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Effects of Biofertilizers on Growth and Yield of Cucumber (*Cucumis sativus L.*) Production: A Species-Level Comparison

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Abstract: Cucumbers (Cucumis sativus L.) are a widely cultivated vegetable crop, known for their nutritional value and economic importance (Peyvest, 2009), especially in sub-Saharan Africa and parts of Asia. In countries like Nigeria, cucumber cultivation has seen rapid growth due to its short growth cycle and high market demand. Enhancing cucumber yield and quality through sustainable practices is vital for both farmers and consumers. Biofertilizers, through mechanisms such as nitrogen fixation, phosphate solubilization, and production of growth-promoting substances, can play a significant role in improving cucumber cultivation (Khan, 2020). Cucumber production faces challenges such as soil nutrient depletion, poor soil management, water stress, and susceptibility to a variety of pests and diseases (Pawar et al., 2020). Given these constraints, there is a growing need to identify sustainable approach that improves the yield and quality of cucumber. Biofertilizers enhance nutrient uptake, improves soil microbial diversity, and promotes plant resilience. This has shown considerable promise in improving both yield and quality in various crops, including cucumbers (Liao et al., 2015). Biofertilizers have attracted widespread interest due to their potential to promote plant growth, improve soil health, and reduce the incidence of soil-borne diseases. These microorganisms include bacteria, fungi, and algae, with each group contributing uniquely to the soil-plant system. The role of biofertilizers in promoting plant growth is diverse as they improve the structure of the soil, fix nitrogen, solubilize phosphorus, decompose organic matter, and enhance the availability of essential nutrients (Verma *et al.*, 2001). Biofertilizers can act as biocontrol agents by suppressing plant pathogens and reducing the need for chemical pesticides (Bashan *et al*., 2014). Biofertilizers represents an essential component of integrated soil fertility management, especially in crops like cucumber (*Cucumis sativus L.*), which is widely grown for its nutritional value and commercial importance in many parts of the world. Among the diverse microorganisms used in biofertilizers, fungi and bacteria are the most common. Fungal species such as *Trichoderma harzianum* and *Penicillium menorum* have been shown to act as effective biocontrol agents by inhibiting pathogenic fungi and promoting plant growth through mechanisms such as the production of plant growth hormones (Sharma *et al*., 2017). *Trichoderma harzianum*, in particular, is known for its ability to degrade organic matter, improve soil structure, and enhance nutrient cycling in soils, which leads to better growth conditions for plants. Additionally, *Penicillium menorum* has been reported to produce various enzymes that aid in the breakdown of soil organic matter and support plant growth by enhancing nutrient availability (Singh *et al*., 2013). Bacterial biofertilizers, such as *Bacillus subtilis*, *Rhizobacteria*, and *Pseudomonas* spp., have also been extensively studied for their roles in promoting plant growth and improving soil health. These microorganisms function through several mechanisms, including nitrogen fixation, phosphorus solubilization, and the production of plant growth-promoting substances like auxins and cytokinins (Mishra and Kaur, 2015). *Bacillus subtilis*, has been shown to improve the yield and disease resistance of cucumbers by enhancing root growth and reducing the severity of fungal infections (Wang *et al*., 2020). Similarly, *Rhizobacteria* are well known for their ability to colonize the rhizosphere, where they facilitate nutrient uptake and enhance plant growth through both direct and indirect mechanisms (Choudhury *et al*., 2017). The response of cucumber varieties to biofertilizer treatments is a crucial aspect of understanding the potential benefits of bio-inoculation. Different cucumber varieties may exhibit varying responses to biofertilizers due to genetic differences in growth characteristics, disease resistance, and nutrient uptake efficiency (Ali *et al*., 2019). Varieties such as Greengo and Lily F1 are commercially grown in different regions, and they may respond differently to inoculation with fungal or bacterial biofertilizers. Understanding how these varieties interact with specific microbial inoculants is vital for optimizing biofertilizer use in cucumber cultivation. Soil health is another critical factor that influences plant growth and productivity. The rhizosphere soil, where plant roots interact with soil microorganisms is a dynamic environment that plays a central role in nutrient cycling, disease suppression and plant growth promotion (Schreiter *et al*., 2014). A healthy and diverse microbial community in the soil can significantly enhance the effectiveness of biofertilizers by improving nutrient availability and reducing soil-borne pathogens. Microbial enumeration and analysis of the soil before and after inoculation with biofertilizers can provide valuable insights into the dynamics of microbial communities and their impact on plant health. In improving cucumber yield, biofertilizers can also enhance the nutritional quality of cucumbers. Proximate analysis (nutrient composition) which

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includes the determination of key nutrients such as moisture, protein, fat, carbohydrates, and minerals, is essential for assessing the nutritional content of cucumbers. The use of biofertilizers may result in improvements not only in yield but also in the overall nutritional profile of the cucumber, thus contributing to better food security and health (Akinmoladun *et al*., 2015). The present study therefore seeks to examine the effects of biofertilizer inoculation on cucumber yield and quality, comparing two species to provide insights into their distinct responses under five biofertilizer treatments, which includes two fungal biofertilizers (*Trichoderma harzianum* and *Penicillium menorum*) and two bacterial biofertilizers (*Bacillus subtilis* and *Rhizobacteria*), alongside a control. Additionally, this study will investigate the physicochemical properties of soil before and after biofertilizer application.

