Growth and Yield of Gherkin (Cucumis Sativus) Under Different Agronomic Practices: A Sustainable Approach

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***Abstract*: Resource use efficiency and food safety are key features of agricultural sustainability. In this study, two sets of experiments were conducted to evaluate the impact of, 1. amending potting media and 2. adding different fertilizers on the growth and yield of gherkin. Two potting media were considered (conventional potting media: M1, field soil: M2) in experiment 1. The corncob (CC); 5%,10%,15% and corncob biochar (CCBC); 5%, 10% were mixed with potting media. Experiment 2 was conducted by incorporating a homemade organic fertilizer (T1), market-available organic fertilizer (T2), and conventional inorganic fertilizer (T3). The experiments were conducted in a controlled environment. In experiment 1, the days taken to first flowering, days taken to first fruit settling, the weight of the harvest, the number of fruits in both media and relative growth rate were comparatively high in 5% CCBC amended potting media. In experiment 2, the best vegetative growth rate was observed in T3and T2 (mean plant height of the last week 148.8 and 147.9 cm, mean leaf growth 4.9 and 5.6 cm, and mean node growth 16 and 15 respectively), whereas the lowest was reported in T1 (97.1, 5.1, 10.5). However, the highest average yields were recorded in T3 and T1 without showing a significant difference. T1; the homemade organic fertilizer resulted in a substantial yield at a low cost.**

***Keywords*: gherkin, corncob, organic cultivation, biochar**

I. INTRODUCTION

The world is moving fast; sustainable consumption and the adoption of resources are essential (Jonker & Harmsen, 2012). The resources available on the earth would be enough only for the Global Ecological Footprint equivalent to one Earth ("one planet"). If it were two Earths, we would need twice as many resources as Earth's capacity. Currently, the Ecological Footprint is equivalent to 1.6 Earths (Zhang et al., 2022). Thus, there is a more significant trend in reusing waste materials in agricultural production (Arfanuzzaman & Atiq Rahman, 2017). However, the quality of products and the environmental cost of production should remain the same while adopting low-cost solutions to agricultural and agronomic practices of agricultural output. Moving toward organic products is another trend in many sectors, including agriculture (Mpanga et al., 2021; Oyetunde-Usman et al., 2021).

Cucumis sativus, commonly called gherkin or pickling cucumber, comprises the cucurbitaceous family. Gherkin is affluent in nutrients (Ca, K), vitamins (A, B1, B2, and C), and energy (Schreinemachers et al., 2018; Yoon et al., 2015) and is widely used in food processing industries. Gherkin is a tropical species vastly grown in Australia, Sri Lanka, and India. World cucumber and gherkin production in 2018 recorded 3.9E+07 metric tons. Gherkin is one of the leading export vegetables of Sri Lanka. In 2018-2019, Sri Lankan cucumber and gherkin production was recorded at 34,864 metric tons harvested from 2555 ha (Department of National Botanic Gardens, 2019). China, Australia, Taiwan, Malaysia, Japan, and Netherland are the targeted markets of the Sri Lankan gherkin.

The demand for organic cucumber is increasing daily. However, organic gherkin production in Sri Lanka is far behind the market. The production should be escalated to fulfill the demand; promoting sustainable technologies is required to manage the available resources to meet targets. Supplementing plant nutrients and enhancing nutrient retention capacity leads to plants' healthy growth and higher yields (Baldi, 2021). Infertility of media is a significant factor in reduction in the yield and growth of most crops since there is a lack of sustainable solutions to restore media fertility. However, adding a suitable mixing material such as biochar has been identified as a potential strategy for minimizing such issues (Kocsis et al., 2020; Mpanga et al., 2021). Corn Cob (CC) is a widespread waste material thrown away from corn (maize) cultivating lands. Typically, one corn plant produces 8.2% cobs on a dry matter basis (Lardy, 2011). Referring to previous studies (Blandino et al., 2016), CC has properties as a soil amendment and potting media in agriculture. Further, waste corncobs are good sources of biochar production and are commonly used as a bioenergy source (Djousse Kanouo et al., 2019). CC and Corn Cob BioChar (CCBC) might enhance soil's chemical and physical properties, such as water holding capacity, nitrogen use efficiency, and organic matter content. Further, adding CC or CCBC may reduce bulk density and improve the soil's porosity and ion exchange capacity. Corncob contains macro elements like N, P, S, and K. Thus, this study evaluated the effects of mixing CC and CCBC at different mixing ratios on gherkin crop performances.

