



Effects of a Biodegradable Seedling Tray Made from Chicken Manure and Banana Pseudostem Fiber on the Early Growth Performance of Tomato (*Solanum lycopersicum*)

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ABSTRACT

The widespread reliance on conventional plastic seedling trays in horticulture exacerbates agricultural plastic pollution and soil degradation, necessitating the development of sustainable alternatives. This study evaluated the efficacy of biodegradable seedling trays, formulated from varying proportions of chicken manure, banana pseudostem fiber, and sawdust biochar, on the early vegetative growth of tomato (*Solanum lycopersicum*). Utilizing a completely randomized design, the research compared three experimental formulations against a commercial plastic control. Performance was assessed 14 days post-germination by measuring plant height and leaf count. Data were analyzed using a one-way analysis of variance and a Kruskal-Wallis test at a 0.05 significance level. Results demonstrated that the commercial control achieved the highest overall mean plant height and leaf count. However, among the biodegradable options, the formulation with the highest banana fiber content yielded significantly greater plant height (3.58 cm) compared to the reduced-fiber alternatives ($F = 18.15, p < .001$) and produced a significantly higher number of leaves ($H = 13.81, p < .01$). While structural integrity and biodegradation rates did not differ significantly across organic formulations, fiber content critically drove moisture dynamics. Although commercial trays facilitated more rapid initial growth, the high-fiber biodegradable trays supported continuous development, presenting a viable ecological alternative. Future studies should prioritize optimizing substrate formulations to enhance nutrient mineralization rates and immediate availability.

Keywords: biodegradable seedling tray, CHIMNARCH, tomato growth, sustainable agriculture, organic materials

Introduction

Plastic pots and trays used to produce seedlings represent a significant source of non-biodegradable pollution (Briassoulis, 2023). They are made from polymers based on the relatively cheap, easy-to-manufacture, and widely available petroleum. The favorable mechanical properties of plastic pots, such as reusability, resilience, lightweight, and resistance to extreme environmental conditions, make them a popular choice for producers and commercial nurseries. Less than 10% of plastic pots are recycled, however, and their buildup in soil reduces porosity, limits air circulation, decreases microbial activity and reduces soil fertility (Tomadoni et al., 2020).



Biodegradable pots to produce seedlings provide an appealing alternative, however, as they decompose in the soil once they have fulfilled their function, reducing pollution and enabling more sustainable agricultural practice (Anirudh et al., 2024).

San Mariano a coastal municipality in the province of Isabela, has a land area of 146,950 hectares, with approximately 19%-22% of its land dedicated to farming, primarily producing corn, rice, and bananas. Because of extensive agricultural production, a large amount of agricultural waste is generated. After harvesting, banana pseudo-stems are often thrown away. Similarly, some poultry farming in the municipality produces chicken manure, which also contribute to the accumulation of agricultural waste when is not properly utilized.

Bio-containers degrade naturally when planted or composted, which attracts sustainability and marketability (Nambutiri et al., 2015). They reduce the pollution associated with plastic waste, they improve pollution and they enhance the condition of the soil when it comes to the growth of subsequent crops, making them a good alternative to the plastic seedling container that has become ubiquitous in commercial nurseries and the farming community (Ko et al., 2023).

Several studies have demonstrated the effectiveness of biodegradable materials derived from agricultural waste to produce seedling pots. Seedling pots that contain recycled tomato and hemp fiber waste with sodium alginate as a binder positively impacted root development in seedlings and the growth of plants (Schettini et al., 2013). Pots made from decomposable waste that are produced from pineapple waste and that are 1 cm thick were found to completely decompose within 45 days and to release essential nutrients such as nitrogen (0.34%) and phosphorus (7.97 mg P/kg) into the soil that are needed to enable the growth of plants (Jirapornvaree et al., 2017).

Researchers are now being urged to create products that are sustainable and to focus on environmentally friendly solutions (Folino et al., 2020). In line with this aim, the development of biodegradable polymers, bioplastics and biomass-derived materials have been widely studied as substitutes for the plastics that are commonly and often exclusively used in the production of seeds and seedlings (De et al., 2021; Coppola et al., 2021).

