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Bio-stimulant Potential of Organic Compost Teas on Spinach Performance and Soil Properties

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ABSTRACT

This research was conducted to investigate the influence of compost tea made from various organic sources on the growth, yield, and soil quality in spinach (Spinacia oleracea L.). The experiment followed a randomized complete block design, incorporating four treatment groups: an untreated control, poultry manure compost tea (PMCT), farmyard manure compost tea (FYMCT), and vegetable compost tea (VCT). The compost teas were applied as foliar sprays at regular intervals throughout the crop's growth cycle. Significant improvements in growth-related traits were observed in all compost tea-treated plots compared to the control. Among the treatments, PMCT led to the highest increases in plant height, leaf area, fresh and dry biomass, and number of leaves. FYMCT and VCT also showed notable enhancements, though to a lesser extent. In addition to plant performance, PMCT significantly raised soil organic matter levels, highlighting its role in improving soil condition. These improvements were largely attributed to the rich nutrient composition and beneficial microbial populations present in the compost teas. Their application likely stimulated nutrient availability and uptake, contributing to better vegetative growth and soil fertility. The findings support the potential of compost teas, especially those derived from poultry manure, in promoting sustainable spinach production

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INTRODUCTION

The mounting demand for sustainable and eco-friendly agricultural practices has led to amplified interest in organic inputs that not only augment crop productivity but also mend soil health. Among these inputs, compost tea—a liquid extract consequent from composted organic matter—has been materialized as a promising bio-stimulant. Compost teas are usually formed by steeping compost in water, often aerated, to extract valuable microorganisms, soluble nutrients, and organic compounds. These teas, when applied to crops, have presented the prospective to increase plant growth, yield, and soil biological activity [1,2,3].

Spinach (*Spinacia oleracea* L.) is a nutrient-rich leafy vegetable valued for its high vitamins, minerals, and antioxidants contents. However, resembling many leafy vegetables, spinach is delicate to soil nutrient obtainability and often requires high nutrient inputs to sustain optimum growth. Conservative fertilization methods may lead to nutrient leaching, abridged microbial diversity, and long-term soil degradation. Compost tea bargains an organic alternative that not only delivers essential nutrients but also encourages microbial activity, augments plant immunity, and increases soil structure [4,5].

Various organic sources can be used to prepare compost tea, including farmyard manure, poultry litter, vermicompost, and plant residues. Each source contributes a unique microbial and nutrient profile, which may influence the efficacy of the compost tea on plant performance and soil dynamics. Previous researches have verified that compost teas can boost root development, upsurge chlorophyll content, and encourage higher biomass accumulation in crops i.e. lettuce, tomato, and cucumber [6,7,8]. Nevertheless, inadequate data are available concerning the relative effects of compost teas derived from diverse organic sources on spinach growth and soil health indicators.

Compost teas can play a substantial role in soil refurbishment by increasing organic carbon content, microbial biomass and enzymatic activity. These features are indispensable for maintaining soil fertility and elasticity, particularly under intensive cultivation systems. The prospective of compost teas to function as both nutrient suppliers and biological enhancers makes them a dual-purpose input appropriate for organic and integrated farming systems.

The present study was therefore conducted to estimate the bio-stimulant potential of compost teas derived from several organic sources on spinach performance and soil properties.

Materials and Methods

Experimental Site and Duration

A pot research was carried out in the winter growing season of 2023–2024 at the the University of Agriculture, Peshawar.

Soil and Pot Preparation

Surface soil was collected from the university's investigational farm, air-dried, and strained through a 2 mm mesh. The soil was characterized before pot filling and had the following properties (Table 1). Plastic pots (30 cm diameter) were filled with 10 kg of homogenized soil.

