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Effect of plantain peels on the yield of Pepper (*Capsicum frutescens* L.)

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Abstract

The research aimed at assessing the impact of the application of plantain peel on the growth and production of pepper (*Capsicum frutescens* L.) in the wet tropical climate of Bayelsa state. A Randomized Complete Block Design (RCBD) was used to perform the experiment with five levels of plantain peel treatment: 0, 2.5, 5.0, 7.5, and 10.0 t/ha, three replications. Growth characteristics like plant height, leaf count, and time taken to flowering and yield parameters like fruit number, weight of fruit, and total yield per hectare were recorded. The application of plantain peels significantly ($p < 0.05$) increased the values of all measured growth and yield parameters when compared to the control treatment. The maximum yield of 6.8 t/ha was recorded in the plot treated with 10.0 t/ha of plantain peels, followed by 7.5 t/ha, which pointed out that organic amendment made nutrient availability, soil fertility, and microbial activity all improved. The higher yield was caused by the balanced release of the essential nutrients and the physical properties of the soil being improved. It is concluded that plantain peel is a phenomenal, eco-friendly and locally accessible organic fertilizer that not only promotes pepper yield sustainably but also lessens the dependency on synthetic fertilizers. The application of 10 t/ha is thus recommended for optimum field performance and sustainable soil management.

Keywords: Plantain peel, pepper yield, organic fertilizer, nutrient recycling, sustainable agriculture

1.0 Introduction

1.1 Background of the Study

The declining soil fertility, lack of proper soil management, and reliance on chemical fertilizers have put a limit on agricultural productivity in most of the developing countries like Nigeria. The use of inorganic fertilizers, although effective in the short run, has resulted in soil acidification, nutrient imbalance, and organic pollution which threaten the sustainability of food supply [1]. Therefore, organic waste: management has become one of the modern agricultural practices that help to sustain the environment. The right use of agricultural and communal wastes not only prevents environmental pollution but also returns the nutrients back to the soil, thus improving the structure and fertility of the soil [2]. In tropical areas, apart from the other waste materials, banana peel is one of the most important biodegradable household and market wastes. In some parts of

Nigeria, after the banana fruit is eaten or processed, a lot of banana peels are thrown away and this causes sanitation problems among the population. Still, it should be noted that the banana peel is a source of plant nutrients which are very important for example potassium (K), phosphorus (P), calcium (Ca), and magnesium (Mg) [3]. If the peels are properly decomposed, they will not only release the contained nutrients slowly but also increase the microbial population, enhance the organic matter content of the soil, and make the soil more water-retentive. Hence, the cultivation of banana peels as a source of organic fertilizer can be an option for sustained crop production and organic farming systems.

1.2 Problem Statement

The high price of synthetic fertilizers is one of the main problems that smallholder farmers face in Nigeria. Most farmers can only afford a very limited amount of fertilizers, which is not enough for optimum crop production, a situation that leads to low yields and food insecurity. On top of that, soil degradation, groundwater contamination, and greenhouse gas emissions [4] are some of the environmental problems caused by the indiscriminate and excessive use of fertilizers. Thus, there is a pressing need for the development of low-cost, eco-friendly, and sustainable soil fertility management strategies that will be able to keep agricultural production going without causing harm to the environment.

1.3 Justification

In southern Nigeria, where the plantain is a staple food, the peels are in abundance. Rather than adding to the waste disposal problem, such peels can be transformed into organic manure which will thus be a naturally enriching factor for soils. The use of the peels as fertilizer aids in converting waste into wealth, decreasing pollution of the environment, and facilitating circular economy practices in agriculture. Moreover, the nutrient content and biodegradability of the peels position them as a viable substitute to chemical fertilizers for smallholder farmers [5]. Thus, this study investigating the use of plantain peels as an organic fertilizer for boosting the growth and yield of pepper, an economically important vegetable crop.

The study intends to find out how different amounts of plantain peels applied can affect the growth and yield of pepper (*Capsicum* spp.) and how much of plantain peels would be the best to apply in the field to get the most yield and encourage organic farming that is sustainable.

