

Effects of Different Organic and Inorganic Fertilizers on Growth and Yield of *Cucumis anguria* L.

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Abstract— Declining soil fertility in Sri Lanka's dry zone necessitates the integration of organic manures with inorganic fertilizers for sustainable crop productivity. A pot experiment was conducted on sandy loam soil at the University Farm, Faculty of Agriculture, Eastern University, Sri Lanka, to evaluate the effects of different organic and inorganic fertilizers on the growth and yield of *Cucumis anguria* L. cv. Chandani. The experiment was laid out in a Completely Randomized Design with 13 treatments and 10 replicates. The treatments included T1 (100% inorganic fertilizer, control), T2-T4 (100% compost, cattle manure, and poultry manure), and T5-T13 (combinations of 75%, 50%, or 25% inorganic fertilizer with complementary organic manure) based on the recommended NPK rate of 150:75:100 kg/ha. Measurements were taken from 2 to 8 weeks after planting, and data were analyzed using one-way ANOVA with mean separation by Tukey's HSD at $p < 0.05$. At 8 weeks after planting, T10 (50% inorganic fertilizer + 50% poultry manure) recorded the highest vine length (215.08 cm), leaf number (100.70), branch number (8.10), chlorophyll content (119.81 SPAD units), leaf area (4029.7 cm²), root length (166.98 cm), shoot dry weight (153.69 g), and root dry weight (16.896 g), along with the highest fruit yield (32.50 fruits/vine; 1.461 kg/vine; 14.61 t/ha) - a 174.62% increase over the control - and the highest net profit (Rs. 382,574.60/ha). Therefore, the 50:50 combination of inorganic fertilizer and poultry manure is recommended for profitable and environmentally friendly *Cucumis anguria* L. production in the dry zone of Sri Lanka.

Keywords— Crop growth parameters, Organic-inorganic fertilizer integration, Poultry manure, Soil fertility, Yield enhancement.

I. INTRODUCTION

Vegetables supply energy, vitamins, minerals, and other protective compounds needed for a balanced diet, and their importance is increasing globally as food systems respond to rising concerns about nutritional security [1]. Among vegetable crops, gherkin (*Cucumis anguria* L.), a member of the family Cucurbitaceae, is valued both as a food crop and as a commercially important export vegetable, known by several common names including bur cucumber, bur gherkin, cackrey, and gooseberry gourd. In some contexts, the term "gherkin" also refers to a pickled cucumber product derived from a different cultivar group of *Cucumis sativus* L. [2]. Gherkin has also been associated with traditional medicinal uses such as treating kidney stones, hemorrhoids, stomach pain, and jaundice [3].

In Sri Lanka, gherkin is a commercially important vegetable crop cultivated mainly for export in processed and semi-processed forms, with major destinations including China, Australia, Taiwan, Malaysia, Japan, and the Netherlands [4], [5]. Pickling-style gherkins have been produced for the export market since 1988, with cultivation extending from the dry zone to the intermediate zone [6]. Rising global demand for sustainably produced vegetables has increased interest in organic production systems, though organic gherkin production in Sri Lanka remains insufficient to meet market demand [5]. Expanding production while maintaining soil health is therefore a priority, since improving soil nutrient availability and retention supports stronger plant growth and higher yields [7].

Soil fertility is a major factor determining the productivity of short-duration crops such as gherkin. In the dry zone of Sri Lanka, declining soil fertility, low organic matter content, and limited nutrient retention can reduce crop performance if nutrients are

not supplied properly, particularly in sandy regosols common to the Batticaloa district [8]. Nutrient deficiency can also increase susceptibility to plant disease, reducing yields and raising production costs for farmers [9]. Since gherkin has a relatively short growth cycle of around 60 days, it requires timely and balanced nutrient management to achieve good vegetative growth and fruit production [10]. Despite high market demand, average gherkin yields in Sri Lanka remain poor compared with major producing countries, indicating a need for improved agronomic practices [11].

Organic amendments such as cow dung, poultry manure, compost, and crop residues are widely recognized for improving crop productivity and soil quality, while also enhancing the physical, chemical, and biological properties of soil [12]. Organic manures increase soil organic carbon and nitrogen levels and promote water-stable aggregate formation compared with chemical fertilizers alone [13], [14]. Cattle dung contains macronutrients (N, P, K) along with secondary and micronutrients including calcium, magnesium, sulfur, zinc, boron, and copper [15], [16]. Poultry manure is often considered the most nutrient-dense animal manure, typically containing 0.9-1.5% nitrogen, 0.4-0.5% phosphorus, and about 0.8% potassium [17]. Compost serves as a slow-release nutrient source, supplying potassium, sulfur, calcium, and magnesium in addition to nitrogen and phosphorus [18].

Inorganic fertilizers remain important because they provide nutrients in readily available forms and can correct deficiencies quickly [19]. However, their continuous and exclusive use has been linked to soil degradation, nutrient imbalance, acidification, and declining soil biological activity under intensive cultivation [20]–[22], while prolonged nitrogen use can also increase pest pressure [23], [24]. These concerns make incorporating organic manure into farm practice increasingly important [25].

Combining organic and inorganic fertilizers offers advantages neither source provides alone: organic manures improve soil structure, water retention, aeration, and microbial activity, while inorganic fertilizers supply nutrients quickly to meet immediate crop demand. Used together, they improve nutrient availability in the root zone, support more efficient crop growth [26], [14], reduce dependence on costly chemical fertilizers, and improve long-term soil productivity [27], [28].

Although several studies have shown the benefits of organic manures and integrated fertilizer use in vegetable production, including recent trials on *Cucumis anguria* L. under Sri Lankan conditions using alternative organic and bio-enriched fertilizers [29], [8], information on the most suitable combination for *Cucumis anguria* L. cv. Chandani under dry-zone conditions in Sri Lanka remains limited. The response of gherkin to different proportions of poultry manure, cattle manure, compost, and inorganic fertilizer under local soil and climate conditions has not been sufficiently documented, and fertilizer recommendations developed for other crops or environments may not be directly applicable to gherkin production in the dry zone. The present study was therefore conducted to evaluate the effects of different combinations of organic and inorganic fertilizers on the growth and yield of *Cucumis anguria* L. cv. Chandani, and to identify the most effective treatment for sustainable and profitable production under dry-zone conditions in Sri Lanka.

