



Effects of Cocopeat and Spent Mushroom Substrate on the Early Growth of Three Tea Clones

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Abstract

Reducing dependence on topsoil in tea nurseries is critical for sustainable plantation management, but viable organic alternatives remain underexplored. This study evaluated the early growth of three tea clones (PKID 1, PKID 2, and PKID 3) grown in three nursery media: soil+subsoil (control), soil+cocopeat, and soil+spent mushroom substrate (baglog), each in a 1:2 ratio with soil. A factorial experiment was arranged in a completely randomized design with four replications, and media nutrient composition (N, P, K, C-organic, C/N) and seedling growth (fresh and dry root weight, shoot–root ratio, seedling quality index) were analyzed using two-way ANOVA. The soil+subsoil medium contained more balanced nitrogen and phosphorus levels, while cocopeat and baglog had very high organic carbon (29–36%) and C/N ratios (77–87). Root biomass, seedling quality index, and overall vigor were highest in soil+subsoil, with PKID 1 performing best among clones. Cocopeat and baglog significantly reduced root growth and seedling quality while increasing shoot–root ratios, indicating poor root–shoot balance, and PKID 3 showed the lowest performance across all media. These findings indicate that cocopeat and baglog are unsuitable as primary nursery media for tea cuttings due to nutrient imbalances, though incorporating them in small proportions with mineral soil or compost could enhance sustainability without compromising seedling quality.

KEYWORDS

Camellia sinensis; Cocopeat; Spent mushroom substrate; Tea clones; Nursery media; Rooting and Seedling quality

1 | INTRODUCTION

Camellia sinensis (L.) O. Kuntze is a perennial evergreen crop of major global economic importance, widely cultivated for its tender young leaves which are processed into black, green, oolong, and specialty teas. Tea plantations cover more than 5 million hectares worldwide, providing livelihoods for millions of smallholder farmers across Asia, Africa, and South America (Rahman et al., 2023). In Indonesia, tea remains an important export commodity and a key source of income for upland farming communities, particularly in West Java, Central Java, and North Sumatra (Putra et al., 2024). Maintaining the productivity and quality of tea plantations depends heavily on the availability of vigorous, uniform planting material, which is typically produced vegetatively through nodal cuttings of selected clones (Ahmed et al., 2022).

Clonal propagation enables the rapid multiplication of elite tea genotypes with desirable agronomic traits such as high yield, quality, and pest or disease tolerance (Dutta et al., 2023). However, the success of clonal propagation depends strongly on the rooting and early growth performance of cuttings, which are influenced by both genetic and environmental factors. Among the environmental factors, the choice of nursery growth medium is critical because it affects root aeration, water retention, nutrient availability, and microbial activity (Gomez et al., 2022). In conventional tea nurseries, a mixture of topsoil and subsoil is commonly used as the rooting medium because it provides stable structure and balanced mineral content. However, the continuous extraction of large volumes of topsoil for nursery operations is unsustainable and contributes to soil degradation,

erosion, and reduced fertility on plantation lands (Chandran et al., 2024).

To reduce dependence on topsoil, there is increasing interest in identifying alternative organic substrates that are more sustainable and readily available. Two promising candidates are cocopeat and spent mushroom substrate (SMS), also known as baglog. Cocopeat is a byproduct of *Cocos nucifera* (coconut) coir processing and is widely used in horticulture for its high water-holding capacity, porosity, and slow decomposition rate (Mahawatte et al., 2023). SMS or baglog is the residual substrate left after mushroom cultivation, typically composed of sawdust, rice bran, and organic supplements partially decomposed by fungal activity (Kim et al., 2022). Both materials are abundant agricultural byproducts that could reduce waste accumulation and provide a circular economy benefit if repurposed as nursery media (Yin et al., 2024).

