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Growth Response of Cayenne Pepper (*Capsicum frutescens* L.) var. San Marino to Biofertilizer Treatment on Organic Conversion Land BBPP Ketindan

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Abstract
This research aims to determine the effect of combining Biocon-NP and *Trichoderma harzianum* biofertilisers on the growth of cayenne pepper var. San Marino is cultivated on organic conversion land during the rainy season. This research employed an experimental method using a Randomised Group Design involving two factors: Biocon-NP dosage (17 grams) and *Trichoderma harzianum* dosage (100 ml per 7 litres of water). The treatments tested consisted of three fertiliser combinations: P0 (50% compost), P1 (25% compost + Biocon-NP), and P2 (25% compost + Biocon-NP + *T. harzianum*). The parameters observed at various observation times were plant height, number of leaves, leaf width, leaf color, and number of flowers and fruits at various observation times. Statistical analysis using two-way ANOVA showed that Biocon-NP had no significant effect. However, the combination with *T. harzianum* resulted in a significant increase in leaf width (6.28 cm) and number of fruits (3.00 fruits). This study showed that combining the two biofertilisers effectively enhances the growth of chilli plants, as evidenced by the increase in leaf width and number of fruits.

Keywords: Biocon-NP; biofertilizer; cayenne pepper; conversion land; *Trichoderma harzianum*

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INTRODUCTION

Cayenne pepper (*Capsicum frutescens* L.) is a type of plantation crop that Indonesian farmers widely cultivate because it has high demand and substantial economic value (Chairunnisak, 2023). Based on Badan Pusat Statistik data (2022), in 2020, cayenne pepper production reached 1.51 million tons with a total harvest area of around 181,043 hectares. This figure increased by 9.76% compared to the previous year's production of 1.37 million tons. The demand for cayenne pepper production is significant because cayenne pepper is classified as a vegetable or horticultural commodity often consumed by the public (Indriani *et al*., 2019). The demand for cayenne pepper continues to increase due to a decrease in the yield of chilli peppers (Ananda *et al*., 2024). Generally, cayenne pepper is used as a spice to increase appetite and add flavour to dishes. In addition, cayenne pepper also has important nutrients for health, such as fat, protein, and carbohydrates (Rohayati and Saleh, 2022). Cayenne pepper is a commodity with great opportunities in the agricultural sector that can continue to be developed (Puspitasari, 2020).

Climate change in the agricultural sector can cause a high risk of loss, such as crop or production failure. One of the climate changes that can affect production is high rainfall. The intensity of rainfall influences the production of cayenne pepper (Togatorop *et al*., 2022). Heavy rainfall affects plants; other environmental factors, such as excessive sun exposure and strong winds, can interfere with plants. Insect and fungal pests found on chilli plants can also cause damage and cause plants to die (Lemaaniah *et al*., 2023). In addition, the use of chemical fertilisers is also still a problem for the environment. Repeated application of chemical fertilisers with inappropriate application methods can accelerate the decline in soil quality and fertility (Soekamto & Fahrizal, 2019). To solve this problem, an alternative solution is to apply biological fertilisers (Prabowo *et al*., 2018).

Biofertilisers contain microorganisms that can increase fertiliser efficiency and soil fertility. One of the microorganisms that play a role in biofertilisers is endophytic bacteria (Nugraheni *et al*., 2022). Endophytic bacteria benefit plants by producing siderophores, indole acetic acid (IAA), abscisic acid, and others (Tian *et al*., 2015). Endophytic bacteria in agriculture act as a trigger for plant growth. Endophytic bacteria can fix free nitrogen in the air, produce phytohormones, and dissolve phosphate. As a biological agent, endophytic bacteria can induce the inhibition of pathogenic microbes in plants (Firdous *et al*., 2019). The mechanism of endophytic bacteria can directly produce secondary metabolite compounds such as siderophores, salicylic acid, Hydrogen Cyanide (HCN), and ethylene (Mardhiana *et al*., 2017). Indirectly, the mechanism of endophytic bacteria functions as a biocontrol agent capable of producing enzymes such as protease, chitinase, and compounds such as antinotes and cyanide (Zhao *et al*., 2016).

Biocon-NP is a biofertiliser that contains endophytic bacteria. Biocon-NP bacteria include *Azotobacter* sp., *Azospirillum* sp., and *Pseudomonas* sp. *Azotobacter* bacteria reduce the growth and development of green plants by producing hormones, increasing the availability and absorption of nutrients through nitrogen synthesis and phosphorus solubility (El *et al*., 2020). *Azospirillum bacteria* provide N and P nutrients to plants by fixing free nitrogen from the air, but do not form a symbiosis with plants (Widawati, 2015). Based on research by Ni'mah and Yuliani (2022), the provision of *Azospirillum* bacteria and corn cob biochar can increase the availability of nitrogen (N) and reduce the effects of salinity stress on plants. *Pseudomonas* bacteria play a role in helping vegetative growth in plants, protecting plants from pathogens, and producing enzymes that play a role in mineralising P-organic into P-inorganic, which can be absorbed by plants (Miftahurrohmat and Sutarman, 2020).