Of these materials, chicken manure is the best known to be used for sustainable agriculture. Poultry (chicken) manure is an organic fertilizer that is high in nutrients and provides necessary elements, including nitrogen, phosphorus, and potassium, which restore soil fertility, improve nutrient cycling, and enhance microbial activity compared to soils that only contain chemical fertilizers (Köninger et al., 2021). Many different researchers have found that poultry manure will increase nutrient content, increase microbial activity, and even improve the soil structure (Hsu & Lai, 2022; Majeed et al., 2021; Ning et al., 2022). Chicken manure is also abundant throughout the year and in sufficient quantity to be a feasible low-cost replacement for chicken manure and other forms of chemical manure. Chicken manure tea increased tomato yields (by up to 45.4 t/ha) even more than inorganic fertilizers, providing the best growth and economic return (Nzoyisaba et al., 2023). Chicken manure is not the only sustainable biomass material that can be used for agricultural and biodegradable product applications.

While animal-based waste such as chicken manure provides nutrients that support plant growth, other agricultural and wood-processing byproducts can also contribute to sustainable and biodegradable agricultural materials. One example is sawdust, a byproduct from wood-processing activities that has gained attention as a sustainable biomass material for agricultural and biodegradable product applications. Studies have shown that sawdust improves organic matter content, enhances moisture retention, and contributes to better soil structure when appropriately incorporated into agricultural systems (Davis et al., 2022). Sawdust-derived



materials, such as biochar, have also been proven to enhance plant growth, soil fertility, and decrease waste disposal concerns (Aryal et al., 2024; Kar et al., 2025). Consequently, the use of sawdust in biodegradable agricultural products can provide a range of environmental benefits.

Banana waste contains a significant volume of cellulose, hemicellulose, and other natural fibers, making it potentially useful as a high-quality reinforcement material in bio-composite or biodegradable pots (Chauhan et al., 2022). Natural fibers have lower health risks than other fibers, are environmentally friendly, recyclable, do not abrade surfaces, and possess high strength-to-weight ratios. Compared to synthetic fibers, natural fibers have abundant availability, cost-effectiveness, low density, positive thermal insulation properties, impressive electrical resistance properties, excellent acoustic properties, and specific strength (Khan et al., 2021; Premalatha et al., 2021; Sumesh et al., 2022).

The mechanical performance of manually extracted natural fibers is largely attributed to their high cellulose content and low microfibrillar angle. During manual extraction these structural characteristics are preserved, minimizing fiber damage to enhanced mechanical strength in fiber-reinforced biodegradable products (Jagadeesh et al., 2021). The inherent properties of banana fiber, such as moisture retention, high strength, flame retardancy, and breathability, can improve the overall health and vitality of cultivated plants (Nguyen & Nguyen, 2021).

The integration of chicken manure with natural fibers such as banana pseudo stem fiber presents a promising approach in the development of biodegradable seedling trays. Previous studies have demonstrated that combining organic waste materials can enhance mechanical strength, improve biodegradability, and reduce pathogen and emission risks when compared to single-material systems (Chung et al., 2021; Isemin et al., 2021). This supports the feasibility of incorporating sawdust as an additional component in biodegradable seedling tray formulation. While there has been work on the constituent applications in the use of chicken manure as an organic fertilizer and use of banana fiber as a biodegradable reinforcing material, in this combination it is not found that any literature report with respect to research on the development and testing of biodegradable seedling tray integrating these materials together into a composite. Particularly, the effects of biodegradable seedling trays with combined organic and natural fiber on tomato growth behavior, mechanical properties, water absorption property and biodegradation behavior are rarely reported.

This study addresses this gap by introducing an innovative biodegradable seedling tray formulated from chicken manure and banana fiber. Unlike conventional plastic trays that contribute to environmental waste, the proposed seedling tray functions not only as a growth container but also as a nutrient-enhancing and environmentally sustainable medium. The objectives of this study are (1) to identify significant differences in the characteristics of CHIMNARCH seedling trays in terms of mechanical strength, water absorption, and biodegradability and (2) to evaluate significant differences in the growth performance of tomato seedlings after two weeks based on plant height and number of leaves.