Several studies have demonstrated the potential of cocopeat and SMS as substitutes or components of nursery media in various crops. For instance, Rahim et al. (2023) found that cocopeat-based substrates improved root growth and water retention in cacao seedlings, while Yin et al. (2024) reported that mixing SMS with soil enhanced seedling vigor and reduced the need for chemical fertilizers in vegetable transplants. These organic materials can also improve soil structure, increase microbial activity, and provide slow-release nutrients as they decompose (Wang et al., 2023). However, their performance is highly context-dependent and varies by crop species and developmental stage (Xie et al., 2022).

For woody perennial species like tea, early seedling quality is especially critical because poor root development or nutrient imbalances in the nursery can have long-term negative impacts on field establishment, growth uniformity, and productivity (Bhutia et al., 2024). The ideal nursery medium for tea should balance high water retention (to maintain constant moisture for rooting cuttings) with adequate aeration and moderate nutrient availability. Excessively organic media, particularly if not fully decomposed, can have very high carbon-to-nitrogen (C/N) ratios and immobilize nitrogen, thereby restricting root growth and overall seedling development (Wang et al., 2023; Zhang et al., 2022). Cocopeat and SMS often have C/N ratios above 50, which can limit their immediate suitability as stand-alone nursery media unless mixed with mineral soils or supplemented with nitrogen sources (Aboagye et al., 2023).

Despite their potential, there is limited published information on the use of cocopeat and SMS as nursery media for tea cuttings, particularly in combination with different tea clones that may vary in rooting and early growth capacity. Clonal variation plays a crucial role in tea propagation success: certain clones are known to root readily and produce vigorous seedlings, while others

are more recalcitrant (Ahmed et al., 2022). Evaluating the interaction between genotype and medium is therefore essential to develop recommendations for sustainable nursery practices. Without this information, widespread adoption of alternative organic media could risk producing substandard planting material and reducing the success rate of field establishment (Gomez et al., 2022; Bhutia et al., 2024).

This study was thus designed to evaluate the suitability of cocopeat and SMS (baglog) as alternative nursery media for clonal tea propagation. Specifically, the experiment compared the early growth performance of three commonly used tea clones (PKID 1, PKID 2, and PKID 3) grown in mixtures of soil+cocopeat or soil+baglog relative to the conventional topsoil+subsoil medium. Key indicators assessed included root and shoot biomass, shoot–root ratio, and seedling quality index. The findings are expected to inform sustainable nursery practices that reduce topsoil extraction while maintaining or improving the quality of tea planting materials for replanting programs in Indonesia and other tea-producing regions.

2 MATERIALS AND METHODS

Plant Material and Experimental Design

Vegetative cuttings from three clonal lines of *Camellia sinensis* (PKID 1, PKID 2, and PKID 3) were used as planting material. These clones are widely cultivated for their high yield potential and represent a range of rooting and early growth capacities. The experiment was arranged in a factorial design consisting of two factors: clone (three levels) and nursery medium (three levels), giving nine treatment combinations. Each treatment was replicated four times, and each replication contained ten cuttings grown individually in polybags. The study followed a completely randomized design (CRD).

Nursery Media Treatments

- Three types of nursery media were tested:
1. **Topsoil + subsoil (1:1 v/v)** was used as the control medium, representing conventional tea nursery practice.
 2. **Soil + cocopeat (1:2 v/v)** was formulated to assess the potential of coconut coir dust as an organic substitute for mineral soil.
 3. **Soil + spent mushroom substrate (baglog) (1:2 v/v)** was formulated to evaluate the use of mushroom production residues as an alternative medium.

All media mixtures were homogenized thoroughly before filling into standard nursery polybags. Cocopeat was finely sieved to remove coarse fibers, while the baglog substrate was air-dried and crumbled prior to mixing. No chemical fertilizers or rooting hormones

were added during the study to allow evaluation of the inherent properties of the media.

Media Chemical Characterization

Samples of each medium type were collected before planting to determine their nutrient content. Analyses included total nitrogen (N), available phosphorus (P), exchangeable potassium (K), organic carbon (C-organic), and the carbon-to-nitrogen (C/N) ratio. These parameters were measured using standard soil and plant analysis procedures. The nutrient data were used to interpret plant growth responses in relation to the physicochemical properties of each medium.

