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Development of Compressed Compost Blocks as a Sustainable Planting Medium Using Pineapple Leaf Waste to Address Urban Agriculture Challenges

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Abstract. This study aims to develop compressed compost blocks as a sustainable planting medium using pineapple leaf waste and soil incorporated with water-retaining hydrogel to facilitate efficient re-expansion upon watering. With a projection of 68% of the world's population living in cities by 2050, this study is very significant in the development of environmentally friendly urban agriculture. Where every year, Malaysia produces more than two million tons of pineapple leaf waste, most of which are burned or simply thrown away. However, studies on the use of pineapple leaves as a compressed planting medium with hydrogel are still very few and limited. The objective of this study is to produce a compressed planting medium with a mixture of soil, pineapple leaves and hydrogel that can re-expand well when exposed to water. Testing was carried out to determine the water infiltration rate and re-expansion of the planting medium, pH value and seed growth rate. Experimental results demonstrate that 500 grams planting medium block containing 5 grams of hydrogel exhibited faster and more uniform expansion when exposed to water. While the mixture with 10 and 15 grams of hydrogel expanded 35 to 52% more than the mixture with 5 grams of hydrogel. The pH value reading showed that between 6.2 to 6.8 is suitable in supporting the growth of seedlings. This study fills the research gap in the management of pineapple leaf waste. This makes it an eco-friendly growing medium as an innovative planting medium for modern agriculture applications.

Keywords: Compost Block, Hydrogel, Urban Farming, Pineapple Leaf, Agriculture Waste

1. INTRODUCTION

Urban farming is becoming increasingly important in addressing global food insecurity. Among the main causes of food shortages are climate change and poor food resource management. By 2050, the United Nations projects that 68% of the world's population will live in urban areas due to greater employment opportunities in cities [1], which will in turn place significant pressure on conventional food production systems. Furthermore, the rapid growth of urban populations exerts additional strain on conventional agriculture, which is largely concentrated in rural areas. Urban farming can serve as one of the solutions to enable the local production of fresh food [2]; however, innovative cultivation systems and efficient growing media are urgently required, considering the limitations of space, irrigation, crop maintenance, and waste management.

One of the main challenges in expanding urban farming is the lack of suitable planting media. Traditional soil and compost are suitable for use, nevertheless they face issues related to portability, inconsistent nutrient availability, and limited water retention capacity, which are significant constraints for urban agriculture [3]. Therefore, appropriate alternatives are needed to integrate waste management with resource efficiency. Malaysia, being one of the world's largest pineapple producers, generates a substantial amount of agricultural waste, particularly pineapple leaves. It is estimated that over 2 million tons of pineapple leaves are discarded or burned annually, contributing to air pollution [4]. Studies have shown that pineapple leaves are rich in cellulose, hemicellulose, and lignin, making them a highly potential raw material for compost and bio-based products [5]. Transforming pineapple leaf waste into compost media not only reduces environmental burden but also adds value to the pineapple industry and agriculture. Figure 1 illustrates pineapple plants cultivated in polybags to support urban farming, which eliminates the need for direct soil planting. Growing pineapples in polybags offers an alternative approach to sustaining pineapple cultivation in urban areas.

Figure 1. Pineapple cultivation in polybags as a sustainable approach to urban farming.

To improve water use efficiency, hydrogel, known as a superabsorbent polymer capable of retaining large amounts of water in soil after irrigation, has been introduced in modern agriculture. Studies have shown that hydrogel can reduce irrigation frequency and enhance crop survival under water-limited conditions [6]. However, research on the integration of hydrogel into compressed compost blocks derived from agricultural waste remains limited. Therefore, this study aims to develop and evaluate compressed planting medium composed of 70% soil and 30% pineapple leaf powder with the addition of hydrogel as a moisture-retaining agent, thereby facilitating the re-expansion of compressed compost. This approach also addresses key challenges in urban agriculture, including transportation and storage, waste management, water resource efficiency, and soil fertility.

