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EFFECTS OF BIOCHAR & VERMICHAR AS A SOIL SUPPLEMENT TO IMPROVE MAIZE PLANT GROWTH

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. Author AJ designed the study and wrote the first draft of the manuscript. Authors GS and VH collected and analysed the data and author RP drafted and designed the final manuscript. All the authors read and approved the final manuscript.

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ABSTRACT

The rapid increase in the volume of waste is one aspect of the environmental problem, that hinders global development. This study explores the possibility of utilizing waste biomass to prepare biochar and vermichar which can be used as soil supplements in plant growth. Biochar is charcoal that is produced by pyrolysis of biomass, in the absence of oxygen and is used as a soil ameliorant for both carbon sequestration and for soil fertility. Here in this work, we explore the production of vermichar which is the synergy between Vermiculture (worm farming) and Biochar (porous charcoal soil improver). The physiological, morphological and, biological parameters of these soil supplements were analyzed. Earthworms used for the production of vermiculture are *Eugenia eudrilus* and *Eisenia foetida*. The plant used for the study is maize. According to our analysis, vermichar is a very good supplement for the soil which increases the N, P, K, C, and organic content of the soil, which is followed by biochar in order to grow a healthy plant. Using this soil supplement the fertility of the soil is protected and the yield is high. From the above work, it is clear that biochar, as well as vermichar, has a great role in plant growth and in increasing soil fertility.

Keywords: Vermiculture; biochar; vermichar; earthworms; soil supplements; pyrolysis.

1. INTRODUCTION

Soil contamination these days has become a world problem of the greatest magnitude. Industrial and technological advancement increased pollutant intake into the environment. The main reasons for contamination are natural processes like a volcanic eruption and weathering of rocks as well as anthropogenic activities such as smelting, mining, and over-application of agrochemicals such as fertilizers and pesticides [1,2]. Hence farmers are in a situation to use this contaminated soil for the production of food crops and which produces low yield with less nutritive elements [3]. The plant requires a number of soil nutrients like nitrogen (N), phosphorous (P), potassium (K) for its growth, but soil nutrients levels may decrease over time after crop harvesting, as nutrients are not returned to the soil. Thus, to fulfill the shortage, a large number of chemical fertilizers are added to the soil which leads to deterioration of the environment causing infinite problems. Thus, the application of vermicomposts as a soil amendment has multiple benefits such as improving soil health, minimizing the disease threat, and controlling soil

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erosion. Vermicompost is produced by the effective interaction of microbes and earthworms that could be used to improve soil fertility. During the vermicomposting, microbes are mainly involved in the biochemical decomposition of organic matter; whereas earthworms drive the process by acclimatizing the substrate which produces a stable soil conditioner called vermicompost [4]. They boost the availability of mineral nutrients including nitrogen (five folds), phosphorus (seven-folds), potassium (eleven folds), and magnesium (two folds) in the soil.

Recently, the use of biochar has been accepted as a sustainable approach because it possesses properties such as high binding capacity and environmental safety. Biochar, also Known as black carbon, is a product derived from organic material rich in carbon (C) and is found in soils in very stable forms, often as deposits. Biochars can persist for long periods of time in the soil at various depths, typically thousands of years. Biochar is a fine-grained porous and carbonaceous solid material synthesized from waste biomass residues under limits oxygen conditions and low to medium temperatures (450-650°C) by slow pyrolysis [5]. Biochar can be produced by thermal decomposition of various kinds of organic feedstocks such as crop biomass, wood, agricultural residues (cereal straw, hazelnut, and peanut shell, wheat straw, etc,), and industrial organic waste (sewage sludge and de-inking paper sludge. Hence in this study, we prepared vermichar by mixing vermicompost and biochar and used them as soil supplements. The application of vermichar to soils for plant growth has been investigated at the laboratory at a small-scale level as an in-situ remediation strategy. However, responses to biochars may depend on the type of Biochar used and the specific characteristics of that Biochar. This work exclusively compares and summarizes the properties of vermicompost, Biochar, and Vermichar its interaction with soil, and its role in plant growth promotion.

2. MATERIALS AND METHODS

2.1 Preparation of Vermicompost

2.1.1 Collection of materials

- Dry leaves were collected from our college garden.
- Cow dung was collected from the nearby cattle shed.
- Earthworms- In the present study the well-known species of Earthworm *Eisenia foetida* and *Eudrilus eugenia* obtained from a vermicompost unit in Manikandam, Trichy, Tamilnadu, India.

