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Comparative Effects of Banana Peel and Eggshell Liquid Bio-fertilizers on the Growth and Yield of Onion (*Allium cepa L .*) and Fluted Pumpkin (*Telfairiaoccidentalis*)

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ABSTRACT

The increasing demand for sustainable and environmentally friendly agricultural practices has stimulated interest in the use of organic bio-fertilizers as alternatives to synthetic fertilizers. This study evaluated the effects of banana peel and eggshell liquid bio-fertilizers on the growth and yield of onion (Allium cepa L.) and fluted pumpkin (Telfairiaoccidentalis). The experiment was conducted at Gombe State University Botanical Garden using a Completely Randomized Design (CRD) with three replicates. Banana peel and eggshell liquid bio-fertilizers were applied at 25, 50, 75, and 100 mL, alongside an NPK fertilizer treatment and an untreated control. Growth parameters, chlorophyll content, biomass, yield, and nutrient composition were evaluated, and the data were analyzed using analysis of variance (ANOVA). Most measured growth and yield parameters showed no statistically significant differences among treatments ($P > 0.05$), although some bio-fertilizer treatments produced numerically comparable responses to the NPK fertilizer under the conditions of this study. The findings indicate that banana peel and eggshell liquid bio-fertilizers may serve as promising organic nutrient sources for vegetable production. However, given the largely non-significant treatment effects and the controlled sack-culture conditions of the experiment, further field-based studies with larger sample sizes and diverse environmental conditions are required before recommending their widespread agricultural use.

Keywords: Banana Peel; Eggshell; Bio-Fertilizer; Onion; Fluted Pumpkin; Sustainable Agriculture; Organic Fertilizer

INTRODUCTION

Sustainable agricultural production is essential for ensuring global food security while minimizing environmental degradation. Vegetables play a vital role in human nutrition by supplying essential vitamins, minerals, dietary fibre, and antioxidants required for healthy living [1,2]. Among commonly cultivated vegetables in Nigeria, onion (*Allium cepa L.*) is an important commercial crop valued for its culinary, nutritional, and medicinal properties, while fluted pumpkin (*Telfairiaoccidentalis*) is widely consumed as a leafy vegetable because of its high nutritional value and socio-economic importance in West Africa [3,4,5]. Improving the productivity of these crops through sustainable nutrient management practices remains a major agricultural priority [1].

The intensive use of inorganic fertilizers has contributed significantly to increased crop productivity; however, prolonged dependence on synthetic fertilizers has raised concerns regarding soil degradation, nutrient imbalance, environmental pollution, and increasing production costs [6]. These challenges have stimulated interest in environmentally friendly nutrient sources capable of sustaining crop productivity while improving soil health. Organic bio-fertilizers prepared from agricultural wastes represent one such alternative because they recycle nutrients that would otherwise contribute to environmental pollution [7,8].

Banana peels and eggshells constitute abundant agricultural wastes that contain plant nutrients capable of supporting crop growth. Banana peels are rich in potassium, phosphorus, calcium, magnesium, and other micronutrients, whereas eggshells serve primarily as a source of calcium carbonate together with smaller quantities of phosphorus and magnesium. Previous studies have reported that organic fertilizers improve soil fertility, nutrient availability, microbial activity, and crop performance while reducing reliance on inorganic fertilizers [8]. However, limited information exists regarding the comparative effects of banana peel and eggshell liquid bio-fertilizers on the growth and yield of onion and fluted pumpkin under controlled cultivation conditions.

Onion and fluted pumpkin were selected because they differ considerably in their growth characteristics and nutrient requirements, thereby providing an opportunity to evaluate whether the two bio-fertilizers produce consistent responses across contrasting vegetable species. Understanding their responses may contribute to the development of low-cost nutrient management strategies suitable for smallholder farmers and promote the utilization of biodegradable agricultural wastes as sustainable fertilizer resources.

Therefore, this study aimed to evaluate the effects of banana peel and eggshell liquid bio-fertilizers on the growth and yield of onion and fluted pumpkin in comparison with NPK fertilizer under controlled experimental conditions. Specifically, the study assessed their influence on vegetative growth, chlorophyll content, biomass production, yield performance, and selected nutrient compositions of both crops.

MATERIALS AND METHODS

Study Area

The experiment was conducted at the Faculty of Science Botanical Garden, Gombe State University, Tudun Wada Campus, Gombe State, Nigeria, located at 10.304483° N latitude and 11.176344° E longitude. The study area lies at an elevation of approximately 500 m above sea level within the Sudan Savannah agroecological zone of northeastern Nigeria. The area experiences a tropical continental climate characterized by two distinct seasons: a rainy season (May–October) and a dry season (November–April). Mean annual rainfall ranges from approximately 850 to 900 mm, while mean annual temperature ranges between 26 and 32°C.