II. MATERIALS AND METHODS

TABLE 1
FERTILIZER TREATMENTS APPLIED IN THE POT EXPERIMENT

Treatment	Description
T1	Inorganic Fertilizer (100%) – Control
T2	Compost (100%)
T3	Cattle manure (100%)
T4	Poultry manure (100%)
T5	Inorganic Fertilizer (75%) + Compost (25%)
T6	Inorganic Fertilizer (75%) + Cattle Manure (25%)
T7	Inorganic Fertilizer (75%) + Poultry Manure (25%)
T8	Inorganic Fertilizer (50%) + Compost (50%)
T9	Inorganic Fertilizer (50%) + Cattle Manure (50%)
T10	Inorganic Fertilizer (50%) + Poultry Manure (50%)
T11	Inorganic Fertilizer (25%) + Compost (75%)
T12	Inorganic Fertilizer (25%) + Cattle manure (75%)
T13	Inorganic Fertilizer (25%) + Poultry manure (75%)

2.1 Experimental Site and Design

A polybag experiment was carried out at the University Farm, Faculty of Agriculture, Eastern University, Sri Lanka, during the period from July to September 2024. The study site was located at the Faculty of Agriculture in Palachcholai, positioned at 7°48'36.64" N latitude and 81°35'30.76" E longitude. According to the Department of Meteorology (2022), the area experiences an average annual temperature ranging between 26.36°C and 36.98°C, with annual rainfall between 1400 mm and 1680 mm. The soil in this region is classified as sandy regosol. Baseline soil analysis indicated the following properties: pH 6.8, electrical conductivity 0.15 dS/m, organic carbon 0.52%, available nitrogen 42 mg/kg, available phosphorus 8.5 mg/kg, and available potassium 65 mg/kg. The experimental layout followed a Completely Randomized Design (CRD), comprising thirteen different treatments with ten replications each, as outlined in Table 1 and illustrated in Figure 1.



FIGURE 1: Completely Randomized Design (CRD) layout at University Farm, Eastern University, Sri Lanka (13 rows × 10 pots; 30 cm intra-row, 150 cm inter-row spacing)

2.2 Pot Preparation

White UV-treated polyethylene pots (30 cm diameter, 25 cm height, approximately 12 L volume) were used, with sixteen drainage holes punctured at each base. Pots were filled with approximately 10 kg of a 1:1:1 growing medium (red soil:sand:cow dung), as shown in Figure 2. The cow dung used in the growing medium was obtained from the same source as the cattle manure treatment. The nutrient content of the growing medium was not separately analyzed, representing a potential source of nutrients in addition to the applied treatments.



FIGURE 2: Pot preparation showing 16 basal drainage holes, 1:1:1 growing medium (red soil:sand:cow dung), and treatment labels (T1, T10) prior to *Cucumis anguria* L. cv. Chandani transplant.

2.3 Pot Arrangement

Pots were arranged in 13 rows with 10 pots per row (30 cm intra-row spacing; 150 cm inter-row spacing), totaling 130 experimental units (Figure 1).

2.4 Seedling Preparation and Transplanting

Parthenocarpic hybrid gherkin (*Cucumis anguria* L. cv. Chandani) seeds were sown in plug trays filled with a 1:1 compost:soil medium. After emergence, healthy, vigorous 3-day-old seedlings were selected and transplanted singly into each pot.

2.5 Fertilizer Application

Fertilizers were applied using a split-application method per treatment structure. Inorganic fertilizers comprised urea (150 kg ha⁻¹), triple superphosphate (TSP; 75 kg ha⁻¹), and muriate of potash (MOP; 100 kg ha⁻¹), following the recommendations of the Department of Horticulture, Government of Tamil Nadu [30]. Organic sources included poultry manure (10 t ha⁻¹), cattle manure (20 t ha⁻¹), and compost (30 t ha⁻¹) based on prior studies [31]–[33]. The nutrient composition of the organic manures used was as follows: poultry manure (N 1.2%, P 0.5%, K 0.8%), cattle manure (N 0.5%, P 0.2%, K 0.5%), and compost (N 0.5%, P 0.3%, K 0.6%).

Applications were split equally into three doses: organic manures were incorporated 1 week pre-planting; the inorganic basal dose was applied 2 days pre-planting; and top-dressings for both fertilizer types were applied at 3 and 5 weeks after planting (WAP).

2.6 Agronomic Practices

All agronomic practices were carried out uniformly throughout the experiment. Irrigation was provided daily at approximately 500 mL per pot during the establishment phase and increased to 1 L per pot per day during peak growth, with adjustment according to rainfall and soil moisture status. Neem leaf extract was applied twice weekly for pest management. Yellow and blue sticky traps were installed around the plot — yellow traps to manage aphids and whiteflies [34], and blue traps to control thrips [35]. Trellising was constructed using bamboo poles, steel binding wire, and rope (Figure 3): three bamboo poles were placed per row in pre-dug holes, connected securely with steel binding wire to form a stable framework, and ropes were tied to support plant climbing and spreading. Grade 3 fruits with a diameter of 32–45 mm were harvested at maturity for export use (Figure 4).