Plant Growth and Seedling Quality Measurements

Cuttings were maintained under standard nursery conditions with uniform irrigation and shading. Data were collected at 32 and 48 weeks after transplanting (WAT) to assess both root and shoot growth performance. The following growth parameters were recorded:

- **Fresh root weight (g)** was roots were gently washed to remove media and immediately weighed using an analytical balance.
- **Dry root weight (g)** was root samples were oven-dried at 70 °C to constant weight.
- **Shoot-root ratio** was calculated as total shoot dry weight divided by root dry weight, representing biomass allocation patterns.
- **Seedling quality index (QI)** was calculated using the standard Dickson formula:

$$QI = \frac{\text{Total Dry Weight (g)}}{\left(\frac{\text{Shoot Height (cm)}}{\text{Stem Diameter (mm)}}\right) + \left(\frac{\text{Shoot Dry Weight (g)}}{\text{Root Dry Weight (g)}}\right)}$$

This index integrates several morphological traits to provide a composite indicator of seedling vigor and transplant potential.

Statistical Analysis

Data were first checked for normality and homogeneity of variance. A two-way analysis of

variance (ANOVA) was conducted to test the effects of clone, nursery medium, and their interaction on each parameter. When significant differences were detected ($p \leq 0.05$), treatment means were separated using Duncan's Multiple Range Test (DMRT) at the 5% significance level. Statistical analyses were performed using SAS version 9.4. The significance of differences among media types was interpreted in relation to their nutrient composition profiles.

3 RESULTS

Chemical Properties of Nursery Media

The chemical analysis revealed substantial differences in nutrient composition between the three-nursery media tested (Table 1). The control medium (soil+subsoil) contained moderate levels of nitrogen (0.21%), phosphorus (34.2 ppm), potassium (0.64 cmol·kg⁻¹), and organic carbon (2.1%). By contrast, cocopeat and baglog mixtures had markedly higher organic carbon contents (29.4% and 35.8%, respectively) but very low nitrogen levels (0.38% and 0.41%), resulting in extremely high C/N ratios (77 and 87, respectively). Potassium was also higher in the organic-based media, while available phosphorus was notably lower than in the control. These results suggest that the cocopeat and baglog media were rich in organic matter but poorly balanced in available nutrients, especially nitrogen and phosphorus, which are critical for root development during the nursery stage.

Fresh Root Weight

Fresh root weight varied significantly among clones and media, with a clear interaction between these factors (Table 2). Across all media, PKID 1 produced the heaviest fresh roots, while PKID 3 produced the lightest. The control medium consistently supported better root development than cocopeat or baglog mixtures. PKID 1 in the control medium had the highest root fresh weight (7.85 g), which was almost double that of the same clone in cocopeat (3.96 g) or baglog (3.45 g). PKID 3 showed poor root development across

Table 1: Nutrient composition of nursery media used for rooting *Camellia sinensis* cuttings

Media	Total N (%)	Available P (ppm)	Exchangeable K (cmol·kg ⁻¹)	Organic C (%)	C/N ratio
Soil + Subsoil (Control)	0.21	34.2	0.64	2.1	10
Soil + Cocopeat	0.38	18.5	0.92	29.4	77
Soil + Baglog	0.41	16.2	1.05	35.8	87

Table 2: Fresh root weight (g) of three tea clones grown in different nursery media at 48 WAT.

Clone	Soil+Subsoil	Soil+Cocopeat	Soil+Baglog	Mean
PKID 1	7.85 a	3.96 b	3.45 b	5.09 a
PKID 2	6.72 a	3.22 b	2.88 b	4.27 b
PKID 3	4.31 b	2.15 c	1.72 c	2.73 c
Mean	6.29 A	3.11 B	2.68 B	-

all media, especially in baglog (1.72 g). The superior root growth in the control medium is likely due to its balanced mineral nutrient content and lower C/N ratio, which support early root formation.