Further, it is imperative to open up the potential pathways of organic gherkin cultivation in Sri Lanka. A few organic fertilizers are available commercially in the country.

However, out of that, very few commercial trades are suitable for gherkin cultivation. Thus evaluating the applicability of those fertilizers in gherkin cultivation is essential. Further, homemade organic fertilizer mixtures are identified as solutions to the above requirements (Melvani et al., 2020). Therefore, this study also focused on estimating the effect of using different organic fertilizers on gherkins' growth and yield performances.

II. MATERIALS AND METHODS

This study consists of two main experiments. The first sets of experiments were conducted to evaluate the effect of mixing different crop residues into the potting media on the growth and yield of gherkins. Secondly, the impact of adding different organic fertilizers was analyzed on the growth and yield of gherkin. The plants were grown under protected houses.

Location

The research study was conducted in Kurunegala district, Sri Lanka, a low country wet zone at 58m from mean sea level. The research was carried out from mid-October to mid-January 2020.

Evaluation of the impact of amending potting media on the growth and yield performance of gherkins

Preparation of CC and CCBC

Waste CCs were collected from farmland and air-dried. The dried CC was ground using a grinder and sieved using a 2mm sieve; coarse and fine CC particles were separated. The coarse and fine particles were mixed in a 1:1 ratio and mixed with the media in pre-desired proportions. Corncob particles larger than 2mm were collected and prepared as biochar using the double barrel method (Hariz et al., 2015). The CCBC were mixed with the media in pre-desired ratios on the weight basis, as shown in table 1.

The experiment was expanded considering the potting media. The recommended media used in protected houses is a composite mixture of coir pith, compost, and sand. In contrast, the gherkins are also planted in the topsoil in the open field applications. Thus, recommended composite mixture (M1) and topsoil (M2) collected from the open field were used as potting media. After air-dried, the potting media were prepared to mix with amendments, CC and CCBC. CC and CCBC were combined with different mixing ratios with two potting media, to evaluate the effect on the growth and yield of the gherkin.

Table 01: CC and CCBC mixing ratios in different treatments

Treatment	Media- M1/ M2 (%)	CC (%)	CCBC (%)
T1	95	5	-
T2	90	10	-
T3	85	15	-
T4	95	-	5
T5	90	-	10
T6 (Control)	100	-	-

The experiment was laid out as a Completely Randomized Design (CRD) experimental design. All the treatments were replicated three times. Each experimental plot contained five plants, and each treatment comprised 15 plants; thus, the total number of plants was 180. The amended media (M1 and M2) were filled into the 18x9 inch black polyethylene (200 gauges) bags. Pots were arranged with 90 cm of inter-row space and 45 cm space with two pots. One seed was planted in a media pot. Pots were irrigated manually until two weeks to prevent possible damage by the automated irrigation system. After two weeks of seeding, automated irrigation was started. The recommended fertilizer mixture was added to plants via the irrigation system, and a foliar application was made as per the recommendation. Crop supporting and removing cotyledon leaf, pruning and were managed in a timely manner. Gherkin growth and yield were recorded as shown in table 2.

The effect of mixing CC and CCBC on the Water Holding Capacity (WHC) of the media

The effect of mixing CC and CCBC in different mixing ratios on WHC of the gherkin potting media was evaluated by performing a pot experiment. The CC and CCBC amended media were filled into 18x9 inch black polyethylene (200 gauge) bags, and pots were arranged with leaching collection pots. The pots were irrigated with 1200 ml of water, and the leachate was collected after one hour. The volume of the leachate was noticed, and the WHC was calculated using equation 1 below. This was repeated for five weeks at one-week interval.

$$WHC=100-((\text{leached water amount})/(\text{Applied water amount})*100) \quad (1)$$

(Brischke & Wegener, 2019)

Evaluation of the impact of adding different kinds of fertilizer on the growth and yield of gherkin

The effects of adding a homemade fertilizer and a market available fertilizer on gherkin growth and yield was compared with the recommended fertilizer application.