The vegetation is predominantly Sudan Savannah, consisting of grasses interspersed with scattered shrubs and trees (NiMET, 2023). The experiment was conducted under ambient environmental conditions using sack cultivation to evaluate the effects of banana peel and eggshell liquid bio-fertilizers on the growth and yield of onion (*Allium cepa L .*) and fluted pumpkin (*Telfairiaoccidentalis*).

Preparation of Banana Peel Liquid Bio-fertilizer

Fresh banana peels were collected from fruit vendors within Gombe metropolis and thoroughly washed with clean water to remove adhering dirt and impurities. The peels were chopped into small pieces, after which 1 kg was transferred into a clean plastic container. Five litres (5 L) of clean water were added, and the container was covered with a muslin cloth to minimize contamination while allowing adequate aeration during fermentation. The mixture was stirred once daily and allowed to ferment at room temperature (approximately 25–30°C) for 5–7 days. At the end of the fermentation period, the mixture was filtered through a fine muslin cloth to obtain the banana peel liquid bio-fertilizer, which was stored in clean plastic containers until application.

Preparation of Eggshell Liquid Bio-fertilizer

Eggshells were collected from domestic sources and thoroughly washed with clean water to remove adhering organic materials. The shells were oven-dried at approximately 100°C for 10–15 min to remove surface moisture before being ground into a fine powder. One kilogram (1 kg) of the powdered eggshells was soaked in 5 L of clean water and maintained at room temperature for 5–7 days with daily stirring. The suspension was subsequently filtered through a muslin cloth to obtain the aqueous eggshell extract used as the liquid bio-fertilizer throughout the experiment.

Experimental Design and Treatment Application

Two independent experiments were conducted simultaneously, one using onion (Allium cepa L.) and the other using fluted pumpkin (Telfairiaoccidentalis Hook. f.). Each experiment was arranged in a Completely Randomized Design (CRD) consisting of 10 treatments with three replicates.

The treatments were:

- Control (no fertilizer application);
- Banana peel liquid bio-fertilizer at 25, 50, 75, and 100 mL;
- Eggshell liquid bio-fertilizer at 25, 50, 75, and 100 mL; and
- NPK fertilizer (15:15:15).

For each crop, each replicate consisted of one planting sack containing one transplanted seedling, giving a total of 30 experimental units (30 sacks) per crop. Since onion and fluted pumpkin were evaluated independently, the study comprised 60 experimental units (60 sacks).

Seeds of both crops were initially raised in nursery beds. After successful germination and seedling establishment, healthy and uniform seedlings were transplanted individually into planting sacks containing the 5kg of the experimental soil. Treatments were assigned randomly to the experimental units to minimize experimental bias.

The respective fertilizer treatments were applied bi-weekly (once every two weeks) throughout the experimental period according to the designated application volumes.

Determination of Growth Parameters

Data on the growth parameters including plant height and number of leaves were recorded bi-monthly (at the interval of two weeks). The plant height was measured using measuring tape and all the leaves were counted to determine the number of leaves of each plant. At harvest, yield-related parameters were measured. For onion, bulb diameter was measured using measuring tape and bulb fresh weight were recorded using weighing balance, while for fluted pumpkin, leaf size, fresh leaf weight, fresh plant biomass and dry plant biomass were measured. Chlorophyll content was also determined using a chlorophyll meter.

Statistical Analysis

Data obtained from the onion and fluted pumpkin experiments were analyzed separately using one-way analysis of variance (ANOVA) in IBM SPSS Statistics version 21 (IBM Corp., Armonk, NY, USA). Where significant treatment effects were detected, treatment means were separated using Duncan's Multiple Range Test (DMRT) at the 5% probability level ($P < 0.05$) (Duncan, 1955).

RESULTS

Nutrient Composition of Planting Soil, Banana Peel, and Eggshell Bio-fertilizers

Table 1 shows that the planting soil contained 0.17 ± 0.01% total N, 44.50 ± 0.70 mg/kg PO_4, 2152.00 ± 13.20 mg/kg Na, 1143.50 ± 8.70 mg/kg K, 5836.00 ± 35.00 mg/kg Ca, and 449.00 ± 3.20 mg/kg Mg. The banana peel bio-fertilizer recorded the highest total N (0.97 ± 0.01%) and PO_4 (728.52 ± 2.73 mg/kg), while the eggshell bio-fertilizer contained 0.15 ± 0.00% total N and 128.03 ± 0.61 mg/kg PO_4. For the cations, the soil contained the highest Na, K, Ca, and Mg concentrations compared with both bio-fertilizers. Among the bio-fertilizers, banana peel extract contained higher N, PO_4, Ca, and Mg than the eggshell extract, whereas the eggshell extract contained higher Na and K concentrations.