2. Literature Review

Good management of agricultural waste is important to reduce greenhouse gas emissions, which contribute to global warming and can also harm human health. In recent years, using compost as a planting medium has gained attention as a way to handle agricultural waste more sustainably. Compost has long been studied as a soil amendment and organic fertilizer, with clear benefits such as improving soil structure and providing nutrients for plants [7]. However, traditional compost still has its challenges, especially in urban settings where space and resources are limited. Storing compost and managing water within it can be difficult, making it less practical for city-based farming.

Hydrogel, a type of water-absorbing polymer, has been introduced as a soil conditioner that helps soil hold more water [8]. Previous study showed that adding hydrogel can increase soil water retention by 30–40%, which helps crops grow better even during dry periods [9]. Similarly, [6] reported that hydrogel can reduce the need for frequent watering by up to 40% per day. This makes hydrogel very useful for urban farming, where efficient water use is a priority since plants are often not grown directly in natural soil.

Researchers have also looked into other alternative growing media. For example, developed compressed blocks made from coir dust and peat [10]. These blocks were lightweight and easy to transport, which made them practical for farming. However, they lacked sufficient nutrients and usually needed extra chemical fertilizers. This shows the need for growing media made from agricultural waste that is naturally rich in nutrients.

One promising option is pineapple leaves, which are produced in very large amounts in Malaysia. While many studies have focused on using pineapple leaves for fiber composites [11], textiles, or bioenergy [12], fewer have explored their use in agriculture. Previous study, found that compost made from pineapple leaves improved soil porosity and nutrient levels, making it a good candidate for planting media [13]. Combining pineapple leaf powder with soil and hydrogel in compressed blocks could therefore provide a nutrient-rich, water-retaining, and sustainable growing medium. At the same time, it also helps to turn agricultural waste into something valuable an innovative solution for urban farming.

3. Research Methodology

The methodological framework of this research was structured to produce compressed planting medium by combining pineapple leaf waste with soil, while hydrogel was incorporated to improve moisture retention and enable efficient re-expansion after watering. A summary of the procedure is presented in the process flow shown in Figure 2, and the subsequent sections describe each step in detail. The planting medium made from soil and pineapple leaf powder were produced using pineapple leaves collected from local farmers in Muadzam Shah, Pahang. The leaves were first cleaned and then dried in an oven for 8 hours at 65 °C. Once dried, the leaves were ground into powder using a blender, as shown in Figure 3(c). Hydrogel was also ground into smaller particles to ensure better mixing with the pineapple leaf powder and soil. Figure 4 illustrates the soil and the soil–hydrogel mixture used in this study. The prepared mixtures were compressed using a manual press machine under a pressure of 4 bar. The resulting compressed planting medium are shown in Figure 4(c).

