Jurnal Agronomi Indonesia
(Indonesian Journal of Agronomy)

ISSN 2085-2916 | e-ISSN 2337-3652
December 2024, *52*(3), 309-318
DOI: https://dx.doi.org/10.24831/jai.v52i3.58866

Research Article

Effect of growing media on the growth of stevia (*Stevia rebaudiana* (Bertoni) Bertoni) tip cuttings

Arif Gozali Warso Saputro [1,*], Muchamad Yusron [2], Raden Vitri Garvita [3], and Gut Windarsih [1]

[1] Program of Biology, Faculty of Science, Universitas Islam Negeri Sultan Maulana Hasanuddin Banten, Jl. Syech Nawawi Al Bantani, Serang 42116, Banten, INDONESIA
[2] Research Center for Estate Crops, Research Organization for Agriculture and Food, National Research and Innovation Agency (BRIN), Jl. Raya Jakarta-Bogor KM 46, Cibinong, West Java 16911, INDONESIA
[3] Research Center for Applied Botany, National Research and Innovation Agency (BRIN), Jl. Raya Jakarta-Bogor KM 46, Cibinong, West Java 16915, INDONESIA
* Corresponding author (✉ arifgozali1234@gmail.com)

ABSTRACT

Stevia is 200-300 times sweeter than sucrose but low in calories, making it a safe alternative for individuals with diabetes or obesity. The utilization of stevia has the potential to reduce reliance on sugar imports. This research aimed to investigate the influence of different growing media on the growth of stevia tip cuttings. This study was conducted from August to December 2023 in Cidokom Village, Cisarua District, Bogor Regency, West Java. The method used was experimental research using a completely randomized design (CRD) with a single factor, which was the composition of the growing media. Six types of growing media were used. The research results showed significant differences among the treatment groups of growing media on various growth parameters of stevia tip cuttings. Stevia tip cuttings planted in soil and manure media showed the best results in cutting height (28.8 ± 2.82 cm) 42 days after planting. Meanwhile, the combination of solid waste agar, sand, mycorrhiza, burnt rice husks, and cocopeat media resulted in the highest number of leaves (22.20 ± 3.20 leaves) and total fresh weight of stevia tip cuttings, around 1.98 ± 0.33 g at 42 days after planting.

Keywords: mycorrhiza; planting media; vegetative growth

Edited by:
Abdullah bin Arif
BRIN

Received:
9 September 2024
Accepted:
18 November 2024
Published online:
18 December 2024

Citation:
Saputro, A. G. W., Yusron, M., Garvita, R. V., & Windarsih, G. (2024). Effect of growing media on the growth of stevia (*Stevia rebaudiana* (Bertoni) Bertoni) tip cuttings. *Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy)*, *52*(3), 309-318

INTRODUCTION

Sugar is a vital food commodity, serving as a key raw material for the food and beverage industry and a household staple (Lajolo et al., 2021). It significantly contributes to the total energy intake for children and adults in many countries (Azaïs-Braesco et al., 2017). However, domestic sugar production often falls short of national needs, prompting some countries to adopt sugar import policies (Sinuraya et al., 2023).

Sugar-importing countries typically import sugar in the form of raw or refined sugar. According to FAO (2023) (the Food and Agriculture Organization), Indonesia ranked as the largest importer of raw sugar globally in 2022-2023, importing 5.8 million tons per year, followed by China with 4.5 million tons per year and the United States with 3.3 million tons per year. Sucrose is the main composition in the manufacture of refined sugar, generally consisting of 99% sucrose, which is made from sugar cane (70%) or sugar beet (30%) (Arshad et al., 2022). Conversely, a high refined sugar intake is linked to numerous health problems and non-communicable diseases, including an increased risk of obesity, metabolic disorders, diabetes, cardiovascular disease, cancer, depression, and cognitive decline (Gillespie et al., 2023). Planning and strategies are needed to reduce dependence on sugar imports, and alternatives like unrefined sugar cane have generated much interest as a healthy substitute due to their nutraceutical properties.

Stevia, a shrub belonging to the Asteraceae family (Perkasa & Mulyana, 2024), has leaves known as "honey leaves" or "sweet leaves" that have been used as an alternative natural sweetener and herbal medicine for hundreds of years in South America, particularly in Paraguay and Brazil (Peteliuk et al., 2021). The sweet taste of stevia leaves comes from the stevioside and rebaudioside A (Reb-A) compounds (Sardar et al., 2022), which make stevia 200-300 times sweeter than sucrose (Abayechaw et al., 2023). In addition, stevioside is beneficial for a diet low in carbohydrates, aids in digestion, aids in weight loss, contains antioxidants, and has a significant role in maintaining normal blood pressure (Lahijanian et al., 2023). Stevia is widely grown in many countries, including Korea, China, India, Japan, and South America, in response to the growing demands of the food, beverage, and pharmaceutical industries for a natural and healthful sweetener (Samuel et al., 2018).

