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Growth Response of Cocoa (*Theobroma cacao* L.) Orthotropic Shoot Cuttings to Growing Media and Concentrations of Shallot-Derived Plant Growth Regulator

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Abstract:
Slow shoot formation and low survival limit propagation of cocoa (*Theobroma cacao* L.) by cuttings. This study evaluated the effects of growing media and shallot extract, a natural plant growth regulator, on the growth of orthotropic shoot cuttings of the Sulawesi 01 clone. The experiment (July–November 2025, Jember, Indonesia) used a split-plot randomized complete block design with three replications. The main plots were growing media: sand (T1), sand + topsoil 1:1 (T2), and sand + topsoil + compost 1:1:1 (T3). The subplots were shallot extract concentrations: 0% (Z0), 50% (Z1), and 100% (Z2). Cutting success, shoot emergence time, shoot length, and shoot diameter were recorded. The media × extract interaction significantly affected cutting success, with the highest success in T2Z2 (71%) and the lowest in T3Z1 (29%). Growing media significantly affected shoot length and diameter at 16 weeks after planting: sand + topsoil produced 5.72 cm shoots and 2.13 mm diameter, about twice the length and 40% greater diameter than the other media. Shallot extract alone and the treatments did not affect shoot emergence time (40–64 days). A sand + topsoil (1:1) medium combined with 100% shallot extract is recommended for propagating cocoa orthotropic cuttings.

Keywords:
cocoa cuttings, growing media, natural auxin, shallot extract, vegetative propagation

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INTRODUCTION

Cocoa (*Theobroma cacao* L.) is a strategic plantation commodity in Indonesia. It creates employment, generates foreign exchange, and provides a year-round source of income for smallholder farmers, who own almost all cocoa plantations in the country. Over the past decade, however, national cocoa production has declined. The main causes are the aging of trees planted several decades ago, pest and disease pressure, and the effects of dry El Niño conditions since 2023. Large-scale replanting is therefore needed, but rejuvenation programs are constrained by the limited availability of high-quality planting material. Producing large numbers of uniform, high-yielding seedlings quickly and at low cost is one of the key steps toward restoring cocoa productivity (Sodré and Gomes Sena, 2019).

Cocoa is an allogamous crop, so seedlings raised from seed segregate and do not reproduce the characteristics of the mother tree. Vegetative propagation overcomes this problem by producing

Volume 02 Number 02
November 2026
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plants that are genetically identical to selected clones. Among vegetative methods, rooted cuttings are attractive because they are simple, require relatively little planting material and skill, and produce uniform plants that reach the productive phase earlier (Vásquez Zamora et al., 2022). Cocoa has dimorphic branching, and cuttings taken from orthotropic (vertical) shoots develop into plants with the normal tree architecture of a seedling, whereas plagiotropic (fan) cuttings produce bushy plants that require more formative pruning (Sodré and Gomes Sena, 2019). The main obstacles of cutting propagation are slow root and shoot formation and a low proportion of cuttings that survive and grow.

The success of cuttings depends on internal factors, such as clone, cutting position, and food reserves, and on external factors, the most important of which are the rooting medium and the supply of auxin. Adventitious root formation is a multistage process that begins with wounding at the cut surface and is controlled mainly by auxin, in interaction with other hormones and with the carbohydrate status of the cutting (Druege et al., 2019; Gonin et al., 2019; Li, 2021). The rooting medium must provide sufficient water while maintaining aeration, because roots forming at the base of a cutting need a continuous supply of oxygen (Yafuso and Fisher, 2019). Sand provides good drainage and aeration, topsoil supplies nutrients and holds water, and compost adds organic matter and nutrients, but each of these components can also have disadvantages when used alone or in excessive proportions. For example, different propagation media produced large differences in rooting and shoot growth of fig cuttings (Shamsuddin et al., 2021; Mafrica et al., 2025), and in cocoa seedlings the growing medium affected growth, biomass, and recovery from water stress (Mintah et al., 2022).

Environmental conditions during propagation are equally important. Leafy cuttings have no roots to replace the water lost through transpiration, so they must be kept under high humidity and moderate light until roots form. Simple propagation chambers made of transparent plastic under shade netting are widely used in cocoa nurseries because they maintain humidity without an expensive misting system (Vásquez Zamora et al., 2022). Under these conditions, the rooting medium is kept close to saturation for several weeks, making drainage and aeration critical. In addition, the position of the cutting on the shoot influences rooting, because basal, middle, and apical cuttings differ in lignification, carbohydrate reserves, and endogenous hormone levels (Druege et al., 2019; Souza et al., 2023). Taking these sources of variation into account is necessary to obtain reliable conclusions about the effects of the medium and the growth regulator.