Preparation of fertilizer and application schedule

Treatment 1: The basal dressing was done by altering the potting media using compost, cow dung, and half-burned paddy husk (Sand 1: Compost 2: Cow dung 1: Half burned paddy husk 1). The homemade fertilizer was prepared using poultry litter-soaked filtrate and rock phosphate. Poultry litter was soaked in water with a mixing ratio of 2 kg to 10 L Additionally, 10 kg of rock phosphate was dissolved in 1 L of 0.1% Sulphuric acid and later diluted with 10 l of water. Seven hundred fifty (750) ml from both solutions were added to each plant weekly.

Treatment 2: A market-available organic fertilizer with an N: P: K ratio of 4:4:2 was applied 150 g per plant weekly. The recommended media for the protected house gherkin; Coir dust 3: Sand 2: Compost 1 was used as the potting media.

Treatment 3: As the third treatment the recommended fertilizer application {Albert-(10-9-16), Yaramilla-(16-16-16), Urea-(46-0-0), TSP-(0-46-0), MOP-(0-0-60), MgSO4-(0-0-0), Ca (NO3)2- (15.5-0-0)} was practiced. The potting media used was the recommended media for the protected house gherkin; Coir dust 3: Sand 2: Compost 1.

Experimental Design

The growth and yield of gherkin plants were evaluated under three different treatments (T1, T2, and T3). The experimental plots were prepared to achieve a CRD arranged with 15 plants with three replicates. Each treatment contained 45 plants, altogether 135 plants for three treatments. The parameters exemplified in table 2 were measured in order to evaluate the effect of different treatments.

Table 2: Parameters observed in experiment 1 and experiment 2

Parameter	Experim ent 1	Experim ent 2
Relative growth rate	X	X
Plant height after germination.	X	X
Days took to first flowering.	X	
Time is taken to the first fruit setting.	X	
Weight of harvest per treatment	X	X
Number of fruits per treatment	X	X

Data Analysis.

Relative Growth Rate (RGR) was calculated to evaluate the difference of plant height changes among treatments over the time.

$$RGR=\ln〖S2-\ln S1〗/((t2-t1)) \quad (2)$$

(Poorter & van der Werf, 1998)

Where, ln; natural logarithm, t1; time one, t1; time two, S1; size one at time one, S2; size two at time two.

Data were analyzed by the Statistical Analysis System (SAS) 2019 package. All the data obtained were subjected to Analysis of Variance (ANOVA). Means were separated using Tukey's Studentized Range Test (TRST) and Dunnett's Test for experiment 1 and experiment 2, respectively. In Experiment 2, the means of T1; homemade organic fertilizer, T2; market available organic fertilizer was compared with the means of T3; market available inorganic fertilizer. Further, mean values obtained from TRST and Dunnett's tests were used to plot bar charts.

III. RESULTS AND DISCUSSIONS

Weather parameters

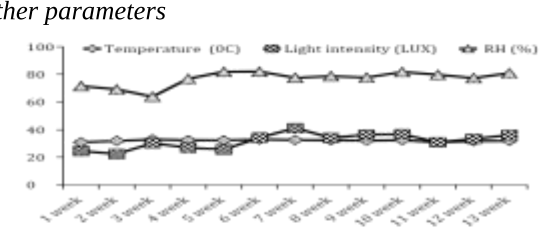


Figure 1: Variation of the weather parameters during the research study

Figure 1 represents the variation of temperature, light intensity and relative humidity throughout the study period. There were no extreme conditions reported during this period and assumed there was no abiotic stress for the plants.

