International Journal of Botany Studies
www.botanyjournals.com
ISSN: 2455-541X
Received: 19-11-2025, Accepted: 18-12-2025, Published: 02-01-2026
Volume 11, Issue 1, 2026, Page No. 13-17

The effects of coconut shell biochar with different levels of inorganic fertilizers on growth and yield of potted *Cucumis anguria* L. (var. Chandani)

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Abstract
The integration of coconut shell biochar with inorganic fertilizers can enhance crop productivity and soil fertility. A polybag experiment was conducted at the University Farm, Eastern University, Sri Lanka, to evaluate the effects of coconut shell biochar combined with different levels of inorganic fertilizers on the growth and yield of *Cucumis anguria* L. (var. Chandani). The experiment used a Completely Randomized Design (CRD) with six treatments and five replicates: T1 (100% inorganic fertilizer), T2 (100% coconut shell biochar 22 t/ha), T3 (25% inorganic fertilizer + coconut shell biochar 22 t/ha), T4 (50% inorganic fertilizer + coconut shell biochar 22 t/ha), T5 (75% inorganic fertilizer + coconut shell biochar 22 t/ha), and T6 (100% inorganic fertilizer + coconut shell biochar 22 t/ha). Crop growth and yield were recorded from 2 to 8 weeks after planting. Results showed that T6 significantly improved vine length (14.38%), number of branches (28.94%), leaves (11%), chlorophyll content (16.23%), leaf area (42.35%), shoot fresh weight (42.73%), shoot dry weight (46.30%), root fresh weight (31.79%), root dry weight (36.04%), fruit number (46.30%), yield per vine (68.18%), and total yield (69.32%) compared to T1. These findings highlight the potential of integrating Coconut shell biochar with 100% inorganic fertilizer application to enhance *Cucumis anguria* growth and yield, which is environmentally friendly and contributes to sustainable agriculture.

Keywords: Coconut shell biochar, inorganic fertilizer, *Cucumis anguria*, growth parameters, and yield parameters

Introduction

Gherkin (*Cucumis anguria* L.), an annual trailing vine of the gourd family, is also known as bur gherkin or west Indian gherkin. It is cultivated for its edible fruit. The gherkin plant is cultivated in warm climates worldwide and is most likely native to southern Africa. Though the "gherkins" that are sold in commercial pickle mixtures are typically tiny, immature fruits of the common cucumber, gherkin fruits can be served raw, cooked, or pickled. Gherkin plants can be grown in any season of the year. It primarily gives family members of landowners and landless workers in rural areas work opportunities (Neelambika *et al*., 2024) [12]. Gherkin grows best in areas up to 1000 meters above sea level. The crop favors average daytime temperatures above 22°C, more than 8 hours of sunlight per day, and an annual rainfall of 1500–2000 mm, well-distributed throughout the year. For optimal development, the soil should be well-drained and rich in organic matter, while saline soils are unsuitable. Red sandy loam soil with good drainage and a pH of 6.5–7.5 is ideal for gherkin cultivation. The crop has angled, slender, rough, hairy stems and tendrils that branch freely (Prabaharan *et al*., 2025) [17].

In comparison to cucumbers, gherkin fruits are smaller. The fruits are dark green in color, range in length from 4.0 to 6.0 cm, and have a diameter of 1.5 to 2.0 cm. The main morphological difference is that the fruits' surfaces are rough or undulating, whereas cucumbers' fruit surfaces are relatively smooth (Bairagi *et al*., 2019) [4]. Due to its ability to generate quick income, gherkin cultivation has gained popularity in many parts of Sri Lanka over the last three decades. Major gherkin-growing areas in the country include Ampara, Mahaweli System B, Monaragala, Polonnaruwa, Badulla, Puttalam, Matale, Anuradhapura, and Kurunegala (Abeyrathna *et al*., 2013) [1].

