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RESEARCH ARTICLE

OPTIMIZING SPINACH (*SPINACIA OLERACEA*) YIELD, SOIL HEALTH AND NUTRIENT CONTENT ENHANCEMENT WITH POULTRY LITTER AND KITCHEN WASTE COMPOST

Jannatun Nayeema[a], Joy Sarker[b]*, Mst. Jannatul Ferdous[a], Rakib Hasan Mashuk[a], Md Sadiqul Amin[a], Khandoker Qudrata Kibria[a]

[a]*Soil, Water and Environment Discipline, Khulna University, Khulna, Bangladesh*
[b]*Bangladesh Agricultural University, Mymensingh, Bangladesh*

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ABSTRACT

The increasing use of inorganic fertilizers is one of the significant causes of environmental pollution. The dependence upon fertilizers can be noticeably reduced with the elevated use of compost prepared from organic residues. Such practice improves the nutrient status of soil as well as saves our environment by managing waste. A study was carried out with nine treatments to show the effects of poultry litter and kitchen waste on soil properties and the growth of spinach plants. Clay loam soil was treated with different combinations of compost made with only poultry litter (PL) and co-compost (CC) prepared poultry litter mixed with kitchen waste by an aerobic process. The results showed that applying CC at 25% to the soil resulted in the highest spinach yield, leaf length, and number, fresh weight, and biological yield. Soil pH was found highest in CC50%, EC was high in PL50%, CEC was high in PL50%, and OC was high in PL25%. The study also showed that the available N of soil was higher by applying CC50%, and the available P, K, and S of soil was higher by applying CC25%. The nutrient content of spinach plants showed noticeable variation due to compost application. Using inorganic fertilizer as control (R)50% showed the highest N, K content of leaves and P content was high by applying CC25% and S content was high by applying PL50%. The findings indicated that co-composting of poultry litter and kitchen waste can be a useful method for boosting plant production and nutrient availability in soil.

KEYWORDS

Poultry litter, kitchen waste, co-compost, nutrient content, spinach

1. INTRODUCTION

Agriculture production in the last 1–2 decades has increased significantly with the help of recent technologies and farm mechanization. However, extensive use of fertilizers, insecticides, and many other pesticides had a negative impact on human health, and environmental pollution and raised the cost of crop cultivation. Pesticide residues in food chains have a well-documented harmful effect and have put the world's life support systems at peril (Ali et al., 2021). In 1989, Japanese researchers provided evidence that compost is the end product of aerobic decomposition of organic matter. In addition, Lal claimed in a review book of Agronomy for Sustainable Development in 2008 that it is frequently considered as a balanced fertilizer in agricultural crop fields and is commonly used as a soil conditioner. The end product of the aerobic decomposition of organic compounds using multiple feedstocks is called co-compost (Giagnoni et al., 2020). Litter, plant remains, and animal manure are the most common ways that soil nutrients are recycled back into the soil. The management of kitchen waste produced by the majority of hotels, motels, restaurants, and households is a challenge that requires urgent attention. Our environment suffers from improper waste management. Since a greater percentage of these wastes are organic, an alternate supply of biodegradable materials that could improve soil might become alluring. Compostable kitchen waste is a sustainable recycling method that decreases landfill disposal when used as a soil additive in crop development (Petersen et al., 2003; Chen and Jiang 2014). One of the largest and fastest-expanding agro-based industries in the world is the poultry sector. In Bangladesh, the commercial poultry industry has expanded quickly. There are many distinct types of waste produced by poultry farms. Poultry litter is a mixture of animal bedding materials like rice or peanut hulls and wood shavings (FSA, 2007). According to Feedlot Services Australia in 2007, a 35 and 49-day-old bird is thought to excrete 0.34 and 0.63 kg of solids, respectively, based on the diet's dry matter digestibility (87.5%). The environment-unfriendly methods of disposing of poultry waste include burning, burying, incineration, and rendering. To lessen their hazard to the environment, cost-effective and environmentally friendly poultry waste treatment techniques are required.

The present research was therefore carried out to investigate the co-composting of poultry litter with kitchen wastes in different combinations to convert these biological wastes into useful nutrient-rich composts for enhancing plant growth. In addition to providing mature compost with the best possible nutrient supply for developing plants, co-composting offers safe disposal. The aim of the research work was the characterization of poultry litter and kitchen waste compost and their effect on soil properties and nutrient content and selective agronomic parameters of Spinach (*Spinacia oleracea* locally known as Palong Shak) by applying these composts.