Synthetic auxins such as indole-3-butyric acid are widely used to stimulate rooting, but they are relatively expensive and not always available to smallholder farmers. Shallot (*Allium cepa* var. *aggregatum*) extract is a low-cost natural alternative that is reported to contain auxins, gibberellins, and thiamine. Shallot or onion extract has improved the growth of cuttings of water apple (Tambunan et al., 2019; Lukman et al., 2022), chrysanthemum (Fadhil et al., 2018), cassava (Ayda et al., 2023), and chaya (Gustiar et al., 2025). The response, however, depends strongly on the concentration and on the growing medium, and several studies found no significant effect of natural growth regulators (Karno et al., 2023). Information on the combined effects of growing media and shallot extract on cocoa orthotropic cuttings is still limited.

Therefore, this study aimed to determine the growth response of cocoa orthotropic shoot cuttings to growing media and shallot extract concentrations, and to identify the combination that gives the highest cutting success and the best shoot growth. We hypothesized that a medium combining sand with a nutrient source would improve cutting growth and that its effect on cutting success would depend on the concentration of shallot extract.

Volume 02 Number 02
November 2026
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METHOD

The research was conducted from July to November 2025 in the nursery of the Seed Technology Laboratory, Politeknik Negeri Jember, East Java, Indonesia. The materials used were orthotropic shoots of the cocoa clone Sulawesi 01, shallot bulbs, sand, topsoil, compost, a nematicide (carbofuran 3%), and a fungicide (propineb 70%). The equipment included propagation chambers made of transparent plastic, 70% shade netting, a thermohygrometer, pruning shears, a blender, a measuring cylinder, a ruler, a digital caliper, filter cloth, and labels.

The experiment was arranged as a split-plot design in a randomized complete block design (RCBD) with three replications. The main plots were three growing media: T1 = sand, T2 = sand + topsoil (1:1, v/v), and T3 = sand + topsoil + compost (1:1:1, v/v/v). The subplots were three concentrations of shallot extract: Z0 = 0% (distilled water, control), Z1 = 50%, and Z2 = 100% (Table 1). The combination of the two factors produced nine treatments, and with three replications there were 27 experimental units, each consisting of eight cuttings (216 cuttings in total). Within each block, the media were randomly assigned to main plots, and the extract concentrations were randomly assigned to subplots within each main plot.

Blocking was based on the cutting position on the orthotropic shoot, as cutting position affects the physiological age and food reserves of the cutting. Basal cuttings were taken from the base of the shoot and had brownish stems, middle cuttings had greenish-brown stems, and apical cuttings were taken from the tip of the shoot, had green stems, and were not in a flushing phase. Each block therefore contained cuttings of one position.

Table 1. Treatment combinations of growing media (main plot) and shallot extract (subplot)

Growing medium	Z0 (0%)	Z1 (50%)	Z2 (100%)
T1 = sand	T1Z0	T1Z1	T1Z2
T2 = sand + topsoil (1:1)	T2Z0	T2Z1	T2Z2
T3 = sand + topsoil + compost (1:1:1)	T3Z0	T3Z1	T3Z2

Note: Each combination was replicated in three blocks (basal, middle, and apical cuttings) with eight cuttings per experimental unit (216 cuttings in total).

The data were analyzed according to the linear model of a split-plot RCBD: $Y_{ijk} = \mu + \rho_k + \alpha_i + \delta_{ik} + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$, where Y_{ijk} is the observation for the *i*-th medium and the *j*-th extract concentration in the *k*-th block, μ is the general mean, ρ_k is the block effect, α_i is the effect of the *i*-th medium, δ_{ik} is the main-plot error (error a), β_j is the effect of the *j*-th extract concentration, $(\alpha\beta)_{ij}$ is the interaction effect, and ε_{ijk} is the subplot error (error b).

Sand and topsoil were obtained from the source and sieved to remove stones, roots, and debris. To suppress soil pests and pathogens, the sand and topsoil were treated with carbofuran 3% at a rate of 250 g per 0.25 m³ of medium and with propineb 70% at 125 g dissolved in 125 L of water and were then covered for two weeks. Compost was sterilized by steaming in a large container for 4 h and allowed to cool. The components were mixed by volume according to the treatments and placed in the propagation beds to a depth of 20 cm.

