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Application of *Trichoderma harzianum* on Cassava Peel Media as a Biofertilizer for the Growth of Tomato Plants (*Solanum lycopersicum* L.)

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Abstract: *Tomato (Solanum lycopersicum L.) is an economically important horticultural crop whose productivity is frequently constrained by soil-borne pathogens and declining soil fertility. Trichoderma harzianum is a beneficial fungus that acts as both a biofertilizer and a biological control agent by enhancing nutrient availability and promoting plant growth. Although numerous studies have reported the positive effects of Trichoderma harzianum on tomato cultivation, information regarding its propagation on cassava peel and the influence of different application methods remains limited. Therefore, this study aimed to evaluate the growth-promoting effect of cassava peel-based Trichoderma harzianum on tomato plants under different application methods and dosages. The experiment was arranged in a Completely Randomized Design (CRD) consisting of five treatments with four replications. The observed parameters included spore density, plant height, number of leaves, fresh weight, and dry weight. Data were analyzed using one-way Analysis of Variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) at a 5% significance level. The results showed that cassava peel medium produced a higher spore density (3.96×10^7 spores mL^{-1}) than rice medium (1.67×10^7 spores mL^{-1}). Soil application of 4 g $polybag^{-1}$ (P2) resulted in the highest plant height and number of leaves, whereas foliar application of 4 g 100 mL^{-1} (P4) produced the highest fresh and dry weights. Overall, cassava peel proved to be an effective alternative substrate for propagating Trichoderma harzianum, while appropriate application methods and dosages enhanced tomato vegetative growth and biomass production.*

Keywords: *Trichoderma harzianum, Biofertilizer, Cassava Peel, Tomato Growth, Application Method.*

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I. INTRODUCTION

Trichoderma harzianum In conventional agricultural practices, productivity improvement still largely depends on the use of synthetic fertilizers and pesticides. Although effective in the short term, excessive use of these inputs may lead to soil degradation, environmental pollution, and imbalance of beneficial soil microorganisms (Rizal et al., 2019). Therefore, environmentally friendly and sustainable alternatives, such as biofertilizers, are increasingly needed (Singh and Yadav, 2020).

One of the most promising biological approaches is the application of *Trichoderma harzianum* as a biofertilizer and biological control agent. Hermosa et al. (2014) reported that *Trichoderma harzianum* promotes plant growth by improving nutrient availability, enhancing root development, and producing phytohormones that stimulate plant growth. In addition to its growth-promoting activity, *Trichoderma harzianum* suppresses soil-borne pathogens through competition, antibiosis, and mycoparasitism (Rizal et al., 2019). More recently, Ismaiel et al. (2024) emphasized that *Trichoderma harzianum* is one of the most promising beneficial fungi for sustainable agriculture because of its adaptability and effectiveness under diverse environmental conditions.

The effectiveness of *Trichoderma harzianum* as a biofertilizer is influenced by the substrate used during its propagation. Gusriani and Koto (2022) reported that cassava peel contains carbohydrates that can be utilized during fungal fermentation, making it a potential substrate for microbial growth. Likewise, Viji et al. (2018) demonstrated that cassava-based substrates supported the mass propagation of Trichoderma spp. Furthermore, Rahmiyah et al. (2023) showed that agricultural wastes could be used as alternative propagation media without reducing fungal performance. Although these studies have demonstrated the potential of cassava peel as a propagation substrate, information regarding the application of cassava peel-propagated *Trichoderma harzianum* using different application methods on tomato growth remains limited.

Therefore, this study aimed to evaluate the growth-promoting effect of cassava peel-based *Trichoderma harzianum* on tomato plants under different application methods and dosages. The results of this study are expected to provide scientific evidence regarding the utilization of cassava peel as an alternative substrate for *Trichoderma harzianum* propagation and to support the development of environmentally friendly biofertilizer technology for sustainable tomato cultivation.

II. EXPERIMENTAL PROCEDURE

This study was conducted from 22 December 2025 to 16 February 2026 at the Laboratory of Plant Protection for Food Crops and Horticulture (LPTPH), Gadingrejo, Lampung, Indonesia. The laboratory activities included inoculum preparation and propagation, while plant cultivation and treatment applications were carried out under controlled environmental conditions to ensure uniform plant growth.