According to Khuluq et al. (2022), a suitable growing environment for stevia in a tropical climate is a highland ranging from 700 to 1500 m asl with a temperature of 20-30˚C. These climatic conditions are very suitable for several regions in Indonesia and similar to its native conditions in South America and several countries that develop stevia, such as Korea, China, India, and Japan, so stevia cultivation has the potential to be developed in Indonesia. In Indonesia, stevia cultivation is currently well-developed in North Tapanuli, Bogor, Cianjur, Sukabumi, and Garut. Based on its potential and benefits, the production of stevia for market supply needs to be increased. While stevia can be propagated generatively using seeds, this method is challenging due to the low germination rate of stevia seeds (Manohar et al., 2022). Vegetative propagation using tip cuttings is a viable alternative (Castañeda-Saucedo et al., 2020). Tip cuttings have several advantages, including producing uniform-sized plantlets in a short time. The success of plant propagation using tip cuttings is partly determined by root formation.

The use of planting media is one way to stimulate root formation and development. Solid waste from seaweed agar extraction contains micronutrients Cu (4.80 ppm), Fe (0.24 ppm), Zn (8.42 ppm), Mn (57.58 ppm), B (32.32 ppm), as well as the macronutrients N (0.20%), P (0.12%), K (0.17%), C-organic (10.96%), Na (0.66%), Ca (0.61%), Mg (0.09%), CEC (13.5 me/100 g), and N/C ratio of 54:7. Solid waste also contained growth hormones consisting of auxins (191 ppm), gibberellin/GA3 (509.5 ppm), cytokinin-kinetin (244.5 ppm), and cytokinin-zeatin (70.5 ppm) (Basmal, Munifah, et al., 2019). According to Basmal, Henrida, et al. (2019), Indonesia produces approximately 29.088 tons of solid waste agar per year from processing seaweed-based agar (*Gracilaria* sp. and *Cottoni* sp.). To date, this waste has not been optimally utilized. Therefore, utilizing solid waste agar as a growing medium can reduce pollution risk and provide added value to the community.

Based on the nutrient content and potential contained in solid waste from seaweed agar as a growing medium, it encourages researchers to describe the effect of the composition of growing media and seaweed agar solid waste on plant growth, especially stevia. The results of this research are expected to lead to the application of the principle of zero waste industry, which is beneficial to the environment and society.

MATERIALS AND METHODS

Research site

This research was conducted from August to December 2023. The study was carried out in a greenhouse located in Cidokom Village, Cisarua District, Bogor Regency, West Java, Indonesia.

Preparation of growing media

The composition of the growing media solid waste agar consisted of 87% dried solid waste agar from seaweeds *Gracilaria* sp., 10% *Sargassum* sp., 1% fish meal, 1% molasses or sugarcane syrup, and 1% hydrogel. The solid waste agar was sun-dried until it became dry, then mixed with dried *Sargassum* sp., fish meal, hydrogel, molasses, and 630 ml functional soil microbes at a concentration of 20%. The microbial composition includes *Bacillus* sp., *Pseudomonas* sp., *Tricodherma* sp., *Azotobacter* sp., *Azospirillum* sp., and P-solubilizing microbes.

On the other hand, the method used was experimental research with a completely randomized design (CRD) with a single factor, which was the composition of the growing media. The planting media consisted of 6 types of media combinations, including (1) sand; (2) soil and manure; (3) burnt rice husk and mycorrhiza; (4) solid waste agar, sand, burnt rice husks, and cocopeat; (5) solid waste agar, sand, mycorrhiza, burnt rice husks, and cocopeat; and (6) solid waste agar, sand, mycorrhiza, and burnt rice husks (Table 1). Cocopeat was steamed for 1-2 hours to reduce tannin levels that can inhibit plant growth. The sand was sieved with a 1.4 cm wire mesh to obtain a relatively homogeneous size. Each media mixture from each treatment was put into black plastic pots measuring 7 cm in height, 6 cm in bottom diameter, and 8 cm in top diameter.

Table 1. Composition of growing media and solid waste agar used.

Treatment	Composition of growing media (%)						
	Solid waste agar	Sand	Mycorrhiza	Cocopeat	Burn rice husk	Soil	Manure
Sand	-	100	-	-	-	-	-
Soil and manure	-		-	-	-	65	35
Burnt rice husks and mycorrhiza	-	-	90	-	10	-	-
Solid waste agar, sand, burnt rice husks, and cocopeat	50	40	-	9	1	-	-
Solid waste agar, sand, mycorrhiza, burnt rice husks, and cocopeat	34	27	32	6	1	-	-
Solid waste agar, sand, mycorrhiza, and burnt rice husks	34	27	32	-	7	-	-

Preparation of tip cuttings

Cuttings were taken from the tips of 2-week-old stevia plants with a height of 5-8 cm (at least 3-4 nodes). The parent plants used for the tip cuttings were not in the flowering phase. The base of the cuttings was soaked in IBA and BAP solutions, each at a concentration of 10 ppm, for approximately 60 minutes.

Planting of cuttings

Cuttings were planted in the morning, around 7:00-9:00 AM Western Indonesia Time (WIT/UTC+7). Before planting, holes 2-3 cm deep were made in the media using chopsticks. After the cuttings were inserted into the holes, the holes were closed by pressing the media around the cuttings to ensure they stood upright. The planted cuttings were placed into pots and covered with ultra-violet plastic.