2. MATERIALS AND METHODS

2.1 Compost Preparation

Poultry litter was collected from a nearby chicken shop, situated at Jashore

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railway station and kitchen waste was collected from a middle-class family home. Composts were prepared under aerobic conditions. Three fresh plastic drums (10 L) were collected and then those drums were washed with water. Collected poultry litter (PL) was crashed with a hammer and poured 10 kg of it into one dram. The co-compost was prepared by mixing kitchen waste and poultry litter in 1:1 ratio. 5 kg of kitchen waste, after removing plastic bags and other non-biodegradable things, was mixed with 5 kg of poultry litter. The mixer poured in the other two drams. The drams were sealed with lids for 120 days but opened every 3–5 days to control the temperature, aeration, and moisture. After composting, the total amount of materials in each drum was mixed thoroughly by rolling the drum. Then, the materials were passed through the sun-drying condition for 7 days. The compost was crashed before their addition to experimental pots. The chemical properties of the compost are given in Table 3.

2.2 Experimental Setup

A pot experiment was conducted at the field laboratory of Soil, Water and Environment Discipline, Khulna University. The soil sample was collected from behind the central library of Khulna University. The GPS reading of the location is 22.8031° North latitude and 89.5323° East longitude. The experimental field lies in the Ganges Tidal Flood Plain (AEZ-13) (SRDI, 2008). The texture of the experimental field is clay loam.

The soil sample was air-dried and pulverized to pass through a 2 mm sieve. Selected basic properties of the experimental soil are presented in Table 2. Nine treatments as listed in Table 1 were replicated thrice in the experiment. Each pot (25 × 22 cm) was filled with 3 kg air-dried soil mixed with the required volume of organic materials.

Table 1: Composition of the treatments

Treatment code	Treatments
T1	Control
T2	R/2
T3	R
T4	PL 0% (only PL)
T5	PL 25% (only PL)
T6	PL 50% (only PL)
T7	CC 0% (KW:PL=1:1)
T8	CC 25% (KW:PL=1:1)
T9	CC 50% (KW:PL=1:1)

PL=Poultry litter, CC=Co-compost (poultry litter+kitchen waste), R=Recommended dose of inorganic fertilizer

Spinach (*Spinacia oleracea***)** was used as a test crop. Seeds were sown on November 2021 after soaking overnight in water. 5 to 10 seeds were sown in every pot with 1.2–2 cm depth and then arranged the pots according to CRD. After germination, only 5 plants were kept in each pot. The intercultural operations such as irrigation, weeding, and pest control, were done as needed during the growing period. After 50 days, when the leaves of spinach grow to the consumable stage, the plants were harvested. Before harvesting, selective agronomical parameters were measured. Plant height was measured in cm from the ground level to the tip of the uppermost awn. Leaf length was measured in cm by keeping the leaves flat. The length of each leaf is measured from the pointy part at one end of the leaf to the point where the leaf joins the stalk at the other end. After harvesting, using an electrical balance, weigh three plants from each pot. Calculate the mean of three plants and keep it notated. The unit will then be g plant^{-1}. The biological weight of the whole plant was measured gravimetrically after 24 hours of oven drying at (60° — 65°)

2.3 Laboratory Analysis

The particle size analysis of the initial soil was done by the hydrometer method as described by Gee and Bauder in 1979. The textural class was determined by Marshall's Triangular coordinate system. The total nitrogen content in the initial soil, plant, and compost was determined by Micro-Kjeldahl following colorimetric measurement as described (Bremner and Mulvaney, 1982). Plants and compost were digested with nitric-perchloric acid (2:1) as described by (Piper, 1966). Total phosphorus in the digested plant, compost samples, and initial soil were determined by the vanadomolybdophosphoric yellow color method by using a UV spectrophotometer (470 nm) (Jackson, 1973). Total K was determined by the Flame Emission Spectroscopic (FES) method as described by Jackson in 1967. The turbidimetric method described by Jackson was used for the determination of the total sulfur of initial soil, digested plant, and compost samples (Jackson, 1973). Organic carbon (OC) content was determined by using the Walkley and Black wet oxidation method (Jackson, 1973). The CEC of the soil samples was measured by the flame photometric method (Chapman, 1965). The pH of both soil samples and compost was determined electrochemically with the help of a glass electrode pH meter (Jackson, 1962). To conduct this soil samples were mixed with distilled water in a 1:2.5 ratio, and compost samples were in a 1:5 ratio. (Jackson, 1962) The electrical conductivity of both soil samples and compost was measured at a soil-water ratio of 1:5 and it was converted into a 1:1 ratio as described by U.S. Salinity Laboratory Staff in 1954 with the help of an EC meter. The soil available N was extracted using 1 N KCl solution and estimated by the alkali distillation method outlined by (Chapman, 1965). Available phosphorus in soil (soil: Olsen extractant = 1:20) (Olsen, 1954) at pH 8.5 was determined by the Molybdophosphoric blue color method by using a UV spectrophotometer (882 nm) described by (Murphy-Riley, 1962). Available K in soils was extracted (NH_4OAc) in a 1:10 soil-to-extractant ratio (Jackson, 1967). Soil available sulfur (soil: extractant = 1:8) was determined by the turbidimetric method (Jackson, 1973).

