GROWTH PERFORMANCE OF SELECTED VEGETABLES UNDER FOLIAR APPLICATION OF AN INTEGRATED BIOFERTILISER-BIOPESTICIDE AND AN INORGANIC FERTILISER

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ABSTRACT

Vegetable production is hampered by declining soil fertility, increasing pest attacks, and over-reliance on costly inorganic fertilisers. While integrated biofertiliser–biopesticide products present a potential sustainable alternative, empirical evidence pertaining to their effectiveness is limited. The study tested three treatments (T0=unfertilised control, T1=Integrated biofertiliser-biopesticide, and T2=Inorganic fertiliser) on the growth and yield of eggplant, green pepper, and cabbage. The experiment was laid out as a Randomized Complete Block Design (RCBD) with three replicate blocks. Foliar application of fertilisers was done twice a week for 10 weeks, and plant height, leaf length, number of leaves, number of branches, fruit diameter, and diameter of cabbage head were monitored. Analysis of variance was carried out on data collected at Weeks 1, 2, 4, 6, 8, and 10 using the model Value ~ Rep + Treatment, with 2 degrees of freedom each for Replication and Treatment, and 4 for Error. Trends across weeks were summarised graphically and quantified by quadratic regression. The integrated biofertiliser–biopesticide (T1) consistently produced the highest vegetative growth and reproductive performance across all three crops, outperforming inorganic fertiliser (T2) and unfertilised control (T0). The strongest effects were at week 10 for eggplant fruit diameter ($F = 36.25$, $p = 0.003$), green pepper fruit number ($F = 18.20$, $p = 0.010$), and green pepper plant height ($F = 138.10$, $p = 0.0002$).Quadratic regression identified three growth patterns: accelerating curves for delayed reproductive traits (fruit production), saturating curves for vegetative traits nearing maturity (plant height, leaf length, and branch number), and dome-shaped curves for cabbage leaf number, which peaked at weeks 6–7 before declining due to leaf senescence during head formation. This model outperformed the linear model, increasing the mean R^2 from 0.817 to 0.928 across 45 fits. Emergence of pests was noted in cabbages under T0 in weeks 8-10. Thus, the integrated biofertiliser-biopesticide can be a potential substitute for scarce, costly, and harmful inorganic fertilisers to boost vegetable productivity.

Keywords: ***Bioslurry, Eco-Friendly, Growth Parameters, Inorganic Fertiliser, Yield Improvement.***

INTRODUCTION

The population of sub-Saharan Africa (SSA) is projected to double by the year 2050 (VanIttersum *et al*., 2016). This raises the need for increased food production to meet the feeding needs of this growing population (Onyutha, 2018), which will in turn worsen the diet-related environmental pressures (Dimkpa *et al.,* 2023). Current diets comprise high-calorie, nutrient-poor foods deficient in protein, vitamins, and minerals (Mustafa *et al.,* 2021). This results in hidden hunger that has devastating effects on the health and economic productivity of the population. This calls for sustainable production of vegetables to curb micronutrient deficiencies (Nordey *et al.,* 2017). Vegetables play a fundamental role in food security and poverty eradication (Turay *et al.,* 2022). Production of enough highly nutritious vegetables is dependent upon soil fertility. However, in most SSA countries, soils are depleted (Agnes, 2020; Guedegbe *et al*., 2018) due to poor soil fertility that has continued to cause low crop productivity on smallholder vegetable farms (Nanyanzi *et al.,* 2018). Declining soil fertility, which is due to continuous cultivation of fields, was reported in 28% of farmers in Africa. In SSA, over 90% of food is cultivated on soils on a continuous basis, leading to annual degradation of a cumulative 12 million hectares (Dimkpa *et al.*, 2023). It is therefore impossible to maintain soil quality in the absence of adequate soil amendment practices, crop rotations, and fallow (Barbier and Hochard, 2014; Jayne and Ameyaw, 2016). The solution to decreasing agricultural productivity is the use of an integrated land management strategy that involves soil rehabilitation through increasing soil organic matter, inorganic and organic fertilisers, and retaining moisture.

In Uganda, vegetable production is profitable but limited by soil fertility depletion (Ssekabembe *et al*., 2003). This is attributed to soil erosion, leaching, and continuous use of the land without replenishing its nutrients (Sanchez and Jama, 2001). Additionally, small-scale vegetable growers are faced with high costs of inorganic fertilisers, which limits their accessibility (Ajayi *et al*., 2009). In a bid to improve soil fertility, some smallholder farmers have resorted to the use of inorganic fertilisers to boost yields (Raimi *et al*., 2017). Despite this shift, the use of inorganic fertilisers is still low compared to the target (Sommer *et al*., 2013). For instance, in Uganda, Kenya, and Tanzania, low crop yield was attributed mainly to poor soil fertility (Keino *et al*., 2015). Soils were limited up to 90% for nitrogen, and 50% for phosphorus, and potassium (Bekunda *et al*., 2002). The low uptake of nutrients by crops is further aggravated by farmers' concerns regarding the negative environmental effects of using inorganic fertilisers (Raimi *et al*., 2017). The challenge of reduced soil fertility is exacerbated by financial constraints that hinder farmers from applying recommended amounts of synthetic fertilisers (Mugo *et al*., 2021).