Maintenance

Watering was adjusted to the condition of the media and could be done twice a day, in the morning from 06:00-07:00 AM WIT and the afternoon from 4:00-5:00 PM. Meanwhile, weeding was performed by pulling out weeds around the planting media.

Harvesting

Harvesting plants for fresh weight measurement was done 42 days after planting (DAP). The harvesting was carried out by removing the growing media from the pots and then cleaning the roots from the planting media using running water to avoid damaging the roots.

Observation of growth parameters

The observed data included plant height, number of leaves, and fresh weight of the plants. The fresh weight of stevia tip cuttings was observed for three parameters, including leaf weight, stem weight, and total plant weight.

Data analysis

Quantitative data, including the percentage of live cuttings, plant height, number of leaves, fresh weight of leaves, fresh weight of stems, and fresh weight of the entire plant, were tested for normality using the Shapiro-Wilk method. If the obtained data were normally distributed, each parameter was analyzed using one-way analysis of variance (ANOVA) with the assistance of the Statistical Program for Social Science (SPSS) version 23 software to determine if there were differences in plant responses among treatment groups. If the analysis of variance showed significant differences, Duncan's multiple range test (DMRT) at a 5% error level was used to determine differences between treatment groups. However, if the data were not normally distributed, a non-parametric test using the Kruskal-Wallis Test was conducted.

Meanwhile, the plant survival percentage was obtained using the following formula:

$$SR = \frac{T_t}{T_o} x\ 100\%$$

in which survival rate = plant survival percentage (%), Tt = number of live cuttings at the end of the observation, and To = number of cuttings at the beginning of the observation.

RESULTS AND DISCUSSION

Percentage of live cuttings

The treatment of planting media significantly affected the percentage of live cuttings on stevia tip cuttings. Based on Table 2, tip cuttings grown in solid waste agar, sand, mycorrhiza, and burnt rice husks produced the highest percentage of live cuttings throughout the entire observation period, with a percentage of 95±0.50% at 42 DAP. On the contrary, a mixture of soil and manure is less appropriate for vegetative propagation in stevia through tip cuttings due to the lowest live cutting shown on the last observation period (42 DAP) with a percentage of 45±0.47% (Table 2).

Table 2. Percentage of live tip cuttings in stevia treated with planting media.

Treatment	Percentage of live cuttings in stevia (%)		
	14 DAP	28 DAP	42 DAP
Sand	100±0.00	90±20.00b	90±0.25bc
Soil and manure	100±0.00	60±16.32a	45±0.47a
Burnt rice husks and mycorrhiza	95±10.0	80±23.09ab	75±1.44abc
Solid waste agar, sand, burnt rice husks, and cocopeat	100±0.00	90±11.54b	80±0.95bc
Solid waste agar, sand, mycorrhiza, burnt rice husks, and cocopeat	100±0.00	100±0.00b	85±0.57bc
Solid waste agar, sand, mycorrhiza, and burnt rice husks	100±0.00	100±0.00b	95±0.50c

Note: Numbers followed by the same letter in each column indicate no significant difference based on the DMRT at the significance level (α) = 5%.

The highest percentage of living cuttings was dominated by a mixture of sand and solid waste agar (Table 2). According to (El Haddadi et al., 2022), the characteristics of good growing media possess physical and chemical properties that can physically support plants. Zhou et al. (2022) stated that the number of plant roots is influenced by soil density as the growing medium. The higher the soil density, the fewer the number of roots. Adding sand to the solid agar waste media mixture can reduce the media's density. With more gaps or pores in the growing media, roots can grow better as they do not need to exert more effort to penetrate the soil than growing in dense media. This is also supported by the research of Abuarab et al. (2019), which found that reduced root permeability results from low oxygen levels and inadequate root aeration, which impact how well plant roots absorb water, especially in intolerant species.

The growing media mixture with a sandy texture has good aeration (air availability) and drainage, and the sufficient weight of the sand makes it easier for the cuttings to stand upright (Freschet et al., 2021) and allows roots to grow in all directions, helping the plants achieve optimal growth.

The low percentage of living cuttings in the soil and manure mixture media is suspected to be due to the density level of the topsoil used. Dense topsoil tends to result in poor aeration, preventing the stevia shoot cuttings' roots from developing optimally. According to Kitila et al. (2022), topsoil and manure planting media produced a smaller number of roots, as much as 8.83 roots, compared to the treatment of topsoil, manure, and sand planting media, which produced a total of 10.43 roots on stem cuttings of chaya plants (*Cnidoscolus aconitifolius* McVaugh).

Dense media cause low porosity and oxygen content, which in turn inhibits root growth. Other research indicates that the initiation of secondary roots increases with higher soil air porosity due to increased oxygen availability (Giuliani et al., 2024).

Plant height

The treatment of planting media also significantly affected the height of stevia tip cuttings. Table 3 shows that tip cuttings planted in a sand medium produced the highest cutting height at 14 DAP, although it was not significantly different from other treatment groups. At 28 DAP, the height of cuttings grown in sand media also produced the highest height of cuttings (19.25±0.89 cm). However, it was significantly different from the other five treatment groups. The different results were obtained at 42 DAP, in which the tip cuttings treated with soil and manure produced the highest cuttings height (28.8±2.82 cm) that was significantly different and higher than the cuttings treated with a mixture of solid waste agar, sand, burnt rice husks, and cocopeat (19.47±3.25 cm) as well as a mixture of solid waste agar, sand, mycorrhiza, and burnt rice husk (22.75±3.22 cm).

