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Bioconversion of Paddy Straw into Vermicompost through Fungal-Earthworm Interactions

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: The primary aim of this research work is to utilize fungal consortium (*Aspergillus oryzae, Aspergillus fumigatus* and *Rhizopus oryzae*) for the partial degradation of paddy straw and thereafter to study the vermicomposting ability with *Eudrilus eugeniae, Perionyx excavatus* and *Lampito mauritii* under monoculture (E I, E II and E III, respectively) and polyculture (E IV) conditions. The pre-digested paddy straw was used in combination with cow dung (1:1 ratio). **Materials and Methods:** This study was conducted for over a period of 50 days. Four experimental treatments i). E I (experimental trays inoculated with *E. eugeniae*) ii). E II (experimental trays inoculated with *P. excavatus*) iii) E III (experimental trays inoculated with *L. mauritii*) and iv) E IV

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(experimental trays inoculated with *E. eugeniae, P. excavatus* and *L. mauritii*) were used for the present study. At the end of the experiments, the chemical nutrients, biological composition were quantified.

Results: The vermicompost obtained from E IV and E I experimental trays were comparatively rich in macro and micro nutrients, microbial populations than the others.

Conclusion: It can be concluded that paddy straw can be pre-digested with a selected fungal consortium and subsequently converted into vermicompost using earthworms, either in monoculture (*E. eugeniae*) or polyculture (*E. eugeniae, P. excavatus*, and *L. mauritii*) systems.

Keywords: Fungal consortium; monoculture; polyculture and vermicompost.

1. INTRODUCTION

Paddy straw is one of the most abundant organic wastes available in our planet, Earth. In India, 36.5 million tonnes of rice is estimated to be produced annually. About 1-1.5kg of straw is produced from every kilogram of the grain harvested and thus, 136.5-150 million tonnes of paddy straw is estimated to be produced annually. Of which, 37% of paddy straw is used as fodder and remaining (63%) is simply disposed of by burning in the field. 3kg of particulate matter, 60 kg of CO, 1460 kg CO_2, 199kg ash and 2kg SO_2 were released while burning 1 tonne of paddy straw. Repeated burning of paddy straw causes health impacts like lung and respiratory diseases on human being and soil erosion (Wang, 2003).

Raw Paddy straw consists of 35-40% of cellulose, 20-24% of hemicellulose and 8-12% of lignin. Decomposition of paddy is very slow due to the presence of high cellulose, lignin complex and silica incrustation. Therefore, the paddy straw needs to be pre-treated with lignin degrading microbes in order to enable the cellulase synthesising microbes to have easy access and convert the biomass into a valuable product.

Several methods, including physical, chemical, physico-chemical, and biological processes, have been suggested in recent years (Saratale et al., 2008). for breaking down materials. Nevertheless, both the physical and chemical pre-treatments necessitate reactors that are high in energy, corrosion-resistant, and can withstand high pressure, consequently leading to elevated pre-treatment costs. Additionally, the use of chemicals before treatment can harm the environment due to the creation and release of methanogens, as well as the production of acidic or alkaline water that requires pre-disposal treatment for environmental protection (Keller and Barron, 1987). Therefore, another method is utilizing microbial pre-treatment, specifically involving fungi, to enhance the digestibility of paddy straw. Microorganisms like brown, white, and soft rot fungi are typically utilized in biological pre-treatment methods to break down lignin and hemicellulose in waste materials. Biological pre-treatment of waste materials offers benefits such as reduced need for manpower, minimal energy usage, faster processing, smaller space requirement, and perceived as environmentally safe and cost-effective technology. The majority of white-rot fungi break down lignin and cellulose at the same time [2]. The literature review indicates that fungi like *Fusarium sp.* (Phutela and Sahni, 2012). *Armillaria sp., Polyporus sp., P. chrysosporium* (Sinegani et al., 2005). *Aspergillus awamorii, Paecilomyces fusisporus*, and *Trichoderma viride* (Goyal and Sindhu, 2011) have been utilized for breaking down paddy straw.

The nutritive value of paddy straw allows it to be utilized as biofertilizer. Before applying it, the waste needs to undergo the proper processing techniques in order to compost effectively. Previous research has shown that vermicomposting is a suitable method for converting energy-rich organic waste into valuable products, such as vermicompost (Kale, 1998). Earthworms speed up the process of turning organic waste into more stable forms by aerating the soil, mixing it up, and influencing the microorganisms in the soil through their waste. Vermicomposting is the process of organic material being stabilized through the combined effort of earthworms and microorganisms (Suthar, 2007). Hence, vermicomposting appears to be a better and more effective method for transforming agricultural waste into a valuable product with minimal input costs.