For smallholder farmers to realise maximum crop yields, adoption of biofertilisers, which are affordable and eco-friendly, is pertinent (Aggani, 2013; Ahsan *et al*., 2012). Biofertilisers contain microorganisms that stimulate plant growth by availing nutrients and growth substances to host plants (Figueiredo *et al*., 2011; Suyal *et al*., 2016; Vessey, 2003). Foliar application of bioslurry to plants supplies them with the recommended nutrients (Warnars and Oppenoorth, 2014), increases soil fertility, and enhances crop productivity (Shao *et al*., 2023). Bioslurry integrated with plant extracts with pesticidal effects has great potential for increasing crop yields and controlling crop pests. Despite this potential, the use of integrated biofertiliser-biopesticides has not been fully embraced by farmers. The current study was conducted to compare the effect of an integrated biofertiliser-biopesticide and an inorganic fertiliser on growth parameters of eggplant, green pepper, and cabbage so as to contribute to sustainable vegetable production in Uganda.

MATERIALS AND METHODS

Study area

Field trials were conducted in Masha sub-county, Isingiro district, southwestern Uganda. The district lies between 00°49′ 59.99'S and 30°49′ 59.99'E, at an average altitude of 1800 mm above sea level (Twongyirwe *et al*., 2019). The district receives an annual rainfall of 1200 mm, with an average temperature ranging from 17 to 30 °C (Nabasumba *et al*., 2020).

Preparation of the integrated bio-fertiliser-biopesticide

Bioslurry was obtained as a by-product from bio-digestion of food wastes: leftover 'posho' (a thick mixture of maize flour and boiling water), banana (*Musa acuminata* Colla) and cassava (*Manihot esculenta* Crantz.) peels mixed with cow dung. Liquid bioslurry was enriched with plant extracts known to have pesticidal effects to form the integrated biofertiliser-biopesticide. To retain the fertilizing quality, the product was stored in liquid form in closed plastic containers.

Growth experiment

An on-farm trial was conducted following a Randomized Complete Block Design (RCBD) with three treatments assigned to plots containing three replicate blocks of 2.5m × 2m each per crop. Treatments were T0 (unfertilised control), T1 (integrated bio-fertiliser- biopesticide), and T2 (inorganic fertiliser), and the three vegetables were: eggplant- *Solanum melongena* L., green pepper -*Capsicum annuum* L., and cabbage - *Brassica oleraceae* L. Soil and biofertiliser physicochemical properties were analysed at the Makerere University Soil, Water and Plant Analytical Laboratory prior to planting.

Soil analysis

Soil samples from experimental plots were analysed. Cabbages were planted at site A in a Randomised Complete Block Design (RCBD) with three fertiliser treatments replicated three times, while eggplants and green pepper were planted at site B following the same design. Soil samples were collected according to Mbatha (2008). Before analysis, soil samples were air-dried, ground, and sieved. The samples were analysed for pH (Mettler-Toledo, AG 8603; Rhoades, 1982), total nitrogen (Murphy and Riley, 1962), available phosphorus; organic matter, exchangeable cations (Potassium (K+), sodium (Na^+), Calcium (Ca^{2+}), Magnesium (Mg^{2+}) (Mehlich, 1953) and soil texture (Bouyoucos, 1962) following routine procedures outlined by Okalebo *et al.* (2002).

Integrated bio-fertiliser-biopesticide analysis

Chemical analysis of the integrated biofertiliser-biopesticide was conducted. The formulation comprised: 1L biofertiliser mixed with extracts of plants that have pesticidal effects +19L of water. A 2ml sample of the integrated biofertiliser-biopesticide was digested with 5ml of a concentrated mixture of sulphuric acid, hydrogen peroxide, selenium powder, and salicylic acid at 360°C. The digest was cooled and diluted to 50 mL with distilled water. Total nitrogen was analysed using the Kjeldahl method (Anderson and Ingram, 1994), and total phosphorus was measured colorimetrically at 880 nm (Okalebo *et al*., 2002).

Vegetable establishment practices

Uniform, healthy seedlings of cabbage, green pepper, and eggplant aged three weeks were obtained from a certified commercial nursery in Mbarara city. The seedlings were acclimatized under field conditions for five days prior to transplanting into experimental plots. All vegetable seedlings were then planted following a RCBD with three treatments replicated three times. For every vegetable type, nine seedlings were planted, but only three were monitored for growth parameters. A distance of 1m was maintained between adjacent plots to minimize spray drift and nutrient interference among treatments. The distance between each of the seedlings was 45cm. Treatments were applied to leaves twice a week for up to 10 weeks. as: T0: No fertiliser + no pesticide (control), T1: Integrated biofertiliser-biopesticide (1L biofertiliser mixed with extracts of plants with pesticidal effects +19L of water), T2: Inorganic fertiliser (60 mls Clear green fertiliser + 20L of water + 30 mls of 5% Cypermethrin (Dudu cyper 5 EC). Cypermethrin is a pesticide.

