Research article

Production of quality compost from Pennywort plant wastes

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Abstract: Composting is an environment-friendly phenomenon that recycles organic materials such as plants converting them into beneficial fertilizers. Hence composting limits the use of toxic chemical fertilizers. The study aimed to prepare compost/bio-fertilizer from a nutrient-rich plant, the pennywort, for organic crop production and to reduce the plant wastes by reusing them for environmental benefits. For this purpose, the plants were mixed with different other additives like rock phosphate, urea, cow dung, and sludge to boost up the quality of compost. Pennywort plant compost alone (without any additive) was considered as a control and aerobic conditions were maintained. Physico-chemical parameters like organic matter, ash content, total nitrogen, pH, electrical conductivity (EC), and level of heavy metals and micronutrients were taken into account. All tested parameters showed a beneficial level in the amended plant composts compared to the plant alone. Therefore, the prepared compost could be very promising for crops improvement. Hence, the present study would prove a significant advancement in the pool of efforts to enhance agricultural welfares. Moreover, the current study provides useful knowledge about enhancing the properties and profile of natural composted products because it can provide an alternate source to increase the fertility of the soil and also a good approach to reduce the pressure of solid waste on the environment.

Keywords: : Composting, Waste management, Pennywort plant, ash content, organic matter count

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1. Introduction

Composting is a recycling process in which organic matter is converted into useful fertilizer under optimum temperature, moisture, and aeration and can be applied directly to land without causing any hazardous impact on the environment [1,2]. A number of technologies have emerged which provide recycling of organic wastes (agricultural, municipal and domestic) into a valuable resource for the improvement of soil conditions in terms of nutrients [3]. Compost is a decomposed organic matter and has a dark, crumbly, and earthy odour. Compost contains various helpful and easily useable nutrients which can improve plant health as well as detoxify the pollutants in the soil and irrigation water [4]. Plant waste material is generally high in carbon, nitrogen, phosphorus, and other micro/ macronutrients which provide food for microbes and keep the soil in balanced healthy conditions. Compost also imparts greater fertility to the soil for a longer time [5]. Pennyworts (*Hydrocotyle umbellata*) have been enormously reported to fight off the toxic and complex pollutants in soil and water [6]. Moreover, these plants have also been stated to massively grow and contribute to waste production in aquatic bodies [7]. Therefore, exploiting pennyworts for compost production can not only help increase crops and soil health but can also reduce the burden of the agricultural waste [8].

When composted, these materials become one of nature's best garden fertilizers and richest mediums for potted plants and a detoxifying tool for contaminated soils. In a developing country, household-level composting opens the greatest potential for cleaning up the environment because most of the urban centres are surrounded by small/large scale agricultural wastes in abundance [9]. The success of the compositing process depends on different factors such as temperature, moisture, oxygen, particle size, the carbon-to-nitrogen ratio, and the degree of turning [10]. Moreover, there is number of factors that have profound effects on composting. These factors usually include the availability of an adequate source of carbon/oxygen, appropriate moisture level, pH temperature and the presence/absence of toxic components [11].

Pennywort is being used the first time for the production of quality compost. Pennywort has been used for medicinal purposes and also for wastewater treatment. Panyakhan *et al.*, [12] suggested that *H. umbellate* is a good candidate for the removal of heavy metals from contaminated water. Similarly, *H. Umbellate* was used for the removal of toxic metals from leather tanneries wastewater treatment plant [13]. Pennywort usually grows in Cooler months and it can be used as a substitute in water hyacinth based water treatment plants [14].

Previous reports have documented the improvement in the soil fertility by compost application along with net improvement in land productivity when applied with chemical fertilizers/additives [15, 16]. Similarly, reports are available which depict the importance of barrel composting plants and that the biochemical quality of the compost produced in the modified composting barrel was found suitable and eco-friendly, efficient and a sustainable solution of organic waste management [17].