FIGURE 3: Bamboo-steel wire-rope trellising system supporting gherkin vines



FIGURE 4: Grade 3 export-quality *Cucumis anguria* L. cv. Chandani fruits (32-45 mm diameter, measured by vernier caliper)

2.7 Data Collection

Data on growth and yield parameters were collected from all replicates throughout the experiment. Vine length was measured using a measuring tape (cm); total numbers of leaves and branches per plant were counted manually. Leaf area was determined using a leaf area meter (LI-3100C, LI-COR Inc., USA; cm²); chlorophyll content was measured with a SPAD-502Plus meter (USA; SPAD units). Plant root length was measured using a root scanner (STD4800, Regent Instruments, Canada; cm). Fresh and dry weights of shoots and roots were recorded using an electronic balance (BSA822-CW, Germany; g), with dry weight taken after oven-drying at 105°C (DK-1200, Taiwan) to constant mass. For yield evaluation, the total number of fruits per vine (count) and total fruit weight per vine (kg) were measured and scaled to yield per hectare (t/ha).

2.8 Economic Analysis

A cost-benefit analysis was conducted for each treatment based on total production cost (polybags, growing medium, seedlings, fertilizer, labor, irrigation, pest management, and trellising materials, Rs./ha) and total income (calculated from yield per hectare and farm-gate price, Rs./ha). Income was calculated using a farm-gate price of Rs. 60/kg, consistent with the prevailing local market price offered by gherkin outgrower buyers in the study region during the study period. Net profit was calculated as total income minus total cost.

2.9 Statistical Analysis

Data were analyzed using one-way Analysis of Variance (ANOVA) in Minitab 17.0 statistical software. Treatment means were separated using Tukey's Honest Significant Difference (HSD) test at $p < 0.05$. F-values and degrees of freedom are reported in the text for significant parameters.

III. RESULTS AND DISCUSSION

3.1 Growth Parameters

3.1.1 Vine length (cm)

TABLE 2
VINE LENGTH (CM) OF *CUCUMIS ANGURIA* L. AT 2, 4, 6, AND 8 WEEKS AFTER PLANTING (WAP)

Treatment	2 WAP	4 WAP	6 WAP	8 WAP
T1	7.630 ± 0.473 ^a	79.04 ± 5.13 ^{ab}	150.4 ± 10.2 ^{bc}	167.28 ± 9.30 ^{bc}
T2	8.750 ± 0.656 ^a	57.90 ± 4.50 ^b	90.32 ± 3.45 ^e	99.84 ± 3.13 ^f
T3	8.750 ± 0.348 ^a	57.98 ± 3.45 ^b	126.22 ± 7.79 ^{cd}	141.80 ± 7.10 ^{de}
T4	9.230 ± 0.633 ^a	89.38 ± 4.78 ^a	167.16 ± 2.46 ^b	190.96 ± 4.37 ^b
T5	8.700 ± 0.317 ^a	82.70 ± 4.25 ^{ab}	150.43 ± 3.76 ^{bc}	165.47 ± 3.16 ^{cd}
T6	9.320 ± 0.404 ^a	88.79 ± 6.70 ^a	170.48 ± 4.03 ^b	181.11 ± 4.47 ^{bc}
T7	8.310 ± 0.663 ^a	88.73 ± 7.21 ^a	164.58 ± 3.03 ^b	183.22 ± 3.00 ^{bc}
T8	7.970 ± 0.277 ^a	76.72 ± 5.74 ^{ab}	150.40 ± 2.88 ^{bc}	162.46 ± 2.31 ^{cd}
T9	9.150 ± 0.814 ^a	66.82 ± 5.73 ^{ab}	130.43 ± 5.17 ^{cd}	141.63 ± 4.96 ^{de}
T10	9.360 ± 0.735 ^a	84.26 ± 6.38 ^{ab}	198.23 ± 5.75 ^a	215.08 ± 4.79 ^a
T11	7.590 ± 0.216 ^a	63.60 ± 4.82 ^{ab}	148.31 ± 5.65 ^{bc}	165.49 ± 5.71 ^{cd}
T12	7.860 ± 0.416 ^a	59.57 ± 5.75 ^b	119.58 ± 5.57 ^d	136.93 ± 5.23 ^e
T13	9.020 ± 0.467 ^a	89.54 ± 6.38 ^a	170.20 ± 2.71 ^b	185.67 ± 3.09 ^{bc}

Means ± standard error (n=10 replicates). WAP = weeks after planting; * = significant ($P < 0.05$), ns = non-significant. Means within columns followed by different letters differ significantly by Tukey's HSD test ($P < 0.05$). $F(12,117) = 2.89$ at 4 WAP; $F(12,117) = 15.32$ at 6 WAP; $F(12,117) = 18.74$ at 8 WAP.

Fertilizer treatment significantly ($P < 0.05$) influenced vine length from 4 to 8 WAP, with no significant difference at 2 WAP (Table 2). The lack of variation at 2 WAP may be attributed to low nutrient demand during the early seedling stage, when plants largely depend on seed reserves and show similar nutrient uptake patterns regardless of treatment [36].

At 4 WAP, the lowest vine length was recorded in T2 (100% compost), followed by T3 (100% cattle manure). This reduced growth may reflect the slow mineralization and gradual nutrient release of organic fertilizers, which may not meet the crop's immediate nutrient requirements during early vegetative growth [37].

At 8 WAP, the highest mean vine length was recorded in T10 (215.08 cm), followed by T4 (190.96 cm), T13 (185.67 cm), T7 (183.22 cm), and T6 (181.11 cm), while the lowest was observed in T2 (99.84 cm). The superior performance of combined treatments over sole organic applications reflects the advantage of integrated nutrient management in sustaining vine growth at later stages, consistent with [38], who noted that compost releases nutrients gradually over an extended period, limiting rapid vegetative growth.

Treatment T10 produced a 28.57% increase in vine length over the control (T1) at 8 WAP. This is consistent with the high nutrient content of poultry manure — particularly nitrogen, phosphorus, potassium, and micronutrients — which promotes vigorous vegetative growth [39] and vine elongation through stimulated leaf development and cell expansion [40], aided by growth-promoting substances such as auxins and gibberellic acid naturally present in poultry manure [41].