Cuttings were collected in the morning from healthy orthotropic shoots of mother plants of Sulawesi 01. Each cutting had three nodes, was approximately 14 cm long, and carried two or three leaves. One-third of each leaf blade was removed to reduce transpiration. The cuttings were sorted to discard diseased material and grouped by position on the shoot (basal, middle, and apical).

One kilogram of shallot bulbs was peeled, chopped, and blended without adding water. The pulp was filtered through a cloth and squeezed to obtain approximately 500 mL of extract. The 100%

Volume 02 Number 02
November 2026
e-ISSN: 3124-8179
p-ISSN: 3124-7865

concentration consisted of 250 mL of undiluted extract, and the 50% concentration was prepared by mixing 250 mL of extract with 250 mL of distilled water. The extract was prepared on the day of planting. The base of each cutting (about 2–3 cm) was soaked in the respective solution for 10 s and planted immediately; control cuttings were soaked in distilled water for the same time.

The cuttings were planted at a depth of 1 cm in propagation beds enclosed in tightly sealed, transparent plastic containers and shaded with 70% shade netting. The plastic enclosure maintained high humidity around the cuttings, while the shade net reduced direct solar radiation. Air temperature and relative humidity inside the nursery were recorded daily with a thermohygrometer. The medium was kept moist by spraying water from outside the containers every morning and afternoon. Diseased or dead cuttings were removed and recorded.

Four variables were observed (Table 2). Shoot emergence time was recorded daily from one week after planting as the number of days until the first bud broke and its leaves opened. Cutting success was determined at 16 weeks after planting (WAP) as the percentage of cuttings in each experimental unit that were alive and had formed both roots and shoots: success (%) = (number of successful cuttings/number of cuttings planted) × 100. Shoot length was measured at 16 WAP from the base to the tip of the new shoot with a ruler, and shoot diameter was measured at 1 cm above the base of the new shoot with a digital caliper.

Table 2. Observed variables, units, and time and method of observation

Variable	Unit	Time	Method
Shoot emergence time	days	Daily from 1 WAP	Days from planting until the first bud had broken and its leaves had opened
Cutting success	%	16 WAP	Percentage of cuttings alive with roots and shoots
Shoot length	cm	16 WAP	From the base to the tip of the new shoot, ruler
Shoot diameter	mm	16 WAP	At 1 cm above the base of the new shoot, digital caliper

Note: WAP = weeks after planting.

The data were subjected to analysis of variance (ANOVA) for a split-plot RCBD. The effect of the growing medium was tested against error a (2 and 4 degrees of freedom), and the effects of shallot extract and the interaction were tested against error b (2 and 12, and 4 and 12 degrees of freedom, respectively). Effects were considered significant when the calculated F-value exceeded the tabulated F-value at $\alpha = 0.05$ ($p < 0.05$). When the interaction was significant, simple effects were compared using Duncan's multiple range test (DMRT) at the 5% level. When only a main effect was significant, means were compared using the least significant difference (LSD) test at the 5% level. Percentage data were arcsine-transformed before ANOVA. Analyses were performed using software on a computer. In addition, the relative difference between treatments was calculated from the means to describe the magnitude of the responses.

RESULTS

During the experiment, air temperature in the nursery ranged from 25.9 to 31.5 °C, and relative humidity ranged from 74% to 82%. The sealed plastic containers maintained high humidity around the cuttings, and the shade net reduced direct radiation, resulting in favorable environmental conditions for cutting propagation. The ANOVA showed that the interaction between growing media and shallot extract had a significant effect on cutting success ($p < 0.05$; Table 3). The growing medium had a significant main effect on shoot length and shoot diameter, whereas shallot extract

Volume 02 Number 02
November 2026
e-ISSN: 3124-8179
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had no significant main effect on any variable. Neither factor nor their interaction significantly affected shoot emergence time.

Table 3. Summary of analysis of variance (F-values) for the effects of growing media (T) and shallot extract (Z)

Variable	F T	F Z	F T×Z	F-table T	F-table Z	F-table T×Z
Shoot emergence time	1.67 ns	0.26 ns	0.25 ns	6.94	3.89	3.26
Cutting success	3.22 ns	1.94 ns	3.62 *	6.94	3.89	3.26
Shoot length	7.03 *	0.23 ns	0.49 ns	6.94	3.89	3.26
Shoot diameter	6.98 *	0.72 ns	1.01 ns	6.94	3.89	3.26

Note: T = growing media; Z = shallot extract; * = significant ($p < 0.05$); ns = not significant. F-table values at $\alpha = 0.05$ for df (2, 4), (2, 12), and (4, 12), respectively.