Growth parameters for cabbages, eggplants, and green peppers

Growth parameters were monitored every two weeks for 10 weeks following application of the inorganic fertiliser and the integrated biofertiliser-biopesticide and for the control (no fertiliser) (Sseremba *et al*., 2017; Nakanwagi *et al*., 2017). Plant height and leaf length were measured according to Amhakhian *et al*. (2010) and Fallovo *et al*. (2008). Analysis of variance was performed at Weeks 1, 2, 4, 6, 8, and 10 using the model Value ~ Rep + Treatment, with 2 degrees of freedom each for replication and treatment, 4 for error, and 8 total degrees of freedom. Where the per-week Treatment effect was significant ($p < 0.05$), Duncan's Multiple Range Test was applied to compare the three treatment means within that single week. Quadratic regression was used to quantify trends in weekly means of growth parameters across the experimental period separately for each vegetable at $\alpha = 0.05$.

RESULTS

Effect of foliar fertiliser application on growth parameters of green pepper

Leaf length, number of leaves, plant height, number of branches, and number of fruits increased over the experimental period across treatments. Green pepper showed the strongest cumulative response to T1 of the three crops for canopy and reproductive traits at the end of the experimental period. Per-week ANOVAs (Table 1) show a significant treatment effect on number of leaves at Week 2 ($F = 16.15$, $p = 0.0121$, *), plant height at Week 8 ($F = 9.62$, $p = 0.0296$, *) and week 10 ($F = 138.10$, $p = 0.0002$, ***), and on number of fruits at Week 10 ($F = 18.20$, $p = 0.0098$, **).

Table 1: Mean squares from ANOVA for treatment effects on green pepper organised by trait and week

Trait	Week	Source	df	Sum Sq	Mean Sq	F value	Pr(>F)
Number of leaves	2	Treatment	2	644.222	322.11	16.15	0.012*
Plant height (cm)	8	Treatment	2	101.56	50.78	9.62	0.029*
No. of fruits	10	Treatment	2	60.67	30.33	18.2	0.0098**
Plant height (cm)	10	Treatment	2	306.89	153.44	138.1	2.04E-04***

*Source: ANOVA_full_table.csv. The Week-10 plant height cm row (F = 138.10, p = 0.0002, ***) is the most highly significant Treatment effect in the entire study. Significance: *** p < 0.001, ** p < 0.01, * p < 0.05, p < 0.10.*

Green pepper plants under T1 reached a mean height of 68.00 ± 1.00 cm compared to 56.33 ± 1.67 cm and 55.00 ± 1.73 cm for plants under T0 and T2, respectively. T1-treated plants produced an average of 13.67 ± 0.88 fruits per plant by Week 10, a 64% advantage over plants under the control (T0) (8.33 ± 0.33) (Table 2). By contrast, T2 conferred essentially no advantage over T0 regarding plant height or fruit number, indicating that the inorganic fertiliser alone was insufficient to drive late-season reproductive performance under the conditions of this trial.

Table 2: Mean growth parameters ($\bar{X}$ ± SD, N=3) of green pepper after different treatments at week 10