2.1.2 Process of vermicomposting

Collected leaf wastes were chopped into small pieces. The chopped waste was mixed with cattle dung in 50:50 ratios. The vermicomposting process was done in plastic containers. The mixture was prepared and kept in bins (plastic trays). This was kept in the vermicomposting room. Bins were sprinkled with water to maintain high moisture content. This was kept for 15 days for decomposition. Two species of earthworms (*E. eugeniae and E .foetida*) were added to each composting bin. The process was monitored till its maturation where there is the development of a small granular vermicast on the surface layer, which indicates the completion of the vermicomposting process. At this stage, watering was stopped before seven days of harvest. Prepared vermicompost was stacked so that the earthworms settle at the bottom and the vermicompost was collected from the top without disturbing the bottom layers. The harvested vermicompost was filtered through a fine sieve in order to get fine uniform vermicompost [6].

2.2 Pyrolysis of Dried Leaves into Biochar

Biochar can be produced in a charring kiln. Commercially available copper tea boiler with a simple design is used as charring tin It has small holes in the bottom (it is raised up on bricks), and has a gap between the lid and the pyrolysis chamber to allow a small amount of air to enter. Dried leaves, that are collected from our college garden are packed into the barrel, lit from the top, and allowed to burn, typically for around 10-15mins. It has to be extinguished physically by starving oxygen. The yield of biochar was calculated by the following equation.

Biochar yield (%) = [mass of biochar(g)/ dried mass of raw textile(g)] $\times$100%

2.3 Characterization of Biochar

2.3.1 FTIR spectroscopy

The prepared biochar was analyzed by Shimadzu FTIR 8300 spectrophotometer in the wavelength between 400cm-1 and 4000cm-1 and in the solid-state using potassium bromide pellets.

2.3.2 Scanning electron microscope (SEM)

Scanning electron microscopic analysis was done using Carel Zeiss (Germany) to measure the size of biochar. The sample was allowed to dry completely by rotary evaporator and grounded well to a fine powder and it was analyzed.

2.4 Preparation of Vermichar

Vermichar is prepared in a 3:1 ratio of compost and grinded biochar. It is added and mixed well into the container and mixed well. So that both the biochar and vermicompost are well distributed and now soil supplement vermichar is ready.

2.5 Treatment with Soil and Cultivation of Maize Plant

Now the soil supplements, Biochar, Vermicompost and Vermichar are mixed with soil in the ratio 10 grams per kg of soil and the growth of maize plant is studied.

Treatments:

Pot 1: Control: Soil + Maize
Pot 2: BC: Biochar + Soil + Maize
Pot 3: VP: Vermicompost + Soil + Maize
Pot 4: VC: Vermichar + Soil + Maize

Plants were maintained under the garden soil conditions. The Plants were watered regularly throughout the experiment.

2.6 Analyzing Quality of Soil by Physiological and Biochemical Parameter

The compositions of soil were analyzed. The following chemical analysis was conducted in the lab and the test result is tabulated in Table-

- pH using a pH meter;
- Electrical conductivity (EC in mS/cm) using a conductivity meter;
- Texture: Texture can be evaluated by two methods, i.e. sieve method and mechanical analysis. The conventionally used method is the sieve methods, although it is an approximation of the particles present in vermicompost.
- Total organic carbon (TOC in %) is obtained after burning 0.5 gm of the sample at 550 C for 60 min in a muffle furnace [7].
- Total nitrogen (N in %) using the Kjeldahl method;
- Total phosphorus (P in %) determined by the colorimetric method using a spectrophotometer;
- Total potassium (K in %) by the absorption method using the Atomic
- Absorption Spectrophotometer (AAS).
- C:N ratio.

2.7 Analysis of Plant Growth by Morphological Parameters

The quality of vermicompost was evaluated from the morphological growth of the Maize plant. The plant growth of each treatment was studied in three pots to make sure that the results were uniform. The following growth parameters were analyzed. They were:

(i) length of shoot
(ii) number of branches
(iii) number of leaves
(iv) number of branches.

The length of the shoot and root was measured with a measuring tape and the data were recorded. The number of branches and leaves were manually counted. The observations were recorded after 50 days of growth.