The current study was planned mainly with the objectives of converting convert pennywort plant waste residues into useful materials for crop production, to modify the plant compost with various amendments to prepare nutrient enriched compost that may be a valuable tool for highly organic crop production in the future and to reduce the time period for conventional composting by additives.

2. Materials and Methods

Study area

The bio-compost production work was carried out at National Agricultural Research Center (NARC), Islamabad.

Chemicals and equipment used in study

Distilled water, sulphuric acid (0.02N), phenolphthalein, lithium chloride, colour reagent, Eriochrome Black T (Indicator), Standard solutions of phosphorus, methionine, Sodium hydroxide (8%), Mixture of HNO_3 +$HClO_4$, *sulphuric acid-selenium (Digestion mixture).*

Electrical Conductivity (EC) meter (Senso-direct, Lovibond, Germany), pH meter (Lutron, WA-2015), Spectrophotometer (Perkin Elmer, UV-Visible, Lambda 3B), physical balance (for weighing), incubator, shaker, beakers, pipettes, cuvette (1 ml), conical flask, volumetric flasks, titration flasks and experimental containers.

Raw materials for composting

The agricultural waste of pennywort (*Hydrocotyle umbellata*) plant collected from the experimental pond of bioremediation setup area of NARC, Islamabad was used as raw material. The plant wastes were being dumped into pond water and mud. The collected plant's materials were dried and hewed into easily biodegradable fractions (Figure 1). Dried shoots, roots, and leaves contained carbon, Nitrogen, phosphorus, potassium, Zn, and iron and were mixed with a different amendment or bulking agents to improve the characteristics of feedstock.

Figure 1: Crushing of the pennywort plant into small pieces

Experimental setup

The experiment was conducted with the following two treatments (*E) each in triplicate to avoid the environmental or experimental preconception or bias: (Figure 2).

- **E1 (Experimental):** Chopped pennywort plant material, mixed with fresh sludge taken from the decomposition of water lettuce (P+S).
- **E2:** Chopped pennywort plant material, layered with urea, three layers of urea with four layers of Pennywort (P+U).
- **E3:** Chopped pennywort plant material, mixed with rock phosphate. Three layers of rock phosphate with four layers of pennywort (P+RP).
- **E4:** Chopped pennywort plant material, mixed with fresh cow dung (P+CD).
- **C (Control):** contained only chopped pennywort plant material (C).

Aerobic conditions were maintained and the boxes were kept in sunlight. During the process of composting the pile was turned manually every 1 week to mix the contents/nutrients evenly.

Figure 2: Different Treatments of compost by mixing pennywort plant

Sampling

Compost samples were harvested after every 15 days and the experiment was conducted for a period of 60 days. At each harvest, compost samples (different amounts in grams for different analysis) were collected from the boxes, air-dried, and converted into powdered form for physicochemical and heavy metal analysis.

Physicochemical analysis of the compost

Standard was used for colour determination through naked eye and was done during the sampling [18]. Human sense of smell was used as a qualitative test for odour [18]. Texture was evaluated based on comparison with previous reports regarding compost production [19].

Determination of organic matter (OM) and ash content (AC)

Compost samples (5g from each replicate of all treatments) were put in the dried porcelain crucibles and then dried for 4 hrs at 105°C in drying oven. The percentage of the OM was calculated according to Miroslav and Vladimir [20].

% Ash Content (AC) = (W1− W2)/W1×100

where:

W1 is the weight of composting materials (sample) at room temperature (30°C);

W2 is the weight of composting materials (sample) at high temperature (105°C in this case).

% Organic Matter (OM) = (100 –OC) %

Determination of pH and electrical conductivity (EC)

Composting sample (20g) was measured subjected to pH and EC measurements through calibrated pH meter and EC meter respectively following Miroslav and Vladimir [20].

Wet Digestion of compost samples

Wet Digestion method was carried out for the elemental analysis, which involved the chemical degradation of samples in the solution with the combination of acids to increase its solubility. This process was carried out following the protocol described in Hseu *et al.*, [21]. The resulting filtrate was preserved at 4°C, until otherwise analyzed.