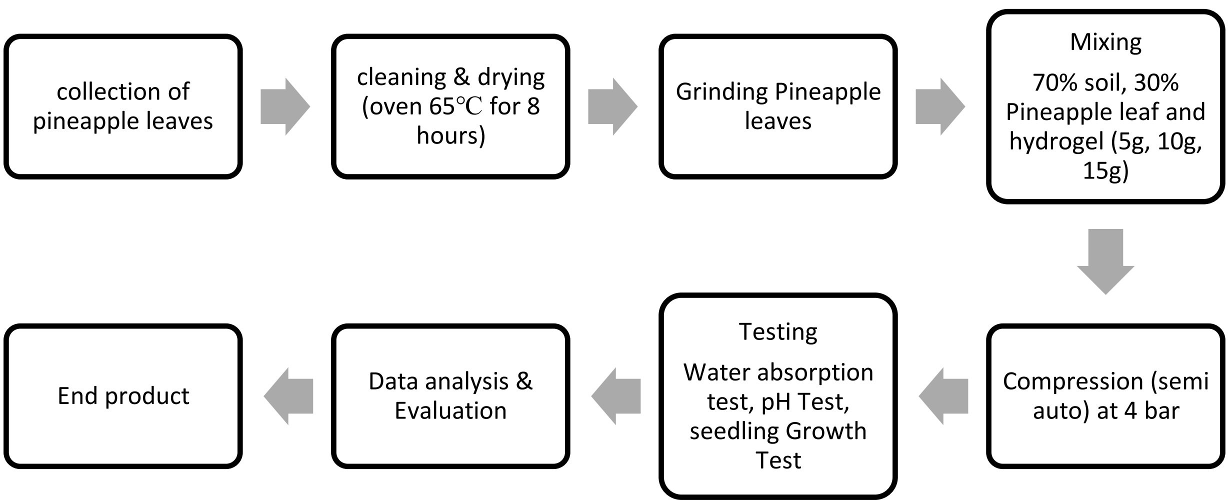

Figure 2. Process flow for producing and testing compressed planting media

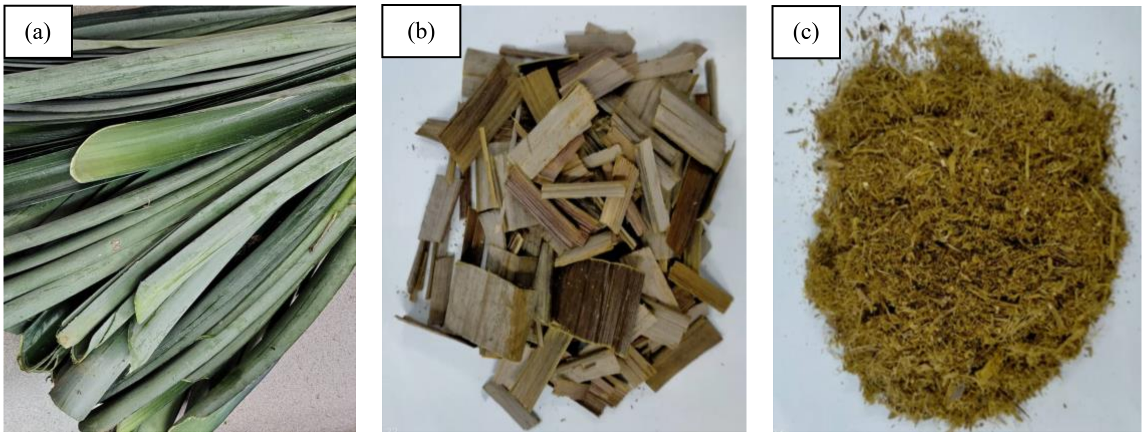

Figure 3. Pineapple leaves: (a) Fresh leaves, (b) Chopped leaves before grinding, and (c) Ground pineapple leaf powder.

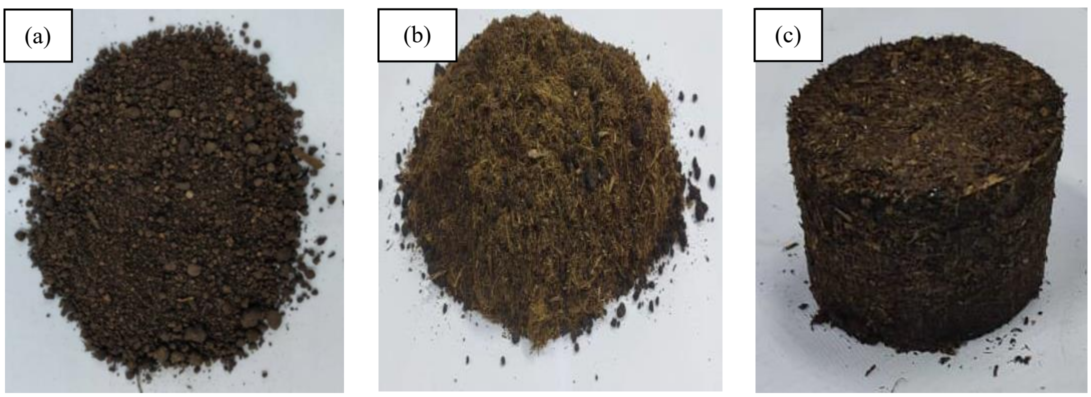

Figure 4. Materials used for producing compressed planting medium: (a) Commercial soil, (b) Mixture of pineapple leaf powder, soil, and hydrogel, and (c) Compressed compost block made from the soil–pineapple leaf powder–hydrogel mixture.