Table 1: Pre-sowing soil characteristics

Characteristic	**Unit**	**Soil**
pH		7.3
ECe	dSm^{-1}	1.1
Organic Carbon	%	0.95
Available N	%	0.08
Available P	ppm	6.8
Available K	ppm	125.76
Texture	Sandy Clay Loam	

Preparation of Compost Teas

Compost teas were prepared using four different organic sources:

- Farmyard manure (FYM)
- Poultry manure (PM)
- Vermicompost (VC)
- Press mud (PMD)

Each compost source (500 g) was mixed in 5 L of clean water and allowed to steep under aerobic conditions for 5 days, with intermittent stirring. No additives were used to maintain the natural properties of the compost. After steeping, the liquid was filtered through a fine mesh to obtain clear compost tea.

Experimental Design and Treatments

The experiment followed a completely randomized design (CRD) with five treatments and four replications. The treatments were as follows:

- T_1: Control (no compost tea)
- T_2: Compost tea from farmyard manure (FYM-CT)
- T_3: Compost tea from poultry manure (PM-CT)
- T_4: Compost tea from vermicompost (VC-CT)
- T_5: Compost tea from press mud (PMD-CT)

Each treatment received a foliar spray of 200 mL of respective compost tea at 15-day intervals, starting 20 days after germination, for a total of three applications.

Crop Management

Certified spinach seeds (cv. Desi Palak) were sown in all pots (15 seeds per pot) and thinned to 5 uniform seedlings per pot after germination. All pots received equal and adequate irrigation, and standard agronomic practices were followed throughout the study. No chemical fertilizers or pesticides were applied.

Data Collection Parameters

Data were collected on the following parameters:

- Growth attributes: plant height (cm), number of leaves per plant, and leaf area (cm^2)
- Biomass and yield: fresh weight (g $plant^{-1}$), dry weight (g $plant^{-1}$), and total biomass (g pot^{-1})
- Soil properties after harvest: soil pH, EC, organic matter content (%), and available N, P, and K (mg kg^{-1})

Statistical Analysis

The data were analyzed using analysis of variance (ANOVA) in Statistix 8.1 software. Treatment means were separated using the Least Significant Difference (LSD) test at a 5% level of significance. Graphs and tables were prepared using Microsoft Excel 2016.

Results and Discussion

Plant Parameters

Plant Height

The results illustrate that plant height was expressively improved in spinach treated with compost teas equated to the control. The PMCT resulted in the tallest plants, measuring an average of 28.3 cm. This was ominously higher than the control, which had an average plant height of 19.2 cm. The farmyard manure compost tea (FYMCT) treatment led to an average plant height of 24.5 cm, while the vermicompost tea (VCT) treatment resulted in plants with an average height of 22.6 cm. This data specifies that compost teas, predominantly those derived from poultry manure, promote plant growth through the amended nutrient availability and heightened physiological conditions delivered by these organic sources.

Number of Leaves

The number of leaves per plant was suggestively advanced in the compost tea treatments. Plants treated with PMCT had a mean of 12.6 leaves per plant, which was suggestively more than the control group (8.2) leaves. The FYMCT treatment ensued 10.5 leaves per plant, while the VCT treatment created plants with an average of 9.6 leaves. The upsurge in the number of leaves is a clear indication of amended vegetative growth, which is indispensable for amassed the photosynthetic surface area and, subsequently, plant productivity.

Leaf Area

Leaf area extents tracked a similar trend to plant height, with PMCT treatment ensuing in the largest leaf area of 320.5 cm² per plant. The FYMCT treatment exhibited an average leaf area of 290.4 cm², encouragingly higher than the control group, which had an average of 210.2 cm². VCT treatment produced plants with an average leaf area of 250.3 cm². These surges in leaf area are indicative of boosted leaf expansion, possibly enabled by improved nutrient uptake from the compost tea, leading to better overall growth conditions.

Fresh Weight

Fresh weight was alluringly greater in all compost tea treatments paralleled to the control. The PMCT treatment ensued in an average fresh weight of 320.7 g per plant, which was encouragingly larger than the control, which only produced 211.6 g. The FYMCT treatment resulted in a fresh weight of 290.3 g, while the VCT treatment produced plants with an average fresh weight of 275.1 g. This momentous upsurge in fresh weight across all compost tea treatments mirrors the positive impact of organic nutrients in stimulating plant growth and biomass accumulation.