The present study was designed to evaluate the effect of *epigeic* and *anecic* earthworms (*E. eugeniae, P. excavatus* and *L. mauritii* under monoculture and polyculture conditions) on the changes in the substrate utilization, chemical nutrients and microbial population in a laboratory

scale vermicomposting of paddy straw (pre-digested with fungal consortium).

2. MATERIALS AND METHODS

2.1 Collection of Substrates and Earthworm Species

Paddy straw and cow dung were collected from nearby areas of our college. The earthworm species *i.e., E. eugeniae, P. excavatus* and *L. mauritii* was collected from Vermiculture Yard of our college. All these species were identified and confirmed by using morphological characters given by Talashilkar and Dosani (Talashilkar and Dosani, 2005), (Blakemore, 2010).

2.2 Procurement of the Fungal Consortium

The fungal consortium which contains *Rhizopus oryzae, Aspergillus oryzae* and *Aspergillus fumigatus* was utilized for the pre-digestion of paddy straw as suggested by Viji and Neelanarayanan (Viji and Neelanarayanan, 2015). The fungal consortium was grown in 1% molasses solution for 7 days.

2.3 Pre-Digestion of Paddy Straw

The fungal consortium, consisting of a 7-day-old culture, was inoculated at a rate of 100 ml per kg of paddy straw and thoroughly mixed. Layers with these combinations were stacked until the heap reached a height of one meter. The moisture content of the substrate was kept at 65% by periodically sprinkling water, and the setup was maintained for 23 days.

2.4 Experimental Set Ups

Plastic trays of 45 × 15 × 30 cm with a hole at the bottom were used as experimental trays. The feed materials were prepared by mixing the pre-digested paddy straw with cow dung in 50:50 ratio and filled in plastic trays. The moisture content was maintained around 40% throughout the study period by periodic sprinkling of adequate quantity of water. After 2 to 3 days, adult earthworms were introduced in to each experimental tray. The experimental design is given in Table 1.

All these experiments were replicated thrice. When the vermicompost was ready by its physical appearance as ascertained by the development of a dark brown to black colour and at this stage watering was stopped. At the end of the experiment, the adult and juveniles were separated from vermicompost by hand sorting. Samples of vermicompost and compost (from control trays) were collected from each experimental trays and air dried at room temperature (28º C). All the samples were stored and labelled in zip lock polythene covers for further analyses.

2.5 Chemical Nutrient Analyses

The methods used for analyzing the nutrient status of compost and vermicompost are summarized in Table 2.

2.6 Quantification of Microbial populations

The total number of Colony Forming Units of bacteria, fungi and actinomycetes present in the vermicompost samples were estimated by serial dilution method. Nutrient Agar for bacteria, Potato Dextrose Agar for fungi and Soil Extract Agar for actinomycetes were used (Tandon, 2005).

Table 1. Experimental design

Experiment Name	Description	Number of Earthworms inoculated
E I	*E. eugeniae* Control	108 -
E II	*P. excavatus* Control	108 -
E III	*L. mauritii* Control	108 -
E IV	*E. eugeniae* + *P. excavatus* + *L. mauritii* Control	36 + 36 + 36 -

Table 2. Methods used for analysing the nutrient status of compost and vermicompost

S. No.	Nutrient analysed	Methodology	References
1	pH	Digital pH Meter (Make: Elico)	Tandon, 2005
2	Electrical Conductivity	Digital Electrical Conductivity Meter (Make: Systronics)	Tandon, 2005
3	Moisture	-	Tandon, 2005
4	Organic Carbon	Partial Oxidation Method	Walkley and Black, 1934
5	Total Nitrogen	Micro Kjeldahl Method	Tandon, 2005
6	Total Phosphorus and Sulphur	Spectrophotometric Method	Tandon, 2005
7	Total Potassium and Sodium	Flame Photometric Method	Tandon, 2005
8	Total Calcium and Magnesium	Versenate Method	Trivedy and Goel, 2005
9	C:N Ratio	-	Anon, 2006

2.7 Statistical Analyses

Paired samples "t" test was used to determine difference between compost and vermicompost in each treatment at 0.001% levels of significance. One way ANOVA and comparison of means based on Duncan's Multiple Range Test were used to determine significant differences between treatments. All these analyses were done by using SPSS (Statistical Package for Social Science) program version 16.0 for windows.