Sustainable agricultural intensification that increases crop production per unit land area is considered an effective strategy to ensure food security for the growing global population. In this context, biochar has emerged as a promising solution and is being widely studied worldwide for its potential advantages. Biochar contains high carbon content and has distinctive physical and chemical properties. Biochar can significantly improve soil quality and crop yield while also enhancing carbon sequestration and reducing greenhouse gas emissions such as CO_2, N_2O, and CH_4 (Vijay *et al*., 2021) [21].

Biochar can be produced from different feedstocks such as shells, nuts, and wood (Kapoor *et al*., 2022) [9]. Coconut shell biochar, which is characterized by its high pH and large micropore surface area, is especially effective in improving soil fertility and availability of nutrients. Its application has been shown to increase crop growth. Due to these physical chemical properties, coconut shell biochar is considered a valuable soil modification to promote crop yield and improve overall soil quality (Zhao *et al*., 2019) [25].

Therefore, this study was undertaken to evaluate the effects of coconut shell biochar with different levels of inorganic fertilizers on growth and yield of *Cucumis anguria* L. in the dry zone of Sri Lanka.

Materials and methods

Experimental site

A polybag experiment was carried out in the university farm, Faculty of Agriculture, Eastern University of Sri Lanka in Palachcholai during the period of July to September 2025. It is located in the latitude of 7°48′42.2″ N and the longitude of 81°35′31.1″ E. This site categorized under the Agro Ecological Zone of low country dry zone (DL2b).

Climate and soil condition

The annual average temperature varies from 26.36ºc to 36.98ºc and the precipitation level on a yearly basis amount varies from 1400 mm to 1680 mm. The soil condition of the area is Sandy Regosols.

Collection of seeds

Certified seeds of gherkin (*Cucumis anguria* L.) variety Chandini RZ F1 (12-79) were used for this experiment.

Treatment structure

There were six treatments and five replications.
T1-100% inorganic fertilizer (Control)
T2-100% coconut shell biochar (22 tons/ ha)
T3-25% inorganic fertilizer with coconut shell biochar (22 tons/ha)
T4- 50% inorganic fertilizer with coconut shell biochar (22 tons/ha)
T5-75% inorganic fertilizer with coconut shell biochar (22 tons/ha)
T6-100% inorganic fertilizer with coconut shell biochar (22 tons/ha)

Experimental design

The poly bag experiment was laid out in Completely Randomized Design with six treatments with five replicates. A number of 30 polybags were used in this experiment.

Preparation of poly bags

This experiment was conducted using UV treated polybags. The size of the polybag was 30×30 cm. A number of 4 holes were made at the bottom of each polybag to facilitate the drainage of excess water. The polybags were filled with top soil, compost and cow dung in the ratio of 1:1:1. A distance of 2 inches was left unfilled from the top of the media to facilitate the irrigation.

Recommended fertilizer application

According to the treatment design, Urea, Triple Super Phosphate (TSP), and Muriate of Potash (MOP) were applied following the recommendations of the Department of Horticulture, Government of Tamil Nadu. The fertilizers were given in three equal splits during the crop cycle, with the basal dose applied two days before planting, followed by top dressings at 3 and 5 weeks after planting.

Table 1: Fertilizer recommendation

Urea(kg/ha)	TSP (kg/ha)	MOP (kg/ha)
150	75	100

Biochar application

Coconut shell biochar was commercially sourced from Riviera Resort, Kallady, Sri Lanka. Larger biochar pieces were crushed into smaller particles using a mortar and pestle before application. After preparing the polybags, the biochar was evenly incorporated by hand into the top 6–10 inches of the polybag media prior to the addition of basal fertilizer. For this study, biochar was applied at a rate of 22 tons per hectare (Laghari *et al*., 2015) [10].

Data collection

Vine length was recorded weekly throughout the growing period using a measuring tape. The total number of leaves and branches was also counted on a weekly basis. Leaf area was determined at the end of the experiment using a leaf area meter (LI–3100, USA), while chlorophyll content was assessed weekly with a chlorophyll meter (SPAD–502 Plus). Fresh and dry weights of shoots and roots were measured using an electronic balance (BSA822–CW, Germany). The total number of pods, total weight of all pods harvested from each vine was recorded. The total yield per hectare was calculated by aggregating the yield data from all plants.