Minerals	Soil	Banana Peel Bio-fertilizer	Eggshell Bio-fertilizer
Total N (%)	0.17±0.01	0.97±0.01	0.15±0.00
PO4 (mg/kg)	44.50±0.70	728.52±2.73	128.03±0.61
Na (mg/kg)	2152.00±13.20	82.66±0.94	653.32±2.95
K (mg/kg)	1143.50±8.70	15.39±0.15	124.45±0.74
Ca (mg/kg)	5836.00±35.00	860.33±1.88	38.29±0.17
Mg (mg/kg)	449.00±3.20	743.53±2.37	512.68±1.05

Table 1: Nutrient Composition of Planting Soil, Banana Peel, And Eggshell Bio-Fertilizers

Effect of Liquid Fertilizers on Plant Height and Chlorophyll Content of Onion

The effects of banana peel bio-fertilizer, eggshell bio-fertilizer, and NPK fertilizer on plant height and chlorophyll content of onion are presented in Table 2. No significant differences ($P > 0.05$) were observed among treatments for plant height at 2, 4, 6, 8, and 10 weeks after transplanting (WAT). Plant height varied numerically among treatments throughout the study. At 10 WAT, the BP100 mL treatment recorded the highest mean plant height (42.33 ± 0.57 cm), while the control recorded the lowest value (29.00 ± 16.82 cm). Likewise, chlorophyll content varied numerically among treatments, ranging from 34.33 ± 30.47 to 59.76 ± 9.50 SPAD units, but these differences were not statistically significant ($P = 0.339$).

Treatments	PH2	PH4	PH6	PH8	PH10	Chlo
Control	42.33±2.51a	29.00±6.92a	37.33±5.68a	27.00±23.43a	29.00±16.82a	59.76±9.50a
BP25 mL	42.66±3.51a	36.00±4.58a	36.50±1.32a	39.33±3.78a	39.66±1.15a	46.96±10.87a
BP50 mL	40.16±2.46a	32.00±2.62a	36.33±5.39a	37.66±6.65a	38.33±2.08a	35.53±17.55a
BP75 mL	43.33±2.51a	31.33±9.01a	30.00±10.44a	30.66±9.29a	34.33±8.96a	34.33±30.47a
BP100 mL	37.66±4.50a	22.50±8.26a	36.83±1.60a	40.66±1.15a	42.33±0.57a	45.40±5.03a
ES25 mL	40.00±4.35a	25.33±5.34a	31.66±5.13a	34.33±4.04a	36.00±1.00a	49.86±11.65a
ES50 mL	39.16±3.40a	26.50±0.86a	31.00±3.60a	34.66±1.52a	38.66±1.52a	40.53±3.98a
ES75 mL	34.00±5.56a	30.50±4.58a	31.33±4.72a	33.33±3.05a	37.33±2.08a	57.13±7.90a
ES100 mL	37.66±5.68a	30.00±3.60a	33.00±2.59a	34.66±2.51a	38.00±2.64a	50.56±6.11a
NPK50 mL	43.66±6.82a	29.00±6.08a	38.66±4.50a	40.33±6.65a	36.66±1.15a	51.03±5.34a
Mean	40.06	29.21	34.26	35.26	37.03	47.11
S.D	4.68	5.97	5.24	8.43	6.18	13.66
P-Value	0.225	0.292	0.379	0.669	0.484	0.339

Note: PH = Plant Height, 2,4,6,8 & 10 = Number of Weeks, Chlo = Chlorophyll, BP = Banana Peel, ES = Egg Shell, NPK=Nitrogen-Phosphorus-Potassium, S.D=Standard Deviation. No Significant Difference Among the Treatments (P>0.05)

Table 2: Effect Of Liquid Fertilizers on Plant Height and Chlorophyll Content of Onion

Number of Leaves, Bulb Diameter, and Bulb Weight of Onion

The fertilizer treatments did not significantly influence the number of leaves, bulb diameter, or bulb weight of onion during the study period. Although numerical variations were observed among treatments, the absence of statistically significant differences indicates that the tested application rates of banana peel bio-fertilizer, eggshell bio-fertilizer, and NPK fertilizer produced comparable effects on onion growth and yield under the prevailing experimental conditions.