Methods

Research Design

An experimental design was employed to evaluate biodegradable seedling trays composed of chicken manure, banana pseudo-stem fiber, cornstarch, and glycerin. Three formulations (Treatments A-C) were developed and compared with commercial plastic trays (control). Outcomes included mechanical strength, water absorption, biodegradability, and



seedling growth performance (plant height and leaf count). Treatments differed by proportion of manure, fiber, and binder while maintaining constant processing conditions.

Locale of the Study

The experiment was conducted in a controlled outdoor setting in Old San Mariano, San Mariano, Isabela. All trays were positioned within a netted mini-greenhouse to standardize exposure to sunlight, temperature, and precipitation while minimizing external disturbances. Environmental conditions were held constant across treatments.

Instrumentation and Materials

Materials included air-dried chicken manure, banana pseudo-stem fiber, cornstarch, glycerin, and distilled water. A standardized tray mold (0.045 m × 0.045 m × 0.05 m; thickness ≈0.004 m) was used as control. Mass measurements were obtained using a digital weighing scale (±0.01 g). Seedling height was measured using a ruler (cm), and leaf number was counted manually.

Mechanical strength was determined via compressive loading until deformation or failure. Compressive strength (σ) was computed as:

$$\sigma = \frac{F}{A}$$

where F is the applied force (N) and A is the loaded surface area (m²). Mass-based loads were converted to Newtons prior to calculation.

Water absorption followed a gravimetric method. Dry mass (W_0) was recorded, samples were submerged in distilled water for 3 minutes at room temperature, surface water was removed, and wet mass (W_t) was recorded. Water absorption (Q) was computed as:

$$Q = \frac{W_t - W_0}{W_0} \times 100$$

Biodegradability was assessed using a soil burial method. Samples were buried in moist soil for 7 days and reweighed. Biodegradation rate (%) was calculated as:

$$\% = \frac{W_0 - W_7}{W_0} \times 100$$

where W_7 is the mass after 7 days.

Data Collection

Preparation

Chicken manure was air-dried and heat-treated at >70 °C for 3 hours to reduce moisture and microbial load. Banana pseudo-stem sheaths were manually separated; fibers were extracted, washed, cut to 1–2 cm, and air-dried. A cornstarch binder (made from ratio of 1:4 starch and water) was heated to gelatinization for about 15 minutes. Glycerin was also prepared as a plasticizer.



Tray Development

Ground chicken manure and prepared banana fiber were weighed and combined according to treatment: Treatment A (90 g manure, 120 g fiber, 90 g binder), Treatment B (120 g manure, 90 g fiber, 90 g binder), and Treatment C (90 g manure, 90 g fiber, 120 g binder). Glycerin (289 g) was added to each mixture. Components were mixed to uniform consistency, molded, surface-coated with cornstarch paste, and air-dried for 24–48 hours. Three replicate per treatment was prepared for experimentation.

Planting and Growth Monitoring

Tomato seeds were sown at 1–2 cm depth in each tray cell containing 20 g soil mixed with 2.5 g burned sawdust. Three seeds were planted per cell. Five groups were established: three treatments and two controls (plastic trays with soil). All trays were maintained in the same enclosure and watered uniformly using measured volumes.

Growth data were collected weekly for one week. Plant height (cm) was measured using a ruler, and leaf count was recorded manually.

Mechanical, Water Absorption, and Biodegradability Testing

Mechanical strength testing was conducted prior to planting. Water absorption and biodegradability tests were performed in triplicate per treatment using the procedures described above.

Data Measurement

All measurements were recorded systematically per treatment. Replicates were maintained for each test condition. Observations included structural integrity, mass changes, plant height, and leaf count.

Data Analysis

Descriptive statistics (mean, percentage) were used to summarize growth and material properties. Mean seedling height and mean leaf count per treatment were computed. One-way analysis of variance (ANOVA) was applied to test for differences among treatments in growth outcomes. Significance was evaluated at $\alpha = 0.05$.

Safety and Risk Assessment

Handling of chicken manure involved biological hazards; researchers used rubber gloves and N95 masks. Thermal processing was conducted with temperature control to reduce pathogen exposure. Sawdust carbonization was performed in a ventilated outdoor area away from flammable materials. Post-experiment waste was disposed of in a designated compost pit to prevent environmental contamination.