The compressed planting medium then tested for water absorption to evaluate their expansion capacity after compression. As shown in Figure 5(a), the blocks were placed into a beaker, followed by the addition of 500 ml of water. Further testing was conducted to assess the growth performance of mustard (*Brassica rapa*) seedlings using the prepared mixtures for 14 days. Within 14 days, mustard seeds can show significant growth and development of roots and leaves. If the evaluation period is less than 14 days, the growth of seedlings is still too minimal [14, 15]. Meanwhile, factors such as nutrient deficiency and pot size will also affect the results. Figure 6 shows growth of mustard seedlings for 14 days using plant media with different hydrogel contents.

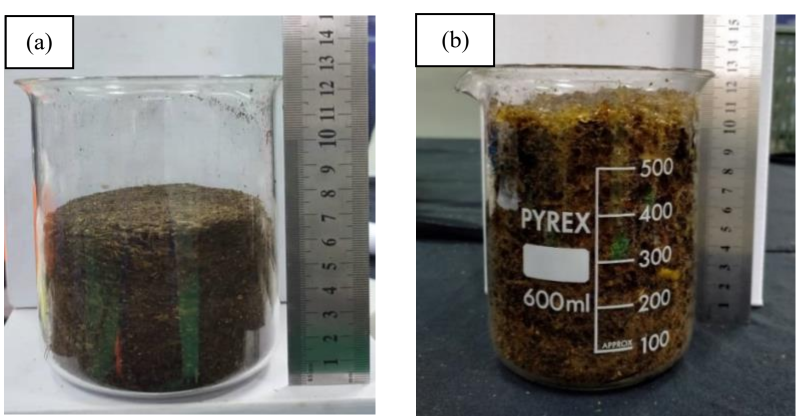

Figure 5. Compressed planting medium for water absorption test: (a) Before water addition, and (b) Expanded block after water absorption

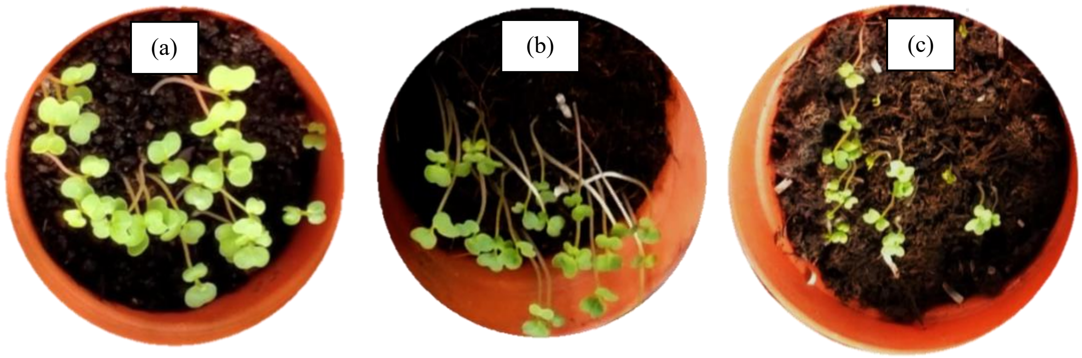

Figure 6. Growth of mustard (*Brassica rapa*) seedlings over 14 days using mixtures of (a) compost soil + 5 g hydrogel, (b) compost soil + 10 g hydrogel, and (c) compost soil + 15 g hydrogel.