The increased vine length under integrated fertilizer application likely reflects the immediate nutrient availability from inorganic sources combined with the sustained release and soil-improving effects of organic manure, enhancing nutrient uptake, photosynthetic efficiency, and assimilate translocation [3]. Sole organic treatments, by contrast, showed comparatively reduced

vine elongation due to limited nutrient availability [42], consistent with [43], who reported increased cucumber vine length with combined NPK and poultry manure application.

3.1.2 Number of leaves

TABLE 3
NUMBER OF LEAVES OF *CUCUMIS ANGURIA* L. AT 2, 4, 6, AND 8 WEEKS AFTER PLANTING (WAP)

Treatments	2 WAP	4 WAP	6 WAP	8 WAP
T1	2.100 ± 0.100 ^a	23.70 ± 2.02 ^{abc}	45.70 ± 1.02 ^{de}	51.40 ± 1.37 ^{de}
T2	2.100 ± 0.100 ^a	16.00 ± 0.894 ^{bc}	36.20 ± 1.91 ^e	41.40 ± 1.91 ^e
T3	2.100 ± 0.100 ^a	14.30 ± 1.47 ^c	37.60 ± 1.17 ^e	42.40 ± 1.53 ^e
T4	2.700 ± 0.153 ^a	24.50 ± 1.72 ^{ab}	76.80 ± 2.87 ^b	83.10 ± 3.53 ^b
T5	2.300 ± 0.153 ^a	27.00 ± 2.33 ^{ab}	55.70 ± 2.60 ^{cd}	59.80 ± 2.52 ^d
T6	2.500 ± 0.167 ^a	27.90 ± 3.61 ^a	54.80 ± 3.71 ^{cd}	60.60 ± 3.40 ^d
T7	2.300 ± 0.153 ^a	27.80 ± 2.32 ^a	55.80 ± 1.57 ^{cd}	62.20 ± 1.85 ^{cd}
T8	2.200 ± 0.133 ^a	25.10 ± 3.53 ^{abc}	55.10 ± 4.38 ^{cd}	59.70 ± 4.17 ^d
T9	2.100 ± 0.100 ^a	18.70 ± 1.95 ^{abc}	41.40 ± 2.46 ^e	47.90 ± 2.35 ^e
T10	2.600 ± 0.163 ^a	24.90 ± 3.10 ^{abc}	95.80 ± 0.854 ^a	100.70 ± 1.37 ^a
T11	2.100 ± 0.100 ^a	18.40 ± 1.44 ^{abc}	38.70 ± 0.895 ^e	42.40 ± 1.17 ^e
T12	2.100 ± 0.100 ^a	16.20 ± 1.85 ^{bc}	37.50 ± 2.13 ^e	41.80 ± 2.21 ^e
T13	2.300 ± 0.153 ^a	27.00 ± 2.21 ^{ab}	59.50 ± 2.40 ^c	72.30 ± 2.00 ^{bc}
F-test	ns	*	*	*

Means ± standard error (n=10 replicates). WAP = weeks after planting; * = significant (P<0.05), ns = non-significant. Means within columns followed by different letters differ significantly by Tukey's HSD test (P<0.05). F(12,117) = 3.42 at 4 WAP; F(12,117) = 42.18 at 6 WAP; F(12,117) = 58.63 at 8 WAP.

Leaf number was significantly (P < 0.05) affected by fertilizer treatment from 4 to 8 WAP, with no significant difference at 2 WAP (Table 3), though T4 and T10 showed numerically higher leaf counts even at this early stage. Poultry manure is known to enhance the population and activity of beneficial soil microorganisms and accelerate humus decomposition, supporting early leaf initiation [44].

At 6 WAP, the highest leaf number (95.8) was recorded in T10, followed by T4 (76.8); T5, T6, T7, T8, and T13 were statistically similar. The lowest counts were in T2 (36.2), T12 (37.5), and T3 (37.6), reflecting the comparatively lower effectiveness of sole organic treatments at this stage.

At 8 WAP, T10 again recorded the highest leaf count (100.7), followed by T4 (83.1) and T13 (72.3) — a 95.91% increase over the control (T1), demonstrating the advantage of integrated nutrient management over single-source fertilization.

This enhanced leaf production likely reflects the balanced nutrient supply from combining fertilizer sources: readily available nutrients from inorganic fertilizer promote rapid early vegetative growth, while the gradual release from poultry manure sustains leaf development at later stages, consistent with the improved nutrient-use efficiency reported for integrated fertilization [45]. Organic manure combined with nitrogen fertilizer has also been reported to increase soil phosphorus availability, further stimulating branching and leaf formation [46]. These findings align with those of [42], [46] and [47] in cucumber and [48] in okra.

3.1.3 Number of branches

TABLE 4
NUMBER OF BRANCHES OF *CUCUMIS ANGURIA* L. AT 4, 6, AND 8 WEEKS AFTER PLANTING (WAP)

Treatments	4 WAP	6 WAP	8 WAP
T1	3.00 ± 0.211 ^{bcd}	4.40 ± 0.221 ^{bcd}	4.80 ± 0.359 ^{bcd}
T2	2.80 ± 0.249 ^{bcd}	3.10 ± 0.314 ^{ef}	3.50 ± 0.224 ^{de}
T3	2.10 ± 0.233 ^d	2.60 ± 0.340 ^f	2.80 ± 0.327 ^e
T4	3.00 ± 0.258 ^{bcd}	6.10 ± 0.233 ^{ab}	8.00 ± 0.298 ^a
T5	3.20 ± 0.249 ^{abcd}	5.20 ± 0.291 ^{abc}	5.40 ± 0.306 ^{bc}
T6	4.50 ± 0.477 ^a	5.10 ± 0.458 ^{abc}	5.40 ± 0.427 ^{bc}
T7	4.00 ± 0.211 ^{ab}	5.70 ± 0.300 ^{ab}	6.10 ± 0.314 ^b
T8	3.30 ± 0.260 ^{abcd}	4.90 ± 0.526 ^{abcd}	5.20 ± 0.467 ^{bcd}
T9	3.10 ± 0.348 ^{abcd}	3.30 ± 0.367 ^{def}	3.60 ± 0.371 ^{cde}
T10	4.00 ± 0.333 ^{ab}	6.20 ± 0.359 ^a	8.10 ± 0.407 ^a
T11	3.10 ± 0.277 ^{abcd}	3.70 ± 0.300 ^{cdef}	4.00 ± 0.394 ^{cde}
T12	2.40 ± 0.427 ^{cd}	3.30 ± 0.367 ^{def}	3.60 ± 0.452 ^{cde}
T13	3.80 ± 0.249 ^{abc}	5.50 ± 0.342 ^{ab}	8.00 ± 0.558 ^a
F-test	*	*	*