3. RESULTS

Vermicomposting process significantly lowered the pH of the vermicompost at the end, and the maximum reduction could be observed in E I and E IV (-14.42%), whereas the E II (-3.39%) showed the lowest reduction for pH. The difference between composted and vermicomposted material for pH level was significant (t test $p<0.001$, for all the treatments).

The Electrical Conductivity gained in the vermicompost when compared to control and the same was in the following order: E III (+84.17%) > E IV (+83.50%) > E I (+83.39%) > E II (+76.96%) and the same was found to be statistically significant (t test; $p<0.001$, for all the experiments).

A significant reduction could be observed in the Moisture content of the vermicompost when compared to their initial and control values. The maximum reduction was observed and recorded in E IV (-72.42% of the initial value) followed by E III (-69.49%), E I (-67.80%) and E II (-57.93%) and the same was found to be statistically significant (t test; $p<0.001$, for all the experiments).

Magnitude of Organic Carbon (OC) was observed to be lower in the end product *i.e.,* vermicompost than its initial and control values. A significant Organic Carbon loss was recorded in E I (- 63.13%) > E IV (-54.83%) > E II (-53.84%) > E III (- 53.15%) as compared to control (t test: $p < 0.001$, for all the experiments).

The vermicompost showed significantly increased Total N content than the initial and compost (t-test: $p<0.001$ for all the experiments except E II). The maximum total N increase was observed in E IV (+77%) followed by E I (+62.4%) > E III (+57%) > E II (+54.62%).

The Total Phosphorus content was significantly higher in vermicompost than the compost (t test: $p < 0.001$, for all the experiments except E I and E II). The maximum increase was observed in E IV (+99.34%) succeeded by E III (+ 99.10%) > E I (+99.02%) > E II (+98.31%).

The Total Potassium content in the vermicompost was significantly (t test: $p<0.001$) higher than the initial level and compost. The increase in the Total Potassium content change was in the order of E IV (+78.16%) > E I (+76.96%) > E III (+73.51%) > E II (+73.04%).

The Total Calcium and Magnesium was observed to be higher in vermicompost than the initial level and control. There was a significant difference (t test: $p< 0.001$) between compost and vermicompost in respect of Ca and Mg except E IV and E I experiments. The Total Sodium was significantly (t test: $p< 0.001$) higher in the vermicompost than the control. The observed and recorded Total Sodium enhancement ranged from 24.07 % (E III) to 50 % (E IV).

The observed increase in Total Sulphur content was to the tune of 66.66% (E I) > 63.95% (E II) > 50.79% (E III) ≈ 50.79% (E IV). The difference between compost and vermicompost was statistically significant (t test: p< 0.001) for different treatments except E II experiment.

As compared to initial values and control, a decreasing trend in C:N ratio could be observed in all the vermicompost obtained from four sets of experiments E IV (88.23%) > E I (85.88%) > E II (80%) ≈ E III (80%) and the same was found to be significant (except E I experiment) (t test: p< 0.001).

A significant increase in microbial population could be observed in the vermicompost (t test: p< 0.001) for different treatments except E II experiment. Statistically, the fungi population increase was not different between E I and E II experiments (t test: p< 0.001).

Table 3. The extent of pH, EC, Moisture and Organic Carbon of vermicompost produced by *E. eugeniae, P. excavatus and L. mauritii* under monoculture and polyculture conditions utilizing Paddy (*Oryza sativa*) Straw (pre-digested with fungal consortium) and cow dung in 50:50 concentrations and compost