Determination of nitrogen, phosphorus and potassium

As described in Wolf *et al.* [22] Di-acid digestion method was used for Phosphorus analysis as involving the analysis through Atomic Absorption Spectrophotometer (AAS) to determine the Phosphorus. Furthermore, air dried compost samples (0.25 g from each replicate) was weighed into 500 ml Erlenmeyer Kjeldahl flask and Kjeldahl catalyst (3.5 g) was added. Nitrogen was calculated as following AOAC [23] and Bremner, [24].

Heavy metals determination (Zinc and Iron)

Two heavy metals (Zinc and Iron) were detected using atomic absorption spectrophotometric (AAS) analyses [25]. Commercial Zinc (Zn) and Iron (Fe) were used as standards. The Analyst ™800 is a fully integrated design for the AA spectrophotometry, incorporating the spectrophotometer. The AAS had a single element and multi element hollow cathode lamp and high intensity electrodes discharge lamps for these elements.

Data analysis

Data analysis and descriptive statistics were carried out using XLSTAT [26] which included the determination of mean, standard deviation and standard error of the data collected. Error bars were calculated and presented in the graphical representation to describe the significance of the data.

Results and Discussion

Physicochemical analysis of the compost

Odor, color and texture

Odor in compost is a result of the release of sulphur compound such as hydrogen sulphide, methyl sulphide and methylmercaptan at the early stage of composting [27]. Odor composting process liberates a highly pungent odor which disappears with the passage of the experiment. All compost treatments showed variation in color. Some treatments became dark color i.e sludge, urea, and cow dung whereas some treatments became lighter in color like rock phosphate (Figure 3).

Figure 3: change in color and texture in all composting treatments with the passage of experiment (60 days)

Ash content and organic carbon

The amount of ash in compost or composting material reflects the microbial level of decomposition of organic matter and stabilization during composting [28]. Moreover, ash content has an inverse relationship with organic matter content. Therefore, in the current study, ash content (%) was decreased gradually during the passage of the experiment (two months) and the maximum decline was observed in cow dung treatment whereas the least value was found in rock phosphate amended treatment compared to that in control (Figure 4A).

During composting, there was a conversion of biodegradable organic matter into volatile carbon dioxide (CO_2) and H_2O and this is removed from the compost material into the atmosphere [29] (Figure 4B). Different additives/amendments are usually applied to enhance the composting process. This would be accompanied by the enhanced biological degradation of organic matter whereby the aeration of composted material is also increased and the nutrient profile of the compost is improved.

When compared to a control sample, E1, E2, E3 and E4 showed an increase of about 12.54% in 13%, 12% and 20% respectively. Hence E2, E3 and E4 showed a significant increase in organic carbon. The organic carbon stabilized after the 5th week indicating maturity of the compost. Heavy usage of easily decomposable organic matter may produce harmful substances in the form of acids [30]. The addition of organic fertilizers i.e. composted and nutrient enriched organic matter will help in improving soil fertility by releasing nutrients in the soil and improving the physiochemical properties. Table 1 depicts the different physiochemical properties of E1 to E4 and the control.

