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Development of Biodegradable Pots from Coconut Coir and Sunn Hemp for *Brassica rapa* L. Cultivation

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Abstract

This study aimed to develop biodegradable bio-pots from coconut coir and sunn hemp (*Crotalaria juncea* L.) for cultivating *Brassica rapa* L. and to evaluate their physical properties and effects on plant growth. The study also aimed to promote agricultural waste utilization as an alternative approach to reducing PM2.5 pollution caused by open-field burning of agricultural residues. The experiment was arranged in a Completely Randomized Design (CRD) with four bio-pot formulations: 100% coconut coir (T1), coconut coir: sunn hemp at ratios of 75:25 (T2), 50:50 (T3), and 25:75 (T4). Water retention capacity, bulk density, and growth performance of *Brassica rapa* L. were evaluated over 30 days. Starting from 15 days old to 45 days old. The results showed that T1 and T2 exhibited the highest water retention capacities at 76.47% and 75.68%, respectively. The T2 formulation showed the highest bulk density (0.13 g/cm3). In addition, *Brassica rapa* L. cultivated in T2 bio-pots tended to exhibit higher dry weight and leaf number compared with other treatments, although no statistically significant differences were observed ($p > 0.05$). These findings indicate that bio-pots made from coconut coir and sunn hemp at a ratio of 75:25 have potential for agricultural applications and could serve as an environmentally sustainable approach for agricultural waste utilization.

Keywords: Bio-pot, coconut coir, sunn hemp, *Crotalaria juncea* L., *Brassica rapa* L., PM2.5

Introduction

The circular economy framework has gained global attention as a strategy for sustainable resource management by promoting the efficient use, reuse, and valorization of resources within production systems. [1] In the context of agricultural production, petroleum-based plastic pots represent a major environmental concern due to their persistence in the environment after use. Biodegradable bio-based alternatives have therefore attracted considerable interest because they decompose naturally, reduce plastic waste accumulation, and minimize root disturbance during transplantation.[2,3]

Various agricultural residues including rice straw, sugarcane bagasse, water hyacinth, and coconut coir have been successfully utilized to

produce biodegradable pots with satisfactory mechanical properties and plant growth performance. In northern Thailand, however, such residues are commonly disposed of through open-field burning, a practice that contributes significantly to seasonal PM2.5 pollution one of the most pressing public health challenges in the region, associated with respiratory and cardiovascular diseases and lung cancer.[4,5] Converting agricultural residues into biodegradable products provides an alternative utilization pathway for agricultural by-products and may reduce reliance on open-field burning.[6,1]

Appropriate agricultural waste management has therefore become an important strategy for reducing air pollution and promoting sustainable agricultural practices.[6] Recent studies have demonstrated that biodegradable pots produced from agricultural residues can serve as environmentally friendly alternatives to conventional plastic containers while supporting satisfactory crop growth and reducing plastic waste generation.[7-9] Bio-pots produced from agricultural residues have also been reported to support the growth and yield performance of Brassica species under greenhouse cultivation conditions.[9]

Coconut coir is a natural organic material widely recognized for its excellent water retention capacity, aeration properties, and high lignocellulosic fiber content, making it suitable for use in growing media and biodegradable agricultural materials.[10] Meanwhile, sunn hemp is a leguminous green manure crop rich in nitrogen and organic matter that can improve soil fertility and physical soil properties.[11] Sunn hemp contains lignocellulosic fibers that have potential for use in biodegradable material production.[12] The complementary properties of coconut coir and sunn hemp may improve both the structural integrity and biodegradability of bio-pots while providing a favorable root environment for plant growth.

