Indian Journal of Ecology (2024) 51(2): 364-369
DOI: https://doi.org/10.55362/IJE/2024/4243

Manuscript Number: 4243
NAAS Rating: 5.38

Impact of Vermicomposting with Soil Enriched with Plastic and Different Biodegradable Wastes on Physical, Chemical, and Biological Parameters of Soil

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***Abstract*:** The present work is a comparative study to understand the impact of various biodegradable wastes (hair, flower, vegetable peel, and spent coffee) and plastic on the soil quality. The biological parameters like the growth rate of worms, biomass gain, and cocoon production rate augmented considerably in soil enriched with all biodegradable waste groups when compared with soil contaminated with plastic. The health parameters of soil like pH, temperature, moisture content, exchangeable acidity, total organic carbon, nitrogen, phosphorus, and potassium (NPK) content significantly increased in soil enriched with vermicompost produced from coffee and vegetable peel wastes when compared with other groups. A moderate enhancement of nutrient parameters of soil was in hair and flower waste. The biological parameters growth rate, biomass gain, and cocoon production of worms in the plastic group was significantly reduced in five months of the composting period compared with other biodegradable vermicompost groups. Plastic-enriched soil showed a marked decrease in the physical, and chemical determinants of soil fertility. The present comparative study on various biodegradable wastes and plastic vermicomposting has evidenced increased soil quality parameters with biodegradable wastes and decreased content of the same because of the presence of plastic during vermicomposting.

***Keywords*:** Vermicomposting, Segregated bio-degradable waste, Plastic, Soil health parameters, Coffee waste, Vegetable peel

Soil health is the sustained capacity of soil to support all vital lives. Continuous valuation of soil quality is very important as the soil is a dynamic constituent of an environment that is endlessly varying by natural and anthropogenic activities. Currently, active research is going on worldwide to understand the quality of soil and soil microenvironment. High use of chemical fertilizers and their over-dependence have degraded the soil health resulting in the decline in soil carbon stocks (Shahane and Shivay 2021). Both globally and in India, to cater to the needs of a large population, and much dependent on chemical fertilizers than organic manure which has resulted in poor nutrient quality of soil and crops produced. The enhancement of divergence of nutrient sources in soil with importance on organic sources, adoption of principles of conservation agriculture, enhancement of soil microbial diversity, recycling of nutrients through the integrated farming system, and composting are potential choices for improving soil health (Basak et al 2021). Composting can preserve and restore soil fertility, along with the conversion of waste into a resource.

Vermicomposting is a technique that uses the earthworm to translate the voluminous waste into manure and bioremediation process that occurs due to the activity of earthworms that helps to reduce any toxicity present in the wastes. Vermicomposting is a sustainable method of improving soil health which is better than the conventional method of mixing chemical fertilizers (Siddiqui et al 2022). Earthworms and mesophilic bacteria work together in a controlled setting to break down solid biodegradable waste in a process known as vermicomposting. This procedure yields a long-lasting form of organic materials (Ahmad et al 2022).

Plastic is one of the amazing inventions by mankind ever since its initiation of use over a century ago. It has become one of the most convenient and versatile materials of interest with a wide range of applications. It is in wide usage in different industries and fields because of its properties ranging from high resistance to corrosion, lightweight, high strength, transparency, low toxicity to durability, and low manufacturing cost. Plastic has so many positive properties, but negative property contributes greatly to environmental pollution is non-biodegradability. Therefore, the high usage of plastic worldwide has resulted in extreme environmental problems (Chae and An 2018). Plastic waste is creating havoc in the environment (both aquatic and terrestrial) presently receiving universal attention. Most studies on plastic pollution have focused on aquatic environments, whereas the effects and hazards of plastic pollution of the soil are less studied. Earthworms have been largely used as the test species in studying the impact of plastic enrichment on the health of the soil and its effects on soil microorganisms, flora, and fauna (Zhang et al 2023). Different types of organic wastes are rich in different nutrient contents. The vegetable peels are rich in minerals, flower wastes in both macro and micro-nutrients, human hair waste in nitrogen and spent coffee waste is rich in many organic compounds. The specific nutrient content of soil specifically supports the growth of some crops. However, there is limited information in the area of segregation of wastes and its impact on vermicompost and soil health. Therefore, current work focuses on the study of plastic enrichment on soil quality and its impact on vermicomposting and soil quality analysis.

