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Preparation, characterization and evaluation of a novel bio-fertilizer from cow dung cake, banana waste (*Musa × paradisiaca*) and eggshell

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Abstract

The extensive use of chemical fertilizers has resulted in soil degradation, nutrient imbalance, environmental pollution, and a decline in beneficial soil microbiota. To address these issues, a value-added biofertilizer was developed from organic waste materials through controlled biological processing. Eggshell waste was utilized as a calcium source and pH buffering agent, banana waste served as a source of potassium and phosphorus, and cow dung cake provided organic nitrogen and a diverse microbial consortium. In the present study, a novel bio-fertilizer was prepared using cow dung cake, banana waste, and eggshell. The prepared biofertilizer was characterized using physicochemical, chemical, and biological parameters. Its effectiveness was evaluated by comparing plant growth with a chemical NPK fertilizer. The results demonstrate that the developed bio-fertilizer improves soil fertility, enhances plant growth, and offers a sustainable alternative to synthetic fertilizers.

Keywords: Banana peel, pH, biofertilizer, physicochemical, eggshell

1. Introduction

The global demand for food production is projected to increase by approximately 60-70% by 2050 due to population growth, urbanization, and changing dietary patterns ^[1]. To meet this demand, modern agriculture has relied heavily on chemical fertilizers, particularly nitrogen (N), phosphorus (P), and potassium (K). Global fertilizer consumption exceeded 190 million metric tons in recent years, with nitrogen fertilizers accounting for nearly 60% of total usage (International Fertilizer Association ^[2]). Although chemical fertilizers have significantly increased crop yields, their excessive and indiscriminate application has resulted in serious environmental and agronomic challenges, including soil degradation, nutrient leaching, eutrophication of water bodies, greenhouse gas emissions, and declining soil microbial diversity ^[3]. Biofertilizers are microbial inoculants containing living or latent microorganisms that enhance plant growth and productivity by increasing the availability and uptake of essential nutrients through biological mechanisms. Unlike synthetic fertilizers, which provide nutrients in chemically soluble forms, biofertilizers operate by fixing atmospheric nitrogen, solubilizing insoluble mineral nutrients, and improving nutrient cycling within the soil-plant system ^[4]. Their effectiveness depends on the successful colonization of the rhizosphere or plant tissues and the establishment of beneficial plant-microbe interactions. The principal groups of biofertilizers include nitrogen-fixing bacteria such as *Rhizobium*, *Azotobacter*, and *Azospirillum*; phosphate-solubilizing microorganisms belonging to genera such as *Bacillus* and *Pseudomonas*; potassium-mobilizing microbes; and arbuscular mycorrhizal fungi (AMF). These microorganisms contribute to plant growth by improving nutrient availability, synthesizing phytohormones, enhancing root development, and increasing plant tolerance to biotic and abiotic stresses ^[5]. In addition, biofertilizers play a significant role in maintaining soil health by promoting microbial diversity, improving soil structure, and sustaining long-term soil fertility. The widespread and intensive use of chemical fertilizers has resulted in numerous environmental and agronomic challenges, including soil degradation, nutrient imbalance, groundwater contamination, and the decline of beneficial soil microorganisms ^[6]. In this context, biofertilizers have gained increasing attention as an integral component of sustainable and integrated nutrient management systems.

Their use has been shown to reduce dependence on chemical fertilizers, lower production costs, and mitigate adverse environmental impacts without compromising crop yields [7]. Therefore, in this study, we deeply focused on preparing a Novel Bio-Fertilizer from Cow Dung Cake, Banana Waste (*Musa × paradisiaca*) and Eggshell which does not affect the growth of plant and soil fertility.

2. Materials and Methods

2.1 Preparation of Bio-fertilizer

A mixed bio-fertilizer was formulated by combining cow dung cake extract, banana peel powder, and eggshell powder. The components were blended in an optimized ratio determined through preliminary trial experiments to achieve a balanced nutrient composition and enhanced microbial activity in the final formulation.

2.2 Optimized Composition

- **Cow dung cake:** 50%
- **Banana peel powder:** 30%
- **Eggshell powder:** 20%

The selected ratio ensures an effective balance of macronutrients (N, K, Ca) and organic matter while supporting beneficial microbial growth.