Several studies have reported the development of biodegradable pots from agricultural residues such as water hyacinth, straw, and other natural fibers.[8] Nevertheless, limited information is available regarding the combined utilization of coconut coir and sunn hemp for the development of biodegradable bio-pots suitable for cultivating *Brassica rapa* L. Although biodegradable bio-pots have been investigated using various agricultural residues, information on the combined utilization of coconut coir and sunn hemp for cultivating *Brassica rapa* L. under Thai conditions remains limited.[13]

This study represents one of the first investigations in Thailand focusing on the combined utilization of coconut coir and sunn hemp fiber for biodegradable bio-pot production and cultivation of *Brassica rapa* L. Unlike previous studies that primarily employed a single agricultural residue, this study explores the synergistic use of two locally available biomass resources to develop environmentally friendly planting containers. Therefore, this study aimed to develop biodegradable bio-pots from coconut coir and sunn hemp, evaluate their physical properties, and investigate their effects on the growth performance of *Brassica rapa* L. The findings of this study may contribute to the utilization of agricultural residues as environmentally friendly agricultural materials, reduce open burning practices, and support sustainable agriculture development

Materials and Methods

Experimental Design

The experiment was conducted using a Completely Randomized Design (CRD) consisting of four bio-pot formulations with ten replications per treatment. The treatments were prepared using different ratios of coconut coir and sunn hemp fibers as follows:

T1 = 100% coconut coir

T2 = coconut coir:sunn hemp at a ratio of 75:25

T3 = coconut coir:sunn hemp at a ratio of 50:50

T4 = coconut coir:sunn hemp at a ratio of 25:75

The study evaluated the physical properties of the bio-pots, including water retention capacity and bulk density, as well as their effects on the growth performance of *Brassica rapa* L. cultivated under greenhouse conditions for 30 days. Starting from 15 to 45 days old. The biodegradable bio-pot formulation was adapted from the method described by Leelahakriengkrai et al. (2025). Coconut coir and ground sunn hemp fibers were used as the primary lignocellulosic materials, replacing Azolla microphylla in the original formulation.

Preparation of Sunn Hemp Materials

Fresh sunn hemp (*Crotalaria juncea* L.) plants and seeds were obtained from the Chiang Mai Land Development Station, Thailand. Seeds were cultivated under field conditions and watered once daily during the early morning. Plants were harvested at approximately 60 days after planting. The harvested biomass was sun-dried for 4–5 days until reaching a constant moisture level. Dried materials were then chopped into small pieces and stored at 4°C prior to use in bio-pot preparation.

Growing Medium

A commercially available potting substrate was used as the growing medium for all treatments. The substrate was uniformly filled into each biodegradable bio-pot prior to transplanting to ensure consistent growth conditions among experimental units.

Preparation of coconut coir

Commercially available coconut coir was used as the primary fibrous material for bio-pot production.

Preparation of Dried sunn hemp fibers

Dried sunn hemp stems were mechanically ground using a feed grinder to obtain fibrous particles for bio-pot production. The ground fibers were collected and stored in sealed polyethylene bags at room temperature until use.

Preparation of Starch Adhesive

A starch-based adhesive was prepared using tapioca starch following a modified method.[7] Briefly, 100 g of tapioca starch was dissolved in 1000 mL of distilled water and heated at 80–100°C with continuous stirring until a transparent viscous gel was formed. The adhesive was cooled to room temperature before being used as a binding agent.

Bio-pot Fabrication

Bio-pots were fabricated according to modified procedures.[14] Coconut coir and dried sunn hemp fibers were mixed according to the designated treatment ratios. Approximately 50 g of starch adhesive was added to each mixture as a binder. The mixtures were manually homogenized and compressed into square molds (9.2 × 9.2 × 4.7 cm).

The molded bio-pots were oven-dried at 60°C for 24 h, removed from the molds, and dried for an additional 24 h to ensure structural stability. Ten bio-pots were produced for each treatment.

Seedling Preparation

Seeds of *Brassica rapa* L. were sown in a commercial potting medium. Fifteen days after sowing, healthy and uniform seedlings, approximately 6 cm in height and with a similar number of leaves, were selected and transplanted into the experimental bio-pots.