2.0 Materials and Methods

2.1 Study Area

The Research Farm of Agricultural and Environmental Engineering, Niger Delta University, located on Wilberforce Island, Bayelsa State, Nigeria was the site of the experiment. The area is situated at latitude 4°58'N and longitude 6°05'E, in the humid tropical rainforest zone with yearly precipitation of 2,000–2,500 mm and a daily temperature of 26–32°C. The soil of the site is classified as sandy loam, derived from alluvial deposits, and is moderately drained. As a precursor to the experiment, composite soil samples from the top 0–15 cm depth were collected for routine analysis of physical and chemical properties to evaluate fertility status.

2.2 Experimental Design

The experiment used a Randomized Complete Block Design (RCBD) layout with five treatments and three replications to reduce experimental error and consider soil heterogeneity.

Each treatment area measured 2 m × 2 m with 0.5 m spacing between plots and 1 m between blocks. The treatment included five levels of plantain peel application as follows:

- T₀: 0 t/ha (Control – no plantain peel applied)
- T₁: 2.5 t/ha of plantain peel
- T₂: 5.0 t/ha of plantain peel
- T₃: 7.5 t/ha of plantain peel
- T₄: 10.0 t/ha of plantain peel

The dried and crushed plantain peels were mixed evenly into the soil in the amount required two weeks before transplanting to facilitate decomposition and mineralization of nutrients.

2.3 Planting Materials

The Capsicum variety used in this study was frutescens L., which is popularly referred to as "bird's eye pepper." This pepper variety is the one that is grown in southern Nigeria most extensively. The pepper seeds were sourced from a reliable Yenagoa-based agricultural inputs dealer and were sown in nursery trays, where they stayed for four weeks before being transplanted. Only the healthiest and uniformly growing seedlings were moved to the field plots that had been prepared beforehand at a distance of 50 cm × 50 cm, resulting in a plant density of 40,000 plants per hectare.

2.4 Crop Management

The plots were kept free of weeds by performing manual weeding every two weeks. Since no chemical fertilizers or pesticides were used during the entire experimental period, the outcome due to the application of only plantain peel was assessed accurately. Irrigation was done whenever necessary to keep the soil moist during the dry seasons.

2.5 Data Collection

Data collection commenced two weeks post-transplanting and continued at intervals of two weeks until the harvest period. The following growth and yield parameters were recorded:

- Plant height (cm): from the base of the plant to the tip of the central stem was measured with a meter rule.
- Leaves per plant: the leaves of the five randomly selected plants per plot were counted manually.
- Number of fruits per plant: counted at ripeness.
- Average fruit weight (g): the weight was obtained using a digital weighing balance from a composite sample of the picked fruits.
- Yield (t/ha): from the total fruit weight per plot, it was calculated and then extrapolated to yield per hectare.

2.6 Statistical Analysis

Data collected were subjected to Analysis of Variance (ANOVA) using the Statistical Analysis System (SAS) software to determine the significance of treatment effects. Where significant differences were observed, treatment means were separated using the Least Significant Difference (LSD) test at the 0.05 probability level as described by [6]. The results were presented in tables to illustrate treatment effects on pepper growth and yield.

3.0 Results and Discussion

3.1 Growth Parameters

The application of plantain peels had a significant effect on the growth parameters of pepper, including plant height, number of leaves, and days to flowering. Results revealed a progressive increase in plant height and leaf number with increasing rates of plantain peel application. At six weeks after transplanting (WAT), plants that received 10.0 t/ha (T_4) recorded the highest mean height of 58.3 cm, followed by 7.5 t/ha (T_3) with 54.7 cm, while the control (T_0) recorded the least height of 38.5 cm (Table 1).

Similarly, the number of leaves per plant increased with higher application rates. The T_4 treatment produced an average of 74 leaves per plant, significantly higher than the control with 46 leaves per plant. The onset of flowering occurred earlier in plants treated with higher rates of plantain peels, indicating improved nutrient availability and vegetative vigor due to the organic amendment.

3.2 Yield Components

The application of plantain peel brought forth a remarkable effect on the parameters associated with yield such as the number of fruits per plant, average fruit weight and total yield per hectare. The control (T_0) had an average fruit count of 16.3 per plant while the treatment with 10.0 t/ha (T_4) had 34.8 fruits as the mean. The maximum average fruit weight of 9.6 g was observed in T_4 , then came T_3 with 8.9 g, and at the bottom of the rank was the control with 6.3 g, the lowest score of all. The total fruit yield per hectare was exemplified by higher plantain peel application rates. While the control plot (T_0) yielded 2.5 t/ha, the highest yield of 6.8 t/ha was credited to plots treated with 10.0 t/ha (T_4). The treatments T_3 and T_4 pointed up significant differences with the control and lower application rates (T_1 and T_2) at $p < 0.05$, thus confirming the plantain peel's role as a nutrient source for the production of pepper.