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I. INTRODUCTION

Agriculture faces major challenges such as soil degradation, nutrient depletion, and overreliance on chemical fertilizers, all of which threaten productivity and environmental sustainability. In response, biofertilizers—natural products containing beneficial microorganisms—have emerged as eco-friendly alternatives that improve soil fertility, promote plant growth, and reduce the need for synthetic inputs. These microorganisms, particularly fungi and bacteria, enhance nutrient cycling, suppress pathogens, and support sustainable crop production.

Cucumber (*Cucumis sativus* L.), a crop of growing economic importance in Nigeria and other regions, is sensitive to soil health and nutrient availability. Biofertilizers like *Trichoderma harzianum*, *Penicillium menonorum*, *Bacillus subtilis*, and Rhizobacteria have shown promise in enhancing cucumber growth, yield, and quality. However, varietal responses to these biofertilizers may differ due to genetic and environmental factors.

This study evaluates the effects of selected fungal and bacterial biofertilizers on the growth, yield, nutritional quality, and soil properties associated with two cucumber varieties—Greengo F1 and Lily F1. It aims to identify sustainable, environmentally sound strategies for improving cucumber production.

II. MATERIALS AND METHODS

A field experiment were conducted at the Teaching and Research Farm of the Federal university of Technology Akure Research Farm, Akure South Local Government, Akure, Nigeria. The experimental site is geographically located within latitude 7º30N, 5º1'E, altitude 364.49m above sea level.

The experimental site measured with 10m x 20m were cleared and all debris were removed. The area were demarcated into two blocks each measuring 10m x 3m. Each block were then divided into 15 plots with each rectangular plot measuring 2m x 2m (4m2) with 0.5m pathway between the plot and 1m space between blocks, making fifteen (15) experimental plots in an experimental block which is a factorial experiment in a Randomized Complete Block Design, replicated three times.

- *Cucumber Varieties:*

- Greengo F1
- Lily F1

- *Soil Amendments:*

- Fungal fertilizer (*Trichoderma harzanium*, *Penicillin menonorum*)
- Bacterial fertilizer (*Bacillus subtilis*, *Rhizobateria*)

- *Control*

Data collection started two weeks after planting and occurred at one-week interval for 6 weeks. Data collected on growth and yield parameters were taken on plant height, number of leaves, number of flowers, and number of fruits. Three plants were selected randomly from each plot and tagged for data collection on growth and yield components.

- *Determination of Physico-Chemical Properties of Soil*

Soil texture, pH, organic matter and soil nutrient status of the air-dried sample were determined using the standard methods (AOAC, 1990). The soil samples were analyzed for total N using Kjedahl digestion and distillation method. Available phosphorus were by the Bray 1 method, exchangeable K, Ca and Mg were determined through extraction with 1M ammonium acetate at pH 7.0 K, Ca, and Mg contents were determined with flame photometer. Soil pH (1:2 soil-water) were determined by pH meter, while organic matter (OM) determination were by dichromate oxidation method.

- *Data Analysis*

The data collected from soil analysis and yield parameters were subjected to statistical analysis using Analysis of Variance (ANOVA). All statistical analyses were performed using Minitab 17 software. Treatment means were separated using Tukey's Honest Significant Difference (HSD) test at the 5% level of significance.

III. RESULTS AND DISCUSSION

Results summarizing the effects of biofertilizers on the height of cucumber is presented in Tables 1 (a and b). Significant differences ($p \leq 0.05$) in height were observed among the different biofertilizers treatments used. Lily F1 variety produced highest plant height at the 2nd week to the 3rd week after treatment application (WAT). At 4WAT to

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5WAT, Greengo F1 variety produced higher plant height, while at the 6th week after treatment application; Lily F1 variety recorded the highest plant height. At 2WAT to 3WAT, significant difference were not observed among treatments. Plot treated with bacillus produced a higher plant height, when compared to other biofertilizer treatments at 4WAT and 5WAT. Plots treated with rhizobium at 6WAT led to the highest plant height among other treatments. This aligns with research that indicates that biofertilizers improves plant growth by enhancing nutrient uptake and increasing disease resistance (Oyetunji et al., 2019). The control treatment (no amendment) recorded the lowest plant height across all weeks after treatment application. This suggests the importance of biofertilizers in promoting cucumber growth.

Table 1a Effects of Cucumber Variety and Biofertilizers on Plant Height (cm)

	Weeks after Treatment Application				
Variety	**2**	**3**	**4**	**5**	**6**
Greengo	14.93a	18.40b	47.26a	59.83a	79.93b
Lily	16.67a	23.00a	38.60b	54.67a	93.07a
Treatment					
Bacillus	17.50a	21.33a	51.33a	65.83a	88.5a
Penicillin	13.33a	20.83a	43.66ab	55.50a	84.83a
Rhizobium	16.83a	22.83a	45.83ab	59.00ab	90.83a
Trichoderma	15.17a	21.50a	40.16ab	60.33a	87.50a
Control	16.17a	17.00a	33.66b	45.58b	80.83a

Means in a Column Followed by the Same Letter(s) are Not Significantly (P<0.05) Different According to Tukey Test.