Table 3. The average height of stevia tip cuttings in the treatment of planting media.

Treatment	Height of stevia tip cuttings (cm)		
	14 DAP	28 DAP	42 DAP
Sand	12.78±1.91	19.25±0.89c	26.50±2.29bc
Soil and manure	11.34±0.31	12.94±0.90a	28.00±1.02c
Burnt rice husks and mycorrhiza	10.79±1.98	16.01±1.99b	26.20±3.15bc
Solid waste agar, sand, burnt rice husks, and cocopeat	10.51±2.57	11.82±0.40a	19.47±3.25a
Solid waste agar, sand, mycorrhiza, burnt rice husks, and cocopeat	12.10±0.37	14.14±1.26ab	26.15±1.45bc
Solid waste agar, sand, mycorrhiza, and burnt rice husks	11.23±1.70	14.33±2.39ab	22.75±3.22ab

Note: Numbers followed by the same letter in each column indicate no significant difference based on the DMRT at the significance level (α) = 5%.

The difference in plant height on sand planting media, which was higher at 28 DAP but became the lowest at 42 DAP, was thought to be due to good aeration at the beginning of growth. Sand planting media had a high porosity, providing good aeration for plant roots. In the early stages of growth 28 DAP, roots got enough oxygen, which promoted rapid growth in the short term. This caused plants on sand media to grow faster than other media that may be denser or less porous. However, as plants grow, sand has a very low water and nutrient retention capacity. Hence, sand cannot store nutrients well. Plants grown in sand media experienced nutrient deficiencies more quickly, causing plant growth to be stunted at 42 DAP. Oxygen in the growth medium plays a critical role, as it determines the root orientation and the metabolic state of the root. The availability of oxygen at the radical level is fundamental for the optimal development of plants since it is required in different priority metabolic processes such as carbohydrate metabolism, nitrate reduction, and symbiotic nitrogen fixation (Roblero et al., 2020).

Based on the observation results at 42 DAP, the stevia tip cuttings grown in soil and manure media showed the greatest height among all treatment groups (Table 2). Manure contains nitrogen (N), phosphate (P), and potassium (K) (Aronsson et al., 2022). According to Wiser & Blom (2016), plant height is influenced by the P-nutrient needed by plants for forming new cells in growing tissues and strengthening the stem. The P-nutrient in the planting media is essential in supporting the availability of phosphorus (P_2O_5) levels to support reproduction. The deficiency of P-element can inhibit the formation of plant organs. Based on the results of research conducted by Li et al. (2020), a low phosphorus nutrient content can reduce plant height, number of leaves, and leaf area of *Gossypium hirsutum* L. The P-element content in manure is approximately 1.75% (Rehman et al., 2020), 1.63% higher than the solid waste agar media, which has a P content of 0.12% (Basmal, Henrida, et al., 2019).

According to research by (Zaman et al., 2017), applying cow manure was found to significantly increase the total N, available P, exchangeable K, Ca, Mg, available S, Zn, and B contents in soils as well as the biomass yield of stevia when compared to the control. In both soils, the amount of cow manure applied was increased to its highest level.

Number of leaves

The treatment of planting media significantly affected the number of leaves on stevia tip cuttings. Based on Table 4, tip cuttings grown in sand planting medium had the highest number of leaves (16.25±0.61 leaves) at 14 DAP and it was significantly different from all other media compositions. At 28 DAP, the number of leaves of stevia tip cuttings treated with sand media (19.25±1.45 leaves) was significantly different and had more leaves than cuttings treated with other three media compositions, including (1) burnt rice husk and mycorrhiza; (2) solid waste agar, sand, burnt rice husks, and cocopeat; as well as (3) solid waste agar, sand, mycorrhiza, and burnt rice husks.

The different results were obtained at 42 DAP, in which tip cuttings grown in solid waste agar, sand, mycorrhiza, burnt rice husks, and cocopeat media had the highest number of leaves (22.20±3.20 leaves) were significantly different and had more leaves than cuttings treated with other two media compositions, including (1) burnt rice husks and mycorrhiza; and (2) solid waste agar, sand, burnt rice husks, and cocopeat.

Table 4. The average number of leaves stevia tip cuttings in the treatment of planting media.

Treatment	Number of leaves stevia tip cuttings		
	14 DAP	28 DAP	42 DAP
Sand	16.25±0.61b	18.65±1.66b	21.22±1.95bc
Soil and manure	12.35±0.78a	17.30±0.30ab	21.00±1.05bc
Burnt rice husks and mycorrhiza	12.80±1.75a	15.15±3.04a	18.16±2.88ab
Solid waste agar, sand, burnt rice husks, and cocopeat	12.92±2.42a	14.17±3.54a	15.25±5.05a
Solid waste agar, sand, mycorrhiza, burnt rice husks, and cocopeat	12.37±1.82a	17.70±0.93ab	22.20±3.20c
Solid waste agar, sand, mycorrhiza, and burnt rice husks	12.95±1.44a	14.30±3.10a	21.08±3.38bc

Note: Numbers followed by the same letter in each column indicate no significant difference based on the DMRT at the significance level (α) = 5%.