Experimental conditions

The cultivation experiment was conducted under ambient open-field conditions during the winter season for 30 days. Throughout the experimental period, plants were exposed to natural sunlight from 07:00 to 18:00 h daily, and no precipitation was recorded.

Determination of Water Retention Capacity

Water retention capacity was determined following the method modified from Nipon Tanpaibulkul et al. (2022). Bio-pot samples were dried at 103–105°C for 1 h and weighed to obtain the initial dry weight (Wd). The samples were then immersed in water until saturation and allowed to drain excess water naturally. Saturated samples were weighed again to obtain wet weight (Ws).

Water retention capacity was calculated using the following equation:

$$w = ((Ws-Wd)x100)/Wd$$

where:

W = water retention capacity (%)

Ws = saturated weight (g)

Wd = dry weight (g)

Determination of Bulk Density

Dried bio-pot samples were cut into 5 × 5 cm sections. The weight and dimensions of each sample were measured to calculate volume[15]. Bulk density was determined using the following equation:

$$\rho b = m/ V$$

where:

ρb = bulk density (g cm^{-3})

m = sample mass (g)

V = sample volume (cm^3)

Evaluation of Plant Growth Performance

Seeds of *Brassica rapa* L. were germinated and grown for 14 days before transplantation into the experimental bio-pots. Uniform seedlings with similar height and leaf number were selected for the experiment.

Each bio-pot contained one seedling and received 20 mL of water daily during the nursery stage until they are 14 days old. Subsequently, the bio-pots were transferred into soil-filled plastic trays (19 × 36.5 × 12 cm), with five pots per tray. Plants were cultivated for 30 additional days under greenhouse conditions and irrigated daily with 40 mL of water per pot.

Plant growth parameters including plant height and leaf number were recorded every three days. At the end of the experiment, plants were harvested and oven-dried at 70°C until constant weight for dry biomass determination.

Statistical Analysis

All experimental data were analyzed using SPSS statistical software (Version 26.0 Data are presented as mean ± standard deviation (SD). One-way analysis of variance (One-Way ANOVA) was used to determine significant differences among treatments. Mean comparisons were performed using Duncan's Multiple Range Test (DMRT) at a significance level of $p < 0.05$.

Results

1. Characteristics of Bio-pot Formulations

Four biodegradable bio-pot formulations were successfully fabricated using different ratios of coconut coir and sunn hemp fibers (Figure 1).

The physical appearance of the bio-pots varied according to the composition of raw materials. Bio-pots containing higher proportions of coconut coir exhibited smoother surfaces and greater structural integrity, whereas formulations with higher sunn hemp content showed rougher textures and minor surface cracking after drying.

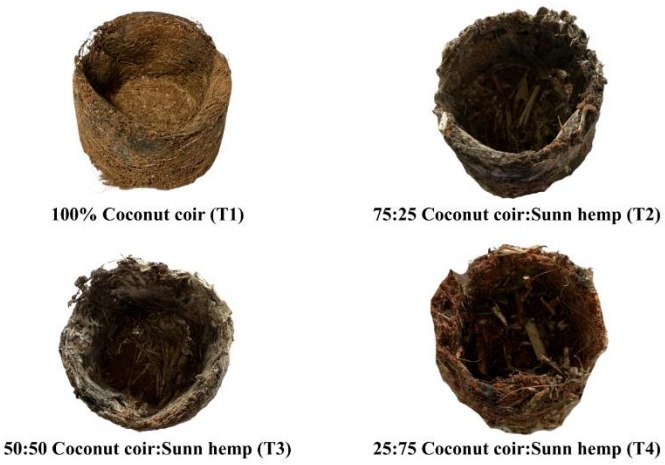


Figure 1. Physical appearance of biodegradable bio-pots produced from different ratios of coconut coir and sunn hemp fibers (T1–T4).