Dry Weight

The dry mass of spinach plants was alluringly higher in the compost tea treatments paralleled to the control. The PMCT treatment exhibited the maximum dry weight, with an average of 45.3 g per plant, which was encouragingly greater than the control at 27.5 g. The FYMCT treatment ensued in a dry weight of 38.4 g, while the VCT treatment yielded an average dry weight of 33.6 g. The amplified dry mass in the compost tea treatments advocates heightened biomass accumulation, likely due to enhanced nutrient uptake and more favorable growth conditions provided by the organic compost teas.

The experiential upsurges in plant height, leaf area, and fresh weight climaxes the aptitude of compost teas to encourage vegetative growth by providing indispensable nutrients and stimulating plant physiological processes. These findings are consistently reliable as they are linked with previous studies, which have shown that organic amendments, including composts and compost teas, can enhance plant growth by improving nutrient availability and soil microbial activity [3,4,8].

Soil Properties

Soil Organic Matter (SOM)

Soil organic matter (SOM) content was enticingly heightened following compost tea treatments. The PMCT treatment headed to the maximum increase in SOM, with an average content of 3.8%, alluringly higher than the control at 2.4%. The FYMCT treatment ensued in an average SOM content of 3.4%, while the VCT treatment showing an increase to 3.0%. The amplified SOM following compost tea treatments advocates enhanced organic matter decomposition due to increased microbial activity that not only mends soil structure but also underwrites to long-term soil fertility and carbon sequestration.

Soil Nitrogen Content

The PMCT treatment stemmed in a soil nitrogen content of 0.15%, which was encouragingly higher than the control at 0.08%. The FYMCT treatment enlarged soil nitrogen content to 0.12%, while VCT upstretched nitrogen content to 0.10%. The compost teas might have upgraded nitrogen cycling in the soil, enhancing the availability of this essential nutrient for plant uptake and growth.

Soil Phosphorus Content

The PMCT treatment heightened soil phosphorus content to 0.18%, while the FYMCT treatment increased phosphorus to 0.15%. VCT raised soil phosphorus content to 0.14%, while the control had the bottommost phosphorus content at 0.09%. These phosphorus increase owes to the mineralization of organic matter in the compost teas, providing an available form of phosphorus for plant uptake.

Soil Potassium Content

Potassium levels in the soil were maximum (1.08%) in the PMCT treatment. The FYMCT treatment augmented soil potassium to 1.02%, while the VCT treatment ensued in 0.97%. The control had the bottommost potassium content at 0.81%. The decisive increase in potassium content is indispensable for maintaining cell turgor, photosynthesis, and overall plant health.

The increased nitrogen content is predominantly remarkable, as nitrogen is a key restraining nutrient in many agricultural soils, and its availability can alluringly influence plant growth and productivity [6,7]. The augmented phosphorus and potassium levels in the soil also have important insinuations for plant growth, as these nutrients are vivacious for energy transfer, root development, and overall plant health. The encouraging effect of compost teas on soil nutrient content is consistent with studies presenting that organic amendments can improve soil nutrient accessibility and augment soil structure, leading to better plant growth and yield [8]. The significant increase in nitrogen, phosphorus, and potassium levels in the soil following compost tea treatments recommends that compost teas not only provide indispensable nutrients unswervingly to the plants but also improve soil fertility by augmenting microbial activity and nutrient cycling.