MATERIAL AND METHODS

Composting: Vermicompost production was performed in plastic containers of 5 kg capacity with a working volume of 1 kg following the bed method using *Eisenia fetida*(Mulla and Pathade 2021). The experiments were in triplicates. Initially, shredded newspapers were soaked for 3 days and bedding was prepared. $1/4^{th}$ of the tub was filled with the prepared newspaper bedding and above those 2 inches of jute was added. To each tub, red soil and bio-waste were added. Except for the waste, other things are common in all the groups. Treatment groups contained plastic waste and leaves, hair waste, flower waste, spent coffee waste, and vegetable peel. After adding waste in separate bins was allowed to soften for a week. Later, the earthworms whose weight and lengths were known were introduced, 20 worms in each bin and covered with coir. The lids of the bins were closed, left in dim light, and shaded closet for 5 days. Daily each group was observed for texture change, moisture content, and condition of worms. Water was sprinkled and worms were supplied with different wastes based on their requirement. Periodically, the worms were assessed for their growth pattern, reproductive rate, and health. Composting took around 4-5 months. In the end, compost was harvested, and soil analysis was done.

Effect on biological parameters: The vermicomposting process was carefully followed each day. The duration of composting, and changes like wastes, soil, and worms were periodically analyzed and recorded. The quality of the compost depends on the organic wastes used for the purpose. Different biological parameters like growth rate, biomass, cocoon production, and living conditions of the worms were studied in different experimental groups following standard protocols (Li et al 2020). The earthworms were carefully taken out of the different vermi-bed groups. Washed with tap water, and blotted with filter paper and weighed with a digital electronic balance. The weights and lengths of worms were recorded from the start of the experiment periodically up to 135 days. Each vermicomposting group was carefully analyzed for the number of cocoons, juveniles, mature worms, and dead worms. After measuring the parameters, earthworms were promptly reintroduced into the respective bins. Based on the data obtained on the biomass, cocoons, and growth rate is calculated for different vermi-bed.

Observations

Growth rate of the worms (GR) =

$$\frac{\text{Final weight} - \text{Initial weight}}{\text{Total composting time} \times \text{Average number of earthworms during composting}} \text{ (mg/worm/day)}$$

Total biomass gain (TBG)

$$\text{TBG} = \frac{\text{Final weight} - \text{Initial weight}}{\text{Initial weight}} \text{ mg}$$

Cocoon production ratio (PR)

$$\text{PR (cocoons/worm/day)} = \frac{\text{Number of cocoons}}{\text{Total composting time} \times \text{Average number of earthworms}} \text{ No. of cocoons/day}$$

Percentage of mortality:

$$\text{Death rate} = \frac{\text{Number of deaths during the process}}{\text{Mid process population}} \times 100$$

Vermicompost harvesting and soil analysis: At the end of 5 months, composting was completed in all the groups. Therefore, ready for harvesting. Soils enriched with compost were prepared for analysis following soil preparation protocol for physical and chemical analysis (Tan 2014). Wet samples were spread on a sheet or a plate, less than 1 cm in thickness for drying in a well-ventilated place. The drying process was observed and lumps were crushed by hands carefully and frequently. Foreign materials such as organic matter, charcoal, shells, etc were removed.The air-dried soil samples were sieved through a screen with 2 mm circular holes. Ground and sieved soil samples were stored in separate air-tight containers for further analysis. For chemical analysis of the soil, 2mm sieved soil was ground, sieved through a 0.5mm mesh screen, and stored in separate air-tight containers.