Parameters	Experiments	E I	E II	E III	E IV
pH	Vermicompost	7.06 ± 0.02	7.97 ± 0.01	7.24 ± 0.02	7.06 ± 0.03
	Compost	8.05 ± 0.03	8.35 ± 8.35	8.26 ± 0.02	8.06 ± 0.02
	Initial Value	6.25 ± 0.08			
	t test	p =0.001	p=0.001	p=0.01	p=0.001
EC (dSm^{-1})	Vermicompost	2.83 ± 0.02	2.04 ± 0.04	2.97 ± 0.01	2.85 ± 0.04
	Compost	1.95 ± 0.02	1.66 ± 0.03	1.07 ± 0.01	1.04 ± 0.03
	Initial Value	0.47 ± 0.05			
	t test	p=0.01	p=0.001	p=0.001	p=0.001
Moisture (%)	Vermicompost	21.17 ± 0.02	27.66 ± 1.52	20.06 ± 0.02	18.13 ± 0.02
	Compost	33.41 ± 0.02	30.73 ± 0.20	29.36 ± 0.01	23.26 ± 0.02
	Initial Value	65.75 ± 0.32			
	t test	p=0.001	p=0.001	p=0.001	p=0.001
Organic Carbon	Vermicompost	15.68 ± 0.01	19.63 ± 0.15	19.94 ± 0.04	19.21 ± 0.02
	Compost	18.86 ± 0.03	26.66 ± 0.32	25.38 ± 0.03	26.17 ± 0.02
	Initial Value	65.75 ± 0.19			
	t test	p=0.001	p=0.001	p=0.001	p=0.001

Table 4. The magnitude of Total Nitrogen, Total Phosphorus, Total Potassium and Total Calcium of vermicompost produced by *E. eugeniae, P. excavatus and L. mauritii* under monoculture and polyculture conditions utilizing Paddy (*Oryza sativa*) Straw (pre-digested with fungal consortium) and cow dung in 50:50 concentrations and compost

Parameters	Experiments	E I	E II	E III	E IV
Total Nitrogen (%)	Vermicompost	1.33 ± 0.02	1.15 ± 0.03	1.19 ± 0.01	2.25 ± 0.04
	Compost	1.03 ± 0.02	1.03 ± 1.03	0.94 ± 0.01	1.13 ± 0.04
	Initial Value	0.05 ± 0.004			
	t test	p=0.001	p=0.065	p=0.001	p=0.001
Total phosphorous (%)	Vermicompost	2.06 ± 0.02	1.19 ± 0.19	2.23 ± 0.02	3.07 ± 0.01
	Compost	1.20 ± 0.01	1.04 ± 0.02	1.18 ± 0.01	1.15 ± 0.02
	Initial Value	0.02 ± 0.004			
	t test	p=0.076	p=0.079	p=0.001	p=0.001
Total Potassium (%)	Vermicompost	3.30 ± 0.01	2.82 ± 0.02	2.87 ± 0.01	3.48 ± 0.00
	Compost	2.48 ± 0.01	1.64 ± 0.02	1.24 ± 0.02	1.17 ± 0.01
	Initial Value	0.76 ± 0.04			
	t test	p=0.001	p=0.001	p=0.001	p=0.001
Total Calcium (%)	Vermicompost	2.65 ± 0.04	2.56 ± 0.01	2.72 ± 0.02	3.16 ± 0.02
	Compost	1.44 ± 0.04	1.41 ± 0.41	1.53 ± 0.53	1.54 ± 0.02
	Initial Value	0.43 ± 0.04			
	t test	p=0.089	p=0.001	p=0.001	p=0.065

Table 5. The propensity of Total Magnesium, Total Sodium, Total Sulphur and C: N ratio of vermicompost produced by *E. eugeniae, P. excavatus and L. mauritii* under monoculture and polyculture conditions utilizing Paddy (*Oryza sativa*) Straw (pre-digested with fungal consortium) and cow dung in 50:50 concentrations and compost

Parameters	Experiments	E I	E II	E III	E IV
Total Magnesium (%)	Vermicompost	1.67 ± 0.02	1.71 ± 0.71	1.96 ± 0.01	1.93 ± 0.03
	Compost	1.03 ± 0.02	1.65 ± 0.65	0.94 ± 0.03	1.06 ± 0.02
	Initial Value	0.27 ± 0.08			
	t test	p=0.059	p=0.001	p=0.001	p=0.082
Total Sodium (%)	Vermicompost	1.64 ± 0.04	1.35 ± 0.04	1.08 ± 0.01	1.36 ± 0.01
	Compost	1.33 ± 0.03	1.21 ± 0.21	0.94 ± 0.02	1.65 ± 0.03
	Initial Value	0.82 ± 0.08			
	t test	p=0.001	p=0.01	p=0.001	p=0.001
Total Sulphur (%)	Vermicompost	1.86 ± 0.02	1.72 ± 0.00	1.26 ± 0.02	1.26 ± 0.02
	Compost	1.27 ± 0.02	1.03 ± 0.01	1.37 ± 0.02	1.02 ± 0.01
	Initial Value	0.62 ± 0.04			
	t test	p=0.01	p=0.067	p=0.01	p=0.01
C:N Ratio	Vermicompost	12:1	17:1	17:1	10:1
	Compost	18:1	26:1	27:1	23:1
	Initial Value	85:1			
	t test	p=0.062	p=0.001	p=0.001	p=0.001

