International Journal of Botany Studies
www.botanyjournals.com
ISSN: 2455-541X
Received: 18-11-2025, Accepted: 17-12-2025, Published: 01-01-2026
Volume 11, Issue 1, 2026, Page No. 1-6

Partial substitution of chemical fertilizer with bio-enriched fertilizer and poultry manure on the growth and yield of *Cucumis anguria* L.

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Abstract
This experiment evaluated the effects of partially substituting chemical fertilizer with bio-enriched fertilizer and poultry manure on the growth and yield performance of *Cucumis anguria* L. grown in polybags in the dry zone of Sri Lanka. The experiment was carried out in a Complete Randomized Design (CRD) with the following treatments; T1- Control, T2 - Inorganic fertilizer (75%) + Cocoly fertilizer, T3 - Inorganic fertilizer (50%) + Cocoly fertilizer, T4 - Inorganic fertilizer (25%) + Cocoly fertilizer, T5 - Inorganic fertilizer (75%) + poultry manure, T6 - Inorganic fertilizer (50%) + poultry manure, T7 - Inorganic fertilizer (25%) + poultry manure with five replicates. The results showed that T2 significantly enhanced all vegetative growth parameters of *Cucumis anguria* L. at 8 WAP including vine length (21.3%), number of leaves (29.64%), leaf area (48.59%), number of branches (30.76%), root length (9.88%), and fresh shoot weight (25.61%) and dry shoot weight (13.57%) and fresh weight of root (37.82%) and dry weight of roots (27.57%). Although no significant difference in total yield was observed between T2 and T3, T2 produced the highest total yield of 23.57 tons per hectare, compared to 10.35 tons per hectare in the control treatment (T1). T2 recorded the highest profitability with a net return of Rs. 865,101.00/ha, establishing it as the most profitable treatment combination. Based on these findings, partial substitution of chemical fertilizer (75%) with cocoly fertilizer shows considerable potential to enhance the growth and yield of *Cucumis anguria* L., in polybag cultivation thereby promoting profitable cultivation in the dry zone of Sri Lanka.

Keywords: Inorganic fertilizer, cocoly, nitrogen and yield parameter

Introduction
Cucumis anguria L., commonly known as gherkin, bur cucumber, or West Indian gherkin, is a valuable vegetable crop belonging to the Cucurbitaceae family (Yoon *et al*., 2015) [29]. Its young fruits are widely used for pickling, cooked as a vegetable, or added to curries (Bindiya & Srihari, 2015) [4]. In Sri Lanka, commercial gherkin production began in 1985 and has since expanded across many regions due to its short cropping period and quick income generation (Abeyrathna *et al*., 2013) [1]. Pickling-type gherkins are grown from the dry to intermediate agro-ecological zones (Uthpala & Marapana, 2017) [24], thriving up to 1,000 m elevation, at mean temperatures above 22 °C, with over 8 hours of sunlight and annual rainfall between 1,500–2,000 mm (Prabaharan *et al*., 2025) [20].

Gherkin fruits are smaller than cucumbers, typically 4.0–6.0 cm long and 1.5–2.0 cm wide, with a rough, undulating surface (Bairagi *et al*., 2019) [3]. Because gherkin has a short 60-day growth cycle, proper and timely fertilizer application is essential to achieve high yields (Abeyrathna *et al*., 2013) [1]. However, continuous reliance on inorganic fertilizers can degrade soil health, increasing fragility and acidification (Xing *et al*., 2025) [26]. Organic fertilizers support sustainable nutrient management but often have low nutrient content and limited availability, making it difficult to meet crop demands using them alone (Morris, 2007) [15]. Combine application of chemical fertilizers with organic manures or crop residues can address these limitations, improve nutrient-use efficiency and reduce losses through leaching, runoff, volatilization, and immobilization (Garg & Bahl, 2008; Zhang *et al*., 2012) [8, 30]. Therefore, this study aimed to examine the impact of partially replacing chemical fertilizer with bio-enriched fertilizer and poultry manure on the growth and yield of *Cucumis anguria* L.

Materials and Methods
Experimental site
A polybag experiment was conducted at the university farm, Faculty of Agriculture, Eastern University, Sri Lanka in Palachcholai during the period of July to September 2025.

Seed collection
The experiment was conducted using seeds of gherkin (*Cucumis anguria* L.) variety Chandini RZ F1 (12-79).