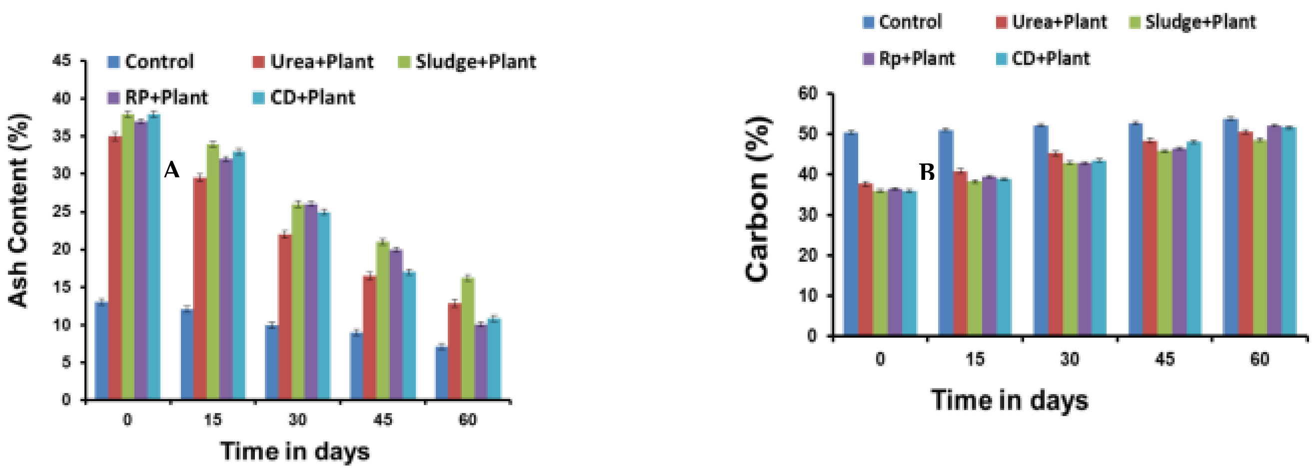

Figure 4: Time course mean Ash content (%) in different compost treatments *H. umbellata*) waste (A)
Time course mean Carbon (%) in different compost treatments of H. umbellata waste (B)

Determination of pH and electrical conductivity (EC)

Neutral (7.0) pH of finished compost is considered normal [31] and most composts have been reported to have a pH between 6 and 8 [32]. There was a gradual decrease in all compost at the initial stages which agrees with the findings of Brinton [36]. This could be attributed to the mineralization of organic matter by bacteria that form acids and anoxic fermentation due to large oxygen consumption by oxic bacteria. After 4 and 5 weeks, there was a gradual and continuous increase in the pH of all treatments except E2 and E3 (Figure 5A). Ideal pH depends on the type of compost application. A lower pH is preferred for certain ornamental plants while a neutral pH is suitable for most applications.

EC was observed to increase in E1, E2 and E3 compared to the control group except for E4 (Figure 5B). According to Strom [32], EC was related to the total soluble salts dissolved in the slurry and was measured in DS/m. The highest EC values were observed in sludge compost, recording an initial average EC of 0.39 DS/m and 6.9 DS/m in the final compost because of the high amount of organic waste which agrees with Tiquia, [33]. Table 1 depicts the EC and pH of E1 to E4 and control.