The number of leaves in the sand treatment produced optimal growth at 14 DAP and 28 DAP compared to other treatments, presumably because sand had a high porosity, allowing the roots to get maximum oxygen. This condition supported rapid vegetative growth, including leaf formation, because sufficient oxygen helps root respiration and increases water absorption and dissolved nutrients. As a result, plants grown in sand may form leaves faster in the early phase. According to Roosta (2024), the presence of oxygen in the growth medium is essential for root development and the overall metabolic processes of plants. However, the highest oxygen levels increase vegetative growth, including the number of leaves on the plant. However, at 42 DAP, plants grew over time and needed more nutrients and water to maintain and form new organs such as leaves. Sand has a very low ability to retain nutrients and water, so when initial nutrient reserves are depleted, plants lack essential nutrients such as nitrogen, which is important for leaf formation.

Solid waste agar, sand, mycorrhiza, burnt rice husks, and cocopeat gave the best results in increasing the number of leaves of stevia tip cuttings (Table 4). Solid waste agar, sand, mycorrhiza, burnt rice husks, and cocopeat contain macronutrients and micronutrients that plants need to grow optimally. The N-nutrient is needed in forming vegetative parts of plants and the process of photosynthesis (Zayed et al., 2023); the more leaves there are, the more the photosynthesis process increases, and the higher the photosynthate is produced. Nitrogen content in the growing media can support the growth of apical branches, the number of leaves that appear on plants, the total area and the number of leaves increase (Fauzi et al., 2024).

Adding functional soil microbes, such as *Azetobacter* sp. and *Azospirillum* sp., to treatments with solid agar waste, sand, mycorrhiza, burnt husks, and cocopeat enhances plant growth. The total nitrogen content found in solid waste agar ranges between 0.15-0.23% (Basmal, Munifah, et al., 2019). These test results do not meet the quality standards according to SNI 2803:2010, which stipulates that the minimum total nitrogen content in solid NPK fertilizer samples should be 8%. Nitrogen compounds in plants are needed for the formation of amino acids into proteins, chlorophyll formation, and to stimulate shoot formation and the development of stems and leaves during the vegetative phase (Barita et al., 2018).

According to (Widawati & Suliasih, 2019), functional nitrogen-fixing microbes, such as *Azotobacter* sp. and *Azospirillum* sp., can increase nitrogen content in plants. *Azotobacter* sp. has been utilized as a biofertilizer that functions as a producer of exopolysaccharides, which can play a role in enhancing nitrogen absorption (Sumbul et al., 2020). Additionally, the nitrogen fixed by *Azospirillum* sp. will be converted into a network, which then, through decomposition, ammonification, and nitrification, will change into an available N form so plants can absorb it. Besides fixing free-N, *Azospirillum* sp. can also produce growth hormones in the form of auxins, cytokinin, and gibberellins (Yasuda et al., 2022).

Fresh weight

The results of Duncan's analysis indicated that the combination of solid waste agar, sand, mycorrhiza, burnt rice husks, and cocopeat produced the highest fresh weight of leaves and total fresh weight of the entire plant compared to all other treatments, 0.78±0.13 g and 1.98±0.33 g, respectively. Meanwhile, the combination of solid waste agar, sand, burnt rice husks, and cocopeat produced the highest fresh weight of stem with an average value of 0.70±0.20 g, which is significantly different from soil and manure (0.45±0.16 g) as well as sand (0.34±0.12 g).

The level of plant metabolic accumulation is determined by the fresh weight of the plant. A high plant fresh weight indicates an optimal plant growth rate and results in biomass accumulation, which is important for obtaining optimal quality plants in the nursery (Gallegos-Cedillo et al., 2021). Plant weight obtained in this study showed that solid waste agar, sand, mycorrhiza, burnt rice husks, and cocopeat were the most optimal treatment combination to increase the fresh weight of leaves (Table 5), where stevia economic value can be calculated based on fresh weight of leaves. This optimal results on wet weight of stevia leaves grown in solid waste agar, sand, mycorrhiza, burnt rice husks, and cocopeat is assumed because solid waste agar has hydrocolloid characteristic in which plant fresh weight is influenced by the water content contained in plant tissue (Diop et al., 2022). However, an increase in the plant's fresh weight does not necessarily correlate with an increase in sugar content, so the measurement of sugar content should be conducted after all.

In addition, the increase in wet weight was also supported by the nutrient content of solid waste agar. Based on the mineral analysis of seaweed agar solid waste conducted by Basmal, Henrida, et al. (2019) solid waste agar contains a variety of macronutrients needed by plants, including N, P, K, C-organic, Na, Ca, Mg, CEC, and an N/C ratio of 54:7. According to (Huang et al., 2021), Ca, Mg, and K function as supporters in the growth of leaf shoots. Magnesium is an essential component of chlorophyll and is required for phloem loading and photo-assimilate transport to sink organs, seeds, roots, and fruits (Sardiana et al., 2022). In plants, when K nutrient deficiency will cause a reduction in leaf number and leaf size (Hasanuzzaman et al., 2018).