The interaction between cucumber variety and biofertilizer treatments is presented in table 2, where significant (p≤0.05) increase in plant height were observed at different weeks after treatment. The highest plant height were observed in Lily variety treated with trichoderma, while the lowest plant height were observed in Greengo variety with control treatment. At 3WAT, Lily variety treated with penicillin and rhizobium produced the same value for plant height, while no significant differences were observed among varieties and treatments at 4WAT. Greengo treated with bacillus produced the highest plant height at the fifth week after treatment application, while at 6WAT; Lily variety treated with bacillus produced the highest plant height. Greengo with control produced the lowest plant height at 2WAT, 3WAT similar to Greengo treated with penicillin, at 4WAT and 5WAT. At 6th week after treatment application, Lily variety with control treatment produced the lowest plant height when compared to other biofertilizer treatments. These finding are consistent with several studies that have demonstrated the positive effects of biofertilizers and suggests that certain biofertilizers may be more beneficial to specific cucumber varieties, which highlights the importance of site-specific biofertilizer application strategies for maximizing growth (Rao et al., 2020).

Table 2a Interactive Effects of Cucumber Variety and Biofertilizers on Plant Height (cm)

		Weeks after Treatment Application				
Variety	**Treatment**	**2**	**3**	**4**	**5**	**6**
Greengo	Bacillus	9.33ab	13.67abc	25.33a	37.67a	34.00ab
	Penicillin	8.00abc	6.33d	21.67a	34.00ab	38.33ab
	Rhizobium	5.67bc	9.33cd	25.67a	25.33b	35.33ab
	Trichoderma	5.66bc	10.33bcd	20.00a	30.00ab	39.67ab
	Control	5.00c	6.33d	17.00a	23.00b	33.67ab
Lily	Bacillus	6.67abc	13.00abcd	22.00a	29.67ab	46.00a
	Penicillin	9.33ab	17.67a	23.33a	31.33ab	33.00ab
	Rhizobium	9.00abc	17.67a	20.67a	24.00ab	31.00ab
	Trichoderma	10.00a	17.33a	28.33a	31.33ab	32.33ab
	Control	6.67abc	12.00abcd	19.67a	31.00ab	26.33b

Means in a Column Followed by the Same Letter(s) are Not Significantly (P<0.05) Different According to Tukey Test.

The results of treatment effects on stem girth is presented in table 3. The varieties of cucumber and treatments significantly (p≤0.05) increase the stem girth from the 4th and 6th week after treatment. Stem girth of varieties had no significant difference at 2WAT, 3WAT, and 5WAT. At 4WAT to 5WAT, Greengo F1 and Lily F1 variety had no significance, however, significant (p≤0.05) difference were observed among treatments at the fourth week after application, where control produced the lowest stem girth and penicillin produced a higher stem girth. In 2011, Maheswari suggests that biofertilizers can play a crucial role in promoting soil fertility and microbial diversity, leading to enhanced plant growth. Control treatment (no amendments) produced the lowest stem girth across all weeks after treatment application. This finding corroborates the results of various studies that report a positive relationship between biofertilizer use and enhanced plant growth compared to zero fertilizer application (Malla et al., 2008).

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Table 3a Effects of Cucumber Variety and Biofertilizers on Stem Girth

	Weeks after Treatment Application				
Variety	**2**	**3**	**4**	**5**	**6**
Greengo	2.64a	3.02a	3.42a	4.31a	4.22a
Lily	2.75a	3.07a	3.43a	4.09a	4.63a
Treatment					
Bacillus	2.62a	3.18a	3.38a	4.58a	4.32a
Penicillin	2.58a	3.12a	3.92a	3.87a	4.50a
Rhizobium	3.08a	3.03a	3.35a	4.18a	4.55a
Trichoderma	2.75a	3.03a	3.50a	4.50a	4.92a
Control	2.43a	2.88a	2.97b	3.86a	3.85b

Means in a Column Followed by the Same Letter(s) are Not Significantly (P<0.05) Different According to Tukey Test.

Interactions between cucumber variety and biofertilizer treatments is presented in table 4, where significant (p≤0.05) increase in stem girth were observed at the 2nd and 6th week after treatment application. Stem girth were observed to be higher in Lily treated with trichoderma, while the lowest observation were in Greengo with control treatment. At 3WAT to 5WAT, Lily variety treated with bacillus produced the highest stem girth. The lowest stem girth were observed in Lily with the control treatments. At 4WAT, no significant difference were observed among treatments. At 6WAT, Lily treated with trichoderma recorded the highest value for stem girth while control treatments for both Greengo and Lily were observed to give the lowest stem girth across all weeks after treatment application. This suggests that trichoderma, a well-known fungal biofertilizer, might have contributed to root health, thereby improving nutrient and water absorption (Vinale et al., 2008). The observed effects of biofertilizers in enhancing stem girth can be attributed to several mechanisms, including improved nutrient availability, enhanced root growth, and the promotion of plant defense mechanisms.