Treatments and experimental design
The polybag experiment was arranged in a completely randomized design (CRD) consisting of seven treatments with five replications each which are presented in the following table 1.

Table 1: Treatments code and its description

Treatment code	Description
T1	Inorganic fertilizer (100%) - Control
T2	Inorganic fertilizer (75%) + Cocoly fertilizer (5 g/plant – at the time of planting 20 kg/acre – at the growth stage)
T3	Inorganic fertilizer (50%) + Cocoly fertilizer (5 g/plant – at the time of planting 20 kg/acre – at the growth stage)
T4	Inorganic fertilizer (25%) + Cocoly fertilizer (5 g/plant – at the time of planting 20 kg/acre – at the growth stage)
T5	Inorganic fertilizer (75%) + poultry manure (10 tons/ha)
T6	Inorganic fertilizer (50%) + poultry manure (10 tons/ha)
T7	Inorganic fertilizer (25%) + poultry manure (10 tons/ha)

Agronomic practices

The experiment was carried out using UV-treated white polybags with dimensions of 30 × 30 cm. A growing medium was prepared by mixing equal parts of red soil, top soil, and cow dung, which was used to fill the polybags. Seeds were sown in plug trays containing cells filled with a 1:1 mixture of compost and top soil. After germination, healthy and vigorous seedlings of good quality were obtained. The seedlings were transplanted into polybags three days after sowing. Trellises were installed using bamboo poles and coconut coir ropes. Grade 3 pods (32–45 mm in diameter) were collected according to international export standard requirements.

Data collection

At 8 weeks after planting (8 WAP), data were collected at the end of the experiment. Vine length was measured with a measuring tape, while the total number of leaves and branches was counted manually. Leaf area was recorded using a leaf area meter (LI-3100, USA), and chlorophyll content was measured using a SPAD chlorophyll meter (SPAD-502 Plus). Fresh and dry weights of shoots and roots were obtained using an electronic balance (BSA822-CW, Germany). The number of pods and the total pod weight per vine were also recorded. Yield per hectare was then estimated by extrapolating the yield obtained from all sampled plants.

Data analysis

The data obtained from the experiment were analyzed using one-way ANOVA in Minitab 17 Statistical Software, and mean differences were determined using Tukey's test at the 5% significance level.

Results and Discussion

Growth parameters

Vine length

The table 2 shows the effects of partial substitution of chemical fertilizer with bio-enriched fertilizer and poultry manure on vine length of *Cucumis anguria* L. at 8 WAP. Treatment 2 recorded the highest mean vine length (193.12 cm), which was statistically similar to Treatment 3 (180.60 cm). These two treatments represented the best-performing groups. The improved vine growth seen in *Cucumis anguria* L. with the combined use of 75% inorganic fertilizer and cocoly fertilizer connects to its rich nutrient profile. This includes cocoly's 15% nitrogen (N), 3% phosphorus (P), and 5% potassium (K) and micro nutrients (Prabaharan *et al*., 2025) [20]. Present findings align with Patil & Narayana, (2017) [19] who reported that the readily available nutrients from inorganic fertilizers, along with their improved absorption and transport within plants, resulted in greater photosynthetic activity, growth, and development compared to treatments with a lower proportion of inorganic fertilizers. Cocoly fertilizer improves the growth and vine length of *Cucumis anguria* L. because of its helpful micro nutrients and bioactive substances, such as polymeric acid substances (PAS), fulvic acid, and polyglutamic acid. PAS is particularly effective as it improves the soil's structure and pH, while also stimulating the plant's metabolic processes and cell division, ultimately promoting the highest vine length (Lankem Agro, 2025) [12].

Number of leaves

The table 2 presents the effects of partially substituting chemical fertilizer with bio-enriched fertilizer and poultry manure on the number of leaves of *Cucumis anguria* L. at 8 weeks after planting (WAP). A significant difference ($p>0.05$) was observed among treatments in leaf numbers. Treatment 2 (T2) showed the highest leaf count (96.20), followed by T3 (81.60), T4 (77.40), T5 (76.80), and T1 (control) (74.20). T2 exhibited a 29.64% increase in the number of leaves compared to the control (T1). Mahmood *et al*. (2017) [14] similarly found that integrated nutrient management significantly increased leaf numbers by 15-30% in various vegetable crops compared to single fertilizer applications. Prabaharan *et al*. (2025) [20] reported that cocoly fertilizer notably increased leaf numbers in *Cucumis anguria,* which is important for the plant's health and photosynthesis. Besides its NPK composition, cocoly fertilizer contains polymeric acid substances, fulvic acid, polyaspartic acid, and polyglutamic acid, which act as bio stimulants enhancing leaf development in Cucurbitaceae crops (Canellas *et al*., 2015) [5].