Dry Root Weight

Dry root weight showed a similar trend to fresh root weight (Table 3). PKID 1 again showed the highest dry root biomass across all media, with the maximum value observed in the control medium (2.45 g at 48 WAT). Both cocopeat and baglog media supported lower dry root accumulation, with reductions of 40–60% compared to the control. PKID 3 consistently had the lowest dry root weight, particularly in baglog (0.58 g). These results reinforce that the high C/N ratios in the organic-based media likely caused nitrogen immobilization, reducing root biomass accumulation during the nursery phase.

Shoot–Root Ratio

The shoot–root ratio differed significantly among treatments and provided insight into biomass allocation patterns (Table 4). Across clones, plants grown in cocopeat or baglog had much higher shoot–root ratios than those in the control medium, indicating disproportionately greater shoot growth relative to root biomass. PKID 1 in baglog had the highest shoot–root ratio (7.2), while PKID 3 in the control had the lowest (3.5). Elevated shoot–root ratios are often considered undesirable in nursery seedlings because they can indicate insufficient root support for subsequent field establishment. These results suggest that while organic-based media did not severely restrict shoot formation, they strongly limited root development, thereby skewing the shoot–root balance.

Seedling Quality Index (QI)

Seedling quality index integrates multiple morphological traits to provide an overall measure of seedling vigor. Across all clones, QI was highest in the control medium and declined markedly in cocopeat and baglog treatments (Table 5). PKID 1 in the control medium recorded the highest QI (0.35), whereas PKID 3 in baglog recorded the lowest (0.08). The reduced QI values in organic media are consistent with their poor root biomass performance and unbalanced nutrient composition, particularly the extremely high C/N ratios which likely induced nitrogen deficiency during the rooting phase.

4 | DISCUSSION

This study investigated the performance of three tea clones (PKID 1, PKID 2, and PKID 3) propagated on three types of nursery media: the conventional soil+subsoil mixture, and two alternative organic-based substrates consisting of soil mixed with cocopeat or spent mushroom substrate (baglog). The results showed a clear and consistent pattern: the soil+subsoil control medium supported superior root development, balanced shoot–root ratios, and higher seedling quality indices compared to the cocopeat and baglog media. This pattern was consistent across all clones, although PKID 1 exhibited generally stronger growth than PKID 2 and PKID 3. These findings demonstrate that while organic byproducts such as cocopeat and baglog hold promise as sustainable media components, their unamended use can compromise tea cutting development, primarily due to imbalanced nutrient composition and excessively high carbon-to-nitrogen (C/N) ratios.

Table 3: Dry root weight (g) of three tea clones in different nursery media at 32 and 48 WAT.

Clone	32 WAT - Soil+Subsoil	32 WAT - Soil+Cocopeat	32 WAT - Soil+Baglog	48 WAT - Soil+Subsoil	48 WAT - Soil+Cocopeat	48 WAT - Soil+Baglog
PKID 1	1.05 a	0.55 b	0.48 b	2.45 a	1.12 b	0.95 b
PKID 2	0.92 a	0.44 b	0.41 b	2.03 a	0.88 b	0.74 b
PKID 3	0.65 b	0.33 c	0.25 c	1.55 b	0.62 c	0.58 c

Table 4: Shoot–root ratio of three tea clones grown in different nursery media at 48 WAT.

Clone	Soil+Subsoil	Soil+Cocopeat	Soil+Baglog	Mean
PKID 1	4.1 b	6.3 a	7.2 a	5.9 a
PKID 2	3.9 b	5.5 a	6.4 a	5.3 b
PKID 3	3.5 b	4.9 a	5.8 a	4.7 c
Mean	3.8 B	5.6 A	6.5 A	-

Table 5: Seedling quality index of three tea clones in different nursery media at 48 WAT.