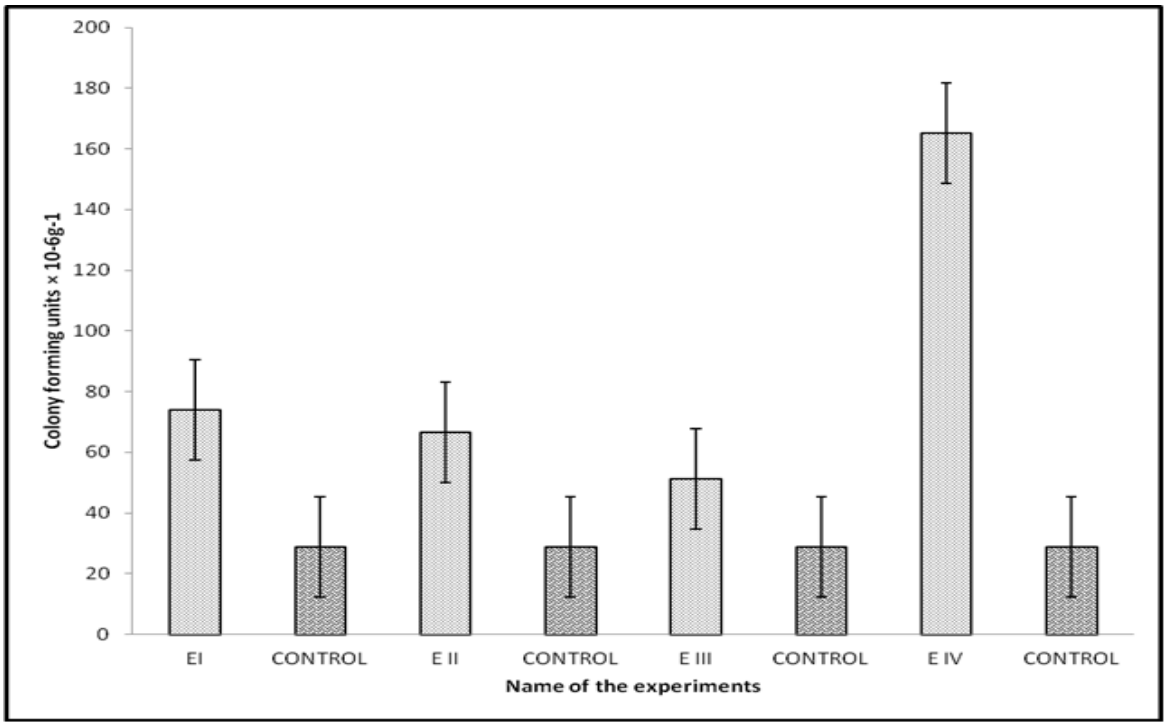

Fig. 1. The quantity of bacterial population of vermicompost produced by *E. eugeniae*, *P. excavatus* and *L. mauritii* under monoculture and polyculture conditions utilizing Paddy *(Oryza sativa)* Straw (pre-digested with fungal consortium) and cow dung in 50:50 concentrations and compost