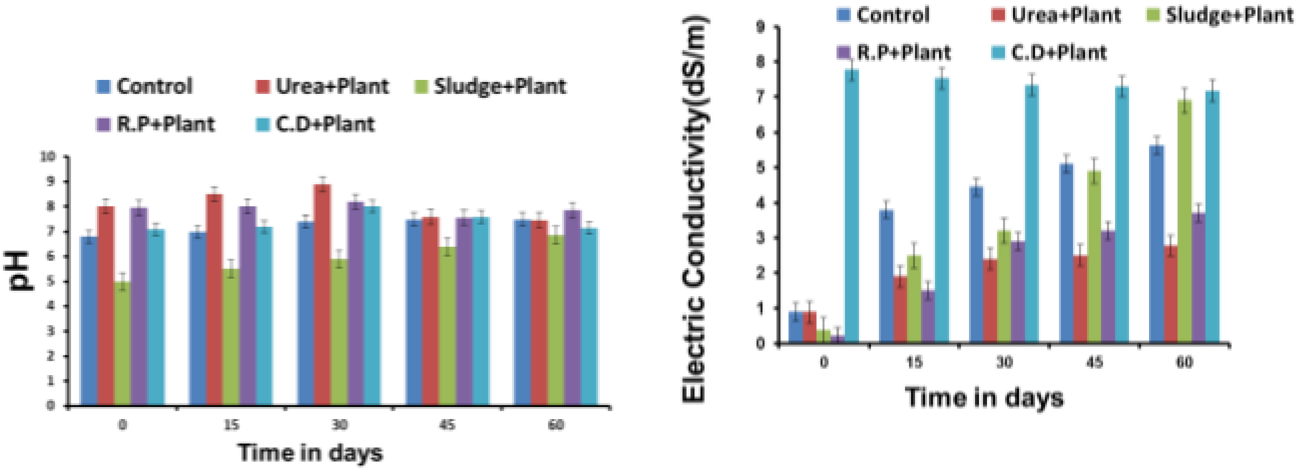

Figure 5: Time course mean pH changes (A) and Electric Conductivity (B) in different compost treatments of *H. umbellate* wastes

Table 1: Mean results of physicochemical parameters in each sample before composting

Parameters	Unit	Control	Sludge	Urea	R.P	C.D
Electrical conductivity(EC)	DS/m	0.9	0.39	0.89	0.22	7.77
pH	-	6.8	5	8	7.96	7.09
Ash Content	%	13	38	35	38	38
Organic Matter (OM)	%	87	65	62	63	62
Total Carbon (C)	%	50.46	35.96	37.7	36.54	35.96

Nitrogen, potassium and phosphorus

Nitrogen content (%) increased in the presence of urea and sludge while it decreased in the presence of rock phosphate and cow dung compared to Control (Figure 6A, Table 2). Nitrogen content began to increase because of loss of dry mass (in terms of carbon dioxide), water (evaporation), and actions of nitrogen-fixing bacteria [34, 35].

Potassium (K) usually expressed as K_2O is most often contained in different types of fertilizers [36]. K_2O contents were found to be highest in compost treatments amended with sludge, cow dung, rock phosphate and control respectively but the lowest level was found in urea amended treatment (Figure 6B, Table 2). The fact is that the sludge taken from the wastewater treatment plant was enriched with microbes and hence high microbial activity boosts the level of potassium [37]. Research conducted by a number of scientists also showed that potassium status in the soil enhanced with the regular application of chemical fertilizers, compost, and green manure [38].

In the current study, the highest phosphorus concentration was observed in treatment with RP (Figure 6C, Table 2). This was due to the addition of rock phosphate to the compost which led to the increase in the phosphorus concentration. This is in line with the findings of Nattinpong and Alissara, [39]. The lowest concentration of phosphorus was observed in the control compost which shows that pennywort plant itself doesn't have much concentration of phosphorus and it is low in basic nutrients required for plant growth. Moreover, Phosphorus is one of the most essential elements required for plant growth. Mobilization of phosphorus and microbial activities in soil increases with the addition of organic fertilizer [40].