Physical Analysis of Soil (Peterson 2020)

Temperature: Three consecutive morning temperatures were determined in different soil samples at 10-15 cm depth and kept for 2 minutes.

Moisture content: Most soil analyses are made on air-dried soil, but their results are routinely expressed on the dry weight basis. Therefore, the moisture content of the air-dried soil has to be determined. The soil samples were dried at 100°C for 24 hrs in a drying oven, cooled in desiccators, and weights were obtained.

Soil moisture content of air-dried soil (%) = [(B – C)/ (B – A)] × 100

Soil moisture correction factor (MCF) = (B – A)/(C – A)

A= Constant weight of the aluminium cup

B= Weight of cup with 10grams of soil

C= Weight of oven-dried and cooled soil

The MCF is used to correct analytical results on air-dried soil to the dry weight.

Physico-chemical analysis of soil (Peterson 2020)

Electrical conductivity: The electrical conductivity of different soil suspensions was measured using a conductivity meter.

pH: Soil pH (H2O) is usually measured in a soil-water suspension of 1:2.5.

Chemical parameters: The exchangeable acidity of soils represents the acidity obtained by titrating the extracted acid with an alkali solution when neutral salts (e.g., KCl) are added to soils. It shows the amount of (a) acid substances like hydrogen ions in a soil solution and (b) hydrogen and aluminium ions adsorbed by soils (clay minerals, etc.). Hydrogen and aluminium ions are exchanged and exuded with cations contained in the soils by an ion exchange reaction. Following a standard procedure, exchangeable acidity was calculated by titrimetric method (Coscione 1998).

Total organic carbon: When organic carbon is heated with a mixture of dichromate and sulfuric acid, it is oxidized to CO_2: $2Cr_2O_7^{2-} + 3C + 16H+ \rightarrow 4Cr_2+ + 3CO_2 + 8H_2O$. Dichromate consumption is proportional to the amount of carbon reacted. By titrating the remaining dichromate with a standard iron (II) solution after the reaction, the amount of organic C is obtained (Peterson 2020).

N, P, and K analysis: The NPK in soil were analysed with rapid soil test kit for testing soil pH and NPKkit from Nice Chemicals.Soil suspension was prepared in distilled water in the ratio: 1:2 ratios in volume (i.e. one cup of soil with 2 cap water) and mixed it thoroughly. The clear supernatant was separated using filter paper. The clear soil extract was used to quantify N-P-K using reagents and followed the directions given in the manual provided with the kit.

Statistical analysis: Statistical analyses were carried out using Tukey post-tests for comparison. All statistical analyses were performed using GraphPad Prism version 5.0.

RESULTS AND DISCUSSION

Biological parameters: The growth rate of worms was significantly improved among all the compost groups compared to worms present in soil with plastic (Table 1). The maximum of 46% enhancement in the growth rate was provided by the coffee vermicompost group. Similarly, biomass gain was increased significantly in hair (18%), coffee (28%), and vegetable peel (20%). The cocoon production rate was better among all the biodegradable compost groups in comparison with plastic. The production was 2, 5, and 3 times better with flowers, coffee, and vegetable peel wastes. Many organisms depend upon the quality of the soil. To study the impact of chemical and plastic pollution, earthworms are studied as the model organisms (Chae and An 2018). Research in the area of solid waste management has enough evidence to prove how soil fertility increases with the addition of biodegradable substances (Ashraf et al 2020, Lal et al 2020). However, there is scarce data on segregated wastes, vermicomposting, and its impact on soil health parameters. Specific micronutrients, minerals, and bioactive may contribute to the quality enhancement of soil and support specific crop plants. There is not much research on separated wastes- For example flower waste from temples, vegetable peel waste from restaurants and kitchens, coffee/ tea sled waste from hotels and food industries, and hair waste from salons.. No mortality was observed in any waste. The earthworms grew rapidly and attained increased biomass and cocoon production in all biodegradable compost groups when compared to plastic. The growth rate biomass gain and cocoon production of worms present in the plastic group was not appreciable in the 5-month composting period when compared with other biodegradable vermicompost groups. Maximum weight gain and highest growth rate were attained in coffee waste. Net biomass gain/earthworm in vermicompost wastes was in the order of: (plastic=flower waste) < (hair waste= vegetable peel) < Coffee waste. Analysis of the cocoon production rate revealed that except in plastic and hair compost groups, in other groups, there was a significant increase in the reproductive rate observed. The cocoon production rate in different vermicompost wastes was