The response of cutting success to shallot extract depended on the growing medium (Table 4). In sand + topsoil (T2), 100% shallot extract increased success to 71%, significantly higher than 0% and 50% extracts (58%). In contrast, in sand (T1) and in sand + topsoil + compost (T3), 100% extract reduced success to 33%, and in T3 the 50% extract gave the lowest success of all treatments (29%). Among the media, T2 achieved the highest success across all extract concentrations. The highest success (T2Z2, 71%) was 2.4 times the lowest (T3Z1, 29%).

Table 4. Interaction effect of growing media and shallot extract on cutting success (%) at 16 WAP

Growing medium	Z0 (0%)	Z1 (50%)	Z2 (100%)
T1 = sand	46 A b	46 A b	33 B b
T2 = sand + topsoil	58 B a	58 B a	71 A a
T3 = sand + topsoil + compost	54 A a	29 B c	33 B b

Note: Means followed by the same uppercase letter in the same row (extract concentrations within a medium) and the same lowercase letter in the same column (media within an extract concentration) are not significantly different according to DMRT at the 5% level.

Because each treatment consisted of 24 cuttings (8 cuttings × 3 blocks), the percentages correspond to the numbers of successful cuttings shown in Table 5. Averaged over the extract concentrations, sand + topsoil gave the highest success (62.5%), followed by sand (41.7%) and sand + topsoil + compost (38.9%). Across the media, the control had a numerically higher success rate (52.8%) than the 50% and 100% extracts (44.4% and 45.8%), which is consistent with the absence of a significant main effect of shallot extract. The overall success of the experiment was 47.7% (103 of 216 cuttings).

Table 5. Number of successful cuttings (out of 24 per treatment) and marginal means of cutting success

Growing medium	Z0 (0%)	Z1 (50%)	Z2 (100%)	Mean (%)
T1 = sand	11	11	8	41.7
T2 = sand + topsoil	14	14	17	62.5
T3 = sand + topsoil + compost	13	7	8	38.9
Mean (%)	52.8	44.4	45.8	47.7

Note: Numbers of successful cuttings were calculated from the percentages in Table 4 (24 cuttings per treatment). Means are percentages of successful cuttings per medium (72 cuttings), per extract concentration (72 cuttings), and overall (216 cuttings).

Volume 02 Number 02
November 2026
e-ISSN: 3124-8179
p-ISSN: 3124-7865



Figure 1. Cocoa cutting with a newly emerged and opened shoot

Successful cuttings were indicated by green buds that had broken dormancy and developed from the leaf axils (Figure 1). Shoot emergence was monitored daily from one week after planting. The mean time to shoot emergence ranged from 40.2 days (T2Z1) to 64.2 days (T1Z2), with an overall mean of 49.7 days (Table 6). Although these differences were not significant, cuttings in sand + topsoil emerged earlier on average (41.6 days) than those in sand (52.5 days) or sand + topsoil + compost (54.9 days), and the combinations of sand + topsoil with 50% and 100% extract gave the earliest emergence.

Table 6. Mean shoot emergence time (days after planting) of cocoa cuttings

Growing medium	Z0 (0%)	Z1 (50%)	Z2 (100%)	Mean
T1 = sand	45.7	47.7	64.2	52.5
T2 = sand + topsoil	44.3	40.2	40.3	41.6
T3 = sand + topsoil + compost	60.6	52.3	51.8	54.9
Mean	50.2	46.7	52.1	49.7

Note: Values are mean days after planting. Differences among treatments were not significant (ANOVA, $p > 0.05$).

The growing medium significantly affected shoot length and shoot diameter at 16 WAP (Table 7). Sand + topsoil produced the longest shoots (5.72 cm) and the largest diameter (2.13 mm). The shoots in this medium were about twice as long as those in sand (2.77 cm) or sand + topsoil + compost (2.84 cm), and their diameter was 38–42% greater. Shallot extract did not significantly affect shoot length (3.58–3.98 cm) or diameter (1.68–1.82 mm). Visual differences in shoot growth among the media are shown in Figure 2.