Number of branches

Table 2 shows partial substitution of chemical fertilizer with bio-enriched fertilizer and poultry manure affected the number of branches in *Cucumis anguria L*. at 8(WAP). Treatment T2 produced the highest number of branches (10.20), significantly outperforming all other treatments, while T1, T3, T4, T5, and T6 showed comparable but lower values. T7 had the lowest number of branches (5.00). These results agree with previous studies showing that nitrogen is essential for shoot branching and vegetative growth (Hou *et al*., 2021; Wahocho *et al*., 2017) [9, 25]. Increased photosynthetic product flow may have supported faster growth and higher branching (Patil, 2016) [17].

Chlorophyll content

Table 2 shows partial substitution of chemical fertilizer with bio-enriched fertilizer and poultry manure influenced chlorophyll content in *Cucumis anguria L.* leaves. At 8 WAP, significant differences were observed among treatments. T2 (106.98) showed the highest chlorophyll content, T3 (98.86) was statistically comparable to T2. T2 demonstrated higher chlorophyll content of leaves 22.67%, and 57.74% compared to T1 (Control). Roba *et al*. (2018)

[22] stated that Sole reliance on inorganic fertilizers can harm soil health by depleting organic matter, disrupting structure, reducing microbial diversity, and causing nutrient leaching, which may also lower plant chlorophyll content and photosynthetic efficiency which consistent with the in present results observed in treatment (T1). Ishfaq *et al*. (2023) [11] reported that nutrients supplied by combined fertilizers fulfill the most limiting nutrient requirements for optimal crop development, which aligns with the present results of this study, where the combined application of cocoly and inorganic fertilizerresulted in significantly higher chlorophyll content. Prabaharan *et al*. (2025) [20] reported that the markedly higher chlorophyll content in plants supplied with cocoly fertilizer can be attributed to its rich nitrogen composition 15%.

Table 2: Effects of partial substitution of chemical fertilizer with bio-enriched fertilizer and poultry manure on vine length, number of leaves, number of branches and chlorophyll content of leaves at 8 WAP.

Treatments	Vine length (cm)	Number of leaves	Number of branches	Chlorophyll content
T1	159.60±2.77^{c}	74.20±2.97^{bc}	7.80±0.80^{b}	67.82±3.00^{d}
T2	193.12±2.68^{a}	96.20±3.10^{a}	10.20±0.37^{a}	106.98±2.77^{a}
T3	180.60±4.19^{ab}	81.60±3.50^{b}	7.40±0.51^{b}	98.86±3.12^{ab}
T4	165.28±5.01^{bc}	77.40±1.12^{bc}	6.80±0.37^{bc}	87.62±5.29^{bc}
T5	164.36±4.56^{bc}	76.80±4.60^{bc}	7.00±0.77^{bc}	88.46±6.06^{bc}
T6	149.20±4.66^{cd}	64.00±2.66^{c}	5.60±0.24^{bc}	75.82±3.56^{cd}
T7	142.10±1.38^{d}	64.80±2.20^{c}	5.00±0.31^{c}	70.54±3.41^{cd}
F test	*	*	*	*

Value represents means ± standard error of 5 replicates. WAP – Weeks after planting; '*' represents significant and 'ns' represents non-significant difference at 0.05 level of probability. Mean value in a column having the dissimilar letter or letters indicates significant difference at 0.05 level of significance by Tukey's Test

Leaf area (cm^2)

Table 3: Effects of partial substitution of chemical fertilizer with bio-enriched fertilizer and poultry on leaf area at 2, 4, 6 and 8 weeks after planting (WAP)

Treatment	Leaf area
T1	3957±142^{c}
T2	5880±114^{a}
T3	4861±159^{b}
T4	4185±228^{bc}
T5	4204±91.3^{bc}
T6	3196±239^{d}
T7	3052±142^{d}
F - test	*

