Growth And Yield Performance of Salad Cucumber (*Cucumis sativus. L*) Cultivated in Novel Potting Mix Enriched with Recycled Plant Tissue Culture Media

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Abstract

Plant tissue culture media waste contains large quantities of essential macro- and micronutrients that are beneficial for commercial plant growth and development. This study explored an environmentally sustainable approach to manage Banana Tissue Culture Waste Media (BTCWM) by incorporating it into a novel growing medium for cultivating salad cucumber (cv. Bonafide F1). A greenhouse experiment was conducted using a completely randomized design with seven different treatments with fifteen replications namely T1 control { 100% coconut coir dust (CD)}, T2 (BTCWM 50%+ CD 40% + sand 10%), T3(BTCWM 40%+ CD 50% + sand 10%), T4 (BTCWM 30% + CD 50% + sand 20%), T5 (BTCWM 20%+ CD 50% + sand 30%), T6 (BTCWM 10%+ CD 50% + sand 40%), T7 (BTCWM 50%+ CD 50%). Our results showed that plant growth varied significantly across treatments. At 11 weeks after planting, T4 and T7 produced the longest vine lengths (871 cm), while T1 had the shortest (860 cm). T7 also demonstrated the highest leaf diameter (25.5cm) and vine diameter (5.9cm) than that of T1 and T2. At the 7 WAP, T7 and T5 exhibited the highest flower production rates, with 8.3 and 7.4 flowers per week respectively, surpassing the control (5.1/week). Subsequently, T7 also led in fruit weight (50.4 g/fruit), followed by T5 (49.2 g/fruit), while the control produced the lowest (29.2 g/fruit). Among all treatments, T7 (50% BTCWM + 50% coir dust) showed the most promising results, suggesting that the plant tissue culture waste media can be utilized in promoting salad cucumber production.

Keywords: Banana tissue culture waste media, Coconut coir, growth media, salad cucumber

I. INTRODUCTION

Plant tissue culture is regarded as a fundamental method for crop propagation in modern agriculture. This research addresses the limited study on using waste-mixed media by focusing on banana tissue culture waste. Disposal of waste plant tissue culture media often leads to nutrient loss and environmental pollution. This is viewed as both a source of environmental pollution and a missing opportunity for resource recovery. This waste is a recognized source of nutrient loss and environmental pollution (Hamdeny et al., 2022) due to its content of residual chemical fertilizers, plant growth regulators (phytohormones), and potential microbial contaminants. Plant tissue culture media is often considered a biohazard because it has been used to grow plant tissues (explants) and might harbor microorganisms (bacteria, fungi) from the culture or the lab environment. Furthermore, the discharge of even trace amounts of artificial phytohormones and heavy metal ions can potentially disrupt the natural development and reproductive cycles of native flora and algae. The current challenge is viewed as both an environmental hazard and a missing opportunity for resource recovery. By converting waste plant tissue culture media into greenhouse substrates, dual benefits are achieved: waste is reduced, and alternative substrates that fulfil the physical and chemical requirements for plant growth are created (Sharma et al., 2019). Salad cucumber *(Cucumis sativus L.)* is an important vegetable crop worldwide and is considered an important vegetable due to its nutritional and culinary value (Shahul et al, 2015). Good management practices are essential for producing high yields of a quality crop.

Recent investigation shows that supplying balanced nutrients with macronutrients like

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nitrogen (N), phosphorus (P), and potassium (K) enhance vegetative growth, flowering, and fruiting. Secondary macronutrients like calcium (Ca) and magnesium (Mg), and micronutrients such as boron (B), iron (Fe), and zinc (Zn), though required in smaller amounts, are also vital for salad cucumber (Moreno et al., 2003). Conversely, deficiencies and/or excesses in any of these nutrients can produce physiological abnormalities associated with lower growth rates, lower fruit yields, and lower fruit quality. As Waste tissue culture media contain essential macronutrients (nitrogen, potassium, phosphorus) and micronutrients essential for plant growth and development, as well as organic compounds such as hormones and vitamins that enhance cellular function (Nasution, 2020). This research was conducted to develop a novel potting mixture utilizing banana tissue culture waste media and to explore the synergistic potential of reusing this waste media as a sustainable substrate component to develop promote salad cucumber (*Cucumis sativus* L.) cultivation.