IIAJ INTERNATIONAL INTEGRATED AGRICULTURAL JOURNAL
Volume 02 Number 02
November 2026
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Table 7. Main effects of growing media and shallot extract on shoot length and shoot diameter at 16 WAP

Treatment	Shoot length (cm)	Shoot diameter (mm)	Change in length vs. sand (%)
Growing medium			
T1 = sand	2.77 b	1.50 b	–
T2 = sand + topsoil	5.72 a	2.13 a	+106.5
T3 = sand + topsoil + compost	2.84 b	1.54 b	+2.5
Shallot extract			
Z0 = 0% (control)	3.98 a	1.68 a	–
Z1 = 50%	3.76 a	1.82 a	–
Z2 = 100%	3.58 a	1.68 a	–

Note: Means with the same letter within a factor and column are not significantly different (LSD, 5%).



(a) (b) (c)

Figure 2. Cocoa cuttings at 16 weeks after planting grown in (a) sand, (b) sand + topsoil (1:1), and (c) sand + topsoil + compost (1:1:1)

Taken together, the results show a consistent ranking of the media. Sand + topsoil ranked first for cutting success, shoot length, and shoot diameter, and numerically for shoot emergence time, whereas sand and sand + topsoil + compost did not differ from each other in shoot length or diameter. Shallot extract altered the ranking of extract concentrations across media, which explains why its main effect was not significant, although its interaction with the medium was significant for cutting success.

DISCUSSION

This study showed that the growing medium was the dominant factor affecting the growth of cocoa orthotropic cuttings, while the effect of shallot extract depended on the medium. A mixture of sand and topsoil (1:1) produced the highest cutting success at all extract concentrations, the longest and thickest shoots, and the earliest average shoot emergence. When combined with 100% shallot extract, this medium gave a success rate of 71%. These results support our hypothesis that a medium combining sand with a nutrient source improves cutting growth, and that the effect of the natural growth regulator depends on the medium.

The superiority of sand + topsoil can be explained by the balance between aeration and the supply of water and nutrients. Adventitious root formation is an energy-demanding process, and the

Volume 02 Number 02
November 2026
e-ISSN: 3124-8179
p-ISSN: 3124-7865

cells at the base of the cutting need oxygen for respiration (Druege et al., 2019). Sand creates large pores that drain quickly and remain filled with air, whereas topsoil contains finer particles and organic matter that retain water and nutrients. A rooting medium must balance these two properties, because both water shortage and waterlogging reduce rooting (Yafuso and Fisher, 2019). In sand alone, the medium probably dried quickly and supplied few nutrients once roots had formed, while in sand + topsoil the cuttings had adequate air at the base and sufficient water and nutrients for the developing roots and shoots. Similar advantages of mixed media over single components have been reported for cuttings of fig and periwinkle (Shamsuddin et al., 2021; Nelka et al., 2026) and for cocoa seedlings in the nursery (Mintah et al., 2022).

Adding compost to the mixture (T3) did not improve growth; in fact, cutting success and shoot growth in T3 were similar to or lower than those in sand alone. The effectiveness of compost in a rooting medium depends on its physical and chemical properties. Compost increases water-holding capacity, and when mixed with topsoil in high humidity, it may reduce air-filled porosity at the base of the cuttings. Although the compost was steamed, organic materials can still decompose in the medium, consuming oxygen and possibly releasing salts or phenolic compounds. These conditions inhibit respiration and cell division at the base of the cutting, which can lead to rot. In propagation studies with compost-based media, rooting was best when compost was combined with an inert, well-aerated material and used in moderate proportions (Souza et al., 2023). For cocoa cuttings, compost should therefore be used in a smaller proportion or replaced by more stable organic materials.

Shallot extract alone had no significant main effect, but its effect on cutting success depended on the medium. In sand + topsoil, 100% extract increased success from 58% to 71%, whereas in sand and in sand + topsoil + compost it reduced success. Shallot extract is reported to contain auxins and other compounds that stimulate root initiation (Tambunan et al., 2019; Lukman et al., 2022). Auxin promotes cell division and differentiation of root primordia at the cutting base, but its effect follows an optimum curve: too little auxin has no effect, and too much can inhibit root and shoot development or increase ethylene production (Wei et al., 2019; Li, 2021). The concentration of active compounds in the crude extract is unknown, and the extract also contains sugars and sulfur compounds that may promote microbial growth at the cut surface. In a well-aerated, moderately moist medium such as sand + topsoil, the auxin in the extract may have stimulated rooting, whereas in drier sand or wetter compost-based media, the same extract may have increased stress or decay at the cutting base. Similar inconsistent responses have been reported: shallot extract improved shoot emergence in chaya cuttings but did not increase overall growth (Gustiar et al., 2025), and natural growth regulators had no significant effect on moringa seedlings (Karno et al., 2023).