2.4 Statistical Analysis

Data were analysed statistically by one-way ANOVA Gomez and Gomez in 1984 to examine whether treatment effects were significant or not. Mean values were compared by R programming software. Moreover, graphs were prepared by using R programming language. In the graph, the different letter indicates significant differences at 0.05% level and the same letter is not significantly different at $p<0.05$ according to the Tukey test. The error bar indicates the standard deviation.

3. Results and Discussion

Some basic properties of the experimental soil, which have a great influence on plant growth, are presented in the following Table 2.

Table 2: Basic properties of the soil

Properties		***Concentration***
Texture		clay loam
	Sand (%)	35
	Silt (%)	25
	Clay (%)	40
pH		7.46
EC **(dS m^{-1})**		2.56
CEC **(cmol kg^{-1})**		23.30
Organic C (%)		1.22
Total N (%)		0.12
Organic matter (%)		2.10
C/N		1:10.17
Total P **(mg kg^{-1})**		238
Total S **(mg kg^{-1})**		170
Total K (%)		0.25

Compost PL and co-compost PL+KW were produced in aerobic conditions; the chemical properties of compost have been tabulated in Table 3.

Table 3: Properties of poultry litter (PL) compost and kitchen waste with poultry litter co-compost (CC)

Parameter	***PL***	***CC (PL+KW)***
Moisture content (%)	29.59	38.38
pH	8.00	8.7
EC (dS m^{-1})	6.22	5.5
CEC (cmol kg^{-1})	232.12	87.05
Organic matter (%)	40.34	37.65
Organic C (%)	23.4	21.84
Total N (%)	1.35	1.27
C/N	1:17.30	1:17.14
Total K (%)	6.29	5.51
Total P (mg kg^{-1})	81.73	54.70
Total S (mg kg^{-1})	3.85	3.13

3.1 Agronomic Parameter

3.1.1 Biological Yield

The biological yield was remarkably influenced by applying various treatments. This yield was noticeably different from the recommended dose of inorganic fertilizer but non-significant by applying the recommended dose of 50% and more significant in the recommended dose (R) of 100% (Figure 1). Again, the biological yield was considerably different by applying PL compost but non-significant by applying PL 25%. The biological yield of plants is also significantly different by applying co-compost of kitchen waste and poultry litter, and the most significant is applying 25% co-compost. The biological yield was found best by applying CC at 25% and the highest yield value was 4.37 g $plant^{-1}$. The lowest yield was found in control of R and CC 0% (2.05 g $plant^{-1}$). Organic fertilizer can produce organic acids that can mobilize insoluble P from the soil to the soil solution in a labile form where P nutrient is often a problem in inhibiting plant growth due to its low availability in the soil (Dotaniya et al., 2016; Hammond et al., 2009).

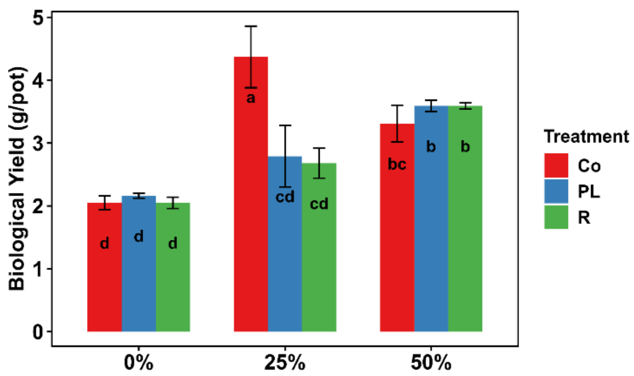

Figure 1: Biological yield analysis of spinach by applying various treatments and rates.

The different letters indicate a significant difference at 0.05% level.

3.1.2 Fresh Weight

Fresh yield per plant ranged from 12.31 g to 32.78 g and the highest fresh weight of the plant was found by applying CC 25% (32.78 g) (Figure 2). The fresh weight of the plant was considerably influenced by various treatments with rates. Fresh weight was not markedly different by applying a 0% rate of all fertilizers, but it was noticeably different by 25% and 50%. Again, the fresh weight of plants was most significant by applying 25% CC. The application of compost showed a significant increase in nutrition minerals in the soil such as N, P, Ca, Mg, and other minerals needed for plant growth (Meunchang et al., 2005).