The BP50 mL treatment recorded the highest numerical values for bulb diameter and bulb weight, suggesting that a moderate application rate of banana peel bio-fertilizer may have provided a favourable nutrient balance for bulb development. However, because these differences were not statistically significant, this observation should be interpreted with caution and cannot be regarded as evidence of superior performance over the other

treatments. The relatively good performance of the banana peel treatments may nevertheless be associated with the availability of essential nutrients, particularly nitrogen and phosphorus, identified in the nutrient analysis of the bio-fertilizer (Table 1), which are known to support vegetative growth and bulb formation.

Likewise, the eggshell bio-fertilizer treatments produced bulb diameter and bulb weight values comparable to those obtained with the NPK fertilizer treatment. This finding suggests that the aqueous eggshell extract supplied sufficient nutrients to maintain normal plant growth, although its effect was not significantly different from either the banana peel bio-fertilizer or the untreated control. The lack of significant treatment effects may have resulted from the relatively high nutrient status of the planting soil, the gradual nutrient release associated with organic bio-fertilizers, and the inherent biological variability among the experimental units.

Treatments	NL2	NL4	NL6	NL8	NL10	OBD	OBW
Control	5.33±0.57a	5.66±1.15a	4.66±0.57a	4.00±3.46a	7.00±1.73a	14.00±2.00a	23.33±2.00a
BP25 mL	6.00±1.00a	5.33±0.57a	5.33±0.57a	5.33±0.57a	8.00±1.73a	12.33±1.52a	11.66±1.52a
BP50 mL	6.33±0.57a	4.33±0.57a	5.33±0.57a	5.33±0.57a	8.33±1.52a	15.33±2.08a	23.66±2.08a
BP75 mL	6.00±1.00a	4.66±1.52a	4.66±1.52a	5.00±1.73a	4.33±4.04a	8.00±7.00a	13.00±7.00a
BP100 mL	5.33±0.57a	4.66±1.52a	4.66±0.57a	5.66±1.52a	6.33±0.57a	14.66±0.57a	20.33±0.57a
ES25 mL	5.33±0.57a	2.66±1.52a	4.00±0.00a	5.00±1.00a	5.66±1.15a	12.33±0.57a	11.66±0.57a
ES50 mL	5.00±1.00a	4.00±0.00a	5.00±0.00a	5.33±0.57a	6.66±1.52a	13.00±1.00a	13.00±1.00a
ES75 mL	5.00±0.00a	5.33±1.52a	4.66±1.15a	5.66±0.57a	7.00±1.00a	13.00±2.00a	20.00±2.00a
ES100 mL	5.66±0.57a	4.66±1.15a	4.33±0.57a	6.33±1.52a	6.33±1.15a	12.00±1.00a	11.33±1.00a
NPK50 mL	6.00±1.00a	4.66±1.52a	4.33±0.57a	5.33±0.57a	5.66±1.52a	14.00±1.73a	20.00±1.73a
Mean	5.60	4.60	4.70	5.30	6.53	12.86	12.86
S.D	0.77	1.30	0.74	1.36	1.88	2.93	2.93
P-Value	0.376	0.244	0.489	0.872	0.334	0.137	0.137

Note: NL = Number Of Leaves, 2,4,6,8 & 10 = Number Of Weeks, OBS = Onion Bulb Size, OBW = Onion Bulb Weight, BP = Banana Peel, ES = Egg Shell, NPK=Nitrogen-Phosphorus-Potassium, S.D=Standard Deviation. Means With The Same Alphabet Down The Column Are Not Significant Statistically At 0.05.

Table 3: Effect of Liquid Fertilizers on Number of Leaves, Bulb Diameter, And Bulb Weight of Onion

Effects of liquid bio-fertilizers on Plant Height, Number of Leaves, and Chlorophyll Content of Fluted Pumpkin

The effects of banana peel bio-fertilizer, eggshell bio-fertilizer, and NPK fertilizer on the plant height and chlorophyll content of fluted pumpkin are presented in Table 4. No significant differences ($P > 0.05$) were observed among treatments for plant height at 2, 4, 6, 8, and 10 weeks after transplanting. Plant height varied numerically among treatments throughout the experimental period. At 2 weeks after transplanting, the highest mean plant height was recorded in the NPK 50 mL treatment (31.00 ± 1.00 cm), whereas the ES100 mL treatment recorded the lowest value (9.66 ± 16.74 cm). By 10 weeks after transplanting, the control treatment recorded the highest mean plant height (36.33 ± 0.57 cm), while the BP25 mL treatment recorded the lowest mean value (10.66 ± 18.47 cm). However, these numerical differences were not statistically significant ($P = 0.477$).