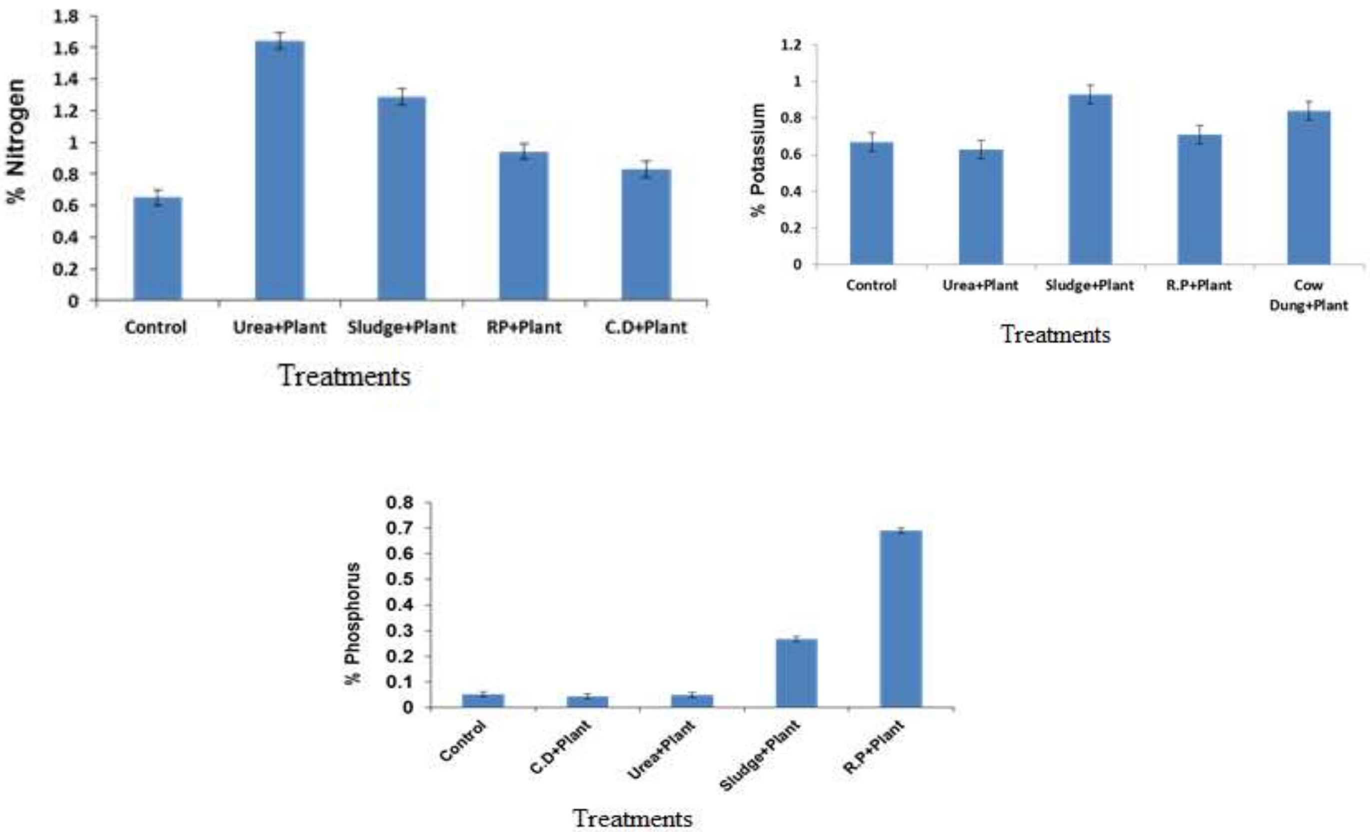

Figure 6: % Nitrogen (A), % Potassium (B) and % Phosphorus (C) in different compost treatments of *H.umbellata*

Table 2: Mean results of final macronutrients in each compost at the end of Composting experiment

Samples	Potassium (%)	Phosphorus (%)	Nitrogen (%)
Control group	0.67	0.051	0.65
Sludge	0.93	0.049	1.289
Urea	0.63	0.042	1.641
Rock phosphate	0.71	0.267	0.941
Cow dung	0.84	0.691	0.829

Carbon to nitrogen ratio (C/N)

Compost samples generally having a high Carbon-to-Nitrogen ratio require additional nitrogen for plant growth. The highest Carbon-to-Nitrogen ratio was observed in the E2 while the lowest was found in E3 (Figure 7) compared to that of control. C/N ratio generally decreased because of carbon loss during the composting process as a result of microbial activities which release CO_2 and H_2O.

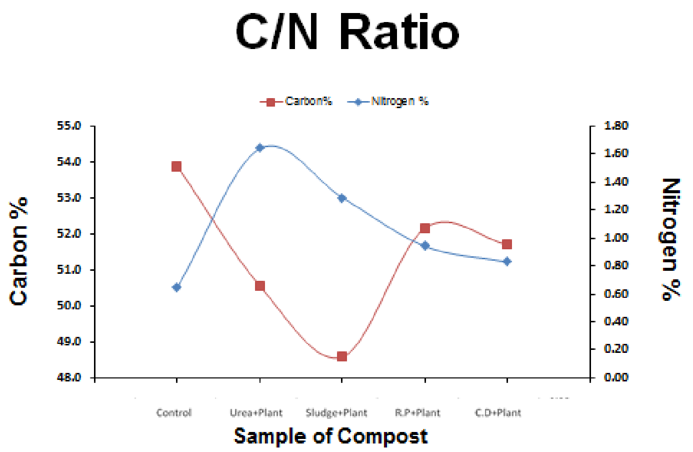

Figure 7: Carbon/Nitrogen ratio in different compost treatments of plant (*Hydrocotyle umbellata*) waste