2. Water Retention Capacity of Bio-pots

Water retention capacity differed among treatments (Figure 2). The highest water retention capacity was observed in T1 (100% coconut coir), with a value of 76.47%, followed closely by T2 (75:25 coconut coir:sunn hemp) at 75.68%. Treatments T3 and T4 exhibited lower water retention capacities at 69.99% and 55.60%, respectively.

The high water retention observed in coconut coir-based bio-pots could be attributed to the lignocellulosic fiber structure and porous morphology of coconut coir, which can effectively absorb and retain moisture. As the proportion of sunn hemp fibers increased, water retention capacity gradually decreased, possibly due to reduced pore space and lower hygroscopic properties of the fibrous material.

Although T1 exhibited the highest water retention, T2 demonstrated comparable moisture retention while maintaining improved structural stability, suggesting that the incorporation of sunn hemp fibers at moderate levels may provide a suitable balance between water-holding capacity and mechanical integrity.

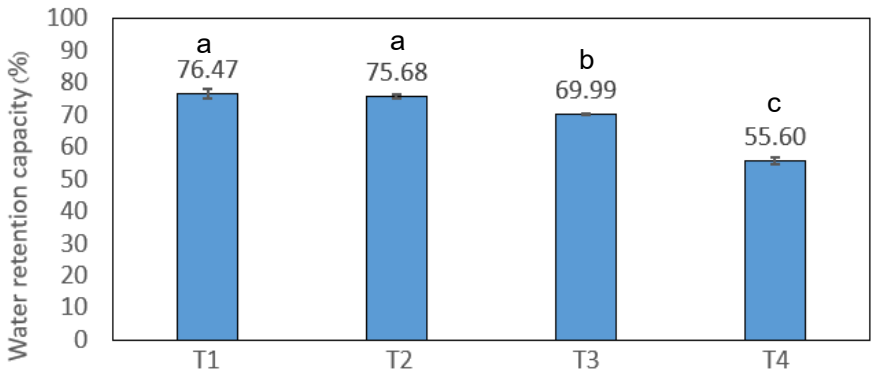


Figure 2. Water retention capacity (%) of biodegradable bio-pots under different treatments.

Note. Different lowercase letters indicate significant differences among treatments according to Duncan's Multiple Range Test (DMRT) at $p < 0.05$.

Table 1. Water retention capacity and bulk density of biodegradable bio-pots.

Treatment	Water retention (%)	Bulk density (g cm^{-3})
T1	76.47 ± 1.42^{a}	0.09 ± 0.004^{a}
T2	75.68 ± 0.57^{a}	0.13 ± 0.004^{b}
T3	69.99 ± 0.20^{b}	0.11 ± 0.002^{b}
T4	55.60 ± 0.99^{c}	0.13 ± 0.005^{c}

Note. Different lowercase letters indicate significant differences among treatments according to Duncan's Multiple Range Test (DMRT) at $p < 0.05$.

3. Bulk Density of Bio-pots

Bulk density values ranged from 0.09 to 0.13 g cm^{-3} (Table 1). T2 and T4 exhibited the highest bulk density values at 0.13 g cm^{-3}, whereas T1 showed the lowest density at 0.09 g cm^{-3}. The increase in bulk density with higher sunn hemp content could be associated with the compact arrangement of fibrous particles within the bio-pot matrix. The higher density observed in these formulations may contribute to improved structural strength and prolong pot stability during cultivation. However, excessively dense materials may reduce air permeability and negatively affect water movement within the substrate. The T2 formulation exhibited a favorable balance between density and water retention, suggesting its potential suitability for biodegradable nursery applications.