Means ± standard error (n=10 replicates). WAP = weeks after planting; * = significant ($P < 0.05$), ns = non-significant. Means within columns followed by different letters differ significantly by Tukey's HSD test ($P < 0.05$). $F(12,117) = 4.18$ at 4 WAP; $F(12,117) = 12.56$ at 6 WAP; $F(12,117) = 32.47$ at 8 WAP.

Branch number differed significantly ($P < 0.05$) among treatments at all sampling stages from 4 to 8 WAP (Table 4), reflecting the strong influence of nutrient management on branching behaviour.

From 4 to 8 WAP, the lowest branch number was consistently recorded in T3 (100% cattle manure); at 8 WAP, T3 showed a 41.67% reduction relative to the control. This may reflect nutrient imbalance and the slower nutrient availability of sole cattle manure, which may favour vertical vine growth over lateral branching, consistent with [32], who observed that higher cow dung rates promoted vine elongation at the expense of branching in cucumber.

At 8 WAP, T4, T10, and T13 were statistically similar. The highest branch number was recorded in T10 (8.1), closely followed by T4 and T13 (8.0) — a 40.91% and 68.75% increase over the control at 6 and 8 WAP, respectively.

The enhanced branching in poultry manure-based treatments likely reflects improved nitrogen availability, which supports protein synthesis and branch initiation [49], consistent with the comparatively higher nitrogen and phosphorus content of poultry manure relative to other organic manures [50]. These findings agree with [51] in gherkin and [42] and [52] in related cucurbits, which documented improved branching under integrated organic-inorganic nutrient management.

3.1.4 Chlorophyll content in leaves

TABLE 5
CHLOROPHYLL CONTENT (SPAD UNITS) OF *CUCUMIS ANGURIA* L. LEAVES AT 2, 4, 6, AND 8 WEEKS AFTER PLANTING (WAP)

Treatment	2 WAP	4 WAP	6 WAP	8 WAP
T1	31.04 ± 1.88 ^a	43.59 ± 3.13 ^c	46.29 ± 2.65 ^c	50.51 ± 4.82 ^c
T2	31.45 ± 1.17 ^a	50.90 ± 1.07 ^{bc}	71.95 ± 5.63 ^b	81.06 ± 7.72 ^b
T3	31.65 ± 1.83 ^a	51.92 ± 3.13 ^{bc}	71.16 ± 3.63 ^b	81.09 ± 5.63 ^b
T4	37.10 ± 2.13 ^a	65.14 ± 5.05 ^{ab}	81.83 ± 3.62 ^b	88.32 ± 4.32 ^b
T5	33.21 ± 1.26 ^a	53.80 ± 2.88 ^{abc}	72.79 ± 6.03 ^b	81.55 ± 6.93 ^b
T6	33.29 ± 1.34 ^a	50.35 ± 4.99 ^{bc}	71.41 ± 7.48 ^b	81.03 ± 8.52 ^b
T7	34.68 ± 1.14 ^a	64.57 ± 3.75 ^{ab}	74.78 ± 4.95 ^b	85.01 ± 6.59 ^b
T8	35.18 ± 1.42 ^a	51.88 ± 2.23 ^{bc}	72.34 ± 6.17 ^b	81.45 ± 7.06 ^b
T9	33.86 ± 1.83 ^a	52.37 ± 4.03 ^{bc}	72.11 ± 6.54 ^b	82.63 ± 5.41 ^b
T10	37.89 ± 1.21 ^a	69.50 ± 1.44 ^a	110.60 ± 3.04 ^a	119.81 ± 3.01 ^a
T11	31.69 ± 1.61 ^a	49.31 ± 2.51 ^{bc}	70.09 ± 5.37 ^{bc}	82.04 ± 6.30 ^b
T12	32.07 ± 1.70 ^a	50.36 ± 3.73 ^{bc}	70.20 ± 5.53 ^{bc}	80.62 ± 7.07 ^b
T13	35.74 ± 1.08 ^a	69.31 ± 2.67 ^a	82.90 ± 3.55 ^b	88.33 ± 3.43 ^b
F- test	ns	*	*	*

Means ± standard error (n=10 replicates). WAP = weeks after planting; * = significant ($P < 0.05$), ns = non-significant. Means within columns followed by different letters differ significantly by Tukey's HSD test ($P < 0.05$). $F(12,117) = 5.82$ at 4 WAP; $F(12,117) = 11.94$ at 6 WAP; $F(12,117) = 10.67$ at 8 WAP.

Chlorophyll content was significantly ($P < 0.05$) affected by fertilizer treatment from 4 to 8 WAP, with no significant difference at 2 WAP (Table 5), consistent with the close link between chlorophyll content and nitrogen-driven nutrient uptake [53]. At 2 WAP, T10 already showed the numerically highest value (37.89) and T1 the lowest.

From 4 WAP onward, T10 (50% inorganic fertilizer + 50% poultry manure) was significantly superior to all other treatments, followed by T13, T7, and T4, while T1 remained consistently lowest. At 6 and 8 WAP, T10 exhibited 138.93% and 137.2% increases over the control, respectively. All fertilized treatments exceeded the control, with combined organic-inorganic treatments producing the highest values overall.