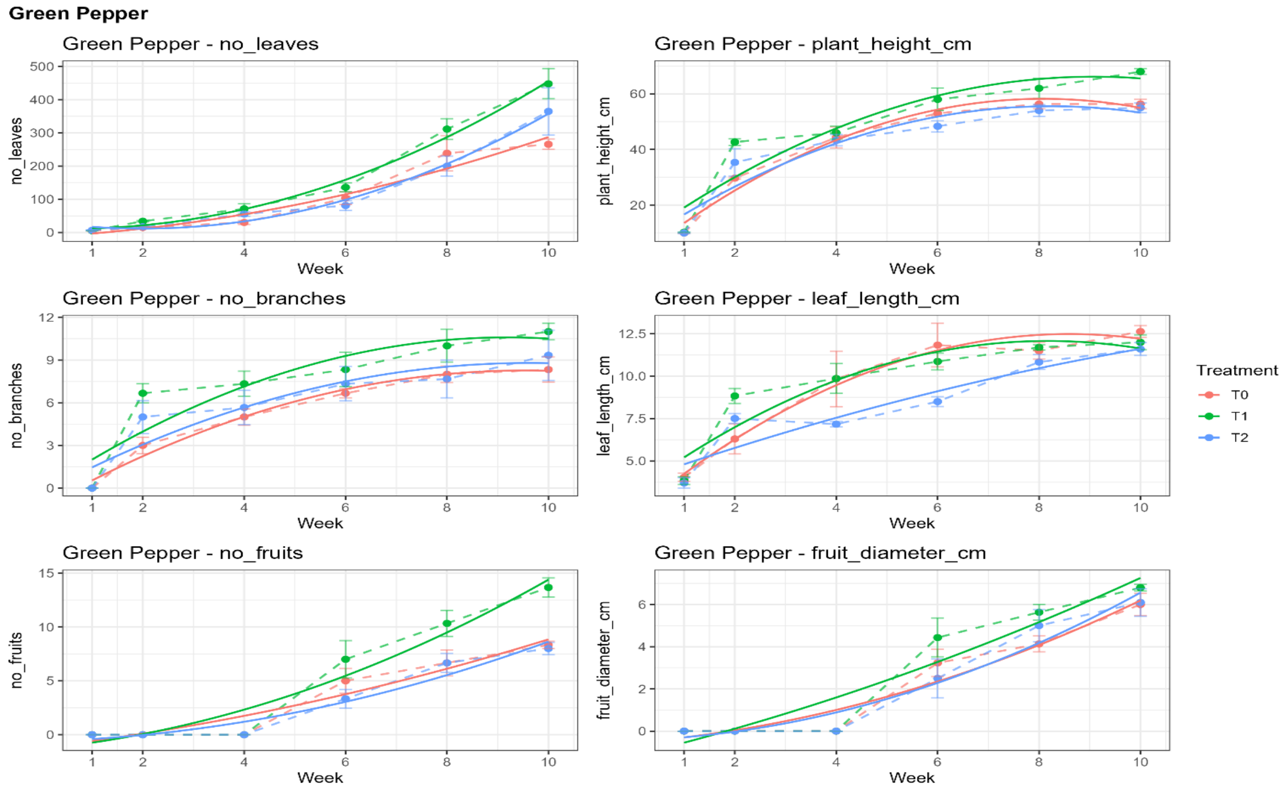
	Treatment		
Growth parameter	**T0**	**T1**	**T2**
Fruit diameter (cm)	6.00 ± 0.53	6.80 ± 0.15	6.10 ± 0.65
Leaf length (cm)	12.63 ± 0.35	12.00 ± 0.44	11.60 ± 0.38
Number of branches	8.33 ± 0.88	11.00 ± 0.58	9.33 ± 1.76
Number of fruits	8.33 ± 0.33	13.67 ± 0.88	8.00 ± 0.58
Number of leaves	265.67 ± 15.50	447.67 ± 45.12	364.67 ± 71.15
Plant height (cm)	56.33 ± 1.67	68.00 ± 1.00	55.00 ± 1.73

Quadratic regression revealed three distinct patterns in growth parameters of green pepper (Figure 1) as: i) vegetative architecture traits (plant height, branch number, leaf length) showed decelerating, saturating curves consistent with plants approaching mature canopy structure; T1 treated plants saturated at higher values while those under T2 and T0 plateaued at the same level, ii) number of leaves under T1 treated plants followed an accelerating curve (R^2 = 0.991), reflecting compounding canopy investment. iii) reproductive traits (number of fruits, fruit diameter (cm) showed accelerating curves with delayed onset. T1-treated plants entered the reproductive phase earliest and accelerated fastest.

Effects of treatments on growth and yield of eggplants

Eggplant exhibited the clearest reproductive divergence between treatments of the three vegetables. Per-week ANOVAs revealed significant treatment effects on fruit diameter at every week from Week 6 onwards (Table 3) and on plant height at weeks 8 and 10 (F = 13.38, p = 0.0169*; F = 7.47, p = 0.0446*).

By week 10, T1-treated plants had produced fruits with a mean diameter of 12.83 ± 1.41 cm compared to T2-treated plants' value of 8.63 ± 1.45 cm (Table 4), while plants under T0 produced no fruits throughout the entire ten-week period. Height under T1-treated plants reached 77.67 ± 2.03 cm by week 10, compared to 57.33 ± 3.18 cm under T0. Number of leaves, leaf length, and number of branches were not significantly different in plants under the three treatments at any week, although T1-treated eggplants produced numerically higher means throughout. Branching began at 4 weeks and increased as plants matured. Fertilised plants (T1 and T2) produced more branches than the control, with the highest number observed in T1-treated plants (7.00 ± 1.00) by week 10 compared to (6.00±1.00) and (5.67 ± 1.52) for plants under T2 and T0, respectively. This indicates that fertiliser application enhanced branching, which supports canopy development and potential fruit production. No fruiting occurred in control plants during the 10-week period. Treatment significantly influenced fruit diameter and plant height, but had no significant effect on the number of leaves, leaf length, or number of branches (Table 3).



Solid curves are the quadratic regressions; dashed lines connect observed means

Fig. 1: Weekly growth and yield trajectories of green pepper under three treatments.