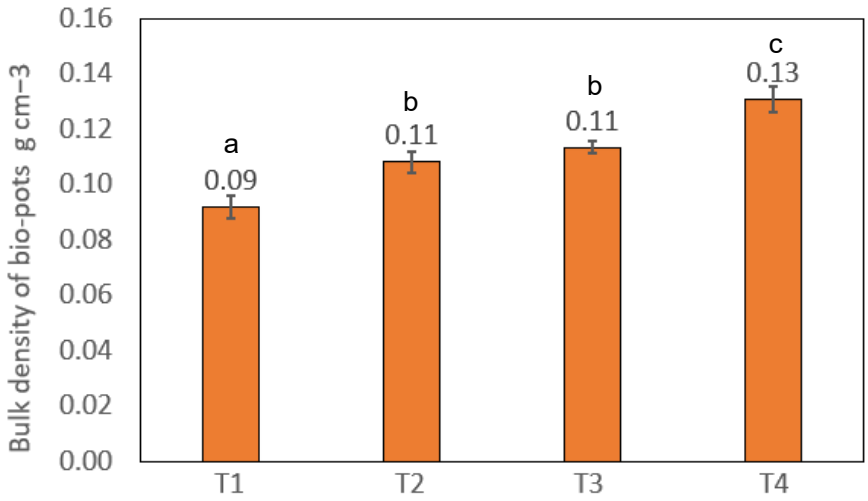


Figure 3. Bulk density of biodegradable bio-pots prepared from different formulations.

Note. Different lowercase letters indicate significant differences among treatments according to Duncan's Multiple Range Test (DMRT) at $p < 0.05$.

4. Growth Performance of *Brassica rapa* L.

4.1 Dry Biomass

Dry biomass accumulation of *Brassica rapa* L. cultivated in different bio-pot formulations is presented in Figure 4. Plants grown in T2 bio-pots tended to produce the highest dry biomass (5.29 g), followed by T3 (5.25 g), T1 (5.21 g), and T4 (5.15 g). However, statistical analysis revealed no significant differences among treatments ($p > 0.05$).

Although the differences were not statistically significant, the observed trend suggests that incorporating sunn hemp fibers at moderate proportions may positively influence biomass accumulation. This effect could be related to the gradual release of nutrients during the partial decomposition of sunn hemp organic matter, particularly nitrogen compounds that support the vegetative growth and dry matter accumulation of *Brassica rapa* L.

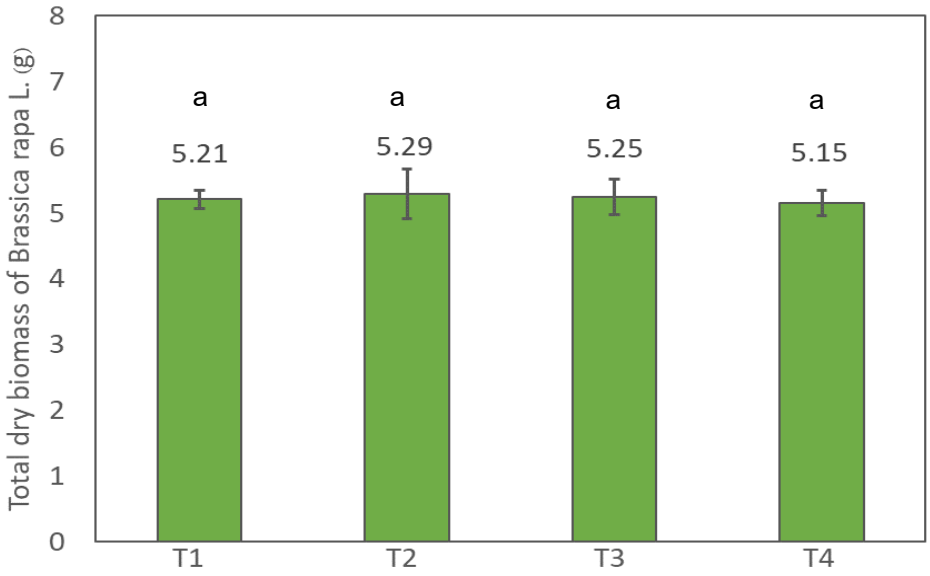


Figure 4. Dry biomass of *Brassica rapa* L. cultivated in different bio-pot formulations.