Higher chlorophyll concentration reflects improved nutrient availability and is directly associated with enhanced photosynthetic efficiency and productivity [54]; [55] similarly reported that combined NPK and poultry manure application increased chlorophyll a and b in maize and sorghum relative to sole applications. Poultry manure supplies nitrogen, phosphorus, potassium, and magnesium, all essential to photosynthesis — nitrogen in particular is a structural component of chlorophyll and directly influences chloroplast formation. Nitrogen availability from both mineral and organic sources enhances amino acid and protein synthesis, contributing to chloroplast development and increased chlorophyll content [41], reflecting the synergistic effect of combined organic and inorganic nutrient sources on chlorophyll synthesis in *Cucumis anguria* L.

TABLE 6
LEAF AREA (CM²) AND ROOT LENGTH (CM) OF *CUCUMIS ANGURIA* L. AT 8 WEEKS AFTER PLANTING (WAP)

Treatments	Leaf area(cm ²)	Root length(cm)
T1	1668.6 ± 5.32 ^e	103.47 ± 7.52 ^e
T2	1452.5 ± 1.01 ^h	72.19 ± 4.66 ^g
T3	1462.9 ± 0.677 ^{gh}	72.81 ± 4.20 ^g
T4	3513.7 ± 1.77 ^b	134.32 ± 10.5 ^c
T5	2008.1 ± 2.86 ^d	104.38 ± 9.96 ^e
T6	2022.5 ± 0.877 ^d	114.54 ± 8.73 ^d
T7	2813.3 ± 3.31 ^c	116.79 ± 4.82 ^d
T8	2015.0 ± 0.262 ^d	104.60 ± 11.8 ^e
T9	1635.0 ± 0.551 ^f	106.27 ± 4.61 ^e
T10	4029.7 ± 2.18 ^a	166.98 ± 7.10 ^a
T11	1477.8 ± 4.80 ^g	86.36 ± 2.56 ^f
T12	1472.0 ± 8.22 ^g	85.15 ± 3.12 ^f
T13	3505.6 ± 1.87 ^b	144.78 ± 7.25 ^b
F-test	*	*

Means ± standard error (n=10 replicates). WAP = weeks after planting; * = significant (P<0.05), ns = non-significant. Means within columns followed by different letters differ significantly by Tukey's HSD test (P<0.05). F(12,117) = 67.42 for leaf area; F(12,117) = 18.36 for root length.

3.1.5 Leaf area (cm²)

Fertilizer treatment significantly (P < 0.05) affected leaf area at 8 WAP (Table 6), a key determinant of photosynthetic capacity and light interception [56]. T10 recorded the highest leaf area (4029.7 cm²), followed by T4 (3513.7 cm²), T13 (3505.6 cm²), and T7 (2813.3 cm²); T5, T6, and T8 did not differ significantly. The lowest leaf area was in T2 (1452.5 cm²), a 12.95% reduction relative to the control, likely reflecting nitrogen immobilization and slower mineralization under compost-only application, limiting nutrient availability during rapid vegetative growth [57].

The superior performance of T10 reflects the synergistic effect of combining poultry manure with inorganic fertilizer: integrated nutrient management enhances vine length, internodal length, leaf number, and leaf area [58], [59], while poultry manure improves soil nitrogen levels and physical/chemical properties that promote greater nutrient uptake and leaf expansion [60]. Similar trends of increased leaf area under combined organic-inorganic fertilization have been reported in cucumber [43], garden egg [61], and cassava [62].

3.1.6 Root length (cm)

Root length was also significantly (P < 0.05) affected by fertilizer treatment at 8 WAP (Table 6). The longest roots were recorded in T10 (166.98 cm), followed by T13 (144.78 cm) and T4 (134.32 cm). The shortest root lengths occurred in T2, T3, T11, and T12, with reductions of 30.23%, 29.63%, 16.54%, and 17.71% relative to the control, respectively — likely reflecting the slow and inconsistent nutrient release from sole organic fertilizers, which can limit root expansion during early growth [37]. T6 and T7 did not differ significantly, nor did T1, T5, T8, and T9.

Superior root development under poultry manure-based treatments likely reflects improved soil physical properties: poultry manure increases moisture retention, aeration, and permeability while reducing bulk density, facilitating deeper and more extensive root penetration [63] and improving water-holding capacity, infiltration rate, and erosion resistance [64]. These findings are consistent with [65], who reported significant increases in tomato root length under combined poultry manure and inorganic fertilizer application.

3.1.7 Shoot fresh weight and shoot dry weight (g)

TABLE 7
SHOOT FRESH WEIGHT (G) AND SHOOT DRY WEIGHT (G) OF *CUCUMIS ANGURIA* L. AT 8 WEEKS AFTER PLANTING (WAP)

Treatments	Shoot fresh weight(g)	Shoot dry weight(g)
T1	235.7 ± 20.6 ^{bc}	51.97 ± 6.55 ^{cd}
T2	202.2 ± 13.4 ^c	40.13 ± 5.18 ^d
T3	222.6 ± 21.3 ^c	40.14 ± 7.65 ^d
T4	369.6 ± 36.2 ^b	77.70 ± 3.67 ^{bc}
T5	251.5 ± 25.2 ^{bc}	55.06 ± 7.82 ^{bcd}
T6	275.8 ± 13.8 ^{bc}	53.25 ± 6.04 ^{bcd}
T7	305.9 ± 39.4 ^{bc}	87.70 ± 8.88 ^b
T8	235.8 ± 38.4 ^{bc}	46.48 ± 9.08 ^{cd}
T9	243.4 ± 28.3 ^{bc}	43.16 ± 8.05 ^{cd}
T10	518.2 ± 11.8 ^a	153.69 ± 3.26 ^a
T11	228.4 ± 23.5 ^c	40.74 ± 7.51 ^d
T12	227.8 ± 26.3 ^c	41.54 ± 7.38 ^d
T13	328.8 ± 47.4 ^{bc}	67.70 ± 8.88 ^{bcd}
F-test	*	*

*Means ± standard error (n=10 replicates). WAP = weeks after planting; * = significant (P<0.05), ns = non-significant. Means within columns followed by different letters differ significantly by Tukey's HSD test (P<0.05). F(12,117) = 9.84 for shoot fresh weight; F(12,117) = 16.52 for shoot dry weight.*

Fresh and dry shoot weights differed significantly ($P < 0.05$) among treatments at 8 WAP (Table 7). T10 recorded the highest fresh (518.2 g) and dry (153.69 g) shoot weights — increases of 119.86% and 195.73%, respectively, over the control. The lowest values occurred in T2 and T3, with dry shoot weight 22.7% below the control. Significant differences were driven primarily by T10; T1, T2, T3, T5, T6, T7, T8, T9, T11, T12, and T13 did not differ significantly from each other for fresh weight, nor did T1, T2, T3, T5, T6, T8, T9, T11, T12, and T13 for dry weight.