2.1 Experimental Design

The experiment was arranged in a Completely Randomized Design (CRD) consisting of five treatments with four replications. Each replication consisted of one experimental unit. The treatments included: control (without *Trichoderma harzianum*), soil application at 2 g/polybag, soil application at 4 g/polybag, foliar application at 2 g/100 mL, and foliar application at 4 g/100 mL. All treatments were randomly assigned to minimize experimental bias and ensure the validity of the results.

2.2 Propagation of *Trichoderma harzianum*

The isolate of *Trichoderma harzianum* was obtained from LPTPH Gadingrejo. The inoculum was propagated using cassava peel as a substrate. A total of 500 g of inner cassava peel was prepared and divided into four stages (125 g each) for sequential inoculation to maintain continuous availability of active inoculum.

The cassava peel was first washed thoroughly, soaked for 5 minutes, and then steamed for 10 minutes to reduce potential contaminants. After cooling to room temperature, the substrate was placed in sterile plastic containers lined with sterile paper. Each stage was inoculated aseptically with a suspension of *Trichoderma harzianum* prepared from actively growing cultures. The inoculated substrates were incubated at room temperature (25–28°C) for 7–14 days until the entire surface was covered with green spores, indicating optimal sporulation and readiness for application.

2.3 Soil Application of *Trichoderma harzianum*

Tomato seedlings aged 17 days after sowing, with 3–4 fully developed true leaves, were transplanted into polybags containing growth media. Soil application treatments were carried out by placing 2 g or 4 g of cassava peel inoculum around the base of each plant.

The application was performed once at the early stage of plant growth to allow the fungus to establish and colonize the rhizosphere. After application, plants were watered regularly to maintain adequate soil moisture, which is essential for microbial activity and root development. This method was intended to promote direct interaction between *Trichoderma harzianum* and the root system, thereby enhancing nutrient uptake and plant growth.

2.4 Foliar Application of *Trichoderma harzianum*

Foliar application was initiated 15 days after transplanting to allow plant adaptation to the new growth medium. The inoculum was prepared by mixing 2 g or 4 g of cassava peel inoculum with 100 mL of sterile distilled water and homogenizing the mixture thoroughly.

The suspension was applied by spraying evenly onto the leaf surfaces until fully wetted. Applications were conducted in the morning to reduce evaporation and increase absorption efficiency. The treatment was repeated at 7-day intervals for four consecutive applications (7, 14, 21, and 28 days after planting). Fresh inoculum aged 7–14 days was used for each application to ensure high spore viability and consistent treatment effectiveness.

2.5 Control Treatment

Control plants were maintained without the application of *Trichoderma harzianum*. All plants, including the control, received the same standard maintenance practices, including regular watering and manual weed removal, to ensure that differences in plant growth were solely due to treatment effects.

2.6 Observed Parameters

The observed parameters included spore density, plant height, number of leaves, fresh weight, and dry weight. Spore density was measured to evaluate the quality and viability of the inoculum produced on cassava peel media. Plant height and number of leaves were measured at 7-day intervals, specifically at 7, 14, 21, and 28 days after planting. Plant height was measured from the base of the stem at the soil surface to the highest point of the plant, while the number of leaves was recorded based on fully expanded true leaves.

Fresh weight and dry weight were measured at the end of the experiment (28 days after planting). Plants were carefully uprooted, cleaned of adhering soil, and weighed to obtain fresh weight. For dry weight measurement, plant samples were placed in paper envelopes and oven-dried at 70°C for 48 hours or until a constant weight was achieved.

2.7 Data Analysis

All collected data were subjected to one-way Analysis of Variance (ANOVA) to determine the effect of treatments. When significant differences were detected at the 5% significance level ($p < 0.05$), Duncan's Multiple Range Test (DMRT) was performed to compare means among treatments. Statistical analysis was conducted to ensure the reliability and validity of the experimental results.

III. RESULTS AND DISCUSSIONS

3.1. Spore Density of *Trichoderma harzianum*



Figure 1. Reaction activity of *Trichoderma harzianum* application on cassava peel media.