Table 4a Interactive Effects of Cucumber Variety and Biofertilizers on Stem Girth

		Weeks after Treatment Application				
Variety	**Treatment**	**2**	**3**	**4**	**5**	**6**
Greengo	**Bacillus**	**2.80a**	**2.80a**	**4.13a**	**4.73a**	**4.50b**
	Penicillin	2.47a	3.10a	3.13a	4.60a	4.37b
	Rhizobium	2.77a	2.77a	3.10a	4.15a	4.27b
	Trichoderma	2.73a	3.77a	3.80a	4.10a	4.23b
	Control	2.40a	2.70a	2.93a	3.97a	3.73b
Lily	Bacillus	6.67abc	3.43a	3.70a	4.43a	4.40b
	Penicillin	9.33ab	3.37a	3.90a	4.40a	4.63b
	Rhizobium	9.00abc	3.00a	3.63a	3.63a	4.60b
	Trichoderma	10.00a	2.97a	3.00a	4.40a	6.10a
	Control	6.67abc	2.60a	2.90a	3.57a	3.43b

Means in a Column Followed by the Same Letter(s) are Not Significantly (P<0.05) Different According to Tukey Test.

Table 5 shows the effects of cucumber variety and biofertilizers on number of leaves. The varieties of cucumber and treatments significantly (p≤0.05) increase the number of leaves from week after treatment application at FUTA. No significant difference were observed at 2nd to 4th week after treatment application. At fifth and sixth weeks after treatment application, plot treated with bacillus produced the highest number of leaves, while the control treatment produced the lowest number of leaves. This finding supports the idea that the effectiveness of biofertilizers on number of leaves is often dependent on both the specific biofertilizer and the plant variety being used (Devi et al., 2017).

Table 5a Effects of Cucumber Variety and Biofertilizers on Number of Leaves

	Weeks after Treatment Application				
Variety	**2**	**3**	**4**	**5**	**6**
Greengo	6.73b	9.67b	21.93a	31.20a	36.20a
Lily	8.33a	15.27a	22.80a	28.27a	33.73a
Treatment					
Bacillus	7.83a	13.35a	23.67a	33.67a	39.83a
Penicillin	7.83a	13.34a	21.67a	32.67a	35.33a
Rhizobium	7.34a	13.16a	22.77a	30.50a	33.00a
Trichoderma	8.00a	11.33a	22.76a	28.33a	34.17a

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Control	7.16a	11.16a	21.17a	23.50b	32.50a

Means in a Column Followed by the Same Letter(s) are Not Significantly (P<0.05) Different According to Tukey Test.

The interactions between cucumber variety and biofertilizer treatments as it relates to number of leaves is presented in tables 6, where significant (p≤0.05) increase in stem girth were observed between the variety to treatment application at the 2nd and 6th week after treatment application. Lily variety treated with bacillus significantly (p≤0.05) increase number of leaves among other treatments, while Lily with control treatment (no fertilizer) led to a reduction in the number of leaves among treatments. Trichoderma, a well-known plant-growth-promoting fungus, is utilized to improve root health and nutrient uptake, which could explain the growth response in the Lily variety (Harman, 2006). Greengo variety may have exhibited lower responsiveness to Trichoderma or Bacillus, possibly due to its inherent genetic characteristics or less favorable interactions with these biofertilizers.

Table 6a Interactive Effects of Cucumber Variety and Biofertilizers on Number of Leaves

		Weeks after Treatment Application				
Variety	**Treatment**	**2**	**3**	**4**	**5**	**6**
Greengo	Bacillus	9.33ab	13.67abc	25.33a	37.67a	34.00ab
	Penicillin	8.00abc	6.33d	21.67a	34.00ab	38.33ab
	Rhizobium	5.67bc	9.33cd	25.67a	25.33b	35.33ab
	Trichoderma	5.66bc	10.33bcd	20.00a	30.00ab	39.67ab
	Control	5.00c	6.33d	17.00a	23.00b	33.67ab
Lily	Bacillus	6.67abc	13.00abcd	22.00a	29.67ab	46.00a
	Penicillin	9.33ab	17.67a	23.33a	31.33ab	33.00ab
	Rhizobium	9.00abc	17.67a	20.67a	24.00ab	31.00ab
	Trichoderma	10.00a	17.33a	28.33a	31.33ab	32.33ab
	Control	6.67abc	12.00abcd	19.67a	31.00ab	26.33b

Means in a Column Followed by the Same Letter(s) are Not Significantly (P<0.05) Different According to Tukey Test.