This enhanced shoot growth in T10 reflects the combined effect of organic and inorganic fertilizers on nutrient availability and dry matter accumulation. Poultry manure contains substantial nitrogen (3.2%), phosphorus (2.2%), and potassium (1.7%), all critical for vegetative growth and biomass production [66]; the added organic manure likely improved soil P and K availability, complementing the rapid nutrient supply from inorganic fertilizer and thereby promoting both shoot and root development [67], [68]. Organic amendments also stimulate soil microbial activity, including phytohormone-producing microorganisms, which enhance nutrient uptake and biomass accumulation [69]. These results align with [70], who reported 19% and 27.3% increases in fresh and dry pepper weights under poultry manure application, and with similar effects reported in corn, tomato, and okra under integrated nutrient management [65], [71].

3.1.8 Root fresh weight and root dry weight (g)

TABLE 8
ROOT FRESH WEIGHT (G) AND ROOT DRY WEIGHT (G) OF *CUCUMIS ANGURIA* L. AT 8 WEEKS AFTER PLANTING (WAP)

Treatments	Root fresh weight(g)	Root dry weight(g)
T1	51.64 ± 2.25 ^{bcd}	8.876 ± 0.421 ^{cd}
T2	16.28 ± 1.05 ^f	3.520 ± 0.242 ^e
T3	31.14 ± 4.68 ^{ef}	6.338 ± 0.570 ^{de}
T4	62.87 ± 4.09 ^b	12.278 ± 0.564 ^b
T5	59.94 ± 1.16 ^b	10.498 ± 0.894 ^{bc}
T6	56.61 ± 1.04 ^{bc}	9.402 ± 0.572 ^{bcd}
T7	64.00 ± 4.66 ^b	12.452 ± 0.818 ^b
T8	42.79 ± 5.86 ^{cde}	7.510 ± 0.424 ^{cd}
T9	39.38 ± 2.68 ^{de}	6.408 ± 0.519 ^{de}
T10	86.68 ± 2.85 ^a	16.896 ± 0.948 ^a
T11	32.59 ± 1.11 ^{ef}	6.478 ± 0.728 ^{de}
T12	31.83 ± 5.68 ^{ef}	6.446 ± 0.451 ^{de}
T13	66.31 ± 1.07 ^b	12.178 ± 0.560 ^b
F-test	*	*

*Means ± standard error (n=10 replicates). WAP = weeks after planting; * = significant (P<0.05), ns = non-significant. Means within columns followed by different letters differ significantly by Tukey's HSD test (P<0.05). F(12,117) = 14.28 for root fresh weight; F(12,117) = 22.15 for root dry weight.*

Fresh and dry root weights also differed significantly ($P < 0.05$) among treatments at 8 WAP (Table 8); root biomass reflects assimilate partitioning within the plant, influenced by species, developmental stage, and environmental conditions [72]. T10 recorded the highest fresh and dry root weights — 67.85% and 90.36% increases over the control, respectively — while T2 recorded the lowest, with reductions of 68.48% and 60.35%.

As discussed above for shoot growth, the superior root development in T10 likely reflects the same combination of nutrient-rich poultry manure and rapidly available inorganic nutrients, improved soil P/K availability, and stimulated microbial activity supporting root elongation and biomass accumulation [67], [69]. These results are consistent with previous reports of increased root biomass under combined organic-inorganic fertilization [68], [65].

3.1.9 Yield parameters

TABLE 9
YIELD PARAMETERS OF *CUCUMIS ANGURIA* L. AT 8 WEEKS AFTER PLANTING (WAP)

Treatments	Number of fruits	Yield per vine(kg)	Yield per hectare(tons/ha)
T1	16.50 ± 1.74 ^{bcde}	0.532 ± 0.182 ^{bc}	5.32 ± 1.82 ^{bc}
T2	8.80 ± 1.04 ^e	0.2815 ± 0.0563 ^c	2.82 ± 0.563 ^c
T3	10.70 ± 1.56 ^{de}	0.3319 ± 0.0643 ^{bc}	3.32 ± 0.643 ^{bc}
T4	22.20 ± 2.90 ^{bc}	0.803 ± 0.146 ^{bc}	8.03 ± 1.46 ^{bc}
T5	18.80 ± 1.16 ^{bcd}	0.588 ± 0.113 ^{bc}	5.88 ± 1.13 ^{bc}
T6	17.20 ± 1.93 ^{bcde}	0.5601 ± 0.0707 ^{bc}	5.60 ± 0.707 ^{bc}
T7	22.80 ± 2.03 ^b	0.840 ± 0.172 ^b	8.40 ± 1.72 ^b
T8	15.10 ± 2.60 ^{bcde}	0.4670 ± 0.0814 ^{bc}	4.67 ± 0.814 ^{bc}
T9	12.50 ± 1.54 ^{de}	0.3883 ± 0.0710 ^{bc}	3.88 ± 0.710 ^{bc}
T10	32.50 ± 2.52 ^a	1.461 ± 0.184 ^a	14.61 ± 1.84 ^a
T11	13.10 ± 1.30 ^{cde}	0.4002 ± 0.0609 ^{bc}	4.00 ± 0.609 ^{bc}
T12	11.50 ± 1.55 ^{de}	0.3638 ± 0.0608 ^{bc}	3.64 ± 0.608 ^{bc}
T13	20.30 ± 3.03 ^{bcd}	0.8334 ± 0.0913 ^b	8.33 ± 0.913 ^b
F-test	*	*	*

Means ± standard error (n=10 replicates). WAP = weeks after planting; * = significant (P<0.05), ns = non-significant. Means within columns followed by different letters differ significantly by Tukey's HSD test (P<0.05). F(12,117) = 8.94 for fruit number; F(12,117) = 7.62 for yield per vine; F(12,117) = 7.62 for yield per hectare.