For experiment combinations see Table 1

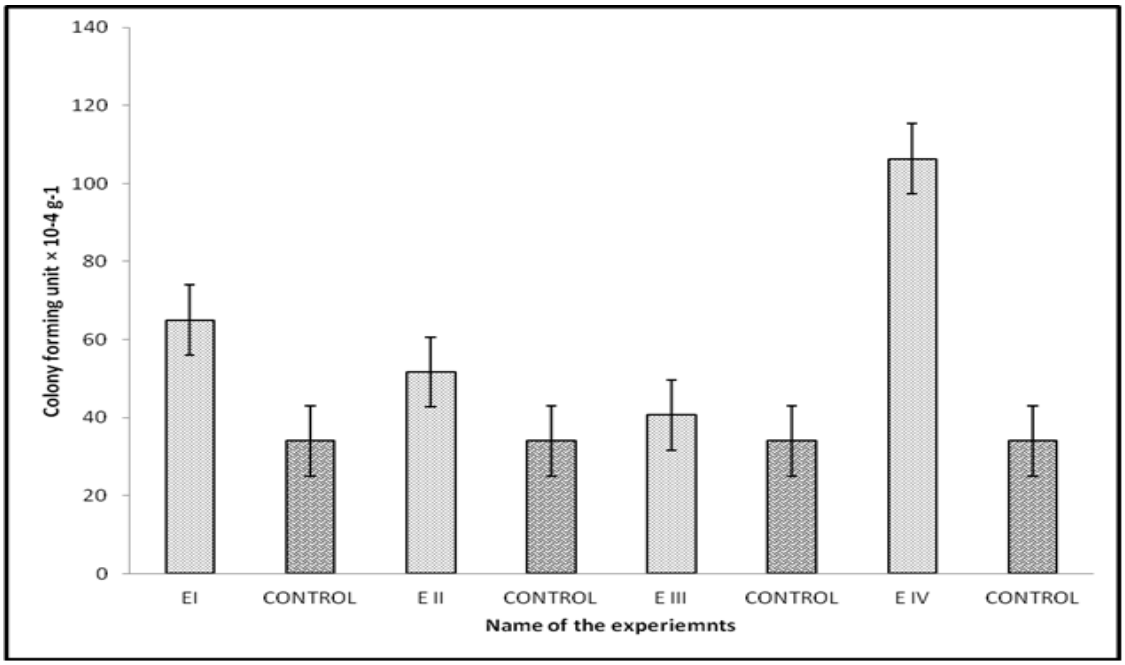

Fig. 2. The magnitude of fungal population of vermicompost produced by *E. eugeniae*, *P. excavatus* and *L. mauritii* under monoculture and polyculture conditions utilizing Paddy *(Oryza sativa)* Straw (pre-digested with fungal consortium) and cow dung in 50:50 concentrations and compost

For experiment combinations see Table 1

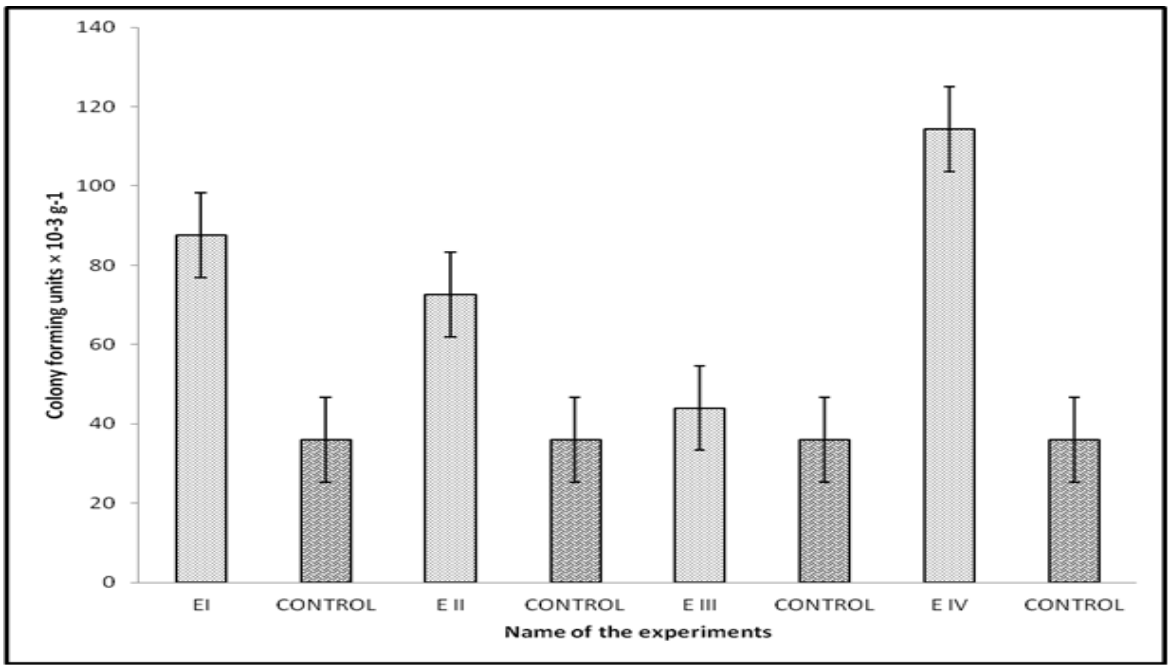

Fig. 3. The propensity of actinomycetes population of vermicompost produced by *E. eugeniae*, *P. excavatus* and *L. mauritii* under monoculture and polyculture conditions utilizing Paddy *(Oryza sativa)* Straw (pre-digested with fungal consortium) and cow dung in 50:50 concentrations and compost