Table 3: Mean squares from ANOVA for treatment effects on eggplant organised by growth parameter and week

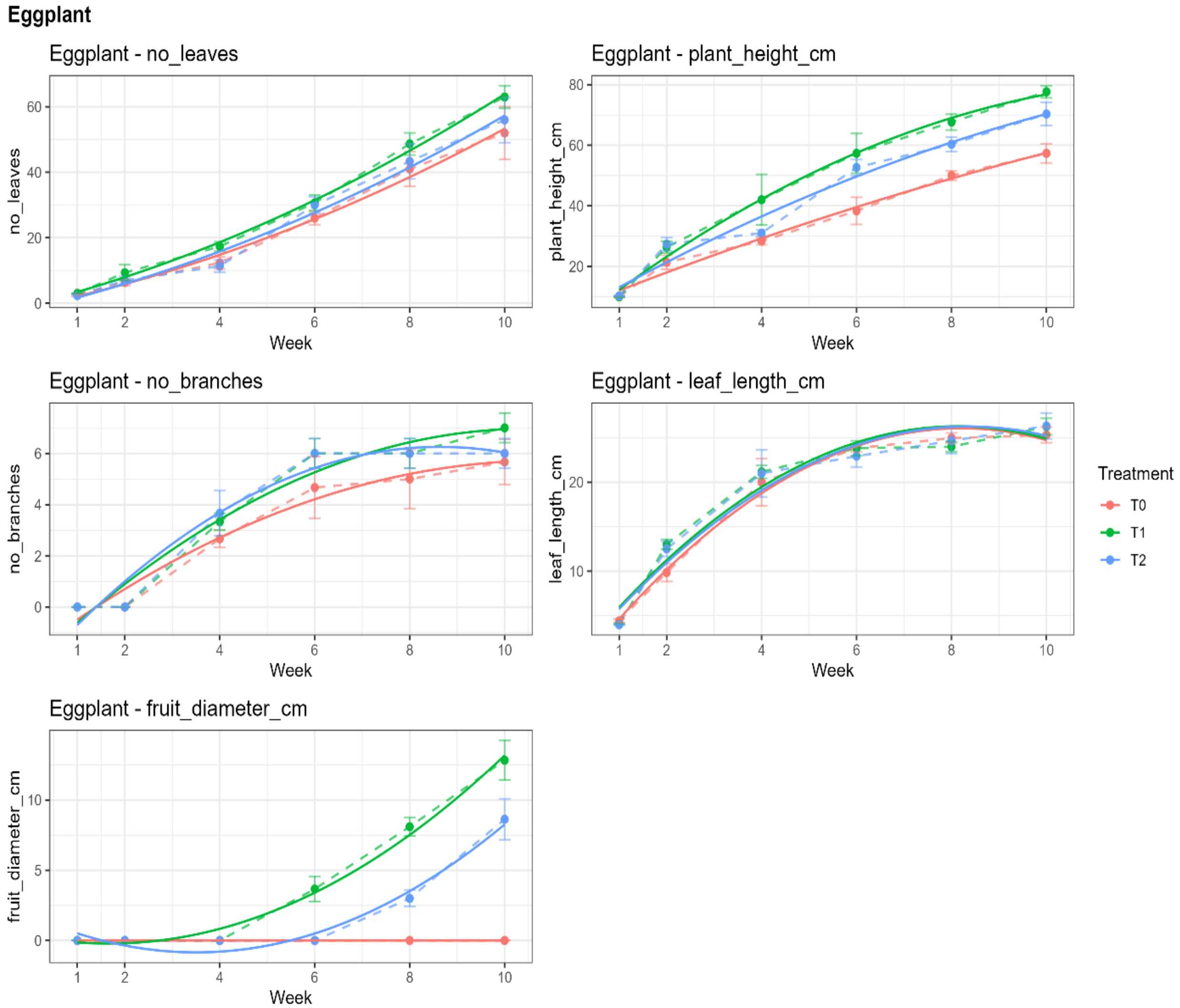
Growth parameter	Week	Source	df	Sum Sq	Mean Sq	F value	Pr(>F)
Plant height (cm)	8	Treatment	2	472.67	236.33	13.38	0.017*
Plant height (cm)	10	Treatment	2	636.22	318.11	7.47	0.045*
Fruit diameter (cm)	6	Treatment	2	26.89	13.44	17.29	0.011*
Fruit diameter (cm)	8	Treatment	2	100.62	50.31	43.37	0.002**
Fruit diameter (cm)	10	Treatment	2	256.87	128.43	36.25	0.003**

*Significance: ** $p < 0.01$, * $p < 0.05$*

Table 4: Mean growth parameters ($\bar{X}$ ±SD, N=3) of eggplant after different treatments at week 10