Similarly, chlorophyll content varied numerically among treatments, ranging from 14.60 ± 25.28 in the BP100 mL treatment to 51.10 ± 3.67 in the control treatment. Nevertheless, statistical analysis showed no significant differences among treatments ($P = 0.948$).

Treatments	PH 2 (cm)	PH 4 (cm)	PH 6 (cm)	PH 8 (cm)	PH 10 (cm)	CHLOR
Control	28.83±4.25a	31.33±3.05a	32.66±1.52a	34.66±0.57a	36.33±0.57a	51.10±3.67a
BP25ml	28.83±4.25a	7.33±3.00a	9.00±5.58a	10.00±17.32a	10.66±18.47a	17.83±30.88a
BP50 mL	17.00±16.52a	19.33±19.33a	24.66±22.81a	28.00±25.53a	29.33±26.35a	33.10±30.47a
BP75 mL	22.50±19.50a	25.33±21.93a	30.66±26.72a	32.33±28.21a	33.66±29.26a	33.26±29.24a
BP100 mL	11.66±20.20a	13.00±22.50a	13.00±22.51a	13.33±23.09a	14.00±24.24a	14.60±25.28a
ES 25 mL	13.66±12.34a	16.00±13.85a	23.00±20.42a	26.66±24.44a	28.33±25.96a	32.80±28.40a
ES 50 mL	11.00±19.05a	11.33±19.62a	11.00±19.05a	13.33±23.09a	14.00±24.24a	17.90±31.00a
ES 75 mL	20.16±13.13a	20.33±18.77a	26.00±22.51a	26.66±24.44a	33.33±28.88a	30.36±27.07a
ES 100 mL	9.66±16.74a	11.00±19.05a	13.00±22.51a	13.33±23.09a	14.33±24.82a	16.16±28.00a

NPK 50 mL	31.00±1.00a	19.26±16.82a	47.16±2.75a	50.00±4.35a	26.56±22.76a	50.96±7.15 a
Mean	18.11	19.26	23.01	25.26	26.56	29.81
S. D	14.37	16.82	19.86	21.75	22.79	25.96
P value	0.676	0.476	0.386	0.456	0.477	0.948

Table 4: Effect of Different Fertilizers on Plant Height (PH) And Chlorophyll Content of Fluted Pumpkin

Number of Leaves, Fresh Biomass, and Dry Biomass of Fluted Pumpkin

The effects of banana peel bio-fertilizer, eggshell bio-fertilizer, and NPK fertilizer on the number of leaves, fresh biomass, and dry biomass of fluted pumpkin are presented in Table 5. No significant differences (P > 0.05) were observed among treatments for the number of leaves at 2, 4, 6, 8, and 10 weeks after transplanting. At 10 weeks after transplanting, the NPK 50 mL treatment recorded the highest mean number of leaves (13.00 ± 2.64), whereas the BP25 mL treatment recorded the lowest value (2.00 ± 3.46). Fresh biomass ranged from 21.00 ± 36.37 g in the BP100 mL treatment to 63.00 ± 8.18 g in the NPK 50 mL treatment, while dry biomass ranged from 11.00 ± 19.05 g in the BP25 mL treatment to 32.33 ± 8.32 g in the NPK 50 mL treatment. However, statistical analysis showed that neither fresh biomass nor dry biomass differed significantly among treatments (P = 0.613 and P = 0.900, respectively).

Treatment	NL 2	NL 4	NL 6	NL 8	NL 10	FB	DB
Control	7.00±3.60a	10.00±4.35a	10.33±3.21a	8.66±1.52a	12.33±4.50a	57.33±11.59a	26.00±6.55a
BP25 mL	1.33±3.51a	2.00±3.46a	2.00±3.46a	2.00±3.46a	2.00±3.46a	26.00±45.03a	11.00±19.05a
BP50 mL	4.66±6.42a	6.66±8.32a	8.33±9.71a	9.00±9.53a	8.33±8.50a	48.33±42.00a	26.66±23.62a
BP75 mL	5.00±5.00a	6.66±8.32a	6.66±6.50a	7.33±6.65a	7.33±6.65a	44.66±38.78a	26.66±23.11a
BP100 mL	3.00±5.19a	4.33±7.50a	4.66±8.08a	4.66±8.08a	3.66±6.35a	21.00±36.37a	12.00±20.78a
ES 25 mL	2.33±2.51a	4.00±3.60a	4.33±4.04a	5.33±4.72a	4.33±3.78a	53.33±47.25a	27.33±23.69a
ES 50 mL	5.66±9.81a	6.66±11.54a	6.66±11.54a	6.33±10.96a	4.66±8.08a	28.66±49.65a	16.66±28.86a
ES 75 mL	6.00±4.00a	6.00±6.00a	7.00±7.00a	6.66±5.85a	6.66±5.85a	41.33±36.29a	23.00±20.66a
ES 100 mL	4.33±7.50a	5.66±9.81a	7.00±12.12a	7.00±12.12a	6.33±10.96a	26.66±46.18a	17.33±30.02a
NPK 50 mL	8.33±2.51a	10.33±3.05a	12.66±4.16a	13.33±2.88a	13.00±2.64a	63.00±8.18a	32.33±8.32a
Mean	4.96	6.23	6.98	7.03	6.86	41.03	21.90
S. D	4.88	6.29	7.00	6.78	6.45	35.13	19.33
P value	0.948	0.920	0.878	0.863	0.548	0.613	0.900