Gusriani and Koto (2022) reported that cassava peel contains carbohydrates that can be utilized during fungal fermentation. These carbohydrates serve as an important carbon source for fungal metabolism, thereby supporting mycelial development and spore formation.

Similarly, Viji et al. (2018) demonstrated that cassava-based substrates were suitable media for the mass propagation of Trichoderma because they supported abundant fungal growth and produced high-quality inoculum. This finding is consistent with the higher spore density obtained in the present study, suggesting that cassava peel can replace conventional propagation media.

The use of agricultural waste as a propagation substrate has also been reported by Rahmiyah et al. (2023), who found that organic residues can be utilized as alternative media for *Trichoderma harzianum* propagation without reducing fungal performance. Utilizing cassava peel not only improves inoculum production but also adds value to agricultural waste through its conversion into biofertilizer.

Table 1. *Trichoderma harzianum* spore density activity test on cassava peel media

Media	Dilution	Total spore density
Kulit Singkong	Ke-1 10^{-1}	3,96 x 10^{7}
Beras	Ke-1 10^{-1}	1,67 x 10^{7}

The propagation of *Trichoderma harzianum* on cassava peel medium successfully produced a spore density of 3.96×10^7 spores mL^{-1}, which was considerably higher than that obtained on rice medium (1.67×10^7 spores mL^{-1}) (Table 1). This result indicates that cassava peel provided a favorable substrate for fungal growth and sporulation.

High spore density is an important indicator of inoculum quality because viable spores enhance the ability of *Trichoderma harzianum* to colonize the rhizosphere after application. Hermosa et al. (2014) explained that successful rhizosphere colonization enables *Trichoderma harzianum* to improve nutrient availability, stimulate plant growth, and suppress soil-borne pathogens. Therefore, the high spore density obtained in this study indicates that cassava peel is a promising alternative substrate for producing effective *Trichoderma harzianum* biofertilizer.

3.2. Plant Height

Plant height increased progressively in all treatments throughout the observation period (Figure 2). However, tomato plants treated with *Trichoderma harzianum* showed greater plant height than the untreated control. Among all treatments, soil application of *Trichoderma harzianum* at 4 g $polybag^{-1}$ (P2) consistently resulted in the highest plant height, indicating that this treatment was the most effective in promoting vegetative growth.

According to Hermosa et al. (2014), *Trichoderma harzianum* promotes plant growth through multiple mechanisms, including improving nutrient availability, enhancing root colonization, and stimulating plant

physiological processes. These mechanisms increase nutrient uptake and support cell division and elongation, which contribute to greater stem growth.

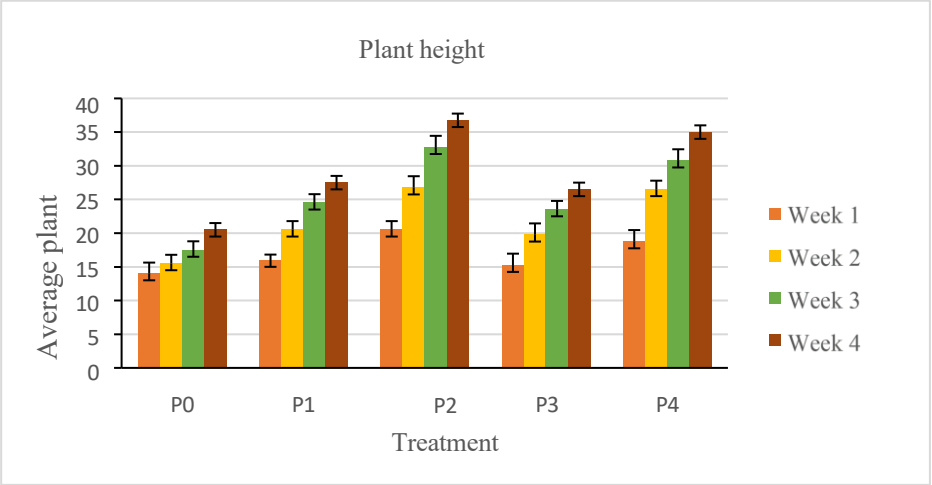


Figure 2. Graph of plant height

The positive effect of *Trichoderma harzianum* on tomato growth has also been reported by Tucci et al. (2011), who found that root colonization by *Trichoderma harzianum* significantly enhanced tomato growth. Their study suggested that successful colonization of the rhizosphere improved nutrient acquisition and increased plant vigor during vegetative development.