Value represents means ± standard error of 5 replicates. WAP – Weeks after planting; '*' represents significant and 'ns' represents non-significant difference at 0.05 level of probability. Mean value in a column having the dissimilar letter or letters indicates significant difference at 0.05 level of significance by Tukey's Test

The table 3 shows the effects of partial substitution of chemical fertilizer with bio-enriched fertilizer and poultry manure on leaf area of *Cucumis anguria* L. at 8 WAP. Treatment T2 (Inorganic fertilizer 75% + Cocoly fertilizer) recorded the highest leaf area 5880 cm2, which was significantly ($p < 0.05$) greater than all other treatments. T2 demonstrated 48.59% higher leaf area compared to T1 (Control). The present result is in agreement with the findings of Prabaharan *et al*., (2025) [20] who reported that the significantly higher leaf area could be attributed to the higher nitrogen content (15%) of cocoly fertilizer, along with the presence of micronutrients (Fe, Zn, and Mg) and polyaspartic acid (PASP). Similarly, Patil & Narayana, (2018) [18] reported that the application of organic manures in combination with inorganic fertilizers enhanced growth attributes, including internodal length, leaf area, number of leaves, vine length, and dry matter production, which is consistent with the results of the (T2) combined cocoly and inorganic fertilizer.

Shoot fresh and dry weight

Table 4 shows the effects of partial substitution of chemical fertilizer with bio-enriched fertilizer and poultry manure on shoot fresh and dry weight of *Cucumis anguria* L. Shoot fresh weight varied significantly, ranging from 218.38 g (T7) to 385.78 g (T2). Treatment T2 (Inorganic fertilizer 75% + Cocoly) and T3 (Inorganic fertilizer 50% + Cocoly) demonstrated superior performance with the highest mean fresh weight. Similarly, shoot dry weight ranged from 57.92 g (T7) to 77.29 g (T2), with T2 and T3 achieving the highest values, followed by T5 (70.30). Treatment 2 showed a 34.41% increase in shoot fresh weight and 13.57% increase in dry weight compared to control (T1). The integrated application of 75% inorganic fertilizer with cocoly increased nitrogen availability, which agrees with findings by Chandru *et al*. (2017) [6] and Ogweno & Niyokuri (2013) [16] on biomass accumulation in *Cucumis anguria* and *Cucurbita pepo*. Cocoly's magnesium (Mg) supports protein synthesis and chlorophyll formation, while iron (Fe) enhances photosynthetic efficiency (Rout & Sahoo, 2015) [23]. Zhang *et al*. (2017) [31] found that PGA application enhanced biomass accumulation in cucumber and Chinese cabbage, while Liu *et al*. (2023) [16] reported that PASP reduces nutrient loss and promotes crop growth, corroborating present findings.

Root fresh weight and dry weight

The table 4 shows the effects of partial substitution of chemical fertilizer with bio-enriched fertilizer and poultry manure on root fresh and dry weight of *Cucumis anguria* L. The results revealed significant differences among treatments in both root fresh weight and root dry weight. The highest mean root fresh weight was observed in T2 (Inorganic fertilizer 75% + Cocoly fertilizer) which was significantly superior to all other treatments. T3 and T5 also recorded a significantly higher and comparable mean root fresh weight. Treatment 2 exhibited an increase in mean root fresh weight of 37.82% and mean root dry weight of 27.57% compared to the control treatment (T1). These results may be attributed to the balanced nutrient supply in Treatment 2, achieved through the integrated application of inorganic fertilizer and bio-enriched Cocoly fertilizer. The enhanced root weight observed with Cocoly fertilizer application could be attributed to the presence of bio-root promoters and PGA (Lankem Agro, 2025) [12]. According toXu *et al*. (2014) [27] γ-PGA (gamma-polyglutamic acid) can significantly increase the dry weight of roots. While Yang *et al*. (2022) [28]. showing that bio-root promoters contain substances like hormones (auxins) boosts the root development and produce stronger and wider root systems.