Table 1. Biological parameters of soil in different vermicompost groups

Vermicompost groups	Biological parameters		
	Growth rate of worms (mg/worm/day)	Total biomass gain (mg)	Cocoon production (Cocoons/worm/day)
Plastic	0.13 ± 0.001	11.98 ± 0.89	0.017 ± 0.00
Hair	0.19± 0.01#	14.3± 0.29#	0.018± 0.01
Flower	0.09 ± 0.011	11.47 ±1.17	0.037±0.01#
Coffee	0.19± 0.002#	15.49± 0.96#	0.06± 0.001#
Vegetable peel	0.185± 0.006#	14.51 ± 1.05#	0.046± 0.001#

Values are Mean ± SE . # Significantly different from plastic vermicompost group in the order of: (plastic=hair waste) < (flower waste) < vegetable peel waste < coffee waste. The maximum reproduction rate of earthworms was achieved in coffee waste. All compostable wastes contain many nutrients, polysaccharides, proteins, polyphenols, tannins, fibres, and antinutrient substances. They may cause toxicity to the crop plants as such when not composted. Vermicomposting is a better method to digest the complex substances present in the wastes and convert them into simple nutrients available in the soil (Sharma and Garg 2019). Therefore positive effect of different organic substances used on the growth rate and biomass increase of *Eisenia fetida* is because of bioremediation through the vermicomposting process.

Plastics are hydrocarbons of polymeric structure enriched with additives for their special properties. After usage both petroleum-derived plastics and bioplastics become a waste that should be properly managed otherwise leads to environmental pollution. The pollution of terrestrial ecosystems directly results in changes in the chemical composition of soil and affects soil structure and functions including the effect on soil organisms. Plastics can adsorb hazardous contaminants, antibiotics, toxicants, and heavy metals (Liwarska 2021). The present study evidences that the vermicompost group with plastic enrichment resulted in a significantly decreased growth rate, biomass gain, and cocoon production rate. This stresses the fact that soil pollution with plastic is degrading the quality of soil and soil organisms like earthworms.

Physical and physicochemical parameters: The soil temperature was decreased by 14% in the plastic group whereas, increased from 7 to 26% among flower, coffee, and vegetable peel compost groups (Table 2). The electrical conductivity was marginally increased in coffee and vegetable peel compost groups. pH was not significantly changed but was slightly increased among all compost groups. Moisture content was increased by 10 to 26% among flower, coffee, and vegetable peel groups. The highest moisture content was in coffee compost soil. The moisture content of the soil decreased by 14% with plastic. Vermicompost can enhance soil fertility physically, chemically, and biologically. Physically, vermicompost-treated soil has ideal pH, temperature, moisture content, electrical conductivity, better aeration, porosity, bulk density, and water retention which enhances the growth of plants (Lim et al 2015). In present study also increased temperature and moisture content were shown in all biodegradable vermicompost groups and a significant decrease in these parameters was in the plastic group. Implying the negative effect of plastic and the positive effect of all biodegradable wastes on the physical parameters of soil quality. There was no significant difference in the parameters: pH and electrical conductivity of all the studied groups.