	Treatment		
Growth parameter	T0	T1	T2
Fruit diameter (cm)	0 ± 0	12.83 ± 1.41	8.63 ± 1.45
Leaf length (cm)	25.33 ± 0.88	26.27 ± 0.93	26.33 ± 1.45
Number of branches	5.67 ± 0.88	7.00 ± 0.58	6.00 ± 0.58
No of leaves	52.00 ± 8.08	63.00 ± 3.46	56.00 ± 6.93
Plant height (cm)	57.33 ± 3.18	77.67 ± 2.03	70.33 ± 3.84

Quadratic regression showed that eggplant fruit diameter in T1-treated plants followed an accelerating curve ($R^2 = 0.991$), reflecting delayed onset of growth from Weeks 1–4, then rising rapidly (Figure 2). T2 followed the same accelerating pattern but at a lower asymptote. Plant height and leaf number were essentially linear ($R^2 > 0.96$ for both models), but the slopes differed substantially: 7.25 cm/week under T1 versus 5.07 cm/week under T0. Leaf length showed clear saturation around week 8.



Solid curves are quadratic regressions of weekly means; dashed lines connect the observed means. Each point is the mean ± SE of three replicates

Figure 2: Weekly growth and yield trajectories of eggplant under three treatments

Effect of treatments on the growth performance of cabbage

Cabbage produced the highest number of significant treatment effects compared to eggplant and green pepper. Eight comparisons were significant ($p < 0.05$) across the six measurement weeks (Table 5). Significant effects on leaf length were detected at every week except weeks 6 and 8, and the highest F-ratio was at week 4 (F = 5431.60, $p < 0.0001$, ***). Number of leaves was significant at weeks 2 and 4 (F = 7.60, p

= 0.0434; F = 11.20, p = 0.0230); plant height at week 4 (F = 29.74, p = 0.0040, **); and head diameter, which is the agronomically critical trait, differed at week 10 (F = 7.93, p = 0.0405, *). By week 10, the mean head diameter of cabbages under T1 reached 18.47 ± 0.32 cm, significantly larger than 14.83 ± 1.01 cm under T0 (a 24.5% gain) and modestly larger than 17.23 ± 0.72 cm under T2 (Table 6).

Table 5: **Mean squares from ANOVA for treatment effects on cabbage, organised by trait and week**

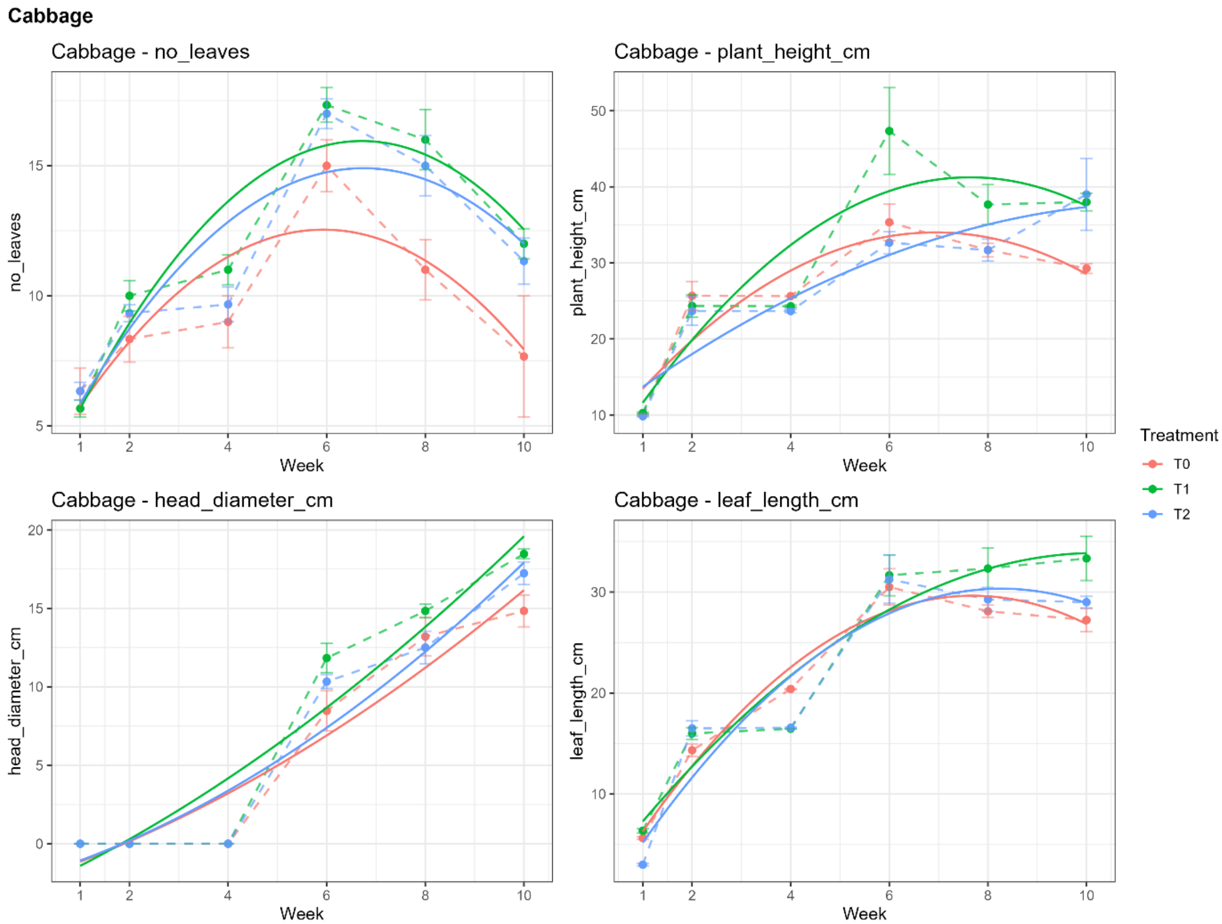
Growth parameter	Week	Source	df	Sum Sq	Mean Sq	F value	Pr(>F)
Number of leaves	2	Treatment	2	4.22	2.11	7.6	0.043*
Number of leaves	4	Treatment	2	6.22	3.11	11.2	0.023*
Head diameter (cm)	10	Treatment	2	20.48	10.24	7.93	0.041*
Leaf length (cm)	10	Treatment	2	59.12	29.55	7.23	0.047*
Plant height (cm)	4	Treatment	2	6.05	3.02	29.74	0.004**
Leaf length (cm)	2	Treatment	2	7.72	3.86	19.86	0.008**
Leaf length (cm)	1	Treatment	2	18.81	9.40	108.50	3.28E-04***
Leaf length (cm)	4	Treatment	2	30.18	15.09	5431.60	1.35E-07***