2.3 Formulation Procedure

The weighed quantities of each component were thoroughly mixed in a clean plastic container. The mixture was homogenized manually using a sterile spatula to ensure uniform distribution of nutrients and microorganisms. Homogenization was considered a critical step to prevent nutrient segregation and to ensure consistent fertilizer

quality. Distilled water was gradually added to maintain an adequate moisture content of approximately 55-60%, which was optimal for microbial activity. The mixture was loosely covered to allow aeration while preventing contamination by insects and dust. The homogenized mixture was subjected to a bio-curing process for 10-15 days at ambient temperature. During this period, the material was intermittently turned or stirred at two-day intervals to maintain aerobic conditions, enhance oxygen diffusion, and ensure uniform microbial colonization. This bio-curing phase served as a critical stabilization and maturation step for the biofertilizer, during which intensified microbial activity promoted the mineralization of labile organic substrates, reduction of phytotoxic compounds, and establishment of beneficial microbial populations essential for nutrient transformation and plant growth-promoting functions.

3. Results & Discussion

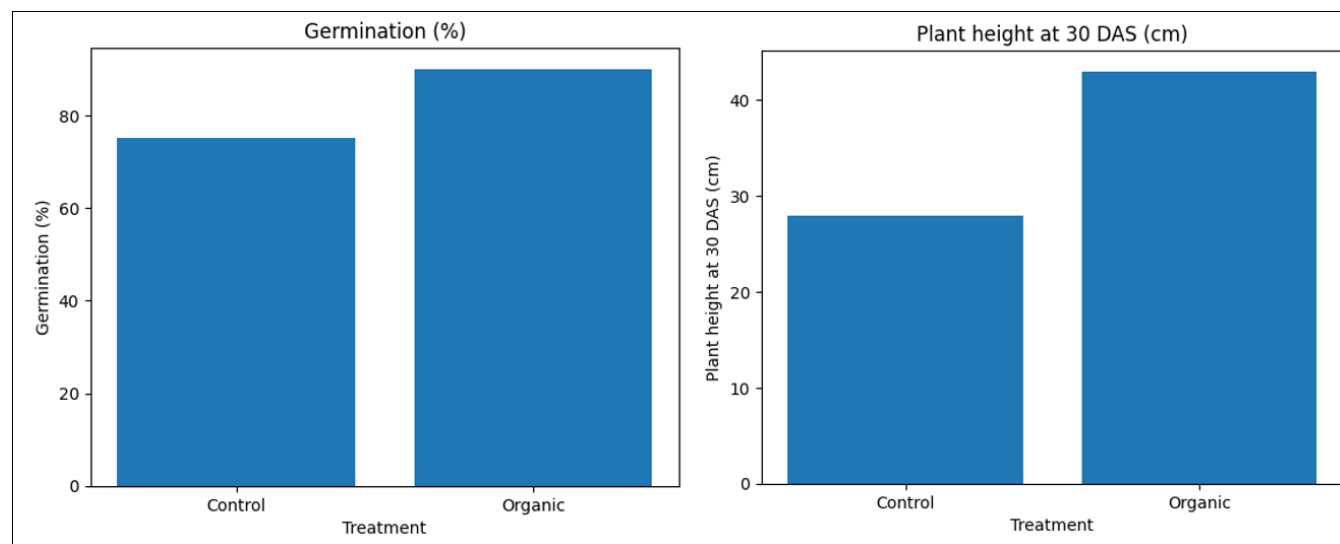
Application of an organic fertilizer comprising cow dung, banana peel, and eggshell significantly influenced the growth, flowering, and yield attributes of lady's finger (*Abelmoschus esculentus*). Treated plants exhibited superior performance compared to the control throughout the growth period.

3.1 Growth parameters

An increase in germination percentage was observed in treated plots (85-90%) compared to control plants (70-75%), indicating improved seedling establishment under organic nutrient management. At 30 days after sowing (DAS), treated plants attained an average height of 40-45 cm, whereas control plants reached only 25-30 cm.