3.3 Statistical Significance

The ANOVA results revealed the presence of significant ($p < 0.05$) differences among treatments regarding all parameters being measured, which included plant height, number of leaves, number of fruits, their weight and total yield per hectare. The Mean separation performed by LSD indicated that T_3 (7.5 t/ha) and T_4 (10.0 t/ha) were not statistically different but were significantly superior to other treatments. This suggests that the optimal yield for pepper might be obtained from the application of between 7.5 and 10.0 t/ha of plantain peel.

Table 1. Effect of Plantain Peel Application on Growth and Yield of Pepper

Treatment (t/ha)	Plant Height (cm)	No. of Leaves	Days to Flowering	No. of Fruits/Plant	Fruit Weight (g)	Yield (t/ha)
$T_0 = 0$ (Control)	38.5	46	42	16.3	6.3	2.5
$T_1 = 2.5$	44.2	53	40	21.7	7.2	3.9
$T_2 = 5.0$	48.9	61	39	25.6	8.1	4.8
$T_3 = 7.5$	54.7	68	37	31.5	8.9	6.2
$T_4 = 10.0$	58.3	74	36	34.8	9.6	6.8
LSD (0.05)	2.7	4.3	1.5	2.6	0.5	0.4

Note: Means followed by different letters are significantly different at $p < 0.05$ (LSD test).

The results obtained prove that the use of plantain peel as an organic fertilizer has a very remarkable influence on the growth and yield of pepper. The better results seen in T₃ (7.5 t/ha) and T₄ (10.0 t/ha) treatments are due to the slow but steady release of potassium and phosphorus which are the main nutrients for the flowering and fruit development. This indicates that among the different rates of plantain peel application the 7.5-10.0 t/ha is the one that should be recommended for the maximum pepper yield under the soil and climatic conditions of Bayelsa State.

3.4 Discussion

The findings of the current investigation showed a great positive impact of plantain peel application on the growth and yield of pepper, thus highlighting its practicability as an organic fertilizer. The gradual increase in the number of plants, leaves, fruits, and yield over time with higher plantain peel application rates can be interpreted as a result of both nutrient being available and soil physical plus biological conditions improved. The peels have very high macro nutrients content especially potassium (K), calcium (Ca), and phosphorus (P) which are absolutely necessary for cell elongation, fruit development, and activating the enzymes in plants [7]. Most probably the release of these nutrients was the result of the decomposition of organic material and the nutrient supply duration was in line with the vigorous growth which experienced at the higher treatment levels. The major yield components, especially at 7.5 t/ha and 10.0 t/ha, were greatly improved probably due to the addition of organic matter from the fossilized plantain peels. Organic matter is capable of making soils more porous thereby allowing water to penetrate and also enables the soil to retain moisture. The better the root system the better the nutrient uptake. The addition of organic matter to the soil according to [8], leads to an increase in its cation exchange capacity and the activity of microorganisms, which besides providing the plants with the essential nutrients through their mineralization, allows to reach the maximum crop productivity. The microbial decay of plantain peels must have been the cause of the large amounts of nitrogen, phosphorus, and potassium available to the plants thus prompting their growing and flowering stages, respectively. The nutrient release from the plantain peel application might be slow enough to accompany the plant demand and prevent nutrient leaching. That is the reason perhaps that the maximum yield of 6.8 tons per hectare was obtained from the 10 t/ha application rate, with 7.5 t/ha being the second best rate [9]. The yield was slightly lower than optimal beyond this application suggesting that the nutrients were at optimum levels and any further application of organic matter would not enhance productivity. This agrees with the results obtained by [10], who reported that liberal application of organic manures led to yield increase of vegetable crops without causing nutrient toxicity or growth suppression. The higher yield was indicative of potassium's main part heaving ever more fruits but rendered fruits of smaller sizes. Potassium comes from plantain peels in high amounts and is a decisive factor behind the plant nutrition and consequently the quality, purity, and even resistance of pepper plants to diseases [11]. That the trend of increasing amounts of fruit in conjunction with the increasing rates of applying plantain peels is seen as a sure indication of the sufficiency of nutrients especially of potassium for the highest yield.