3. RESULTS AND DISCUSSION

The purpose of vermichar production is known to improve the soil fertility and plant growth. Following exhibits (Photos 1, 2) the results in this study.

The production of Biochar from agricultural waste like rice straw, dry leaves have more energy production and gives nutritive elements to soil, which remediates soil fertility. Since these plant products is rich in cellulose and hemicellulose, they produce key elements like carbon, oxygen and hydrogen which is the basic requirement for plant growth. The yield of biochar was calculated by the following equation.

Biochar yield (%) = [mass of biochar(g)/ dried mass of raw textile(g)] $\times$100%

Nearly 1 kg of dried leaves were been put in to this unit, and around 250gms of biochar remains were recovered and therefore yield of biochar was 250 gms.

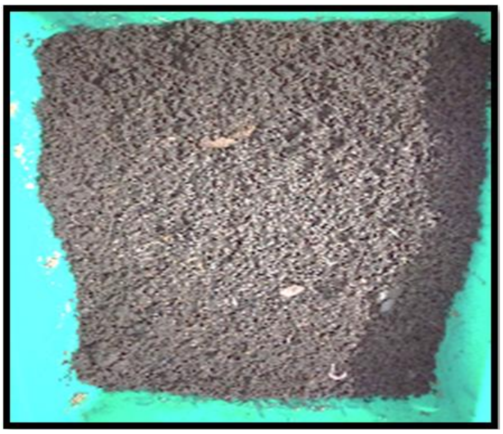
3.1 Characterization of Biochar

3.1.1 Scanning electron microscope

The surface morphology of Biochar was examined and the Fig. 1 shows the average particle size of biochar respectively.

The biochar characterization can be done using various modern techniques such as Scanning Electron Microscopy (SEM), Fourier Transform Infrared Spectrometer (FTIR), Thermo Gravimetric Analysis (TGA), X-Ray Diffraction (XRD), Brunauer Emmett Teller (BET), Nuclear Magnetic Resonance (NMR), Raman spectroscopy, etc. [8]. SEM analysis shows increase in surface area of biochar samples as the pyrolysis temperature is increased (Fig. 2). According to [9], the presence of Methanol or other alcohols groups in biochar will contribute to form mesoporous materials with fibrous, high surface area, large pore volume and open web-like structures. In a view [10], the presence of hydrophilic and the strongly polarity compound will increase the pore size and surface area. Because of this reason they have good water holding capacity.