Note. No significant differences were observed ($p > 0.05$)

4.2 Leaf Number

The average leaf number of *Brassica rapa* L. at 45 days after cultivation is shown in Figure 5. Plants grown in T1 bio-pots produced the highest mean leaf number (12.60 leaves), whereas T2, T3, and T4 exhibited similar values of approximately 12 leaves per plant. No statistically significant differences were observed among treatments ($p > 0.05$).

The similarity in leaf production among treatments indicates that all bio-pot formulations were capable of supporting normal vegetative growth without any observable adverse effects on plant development.

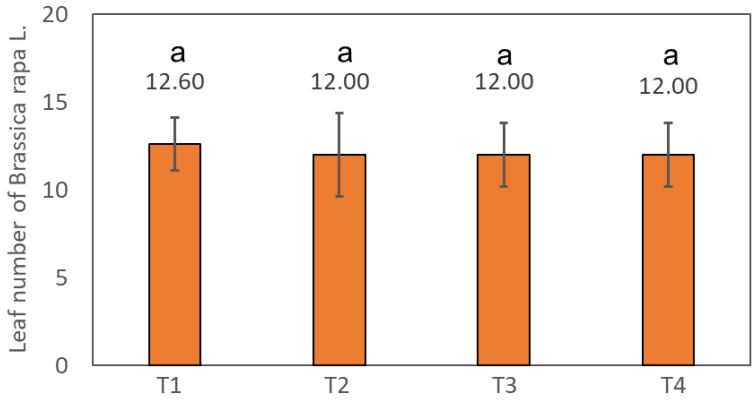


Figure 5. Average leaf number of *Brassica rapa* L. cultivated in different bio-pot formulations.

Note. No significant differences were observed ($p > 0.05$)

4.3 Plant Height

Plant height increased progressively throughout the experimental period in all treatments (Table 2 and Figure 6). At 30 days after transplantation, T3 and T4 exhibited slightly greater plant height values (25.3 ± 1.0 cm) compared with T1 (25.0 ± 0.9 cm). Nevertheless, no statistically significant differences were detected among treatments ($p > 0.05$). all formulations supported plant growth equally well.

Table 2. Plant height of *Brassica rapa* L. cultivated in different bio-pot formulations over 30 days.

Treatment	Plant height of *Brassica rapa* L. cultivated in different bio-pot formulations over 30 days (Day)										
	0	3	6	9	12	15	18	21	24	27	30
T1	6.0±0.1	6.8±0.2	7.9±0.3	9.2±0.4	10.7±0.4	12.5±0.5	14.3±0.6	16.4±0.6	18.8±0.7	21.4±0.7	25.0±0.9
T2	6.0±0.1	6.8±0.3	7.9±0.3	9.3±0.4	10.8±0.4	12.5±0.5	14.3±0.6	16.5±0.7	18.9±0.7	21.5±0.7	25.1±0.9
T3	6.0±0.1	6.8±0.3	7.9±0.4	9.3±0.4	10.9±0.5	12.6±0.5	14.4±0.6	16.5±0.7	19.0±0.8	21.5±0.8	25.3±1.0
T4	6.0±0.1	6.9±0.3	7.9±0.3	9.4±0.5	10.9±0.5	12.7±0.6	14.5±0.7	16.6±0.8	19.0±0.8	21.6±0.8	25.3±1.0

No significant differences among treatments were detected (ANOVA, $p > 0.05$).

Discussion

The present study demonstrated that coconut coir and sunn hemp fibers can be successfully utilized for the fabrication of biodegradable bio-pots suitable for the cultivation of *Brassica rapa* L. Coconut coir-based formulations exhibited superior water retention capacity, which could be attributed to the porous lignocellulosic structure of coconut fibers capable of retaining large amounts of water within capillary spaces[10]. Similar findings were Similar findings were reported by Iriany et al.[8], who observed high moisture retention in bio-pots prepared from coconut coir and water hyacinth fibers.