But still, there were certain limitations and unexpected results noticed. The application rate of 10.0 t/ha, which was the highest, not only gave the largest yield but also had a minor impact on the fruit ripening interval as compared to moderate applications [12]. It might be nitrogen immobilization for some time which delayed the decomposing process or soil moisture retention that caused physiological maturity delay. Furthermore, the research was done in a single growing season under controlled field conditions, thus, different results may come out in the case of using different soils and climates, as well as peppers' varieties [13]. Hence, it is mandatory to conduct long-term field trials to assess the residual and cumulative effects of plantain peel application on soil fertility and crop productivity fully. The study results are in line with previous findings that

pointed out the advantages of the application of organic wastes in the sustainability of agriculture [2], [14]. The remarkable growth and the yield of the pepper correspond to the application of plantain peel, thus reinforcing its position as a natural, cheap, and green alternative to synthetic fertilizers. Nutrient mineralization dynamics, long-term soil health effects, and the potential merging of plantain peel compost with other organic materials to optimize nutrient balance and productivity across different agro-ecological zones should be addressed in future studies [15].

4.0 Conclusion and Recommendation

4.1 Conclusion

The results of the current investigation quite evidently show that the use of plantain peels as an organic fertilizer had a great impact on the development and yield of pepper (*Capsicum frutescens* L.) in the specific conditions of Bayelsa State, Nigeria. With the highest 10 t/ha (T_4) treatment yielding 6.8 t/ha, the data revealed that higher plantain peel rates led to increased plant height, number of leaves, and overall yield. The nutrient composition and slow mineralization of the plantain peels supplied nitrogen, phosphorus, and potassium which are essential for vigorous vegetative growth and fruit development. The addition of plantain peels into the soil not only ensured the increase of the crop but also played a significant role in the soil fertility by the organic matter addition which in turn leads to the better soil structure, moisture retention, and microbial activity. These advantages all together will be the support for the sustainable pepper production while at the same time minimizing the use of costly and harmful synthetic fertilizers from the environmental point of view. In addition, the use of plantain peels is a waste management method that can be considered as a practical solution, making the agricultural residues into useful soil amendments. This practice has a double advantage of increasing the crop yield and of lessening the environmental pollution which is related to the improper disposal of plantain waste.

The conclusion is that a dose of 10 t/ha of plantain peels is the best choice for the highest yield of pepper. Moving to this practice will not only keep the soils healthy and fertile but will also promote the farming systems which are environmentally friendly and compatible with the principles of sustainable agriculture and the recycling of resources.

4.2 Recommendations

The conclusions drawn from the research conducted about the influence of the application of plantain skins on the yield of pepper (*Capsicum frutescens* L.) are taken as a basis for the following recommendations that intend to support the cultivation of sustainable agriculture and efficient soil management of fertility:

4.2.1 For Farmers

The farmers are asked to change their ways and turn to the plantain peels as the source of organic fertilizer to get better growth and yield of pepper. The optimal application rate of 10 t/ha was distinguished by the research which resulted in significant improvements in plant growth, fruit development, and overall yield. This application rate guarantees an ample supply of potassium, nitrogen, and phosphorus which are the three most important nutrients required for the proper growth of the plants. However, farmers must decompose the plantain peels well before mixing them with the soil in order to enhance the release of nutrients and avoid the temporary immobilization of nutrients. This practice is going to cut down on production costs and also gradually improve the soils' fertility while reducing the reliance on costly synthetic fertilizers.

4.2.2 For Researchers

It is suggested that further research be carried out in order to understand better the mechanisms of plantain peels that affect soil and crop productivity. Future research should revolve around the following topics:

1. Nutrient Mineralization Rates: The study of the release rate of nutrients during the decomposition of plantain peels in different soil and climatic conditions.

2. Long-Term Soil Health Effects: The analysis of the impact of continuous application on soil organic matter, microbial activity, and overall soil fertility over the course of several cropping seasons.

3. Performance Across Soil Types and Agro-Ecological Zones: The assessment of the effectiveness of plantain peel amendments in different soils and regions to establish wider applicability and region-specific recommendations.

4. Integration with Other Organic Materials: The investigation of the synergistic effects of plantain peels when combined with other organic wastes or composts to optimize nutrient balance and increase crop productivity.

The research findings will give valuable inputs for the production of standard organic fertilizers and the implementation of sustainable soil management practices.

Declaration of Conflicting Interests

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