The absence of a main effect of shallot extract is also consistent with research on cocoa cuttings with synthetic auxin. Vásquez Zamora et al. (2022) obtained the best rooting and survival of cocoa cuttings without IBA or with the lowest IBA dose, indicating that orthotropic cocoa cuttings may already contain sufficient endogenous auxin. Orthotropic shoots are physiologically younger than plagiotropic branches and generally root more easily (Sodré and Gomes Sena, 2019). When endogenous auxin is adequate, an exogenous supply has little additional effect and may even be inhibitory. The short soaking time used in this study (10 s) may also have limited the uptake of active compounds. Studies with longer soaking times or with defined concentrations of the active compounds are needed.

Shoot emergence time was not affected by the treatments, although it was, on average, earlier in sand + topsoil. During the first weeks after planting, cuttings rely mainly on the carbohydrate reserves stored in the stem and leaves to support bud break, because roots are not yet formed and

Volume 02 Number 02
November 2026
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nutrient uptake from the medium is minimal (Druege et al., 2019; Amanah et al., 2022). Bud break is therefore controlled more by the physiological condition of the cutting, such as its position on the shoot, its food reserves, and the activity of its meristems, than by the medium or the growth regulator. The blocking-by-cutting position used in this study removed part of this variation from the error, but the large differences in emergence time among combinations (40–64 days) suggest that considerable variation between cuttings remained.

In contrast, shoot length and diameter at 16 weeks were strongly influenced by the medium. Once roots have formed, the growth of the new shoot depends on the uptake of water and nutrients from the medium. Primary meristems at the shoot tip drive elongation, while the vascular cambium produces secondary tissues that increase stem diameter (Inácio et al., 2022). The greater length and diameter in sand + topsoil indicate that this medium supported both processes better than the other media. Thicker shoots are generally associated with better seedling quality and field establishment, so the medium affects not only the success of propagation but also the quality of the resulting plants. A similar effect of the medium on cutting growth has been reported for fig cuttings, in which the medium affected root and shoot growth more than the cutting type (Mafrica et al., 2025).

The microclimate in the propagation chamber (25.9–31.5 °C and 74–82% relative humidity) was within the range suitable for leafy cuttings, so the differences between treatments can be attributed mainly to the media and the extract rather than to environmental stress. Nevertheless, daytime temperatures above 30 °C, combined with a permanently moist medium, favor fungal and bacterial growth at the cutting base. This may partly explain why the media richer in organic matter, and the higher concentration of a sugar-rich extract in these media, reduced success. Good sanitation of the medium, as carried out here with a nematicide, a fungicide, and steaming of the compost, is therefore essential, and ventilation of the chamber once roots have formed may further reduce losses (Vásquez Zamora et al., 2022; Souza et al., 2023).

From a practical perspective, the combination of sand + topsoil (1:1) and 100% shallot extract is simple, inexpensive, and easily adopted by cocoa farmers and nurseries. Both materials are locally available, and the extract can be prepared without special equipment. The success rate of 71% obtained with this combination approaches the generally acceptable level of about 70% for a practical propagation system. However, the overall success of 47.7% indicates that further improvement is needed. This study has several limitations: only one clone was used, root characteristics were not measured, the extract's auxin content was not analyzed, and the media's physical and chemical properties were not determined. Future studies should measure root number, length, and biomass; characterize the porosity and nutrient content of the media; test lower compost proportions and longer soaking times; and evaluate the field performance of the rooted cuttings.

CONCLUSION

The growing medium and shallot extract interacted to influence the success of cocoa orthotropic cuttings, with the highest success (71%) obtained in sand + topsoil (1:1) combined with 100% shallot extract, and the lowest (29%) in sand + topsoil + compost with 50% shallot extract. Sand + topsoil also produced the longest shoots (5.72 cm) and the largest shoot diameter (2.13 mm) at 16 weeks after planting, whereas shallot extract alone did not significantly affect shoot growth, and none of the treatments affected shoot emergence time. A sand-topsoil (1:1) medium, combined with 100% shallot extract, is therefore recommended as a simple, low-cost method for propagating cocoa using orthotropic cuttings.

Volume 02 Number 02
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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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