Note: NL=Number of leaves, 2,4,6,8 & 10 = Number of Weeks, BP = banana peel, ES = egg shell, NPK=Nitrogen-Phosphorus-Potassium, S.D=Standard Deviation. Means with the same alphabet down the column are not significant statistically at 0.05.

Table 5: Effect of Different Fertilizers of Number of Leaves, Fresh Biomass (FB) And Dry Biomass (DB) Of Fluted Pumpkin

DISCUSSION

Effect of Liquid Fertilizers on Plant Height and Chlorophyll Content of Onion

The application of banana peel bio-fertilizer, eggshell bio-fertilizer, and NPK fertilizer did not produce statistically significant differences (P > 0.05) in onion plant height throughout the experimental period. Although numerical differences were observed among treatments, these differences were insufficient to demonstrate a significant treatment effect under the experimental conditions. The reduction in plant height observed at four weeks after transplanting across most treatments was likely associated with transplant shock, during which the transplanted onion seedlings experienced temporary leaf bending, senescence, and shedding of older leaves before becoming established and producing new vegetative growth [16]. Following recovery, plant height generally increased across all treatments until harvest.

The absence of significant differences among treatments may be attributed to several factors. First, the planting soil contained appreciable amounts of essential nutrients (Table 1), which may have supplied adequate nutrients for onion growth and thereby reduced the observable response to the applied bio-fertilizers (Brady & Weil, 2017). Secondly, the relatively short experimental period and the gradual release of nutrients from the bio-fertilizers may have limited the expression of significant treatment effects. Furthermore, the inherent variability among individual plants, as reflected by the relatively large standard deviations observed in some treatments, may have reduced the statistical power to detect treatment differences.

Although the 100 mL banana peel bio-fertilizer (BP100 mL) recorded the highest mean plant height at 10 weeks after transplanting, this numerical advantage should be interpreted with caution because it was not statistically different from the other treatments. This observation nevertheless suggests that higher application rates of banana peel bio-fertilizer may

provide sufficient nutrients to support vegetative growth, particularly because banana peels are known to contain appreciable quantities of nitrogen, phosphorus, potassium, and other essential mineral elements that contribute to plant development.

Similarly, chlorophyll content did not differ significantly among treatments, indicating that the fertilizer applications did not substantially influence chlorophyll accumulation in onion leaves under the conditions of this study. Since chlorophyll synthesis depends largely on adequate nitrogen availability and overall plant nutritional status, the similarity in chlorophyll content among treatments suggests that the nutrients available from both the soil and the applied fertilizers were sufficient to maintain normal leaf physiological activity throughout the experiment [16-19].

Effect of Liquid Fertilizers on Number of Leaves, Bulb Size, And Bulb Weight of Onion

The application of banana peel bio-fertilizer, eggshell bio-fertilizer, and NPK fertilizer did not produce statistically significant differences ($P > 0.05$) in the number of leaves, bulb diameter, or bulb weight of onion. Although numerical differences were observed among the treatments, these differences were insufficient to demonstrate a significant effect of fertilizer application on onion growth and yield under the conditions of the present study.

The BP50 mL treatment produced the highest numerical values for bulb diameter and bulb weight, while BP25 mL and ES25 mL recorded the lowest bulb weights. Although these observations may suggest that moderate application rates of banana peel bio-fertilizer favoured bulb development, the absence of statistical significance indicates that these numerical differences should be interpreted cautiously. Consequently, it cannot be concluded that the BP50 mL treatment was superior to the other fertilizer treatments [8].