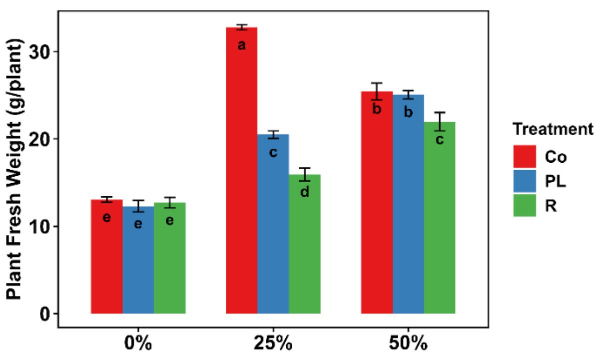

Figure 2: Plant fresh weight analysis of spinach by applying various treatments and rates. The different letters indicate a significant difference at 0.05% level.

3.1.3 Plant Height

Plant height was noticeably influenced by different treatments irrespective of their application rate (Figure 3). Co-composting produced plants with a maximum height (25.5 cm) compared with both control and compost addition in soil. The influence was observed noticeably higher at a 25% rate of application (Figure 3). The plant height of spinach plants in the co-compost of used coffee grounds and cat manure as amended soil was much higher than that of spinach grown in the compost-amended soil containing chicken manure (Keeflee et al., 2020). Researchers showed the effects of different rates of composted KW (kitchen waste) and PM (poultry manure) amendments on the growth and yield of another leafy plant (Corchorus olitorius) at a rate of 15 t ha^{-1}, the mean plant height was higher with PM than with KW, and it was 24.96 cm (Oladele et al., 2018). This could also be attributed to the large quantities of available phosphorus and available potassium contained in the chicken manure. A study indicated that the soil could be enhanced with the application of organic material which tends to decompose and release relatively large amounts of nitrogen into the soil before planting each fresh crop to boost yield (Rao, 1991).

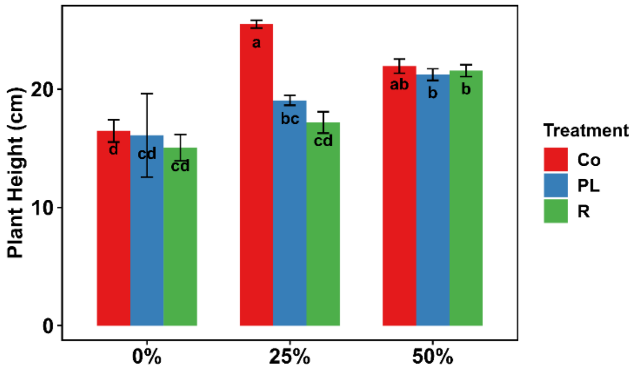

Figure 3: Plant height analysis of spinach by applying various treatments and rates. The different letters indicate a significant difference at a 0.05% level.

3.1.4 Number of Leaves

In most cases, the leaf number of plants was noticeably affected by different treatments. Again, the leaf number of plants was most significant by applying co-compost of kitchen waste and poultry litter 25%. The lowest plant height was found in control of the recommended dose 0% (15.5 cm) (Figure 4). This observation could be attributed to a better supply of nitrogen mineral elements during the composting process which enhanced leaf growth conditions for spinach (Ryckeboer et al., 2003). A study showed that poultry manure significantly increased the number of leaves in *Corchorus olitorius* compared to KW. The different rates of amendment applied increased the number of leaves. The Corchorus grown in soil without amendment gave the least mean number of leaves, while those grown with 15 t ha^{-1} of the amendment gave the highest number of leaves recorded.

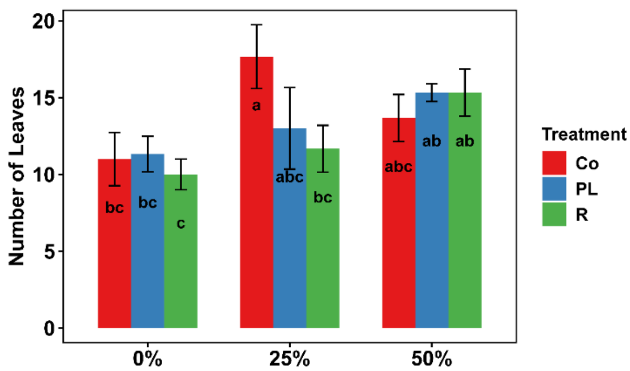

Figure 4: Number of leaves analysis of spinach by applying various treatments and rates. The different letters indicate a significant difference at 0.05% level.

3.1.5 Leaf Length

Leaf length measurements are presented in Fig 1e which significantly varies among treatments at 25% and 50% application rate. Leaf length ranged from 13.74 cm to 19.66 cm and CC at a rate of 25% produced leaves with the highest length (19.66 cm) (Figure 5). The lowest leaf length (13.74 cm) was found in control of the recommended dose. A study showed that the leaf length of spinach grown in the co-compost of spent coffee grounds and cat manure as amended soil was significantly greater than those grown in the chicken manure compost-amended soil (Keeflee et al., 2020). A study on yield and quality of leafy vegetables grown with organic fertilizers showed that vegetables grown with organic fertilizers grew better and resulted in a higher total yield than those grown with chemical fertilizers (Xu et al., 2005).