Table 4: Effects of partial substitution of chemical fertilizer with bio-enriched fertilizer and poultry manure on shoot fresh weight, shoot dry weight, root fresh weight and root dry weight of *Cucumis anguria* L. at 8 WAP

Treatment	Shoot fresh weight (g)	Shoot dry weight (g)	Root fresh weight (g)	Root dry weight (g)
T1	287.00 ± 12.70^{b}	68.05 ± 1.30^{c}	81.14 ± 2.47^{c}	10.30 ± 0.38^{bc}
T2	385.78 ± 8.58^{a}	77.29 ± 0.86^{a}	111.83 ± 1.87^{a}	13.14 ± 0.38^{a}
T3	359.95 ± 9.13^{a}	75.06 ± 1.30a^{b}	95.89 ± 3.47^{b}	11.29 ± 0.29^{b}
T4	300.40 ± 12.4^{b}	69.38 ± 1.23^{c}	78.21 ± 3.55^{c}	9.98 ± 0.34^{c}
T5	311.27 ± 9.11^{b}	70.30 ± 0.72^{bc}	84.86 ± 3.37b^{c}	10.79 ± 0.30^{bc}
T6	229.89 ± 9.00^{c}	61.36 ± 1.38^{d}	74.92 ± 1.91^{c}	9.66 ± 0.29^{c}
T7	218.38 ± 5.68^{c}	57.92 ± 1.03^{d}	73.03 ± 1.72^{c}	9.57 ± 0.21^{c}
F-test	*	*	*	*

Value represents means ± standard error of 5 replicates. WAP – Weeks after planting; '*' represents significant and 'ns' represents non-significant difference at 0.05 level of probability. Mean value in a column having the dissimilar letter or letters indicates significant difference at 0.05 level of significance by Tukey's Test

Root Length (cm)

Table 5: Effects of partial substitution of chemical fertilizer with bio-enriched fertilizer and poultry manure on root length at 8 weeks after planting (WAP).

Treatment	Root length (cm)
T1	1437.6±4.57^{b}
T2	1579.8±15.1^{a}
T3	1549.8±17.2^{a}
T4	1413.8±2.15^{b}
T5	1452.8±11.5^{b}
T6	1358.2±4.61^{c}
T7	1354.6±3.87^{c}
F - test	*

Value represents means ± standard error of 5 replicates. WAP – Weeks after planting; '*' represents significant and 'ns' represents non-significant difference at 0.05 level of probability. Mean value in a column having the dissimilar letter or letters indicates significant difference at 0.05 level of significance by Tukey's Test.

The table 5 shows the effects of partial substitution of chemical fertilizer with bio-enriched fertilizer and poultry manure on root length of *Cucumis anguria* L. The root length of plants showed significant ($p < 0.05$) difference among treatments. T2 (Inorganic fertilizer 75% + Cocoly fertilizer) 1579.8cm and T3 (Inorganic fertilizer 50% + Cocoly fertilizer) 1549.8 cm recorded the highest root lengths, both statistically similar and significantly superior to the other treatments. Treatment 2 exhibited an increase in mean root length of 9.88% compared to the control treatment (T1). Cocoly. (2025) [7] showed that cocoly fertilizer, includes 15% nitrogen, 3% phosphorus, 5% potassium, and bio root promoters enhance root biomass accumulation and lateral root formation align with the present findings. Vejan *et al*. (2016) Revealed that bio-root promoters increased total root length and biomass by enhancing cell division and elongation, with root length increases ranging from 20% to 80%, depending on the promoter type, application method, and environmental conditions. Huang *et al*. (2021) [10] reported that integrated nutrient management (INM) significantly enhances root growth and development by optimizing the supply of essential nutrients through a balanced combination of organic and inorganic sources, which agrees with the results of T2 and T3.

Yield parameters

Table 6: Effects of partial substitution of chemical fertilizer with bio-enriched fertilizer and poultry manure on number of fruits per vine, yield per plant and yield per hectare

Treatments	Number of fruits	Yield per plant (kg)	Yield per hectare (tons/ha)
T1	9.0 ± 0.44^{c}	0.86 ± 0.06^{c}	10.35 ± 0.73^{c}
T2	19.8 ± 1.91^{a}	1.96 ± 0.18^{a}	23.57 ± 2.22^{a}
T3	16.8 ± 1.50^{ab}	1.64 ± 0.08^{ab}	19.67 ± 0.98^{ab}
T4	14.6 ± 1.29^{b}	1.40 ± 0.12^{b}	16.82 ± 1.51^{b}
T5	14.4 ± 0.40^{b}	1.47 ± 0.02^{b}	17.60 ± 0.34^{b}
T6	8.4 ± 0.74^{c}	0.90 ± 0.10^{c}	10.85 ± 1.20^{c}
T7	5.8 ± 0.49^{c}	0.74 ± 0.09^{c}	8.90 ± 1.12^{c}
F – test	*	*	*