The incorporation of sunn hemp fibers increased the bulk density of the bio-pots, suggesting improved compactness and structural stability.. However, excessive proportions of sunn hemp fibers reduced water retention capacity and produced rougher surfaces after drying. This observation could be related to differences in fiber morphology and packing arrangement within the composite structure[4] , who found that biomass composition significantly affected the physical properties and durability of biodegradable seedling containers.

Although no statistically significant differences were observed in plant growth parameters, *Brassica rapa* L. cultivated in T2 bio-pots produced the highest mean dry biomass, although the differences were not statistically significant. This trend could be associated with the nitrogen-rich nature of sunn hemp, a leguminous species that has been reported to improve soil nitrogen availability following decomposition[16]. This process could improve nutrient availability in the rhizosphere and support vegetative growth.

Importantly, the present findings demonstrate that biodegradable bio-pots produced from coconut coir and sunn hemp fiber were able to support the growth of *Brassica rapa* L. at a level comparable among the tested formulations. These results indicate that agricultural residues can be utilized as raw materials for biodegradable bio-pot production without observable adverse effects on plant growth under the conditions of this study.

The utilization of coconut coir and sunn hemp fiber for bio-pot production is consistent with the circular economy concept by promoting the value-added use of agricultural by-products. Although the environmental impacts were not directly evaluated in this study, the conversion of agricultural residues into biodegradable products has the potential to provide an alternative utilization pathway that may reduce the need for residue disposal through open-field burning. Therefore, this approach could contribute to more sustainable agricultural waste management and supports further development of environmentally friendly agricultural materials.

Furthermore, preliminary biodegradation observations indicated that all bio-pot formulations gradually decomposed under cultivation conditions while maintaining sufficient structural stability during plant growth. This characteristic is advantageous for transplant production because biodegradable pots could be transplanted directly into soil without generating plastic waste or causing root disturbance[11].

Nevertheless, additional studies focusing on mechanical strength, degradation rate, nutrient release dynamics, and economic feasibility are still required to further improve the practical application and commercial scalability of these biodegradable bio-pots. In practical applications, the developed bio-pots may potentially be utilized in community-based agricultural systems, organic vegetable production, and environmentally friendly nursery management. Such applications may enhance the value of agricultural residues while promoting sustainable agricultural practices at the local level.

Conclusion

This study demonstrated that biodegradable bio-pots were successfully developed from coconut coir and sunn hemp fiber for the cultivation of *Brassica rapa* L. The proportions of raw materials influenced the physical properties of the bio-pots, particularly water retention capacity and bulk density. Bio-pot formulations containing higher proportions of coconut coir exhibited superior water retention, whereas increasing sunn hemp content contributed to higher bulk density and improved structural stability.

Among the tested formulations, the coconut coir hemp ratio of 75:25 (T2) provided a favorable balance between water retention capacity and structural stability. In addition, *Brassica rapa* L. cultivated in T2 bio-pots tended to produced the highest mean dry biomass, although the differences were not statistically significant ($p > 0.05$). These findings indicate that moderate incorporation of sunn hemp fibers can produce biodegradable bio-pots with suitable physical properties while supporting plant growth under the conditions of this study.

Overall, the present findings demonstrate the feasibility of utilizing coconut coir and sunn hemp fiber as raw materials for biodegradable bio-pot production. This approach supports the value-added utilization of agricultural residues and provides a potential alternative to conventional plastic nursery containers, thereby aligning with the concept of sustainable agricultural material development.

Nevertheless, further studies on mechanical strength, biodegradation rate, nutrient release dynamics, economic feasibility, and large-scale production systems are recommended to improve the practical application and commercial development of biodegradable bio-pots.

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