a. Vermibed in plastic trays



b. Vermicompost

c. Earthworms used for the study

Photo 1. Preparation of vermibed and vermicompost

a. Charring Kiln

b. Biochar

Photo 2. Steps in biochar preparation

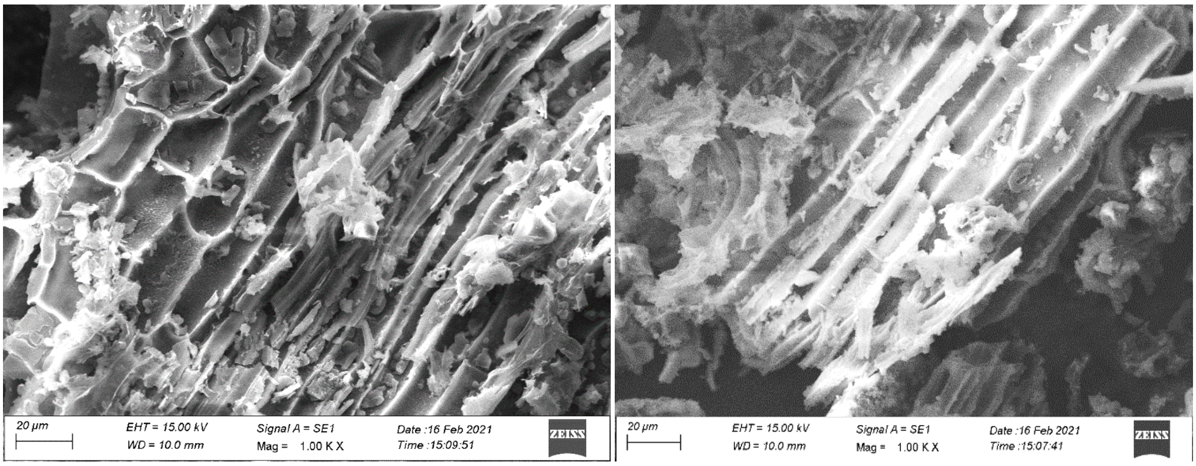


Fig. 1. Surface morphology of biochar in scanning electron microscope

3.1.2 FTIR spectroscopy

FTIR was conducted to determine the functional group presented on biochars surface. Based on Fig. 2, the band at 3484 cm−1 represented the stretching vibrations of the OH groups, which could be attributed to the adsorbed water on the bio char. It showed the intensity and shaped was strong. Other than that, the band at 1567.92 cm-1 represented the stretching variations C=C aromatic. The double bonds appeared as medium to strong absorptions. Based on the C=C bond, it indicated the presence of adjacent carbon in the bio chars. At band 1424.58 cm-1, it represented the stretching variations of the C-OH. It showed strong intensity of hydroxyl group. This showed alkynes group present in the bio chars. At the end of the data, it showed that the graph was interrupted due to high temperature during pyrolysis until diminish all the functional groups [11].

3.2 Analysing Quality of Soil by Physiological and Biochemical Parameter

The compositions of soil were analyzed. The following chemical analysis was carried out in the lab and the test result is shown in Figs. 3 & 4.

3.3 Nutritive Content in Soil and Soil Supplements

The nutrient content in vermicompost varies depending on the waste materials that are being used for compost preparation. If the waste materials are heterogeneous one, there will be a wide range of nutrients available in the compost. If the waste materials are homogeneous one, there will be only certain nutrients are available. Here in this study, we used cow dung, dried leaves, and sticks for preparing compost, and earthworms *Eisenia foetida* and *Eudrilus eugenia* are used. Vermichar was prepared from biochar and vermicompost. A fine, granular, odorless, black peat-like structured compost was obtained after fifty days. Then vermichar is prepared by mixing this vermicompost and biochar and amended in the soil as supplements. After the 50 days of growth of maize, the plant's soil was collected and were analyzed for nutrient content. The soil was rich in N, P, and K contents. The result showed that the nutrient content of all the samples was significantly higher than that of the control (Table 1). It might be due to the reason that control treatment lacked soil supplements. It was found that no matter whatever was the substrate used for composting, the NPK content of treated samples was higher than that of control [12]. The highest amount of nitrogen content was present in Biochar treated soil, while potassium is high in Vermicompost treated soil and the vermichar treated soil shows the highest Phosphorous, carbon and Samples.

3.4 Analysis of Plant Growth by Morphological Parameters

The quality of soil supplements was evaluated from the morphological growth of the Maize plant.

Table 2 and Photo 3 show the comparative results of all growth parameters and the quality of vermicompost in the growth of the pea plant. The following growth parameters were analyzed. They were (i) length of shoot, (ii) number of branches, (iii) number of leaves, (iv) number of branches, (v) Weight of the plant, and (vi) Moisture content of the plant. The plant growth was also showing similar results the vermichar treated soil has good growth compared to vermicompost and biochar treated soil supplements.