Table 5. Average fresh weight of stevia tip cuttings in various planting media treatments.

Treatment	Fresh weight (g)		
	Leaves	Stem	Total
Sand	0.29±0.02a	0.34±0.12a	1.06±0.31a
Soil and manure	0.54±0.13bc	0.45±0.16ab	1.60±0.21b
Burnt rice husks and mycorrhiza	0.50±1.16ab	0.50±0.08abc	1.62±0.34b
Solid waste agar, sand, burnt rice husks, and cocopeat	0.68±0.14bcd	0.70±0.20c	1.74±0.07b
Solid waste agar, sand, mycorrhiza, burnt rice husks, and cocopeat	0.78±0.13d	0.65±0.12bc	1.98±0.33b
Solid waste agar, sand, mycorrhiza, and burnt rice husks	0.75±0.18cd	0.63±0.04bc	1.90±0.35b

Note: Numbers followed by the same letter in each column indicate no significant difference based on the DMRT at the significance level (α) = 5%.

CONCLUSIONS

Based on the research results, it can be concluded that stevia cuttings planted in soil and manure medium provided the best results in cutting height (28.8±2.82 cm) and the number of leaves (28.81±2.82 leaves) 42 days after planting (DAP). Moreover, the best combination of agar solid waste, sand, mycorrhiza, burnt husk, and cocopeat gave the highest number of leaves (22.20±3.20 leaves) and fresh weight of stevia cuttings, which was approximately 1.98±0.33 g at 42 DAP, where stevia economic value can be calculated based on fresh weight of leaves.

ACKNOWLEDGEMENTS

The authors would like to thank the Stevia Research Team and the National Research and Innovation Agency (BRIN) for providing the opportunity to participate in the research. Thanks also to Mr. Jamal Basmal, Mr. Udin, and other colleagues who have helped with the field activities.

REFERENCES

Abayechaw, D., Lire, H., & Tamrat, W. (2023). Health benefits and risk of sugar consumption and the alternative use of stevia. *Journal Nutrition and Food Processing*, *6*(1), 107. https://doi.org/10.31579/2637-8914/107

Abuarab, M. E., El-Mogy, M. M., Hassan, A. M., Abdeldaym, E. A., Abdelkader, N. H., & El-Sawy, M. B. I. (2019). The effects of root aeration and different soil conditioners on the nutritional values, yield, and water productivity of potato in clay loam soil. *Agronomy*, *9*(8), 418. https://doi.org/10.3390/agronomy9080418

Aronsson, H., Nyström, S., Malmer, E., Kumblad, L., & Winqvist, C. (2022). Losses of phosphorus, potassium and nitrogen from horse manure left on the ground. *Acta Agriculturae Scandinavica Section B: Soil and Plant Science*, *72*(1), 893–901. https://doi.org/10.1080/09064710.2022.2121749

Arshad, S., Rehman, T., Saif, S., Rajoka, M. S. R., Ranjha, M. M. A. N., Hassoun, A., Cropotova, J., Trif, M., Younas, A., & Aadil, R. M. (2022). Replacement of refined sugar by natural sweeteners: focus on potential health benefits. *Heliyon 8*(9), e10711. https://doi.org/10.1016/j.heliyon.2022.e10711

Azaïs-Braesco, V., Sluik, D., Mailot, M., Kok, F., & Moreno, L. A. (2017). A review of total & added sugar intakes and dietary sources in Europe. *Nutrition Journal, 16*(6), 1-15. https://doi.org/10.1186/s12937-016-0225-2

Barita, Y., Prihastanti, E., Haryanti, S., Subagio, A., & Ngadiwiyana, N. (2018). The influence of granting NPK fertilizer and nanosilic fertilizers on the growth of Ganyong plant (*Canna edulis* Ker.). *Journal of Physics: Conference Series*, *1025*, 012054. https://doi.org/10.1088/1742-6596/1025/1/012054

Basmal, J., Henrida, M. L., Kusumawati, R., & Nurhayati, N. (2019). Growth hormone, nitrogen and potassium content in the formulated solid waste from agar processing for fertilizer application. *Squalen Bulletin of Marine and Fisheries Postharvest and Biotechnology*, *14*(3), 131–139. https://doi.org/10.15578/squalen.v14i3.385

Basmal, J., Munifah, I., Rimmer, M., & Paul, N. (2019). Identification and characterization of solid waste from *Gracilaria* sp. extraction. *IOP Conference Series: Earth and Environmental Science*, *404*, 012057. https://doi.org/10.1088/1755-1315/404/1/012057

Castañeda-Saucedo, M. C., Tapia-Campos, E., Ramírez-Anaya, J. D. P., & Beltrán, J. (2020). Growth and development of stevia cuttings during propagation with hormones in different months of the year. *Plants*, *9*(3), 294. https://doi.org/10.3390/plants9030294

Diop, C. I. K., Trigueros, E., Sanz, M. T., Beltran, S., & García-Tojal, J. (2022). Pressurized hot water-assisted recovery of crude residual agar from a never-dried algae industry waste stream: A Box-Behnken design approach. *Food Hydrocolloids*, *129*, 1075664. https://doi.org/10.1016/j.foodhyd.2022.107664

