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Impact of tapioca adhesive on water-holding capacity in pot compost for tomato nurseries

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ABSTRACT

Water supply is one of the determining factors for successful production during tomato cultivation. Many farmers still carry out vegetable seedling activities using polybags and provide water daily. This research aims to find out whether this potting compost can store water well to be an alternative to polybags as a planting medium. Pot compost with tapioca adhesive has good water absorption and storage capabilities, which can help increase water storage capacity, reducing the need for irrigation water. This research uses a descriptive analysis method with the parameters measured including vegetative growth, length and width of cracks in compost pot, and compost weight before and after watering. The vegetative observations of tomato plants showed that treatment T1 had better growth than treatments T2 and T3 in plant height which averaged 56.40 mm and an average number of leaves of 5.20 strands on day 14. However, treatment T2 had better shape resistance than treatment T1 which only had an average crack length of 25 mm and an average crack width of 2.20 mm. In observations of measuring the water holding capacity of pot compost, treatment T3 was found to be the most optimal in storing water because on day 6 it still stored 12 ml of water compared to treatments T2 and T1. If this research is applied to large-scale plant nurseries, it can reduce plastic waste originating from polybags.

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1. INTRODUCTION

Water resources are one of the main biological components that play a vital role in supporting human life and ecosystem sustainability. Water is a basic necessity in various sectors, including households, industry, and agriculture (Lestari et al., 2021). In the agricultural sector, water plays a very important role because it is directly related to plant physiological processes such as photosynthesis, transpiration, and nutrient transport. Water shortages will cause plant stress and reduce productivity. Therefore, proper water management is a fundamental factor in successful crop cultivation.

Determining plant water requirements is an important step to ensure that the water supply during the growth phase is optimally met (Maigiska, 2018). At the seedling stage, the growing medium must be able to retain water well, maintain moisture, and provide a microenvironment that supports root development. Plastic polybags have been a practical and economical choice for nursery-stage (Astina et al., 2022). However, the massive use of polybags causes environmental problems because they are difficult to decompose, contaminating the soil, and produce increasing amounts of plastic waste. This challenge led to the development of innovative, environmentally friendly, and sustainable seedling media. One such innovation is the use of compost in the form of pots, or compost pots. Compost pots are considered a promising alternative because they can replace polybags while providing physical, chemical, and biological benefits to plants (Novita et al., 2018). Compost, as the main ingredient, has several important characteristics, including high organic content, crumbly structure, good cation exchange capacity (CEC), ability to improve soil structure, and high-water absorption. The organic matter content in compost can form stable soil aggregates, thereby increasing porosity and water storage capacity. With these properties, compost can retain water better than inorganic media and maintain moisture longer. This is very beneficial in the early

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stages of plant growth, which require moist and stable media conditions.

Compost pots not only benefit plant growth but also play a role in soil and water conservation, especially in areas with high erosion risk. Intensive farming system areas with steep slopes, high rainfall, or easily eroded soil conditions usually face major challenges in maintaining soil erodibility. Water that falls on the soil surface tends to flow as runoff, carrying soil particles and causing the loss of fertile topsoil and increasing erosion yield. In this context, the use of potted compost can be strategic to both reduce erosion yield and save water. Irrigation or rainfall will not directly destroy the pot. In this sense, the potted compost reduces soil erodibility due to compact design. In contrast, the pot will store water longer, which will release slowly, thereby reducing the need for irrigation and helping to maintain moisture. When potted compost is planted directly into the soil, the organic material decomposes naturally and helps improve the soil's ability to retain water and improve soil structure, making it resistant to erosion (Andriyani et al., 2022).

The characteristics of compost are rich in organic matter, which helps improve infiltration and reduce surface runoff, making the soil more capable of absorbing rainwater. Thus, the use of potting compost is not only beneficial for seedling cultivation but also contributes to land conservation efforts in erosion-prone areas. The higher the stability of soil aggregates due to the influence of organic matter in compost, the less likely soil particles are to be released and carried away by water. Therefore, potting compost can be integrated as part of soil and water conservation strategies in dry, undulating, or highland areas.

In making potting compost, a binding agent is needed to ensure that the pot structure is solid and does not crack easily. Tapioca flour is a commonly used binding agent because it has good adhesive properties. Tapioca contains starch that gelatinizes when heated and mixed with water, forming a sticky layer that can bind compost particles together (Utari et al., 2015). Tapioca is environmentally safe and biodegradable, and it maintains the strength of the pot during the seedling stage, including resisting cracks caused by repeated watering. This is important so that the compost pot remains sturdy until the plants are ready to be transplanted.