Statistical analysis

The data collected in this experiment were subjected to one-way analysis of variance (ANOVA) using Minitab 17 Statistical Software and means were compared by Tukey's test at 5% significant level.

Results and Discussion

Vine length

Table 2 revealed that there is a significant difference ($p<0.05$) between treatments on vine length of *Cucumis anguria* L. at 8 WAP. Treatment 6 (100% inorganic fertilizer + coconut shell biochar) exhibited the highest vine length of 159.04 cm compared with T1 (control). Treatment 2 (only coconut shell biochar) recorded the lowest vine length of 116.44 cm. Graber *et al*. (2010) [7] reported that biochar improved pepper and tomato growth even under adequate water and fertilizer, mainly by promoting plant health, encouraging beneficial microbes, and releasing compounds that stimulate plant growth and defense. Furthermore, Biochar enhances soil physical and chemical properties, including aeration, nutrient retention, and water holding capacity (Premalatha *et al*., 2023) [18], which may have contributed to the increased vine length observed in this study.

Number of leaves

According to Table 2, there was no significant difference ($P>0.05$) among T1, T4, T5, and T6 for the number of branches at 8 WAP. However, Treatment 6 recorded the highest number of leaves (92.80), followed by T5 (90.00), T4 (85.00), and T1 (83.60). Treatment 6 (100% inorganic fertilizer + coconut shell biochar) produced a higher number of leaves than the control (T1), representing an 11% increase. These results align with Wekgari *et al*. (2024) [23], who reported that integrating inorganic fertilizer with biochar significantly increases leaf production compared to using either input alone. The increase in leaf number with higher fertilizer levels may be attributed to enhanced nitrogen availability, which promotes cell division, cell elongation, and photosynthetic efficiency in biochar-amended soils. Similar findings were also reported by Agegnehu *et al*. (2016) [2], who observed improved fertilizer use efficiency and greater plant growth when biochar was combined with inorganic fertilizer.

Number of branches

As shown in Table 2, there is a significant difference ($p<0.05$) in the number of branches among the treatments. Treatment 6 (9.8) recorded the highest number of branches at 8 WAP, followed by T5 (9.2), while T2 (100% coconut shell biochar) had the lowest. Compared to the control (T1), T6 showed a clear increase in branch number. The combined use of biochar and nitrogen fertilizer likely improved soil quality, promoting plant growth by increasing height, tiller number, and leaf size. This effect may be attributed to enhanced nutrient availability, reduced nutrient losses, higher levels of P, K, Ca, and Mg, and improved soil structure with reduced acidity (Oladele *et al*., 2019) [14], which likely contributed to the increased number of branches observed in this study.

Chlorophyll content

Table 2 showed that there is a significant difference (p<0.05) between treatments in chlorophyll content. At 8 WAP, T6 (65.72) recorded the highest chlorophyll content, followed by T5 (62.12), T1 (56.54), T3 (54.36), and T4 (52.24), with no significant differences (P > 0.05) among them, while T2 (26.90) was significantly lower. T6 showed a 16.23% increase in chlorophyll content over the control (T1). These results are consistent with studies in peanut (Arachis hypogaea L.), where biochar application significantly increased leaf nitrogen content (Wang *et al*., 2021) [22]. Biochar has been shown to enhance nitrogen assimilation and chlorophyll concentration in flag leaves (Ali *et al*., 2020) [3], which may explain the higher chlorophyll content observed in gherkin in the present study.