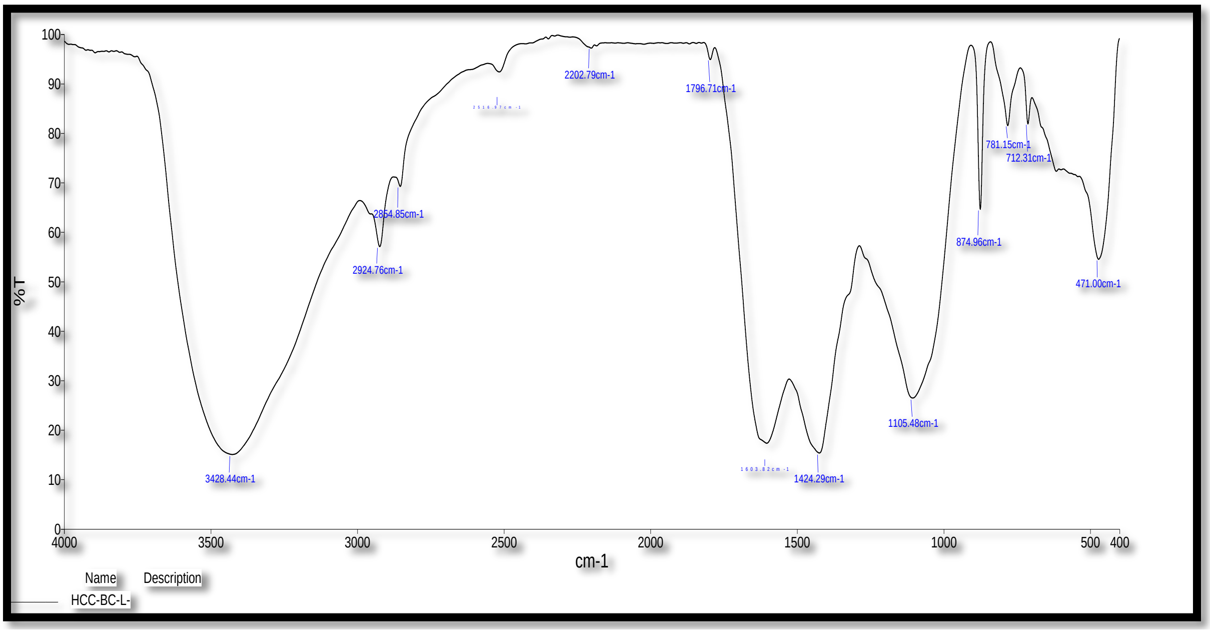


Fig. 2. FTIR spectra of biochar

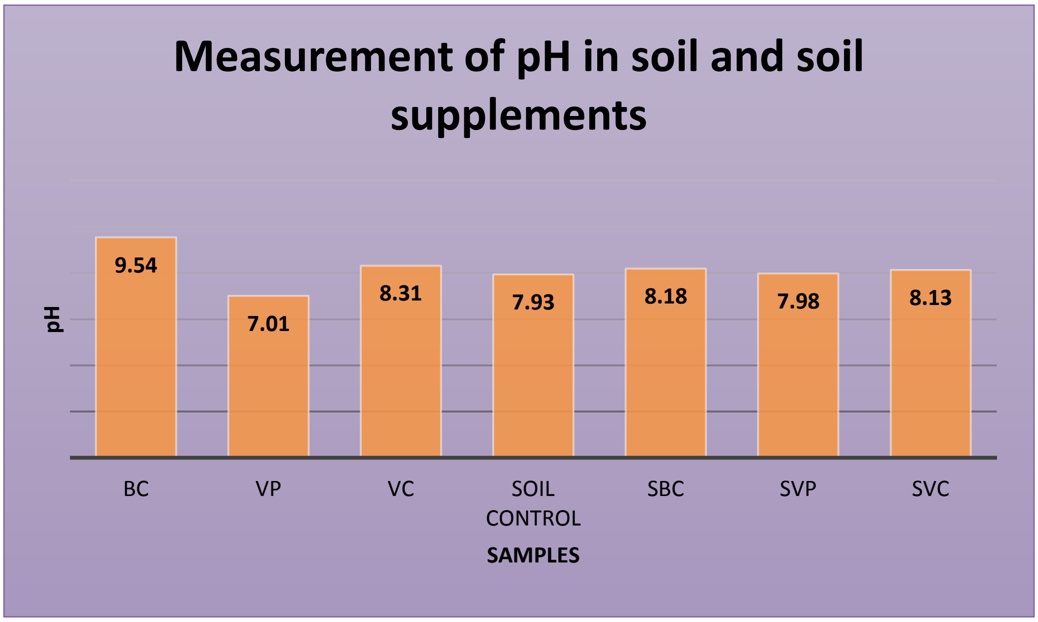


Fig. 3. pH levels in soil and soil supplements

Table 1. Common Nutrient content present in the samples

Samples	N %	P %	K %	C %	Organic matter%
BC-Biochar	1.2	.374	3.2	15.6	25.6
VP-Vermicompost	0.81	1.366	3.7	13.5	23.8
VC- Vermichar	2.9	1.617	0.14	14.3	26.7
Soil –Control	0.55	0.242	2.24	0.87	1.802
SBC (Soil + Biochar)	3.68	0.319	0.12	13.4	20.78
SVP (Soil + Vermicompost)	2.07	0.314	0.14	4.5	5.56
SVC (Soil + Vermichar)	2.9	0.175	0.107	12.7	28.3