Similar findings were obtained by Maryani et al. (2020), who reported that soil application of *Trichoderma harzianum* significantly increased tomato plant height by promoting root development and improving nutrient absorption. Better root performance enables plants to absorb water and mineral nutrients more efficiently, resulting in continuous vegetative growth.

The higher plant height observed in treatment P2 indicates that soil application provided more favorable conditions for *Trichoderma harzianum* establishment than foliar application. Ismaiel et al. (2024) explained that the ability of *Trichoderma harzianum* to establish in the rhizosphere is one of the major factors determining its effectiveness as a plant growth-promoting fungus. Therefore, soil application at 4 g polybag^{-1} was considered the most effective treatment for increasing tomato plant height.

3.3. Number of Leaves

The application of *Trichoderma harzianum* significantly increased the number of tomato leaves compared with the untreated control (Figure 3). All treatments receiving *Trichoderma harzianum* produced more leaves than the control, with P2 (soil application at 4 g polybag^{-1}) recording the highest number of leaves. This result indicates that soil application at the higher dosage was more effective in promoting vegetative growth.

Leaf formation is closely associated with nutrient availability, particularly nitrogen, phosphorus, and potassium, which are essential for cell division, chlorophyll synthesis, and photosynthesis. Lakitan (2011) explained that adequate nutrient availability supports leaf initiation and expansion, resulting in increased vegetative growth.

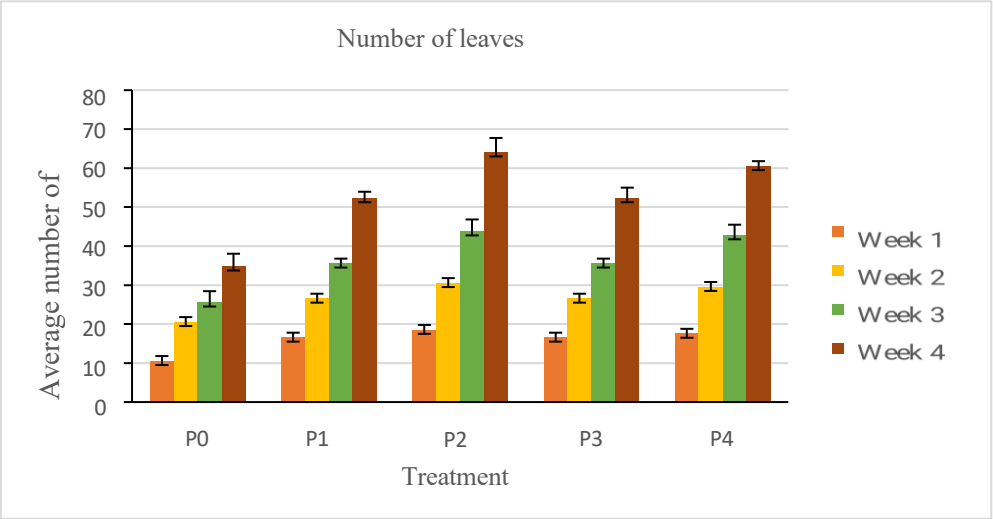


Figure 3. Graph of number of leaves

In addition to improving nutrient availability, *Trichoderma harzianum* promotes plant growth by enhancing root colonization and increasing nutrient uptake efficiency. Hermosa et al. (2014) reported that *Trichoderma harzianum* interacts with plant roots, improves nutrient acquisition, and stimulates physiological processes that contribute to vegetative development, including leaf formation.

Similar findings were reported by Maryani et al. (2020), who observed that soil application of *Trichoderma harzianum* significantly increased the number of tomato leaves compared with untreated plants. Enhanced root development enables plants to absorb water and nutrients more efficiently, thereby supporting the formation of new leaves.