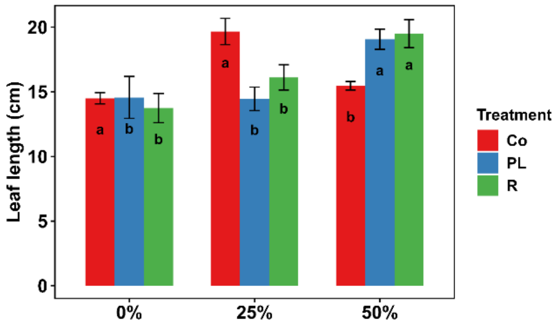

Figure 5: Leaf length analysis of spinach by applying various treatments and rates. The different letters indicate a significant difference at 0.05% level.

3.2 Plant Nutrient Status

3.2.1 N Content

The nitrogen (N) content of spinach plants was significantly affected by different fertilizers at rates of 25% and 50% but not significant at 0%. The highest N content was found in R 50% (0.90%) where the recommended dose of inorganic fertilizer was applied at 50%. The lowest N content (0.53%) was found in PL at 0% where poultry litter was applied at 0% (Figure 6). According to research in 2018, organic fertilizer can greatly increase the nitrogen content of spinach leaves (Hongdou et al., 2018). By promoting plant uptake of nitrogen and microbial immobilization, as well as reducing leaching and gaseous losses of nitrogen and increasing the retention of applied fertilizer N in the soil-plant system, compost made from fruit scraps, manure, and kitchen waste can also increase crop yields (Steiner et al., 2010).

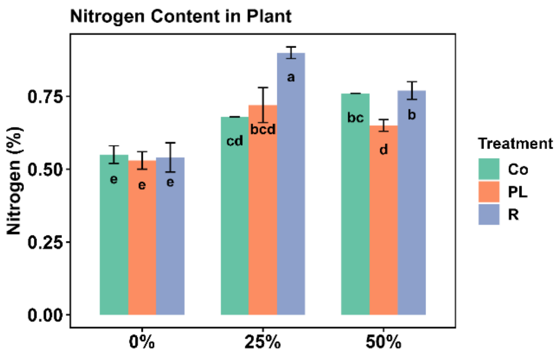

Figure 6: Plant nitrogen analysis of spinach by applying various treatments and rates. The different letters indicate a significant difference at a 0.05% level.

3.2.2 P Content

The phosphorus (P) content result of spinach plants was shown in Figure 7 and P content was significantly affected by different compost rates. The highest P content was found by applying CC 25% and the value was 1.22 mg kg^{-1}. The lowest P content value was found in the control and CC 0% (0.34 mg kg^{-1}) (Figure 7).

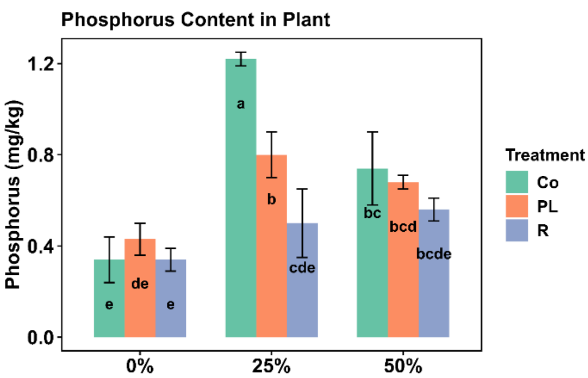

Figure 7: Plant phosphorus analysis of spinach by applying various treatments and rates. The different letters indicate a significant difference at a 0.05% level.

3.2.3 K Content

The potassium (K) content of spinach plants was considerably influenced by the application of different rates of compost (Figure 8). The highest content was found in Co 25%, where co-compost of kitchen waste and poultry litter was applied at a rate of 25 % (Figure 8), and the value was 6.95%. Again, the lowest K content of spinach was found in PL 0% (3.15%), where poultry litter was applied at 0% (Figure 8).

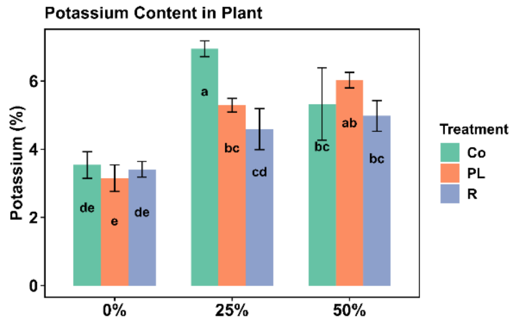

Figure 8: Plant potassium analysis of spinach by applying various treatments and rates. The different letters indicate a significant difference at a 0.05% level.