4. RESULTS AND DISCUSSION

Tests were conducted on all hydrogel mixing ratios. The pH analysis and compact expansion shown in Table 1, indicated that all 70:30 soil–pineapple leaf powder mixtures with hydrogel maintained an optimal pH between 6.2 and 6.8. Water absorption also increased with higher hydrogel content. The compressed planting medium with hydrogel expanded rapidly when water was added, requiring less than one minute to fully swell. The results demonstrate that 500 grams planting medium block containing 5 grams of hydrogel exhibited faster and more uniform expansion when exposed to water. While the mixture with 10 and 15 grams of hydrogel expanded 35 to 52% more than the mixture with 5 grams of hydrogel. In the 15 g hydrogel mixture, a larger amount of hydrogel was clearly visible after water addition, resulting in excessive expansion of the block. The 5 g hydrogel mixture demonstrated good water retention while maintaining consistent block stability, which aligns with [16], who reported that moderate hydrogel application could increase soil water-holding capacity by up to 40%. However, excessive hydrogel content (10 g and 15 g) led to over-expansion and weaker block stability.

Table 1. pH readings and expansion rate of compact planting medium after water absorption test.

Medium	pH Range	Expansion Rate
70:30 + 5 g Hydrogel	6.2–6.8	Stabil
70:30 + 10 g Hydrogel	6.2–6.7	Over
70:30 + 15 g Hydrogel	6.2–6.7	Over

Further testing was conducted by planting mustard (*Brassica rapa*) seeds using the three different hydrogel formulations. Figure 5 shows the growth performance of the seedlings over a 14-day period. As observed in Figures 5(b) and 5(c), seedlings grown in the mixtures containing 10 g and 15 g of hydrogel exhibited clear signs of nutrient deficiency compared to those cultivated in the 5 g hydrogel mixture (Figure 5a). This finding suggests that a higher hydrogel content reduces the nutrient availability within the planting medium. Table 2 summarizes the observations on mustard seedling growth over the 14-day period.

The results also indicate that although higher hydrogel contents (10 g and 15 g) improved soil moisture levels, they were not suitable for seed germination. Seedlings with fragile root systems struggled to absorb nutrients effectively in media with excessive hydrogel. This aligns with findings by [17], who reported that excessive water storage can reduce soil aeration and create mechanical resistance, thereby limiting nutrient uptake by delicate emerging roots. Consequently, seedlings grown in media with higher hydrogel concentrations exhibited weaker root development and stunted early growth compared to those grown in the 5 g hydrogel mixture, which maintained a better balance of water retention and nutrient availability.

Table 2. Comparison of mustard (*Brassica rapa*) seedling growth over 14 days using three different hydrogel mixtures.

Medium	Observation (Day 14)	Growth Condition
Soil + Pineapple leaf + 5g Hydrogel	Healthier seedlings	Good
Soil + Pineapple leaf + 10g Hydrogel	Weak seedlings	Moderate
Soil + Pineapple leaf + 15g Hydrogel	weak seedings	Slow

5. Conclusion

The compressed planting medium composed of 70% soil, 30% pineapple leaf powder, and 5 g of hydrogel demonstrated optimal water absorption and supported better seedling growth. This makes it an eco-friendly growing medium that is highly suitable for urban agriculture, as its compact form expands rapidly when sufficient water is added. The compressed planting medium are also easy to transport, require less storage space, and are convenient to use in urban farming applications.

These findings highlight that the use of agricultural waste, such as pineapple leaves, combined with hydrogel in the development of compressed planting media holds great potential for advancing sustainable urban agriculture. This approach not only reduces the large volume of organic waste that is often discarded without value but also transforms it into an environmentally friendly value-added product. Hydrogel, in turn, enhances water retention capacity, thereby reducing the dependence on frequent irrigation and promoting more efficient water use. The combination of these innovations contributes to more sustainable urban farming practices by utilizing local resources, lowering costs, and supporting food security goals in densely populated areas.

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