The advantage of compost pots in absorbing and retaining water makes them a simple but effective technology in facing the challenge of reduced irrigation water availability. Amidst climate change, which has led to longer dry seasons and increased pressure on water resources, the existence of water-efficient growing media is invaluable. In addition, the ability of pot compost to reduce evaporation helps maintain a more stable water supply around the roots. This potential is highly relevant for promoting sustainable, efficient, and environmentally friendly agricultural practices (Andriyani et al., 2024).

This study aims to determine the effectiveness of pot compost in binding water and reducing water loss through evaporation, and providing nutrition for plants. The results of this study are expected to provide a scientific basis for the use of pot compost as an alternative to polybags that are not only environmentally friendly but also contribute to water and soil conservation, and can be a practical solution for areas with high erosion potential and limited irrigation water.

2. MATERIAL AND METHODS

2.1. Research location and time

This research was carried out in two places, namely Tumpuk Renteng village, Turen district, Malang regency, and the second location was at the Faculty of Agricultural Technology, University of Jember, which is located in Sumbersari village, Sumbersari district, Jember regency. The materials used in this study were compost pots made from cattle manure, tapioca, and water. Organic fertilizer derived from cattle manure has a loose and smooth texture after proper composting. This texture allows it to mix well with the soil and improve the soil structure by increasing porosity and aeration, and has fine grains.

2.2. Research methods

Potted compost is made by mixing tapioca flour according to Table 1. Potting compost is made by mixing tapioca flour according to the mixture determined in Table 1, with a diameter of 5 cm and a height of 8 cm. The potting compost that will be planted with seeds is given a hole with a diameter of 1 cm first in the center 1 cm deep. The measurement of watering volume refers to Sulistyowati et al. (2021), which has been modified. The watering volume is determined by determining the field capacity of the pot compost that has been made. The dry potted compost is weighed to determine its initial weight, then watered with 100 ml of water until saturated, and then weighed as the weight of the potted compost in a saturated state. Plant vegetative growth measurements were carried out to determine whether there was a significant effect of the treatment of tapioca and cow compost composition variations on plant vegetative growth. The parameters measured in the vegetative growth of this plant include plant height and the number of leaves measured during the 14-day nursery period. Measurement of the resistance level of potting compost is needed to determine the level of resistance to the use of potting compost during the nursery period, which is for 14 days. The parameters measured to determine the level of resistance of the shape of this potted compost include the length and width of cracks that arise in the potted compost.

Table 1. Combined treatment of tapioca flour and organic fertilizer composition

No	Kode	Treatment	Information
1	T1	Tapioca flour 5%, organic fertilizer 95%	The composition of the mixture of tapioca flour and organic fertilizer used refers to the research (Haidar, 2022)
2	T2	Tapioca flour 7.5%, organic fertilizer 92.5%	
3	T3	Tapioca flour 15%, organic fertilizer 85%	

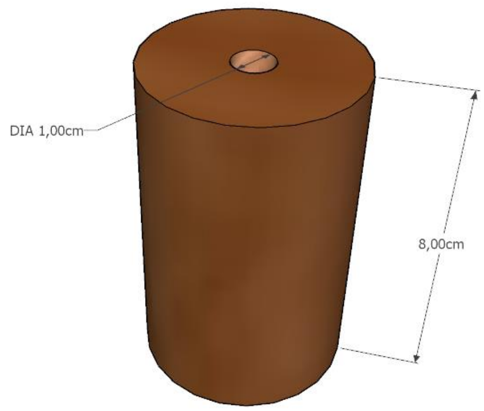


Figure 1. Pot hole diameter and height

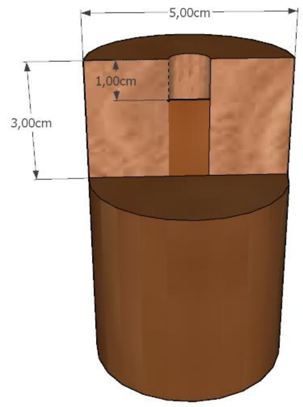


Figure 2. Inside the pot compost

3. RESULTS

3.1. Compost pot model design for nursery

The compost pot was made by mixing tapioca flour according to the mixture specified in Table 1 with a diameter of 5 cm and a height of 8 cm. The overall shape of the compost pot can be seen in Figure 1. The compost pot will be planted with seeds, which is first given a hole with a diameter of 1 cm in the centre, 1 cm deep.