Effects of cucumber variety and biofertilizers on number of flowers is presented in table 7 (a and b). Beginning from the fourth week after treatment application to the fifth week after transplanting, no significant difference were observed at FUTA for both varieties and treatments applied. This finding aligns with previous studies that reported variable responses in flowering times and frequencies among cucumber varieties (Aslam et al., 2019). At 6WAT, Lily F1 variety significantly (p≤0.05) increase the number of flowers. This could be attributed to the superior genetic characteristics of the Lily F1 variety, which is known for its higher yield potential and better adaptability to environmental stressors (Ali et al., 2018). . For treatments, bacillus recorded the highest number of flowers when compared to other biofertilizer treatments. In line with the findings of other studies, bacillus biofertilizer treatment also significantly increased the number of flowers compared to the other treatments, including rhizobium, penicillin, and trichoderma (Sah et al., 2021). Bacillus treatment are known for their plant growth-promoting effects, including enhanced flowering through improved nutrient availability and plant health (Sharma et al., 2020).

Table 7 Effects of Cucumber Variety and Biofertilizers on Number of Flowers

	Weeks after Treatment Application		
Variety	**4**	**5**	**6**
Greengo	2.87a	4.43a	4.23b
Lily	2.27a	4.33a	7.33a
Treatment			
Bacillus	3.67a	5.83a	7.67a
Penicillin	2.50a	3.67a	4.74ab
Rhizobium	3.17a	4.00a	7.33a
Trichoderma	1.83a	4.67a	5.17ab
Control	1.67a	3.50a	4.00b

Means in a Column Followed by the Same Letter(s) are Not Significantly (P<0.05) Different According to Tukey Test.

➢ *Interactive Effects of Cucumber Variety and Biofertilizers on Number of Flowers*

Interactions between cucumber variety and biofertilizer treatments in relation to number of flowers is presented in table 8, where there were no significant (p≤0.05) increase in number of flowers observed at four and five weeks after treatment application between the two varieties to treatment application. Lily treated with bacillus recorded the highest number of flowers at 6WAT, while the lowest number of flowers were recorded in Greengo variety treated with penicillin and no amendment (control) plots. This aligns with the findings of Mahmood et al. (2020), who found that not all

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biofertilizers are equally effective across different plant varieties, as their effectiveness often depends on plant-bacteria compatibility. This finding indicates a synergistic effect between the genotype (Lily F1) and the biofertilizer treatment, which may have enhanced the plant's ability to flower. The lack of significant differences in flowering between the treatments at fourth and fifth week after treatment application could be attributed to the time required for biofertilizers to show their full effect. Many biofertilizers, including Bacillus, take some time to establish and exert their effects on plant growth (Ranjan et al., 2020). As such, the lack of early differences may reflect the time needed for microbial populations to build up and influence flowering.

Table 8 Interactive Effects of Cucumber Variety and Biofertilizers on Number of Flowers

		Weeks after Treatment Application		
Variety	**Treatment**	**4**	**5**	**6**
Greengo	Bacillus	5.00a	5.33a	3.48bc
	Penicillin	4.00a	4.00a	3.00c
	Rhizobium	3.00a	4.33a	6.00bc
	Trichoderma	1.33a	5.33a	5.67bc
	Control	1.00b	3.33a	3.00c
Lily	Bacillus	2.00a	7.00a	12.33a
	Penicillin	2.33a	3.67a	6.00bc
	Rhizobium	2.33a	4.00a	5.00bc
	Trichoderma	3.33a	4.00a	8.67ab
	Control	1.33a	3.00a	4.67bc

Means in a Column Followed by the Same Letter(s) are Not Significantly ($P<0.05$) Different According to Tukey Test.

Figures one (a and b) show the interaction between the two varieties and treatments in number of fruits at the two locations. At FUTA, Greengo F1 variety treated with trichoderma significantly ($p \leq 0.05$) increased the number of fruits when compared to other treatments, while Lily F1 variety treated with no amendments (control) recorded the lowest number of fruits. Trichoderma is known for its ability to suppress plant pathogens, thereby reducing stress and allowing plants to allocate more resources to fruit growth (Hameed et al., 2018). The increase in fruit production in Greengo F1 with Trichoderma treatment may be due to the improved plant vigor and reduced pathogen stress, which allows the plant to allocate more resources to fruit development. The Lily F1 variety, when treated with no amendments (control), recorded the lowest number of fruits. This finding underscores the potential limitations of not using biofertilizers, as untreated plants often experience suboptimal growth and reproductive success (Ali et al., 2018). The reduced fruit set observed in the control plots could be attributed to nutrient deficiencies or insufficient microbial activity in the rhizosphere, which biofertilizers such as trichoderma can help alleviate.