Chemical parameters: The exchangeable acidity of soil with plastic was not significantly different from the control group. However, it was significantly increased among all the biodegradable waste groups 39% (flower) to 67% (coffee) (Table 3 and Table 4). Total organic carbon increased marginally (14-15%) with hair and flower composts. There was a 40% increase in total carbon content because of vegetable peel. Thesignificant enhancement (76%) in this parameter was found with coffee waste composting. NPK content was also significantly improved among all biodegradable compost groups when compared to control and plastic groups. The plastic group was not significantly different from the control. Coffee waste compost gave a better result (nitrogen-high; phosphorus-very high; and potassium-high) amongst all other groups. Vermicomposting increases the acidity of the soil. Exchangeable acidity shows the amount of (a) acid substances like hydrogen ions in a soil solution and (b) hydrogen and aluminium ions adsorbed by soils (clay minerals, etc.). Hydrogen and aluminium ions are exchanged and exuded with cations contained in the soils by an ion exchange reaction. Soil exchangeable acidity regulates the amount of lime necessary to increase the soil pH which in turn will help in

Table 2. Physical and physicochemical parameters of soil in different vermicompost groups

Vermicompost groups	Physical parameters			
	Soil temperature (°C)	Electrical conductivity (mS/cm)	Soil pH	Soil moisture (% moisture content)
Control	39 ± 0.68	0.46±0.003	8.5±0.02	39.0 ± 0.68
Plastic	33.6 ± 0.52*	0.48±0.002	8.75 ± 0.01	33.6 ± 0.52*
Hair	38.7 ± 0.75	0.48±0.008	8.71±0.01	38.7 ± 0.75
Flower	43.0 ± 0.75*#	0.47±0.003	8.72 ±0.02	43.0 ± 0.75*#
Coffee	49.2 ± 0.1*#	0.48 ± 0.006	8.79 ± 0.01	49.3 ± 1.01*#
Vegetable peel	41.9 ± 0.2#	0.48 ± 0.005	8.75 ± 0.02	41.9 ± 0.2#

Values are Mean ± SE (n=3) , * Significantly different from Control; # Significantly different from plastic vermicompost group,Data was analyzed by Tukey's Multiple Comparison Test the absorption of minerals by plants for their growth and development (Onwuka et al 2016). Total organic carbon is the carbon deposited in the organic matter and contributed by the decomposition of plant/animal matter in soil. The process of vermicomposting improves the total organic carbon content of the soil. This parameter influences many soil characteristics like water retention, aeration, and nutrient turnover (Tesfamariam 2022). Nitrogen, phosphorus, and potassium (NPK) are the main soil nutrients. These are the three essential macronutrients required for plant growth. This chemical parameter of soil helps strengthen plants' abilities to resist diseases and plays a vital role in increasing the quality and quantity of crops (Yadav et al 2020). The current study demonstrated that the vermicompost group with plastic enrichment has resulted in no change from the control group in the chemical parameters of soil quality like exchangeable acidity, total organic carbon, and nutrient indicator i.e., NPK content. All biodegradable waste vermicompost groups have shown a significant increase in the above said parameters. Thus, supporting the significance of vermicomposting in improving chemical parameters of soil and the negative impact of plastic's presence in soil during vermicomposting. To sum up the chemical characteristics of soil in different vermicompost wastes were in the order of: control=plastic < flower waste = Hair waste < vegetable peel waste < coffee waste.

Table 3. Chemical parameters of soil in different vermicompost groups

Vermicompost groups	Exchangeable acidity (centimoles/Kg)	Total organic carbon (% carbon/100 gm of soil)
Control	1.27 ± 0.04	30.13 ± 0.18
Plastic	1.25 ± 0.02	30.39 ± 0.56
Hair	2.63 ± 0.08*#	34.77 ± 0.83*#
Flower	1.77 ± 0.08*#	34.43 ± 0.72*#
Coffee	3.87 ± 0.18*#	52.9 ± 0.95*#
Vegetable peel	3.4 ± 0.26*#	42.2 ± 1.18*#

Values are mean ± SE (3 replicates in each group). Data was analyzed by Tukey's Multiple Comparison Test.
*- Significantly different compared to control; #- Significantly different compared to the plastic vermicompost group

Table 4. Nitrogen, phosphorus, and potassium contents in different vermicompost groups