Value represents means ± standard error of 5 replicates. WAP – Weeks after planting; '*' represents significant and 'ns' represents non-significant difference at 0.05 level of probability. Mean value in a column having the dissimilar letter or letters indicates significant difference at 0.05 level of significance by Tukey's Test

The results showed that treatment 2 (inorganic fertilizer 75% + cocoly fertilizer) recorded the highest performance across all yield parameters. It produced the greatest number of fruits per plant (19.8), the highest mean yield per plant (1.96kg), and the maximum yield per hectare (23.57tons/ha). These values were significantly comparable to treatment 3 (inorganic fertilizer 50% + cocoly fertilizer), showed a fruit number of (16.8), and yield values of (1.64) kg per plant and (19.67) tons per hectare. Treatment 2 resulted in increases of 120% in the number of fruits, 127% in yield per plant (kg), and 127.72% in yield per hectare compared to T1 (control), whereas treatment 3 showed increases of 86.69% in the number of fruits, 90.69% in yield per plant (kg), and 90.04% in yield per hectare compared to

T1. Overall, the findings clearly indicated that T2 and T3 were the most effective treatments. The observed superior yields from the inorganic and bio-enriched fertilizer combination correlate with findings from Akram *et al.* (2024) [2] who reported that the growth and yield of various crops are enhanced when organic and inorganic amendments are applied together. The nutrient-rich formulation of cocoly fertilizer further promotes growth and improves yield. It has increased nitrogen content 15%, essential micronutrients, and bioactive compounds, stimulated strong vegetative growth, increased flowering, improved fruit set, and increased the number of pods per vine (Prabaharan *et al*., 2025) [20].

Cost benefit analysis

The results show that Treatment T2 (75% inorganic fertilizer + Cocoly fertilizer) outperformed all other treatments. Additionally, T2 and T3 (50% inorganic fertilizer + Cocoly fertilizer) showed significantly higher and comparable yield parameters, including number of fruits per vine, yield per plant, and total yield per hectare. T2 achieved the highest yield of 23.57 tons per hectare with maximum net profit of Rs. 865,101.00 per hectare, while T3 recorded 19.67 tons per hectare with net profit of Rs. 632,600.00 per hectare.

Based on these findings, it is recommended to apply 75% inorganic fertilizer combined with cocoly fertilizer to maximize yield of *Cucumis anguria* L. This integrated approach offers an effective strategy for achieving higher profitability and sustainable cultivation in the dry zone of Sri Lanka.

Table 7: Cost benefit analysis of *Cucumis anguria* L.

Treatments	Yield per ha (tons/ha)	Cost (Rupees/ha)	Income (Rupees/ha)	Net Profit (Rupees/ha)
T1	10.35 ± 0.73^{c}	511974.00	621000.00	109026.00
T2	23.57 ± 2.22^{a}	550000.00	1414200.00	865101.00
T3	19.67 ± 0.98^{ab}	547600.00	1180200.00	632600.00
T4	16.82 ± 1.51^{b}	545200.00	1009200.00	464000.00
T5	17.60 ± 0.34^{b}	524548.00	1056000.00	531452.00
T6	10.85 ± 1.20^{c}	522153.00	651000.00	128847.00
T7	8.90 ± 1.12^{c}	519758.00	534000.00	14242.00

Value represents means ± standard error of 5 replicates. WAP – Weeks after planting; '*' represents significant and 'ns' represents non-significant difference at 0.05 level of probability. Mean value in a column having the dissimilar letter or letters indicates significant difference at 0.05 level of significance by Tukey's Test.

Conclusion

This study tested whether partial substitution of the chemical fertilizer with bio-enriched fertilizer or poultry manure could improve the growth and yield of *Cucumis anguria L.* in polybag cultivation in Sri Lanka's dry zone. The treatment combining bio-enriched fertilizer with 75% inorganic fertilizer (T2) showed the best overall vegetative growth and produced the highest yield (23.57 t/ha), much higher than the control (10.35 t/ha). Although T2 and T3 had similar yields, T2 was the most profitable, giving the highest net return of Rs. 865,101/ha. The findings indicate that partially substituting chemical fertilizer with bio-enriched fertilizer, especially Cocoly, improves both economic returns and environmental sustainability.

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