Table 1: Effect of Organic Fertilizer on Growth and Yield of Lady's Finger (*Abelmoschus esculentus*)

Parameter	Control	Organic Treatment
Germination (%)	75	90
Plant height at 30 DAS (cm)	28	43
Number of leaves per plant	9	15
Days to first flowering	47	39
Number of fruits per plant	9	16
Average fruit length (cm)	9	14



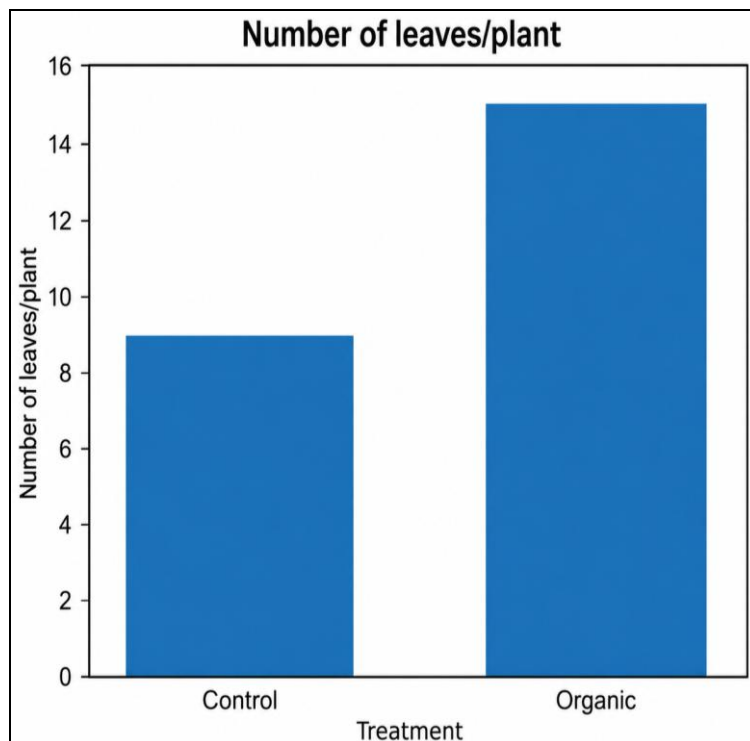
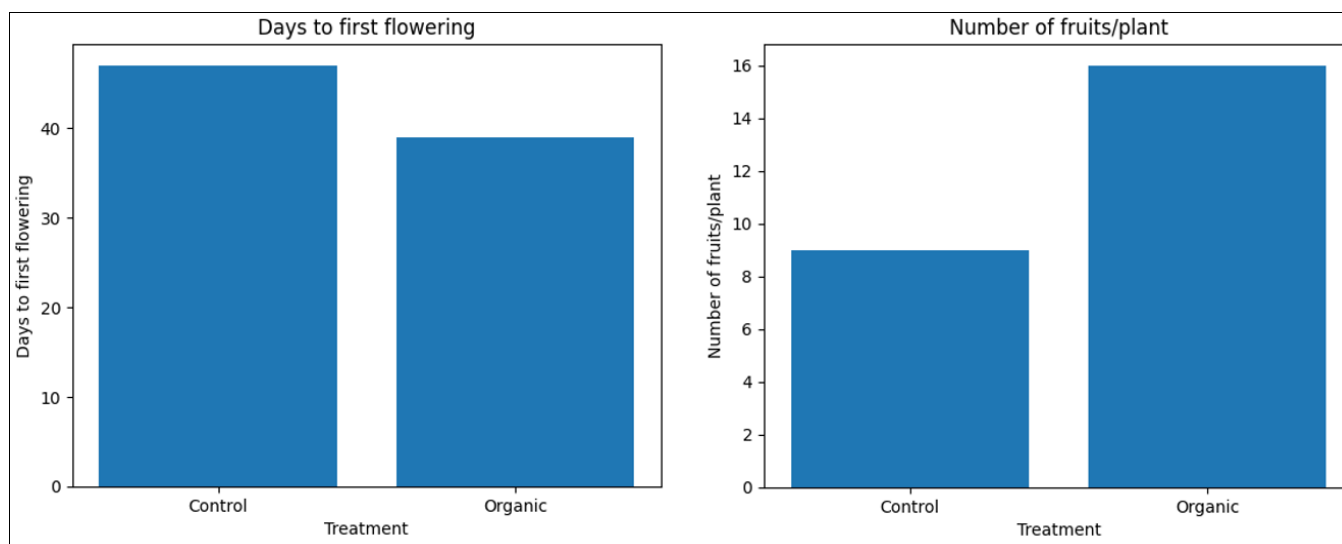


Fig 1: Comparison of effect of Growth of Lady's Finger (*Abelmoschus esculentus*)

The number of leaves per plant was also higher in treated plants (14-16 leaves) compared to control (8-10 leaves), reflecting enhanced vegetative growth were shown in Table 1 and it is shown in Figure 1. The improvement in growth parameters can be attributed to the availability of nitrogen and organic matter from cow dung, which enhances microbial activity and nutrient mineralization in the soil, leading to better nutrient uptake.