Results and Discussion

Prior to inferential testing, all parametric assumptions were tested for violation using Shapiro-Wilk test for normality and Levene's test for homogeneity of variance. No violation was found in any data in terms of normality and homogeneity of variance.

Mechanical Strength

Table 1 summarizes compressive strength across treatments. Treatment A yielded the highest mean ($M = 351.34$), followed by Treatment C ($M = 315.23$) and Treatment B ($M = 288.26$). Despite numerical differences, testing using Welch's one-way ANOVA indicated no statistically significant variation among treatments, $F(2,6) = 0.2476$, $p = .794$.

The absence of statistical significance indicates that within the tested composition range, variations in fiber, manure, and binder proportions did not materially alter load-bearing capacity. Fiber-rich formulations showed higher mean values, consistent with prior findings (Zhang et al., 2019; Yuan et al., 2021), but variability across replicates limited inferential strength. The material system likely exhibits comparable internal bonding characteristics across formulations, with moisture sensitivity and heterogeneity contributing to dispersion in measurements.

Table 1
Mechanical Strength

Treatments	N	Mean	SD	SE	$F(2,6)$	p	Decision
Treatment A	3	351.34	134.99	77.93	0.2476	0.794	Failed to Reject H_0
Treatment B	3	288.26	56.14	32.41			
Treatment C	3	315.23	151.66	87.54			

Note. significance at 0.05 level

Water Absorption

Water absorption differed across treatments (Table 2). Treatment A recorded the highest mean (55.782%), followed by Treatment C (52.406%) and Treatment B (34.606%). One-way ANOVA confirmed a statistically significant difference, $F(2,6) = 9.68$, $p = .041$. Post hoc using Tukey's HSD confirms that Treatments A and C are statistically similar while Treatment B had the lowest water absorption.

Treatment A's highest score can be explained due to the higher content of banana fiber, a natural component known for its water holding ability. In contrast, Treatment B had the lowest absorption which shows that reduced fiber content limits the tray's ability to take up water.

Higher absorption in fiber-rich formulations supports evidence that lignocellulosic materials enhance moisture retention (Ishara et al., 2024). Reduced fiber content in Treatment B corresponded with lower water uptake. Cornstarch contribution in Treatment C likely moderated absorption through hydrophilic interactions (Sultan et al., 2017). The result indicates that water retention is composition-sensitive, unlike mechanical strength.

Table 2
Water Absorption of CHIMNARCH Trays

Treatments	N	Mean	SD	SE	$F(2,6)$	p	Decision
Treatment A	3	55.782 ^a	7.19	4.15	9.68	0.041	Reject H_0
Treatment B	3	34.606 ^b	3.67	2.12			
Treatment C	3	52.406 ^a	13.85	8.00			

Biodegradability

Biodegradation rates (Table 3) were numerically higher in Treatments B (14.754%) and C (15.175%) than in Treatment A (5.199%). However, differences were not statistically significant, $F(2,6) = 2.4633$, $p = .206$. This means that the test failed to reject the null hypothesis.

Despite differences in material composition in the three formulations, it performs relatively similar rate in terms of biodegradability. The lack of statistical significance indicates

that decomposition rates were broadly comparable within the 7-day observation window. Numerical variation suggests sensitivity to organic composition, but short exposure duration and limited replication constrain detection of meaningful differences. Prior work (Duarte et al., 2025; Elashry et al., 2025) indicates fiber content influences degradation; however, such effects may require longer incubation periods to manifest.

Table 3

Biodegradability of CHIMNARCH Trays

Treatments	N	Mean	SD	SE	F (2,6)	p	Decision
Treatment A	3	5.199	5.222	3.015	2.4633	0.206	Failed to
Treatment B	3	14.754	5.08	2.933			Reject Ho
Treatment C	3	15.175	10.413	6.012			

Plant Performance in Developed Trays versus Commercial Tray

Plant Height (14 Days)

A one-way analysis of variance (ANOVA) revealed a highly significant difference in plant height among the treatments after 14 days, $F = 18.15$, $p < .001$. A Tukey HSD post hoc analysis was conducted, revealing that the Control group ($M = 4.84^a$ cm) significantly outperformed the experimental biodegradable trays. Among the developed experimental trays, Treatment A ($M = 3.58^b$ cm) was significantly taller than Treatment B ($M = 3.04^c$ cm). Treatment C ($M = 3.26^{bc}$ cm) did not differ significantly from either Treatment A or B.