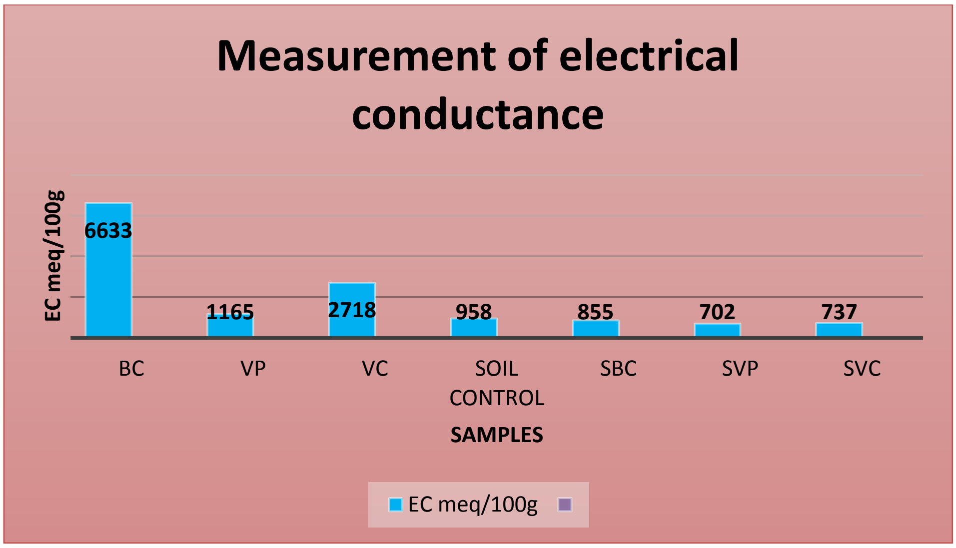


Fig. 4. EC values in soil & soil supplements

Table 2. Comparative morphological growth parameter of maize plants

Treatment of Maize plant	No. of. Leaves	Leaf length in cm	Shoot length in cm	Root Length in cm	Weight of the plant in gm	Dry weight of plant in gm	Moisture content % (W-D/W)x100
Control	3	15	10	6	1	0.5	40
Soil + Biochar	5	22	34	10	2.01	1.005	50
Soil + Vermicompost	4	30	35	10	1.53	0.765	50
Soil + Vermichar	6	39	53	16	7.95	3.975	50

Panta & Yami, [13] found that the decomposition process was enhanced and nutrient content was increased due to the presence of earthworms and aerobic heterotrophic population of microbes. The increased content of plant useable forms of nitrogen, phosphorous, and potassium might be due to the rapid mineralization of wastes due to the action of earthworms [14,15]. It was cited as well as explained that the quality of vermicompost always depends on the type of substrate used for composting [16]. However, the mixture of vermichar, biochar, and vermicompost was suitable for the growth of high-quality maize plants. Its yield and quality vary significantly with the production technology and process parameters, which also affect its performance in agro and forestry systems [17].

a. Vermicompost as soil Supplement

b. Biochar as soil Supplement

c. Vermichar as soil supplement

d. soil treatments and control Plant

Photos 3. Cultivation of maize plant using soil supplement

Thus, this approach of utilizing vermichar and biochar represents an attractive, efficient, and eco-friendly method in the treatment and management of solid wastes generated from all sources such as industrial, agricultural, and domestic. The other added advantage is that this approach focuses on the conservation of resources and their sustainable utilization.

4. CONCLUSION

Vermichar is a cost-effective technology to produce high-quality manure from bio-degradable solid wastes with the help of earthworms. Therefore, it has a great role in waste management and in promoting organic agriculture. Discarded crop residues and menacing crop weeds can be utilized as substrates for vermicomposting to produce a nutrient-rich soil conditioner. Biochar of leaf litter, crop residues, and weeds can be an effective solution to waste and weed management in farm, forest, and urban areas. Furthermore, it can be a great source for the much-needed organic fertilizer. The type of substrate used can influence the quality and nutrient content of vermicompost. This study found that any suitable substrate subjected to vermicomposting makes better compost than the conventional cow dung compost. Furthermore, a mixture of cow dung with other plant residues makes a better substrate which yields vermicompost with enhanced nutrient content. Among different substrates used for vermichar was found most effective which contained the highest phosphorous, carbon, and organic content followed by biochar. Though the phosphorous content was highest in vermicompost. However, it can be concluded that all the substrates or soil supplements are efficient and further research has to do in formulating high manuring potential for plants to yield largely.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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