3.2.4 S Content

The sulfur (S) content of spinach plants was significantly influenced by different compost rates under study (Figure 9). The highest S content was found by applying PL 50% and CC 50% and the value was 3.07 mg kg^{-1}. The lowest S content value of spinach was found by applying R 50% where the recommended dose of inorganic fertilizer was 50% (1.60 mg kg^{-1}) (Figure 9).

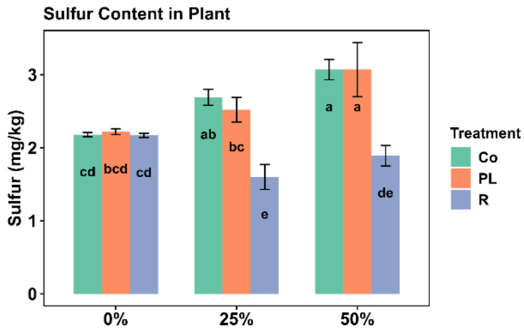

Figure 9: Plant sulfur analysis of spinach by applying various treatments and rates. The different letters indicate a significant difference at a 0.05% level.

3.3 Soil Properties

3.3.1 Organic C

The highest organic carbon was found in the soil by applying PL 25% (2,379%) and the lowest in control (R 0%) (0.6435%). The organic carbon (OC) of soil was significantly influenced by applying various treatments at 25% and 50% rates but not significant at 0%. And the most marked by applying 25% PL and 50% CC (Figure 10). This trend can be due to the biodegradation and mineralization activities of the soil microflora, which intensify in response to applied organic matter (Schroder et al., 2008). Again, it was reported that the incorporation of compost into soil increased soil carbon (Mylavarapu and Zinati, 2009).

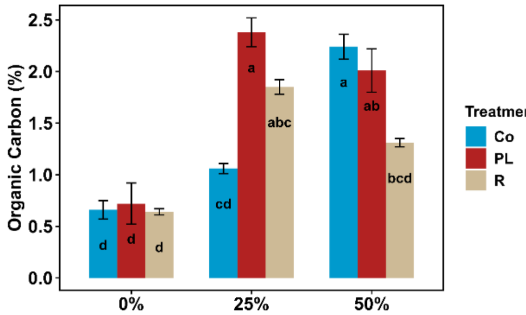

Figure 10: Organic C of the post-harvest soil. The different letters indicate a significant difference at a 0.05% level.

3.3.2 CEC

The cation exchange capacity (CEC) of the soil was considerably influenced by applying various treatments, yet not significant by 0% of all fertilizers, where significantly affected by 25% and 50% of all treatments. (Figure 11). Again, this property of soil was found best significant as well as highest by applying PL 50% (Figure 3b) and the value was (80.28 cmol kg^{-1}). The lowest CEC was found by applying R at 25% (45.46 cmol kg^{-1}). Since compost has a high cation exchange capacity, adding it to the soil can raise the soil CEC. Humic acids, which make up a large portion of compost, have carboxylic acid groups that can bind positively charged multivalent ions like Mg^{2+}, Ca^{2+}, Fe^{2+}, and Fe^{3+} as well as trace metals like Cd^{2+} and Pb^{2+} (Pedra et al., 2008).

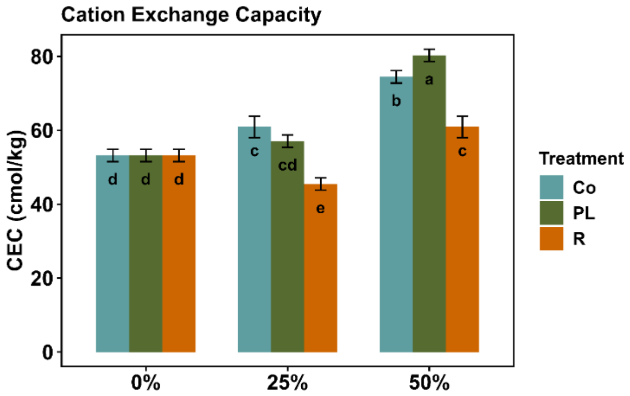

Figure 11: CEC of the post-harvest soil. The different letter indicates a significant difference at a 0.05% level.