Effect of mixing crop residues into the potting media on the growth and yield performance of gherkins

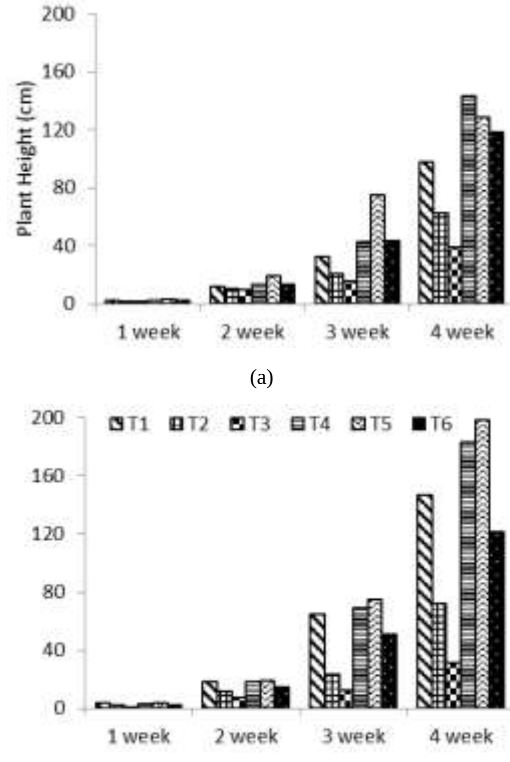


Figure 2: The effect of adding CC and CCBC on weekly plant growth in (a) M1 media (b) M2 media

Figure 2 exemplifies the weekly plant height of gherkin over four weeks of six treatments. The average plant height was noticeably higher in the potting media prepared with topsoil (M2) than the conventional recommended composite mixture in all the treatments. An outstanding plant height was observed in CCBC treated plants over the other in both M1 [Figure 2 (a)] and M2 [Figure 2 (b)] media. As shown in Figure 2 (a), 5% and 10% CCBC plants had the maximum average plant heights, higher than the control. Further, a decreasing trend of plant height with the increasing CC mixing ratios was also observed. In M2 media (topsoil amended), the average plant height of the T5 was comparatively higher during the plant growth. Further, the average plant height of the 5% CC amended plants (T1) was noticeably higher than the control. However, 15% of CC amended plants (T3) showed the lowest average plant height during all four weeks of the growth stage in M1 and M2. According to the statistical analysis (ANOVA), no significant difference was observed at a 0.05 level of probability among the tested treatments in M1 and M2 media. According to the Nguyen & Drakou, (2021), most sustainable way of enhancing the soil quality without damaging the biological balance is by adding crop residues, which are beneficial to soil physicochemical properties.

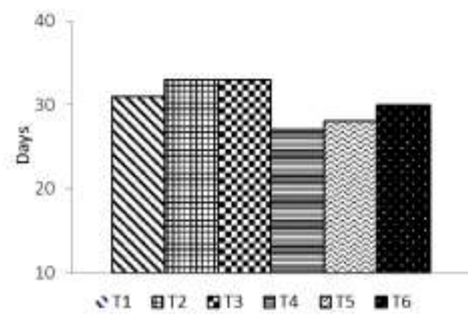
Table 3 and 4 shows the RGR observed among treatments both in M1 and M2 media. The highest RGR was recorded in the CCBC mixed and control treatments in both media facilitated by faster and individual accumulate biomass. Furthermore, the lowest was detected in the CC treated pots.