Analysis of Heavy Metals

Zinc and Iron:

An appreciable zinc and iron Concentrations (%) was found in E1 and E4 compared to the control group while E2 and E3 also exhibited enough concentration of both metal ions (Table 3). The results conform with Naidu *et al*., [41] who reported that zinc and iron contents could be increased by making appropriate amendments. This can be attributed to the availability of suitable conditions and feedstock for the indigenous organic matter degrading microorganisms (analysis not conducted in this study).

In general, metal concentrations increase during composting which is due to volume reduction in compost material as a result of loss of matter (decomposition) [42].

Hence, zinc and iron are important sources of bio-fortification in crop plants which have a significant role in improving the quality of the crops [43, 44].

Table 3: Mean concentrations of Heavy Metals in each compost at the end of composting experiment

Samples	Zinc (ppm)	Iron (ppm)
Control Group	0.436	30.005
Sludge (E1)	2.093	38.89
Urea (E2)	1.956	34.169
Rock Phosphate (E3)	0.6805	34.21
Cow Dung (E4)	2.0001	38.625

Comparison of all five compost types (amendments)

Different amended compost treatments showed versatility in the final compost produced. Pennywort plant itself can be converted to very useful organic compost for crop protection and nourishment. However, different amendments in this study were made to check the enhanced physic-chemical properties of the control compost (only pennywort). No one compost type could be concluded as the perfect one but indicated a specific enhanced character. Therefore, all the amendments produced quality compost and each one can be used for multiple purposes depending upon the quality of the soil (Table 4). All the amendments showed variety in the result which shows the efficiency of our project. There is no single treatment that can be considered most ideal for every type of soil.

Furthermore, good compost can be developed by mixing equal volumes of all five types of composts for providing all required nutrients and properties to soil.

Table 4: Comparison of all five compost types (amendments)

Compost type	Enhanced physico-chemical character	Usefulness
Control (only plant)	Organic matter, carbon	To increase fertility of soil
Urea with plant	C/N, Nitrogen, Iron	To enhance nitrogen content
Cow Dung with Plant	Electrical Conductivity	To enhance mineral salts
Rock Phosphate in Plant	pH (neutral), Phosphorus	To adjust the pH of acidic or alkaline soils
Sludge with Plant	Potassium, Zinc	To enhance or fulfill potassium contents

Conclusion

Organic waste material can be converted into valuable organic compost which can increase the fertility of the soil. The application of a combination of various amendments as feedstock in pennywort plants such as; rock phosphate, sludge, cow dung, and urea showed positive effects on enhancing the nutrient value of pennywort compost. Thus, the current effort was proved to be an excellent addition to the existing pool of efforts to boost up Pakistan's agricultural economy. In the current era, human health and the environment is at high rate of risk due to the extensive use of chemical fertilizers which enter and stay in the food chain. This study can develop public attention towards the use of green manure as fertilizer which is free of any poisonous or toxic side effects. Hence, this study can be concluded as a great effort towards the cleanliness of the environment and indirectly a source of improving and maintaining human health and ecosystem natural cycles. Moreover, this study can prove an efficient platform for highlighting the significance of tiny aquatic plants (specifically pennywort) in protecting and saving our food, economy and environment. Furthermore, it may be regarded as a connection with the efforts to reduce the pressure of solid wastes faced by Pakistan. Hence, this study can be extended to a larger scale as a useful strategy in the field of waste to energy.

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Conflict(s) of interest

There is no conflict of interest about the research, authorship, and/or publication of this article.

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