Fruit number, yield per vine, and yield per hectare were significantly (P < 0.05) influenced by fertilizer treatment at harvest (Table 9). T10 recorded the highest number of fruits (32.5), yield per vine (1.461 kg), and yield per hectare (14.61 t/ha) — a 174.62% increase over the control — with no significant differences in yield per hectare among the remaining treatments. Considerable yields were also obtained in T7 (8.4 t/ha), T13 (8.33 t/ha), and T4 (8.03 t/ha), while the lowest yields occurred in T2 (2.82 t/ha) and T3 (3.32 t/ha), relative to the control (5.32 t/ha).

The superior fruit yield in T10 likely reflects the combined effect of poultry manure and inorganic fertilizer in enhancing vegetative growth and reproductive development. Poultry manure supplies essential macronutrients (N, P, K) and micronutrients (Ca, Mg, S, Cu, Na, Fe, Mn, B, Mo, Zn) critical for photoassimilate synthesis and fruit formation [61], while also improving soil nutrient availability, bulk density, and water-holding capacity, supporting faster meristematic cell division and nutrient uptake [60]. Microbial populations in poultry manure further sustain nitrogen mineralization, meeting crop nitrogen demand throughout the growth period [73]. These results are consistent with reported increases in fruit number and yield under integrated fertilization in cucumber [47] and okra [71], [48], indicating that combining inorganic fertilizer with poultry manure is an effective strategy to maximize yield in *Cucumis anguria* L.

3.1.10 Cost-benefit analysis

TABLE 10

COST-BENEFIT ANALYSIS OF *CUCUMIS ANGURIA* L. UNDER DIFFERENT FERTILIZER TREATMENTS (RS./HA)

Treatment	Yield (t/ha)	Total Cost (Rs./ha)	Total Income (Rs./ha)	Net Profit (Rs./ha)
T1	5.32	477,941.50	319,200.00	-158,741.50
T2	2.815	517,300.00	168,900.00	-348,400.00
T3	3.319	480,940.00	199,140.00	-281,800.00
T4	8.03	510,100.00	481,800.00	-28,300.00
T5	5.88	487,783.45	352,800.00	-134,983.45
T6	5.601	478,723.45	336,060.00	-142,663.45
T7	8.40	485,893.45	504,000.00	18,106.55
T8	4.670	497,625.40	280,200.00	-217,425.40
T9	3.883	479,505.40	232,980.00	-246,525.40
T10	14.61	494,025.40	876,600.00	382,574.60
T11	4.002	507,463.99	240,120.00	-267,343.99
T12	3.638	480,163.99	218,280.00	-261,883.99
T13	8.334	501,613.99	500,040.00	-1,573.99

The cost-benefit analysis (Table 10) shows T10 (50% inorganic fertilizer + 50% poultry manure) as the most economically viable treatment, achieving both the highest yield (14.61 t/ha) and the highest net profit (Rs. 382,574.60/ha) once full production costs — fertilizer, labor, irrigation, pest management, and trellising — were included. This represents an increase of Rs. 541,316.10/ha over the net loss recorded under the control, T1 (Rs. -158,741.50/ha). Only T7 (Rs. 18,106.55/ha) also achieved a positive net profit; all other treatments, including sole poultry manure (T4) and 25% inorganic + 75% poultry manure (T13), resulted in net losses despite relatively high yields in some cases.

These results indicate that the economic advantage of T10 is not attributable to yield alone but to an efficient balance between input cost and productivity. The combined application of 50% inorganic fertilizer and 50% poultry manure therefore represents the most practical and profitable strategy for farmers seeking sustainable and economically viable *Cucumis anguria* L. production in the dry zone of Sri Lanka. The economic analysis was based on a single season and a farm-gate price of Rs. 60/kg, consistent with the prevailing local market price offered by gherkin outgrower buyers in the study region during the study period. Multi-season analysis and sensitivity to input prices would further strengthen these conclusions.

IV. CONCLUSION

Treatment T10 (50% inorganic fertilizer + 50% poultry manure) was consistently the most effective for enhancing the growth, yield, and profitability of *Cucumis anguria* L. under dry-zone conditions, remaining economically viable alongside T7 once full production costs were considered. These results demonstrate that combining poultry manure with inorganic fertilizer improves nutrient-use efficiency more effectively than either source applied alone, and the 50:50 combination is recommended for farmers in Sri Lanka's dry zone to optimize *Cucumis anguria* L. production.

Limitations of the Study: The study was conducted as a pot experiment, which may not fully reflect field conditions where root growth is unrestricted and soil-plant interactions are more complex. The study was conducted over a single season at a single location; multi-season and multi-location trials are needed to confirm the generalizability of the findings. Soil properties before and after the experiment were not fully characterized, which limits the interpretation of nutrient dynamics. The growing medium contained cow dung, which may have contributed nutrients in addition to the applied treatments. Future research should include field validation, multi-season trials, soil nutrient dynamics analysis, and assessment of long-term effects on soil health.

Future Research Directions: Future studies should: (1) validate these findings under field conditions; (2) assess the long-term effects of the recommended treatment on soil health and productivity; (3) evaluate the economic viability over multiple seasons and under varying market conditions; (4) investigate the mechanisms of nutrient synchronization between inorganic and organic sources; and (5) examine the residual effects on subsequent crops.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to this study.

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