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CIRCULAR NURSERY MEDIA: BANANA STEM COMPOST AND WATERING REGIMES FOR OIL PALM

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ABSTRACT

Agricultural-waste valorization can improve nursery sustainability when organic residues are converted into functional growing-media amendments. This study evaluated banana stem organic matter and watering frequency, individually and interactively, on oil palm (Elaeis guineensis Jacq.) seedlings at the pre-nursery stage. A 3 x 3 factorial randomized block design with three replications was used in Medan Selayang, North Sumatra, beginning in July 2025. Banana stem organic matter was applied at 100, 200, and 300 g/polybag (B1-B3), while watering was imposed once daily, twice daily, or once every two days (P1-P3). Plant height, stem diameter, leaf area, and leaf number were measured from 5 to 12 weeks after planting (WAP). Banana stem organic matter significantly affected plant height at 5 and 12 WAP, with B3 producing the highest values (6.47 and 20.36 cm). Watering frequency did not significantly affect plant height, stem diameter, or leaf area, but significantly affected leaf number at 6 WAP, where P2 produced 1.93 leaves. No significant interaction was detected for the measured variables, although B3P2 produced the highest stem diameter (9.90 mm) and B3P3 the highest leaf area (27.44 cm2) at 12 WAP. These findings indicate that 300 g/polybag banana stem organic matter can support seedling height while moderate watering regimes may preserve growth, offering a circular approach to pre-nursery management.

Keywords: banana stem compost; circular agriculture; oil palm; pre-nursery; watering frequency.

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INTRODUCTION

Oil palm (Elaeis guineensis Jacq.) remains a strategic plantation crop in Indonesia, and seedling quality is a critical determinant of later field performance. Nursery management therefore requires a growing medium that supports root development, nutrient availability, aeration, and water retention. Organic amendments have been used to improve soil properties and reduce dependence on mineral inputs in oil palm systems (Comte et al., 2013; Agung et al., 2019). In pre-nursery production, media quality and water management are particularly important because young seedlings have limited root volume and are more sensitive to short-term changes in moisture and nutrient supply (Nasution et al., 2014; Dwiyana et al., 2015).

Banana stems are abundant agricultural residues containing structural organic matter and plant nutrients that can be returned to the production cycle rather than discarded. Composting converts this residue into a more stable amendment and can improve media structure, water-holding capacity, and nutrient retention (Kusumawati, 2015; Bahtiar et al., 2016). Previous studies have reported positive growth responses of oil palm seedlings to organic materials and plant-waste composts, although the magnitude of response depends on dose, decomposition status, and nursery conditions (Syah et al., 2023; Pratama et al., 2022). This creates an opportunity to frame banana stem use not only as fertilization, but as circular nursery management that simultaneously addresses residue utilization and seedling input efficiency.

Water availability interacts conceptually with organic amendments because water controls nutrient dissolution, transport, cell turgor, and leaf expansion. However, frequent watering may not always improve growth when the growing medium already retains sufficient moisture, whereas inadequate or excessive water can restrict root function (Hastuti et al., 2018; Ropindo Saragih et al., 2016). Earlier nursery work indicates that oil palm responses to watering frequency can be weak when treatments remain within a physiologically tolerable moisture range (Syahputra et al., 2017). Factorial plant-growth studies published in Algebra also demonstrate the value of testing both main and interaction effects when evaluating crop-management inputs (Hasibuan et al., 2024; Azhari et al., 2025).

Oil palm development in Indonesia is supported by extensive agronomic knowledge on crop requirements, nursery standards, and plantation management (Badan Pusat Statistik, 2022; Fauzi et al., 2014; Fauzi et al., 2020; Lubis & Widanarko, 2011; Pahan, 2012; Rival & Levang, 2014). Banana-stem composting has also been explored beyond oil palm, strengthening the broader rationale for recycling this residue into plant-production systems (Pranata, 2019). From a physiological perspective, water availability regulates turgor, photosynthesis, and nutrient transport, which explains why watering treatments may affect leaf initiation before other morphological traits respond (Salisbury & Ross, 1992). The oil palm genotype and early vegetative performance also influence the interpretation of nursery growth responses (Rahmawati, 2023).

The novelty of this study lies in evaluating banana stem organic matter as a circular nursery-media amendment together with practical watering schedules under a factorial design, thereby testing whether residue-based media can maintain early oil palm growth under less intensive watering. The objectives were to determine the effects of banana stem organic matter, watering frequency, and their interaction on plant height, stem diameter, leaf area, and leaf number of oil palm seedlings during the pre-nursery stage.