For experiment combinations see Table 1

4. DISCUSSION

The fungal population plays a crucial role in the composting process by breaking down complex organic materials like lignin, cellulose, and hemicellulose found in plant matter. Fungi secrete enzymes that help decompose these tough compounds, accelerating the composting process and improving the breakdown of organic matter. Their activity contributes to nutrient cycling, producing humus-rich compost, and enhancing soil fertility. Fungal species like *Aspergillus, Trichoderma, Rhizopus* are often dominant in composting environments, particularly during the later stages of decomposition when they efficiently process resistant materials.

The pH in all the experiments was comparatively lower in the vermicompost than its initial and control values. The pH values measured for each treatment fell within the optimal range of 6.5-8 for compost intended for agricultural purposes (Rostam, 2011), (David, 2013), (Chrohn, 2016). The lower pH value seen during vermicomposting may be caused by the earth worms' generation of carbonic acid and CO_2 during the decomposition process. It might also be explained by the increased nitrogen mineralization that occurs during vermicomposting. Ammonification and the creation of NO3 during the breakdown of organic waste may be the cause of an increase in soil pH during composting. Furthermore, the production of NH4+ ions may also be responsible for the decreased pH level of vermicomposting. According to Suthar and Singh (Suthar and Singh, 2008) research, when composting is contrasted with vermicomposting, a higher pH value is seen.

The Electrical Conductivity (EC) values were found to be higher in the final product *i.e.,* vermicompost obtained from all the experimental trays than the initial and control values. Based on the findings discussed earlier, it can be concluded that the salt levels were significantly higher in vermicompost (experimental group) compared to traditional compost (control group). According to Guoxue et al.,2001 Tognetti et al., 2007 Garg et al., 2006 and Yadav and Garg, 2011. Loss of weight of organic matter and 2. Release of Phosphate, Ammonium, Calcium, Magnesium and Potassium may be the reasons for EC increase in vermicompost.

The moisture content of the vermicompost harvested from all the experimental trays were significantly lower than the initial and control values. Moisture content is also one of the most important components in organic fertilizers. According to SNI, the moisture content ranges from 8 to 25%. Our results fall in line with the SNI range. Yadav and Gupta, 2011 pointed out that the moisture content can differ based on the substrate selected for composting, as each substrate may contain varying levels of moisture. According to Tandon, 2005, the ideal moisture level for high-quality vermicompost ranges from 20 to 30%. In contrast, Sebayang et al*.,* 2022 reported that the worms and microorganisms in vermicompost had a higher capacity to store water than the control treatment.

Organic Carbon loss was observed in end product *i.e.,* vermicompost collected from all the experimental trays as compared to the control and the initial values. Garg and Kaushik, 2003 found that between 20-45% of organic carbon was lost as CO from various industrial sludge during vermicomposting. The process of vermicomposting involves earthworms consuming organic matter and microbial breakdown. Earthworms change the conditions of the substrate, leading to carbon loss through microbial respiration and mineralization of organic matter. In harmony with this finding, Kassa et al*.,* 2014 study shows that higher percentage of organic carbon was recorded during vermicomposting when compared to conventional composting method.

Result indicates that the vermicompost exhibited a notably higher total N content compared to the initial values and compost. Cynthia and Rajeshkumar, 2012 observed a rise in TN levels in sugar mill effluent, attributed to worms decomposing waste to speed up nitrogen mineralization. Earthworms increase the nitrogen levels in vermicompost by decomposing dead earthworm tissues, while microbial processes in vermicomposting systems also contribute to nitrogen enrichment (Sebayang et al., 2022). The findings of the current study align with previous observations. In contrast, Hobson et al*.,* 2005 reported that the reduction in TN concentrations in vermicomposting due to *in vivo* denitrification within the worms' digestive tract. Part of the N content in the initial substrate is also transformed into earthworm protein.