3.2 Flowering and fruiting response

Early flowering was recorded in organically treated plants, with first flowering occurring at 38-40 DAS, while control plants flowered at 45-48 DAS. The number of fruits per plant increased significantly in treated plants (15-18 fruits) compared to control (8-10 fruits). Fruit length was also higher in treated plants, ranging from 12-15 cm, whereas control fruits measured only 8-10 cm tabulated- Table 1 and shown in Figure 2.



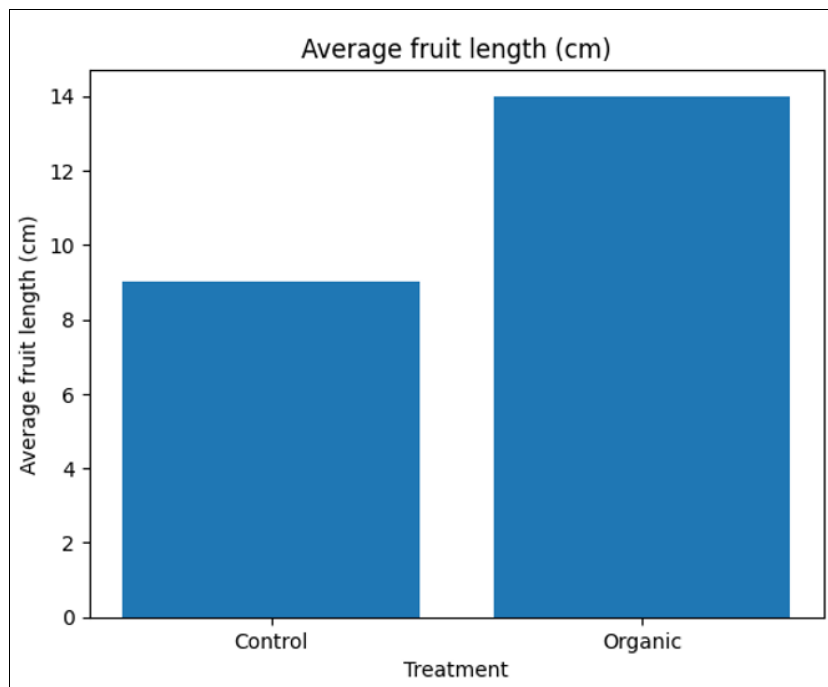


Fig 2: Comparison of effect of yield of Lady's Finger (*Abelmoschus esculentus*)

Banana peel supplementation contributed potassium and phosphorus, which are essential for flower initiation, fruit set, and translocation of photosynthates. Adequate potassium availability is known to reduce flower drop and improve fruit development, which explains the observed increase in fruit number and size.

3.4 Fruit quality and yield

Fruits harvested from treated plants were uniform in shape, tender, and deep green in color, indicating improved quality. Control plants produced comparatively thinner and uneven fruits. The enhanced fruit quality may be attributed to calcium supplied by eggshells, which strengthens cell walls, improves fruit firmness, and reduces physiological disorders.

3.5 Integrated nutrient effect

The combined application of cow dung, banana peel, and eggshell resulted in a balanced and slow-release nutrient supply, improving soil fertility and sustaining plant growth over time. Unlike chemical fertilizers, this organic treatment enhanced soil physical and biological properties while minimizing nutrient loss and environmental impact.

Overall, the results demonstrate that the integrated organic fertilizer significantly improves growth, yield, and quality of lady's finger, highlighting its potential as a sustainable alternative to conventional fertilizers.

4. Conclusion

The findings of the present investigation indicate that the application of organic fertilizer derived from cow dung, banana peel, and eggshell exerted a positive influence on the growth and yield of lady's finger (*Abelmoschus esculentus*). Organically treated plants showed improved germination, enhanced vegetative growth, early onset of flowering, and increased fruit number and size when compared with the control. The observed improvements may be attributed to the integrated and balanced supply of essential macro-nutrients, particularly nitrogen, potassium, phosphorus, and

calcium, along with improved soil physical and biological properties. The slow and sustained release of nutrients from the organic inputs ensured better nutrient uptake and minimized losses. In conclusion, the combined application of cow dung, banana peel, and eggshell proved to be an effective and sustainable nutrient management strategy for lady's finger cultivation and can be recommended as an eco-friendly alternative to synthetic fertilizers for improving crop productivity and soil health.

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