Another microorganism utilised in biological agents is the fungus *T. harzianum*. *Trichoderma harzianum* can destroy other microorganisms through the mechanism of antibiosis, which is an antagonistic interaction between pathogens and fungi. This antagonistic fungus produces antibiotic compounds that can inhibit the growth of microorganisms, thus acting as antimicrobials (Muhibuddin *et al*., 2021). The mechanisms used by *Trichoderma* sp. to inhibit the growth of pathogenic fungi include parasitism, lysis, competition, and antibiotics. This antagonistic mechanism is carried out through the production of toxins, which include the enzymes β-1,3-glucanase, chitinase, and cellulase. These enzymes can disrupt the outer structure of pathogenic cells, inhibit growth, and even cause pathological damage to these microorganisms (Dwiastuti *et al*., 2017).

Based on this, this study aims to determine the growth response of cayenne pepper plants after given combined application of Biocon-NP and *T. harzianum* biofertilisers on organic conversion land during the rainy season. Observations were made on the application of this biofertiliser as a biological agent, focusing on various growth parameters of cayenne pepper plants.

MATERIALS AND METHODS

This research was an experimental research conducted from February to May 2024 at the Balai Besar Pelatihan Pertanian Ketindan Lawang, Malang, East Java Province. This research was conducted using a Randomized Group Design (RGD) consisting of two factors with three treatments and six replicates: (1) 50% compost (13.8 kg), (2) 25% compost (8.1 kg) and Biocon-NP (17 g), (3) 25% compost (8.1 kg) and Biocon-NP (8.5 g), and *T. harzianum* (100 ml/7 L of water). Parameters observed consisted of plant height (cm), number of leaves (leaf), leaf width (cm), leaf color (leaf), number of flowers (flower), and number of fruits (fruit).

Biofertiliser treatments were given on seeds and soil. In the seed treatment, cayenne pepper seeds were soaked with 12 L warm water mixed with 75 g of biofertiliser and two chicken eggs. The aim was to select the best seeds that have been soaked for approximately 1 hour.

After that, land preparation was carried out, which included land clearing, soil loosening, making treatment beds with a size of 40 x 50 cm, providing essential fertiliser in the form of 140 kg of goat manure, watering the beds, making mulch and planting holes for a total of 154 plants. The soaked seeds were transferred into seeding trays containing humus soil, with one seed per tray hole. The seeds were watered every day and observed for growth. Before manure application, 125 grams of biofertiliser and two eggs were mixed in 10 litres of water in each Biocon treatment and allowed to stand for 24 hours before being applied as base fertiliser. Environmental conditions were measured before and after treatment. Chilli seeds that were 7 days old then transplanted into the soil that had been given the Biocon-NP treatment at the beginning. Watering was done daily, and organic pesticides such as liquid smoke and clove oil were applied.

The post-planting biological fertiliser treatment was carried out in each phase: the vegetative phase at 14 days after planting (DAP); the first generative phase at 35 DAP; and the second at 92 DAP. Before being given biological fertiliser treatment of Biocon-NP and *T. harzianum*, Biocon-NP was incubated for 24 hours on the day before treatment and NPK fertiliser 16:16:16 synthetic fertiliser was applied to all treatment beds. The dosage of Biocon-NP and *Trichoderma harzianum* was 8.5 g of Biocon-NP mixed with 25% compost, resulting in 8.1 kg for 54 plants. At the same time, *Trichoderma* was given 100 ml/7 L of water for 54 plants, which was done by the droplet method. Fertilisation was done every morning. Crop maintenance includes the application of clove oil to reduce the presence of pests on plants. The use of clove oil can also repel vector pests, such as aphids and ticks due to repellent and antiparasitic properties of eugenol, which disrupts the nervous system of the pests (Lestari *et al*., 2024).

Plant growth was measured in each phase by constantly measuring environmental conditions, including ph, temperature, and humidity. Leaf colour chart (LCC) was used to examine leaf colour. Furthermore, observation data were recorded and analysed after taking measurements. Data analysis was carried out using SPSS 26, the normality test (Kolmogorov-Smirnov), and then the homogeneity test using the One-Way Anova method with a significance level of 0.05. Then, Duncan's post hoc test was conducted to determine the statictical difference at significance level of 5%.