Table 3: Relative Rate of Growth of M1 in experiment 1

Treatment	RGR
T1M1	0.125
T2M1	0.123
T3M1	0.131
T4M1	0.152
T5M1	0.134
T6M1	0.146

Table 4: Relative Rate of Growth of M2 in experiment 1

Treatment	RGR
T1M2	0.139
T2M2	0.128
T3M2	0.123
T4M2	0.147
T5M2	0.150
T6M2	0.147



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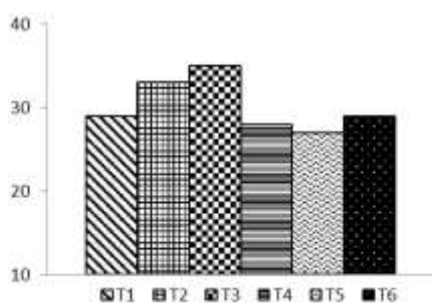
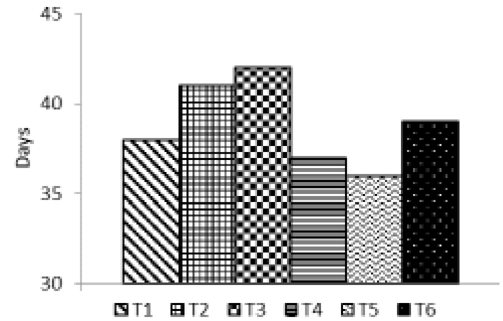


(b)

Figure 3: Time took to start flowering in (a) M1 media (b) M2 media

The time taken for the first flowering in different treatments are shown in Figure 3. The shortest time was observed in CCBC treated plants in both media, whereas the longest was observed in 15% CC treated plants. A significant difference was observed among treatments in both M1and M2 media at 0.05 level of probability.



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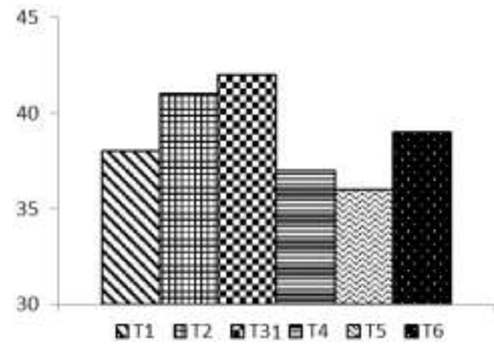
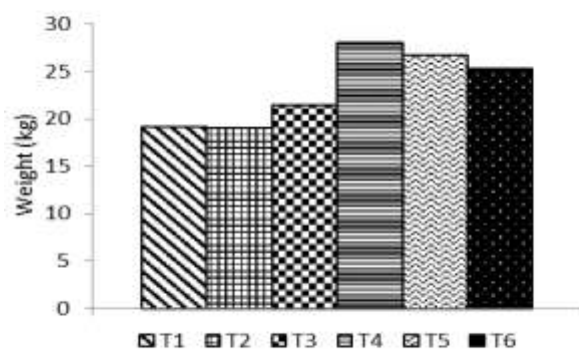


(b)

Figure 4: Time took to first fruit settling in (a) M1 media and (b) M2 media.

Figure 4 shows the average time taken for the first fruit setting of the different treatments in M1 [Figure 4 (a)] and M2 [Figure 4 (b)] media. The lowest average time taken for the first fruit setting was observed in both media at 10% CCBC treated plants, whereas the longest time was observed in 15% CC treated plants. The time taken by the untreated plants were higher than all CCBC treated plants and 5% CC treated plants. However, it was observed that the increasing percentage of CC had extended the average time taken for the first fruit setting. According to the statistical analysis (ANOVA- TRS Test), a significant difference is observed at a 0.05 level of probability among M1 and M2 media treatments.



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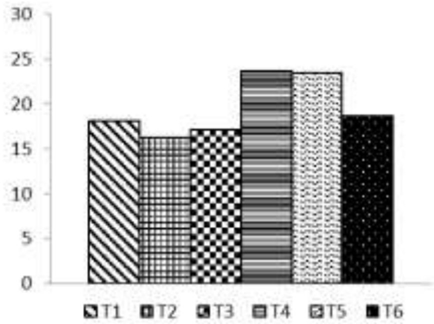
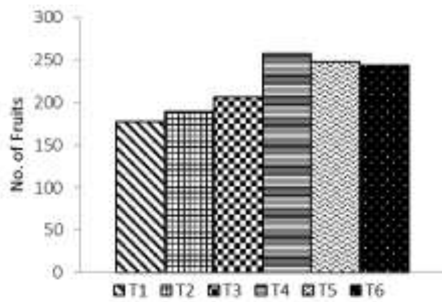


(b)

Figure 5: The average weight of the harvest in (a) M1 media (b) M2 media

The average fruit weight of the plants grown under M1[Figure 5 (a)] and M2 [Figure 5 (b)] media is shown in Figure 5, and there is no disparate difference observed. However, the highest fruit weights were observed in CCBC treated plants in both media, whereas lower weights were observed in CC-treated plants. According to the statistical analysis (ANOVA-TRS Test), there is a significant difference observed in M1 media for all tested treatments at a 0.05 level of probability, and the p-valve was 0.045. However, there was no significant difference observed in M2 media, and the p-value was 0.77.