RESEARCH METHODS

The experiment was conducted at Jl. Trompet, Medan Selayang Ringroad, North Sumatra, Indonesia, at approximately 30 m above sea level, beginning in July 2025. Oil palm germinated seeds (PPKS DxP Simalungun) were planted in 18 x 25 cm polybags containing topsoil mixed with banana stem organic matter according to treatment. The study used a factorial randomized block design with two factors and three replications. Factor B consisted of B1 = 100 g/polybag, B2 = 200 g/polybag, and B3 = 300 g/polybag banana stem organic matter. Factor P consisted of P1 = watering once daily, P2 = watering twice daily, and P3 = watering once every two days. The 3 x 3 treatment combinations generated 27 experimental plots, each containing five seedlings, for a total of 135 plants. Three plants per plot were used as samples.

Banana stems were chopped and composted with dry leaves, rice husks, and manure at an approximately 1:1:1 ratio. EM4 was added as a decomposer, the mixture was maintained moist and aerated, and the material was turned every 1-2 weeks until mature. Plant height, stem diameter, leaf area, and leaf number were observed from 5 to 12 WAP. Leaf area was estimated from leaf length x

width x 0.52. Data were subjected to analysis of variance for the randomized block factorial model. When a treatment effect was significant, mean separation was performed using Duncan's Multiple Range Test at the 5% level.

RESULTS AND DISCUSSION

Across 5-12 WAP, seedling growth increased consistently in all treatments. The strongest treatment signal occurred for plant height: banana stem organic matter significantly affected height at 5 and 12 WAP, whereas watering frequency and the interaction were not significant for height throughout the observation period. At 12 WAP, B3 reached 20.36 cm compared with 19.42 cm for B2 and 18.98 cm for B1. This pattern suggests that the higher organic-matter dose provided a measurable advantage after sufficient time for decomposition and nutrient release.

Table 1. Mean plant height of oil palm seedlings under banana stem and watering treatments

Treatment	5	6	7	8	9	10	11	12
B1	5.59	7.13	8.23	9.74	10.93	12.79	16.07	18.98
B2	6.22	7.41	8.41	9.91	11.6	12.83	16.02	19.42
B3	6.47	7.67	8.54	9.78	11.55	13.79	16.67	20.36
P1	6.05	7.31	8.29	9.68	11.13	12.91	15.8	19.29
P2	6.15	7.46	8.46	9.92	11.62	13.27	16.36	19.82
P3	6.09	7.44	8.43	9.83	11.33	13.24	16.6	19.65

Values are means in cm. Banana stem organic matter significantly affected plant height at 5 and 12 WAP; watering frequency was not significant.

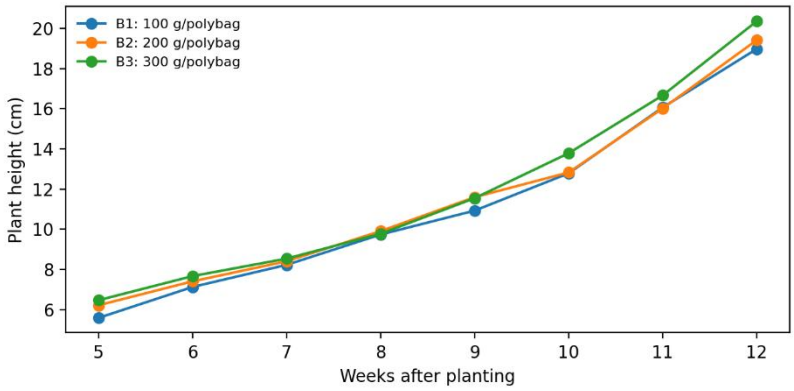


Figure 1. Plant-height development under banana stem organic matter doses.

The height response is biologically plausible because decomposed banana residues contribute organic carbon and nutrients while improving physical properties of the medium. Organic matter can increase aggregate stability and water retention and can gradually release nutrients as mineralization proceeds (Comte et al., 2013; Kusumawati, 2015). The delayed reappearance of a significant effect at 12 WAP is consistent with a slow-release mechanism rather than an immediate fertilizer-like response. Similar nursery studies have reported improved vegetative growth after organic amendments or plant-based organic inputs (Agung et al., 2019; Pratama et al., 2022; Syah et al., 2023).

Table 2. Selected growth responses at 12 WAP

Factor	Level	Height (cm)	Stem diameter (mm)	Leaf area (cm2)	Leaves
Banana stem	B1	18.98	9.55	25.33	4.4
Banana stem	B2	19.42	9.7	24.13	4.78
Banana stem	B3	20.36	9.87	25.98	4.82
Watering	P1	19.29	9.59	24.71	4.48
Watering	P2	19.82	9.82	25.47	4.77
Watering	P3	19.65	9.71	25.25	4.74

Only plant height differed significantly among banana stem doses at 12 WAP; the other listed main-effect means were not significantly different at the 5% level.