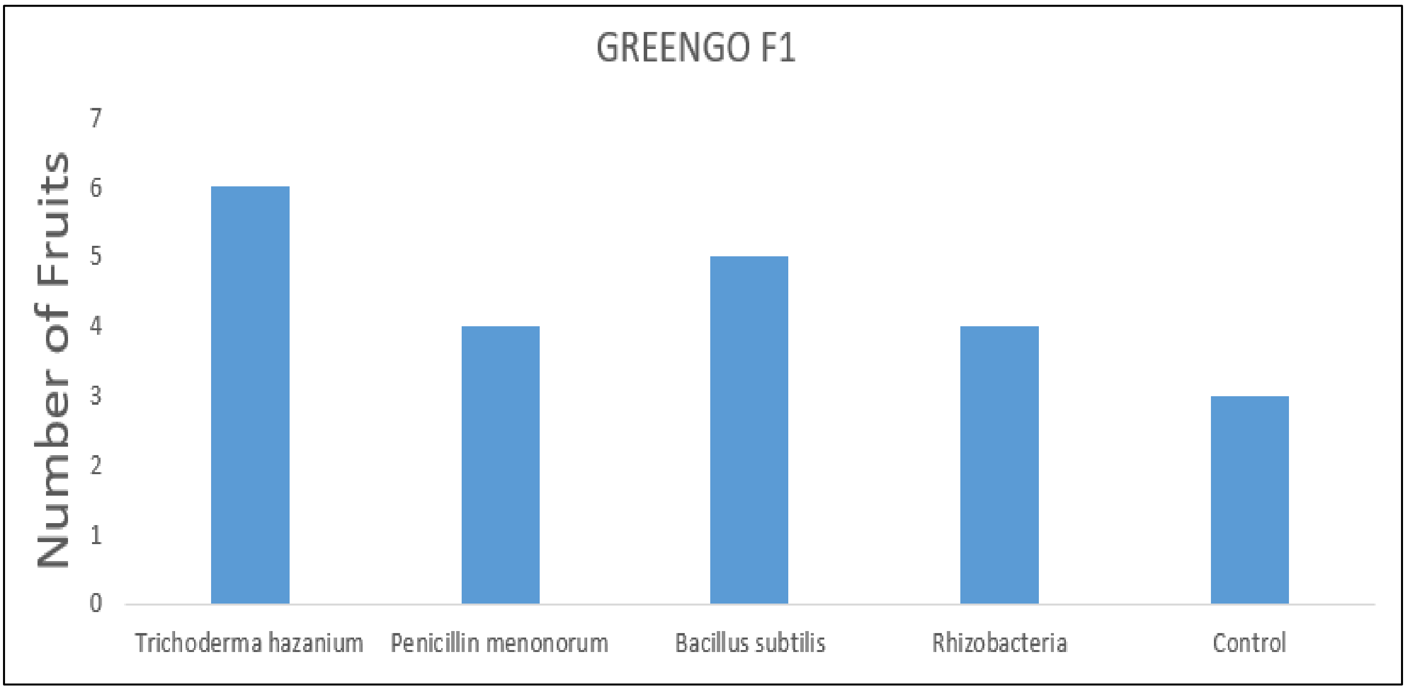

Fig 1a Effects of Cucumber Variety and Biofertilizers on Number of Fruits

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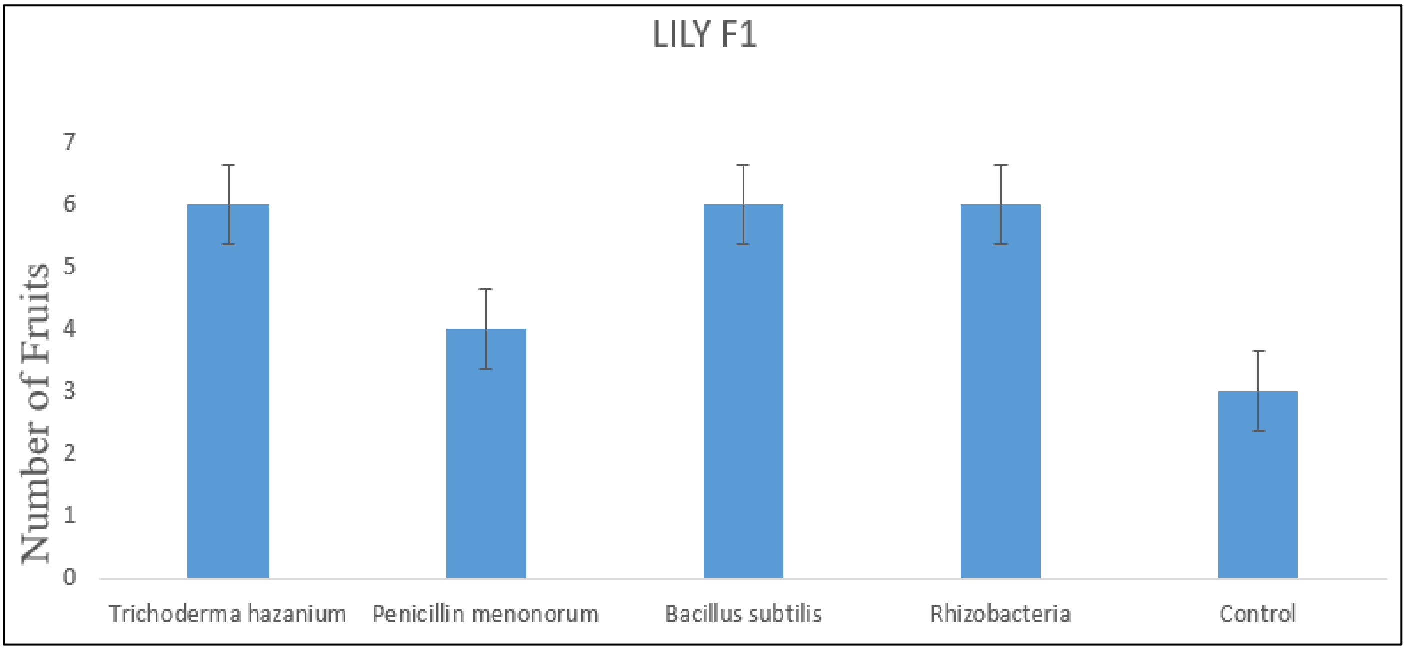