II. MATERIALS AND METHODS

A. *Study area*

This study was carried out in a semi-automated controlled greenhouse facilities at Mike Flora Pvt Ltd in Rajagiriya, Sri Lanka, The semi-automated greenhouse featured day/night temperature at 26ºC/24ºC, humidity (70-75%), and light (<1800μmolm^{-2}s^{-1}) were adjusted to ensure optimal plant growth and development throughout the trial. The insect-proof net (mesh size 60) and side walls of the greenhouse were washed, and fumigation was carried out using insecticide (Abamectin 18 ml/l) prior to the experiment. The study area experiences annual rainfall of approximately 2500 mm and temperatures ranging from 25°C to 30°C.

B. *Preparation of the potting media and the crop management.*

The coconut coir dust and river sand were collected from the local suppliers and were sterilized by using Captan (1g/ll) and covered using transparent polythene for a week before formulating seven growing media by mixing with banana tissue culture waste media (BTCWM), coconut coir and sand in predetermined weight ratios (Table 01).

Table 01: Treatment regime of novel greenhouse potting mixtures for salad cucumber cultivation

Treatments	Composition of potting media (w/w ratio)		
	Banana tissue culture waste media	**Coconut Coir**	**Sand**
T1(Control)	-	100%	-
T2	50%	40%	10%
T3	40%	50%	10%
T4	30%	50%	20%
T5	20%	50%	30%
T6	10%	50%	40%
T7	50%	50%	-

Seeds of the salad cucumber variety (*cv.* Bona Fide F1 hybrid) were sown on 5l volume of U.V treated polybags with the above modified growth media (Table 01). A total of 105 polybags were used for seven treatments, with one seed sown per pot. Germination percentages over a period of nine-days were recorded. Drip irrigation was used to maintain consistent moisture levels. Three weeks after seed germination, salad cucumber vines were trained on nylon strings to grow upward. Subsequently, at four weeks after planting, pruning of mature leaves, stems, and side branches were practiced on weekly basis (Chand, 2014).

C. *Experimental Design and Data Analysis*

A completely Randomized Design (CRD) was used for this experiment, with seven treatments and fifteen replications. A comprehensive assessment protocol was implemented to ensure robust monitoring and analysis of plant growth and productivity. Starting the week after seed germination, weekly evaluations were recorded for critical growth metrics such as plant height, diameter, branch and leaf count, and leaf dimensions. Subsequently, at reproductive stage, the flower developmental rates (Number of flowers/week/plant) were recorded. At harvest, fruit traits viz; fruit count, length, diameter, and fresh weight were measured and final yield were determined at plant levels. Finally, the collected data were subjected to an analysis of variance (ANOVA) was performed using SPSS (25 Vision) software to analyze the data and a Turkey post- hock test was performed to find out the significance between the treatments at P<0.05.

III. Results and Discussion

A. Production of leaves

The data show the average number of leaves per plant for different substrate potting mixtures, A total of 90 to 100 leaves were produced by the individual salad cucumber plants. None of the treatments showed a significant (P > 0.05) difference in leaf production rates among the treatments. (Figure 02).