Table 2: Effect of coconut shell biochar combined with different levels of inorganic fertilizers on vine length, number of leaves, number of branches and chlorophyll content of leaves at 8 WAP of *Cucumis anguria* L

Treatments	Vine length (cm)	Number of leaves	Number of branches	Chlorophyll content
T1	139.70 ±2.06^{c}	83.60±2.42^{ab}	7.6±0.24^{cd}	56.54±6.05^{a}
T2	116.44±2.94^{e}	70.60±2.99^{c}	6.6±0.40^{d}	26.90±0.76^{b}
T3	127.50±3.82^{d}	77.00±2.61^{bc}	8.4±0.24^{abc}	54.36±2.29^{a}
T4	140.12±1.30^{bc}	85.00±1.10^{ab}	8.0±0.31^{bcd}	52.24±2.55^{a}
T5	150.22±1.92^{ab}	90.00±2.53^{a}	9.2±0.37^{ab}	62.12±4.07^{a}
T6	159.04±1.12^{a}	92.80±1.88^{a}	9.8±0.37^{a}	65.72±3.40^{a}
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)

There is a significant difference (p<0.05) among the treatments in the leaf area as shown in Table 3. T6 recorded the highest leaf area (6184 cm²), followed by T5 (5614 cm²), with no significant difference between them (P > 0.05). T2 showed the lowest value (2390 cm²) and was significantly different from all other treatments. T6 (100% inorganic fertilizer + coconut shell biochar) produced a 42.35% higher leaf area than the T1(control). According to Graber *et al*. (2010) [7] reported that biochar combined with appropriate fertigation improves leaf area and overall plant vigor. Similarly, Hui (2021) [8] reported that biochar enhances plant biomass production, which may contribute to increased leaf area. Thus, the observed increase in leaf area with T6 aligns well with established biochar effects on soil and plant growth, confirming that the integration of biochar with inorganic fertilizer enhances leaf development and overall plant productivity in *Cucumis anguria* L.

Root length (cm)

According to the findings derived from the statistical analysis, there is significant (p<0.05) difference in root length due to the effect of coconut shell biochar combined with different levels of inorganic fertilizer (Table 3). T6 showed the highest root length (1871.8 cm), followed by T5 (1849.8 cm), with no significant difference between them (P > 0.05). T6 recorded a 22.43 percent increase in root length compared to the control (T1,1528.8 cm) and was significantly different from it. The present study is consistent with Xiang *et al*. (2017) [24], who reported that the application of biochar significantly improved root traits, including increases in root biomass, surface area, root length, and the number of root tips. This indicates that biochar mainly enhances root morphology, thereby improving nutrient and water uptake rather than directly increasing overall biomass. Similarly, Dunsin *et al*. (2016) [6], observed that kale (*Brassica oleracea*) can achieve better growth when cultivated in soil amended with biochar. Plants grown in biochar-amended soil exhibited enhanced vegetative growth, including increased plant height, root length, and fresh and dry biomass, along with higher yield, improved mineral content, and nutrient content compared to plants receiving only chemical fertilizer.

Table 3: Effect of coconut shell biochar combined with different levels of inorganic fertilizer on root leaf area, root length of *Cucumis anguria* L.

Treatments	Leaf area (cm²)	Root length (cm)
T1	4344 ± 115 b	1528.8 ± 4.96 c
T2	2390 ± 36.6 d	857.86 ± 5.40 e
T3	3424 ± 116 c	1247.2 ± 11.2 d
T4	4633 ± 158 b	1572.9 ± 5.64 b
T5	5614 ± 171 a	1849.8 ± 16.00 a
T6	6184 ± 170 a	1871.8 ± 7.73 a
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.

Shoot fresh and dry weight (g)

As demonstrated in Table 4, there is a significant difference (p<0.05) among the treatments in shoot fresh weigh and dry weight. The highest fresh and dry shoot weights were recorded in T6, followed by T5. However, the difference between T6 and T5 was not significant (P > 0.05). The improved shoot growth may be attributed to interactions between biochar and soil microorganisms, which enhance nutrient availability and soil water retention. Such effects can vary with biochar type and pyrolysis temperature (Olszyk *et al*., 2020) [15]. Furthermore, Zhao *et al*. (2024) [26] found that combining biochar with chemical fertilizer improved soil properties and increased cabbage biomass compared to using chemical fertilizer alone.