Figure 2 shows a visualization of the overall shape of the compost pot, including the planting hole in the center. This hole has a diameter of 1 cm and a depth of 1 cm, which serves as a place to put the seeds so that they are stable and at a uniform planting depth. The design of the planting hole also helps maintain aeration and facilitates germination.

The dimensions and shape of the compost pot are tailored to the needs of early plant growth, namely, providing sufficient media space, facilitating transfer to the field without damaging the roots, and allowing the pot to gradually decompose in the soil. With these specifications, the compost pot not only functions as a temporary container but also becomes a source of organic material when it degrades.

3.2. The compost pot water holding capacity

The compost pot water holding capacity is an indicator to identify the ability of compost pot to conserve water. Measurement of water trapped in potting compost during watering is used to determine the binding power of water in potting compost. Measurements of the amount of water held in each can be seen in Table 2.

3.3. Vegetative growth of tomato plant seedlings

Data on the vegetative growth of tomato plants was obtained through measurements of plant height taken over a 14-day seedling period. Based on Figure 3, the height data of tomato plants in the T1, T2, and T3 treatments produced different data. The measurement on day 14 showed that T1 had a higher average plant height growth, followed by T2 and T3, where the stem growth was shorter than the other two treatments. The data on the number of plants showed results that were not much different from the data on plant height. The T1 treatment had an average higher number of leaves than the T2 and T3 treatments. Factors that affect the growth of the number of leaves are water, nutrients, and sunlight availability for photosynthesis. In the vegetative observation of this plant, it was found that the treatment with a lower tapioca composition had better stem growth and number of leaves than the treatment with a higher tapioca composition. This can be caused by the nitrogen content in cattle manure being higher than tapioca.

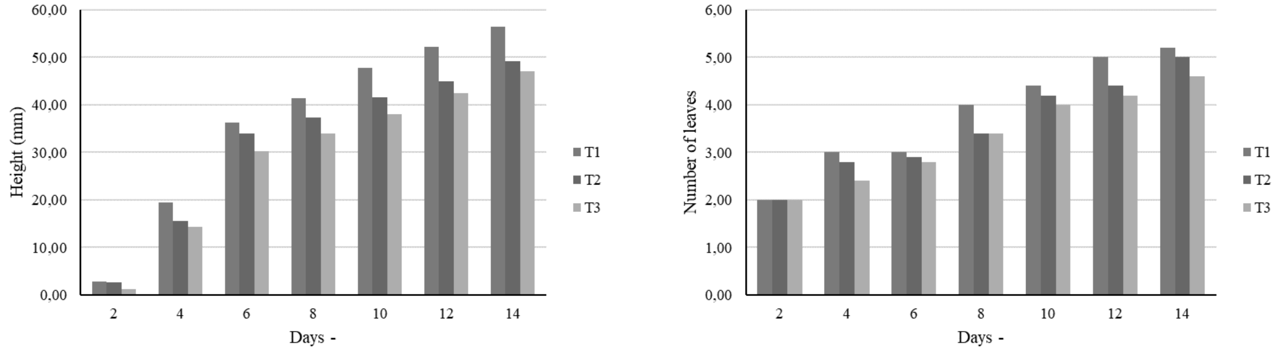
3.4. Potted compost resistance during the nursery period

Based on the research that has been conducted, data on the length and width of cracks in potting compost were obtained during the 14-day nursery period. The length of potted compost cracks from 3 treatments shows that there are cracks that tend to arise at one point and widen as the days go by, forming a fracture on one side of the potted compost (Fig. 4). The observation results of the length and width of potted compost cracks have different averages. The measurement on the 14th day showed that T3 with a tapioca composition of 15% had an average crack length of 55.60 mm and an average crack width of 4.60 mm, which treatment had the highest value compared to T2 and T1.