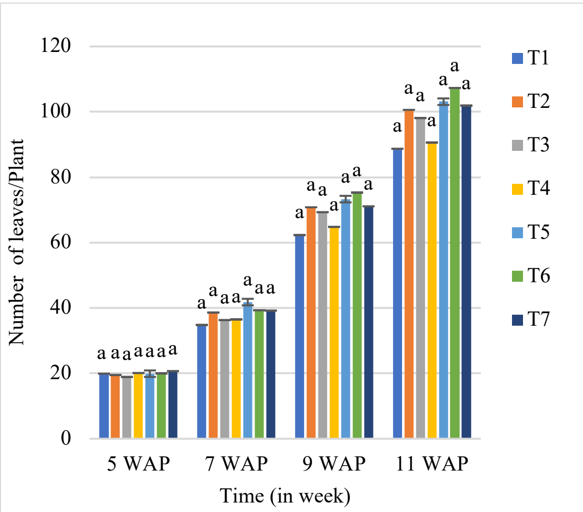

Figure 02: Number of leaves produced in salad cucumber with various potting media during 5-11Weeks ffter planting

B. Leaf Length(cm) and Leaf Width (cm)

The study found significant differences (P < 0.05) in leaf length among treatments. At 11 weeks after planting (WAP), plants grown in T7 (50% WATCM and 50% coconut coir mixture) had the largest leaf length (25.5 cm) and leaf width (25.7 cm), and the smallest was in T2 leaf length (23.1 cm) and leaf width (23.0 cm) which are smaller than those in the control treatment (T1). These differences may be due to influence of nutrient availability, water retention, and aeration provided by the different mixtures.

According to , the in Johnson and Mirza, (2020) proved leaf length might be due to the presence of nitrogen as it is essential for the plant right from sowing to the growth and development of the plant. Increases the vegetation of the crop, size of the leaves increases which enhances the photosynthetic activity of the plant. These findings agree with Monib et al. (2023) , who found that micronutrients such as B, Zn, Cu, Fe, and Mn has been proven to improve plant height, number of branches/plant, fruit length, fruit diameter, fruit yield/ha, and marketable fruit yield/ha in crops such as tomato and cauliflower.

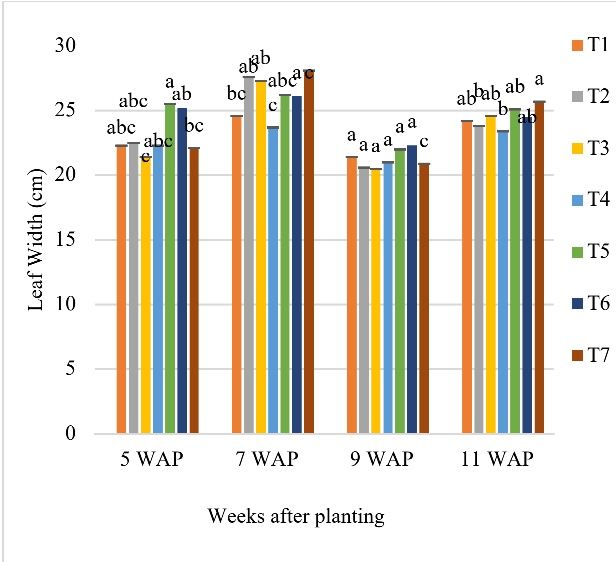

Figure 03: Leaf width (cm) of salad cucumber growth from 5-11 week after planting.

C. Vine length (cm)

Vine length was significantly (P<0.05) affected by different media treatments. The longest vines (871 cm) were recorded in T4 and T7 at 11 weeks after planting (WAP). The shortest (860 cm) vine length was in T1 (control) at 11 weeks after planting (WAP). It might be due to the presence of all the required nutrients, vitamins and amino acids are present in the tissue culture media. WATCM can serve as a source of nutrients and organic matter, potentially enhancing plant growth. However, the composition of WATCM varies, and its effects may depend on the specific source and processing methods.

The addition of Banana Tissue Culture waste media has a positive impact on plant development since they contain essential nutrients and improved physical properties of soil (Awasthi et al., 2015; Goyal et al. 2005). Coconut coir acts as a substrate for agricultural purposes and because of its characteristics regarding water retention

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and aeration, it can positively affect plant development (Abad *et al.*, 2005). Media containing low concentrations of BTCWM showed the poorest performance compared to the 50% concentration, likely due to a deficiency in critical nutrients. This observation supports the findings of Johnson and Mirza (2020), who emphasized that both nutrient deficiencies and excesses can lead to various physiological disorders in plants and their fruits.