Fig 1b Effect of Cucumber Variety and Biofertilizers on Number of Fruits

Table 9 shows the effects of cucumber variety and biofertilizer treatments on weight, girth, and length of fruits. Here, Lily F1 variety significantly ($p \leq 0.05$) increased the weight, girth, and length of fruits when compared to Greengo F1 variety. For treatments, plots treated with Bacillus fertilizer significantly increased the weight, girth, and length of fruit among all treatments applied. The superior weight in Lily F1 could be attributed to its genetic predisposition for higher fruit mass, as it is known to produce larger fruits compared to many other varieties. Regarding biofertilizer treatments, plots treated with Bacillus demonstrated the highest fruit weight. Bacillus is well known for its role in improving nutrient availability, particularly phosphorus, which is essential for fruit development and enlargement (Sharma et al., 2020). Biofertilizer treatments, particularly Bacillus, again had a positive effect on fruit girth, further emphasizing the role of Bacillus in promoting the development of larger and more robust cucumbers. Sah et al. (2021) reported similar results, where Bacillus-treated cucumbers exhibited increased fruit girth due to enhanced root growth and better nutrient uptake. Lily F1 showing longer fruits compared to Greengo F1 supports the notion that variety plays a significant role in determining the physical characteristics of cucumber fruits, including their length. Genetic factors related to fruit elongation could be more pronounced in varieties like Lily F1, which may have been selected for traits that favor larger fruits (Rashid et al., 2019).

Table 9 Effects of Cucumber Variety and Biofertilizers on Selected Fruit Parameters (Weight, Girth, and Length).

	Weeks after Treatment Application		
Variety	**Fruit Weight**	**Fruit Girth**	**Fruit Length**
Greengo	381.51b	17.90b	22.21a
Lily	477.39a	19.68a	20.49a
Treatment			
Bacillus	500.96a	19.86a	23.63a
Penicillin	387.98a	18.95ab	21.37ab
Rhizobium	443.74a	17.97ab	19.83b
Trichoderma	443.75a	19.55ab	22.30a
Control	370.85a	17.63b	19.62b

Means in a Column Followed by the Same Letter(s) are Not Significantly ($P<0.05$) Different According to Tukey Test.

Table 10 shows the interactive effects of cucumber variety planted with the biofertilizers treatments as it influences the fruit weight, girth, and length. For fruit weight, Lily F1 variety treated with trichoderma significantly ($p \leq 0.05$) increased the weight of fruit, while Greengo with no amendments produced the lowest fruit weight. For fruit girth, Lily treated with trichoderma significantly ($p \leq 0.05$) increase the fruit girth, while Greengo with no amendment (control) produced the lowest fruit girth. Highest fruit length were recorded in Greengo treated with bacillus and the lowest length of fruit were observed in Greengo with zero amendment (control). The positive effect of trichoderma on fruit girth is likely due to its ability to enhance soil nutrient availability, particularly in terms of phosphorus, which is crucial for fruit development and expansion (Kumar et al., 2021). The significant effects observed in fruit weight, girth,

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and length suggest that biofertilizers, particularly Trichoderma and Bacillus, can enhance cucumber production by promoting better growth and improving fruit quality. This is especially relevant for commercial cucumber growers who seek to increase yield and marketable quality.

Table 10 Interactive Effects of Cucumber Variety and Biofertilizers on Selected Fruit Parameters (Weight, Girth, and Length).

		Weeks after Treatment Application		
Variety	**Treatment**	Fruit Weight	Fruit Girth	Fruit Length
Greengo	Bacillus	496.19ab	19.88abc	23.96a
	Penicillin	332.59ab	17.33bc	18.57b
	Rhizobium	461.48ab	19.47abc	20.26ab
	Trichoderma	337.16ab	16.77bc	21.47ab
	Control	280.22b	16.13c	18.20b
Lily F1	Bacillus	505.74a	20.27ab	23.30ab
	Penicillin	461.48ab	19.88abc	21.46ab
	Rhizobium	438.81ab	19.33abc	21.27ab
	Trichoderma	554.90a	21.13a	24.33a
	Control	426.02ab	17.93abc	20.67ab

Means in a Column Followed by the Same Letter(s) are Not Significantly (P<0.05) Different According to Tukey Test.