The higher number of leaves observed in treatment P2 indicates that soil application allowed *Trichoderma harzianum* to establish more effectively in the rhizosphere than foliar application. Consequently, plants were able to utilize nutrients more efficiently, leading to improved vegetative growth and increased leaf production.

3.4. Dry Weight

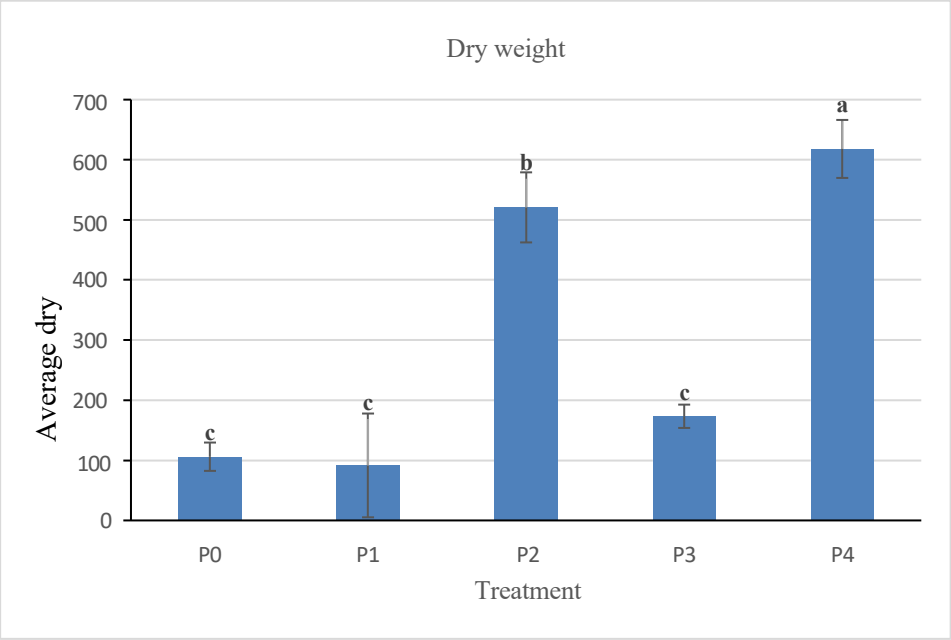


Figure 4. Graph of dry weight

Dry weight is an important indicator of plant biomass accumulation because it represents the amount of organic matter produced through photosynthesis after water has been removed from plant tissues. As shown in Figure 4, all treatments receiving *Trichoderma harzianum* produced higher dry weight than the untreated control. The highest dry weight was recorded in P4 (foliar application at 4 g 100 mL^{-1}), indicating that this treatment was the most effective in increasing biomass accumulation.

According to Lakitan (2011), dry weight reflects the net accumulation of photosynthates in plant tissues and is closely associated with photosynthetic efficiency and nutrient availability. Increased dry weight therefore indicates better plant growth and biomass production.

Kumar et al. (2021) reported that foliar application of *Trichoderma harzianum* enhanced plant physiological activity by improving nutrient utilization and stimulating metabolic processes. These responses increased photosynthetic performance and promoted greater biomass accumulation.

The beneficial effects of *Trichoderma harzianum* on biomass production were also emphasized by Moreno et al. (2025), who explained that *Trichoderma harzianum* improves plant productivity by enhancing nutrient acquisition, promoting plant growth, and increasing tolerance to environmental stress. These mechanisms enable plants to allocate more assimilates to structural tissues, resulting in greater dry biomass.

The present study demonstrated that foliar application at 4 g 100 mL^{-1} was more effective than soil application in increasing dry weight. This finding suggests that the application method influences the physiological response of tomato plants, particularly in biomass accumulation during vegetative growth.