Root fresh and dry weight (g)

As shown in Table 4, root fresh and dry weights differed significantly among treatments ($p < 0.05$). The highest values were recorded in T6, followed by T5, although the difference between these two treatments was not significant ($p > 0.05$). Compared to T1 (100% inorganic fertilizer), T6 (100% inorganic fertilizer + coconut shell biochar) produced significantly higher fresh and dry root weights. Similar findings were reported by Li *et al*. (2022) [11], who observed that adding biochar to saline sodic paddy soil enhanced root length, volume, dry weight, and the root shoot ratio across all growth stages. Furthermore, the combined application of biochar and fertilizer resulted in higher fresh and dry root weight than biochar or fertilizer applied alone, indicating that biochar enhances nutrient retention and uptake, which promotes root biomass development (Ng`andu and Taulu, 2025) [13].

Table 4: Effect of coconut shell biochar with different levels of inorganic fertilizer on shoot fresh weight, shoot dry weight, root fresh weight and root dry weight of *Cucumis anguria* L.

Treatment	Shoot fresh weight (g)	Shoot dry weight (g)	Root fresh weight (g)	Root dry weight (g)
T1	309.53±1.66^{b}	57.34±0.82^{c}	95.07±2.07^{c}	12.79±0.32 ^{b}
T2	155.02±5.60^{d}	46.94±1.29^{d}	61.82±3.51^{d}	8.33±0.21^{c}
T3	229.30±3.96^{c}	52.28±0.51^{cd}	71.91±3.16^{d}	9.91±0.50^{c}
T4	313.43±2.36^{b}	65.45±1.72^{b}	111.30±3.33^{b}	12.92±0.13^{b}
T5	431.45±3.13^{a}	77.96±2.11^{a}	120.03±2.62^{ab}	15.46±0.91^{a}
T6	441.81±2.87^{a}	83.89±1.82^{a}	125.30±2.18^{b}	17.40±0.46^{a}
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.

Yield parameters

The overall analysis demonstrated that T6 (100% inorganic fertilizer + coconut shell biochar) significantly ($p < 0.05$) outperformed the other treatments in terms of number of pods per vine, yield per vine and total yield (Table 5). These results align with Osaji *et al*. (2017) [16], who reported that biochar application enhances soil fertility, resulting in longer cucumber vines, increased fruit number, and greater fruit length. Biochar's ability to modify soil acidity and increase cation exchange capacity enhances nutrient availability, thereby supporting improved crop productivity and overall yield (Biederman and Harpole, 2013) [5]. Similarly, Sadiq *et al*. (2024) [19] found that combining biochar with inorganic NPK fertilizer improved soil quality and increased cucumber yield. These findings further support the present study, where integrating biochar with inorganic fertilizers enhanced nutrient use efficiency and total yield in *Cucumis anguria*.

Table 5: Effect of coconut shell biochar with different levels of inorganic fertilizer on number of pods per vine, yield per vine and total yield *of Cucumis anguria L.*

Treatment	Number of fruits per vine	Yield per vine (kg)	Total yield (tons/ha)
T1	11.40±0.92^{c}	1.10±0.12^{b}	13.79±1.57^{b}
T2	3.40±0.51^{d}	0.27±0.03^{c}	3.37±0.47^{c}
T3	10.60±0.74^{c}	1.08±0.10^{b}	13.59±1.31^{b}
T4	12.40±1.29^{bc}	1.22±0.13^{b}	15.33±1.65^{b}
T5	16.00±1.00^{ab}	1.77±0.09^{a}	22.24±1.21^{a}
T6	18.80±0.49^{a}	1.85±0.07^{a}	23.35±1.00^{a}
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.

Conclusion

The analysed data showed that T6 (100% inorganic fertilizer + coconut shell biochar) was significantly superior across all growth and yield parameters of *Cucumis anguria* L. Treatment 6 recorded the highest yield per vine (1.85 kg). Similarly, T6 achieved the highest total yield per hectare (23.35 tons/ha). Application of coconut shell biochar with inorganic fertilizers gives a sustainable and ecofriendly approach to enhancing crop productivity in sandy soils while reliance on inorganic fertilizers.

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