The comparable performance of the banana peel and eggshell bio-fertilizers with the NPK fertilizer treatment suggests that both organic fertilizers were capable of supporting onion growth and bulb development to levels comparable with those obtained using inorganic fertilizer. Similar observations have been reported by Adekiya, who found that organic nutrient sources can sustain vegetable growth and productivity while improving soil quality [8]. Likewise, Khanyile reported that fermented banana peel fertilizer contains appreciable quantities of nitrogen, phosphorus, and other mineral nutrients capable of supporting crop growth [9]. The relatively higher nitrogen and phosphorus concentrations recorded in the banana peel bio-fertilizer may have enhanced vegetative growth and assimilate production required for bulb development. Although the eggshell bio-fertilizer contained relatively lower concentrations of soluble nutrients, it also maintained bulb development comparable to that obtained with NPK fertilizer, suggesting that it supplied sufficient nutrients to sustain normal plant growth [10].

The lack of significant treatment effects may also be explained by the relatively fertile nature of the planting soil, as indicated by its appreciable mineral nutrient content (Table 1). Under such conditions, the contribution of the applied fertilizers may have been supplementary rather than sufficient to produce statistically detectable improvements in growth and yield. Similar findings have been reported by Agegnehu, who observed that the response of crops to organic nutrient amendments is often less pronounced in soils with moderate to high native fertility [11]. Furthermore, the gradual mineralization and slow nutrient release associated with organic fertilizers may delay nutrient availability compared with readily soluble inorganic fertilizers [12]. The relatively large variability observed among treatments may also have reduced the statistical power to detect significant differences.

Overall, these findings indicate that the liquid banana peel and eggshell bio-fertilizers performed comparably to NPK fertilizer in supporting onion growth and bulb production. This agrees with recent studies showing that bio-fertilizers prepared from biodegradable agricultural wastes can partially substitute inorganic fertilizers while promoting environmentally sustainable crop production and waste recycling [13-15].

Effect of Liquid Fertilizers on Growth Parameters of Fluted Pumpkin

The application of banana peel bio-fertilizer, eggshell bio-fertilizer, and NPK fertilizer did not significantly influence the plant height or chlorophyll content of fluted pumpkin throughout the experimental period. Although numerical differences were observed among treatments, these differences were not statistically significant ($P > 0.05$), indicating that the fertilizer treatments produced comparable vegetative responses under the conditions of the study. Similar findings have been reported by Adekiya and Agegnehu, who observed that organic nutrient sources often produce growth responses comparable to inorganic fertilizers, particularly where soil nutrient availability is already adequate [11, 13].

The numerical variation in plant height among treatments may have reflected differences in plant establishment, nutrient availability, and natural biological variability rather than treatment effects. Furthermore, mortality of a few experimental plants due to rodent damage during the course of the experiment contributed to reductions in treatment means and increased variability within some treatments. Such losses inevitably reduce experimental precision and statistical power, making it more difficult to detect significant treatment effects, especially when the number of replicates is limited [14]. Similar reductions in statistical sensitivity due to field losses and environmental variability have been reported in vegetable fertilizer experiments.

Similarly, chlorophyll content remained statistically comparable across all treatments, suggesting that the nutrient supply from the banana peel bio-fertilizer, eggshell bio-fertilizer, NPK fertilizer, and the planting soil was sufficient to maintain normal chlorophyll synthesis and leaf physiological activity. Chlorophyll concentration is closely associated with plant nitrogen status and photosynthetic efficiency and therefore serves as a reliable indicator of crop nutritional condition [15].

The comparable chlorophyll values observed in the present study suggest that none of the fertilizer treatments substantially altered the photosynthetic capacity of fluted pumpkin, a finding that agrees with reports by Adekiya and Khanyile, who observed comparable leaf chlorophyll levels among plants supplied with organic nutrient sources.

The absence of significant treatment effects may also be associated with the relatively high nutrient status of the planting soil, which contained appreciable concentrations of essential mineral elements (Table 1). Consequently, the applied bio-fertilizers likely served as supplementary nutrient sources rather than producing measurable improvements in vegetative growth. Furthermore, the gradual mineralization and slow release of nutrients characteristic of organic fertilizers may have limited their short-term effects on plant growth compared with readily available inorganic fertilizers [11,12]. Similar observations have been reported in studies evaluating organic nutrient amendments in vegetable production, where soil fertility status strongly influenced crop response to fertilizer application.

The findings indicate that banana peel and eggshell bio-fertilizers supported the vegetative growth of fluted pumpkin to a level comparable with the NPK fertilizer. These results demonstrate the potential of biodegradable household wastes as alternative nutrient sources capable of sustaining vegetable production while reducing dependence on synthetic fertilizers. Their utilization also contributes to environmentally sustainable waste recycling and improved soil health, which are increasingly promoted as important components of sustainable agricultural systems [9,11,12].