Table 2. Water holding capacity

Day to -	T1		T2		T3	
	SW (ml)	Pot (g)	SW (ml)	Pot (g)	SW (ml)	Pot (g)
0	100	390	100	390	100	390
1	34.2	323.2	35	324	59.8	348.8
2	22.2	311.2	24	313	49.8	338.8
3	20.6	310.6	25.4	315.4	40	330
4	2	292	12	302	35	325
5	-	290	6.4	296.4	20	310
6	-	-	0	290	12	302
7	-	-	-	-	-	290

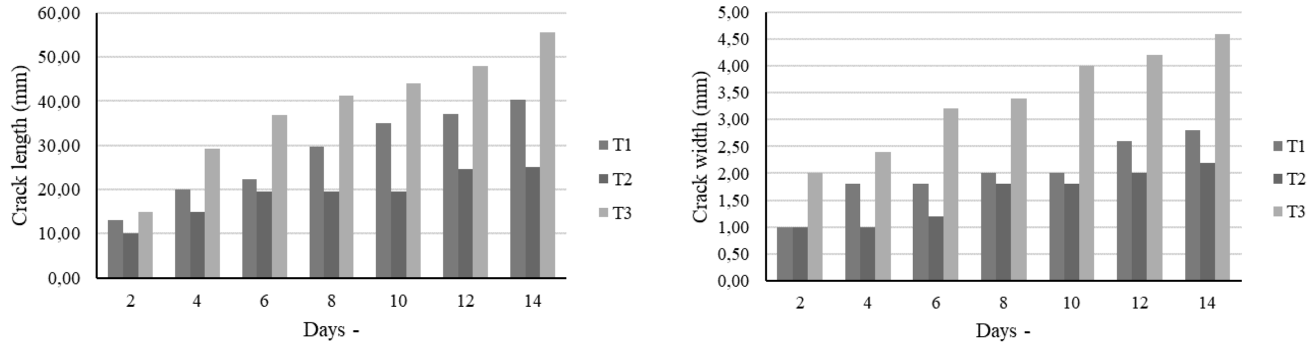
Remarks: SW: Stored water; Pot: Weight of planting medium



(a) (b)

Remarks: T1: Tapioca flour 5%, organic fertilizer 95%; T2: Tapioca flour 7.5%, organic fertilizer 92.5%; T3: Tapioca flour 15%, organic fertilizer 85%

Figure 3. Plant height growth graph; (a) Plant height, (b) Number of leaves



(a) (b)

Remarks: T1: Tapioca flour 5%, organic fertilizer 95%; T2: Tapioca flour 7.5%, organic fertilizer 92.5%; T3: Tapioca flour 15%, organic fertilizer 85%

Figure 4. Graph of the onset of cracks; (a) crack length, (b) crack width

Both graphs show that the T2 treatment has a milder level of damage than the other two treatments. This condition can be caused by several factors, one of which is the high binding capacity of the compost to water. Treatments that easily absorb water can cause the material to become softer and less rigid, reducing its structural strength. In the T2 treatment, the level of damage is lighter than the other treatments, this can happen because the water binding capacity in the T2 treatment is lower than the other treatments, high absorption can make the material more susceptible to physical and mechanical stress This situation can be caused by several factors, one of which is the high binding power of compost to water.

4. DISCUSSION

The starch content in tapioca flour possesses hydrophilic characteristics, meaning it has a natural tendency to attract and absorb water (Hazrati et al., 2021). This inherent property of starch influences the behavior of potted compost, especially in treatments where tapioca concentration is high. In the T3 treatment, which contains the highest proportion of tapioca flour, this hydrophilic nature results in greater water absorption compared to the other treatments. The starch molecules in tapioca are capable of swelling when they come into contact with water, allowing the potting material to retain a larger volume of moisture. This swelling process creates a gel-like consistency, increasing the water-holding capacity of the compost pot but also affecting its structural firmness (Syafri et al., 2025).

However, greater water absorption does not necessarily indicate better performance. Romdoni et al. (2023) explain that the low water absorption observed in the T1 and T2 treatments can be attributed to the compactness of the compost pot surface and the particle size of the organic matter used in its production. Smaller organic matter particles create a denser and more uniform structure, reducing the space available for water to infiltrate (Mendrofa & Gulo, 2024). While this characteristic may limit water absorption, it also enhances the mechanical strength of the pot by reducing pore spaces that serve as stress points. Oxygen availability within the compost structure also affects water content, as oxygen facilitates the movement and evaporation of moisture within the material. The placement of composting containers further influences water retention, where varying environmental temperatures can result in significantly different moisture levels due to evaporation rates and microbial activity during the composting process.

The raw materials used in compost pot production, as well as the quantity and proportion of those materials, also play a substantial role in determining the pot's ability to absorb water. As emphasized by Sinaga and Dewi (2023), different raw materials possess different water absorption capacities.