The Total Phosphorus concentration in vermicompost was substantially higher than in

initial and compost. The present finding was agree with the reports of Kaushik and Garg, 2003 and Suthar, 2007 who demonstrated similar increase in total phosphorus of vermicomposted materials. The increased overall P level in vermicompost is due to phosphorous release through alkaline phosphatase enzyme produced by phosphate solubilizing bacteria and actinomycetes (Bayon, 2006),(Huang and Xia, 2018),(Kaur et al., 2010) and earth warm activity which converts insoluble phosphorus in to soluble forms.

Significantly greater level of Total Potassium was observed in the vermicompost than the initial value and compost. During the vermicomposting of organic materials, the increase in Total Potassium levels and its conversion into minerals can be attributed to the action of potassium-solubilizing enzymes found in either earthworms' digestive systems or the microorganisms present in the vermicompost (Tesfaye, 2017).

The Total Calcium and Magnesium were observed to be higher in vermicompost than the initial level and control. The rise in Total Ca and Mg levels may be associated with the actions of earthworms, as they effectively convert insoluble Ca and Mg into a soluble form (Suthar, 2007) leading to a greater concentration of Ca and Mg in vermicompost.

The Total Sodium was significantly higher in the vermicompost than the control. Similar observations have been reported by Murali and Neelanarayanan, 2011, Selvamuthukumaran and Neelanarayanan, 2012 and Viji and Neelanarayanan, 2013, where as the present findings are in contradiction to the findings of Kaur et al*.,* 2010 that the depletion of sodium in the vermicompost might be a result of the earthworms using salts.

After vermicomposting, all the experiments showed higher concentration of Total Sulphur in the vermicompost than the initial level and control. The enhancement in TS mainly depends on i) earthworm activities, ii) intensive microbial loads and iii) activity of microorganisms. The present findings corroborate to those of Selvamuthukumaran and Neelanarayanan, 2012, who demonstrated that higher S concentration in the vermicompost prepared from leaves litter. The impact of earthworms on sulphur mineralization is not well studied and reported by previous authors; hence a detailed studies about sulphur transformation during vermicomposting process need to be taken by researchers.

A decreasing trend in the C:N ratio was found in vermicompost as compared to initial value and compost. The decrease in C:N ratio was a result of increased carbon loss from microbial respiration as CO_2, along with higher nitrogen levels and waste stabilization by worms (Rekha et al., 2018). The presence of microorganisms and worms may effectively break down organic matter and lower the C/N ratio. An optimal organic fertilizer has a C/N ratio of about 20. Vermicompost obtained from this study showed a C:N ratio less than 30, indicating acceptable quality and our results are in line with the National Organic Fertilizer Standard Level.

The microbial population *viz.,* bacteria, fungi and actinomycetes was significantly higher in vermicompost than the compost. There are many studies focusing the increase of microbial population in earthworm-excreted or -processed material than the parent material. Recent developments in the country as well as at the global level is the application of detritivorous epigeic earthworms for organic manure/vermicompost production from biodegradable organic materials recovered from agricultural lands, agro-based industries, and municipal solid waste. This field of study is closely associated with earthworm microbe interactions. The quality of the manure or vermicompost depends on microorganisms associated with the process of decomposition. Earthworms' activities are closely associated with microbial activities. Primarily moisture is playing a major role in microbial population maintenance as it has been reported by Prakash et al., 2010 and Enebe and Erasmus, 2023.

5. CONCLUSION

The use of paddy straw as a raw material for the production of vermicompost can potentially help to convert this waste into value added product *i.e.,* vermicompost. Moreover, the Vermicomposting earthworm species *viz., E. eugeniae, P. excavatus* and *L. mauritii* grew and reproduced favourably in paddy straw pre-digested with fungal consortium. The fungal consortium (includes *A. oryzae, A. fumigatus* and *R. oryzae*) is required for the quick conversion of paddy straw into vermicompost/compost. All the earthworm species under monoculture and polyculture were found suitable in the present study for bioconversion of paddy straw into

vermicompost. However, the vermicompost obtained from E IV and E I experimental trays were rich in macro and micro nutrients besides microbial populations. Therefore, it may be concluded and further recommended that the Paddy Straw may be pre-digested with the chosen fungal consortium and be converted into vermicompost by using *E. eugeniae* under Monoculture and *E. eugeniae, P. excavatus* and *L. mauritii* under Polyculture conditions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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