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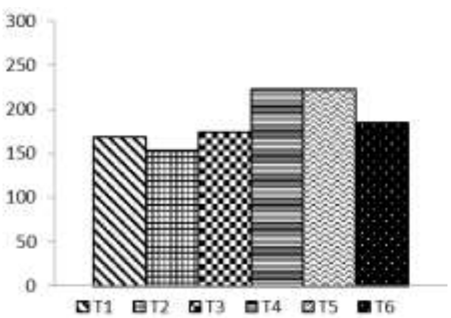
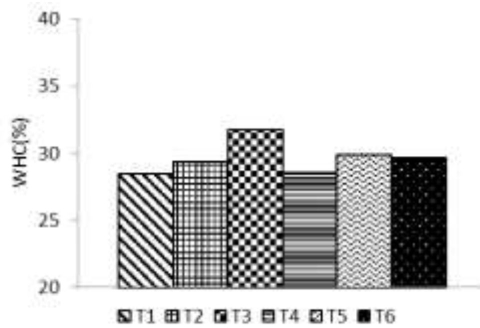


(b)

Figure 6: The average fruit count of the harvest in (a) M1 media (b) M2 media

The average fruit count under the tested conditions is shown in Figure 6. As presented there, the maximum average fruit count was observed in CCBC treated plants. Furthermore, the average fruit count of CC-treated plants was lesser than the control. The same scenario was observed in both M1 and M2 media. However, the average fruit count of the M1 media was higher than that of M2 media for the tested treatments. According to the statistical analysis (ANOVA- TRS Test), a significant difference was observed among the treatments done for M1 media, at a 0.05 level of probability. The p valve (0.034) was less than the targeted CI level. However, no significant difference was observed among the treatments done for M2 media. Moreover, a study by Djousse Kanouo et al., 2019, revealed that maize straw and corn cob biochar could improve the soil properties, nutrient retention, and plant growth.

Effect of mixing crop residues into the potting media on Water holding capacity



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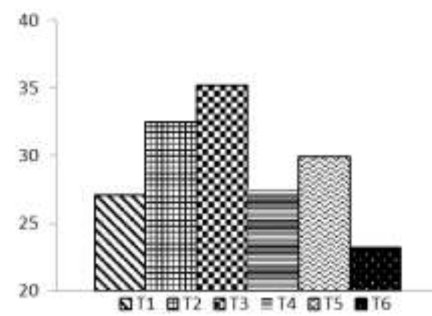


(b)

Figure 7: The water holding capacity of (a) M1 media (b) M2 media

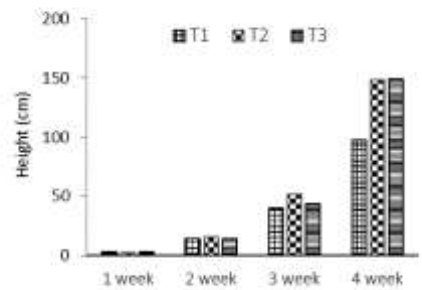
Figure 7 represents the WHC of the tested amendments mixed with two different media, M1 and M2. There is no observable difference in WHC in M1 media [Figure7 (a)]; statistical analysis also shows no significant difference and a 0.05 CI level. This might cause by the high organic matter content in M1 media due to the coir pith and compost.

However, in M2 media, the WHC increased with the increasing CC mixing ratio [Figure 7 (b). The same pattern was observed in the CCBC amended treatments; however, the WHC of the CCBC treated potting mixture was lower than the CC treated one. Furthermore, the WHC of all the tested treatments was higher than the control treatment in M2 media, the topsoil. According to the statistical analysis (ANOVA-TRS Test), a significant difference is observed at the 0.05 confidence level. The organic matter content might be lower in the topsoil than in the M1 potting media. Adding CC and CCBC directly affects the organic matter content in the M2 potting mixture, which might enhance the WHC of the media.