3.5. Fresh Weight

Fresh weight is an important parameter for evaluating plant growth because it reflects the accumulation of water and biomass during the vegetative stage. As presented in Figure 5, the application of *Trichoderma harzianum* significantly increased the fresh weight of tomato plants compared with the untreated control. The highest fresh weight was recorded in P4 (foliar application at 4 g 100 mL^{-1}) with a value of 2888.50 g, followed by P2 (soil application at 4 g $polybag^{-1}$) with 2639.50 g, whereas the control treatment (P0) produced the lowest fresh weight (1045.75 g). These results indicate that *Trichoderma harzianum* enhanced biomass accumulation, particularly when applied as a foliar treatment at the higher dosage.

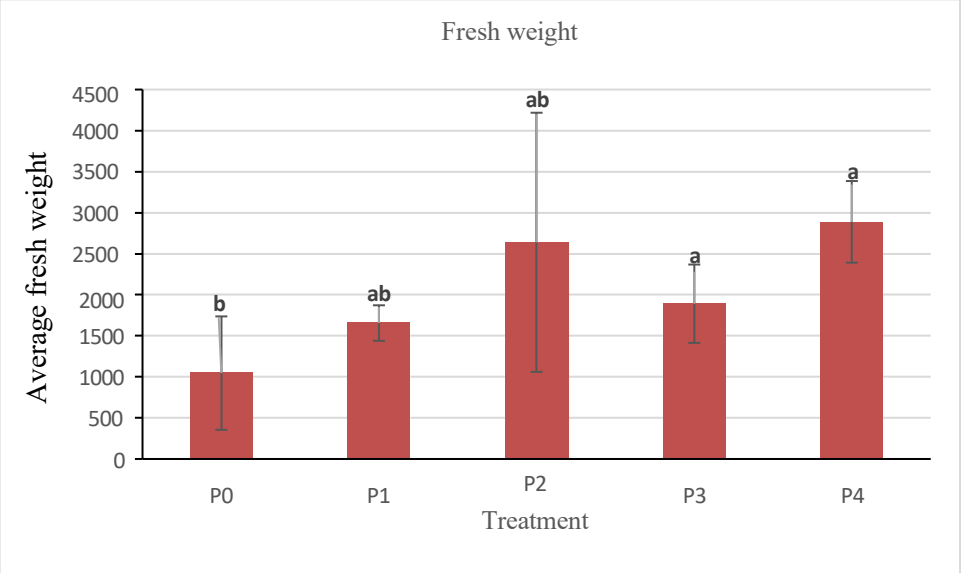


Figure 5. Graph of fresh weight

According to Lakitan (2011), fresh weight is closely related to plant water content and the accumulation of photosynthetic products in plant tissues. Plants with greater nutrient uptake and higher photosynthetic activity generally produce higher fresh biomass because of increased cell expansion and tissue development.

The increase in fresh weight observed in the present study is consistent with the findings of Kumar et al. (2021), who reported that foliar application of *Trichoderma harzianum* significantly improved tomato growth and biomass production. The authors suggested that foliar application enhanced plant physiological performance by improving nutrient utilization and metabolic activity, resulting in greater biomass accumulation.

Similarly, Abedin et al. (2018) found that the application of *Trichoderma harzianum* -based biofertilizer significantly increased tomato growth and yield compared with untreated plants. Improved nutrient availability

and enhanced plant vigor contributed to greater biomass production throughout the growing period.

The superior fresh weight obtained from treatment P4 indicates that foliar application at 4 g 100 mL^{-1} provided the most favorable response for biomass accumulation. This result suggests that an appropriate dosage and application method of *Trichoderma harzianum* can improve vegetative growth by increasing nutrient utilization and promoting plant development.

IV. CONCLUSION

The present study demonstrated that cassava peel is a promising alternative substrate for the propagation of *Trichoderma harzianum*, producing a higher spore density than the conventional rice medium. The application of cassava peel-based *Trichoderma harzianum* significantly enhanced tomato growth, with soil application at 4 g $polybag^{-1}$ being the most effective treatment for increasing plant height and number of leaves, whereas foliar application at 4 g 100 mL^{-1} produced the highest fresh and dry weights. These findings indicate that the appropriate application method and dosage of *Trichoderma harzianum* can improve vegetative growth and biomass accumulation in tomato plants. Therefore, cassava peel has considerable potential as a low-cost and sustainable substrate for the production of *Trichoderma harzianum* biofertilizer.

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