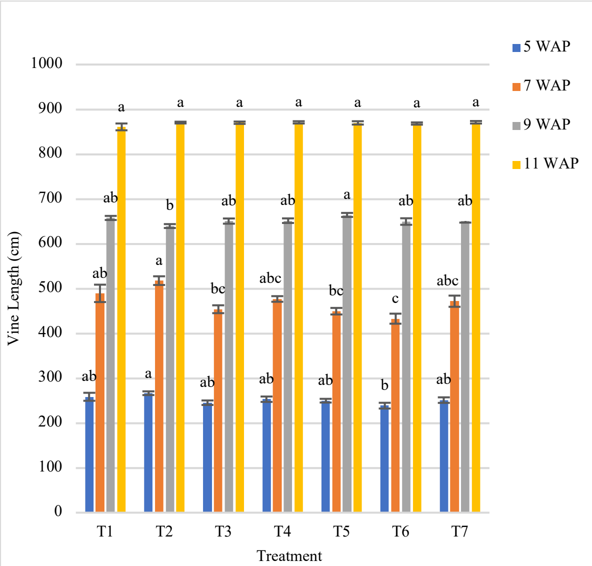

Figure 04: Leaf Length(cm) of salad cucumber from 5 to 11 week after planting.

D. Vine diameter

The significant ($p<0.05$) differences in vine diameter started to occur from 9 WAP. At 9 WAP, the highest vine diameter (5.6cm) was observed in both the control treatment (T1: 100% coconut coir dust) and treatment T7 (BTCWM 50% + CD 50%). The lowest vine diameter at 9 WAP (4.6 cm) was reported in treatment T3 (BTCWM 40% + CD 50% + sand 10%). When compared to control (T1), treatments T2, T4, T5 and T6 were significantly similar ($p>0.05$) (5.3, 5.2, 5.4 and 5.4 cm, respectively) while T3 had a lower diameter (4.8cm). Similarly, at 11 WAP, the control treatment (T1) and treatment T7 again demonstrated the highest vine diameters, both reaching 5.9cm. The greatest vine growth at T7 might be associated with the presence of sand, while improving drainage might have diluted the organic matter and nutrient availability, or altered the water retention characteristics in T3 to a suboptimal level, thereby hindering vine growth (Goyal et al., 2005). Schroeder (2014), stated that the vine diameter is an important indicator of the overall viability of the plant and its photosynthetic capacity, which influences yield, indicating that substrate composition had a major effect on plant growth variables.

E. Weekly Flower production rate

Flowering data were systematically recorded at weekly intervals, commencing at 4 WAP, and continuing until 11 WAP. Statistical analysis revealed a significant difference in the number of flowers among the treatments at 6 WAP, 7 WAP, 9 WAP, and 11 WAP ($P<0.05$). At 6 WAP, the highest mean number of flowers was observed in treatment T6 (5.2 flowers/week) (BTCWM 10% + CD 50% + Sand 40%) followed by T7 (4.6 flowers/week) (BTCWM 50% + CD 50%), with a significant difference in flower numbers when compared to other treatments, including the control (3.4 flowers/week). At 7 weeks after planting (WAP), flower production reached its peak, with Treatment T7 (BTCWM 50% + CD 50%) recorded the highest mean number of flowers at 8.3/week. This was followed by Treatment T5 (BTCWM 20% + CD 50% + Sand 30%), which had a mean of 7.4 flowers.