Biochar improves the soil porosity, and aggregate stability and lowered the bulk.

density. Further, Sawdust and corn cobs derived biochar has shown the significant capability to use for sustainable soil and crop management (Phares et al., 2020; Siedt et al., 2021; Verheijen et al., 2010).

The effect of the use of different organic fertilizers in gherkin growth and yield performances



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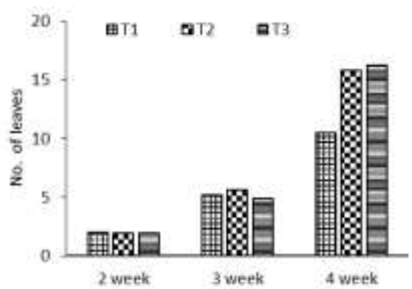

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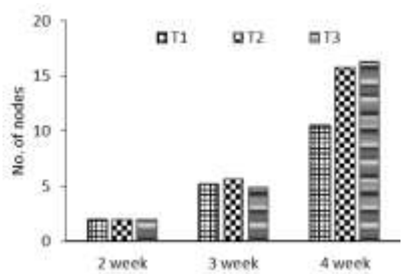


(c)

Figure 8: The average plant height (a), number of plant leaves per plant (b) and the average number of nodes per plant (c) observed under tested conditions

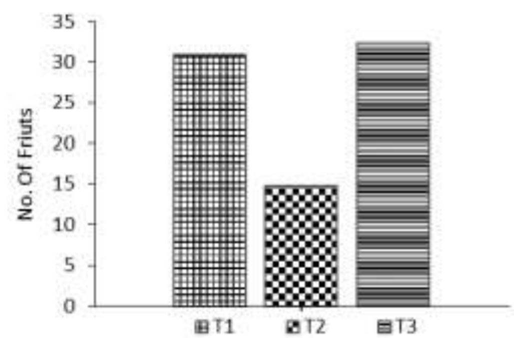
Figure 8 shows the plant growth performances; the average plant height [Figure 8 (a)], the average number of leaves per plant [Figure 8 (b)], and the average number of nodes per plant [Figure 8 (c)] under the tested conditions. There was no notable difference in the average plant height, the number of plant leaves per plant or the average number of nodes per plant in all the tested treatments up to the third week of planting. However, from the 3rd week onwards, the maximum growth performances reported in all the tested growth parameters were higher in treatments 3 and 2 than in treatment 1, the homemade organic fertilizer. Thus, it was noticed that the best vegetative growth rate was observed in T3, and there was no significant difference in vegetative growth between T3, control treatment and T2, the commercial organic fertilizer application. At the same time, the significant lowest vegetative growth was reported at T1treatment, the homemade fertilizer application. Moreover, Khan et al., (2019) concluded that the fertilizer mixture which contained equal percentages of FYM, Poultry manure, Vermi Compost and NPK was the best treatment combination among the tested treatments of organic and inorganic fertilizer in terms of growth and yield attributes of cucumber.

Another study on cucumber growth has revealed that the combined application of farmyard manure and inorganic fertilizer was the best combination in their cropping practices (Eifediyi & Remison, 2010).

Table 6 shows the RGR showed by different treatments. According to the RGR calculations the highest was recorded by T2 and T3, whereas the lowest by T1. This reveals the greater nutrient availability and resource acquisitions at the T2 and T3 media than the T1 media. T1 media; a composition of slow nutrient releasing medium might facilitate continuous and slow nutrient releasing pattern (Shaji et al., 2021).