El Haddadi, R., El Mekkaoui, A., Zouahri, A., Ouazzani Touhami, A., & Douira, A. (2022). Effect of growing media on morpho-physiological quality attributes of Tetraclinis articulata seedlings. *Forest Science and Technology*, *18*(3), 108–117. https://doi.org/10.1080/21580103.2022.2104936

FAO. (2023). *World Food and Agriculture – Statisctical Yearbook 2023.* Food and Agriculture Organization of The United Nations. https://doi.org/10.4060/cc8166en

Fauzi, D. A., Isnaeni, S., & Nurhidayah, S. (2024). The influence of nutrient concentration and hydroponic growing media on the growth and yield of pagoda mustard greens (*Brassica narinosa* L.). *Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy)*, *52*(1), 122–129. https://doi.org/10.24831/jai.v52i1.50604

Freschet, G. T., Pagès, L., Iversen, C. M., Comas, L. H., Rewald, B., Roumet, C., Klimešová, J., Zadworny, M., Poorter, H., Postma, J. A., Adams, T. S., Bagniewska-Zadworna, A., Bengough, A. G., Blancaflor, E. B., Brunner, I., Cornelissen, J. H. C., Garnier, E., Gessler, A., Hobbie, S. E., McCormack, M. L. (2021). A starting guide to root ecology: strengthening ecological concepts and standardising root classification, sampling, processing and trait measurements. *New Phytologist, 232*(3) 973–1122). https://doi.org/10.1111/nph.17572

Gallegos-Cedillo, V. M., Diánez, F., Nájera, C., & Santos, M. (2021). Plant agronomic features can predict quality and field performance: a bibliometric analysis. *Agronomy*, *11*(1), 2305. https://doi.org/10.3390/agronomy11112305

Gillespie, K. M., Kemps, E., White, M. J., & Bartlett, S. E. (2023). The Impact of Free Sugar on Human Health—a narrative review. *Nutrients 15*(4), 889. https://doi.org/10.3390/nu15040889

Giuliani, L. M., Hallett, P. D., & Loades, K. W. (2024). Effects of soil structure complexity to root growth of plants with contrasting root architecture. *Soil and Tillage Research*, *238,* 106023. https://doi.org/10.1016/j.still.2024.106023

Hasanuzzaman, M., Bhuyan, M. H. M. B., Nahar, K., Hossain, M. S., Al Mahmud, J., Hossen, M. S., Masud, A. A. C., Moumita, M., & Fujita, M. (2018). Potassium: A vital regulator of plant responses and tolerance to abiotic stresses. *Agronomy, 8*(3), 31. https://doi.org/10.3390/agronomy8030031

Huang, W. T., Xie, Y. Z., Chen, X. F., Zhang, J., Chen, H. H., Ye, X., Guo, J., Yang, L. T., & Chen, L. S. (2021). Growth, mineral nutrients, photosynthesis and related physiological parameters of citrus in response to nitrogen deficiency. *Agronomy*, *11*(9), 1859. https://doi.org/10.3390/agronomy11091859

Khuluq, A. D., Widaryanto, E., Ariffin, A., & Nihayati, E. (2022). Adaptive strategy of *Stevia rebaudiana* to environmental change in tropical climate based on anatomy and physiology characteristics. *Biodiversitas*, *23*(11), 5710–5717. https://doi.org/10.13057/biodiv/d231122

Kitila C., Mohammed, W., & Woldetsadik, K. (2022). Influence of rooting media, number of nodes and seedling growing methods on rooting, seedling establishment and early growth of Chaya (*Cnidoscolus aconitifolius* McVaugh) stem cuttings at Dire Dawa, Eastern Ethiopia. *Archives of Anatomy and Physiology*, *7*(1), 013–025. https://doi.org/10.17352/aap.000020

Lahijanian, S., Eskandari, M., Akhbarfar, G., Azizi, I., Afazel, M., & Ghobadi, C. (2023). Morphological, physiological and antioxidant response of *Stevia rebaudiana* under in vitro agar-induced drought stress. *Journal of Agriculture and Food Research*, *11,* 100495. https://doi.org/10.1016/j.jafr.2023.100495

Lajolo, F. M., Yokoyama, S. M., & Gianotto, A. C. (2021). Sugar derived from genetically modified sugarcane. *Food Science and Technology*, *41*(1), 1–7. https://doi.org/10.1590/fst.30619

Li, H., Wang, J., Ali, S., Iqbal, B., Zhang, H., Wang, S., Chen, B., & Zhou, Z. (2020). Agronomic traits at the seedling stage, yield, and fiber quality in two cotton (*Gossypium hirsutum* L.) cultivars in response to phosphorus deficiency. *Soil Science and Plant Nutrition*, *66*(2), 308–316. https://doi.org/10.1080/00380768.2019.1709543

Manohar, K. A., Shukla, G., Roy, B., & Chakravarty, S. (2022). Effects of plant growth regulators and growing media on propagation and field establishment of *Stevia rebaudiana*: a medicinal plant of commerce. *CABI Agriculture and Bioscience*, *3*, 4 https://doi.org/10.1186/s43170-021-00072-5