At 9 WAP, T5 continued to perform well compared to the control, recording a mean flower count of 5.5, followed by treatment T7 with 4.9 flowers. However, the difference between T5 and T7 was not statistically significant. By 11 WAP, treatment T5 (BTCWM 20% + CD 50% + Sand 10%) maintained the highest mean number of flowers at 5.9, followed closely by T7 with 5.5 flowers. Both treatments recorded significantly higher flower counts than the control (T1), which had a mean of 3.1 flowers. The differences in significance between weeks suggest that the potting media used to grow the plants had an effect on flowering that appears to be dynamic, or the difference is more prominent in specific physiological periods in the reproductive life cycle of the plant (Shibaeva et al., 2013).

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Table 02: Effects of potting mixture on the production of flowers in salad cucumber (flowers/plant/week).

Treatments	5 WAP	7 WAP	9 WAP	11 WAP	Total flowers/plant
T1	1.9 ± 0.4 ^{a}	5.1 ± 0.7^{ab}	2.7 ± 0.3^{c}	3.1 ± 0.2^{b}	37.87 ± 3.9^{c}
T2	1.8 ± 0.4 ^{a}	5.6 ± 0.6^{ab}	4.0 ± 0.3^{bc}	2.6 ± 0.2^{b}	43.4 ± 2.6b^{c}
T3	2.3 ± 0.4^{a}	4.8 ± 0.6^{b}	4.3 ± 0.4^{ab}	3.4 ± 0.4^{b}	44.93 ± 5.0^{bc}
T4	2.0 ± 0.5 ^{a}	5.1± 0.7^{ab}	4.5 ± 0.3^{ab}	5.7 ± 0.2^{a}	52.3 ± 4.58^{abc}
T5	1.4 ± 0.3 ^{a}	7.40 ±1.1^{ab}	5.5 ± 0.3 ^{a}	5.9 ± 0.1^{a}	62.8 ± 3.0^{a}
T6	1.7 ± 0.3^{a}	5.1 ± 0.9^{ab}	5.1 ± 0.4^{ab}	5.0± 0.4^{a}	58.4 ± 2.8^{ab}
T7	1.8± 0.3^{a}	8.3± 0.7^{a}	4.9 ± 0.2^{ab}	5.5 ± 0.3^{a}	62.1 ± 3.1^{a}
F	0.54	3.13	7.39	24.17	6.77
P	*0.778*	*0.008*	*0.01*	*0.001*	*0.001*

F. *Total number of fruits, fruit weight (g) and the fruit sizes*

Treatments (T1–T7) were compared with the control (T1) across four yield traits namely total fruit number, fruit length, fruit width and fruit weight. Significant differences were observed among the treatments (P <0.05).

The control treatment (T1) recorded the lowest fruit number overall. A similar trend was observed for total fruit weight. Treatment T7 yielded the highest mean total fruit weight at 7369.6 g, which was significantly greater (p < 0.05) than that of the control (T1), which recorded 3792.1 g. Treatments T5 (6924.3 g) and T6 (7145.2 g) also produced significantly higher total fruit weights than the control (p < 0.05). The reason for significant increase in the number of fruits and total fruit weight produced in treatments that included BTCWM might be due to the addition of this banana tissue culture waste media had a positive influence on reproductive output of salad (Awasthi et al., 2015).

A statistically significant difference (P<0.05) was observed for both the total number of fruits and the total fruit weight, indicating that the various growth media formulations had a discernible impact on these yield components. Treatment 7 (T7), composed of 50% Banana Tissue Culture Waste Media (BTCWM) and 50% coconut coir dust (CD), recorded the highest mean number of fruits at 50.40. This was significantly higher (p < 0.05) than the control treatment (T1), which consisted of 100% CD and produced a mean of 29.27 fruits. Other treatments, such as T5 and T6, also produced a significantly higher number of fruits compared to the control treatment (T1), with mean values of 59.53 fruits for T5 and 49.07 fruits for T6.