Clone	Soil+Subsoil	Soil+Cocopeat	Soil+Baglog	Mean
PKID 1	0.35 a	0.18 b	0.14 b	0.22 a
PKID 2	0.29 a	0.15 b	0.12 b	0.19 b
PKID 3	0.21 b	0.10 c	0.08 c	0.13 c
Mean	0.28 A	0.14 B	0.11 B	-

Influence of Media Nutrient Composition on Root Development

The chemical analysis of the nursery media (Table 1) revealed that cocopeat and baglog mixtures were extremely rich in organic carbon (29–36%) but contained relatively low nitrogen (0.38–0.41%) and phosphorus (16–18 ppm), resulting in C/N ratios of 77–87. In contrast, the soil+subsoil control had much lower organic carbon (2.1%) but balanced nitrogen (0.21%) and higher phosphorus (34.2 ppm). These results align with previous reports indicating that organic residues with high C/N ratios can immobilize nitrogen during microbial decomposition, thereby limiting its availability to plants during early root development (Wang et al., 2023; Aboagye et al., 2023). Nitrogen is critical for the synthesis of proteins, enzymes, and nucleic acids that support root meristem activity, while phosphorus promotes root initiation and elongation (Mehta et al., 2023). The nutrient imbalance in cocopeat and baglog likely created suboptimal conditions for root growth in tea cuttings, explaining their lower fresh and dry root weights.

This finding is consistent with studies on other woody perennials where excessive organic matter without mineral supplementation reduces root growth. For example, Yin et al. (2024) reported that vegetable seedlings grown in pure spent mushroom substrate had poor root development unless supplemented with nitrogen-rich amendments. Similarly, Rahim et al. (2023) found that cacao cuttings rooted poorly in pure cocopeat unless blended with composted manure to correct its low nutrient content. These studies, together with the present results, emphasize that nutrient balance—especially adequate nitrogen and phosphorus—must be ensured when using high-carbon organic materials as nursery media.

Clonal Variation in Rooting Performance

Across all media, PKID 1 consistently produced the highest fresh and dry root biomass, while PKID 3 had the poorest root development (Tables 2 and 3). This reflects intrinsic genetic variation among clones in rooting capacity and early vigor, which is well-documented in *Camellia sinensis*. Ahmed et al. (2022) reported significant differences in root initiation rates and root mass among 12 tea clones under identical nursery conditions, attributing the variation to genotypic differences in auxin sensitivity and carbohydrate reserves. Bhutia et al. (2024) similarly observed that vigorous clones form roots earlier and accumulate greater biomass during the first 12 months in the nursery.

The superior performance of PKID 1 in this study suggests that it possesses more active root meristems or greater endogenous carbohydrate and hormone

reserves that facilitate adventitious root formation even under suboptimal nutrient conditions. By contrast, PKID 3 appears more sensitive to nutrient limitations, which may explain its particularly poor response in the cocopeat and baglog media. This highlights the importance of selecting clones with inherently high rooting ability when testing new or marginal nursery media to avoid confounding genetic and substrate effects (Dutta et al., 2023).

Shoot–Root Biomass Allocation

The shoot–root ratio provides insight into how seedlings allocate biomass between aboveground and belowground organs. In this study, seedlings grown in cocopeat or baglog had much higher shoot–root ratios than those in soil+subsoil (Table 4), indicating a disproportionate allocation to shoot biomass at the expense of root development. This imbalance is often considered undesirable in nursery seedlings because an undersized root system cannot support rapid shoot growth during transplanting and field establishment (Gomez et al., 2022).

The elevated shoot–root ratios in the organic media likely reflect a compensatory response to nutrient limitation, where seedlings prioritize leaf development to enhance photosynthetic capacity under stress (Xie et al., 2022). However, this strategy comes at the cost of root growth, resulting in structurally weak seedlings that are vulnerable to water stress and transplant shock. Similar findings have been reported in tea by Mehta et al. (2023), who showed that cuttings with shoot–root ratios above 6.0 had poor survival after field planting, whereas those with ratios between 3.0–4.5 exhibited the highest establishment rates.

Seedling Quality Index as an Integrative Indicator

The seedling quality index (QI) integrates height, stem diameter, and biomass distribution to provide a holistic assessment of seedling vigor. In this study, QI values were highest in soil+subsoil media and markedly lower in cocopeat and baglog (Table 5). PKID 1 in soil+subsoil achieved a QI of 0.35, while PKID 3 in baglog had only 0.08, indicating very poor structural quality. According to Dickson's standard, a QI above 0.25 is generally considered acceptable for woody seedlings, whereas values below 0.15 signal low-quality stock (Bhutia et al., 2024). Thus, only the control medium produced seedlings of acceptable quality across clones.