Stem diameter and leaf area were not significantly affected by either main factor or by their interaction. Nevertheless, numerical maxima occurred in B3 for stem diameter (9.87 mm) and leaf area (25.98 cm2), while P2 produced 9.82 mm stem diameter and 25.47 cm2 leaf area. The lack of statistical separation indicates that the watering schedules likely remained within a moisture range sufficient to prevent strong water stress. Young oil palm seedlings can maintain comparable

vegetative growth when water supply remains above limiting thresholds, and organic matter may further buffer short-term variation by improving media moisture retention (Dwiyana et al., 2015; Ropindo Saragih et al., 2016).

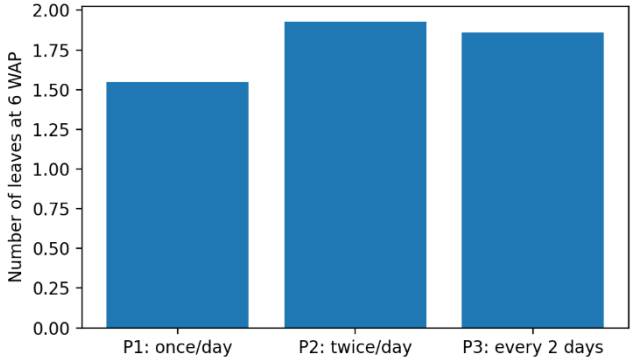


Figure 2. Mean leaf number at 6 WAP under watering-frequency treatments.

Watering frequency significantly affected leaf number at 6 WAP, when P2 produced 1.93 leaves compared with 1.86 leaves under P3 and 1.55 leaves under P1. This transient response may reflect the sensitivity of the shoot apical meristem to water availability during early leaf initiation. Once roots expanded and seedlings acclimated, the treatment differences disappeared. Water supports cell expansion and nutrient transport, but additional irrigation is unlikely to improve growth once moisture demand is satisfied (Hastuti et al., 2018; Syahputra et al., 2017). Thus, the absence of persistent differences should not be interpreted as water being unimportant; rather, it suggests that all three schedules generally supplied adequate moisture under the experimental conditions.

Table 3. Descriptive maxima of treatment combinations at 12 WAP

Variable	Highest combination	Value	Statistical interaction
Plant height	B3P2	21.05 cm	Not significant
Stem diameter	B3P2	9.90 mm	Not significant
Leaf area	B3P3	27.44 cm^2	Not significant
Leaf number	B2P2/B2P3/B3P3	4.90 leaves	Not significant

The interaction between banana stem organic matter and watering frequency was not significant for any measured variable.

No significant banana stem x watering interaction was detected. This is an important management finding because it indicates that the effect of the organic amendment did not depend strongly on a particular watering frequency within the tested range. Although B3P2 and B3P3 produced the largest descriptive values for several traits, those numerical differences were not statistically reliable. A practical interpretation is that banana stem organic matter may be used as a media amendment without requiring a narrowly defined watering schedule, provided moisture remains adequate. This aligns with the circular-agriculture rationale: organic residue can be recycled into the nursery while irrigation intensity can be managed according to local weather and media moisture rather than assumed to require maximum frequency.

The present findings also refine earlier reports by showing that the clearest response was plant height, not all vegetative traits. This distinction is useful because some organic-amendment studies report broad positive responses, while field conditions, decomposition stage, nutrient release, and initial media fertility can moderate treatment effects (Bahtiar et al., 2016; Agung et al., 2019). The factorial approach, comparable to crop-response experiments reported by Hasibuan et al. (2024) and Azhari et al. (2025), helps separate main effects from apparent numerical interactions and avoids overinterpreting the highest treatment combination when the interaction term is not significant.

CONCLUSIONS

Banana stem organic matter improved oil palm seedling height at 5 and 12 WAP, with 300 g/polybag (B3) producing the highest height at 12 WAP (20.36 cm). Watering frequency did not significantly affect plant height, stem diameter, or leaf area, but twice-daily watering (P2) increased leaf number at 6 WAP to 1.93 leaves. The interaction between banana stem organic matter and watering frequency was not significant for any measured variable. These results support the use of 300 g/polybag banana stem organic matter as a circular pre-nursery media amendment, while indicating that watering schedules within the tested range can be adjusted pragmatically to environmental moisture

conditions. Future work should extend observations into the main-nursery stage and include root biomass, dry matter, media chemical properties, and actual water-use efficiency.

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