Perkasa, A. Y., & Mulyana, E. (2024). Indonesian perspective: identification of stevia plant (*Stevia rebaudiana* Bertoni M.) as medicine prospects. *Selcuk Journal of Agricultural and Food Sciences*. *38*(1), 182-192. https://doi.org/10.15316/sjafs.2024.017

Peteliuk, V., Rybchuk, L., Bayliak, M., Storey, K. B., & Lushchak, O. (2021). Natural sweetener *Stevia rebaudiana*: functionalities, health benefits and potential risks. *EXCLI Journa, 20,* 1412–1430. https://doi.org/10.17179/excli2021-4211

Rehman, S. U., Aslam, Z., Belliturk, K., Ahmad, A., Nadeem, M., & Waqas, M. (2020). Vermicomposting in Pakistan: current scenario and future prospectives. *Modern Concepts & Developments in Agronomy*, *6*(1), 617-619. https://doi.org/10.31031/mcda.2020.06.000629

Roblero, M. D. J. M., Pineda, J. P., León, M. T. C., & Castellanos, J. S. (2020). Oxygen in the root zone and its effect on plants. *Revista Mexicana Ciencias Agrícolas*, *11*(4), 931-943. https://doi.org/10.29312/remexca.v11i4.2128

Roosta, H. R. (2024). The responses of pepper plants to nitrogen form and dissolved oxygen concentration of nutrient solution in hydroponics. *BMC Plant Biology*, *24*, 281. https://doi.org/10.1186/s12870-024-04943-7

Samuel, P., Ayoob, K. T., Magnuson, B. A., Wölwer-Rieck, U., Jeppesen, P. B., Rogers, P. J., Rowland, I., & Mathews, R. (2018). Stevia leaf to stevia sweetener: exploring its science, benefits, and future potential. *Journal of Nutrition*, *148*(7), 1186S-1205S. https://doi.org/10.1093/jn/nxy102

Sardar, H., Waqas, M., Naz, S., Ejaz, S., Ali, S., & Ahmad, R. (2022). Evaluation of different growing media based on agro-industrial waste materials for the morphological, biochemical and physiological characteristics of stevia. *Cleaner Waste Systems*, *3,* 100038. https://doi.org/10.1016/j.clwas.2022.100038

Sardiana, I. K., Kusmiyarti, T. B., & Roni, N. G. K. (2022). Magnesium fertilizer increased growth, rhizome yield, and essential oil content of ginger (*Zingiber officinale*) in organic field. *PLANTA TROPIKA: Jurnal Agrosains (Journal of Agro Science)*, *10*(2), 132–139. https://doi.org/10.18196/pt.v10i2.11406

Sinuraya, J. F., Suryadi, M., Ariningsih, E., Ashari, A., & Puwantini, T. B. (2023). Policy and action plan to increase national sugar production. *IOP Conference Series: Earth and Environmental Science*, *1153*, 012011. https://doi.org/10.1088/1755-1315/1153/1/012011

Sumbul, A., Ansari, R. A., Rizvi, R., & Mahmood, I. (2020). Azotobacter: a potential bio-fertilizer for soil and plant health management. *Saudi Journal of Biological Science,* *27*(12), 3634–3640. https://doi.org/10.1016/j.sjbs.2020.08.004

Widawati, S., & Suliasih, S. (2019). Potency of nitrogen fixing bacteria isolated from POME disposal pond and their effect on the growth of *Caesalpinia pulcherrima* (L) Sw. *IOP Conference Series: Earth and Environmental Science*, *308*, 012043. https://doi.org/10.1088/1755-1315/308/1/012043

Wiser, L., & Blom, T. J. (2016). The effect of nitrogen and phosphorus ratios and electrical conductivity on plant growth. *American Journal of Plant Sciences*, *7*(12), 1590–1599. https://doi.org/10.4236/ajps.2016.712150

Yasuda, M., Dastogeer, K. M. G., Sarkodee-Addo, E., Tokiwa, C., Isawa, T., Shinozaki, S., & Okazaki, S. (2022). Impact of *Azospirillum* sp. B510 on the rhizosphere microbiome of rice under field conditions. *Agronomy*, *12*(6), 1367. https://doi.org/10.3390/agronomy12061367

Zaman, M. M., Chowdhury, T., Nahar, K., & Chowdhury, M. A. H. (2017). Effect of cow dung as organic manure on the growth, leaf biomass yield of *Stevia rebaudiana* and post-harvest soil fertility. *Journal of the Bangladesh Agricultural University*, *15*(2), 206-211. https://doi.org/10.3329/jbau.v15i2.35064

Zayed, O., Hewedy, O. A., Abdelmoteleb, A., Ali, M., Youssef, M. S., Roumia, A. F., Seymour, D., & Yuan, Z. C. (2023). Nitrogen journey in plants: from uptake to metabolism, stress response, and microbe interaction. *Biomolecules* *13*(10), 1443. https://doi.org/10.3390/biom13101443

Zhou, J., Zhang, Z., Xin, Y., Chen, G., Wu, Q., Liang, X., & Zhai, Y. (2022). Effects of planting density on root spatial and temporal distribution and yield of winter wheat. *Agronomy*, *12*(12), 3014. https://doi.org/10.3390/agronomy12123014