*The Week-4 leaf length(cm) row (F = 5431.60, p < 0.0001) reflects an exceptionally tight distribution within treatments at that measurement. Significance: ***p<0.0001, ** p < 0.01, * p < 0.05*

Table 6: Mean growth parameters ($\bar{X}$ ±SD, N=3) of cabbage after different treatments at week 10

	Treatment		
Growth parameter	**T0**	**T1**	**T2**
Head diameter (cm)	14.83 ± 1.01	18.47 ± 0.32	17.23 ± 0.72
Leaf length (cm)	27.23 ± 1.13	33.33 ± 2.19	29 ± 0.58
Number of leaves	7.67 ± 2.33	12 ± 0.58	11.33 ± 0.88
Plant height (cm)	29.27 ± 0.64	38 ± 1.15	39 ± 4.73

Quadratic regression revealed a striking non-linear pattern (Figure 3). The mean number of leaves in cabbage followed a dome-shaped trajectory peaking at week 6.7 under T1 (R^2 = 0.877) declining thereafter as outer leaves reached senescence during head formation. Mean number of leaves in T0 treated plants peaked earlier (week 5.9) and at a lower amplitude. Plant height in T1 and T2 treated cabbages plateaued around 38–39 cm by week 10, both substantially above the T0 plateau of 29.27 cm. This pattern suggests that for plant height, nutrient availability was the limiting factor, regardless of whether delivered via the integrated biofertiliser-iopesticide or organic fertiliser regimes.



Solid curves are quadratic regressions; dashed lines connect observed means. The dome-shaped trajectory of the number of leaves (top-left) is the clearest example of non-linear growth in the study; head_diameter_cm (bottom-left) shows the agronomically critical advantage of T1.

Fig. 2: Weekly growth and yield trajectories of cabbage under three treatments

DISCUSSION

The growth and productivity of cabbage, eggplants, and green pepper were strongly influenced by soil properties and fertiliser treatments. Although the crops differ in physiology and nutrient requirements, all the three showed a similar response pattern, with the integrated biofertiliser-biopesticide treatment (T1) consistently outperforming both the inorganic fertiliser (T2) and the control (T0). This was most pronounced for late-season reproductive output on eggplant fruit production and number of green pepper fruits and also for canopy traits driven by sustained vegetative investment for green pepper plant height and cabbage head diameter. The low mean values of all growth parameters in the control treatment could be attributed to the insufficient supply of nutrients to vegetables, resulting in reduced plant productivity (Shangguan *et al*., 2000; Rahman *et al*., 2008). Some studies reported higher growth performance when biofertiliser and inorganic fertiliser were blended compared to when applied singly (Akter *et al*., 2021; Sime *et al*., 2025). This pattern was strikingly consistent across botanically distant species (Solanaceae and Brassicaceae), strengthening the inference that the response was driven by the integrated biofertiliser-biopesticide treatment regime rather than by crop-specific physiological idiosyncrasies.