There were no significant differences for fruit length across treatments (P > 0.05). The average fruit length ranged from 16.7 cm to 23.9 cm. The fact that there was no significant difference in individual fruit size parameters, despite significant differences in total yield, suggests the treatments stimulated the production of more fruits rather than producing larger individual fruits. These findings correlate with earlier studies of (Perera et al., 2024) , who observed that showing optimization of growth media was only observed to affect yield quantity.

The highest fruit weights were recorded in T7 (7369.6 ± 221.1 g) and T6 (7145.2 ± 325.47 g), while the control treatment had the lowest fruit weight (3792.1 ± 395.3 g). Overall, the T6 and T7 treatments consistently outperformed the control and most other treatments in terms of fruit yield, especially in terms of total fruit number and fruit weight. Tissue culture media comprises of micro and macro nutrients, vitamins, amino acids and growth regulators as nutrient composition. The improved yield might be associated with the presence of all nutrients along with proper drainage and nutrient retention at T7 (50% BTCWM and 50% coconut coir).

The presence of macro nutrients, namely Phosphorus is essential in young plants for the development of various elements such as ATP for energy production, Crop maturation, flowering, fruiting, germination, ripening and enhancing of grain quality is seen with this nutrient (Johnson and Mirza, 2020).

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Table 03: Effects of potting media treatment on the fruit length, fruit diameter and fruit weight.

Treatments	Total no fruits /plant	Fruits Size		Fruit weight (g/plant)
		Fruit length (cm)	Fruit Diameter (cm)	
T1	29.27 ± 3.11[d]	17.1 ± 0.2 [a]	13.2 ± 0.2[a]	3792.1 ± 395.3[c]
T2	35.27 ± 2.50[cd]	16.9 ± 0.3 [a]	13.2 ± 0.3[a]	4770.9 ± 350.4[c]
T3	39.33 ± 3.73[bcd]	16.9 ± 0.1 [a]	13.2 ± 0.2[a]	5394.5 ± 533.21[bc]
T4	35.27 ± 3.57[cd]	16.9 ± 0.2 [a]	13.4 ± 0.2[a]	4718.9 ± 476.75[c]
T5	49.53 ± 1.76[ab]	23.9 ± 5.0 [a]	13.4 ± 0.2[a]	6924.3 ± 217.3[ab]
T6	49.07 ± 2.15[abc]	16.7 ± 0.3 [a]	15.5 ± 2.3[a]	7145.2 ± 325.47[a]
T7	50.40 ± 1.32[a]	17.1 ± 0.3 [a]	13.0 ± 0.2[a]	7369.6 ± 221.1[a]
F	9.76	1.92	1	14.01
P	*0.001*	*0.085*	*0.429*	*0.001*

IV. CONCLUSION

The present study analyzed the growth and yield performance of salad cucumber production in novel potting mixes containing banana tissue culture waste media (BTCWM) grown under greenhouse conditions. The results indicated maintained comparisons among treatments, where vine growth, leaf size, flower number, and total fruit yield were significantly different. In particular, the longest and widest vine, advanced leaf length and width and flower production rates were significantly enhanced in treatments containing BTCWM, eventually exhibited the highest number of flowers, the total number of fruits particularly with T7. Hence, our findings suggest that BTCWM is an effective alternative media component to partially replace conventional potting media, as using BTCWM improves the availability of nutrients to salad cucumber plants to sustain crop growth and development. Further investigations are required in non-controlled environmental conditions trials to determine the utility of BTCWM in research and allow further take up of the waste media by growers. In summary, waste tissue culture media has the potential that can be reused in horticultural crops to enhance crop production.

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ABBREVIATIONS

- PTCM Plant Tissue Culture Media
- WPTCM Waste Plant Tissue Culture Media
- BTCWM Banana Tissue Culture Waste Media
- WAP Weeks After Planting
- WBP Weeks Before Planting
- CRD Completely Randomized Design
- ANOVA Analysis of Variance
- SPSS Statistical Package for the Social Sciences
- cm Centi Meter
- l Litre
- ml Milli Litre