Organic fertilizer such as cattle manure generally has high water retention due to their fibrous and porous structure, whereas tapioca flour offers water-binding ability through its starch molecules (Nasrullah et al., 2023; Syafri et al., 2025). When these materials are combined in varying proportions, the resulting physical and chemical characteristics of the compost pot will differ. Higher tapioca concentration increases compactness and hydrophilicity, while higher organic fertilizer increases porosity and water drainage.

The presence of cavities within the compost pot structure affects the likelihood of cracks forming over time (Nafisah et al., 2023). Cavities can develop due to improper mixing of ingredients, the composition of the raw materials, and variations in the particle size of organic matter. If the mixture contains coarse particles or is not adequately compacted, voids will form within the structure, creating weak points that make the pot susceptible to cracking. These weak points become more vulnerable when exposed to moisture fluctuations, mechanical pressure, or microbial degradation.

The type of material and the size of the particles used in the compost pot mixture directly influence its structural integrity. Lestari et al. (2022) found that smaller particle sizes are more advantageous for bio pot formation because they compact more easily, reducing pore space and increasing the density of the final product. Denser material tends to have fewer cavities, thus reducing the likelihood of crack formation. However, while smaller particles enhance structural strength, they also reduce permeability and aeration, which may negatively affect seedling root development if not properly balanced with other materials that promote porosity.

Treatments that strongly absorb water, such as T3, can cause the compost material to become softer and less rigid, compromising its structural strength. High moisture absorption may lead to expansion and weakening of the matrix, increasing the possibility of surface deformation, swelling, and damage during handling or watering. Additionally, excessive moisture within the compost pot can foster microbial activity that accelerates decomposition, further reducing the pot’s durability.

In contrast, the T2 treatment exhibits a lighter level of damage compared to T1 and especially T3. This may be due to the balanced proportion of tapioca and organic fertilizer in T2, resulting in moderate water-binding capacity. The lower water-binding ability in T2 prevents excessive softening and helps maintain rigidity while still allowing sufficient moisture retention for plant growth. This finding is consistent with the explanation provided by Mirad et al. (2023), who stated that both microbiological and chemical processes can contribute to pot degradation, and moisture content serves as a critical determinant of the rate at which such damage occurs. High moisture levels accelerate microbial colonization and decomposition, leading to faster deterioration of compost-based pots (Saibi & Tolangara, 2017). Thus, treatments with higher moisture levels, such as T3, naturally experience more severe damage due to this increased biological activity.

Therefore, while T3 exhibits optimal water absorption due to its high tapioca content, this characteristic also makes it more vulnerable to structural failure. T1 and T2, on the other hand, exhibit lower water absorption, which reduces their susceptibility to microbial degradation but may impact water availability for seedlings. The challenge lies in finding a balance between water absorption and structural durability, as excessive emphasis on one component may compromise the overall functionality of the compost pot. The findings from Hazrati et al. (2021), Romdoni et al. (2023), Nafisah et al. (2023), and other supporting studies collectively highlight the importance of determining the appropriate composition of organic matter and adhesive materials to produce compost pots that are both strong and effective in supporting plant growth.

5. CONCLUSION

The findings indicate that increasing the amount of tapioca flour (starch adhesive) strengthens the pots (T3), improves their water-holding capacity, and reduces the need for irrigation. In contrast, vegetative observation of tomato plants found that the T1 treatment had better growth than the T2 and T3 treatments, both in terms of plant height, which averaged 56.40 mm, and the average number of leaves was 5.20 on the 14th day. However, excessive use of tapioca can reduce plant growth performance, likely due to its low nitrogen and protein content compared to cow manure, which contains higher nitrogen levels that support vegetative growth. Optimal plant height and leaf number were observed in treatments with higher cow manure content, particularly T1, due to better nutrient availability. Furthermore, the physical properties of pot compost, such as particle size and density, impact the pot's susceptibility to cracking and structural damage. Treatments with high water absorption showed more structural degradation due to increased moisture retention, while T2 demonstrated better resistance to damage. Overall, balancing nutrient-rich organic material with appropriate physical composition is key to optimizing both plant growth and pot durability. In this sense, a medium dose of tapioca flour gives compromise results for both water and soil conservation and the vegetative plant period.

Declaration of Competing Interest

The authors declare that no competing financial or personal interests may appear to influence the work reported in this paper.

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