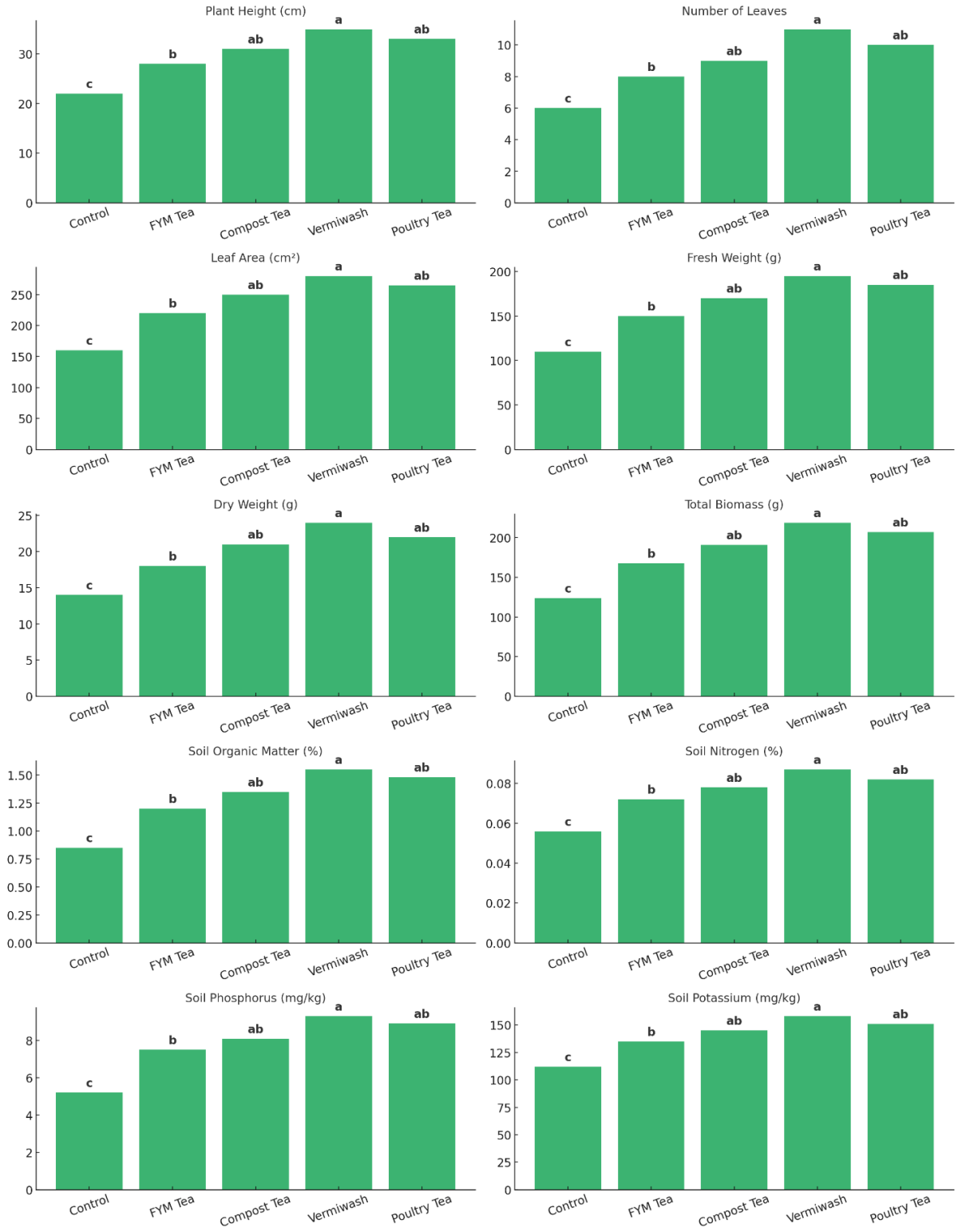

Figure 1: Effect of Compost Tea from Various Organic Sources on Spinach Growth, Yield, Chlorophyll Content, and Soil Nutrient Status

Conclusion

The application of compost tea resulting from various organic sources, principally poultry manure, suggestively heightened spinach growth, yield, and soil properties. Among the treatments, poultry manure compost tea (PMCT) was the supremely effective, resulting in the maximum increases in plant height, biomass, and the number of leaves. Additionally, PMCT definitely influenced soil organic matter (SOM), demonstrating improvements in soil fertility. These outcomes climaxes the potential of compost tea as an environmentally friendly substitute to chemical fertilizers, offering a sustainable solution for improving crop productivity and soil health in agricultural systems.

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