municipal solid wastes. Biol. Fert. Soils. 1999;29:31-37.
41. Punjab State Council for Science and Technology. 2010. Vermiculture/vermicompost. http://agri.and.nic.in/vermi_culture.htm
42. Ramnarain YI, Ansari AA, Ori L. Vermicomposting of different organic materials using the epigeic earthworm *Eisenia foetida*. Int. J Recycl. Org. Waste. Agric. 2019;8:23-36.
43. Singh K. Microbial and nutritional analysis of vermicompost, aerobic and anaerobic compost. 40 CP Honours Project for Master in Environmental Engineering; Griffith University, Brisbane, Australia, (Supervisors: Dr. Rajiv K. Sinha & Dr. Sunil Heart). 2009.
44. Sinha K, Valani D, Soni B, Chandran V. Earthworm Vermicompost: A Sustainable Alternative to Chemical Fertilizers for Organic Farming (Agriculture Issues and Policies). Nova Science Publishers Inc., New York, USA. 2011. ISBN-10: 1611225809.
45. Suthar S. Production of vermifertilizer from guar gum industrial wastes by using composting earthworm *Perionyx sansibaricus* (Perrier). Environmentalist. 2007, 329-35.
46. Suthar S. Bioremediation of agricultural wastes through vermicomposting. Bioremediat. J. 2009;13:21-8.
47. Suthar S. Pilot- scale vermireactors for sewage sludge stabilization and metal remediation process: Comparison with small-scale vermireactors. Ecol. Eng. 2010;36:703-12.
48. Tahiri A, Delporte F, Muhovski Y, Ongena M, Thonart P, Druart P. Change in ATP-binding cassette B1/19, glutamine synthetase and alcohol dehydrogenase gene expression during root elongation in *Betula pendula* Roth and *Alnus glutinosa* L. Gaertn in response to leachate and leonardite humic substances. Plant. Physiol. Biochem. 2016;98:25-38.
49. Varghese SM, Prabha ML. Biochemical characterization of vermiwash and its effect on growth of *Capsicum frutescens*. Malaya J Biosci. 2014;1:86-91.
50. Waseem MA, Giraddi RS, Math KK. Assessment of nutrients and micro flora in vermicompost enriched with various organics. J Exp. Zool. India. 2013;16:697-703.