Groups	NPK Content		
	Nitrogen	Phosphorus	Potassium
Control	Low	Medium*	Low
Plastic	Low	Low	Low
Hair	Medium*	Medium*	Medium*
Flower	Medium*	Medium*	Medium*
Coffee	High**	Very high**	High**
Vegetable peel	Medium*	High	Medium*

Values are Mean ± SE (n=3), *Significantly different from Control; # Significantly different from plastic vermicompost group, Data was analyzed by Tukey's Multiple Comparison Test

Generation of waste is an ecological problem but vermicomposting is a technology that utilizes this problematic waste in an eco-friendly method to generate nutrient-rich compost. This technology is appropriate due to its simplicity, cost-effectiveness, and efficiency in degrading all types of non-toxic biodegradable wastes. Numerous decomposable wastes are reported to have various nutrient proportions supporting different types of crop production (Tesfamariam et al 2022). Composting and vermicomposting both are regarded as suitable ways to manage organic waste because they not only solve waste disposal issues but also produce useful bio-amendment agents (organic fertilizer). Specifically, vermicomposting is a superior process when compared to composting, as this technique results in an increased rate of decomposition of organic matter and results in high nutrient value of soil. This is because of the beneficial bacterial interaction, and higher concentration of hormones and enzymes by the earthworms that could encourage the growth of crop plants and discourage plant pests (Wu et al 2014). Besides, vermicompost produced higher concentrations of hormones and enzymes that could stimulate plant growth and discourage plant pathogens. Therefore, in the current study, we have studied the quality of soil enriched with vermicomposting from different types of wastes like hair, vegetable peel, coffee sludge, and flowers. Plastic has also become a nuisance because of its non-biodegradability and overuse. Studies showing the impact of soil health because of plastic pollution are inadequate (Bläsing and Amelung 2018).

Vermicompost can enhance soil fertility physically, chemically, and biologically. Physically, vermicompost-treated soil has ideal pH, temperature, moisture content, electrical conductivity, better aeration, porosity, bulk density, and water retention which enhances the growth of plants (Lim et al 2015). This is demonstrated by us also as increased temperature and moisture content were shown in all biodegradable vermicompost groups and a significant decrease in these parameters was shown in the plastic group. Implying the negative effect of plastic and the positive effect of all biodegradable wastes on the physical parameters of soil quality. There was no significant difference in the parameters: pH and electrical conductivity of all the studied groups.

CONCLUSIONS

Vermicomposting is an amazing technique for increasing the nutrient content of soil. The biological parameters like the growth rate of worms, biomass gain, and cocoon production rate augmented considerably in soil enriched with all biodegradable waste groups when compared with soil contaminated with the plastic group. The health parameters of soil like Ideal pH, temperature, moisture content, exchangeable acidity, total organic carbon, and NPK content significantly increased in soil enriched with vermicompost produced from coffee and Vegetable peel wastes when compared with other groups. The moderate enhancement of nutritive parameters of soil was seen in hair and flower waste. Considering the potential contribution to soil fertility by coffee and vegetable peel waste, there is a need to consider them for further studies and employ them in enhancing the fertility of naturally degraded ecosystems as well as agroecosystems. While plastic enriched soil showed decreased content of all the health-determining factors of the soil. Vermicomposting decreases environmental pollution and enhances soil health for sustainable development. In the future, more eco-friendly techniques to be explored to convert the enormous amount of energy present in the organic wastes to nutrients for sustainable soil health and plant growth. The comparative study of both degradable waste and non-degradable plastic waste indicates the negative effects produced by plastic on soil. There is more scope for research in this area to study and lessen the pollution caused by plastic waste and the best disposable techniques to be explored.

AUTHORS CONTRIBUTION

Dr. V Sriranjini has conceived, designed and wrote the paper. Anusha, Deekshitha and Jalaja performed the experiments and did statistical analysis.

ACKNOWLEDGEMENTS

The authors sincerely thank the management of BMS College for Women, Autonomous for the grant of in-house project funds to carry out the experiments.

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Received 21 September, 2023; Accepted 12 March, 2024