Number of Leaves, Fresh Biomass, and Dry Biomass of Fluted Pumpkin

The application of banana peel bio-fertilizer, eggshell bio-fertilizer, and NPK fertilizer did not significantly affect the number of leaves, fresh biomass, or dry biomass of fluted pumpkin. Although numerical differences were observed among treatments, the absence of statistically significant differences indicates that the fertilizer treatments produced comparable effects on vegetative growth and biomass production under the conditions of this study. Similar observations have been reported in studies evaluating organic nutrient sources in vegetable production, where improvements in vegetative growth and biomass were often numerically evident but not statistically significant, particularly under conditions of adequate soil fertility and limited experimental duration.

The NPK 50 mL treatment recorded the highest numerical values for the number of leaves, fresh biomass, and dry biomass. However, these values were not significantly different from those obtained with the banana peel and eggshell bio-fertilizer treatments. Consequently, the numerical differences should be interpreted cautiously and cannot be regarded as evidence of superior fertilizer performance. Similar findings have been reported by Chandini, who noted that organic fertilizers frequently produce crop growth responses comparable to inorganic fertilizers because of their gradual nutrient release and sustained nutrient availability.

The comparable biomass production observed among treatments suggests that both banana peel and eggshell bio-fertilizers supplied nutrients sufficient to support normal vegetative growth and biomass accumulation. This finding is consistent with the nutrient composition of the bio-fertilizers (Table 1), particularly the relatively higher nitrogen and phosphorus contents of the banana peel bio-fertilizer, which are essential for leaf expansion, chlorophyll formation, photosynthesis, and dry matter accumulation [9]. Likewise, although the eggshell bio-fertilizer contained lower concentrations of soluble nutrients, it maintained biomass production comparable to the other treatments, suggesting that it contributed to maintaining adequate plant nutrition throughout the experimental. These findings agree with reports that organic fertilizers derived from agricultural wastes can effectively support vegetative growth while improving nutrient use efficiency and promoting sustainable crop production.

The lack of significant treatment effects may be attributed to the relatively high fertility of the planting soil, which likely provided an adequate supply of essential nutrients throughout the experimental period. Furthermore, the gradual mineralization and slow nutrient release associated with organic bio-fertilizers, together with the relatively high variability among experimental units, may have reduced the ability to detect statistically significant differences among treatments. In the present study, variability was further increased by the loss of some fluted pumpkin plants due to rodent damage during the experiment, which influenced the treatment means because all experimental units were retained in the statistical analysis. Such field losses reduce experimental precision and statistical power, particularly in studies with relatively few replicates [14].

The findings indicate that banana peel and eggshell liquid bio-fertilizers supported leaf production and biomass accumulation at levels comparable to those obtained with NPK fertilizer. These results demonstrate that bio-fertilizers prepared from biodegradable household wastes have considerable potential as environmentally friendly nutrient sources for fluted pumpkin cultivation. Their use may contribute to reducing dependence on synthetic fertilizers while simultaneously promoting sustainable waste recycling, improved soil health, and environmentally sustainable agricultural production.

CONCLUSION

The present study evaluated the effects of banana peel and eggshell liquid bio-fertilizers on the growth and yield of onion (Allium cepa L.) and fluted pumpkin (Telfairiaoccidentalis Hook. f.) under field conditions. Although numerical variations were observed among fertilizer treatments, most growth and yield parameters did not differ significantly ($P > 0.05$). Nevertheless, the banana peel and eggshell bio-fertilizers supported plant growth and yield at levels comparable to those obtained with the NPK fertilizer treatment, indicating their potential as alternative nutrient sources for sustainable crop production.

The nutrient analysis demonstrated that the banana peel bio-fertilizer contained relatively higher concentrations of nitrogen

and phosphorus than the eggshell bio-fertilizer, which may have contributed to its generally higher numerical performance in some growth and yield parameters. However, the relatively fertile planting soil and the gradual release of nutrients from the organic bio-fertilizers likely reduced the magnitude of treatment differences observed during the experiment.

Overall, the findings suggest that liquid bio-fertilizers prepared from banana peels and eggshells have potential for recycling biodegradable household wastes into environmentally friendly fertilizers capable of supporting onion and fluted pumpkin production. Their use could contribute to reducing dependence on inorganic fertilizers while promoting sustainable agricultural practices and waste management.

Further studies involving larger sample sizes, different soil types, additional application rates, and improved protection against field losses are recommended to better establish the agronomic efficiency and long-term benefits of these bio-fertilizers.

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