Tables 11 (a, b, c, and d) show the effects of biofertilizers on proximate composition of cucumber. For Lily F1 variety, penicillin biofertilizer led to the highest moisture content among the treatment applied at FUTA, while lowest moisture content were recorded in rhizobacteria. Rhizobacteria recorded the highest ash (%) and fat content (%). The lowest ash content were observed in trichoderma, while penicillin recorded the lowest fat content. Highest fibre content were observed in the control treatment, while the lowest value for fibre were obtained in trichoderma biofertilizer. The application of trichoderma-based biofertilizer recorded the highest protein, while bacillus biofertilizer recorded the lowest value for protein content. Bacillus subtilis increased the carbohydrate content of cucumber fruits; however, the lowest content were recorded in trichoderma harzianum. For Greengo variety, bacillus subtilis recorded the highest moisture content when compared to other treatments, while penicillin menonorum produced the lowest value. Ash content were higher in cucumber nurtured with rhizobacteria, while the lowest value were observed in the control treatment. Fat content were high in rhizobacteria when compared to other treatments. The lowest fat content were observed in penicillin treatment. Rhizobacteria were high in fibre, while it fibre content were of lower value in penicillin and control treatment. Protein were observed to be high in penicillin when compared to other fertilizer treatment and very low in trichoderma. For carbohydrate, trichoderma were observed to be very high in CHO and lowest value were observed in fruit grown with rhizobacteria. The higher moisture content in the penicillin-treated plants can be attributed to the role of penicillin in promoting water retention in plant tissues (Zaidi et al., 2009). Trichoderma's effect of reducing ash content may indicate its potential for influencing mineral absorption through mechanisms like nutrient mobilization (Sharma et al., 2013). Rhizobacteria's high fat content could be linked to its role in enhancing the synthesis of lipid-based molecules (Berger et al., 2013). These findings align with studies by Babalola et al. (2014), who found that rhizobacterial strains positively influenced plant lipid synthesis, while biofertilizers such as Bacillus spp. and Trichoderma spp. have been shown to have varying effects on lipid content, depending on their interactions with plant growth (Saharan and Nehra, 2011). This finding is also consistent with those of Inderjit et al. (2011), who reported that trichoderma species can enhance plant protein levels by improving nitrogen assimilation processes in plants.

Table 11a Effects of Cucumber Variety Biofertilizers on Nutrient Composition of Cucumber (LILY F1)

Treatments	**MC (%)**	**ASH (%)**	**FAT (%)**	**C FIBRE (%)**	**PROTEIN (%)**	**CHO (%)**
Penicillin menonorum	94.560	0.274	1.062	0.660	2.146	1.298
Trichoderma harzianum	94.437	0.173	1.262	0.588	2.760	0.780
Bacillus subtilis	94.100	0.268	1.216	0.796	1.980	1.779
Control	93.586	0.356	1.321	0.970	1.988	1.680
Rhizobacteria	93.469	0.382	1.456	0.887	2.246	1.560

Table 11b Effects of Cucumber Variety and Biofertilizers on Nutrient Composition of Cucumber (GREENGO F1)

Treatments	**MC (%)**	**ASH (%)**	**FAT (%)**	**C FIBRE (%)**	**PROTEIN (%)**	**CHO (%)**
Penicillin menonorum	93.460	0.360	1.036	0.636	2.692	1.876
Trichoderma harzianum	93.840	0.274	1.096	0.880	1.986	1.924
Bacillus subtilis	93.918	0.288	1.116	0.700	2.200	1.873
Control	93.800	0.260	1.118	0.647	2.168	1.800
Rhizobacteria	93.482	0.394	1.240	1.378	2.382	1.246

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Tables 12 summarizes the basic soil nutrient status at the two locations. Bulk density and Clay were higher at FUTA than at Odudu Community. Silt were high in Odudu Community than FUTA, while sand were higher at FUTA when compared to Odudu Community. The textural class for both locations is sandy-loam. pH of soil in FUTA were higher than the soil in Odudu Community. Organic carbon and organic matter were higher at FUTA than Odudu Community were. For N, P, K, Na, Ca, and Mg, result from the analysis shows higher value at Odudu Community than at FUTA. The pH levels were higher, indicating more neutral or slightly alkaline soils, which may be more conducive to the growth of certain microorganisms, such as Bacillus and Rhizobium, which prefer neutral to slightly alkaline pH (Owino et al., 2020). Organic carbon and organic matter were also higher at FUTA, which is consistent with its higher clay content and bulk density. Organic matter is crucial for improving soil structure and fertility by providing nutrients for plants and microorganisms alike (Hernandez et al., 2021).

Table 12 Physio-Chemical Properties of the Experimental Soil

Physical properties	**Before Treatment Application**	**After Treatment Application++++**
Buck density (g/cm^3)	0.29	0.27
Cay (%)	14.00	13.00
Silt (%)	13.20	14.60
Sand (%)	72.80	72.40
Textural class	Sandy-Loam	Sandy-Loam
Chemical properties		
pH	5.7	5.52
Organic carbon (%)	1.72	1.63
Organic matter (%)	2.98	2.81
N (%)	0.15	0.22
P (ppm)	0.15	7.39
K (Meq L^{-1})	0.19	0.41
Na	0.04	0.52
Ca	1.07	5.20
Mg	0.17	0.60

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