Lower growth across the biodegradable trays relative to the control expectations may reflect early-stage phytotoxicity from manure decomposition or suboptimal aeration within the material matrix. Organic matrices can delay immediate nutrient availability due to a mineralization lag (Mohammed, 2018; Pandey et al., 2017). These results indicate the functional viability of the biodegradable trays, albeit with reduced short-term efficiency compared to the standard commercial control method.

Table 4

Plant Height After 14 Days

Treatments	N	M	SD	SE	F	p	Decision
Control	5	4.84 ^a	0.88	0.39	18.15	< .001	Reject H_0
Treatment A	5	3.58 ^b	0.71	0.32			
Treatment B	5	3.04 ^c	0.39	0.17			
Treatment C	5	3.26 ^{bc}	1.09	0.49			

Number of Leaves (14 Days)

Table 5 presents the number of leaves of the plants after 14 days under the different treatment groups. A Kruskal-Wallis one-way ANOVA revealed that leaf count differed significantly among the treatments, $H = 13.81$, $p = .008$. Post hoc analysis revealed that the Control group exhibited the highest mean leaf count ($M = 3.80^a$), indicating more rapid leaf development compared to the experimental treatments. Among the biodegradable trays, Treatment A ($M = 2.60^b$) produced significantly more leaves than Treatment C ($M = 1.60^c$), while Treatment B ($M = 2.00^{bc}$) did not significantly differ from either Treatment A or C.

Reduced leaf production in the experimental trays may be associated with moisture imbalances and constrained root development within the biodegradable matrix. While organic substrates are known to support gradual nutrient release (Runze Li et al., 2022), the early-stage

structural and chemical conditions of the developed trays may limit immediate vegetative expansion. Eventually, Treatment A provided the most optimal conditions among the organic alternatives, highlighting its formulation's potential in balancing moisture retention and nutrient availability.

Table 5

Number of Leaves After 14 Days

Treatments	N	M	SD	SE	H	p	Decision
Control	5	3.80 ^a	1.10	0.49	13.81	.008	Reject H_0
Treatment A	5	2.60 ^b	0.89	0.40			
Treatment B	5	2.00 ^{bc}	0.00	0.00			
Treatment C	5	1.60 ^c	0.89	0.40			

Conclusion and Recommendations

The results indicate that compositional variation within the tested range does not materially influence structural integrity or short-term biodegradation, but it significantly affects water absorption and, indirectly, early plant growth. Fiber content emerges as the primary driver of moisture dynamics, which in turn influences seedling performance.

The biodegradable trays demonstrate functional adequacy but do not match the short-term growth efficiency typically associated with conventional systems. This gap is attributable to delayed nutrient release, possible transient phytotoxicity, and variability in moisture regulation. Thus, the current formulations are operationally viable but not yet optimized for early-stage growth performance.

The findings imply that optimization should prioritize controlled nutrient availability and moisture balance rather than further structural modification. Extending biodegradation assessment periods and increasing replication are necessary to resolve material performance differences with higher statistical power. At present, the system is suitable for low-intensity or sustainability-oriented applications but requires refinement for performance-critical agricultural use. Future researchers are encouraged to test CHIMNARCH trays with crops other than tomatoes to assess their versatility. Improvements in tray strength should be considered to enhance durability and the performance of the trays should be evaluated under different environmental conditions to determine their adaptability and effectiveness in various settings.

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Conflict of Interest

The authors declare no conflicts of interest regarding the publication of the study. This research was conducted as part of an academic requirement and received no external funding from commercial organizations.

Artificial Intelligence (AI) Declaration Statement

In compliance with the Department of Education policy regarding the responsible use of artificial intelligence (AI), OpenAI's ChatGPT (2026 version) was utilized solely as an editorial support tool for this research.

The application of AI was strictly limited to correcting grammatical errors, improving sentence clarity, enhancing structural organization, and refining the text to suit an academic journal format. AI was not employed to generate research data, perform computations, formulate results, or replace original analytical work. All experimental execution, data collection, computations, interpretations, and final conclusions remain the exclusive intellectual output of the researchers.