3.3.3 pH

The pH was found to be noticeably higher by applying CC 50% (8.27) than any other treatment, whereas the lowest by applying PL 50% (7.27). The pH of the soil is not significantly affected by applying a 0% rate of all fertilizer and is best significant by CC 50% (Figure 12). Researcher state that the effect of compost addition on soil pH is not well understood (Butler et al., 2008). However, the application of PL 50% results in a low pH because microorganisms produce organic acid. A study reported in 1994, the high pH in the other treatments was consistent with ammonium formation from protein degradation (Mahimaraja et al., 1994). The addition of basic cations, ammonification, and the creation of NH_3 during the decomposition of the additional compost are the main causes of an increase in soil pH following the addition of compost made from poultry litter (Hubbard et al., 2008). The pH of soils modified with compost can rise as a result of the adsorption of H^+ ions, the establishment of reducing conditions as a result of increased microbial activity, and the displacement of hydroxyls from sesquioxide surfaces by organic anions (Pocknee and Sumner, 1997).

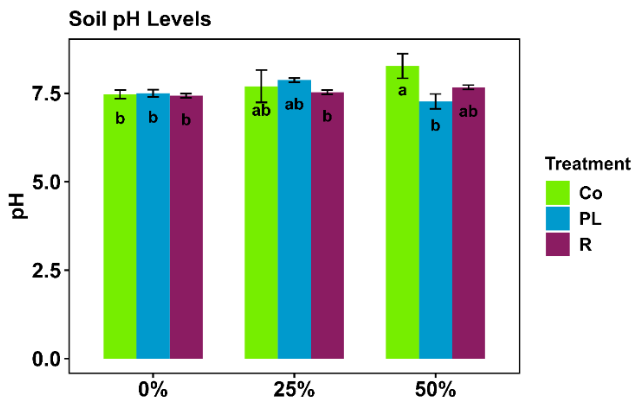

Figure 12: pH of the post-harvest soil. The different letters indicate a significant difference at a 0.05% level.

3.3.4 EC

The maximum electrical conductivity (EC) value was found in the soil by applying PL 50% (6.56 dS m^{-1}) and the lowest by applying R 100% (0.33 dS m^{-1}). The EC of soil is significantly affected by applying PL and coa-compost but not significantly affected by applying the recommended dose (R) of inorganic fertilizer. (Figure 13).

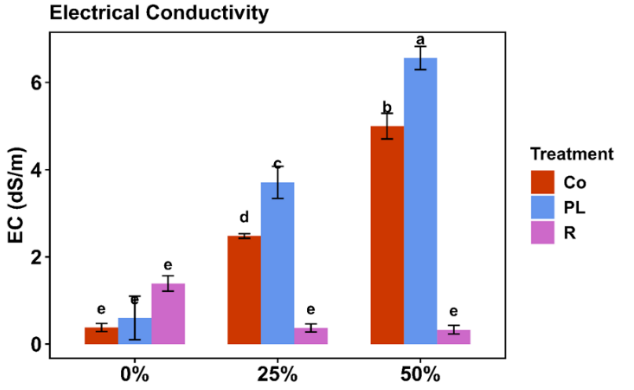

Figure 13: EC of the post-harvest soil. The different letters indicate a significant difference at a 0.05% level.

3.3.5 Available N

The maximum water-soluble N% was found on the soil by applying CC 50% and the value was 5.74%. The minimum water-soluble N% was found on the soil by applying inorganic fertilizer at a recommended dose (R) of 50%and the value was 0.42%. Water-soluble N% of the soil was noticeably influenced by applying various treatments at 25% and 50% rates but not significant at 0% (Figure 14). The available N% of soil was made most significant by applying CC 50% (Figure 14).

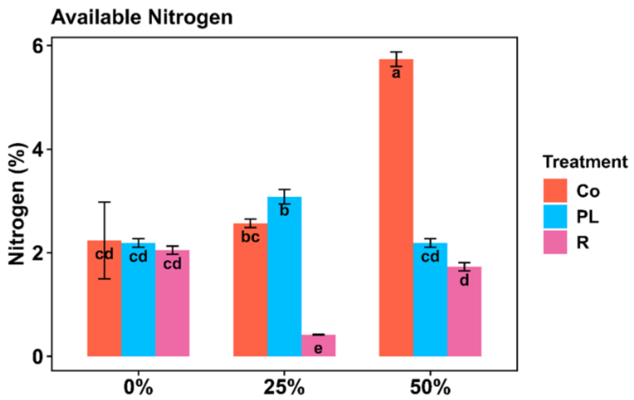

Figure 14: Available N of the post-harvest soil. The different letters indicate a significant difference at a 0.05% level.

3.3.6 Available P

Soil available P was considerably affected by various treatments at 25% and 50% rates but not significantly at 0%, and the most significant was applying 25% and 50% of CC (Figure 15). It was found to be highest when CC 25% was applied (Figure 15), with a value of 178.72 mg kg^{-1}. The lowest available P of soil was observed in the control, where inorganic fertilizer was 0% (46.93 mg kg^{-1}).