Table 6: Relative Rate of Growth (RGR) observed in experiment 2

Treatment	RGR
T1	0.124
T2	0.139
T3	0.139



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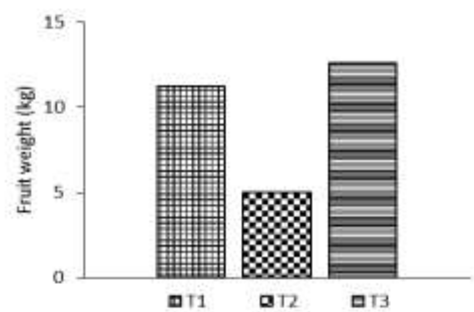

(b)

Figure 9: Effect of the different treatments on the number of fruits per plant (a) and fruit weight per plant (b)

Figure 9 shows the average plant yield parameters; the number of fruits per plant [Figure 9 (a)], and fruit weight per plant [Figure 9 (b)] obtained in different treatments. The highest average number of fruits was observed in treatment 3, followed by treatment 1. However, there is no significant yield difference in T3 and T1; homemade organic fertilizer application. Significant lowest yield performance was shown in treatment 2. These results agree with (Mae Z et al, 2022) who revealed that the addition of organic fertilizers increases the plant growth and yield of the cucumber plant.

The cost comparison

Although Sri Lankan farmers also earn comparatively high net profit from gherkin production, low-cost, high-quality ingredients with lesser environmental impact are more critical in gherkin cultivation. Table 3 illustrates the average cost per plant spent for potting media and fertilizer usage in different treatments.

Table 5: The average cost per plant spent for potting media and fertilizer application in different treatments

Treat ment	Ingredient	Unit price (LKR)	Number of units required	Total price (LKR)
T1	Sand	13.50	54 kg	729.00
	Compost	12.00	108 kg	1296.00
	Cow dung	15.00	54 kg	810.00
	Paddy husk	10.00	54 kg	540.00
	Poultry litter	5.00	20 kg	100.00
	0.1% H_2SO_4 Acid	180.00	10 L	1800.00
	Rock Phosphate	30.00	10 kg	300.00
	Total price for 45 plants			**5575.00**
	Price per plant			**123.00**
T2	Coir dust	20.00	135 kg	2700.00
	Sand	13.50	90 kg	1215.00
	Compost	12.00	45 kg	540.00
	Market available organic fertilizer	35.00	100 kg	3500.00
	Total price for 45 plants			**7955.00**
	Price per plant			**176.00**
T3	Coir dust	20.00	135 kg	2700.00
	Sand	13.50	90 kg	1215.00
	Compost	12.00	45 kg	540.00
	Market available inorganic fertilizer			12645.00
	Total price for 45 plants			**17100.00**
	Price per plant			**380.00**

For each treatment, 45 plants were used; thus, according to the calculation, the lowest cost per plant was noticed in T1 (123.00 LKR), the homemade fertilizer application. The highest price; is 380.00 LKR per plant spent in T3. However, when considering the yield performances, T1 gives a considerable yield without a significant difference from the T3 yield at a low cost.

IV. CONCLUSIONS

Amending the potting media is an integral activity in maximizing resource use efficiency in agriculture. The concept was examined using CC and CCBC on the growth and yield of gherkin. According to the results obtained, the CCBC mixed media performed well than the raw CC. The days taken to first flowering, days taken to first fruit settling, the weight of the harvest, the number of fruits in both media, relative growth rate was comparatively high in CCBC amended potting media. Among the CCBC amended potting mixtures, the 5% CCBC mixing ratio was the best. However, the highest WHC was observed in raw CC amended topsoil, while the lowest was observed in the non-amended top soil media.

Improving Cucumber organic production under protective houses becomes extremely important to meet the increasing demand. Thus, a set of experiments was conducted to evaluate the impact of incorporating a homemade organic fertilizer (T1), market available organic fertilizer (T2), and compared the yield and growth performances of gherkin with market available inorganic fertilizer (T3). According to the recorded results, it was noticed that: the best vegetative growth rates were observed in T3 and T2, whereas the lowest was reported in T1. However, the yield performances were high in T3 and T1. The lowest yield was reported in T2. There was no significant difference in the average number of fruits and average fruit weight between T1 and T3. The lowest cost per plant was notified in T1; the homemade fertilizer application. However, T1 gives a considerable yield at a low-cost when considering the yield performances.

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