The soil in the experimental plots was slightly acidic (pH 5.42–5.44), which is suboptimal for vegetable growth. Vegetable plants generally perform poorly in acidic soils with pH 4.5-5.5 or in alkaline soils above 7.5 (Ronen and Greenhouses, 2016). The optimal pH range for vegetables is 5.5-7.0, ensuring high availability of essential nutrients (Liu and Hanlon, 2012).

Soil from plot B, where eggplant and green pepper were grown, had a moderately acidic pH (5.44), moderate organic matter (3.34%), relatively high nitrogen (0.21%), and a sandy clay loam texture (64% sand, 28% clay, 8% silt). Although slightly below the optimal pH for eggplants (5.5-7.0), the soil was suitable for cultivation, with fertiliser treatments likely offsetting limited nutrient availability. The experimental plot had high available phosphorus 0-7 mg P kg^{-1} (Clements and McGowen, 1994), exchangeable potassium (1.344 cmol/kg), and moderate magnesium (0.59 cmol/kg), supporting metabolic activity, photosynthesis, and plant vigor. Moderate organic matter and adequate nitrogen enhanced nutrient retention, root development, and vegetative growth, contributing to increased growth in fertilised treatments. The sandy clay loam texture also provided good drainage, aeration, and moisture retention, facilitating nutrient uptake and overall healthy growth of eggplant and green pepper. According to Berhanu (1980), adequate total soil nitrogen for plant growth is 0.12–0.25%, which is higher than the levels detected in the experimental plots. The low nitrogen content meant that vegetables efficiently utilised the nitrogen from applied fertilisers (T1 and T2), enhancing growth and development. The integrated biofertiliser–biopesticide also supplied readily available nutrients through decomposition, similar to findings by Bonten *et al*. (2014). Cabbage growth was strongly influenced by the experimental soil, which was moderately acidic (pH 5.42) with low organic matter (0.96%) and low nitrogen (0.07%), suboptimal for cabbage production (optimal pH 6.0–7.5). These conditions limited nutrient availability, resulting in fewer leaves, shorter plants, and smaller heads in the unfertilised control (T0). Low organic matter and sandy soil texture (72% sand, 20% clay, 18% silt) further reduced nutrient and water retention, contributing to slower growth. The improved performance under the integrated biofertiliser–biopesticide treatment (T1) is attributed to enhanced microbial activity, better nutrient cycling, and compensation for nutrient losses, despite moderate exchangeable cations (K^+ 0.42, Ca^{2+} 4.53, Mg^{2+} 0.56 cmol/kg) being less available due to soil acidity. All crops demonstrated significant increases in vegetative growth and reproductive structures under T1, confirming the general efficacy of integrated biofertiliser application. The inorganic fertiliser treatment (T2) improved growth relative to the control but was consistently less effective than T1. These results align with Akpan et al., (2020), who reported increases in leaf number, plant height, and fruit number in pepper following soil amendment with bioslurry, and with Yamika *et al.* (2019), who observed increased cucumber leaf length from bioslurry application. Although T2 provided readily available nutrients, it did not enhance soil biological activity, limiting its impact on long-term growth and plant vigor. The significant effects of both fertilisers on vegetable growth indicate their importance in enhancing growth and development. Integrated biofertiliser-biopesticide could replace inorganic fertilisers, reducing chemical use and environmental pollution. Control cabbages were attacked by pests, whereas treated plants were protected, highlighting the pesticidal effects of plant extracts in the bioslurry and 5% cypermethrin in the inorganic fertiliser. Other studies have also shown that organic fertilisers can produce higher yields than inorganic fertilisers (Eifediyi *et al.,* 2010; Dalal *et al.,* 2014; Zainab *et al.,* 2016). The integrated bio-fertiliser/biopesticide regime, by combining organic substrate inputs with biological pest control, likely supported a broader spectrum of soil and plant-microbe interactions, translating into more reliable late-season performance.

The diversity of growth shapes that emerged required quadratic rather than linear regression. Three patterns repeatedly identified were accelerating curves with delayed onset, saturating-decelerating curves that plateau as plants approach a mature ceiling, and dome-shaped curves with a peak followed by decline, which the linear model could not accurately describe.

CONCLUSION

In conclusion, the effects of fertiliser treatment were comparable at the start, but significant effects emerged progressively and were strongest at Weeks 8–10. Fertiliser type significantly influenced the growth and productivity of cabbage, eggplant, and green pepper in moderately acidic, low-fertility sandy to sandy-clay soils. The integrated biofertiliser-biopesticide treatment (T1) consistently outperformed inorganic fertiliser (T2) and the unfertilised control (T0) on a majority of growth and yield traits in all three vegetables due to improved nutrient availability, enhanced soil biological activity, and sustained nutrient release. While T2 improved growth compared to the control, it was less effective than T1 for long-term soil fertility and plant vigor. Thus, these results support the integrated bio-fertiliser-biopesticide as a viable and superior alternative to conventional inorganic fertilisation for smallholder production of eggplant, green pepper, and cabbage.

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