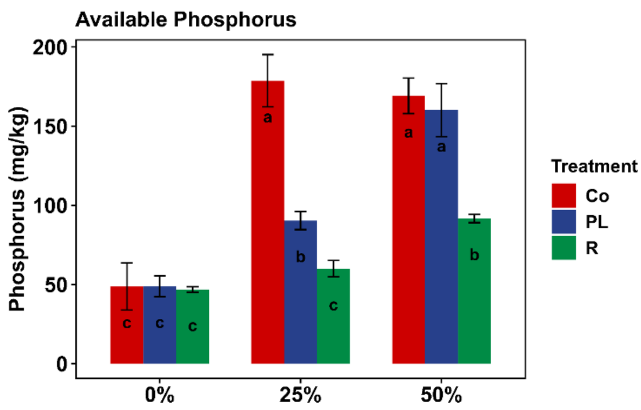

Figure 15: Available P of the post-harvest soil. The different letters indicate a significant difference at a 0.05% level.

3.3.7 Available K

The maximum water-soluble K was found on the soil by applying CC at a rate of 25% and the value was 0.87%. The minimum water-soluble K % was found on the soil by applying inorganic fertilizer at the recommended dose of 100% and the value was 0.03%. Water-soluble K % of the soil was significantly influenced by applying various treatments at 25% and 50% rates but not significant at 0% (Figure 16).

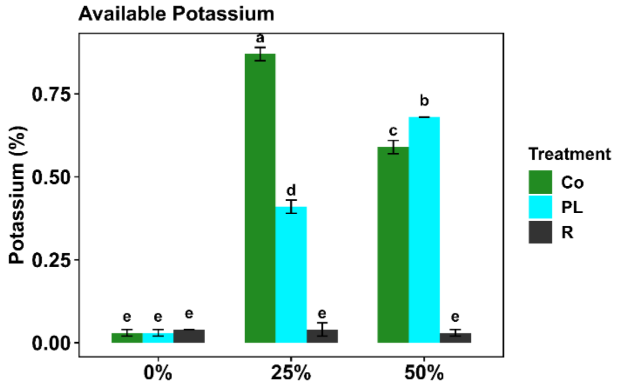

Figure 16: Available K of the post-harvest soil. The different letters indicate a significant difference at a 0.05% level.

3.3.8 Available S

Available S of soil was markedly influenced by different treatments at rates of 25% and 50% but not significant at 0% and the most significant was applying 25% co-compost (Fig 17). Moreover, it was found best by applying CC at 25% and the highest value was 1.03 mg kg^{-1}. The lowest value of available soil S was found in PL 0% (0.06 mg kg^{-1}) (Figure 17).

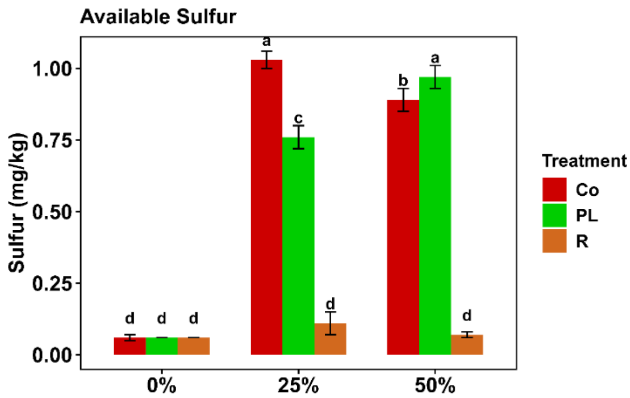

Figure 17: Available S of the post-harvest soil. The different letters indicate a significant difference at a 0.05% level.

4. Conclusion

The result reveals that agronomic parameters such as plant height, leaf number, leaf length, fresh yield, and biological yield of spinach plants were significantly higher in most cases by applying co-compost of poultry litter and kitchen waste. Based on the number of leaves, fresh weight and biological yield, the application of co-compost of kitchen waste and poultry litter is best for use and it is recommended to use as a soil amendment for the growth of spinach. The best significance of organic C of soil by applying PL and other available nutrients like P, K, and S is significantly higher by applying Co 25%, but available N was higher by applying Co 50%. Soil pH, EC, and CEC were also significantly affected by different rates of compost and fertilizer. The N content of spinach plants was higher by applying the recommended dose of inorganic fertilizer. The highest K and P content was found by applying a co-compost of kitchen waste and poultry litter was applied, and the highest S content was found by applying PL and Co.

Authors Contribution

Author Jannaatul Nayeema conceptualized the study and prepared the initial draft of the manuscript. Author Joy Sarker analyzed the data and performed statistical evaluations with graphs. Author Md Sadiqul Amin and Dr. Khandoker Qudrata Kibria supervised the research guided the study and also reviewed the draft. Author Mst. Jannatul Ferdous and Rakib Hasan Mashuk collected and organized the data.

Disclosures

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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