Low QI values in the organic-based media are attributable to their low root biomass and high shoot–root ratios. This pattern mirrors observations in other crops where organic substrates with high C/N ratios reduced QI values. For instance, Chandran et al. (2024) found that forest tree seedlings grown in high-

carbon sawdust substrates had QI values below 0.15, whereas those in balanced soil mixes reached 0.30–0.40. Such results reinforce that root development is a primary determinant of seedling quality, and any medium that restricts root growth will inherently produce lower QI seedlings.

Limitations of Cocopeat and Baglog for Tea Cuttings

Although cocopeat and baglog have attractive physical properties such as high porosity and water-holding capacity, their chemical limitations likely outweighed these benefits in this study. Cocopeat is known to contain high lignin and cellulose content with slow decomposition rates, which limits nutrient release during early stages (Mahawatte et al., 2023). Baglog, composed mainly of sawdust residues, also retains a very high C/N ratio and may contain phenolic residues from mushroom cultivation that can inhibit root growth if not fully decomposed (Kim et al., 2022; Yin et al., 2024).

The excessive organic matter in these media can also create anaerobic conditions if overwatered, further inhibiting root initiation (Liu et al., 2022). In tea, which is a woody perennial with relatively slow initial growth, a stable mineral nutrient supply is more critical than the high water retention offered by cocopeat or baglog (Gomez et al., 2022). Therefore, while these materials could be used as partial components in mixed media formulations, they are unsuitable as major media components for direct rooting of tea cuttings without pre-composting or mineral supplementation.

Implications for Sustainable Nursery Management

From a sustainability perspective, reducing topsoil extraction is an important goal for tea plantations, as overharvesting nursery soil contributes to erosion and long-term fertility decline (Hossain & Roy, 2023; Chandran et al., 2024). However, the results of this study demonstrate that unamended use of high-carbon organic residues like cocopeat and baglog cannot yet replace soil-based media for tea propagation. Instead, an intermediate approach may be more effective—using these organic materials as partial substitutes ($\leq 25\text{--}30\%$ by volume) combined with mineral-rich soil or composted manure to improve nutrient balance.

Such integrated media have shown promising results in other perennial crops. Rahim et al. (2023) achieved high rooting success in cacao cuttings using 30% cocopeat blended with composted soil, while Yin et al. (2024) improved vegetable seedling quality by mixing 25% spent mushroom substrate with vermicompost. These studies support the view that organic byproducts can enhance physical properties and sustainability when properly balanced with

nutrient-rich components. Future research should therefore focus on optimizing the blending ratios of cocopeat and baglog for tea cuttings, as well as evaluating their performance after partial composting or nitrogen enrichment to lower their C/N ratios.

Conclusion

This study showed that nursery media strongly influence the early growth performance of *Camellia sinensis* cuttings. The conventional soil+subsoil medium supported superior root biomass accumulation, balanced shoot–root ratios, and higher seedling quality indices compared to mixtures containing cocopeat or spent mushroom substrate (baglog). Cocopeat- and baglog-based media had very high organic carbon content and C/N ratios but low nitrogen and phosphorus availability, which likely caused nutrient immobilization and restricted root development.

Among the three clones, PKID 1 consistently exhibited the strongest growth and highest quality indices, while PKID 3 was the weakest across all media, indicating clear clonal variation in rooting ability. The poor performance of all clones in cocopeat and baglog suggests that these materials are unsuitable as major nursery medium components for tea without further composting or nutrient enrichment.

To improve sustainability, these organic byproducts could be used in combination with mineral soil or compost at lower proportions ($\leq 30\%$) to enhance physical properties without compromising nutrient balance. Such mixed-media approaches may help reduce topsoil extraction in tea nurseries while maintaining high-quality planting material for field establishment.

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