RESULTS

Environmental conditions are one of the important factors in supporting the process of plant growth and development. Environmental factors that affect plant growth and development include sunlight, temperature, water supply, air composition in the soil, soil ph, nutrient supply, and biotic factors that significantly affect plant development (Tenda *et al.*, 2022). In this study, environmental factors that influence the growth process of cayenne pepper are ph, temperature, and humidity, which are presented in Table 1 as follows.

Table 1. Recorded environmental condition during treatments

Parameters	7 DAP	14 DAP	35 DAP	91 DAP
pH	5	5	5	7
Temperature (^{o}C)	30	29	33	30
Soil Moisture (%)	67	66	66	64

Based on Table 1, the temperature and pH of the environmental conditions data show that in the 4 months of the research period, the pH ranged from 5 to 7. However, several factors need to be considered to achieve optimal growth. Soil ph, which ranges from 5 to 7, was still within the tolerance limits of plants. Based on measurements of environmental conditions in the study area, the ambient temperature ranged from 29°C to 33°C. Although the highest temperature reached 33°C, the San Marino chilli var. Has adapted well to extreme environmental conditions. This temperature is still within the tolerance limit of chilli plants. Lower or higher temperatures between 25°C and 32°C are considered ideal for optimal growth of chilli plants (Salim, 2024).

Table 2. Treatment of cayenne pepper on 91 days after planting (DAP)

Treatment	Recorded parameters at 91 DAP					
	Plant Height (cm)	**Number of Leaves**	**Leaf Width**	**Leaf Color**	**Number of Flowers**	**Number of Fruits**
Control	59,08±4,96	142,167±50,04	4,54±0,64^a	3,83±0,40	1,33±1,03	1,33± 0,81^a
Biocon-NP	49,65±8,81	137,66±53,11	5,50±0,49^b	3,50±0,54	1,50±1,37	1,16±0,98^a
Biocon-NP and *T. harzianum*	58,05±10,19	167,16±45,41	6,28± 0,75^c	3,66±0,51	1,83±1,60	4,00±2,00^b

Notes: Numbers followed by the same letter in the row are not significantly different at the 0.05 Duncan test.

Table 2 presents the interaction of cayenne pepper plant height with Biocon-NP and Trichoderma harzianum treatment. Table 2 shows that the treatment of Biocon-NP and *T. harzianum* did not significantly affect plant height. The observation showed that the control treatment produced taller chilli plants than Biocon-NP and the combination of Biocon-NP with *T. harzianum* at 14, 35, and 91 DAP. At 91 DAP, the highest height was found in the control treatment (59.08 cm) and the lowest in Biocon-NP (49.65 cm).

The analysis results show that treating Biocon-NP and *Trichoderma harzianum* did not significantly affect the number of leaves (Table 2). Based on observations on the number of leaves of chilli plants, at 14 DAP, the control treatment and the combination of Biocon-NP with Trichoderma harzianum produced the highest number of leaves, namely 10 leaves. In contrast, the Biocon-NP treatment produced nine strands. At 91 DAP, combining Biocon-NP and *Trichoderma harzianum* produced the highest number of leaves, with 167 leaves, while the Biocon-NP treatment produced 138 leaves.

Data on leaf width shows that the combination of biological fertilisers had a significant effect on the width of the leaves at the age of 91 DAP (Table 2). The observation of leaf width of chilli plants at the ages of 14, 35, and 91 HST showed that the combination treatment of Biocon-NP and *T. harzianum* showed a leaf width that tended to be greater than the Biocon-NP and control treatments. Duncan's test supported that the combination treatment of Biocon-NP and *T. harzianum* was significantly different at 91 HST. The use of a combination of biological fertilisers began to show a significant effect on the development of leaf width at 91 HST. Although there was no significant effect at the early growth stage (14 and 35 HST), the observation results showed that the effect of the fertiliser combination treatment was only visible at the advanced growth stage. The statistical tests conducted reinforced this conclusion, providing scientific evidence of the effect of different treatments at different growth stages.

Based on the results of the mean difference test in the vegetative to generative period with the treatment of a combination of Biocon-NP and *Trichoderma harzianum* biofertiliser, measurements were made using a leaf colour chart to see the colour differences in each leaf colour chart (LCC). The LCC displays shades of green ranging from light green (scale 1) to dark green (scale 5), which represent different levels of nitrogen content in the leaf. The colour differences can be seen in Figure 1 while for the measurement results of the treatment of a combination of Biocon-NP biological fertiliser and *T. harzianum* is presented in Table 2.

Figure 1. Leaf colour chart (LCC) (Kulkarni dan Das, 2023)

Table 2 shows that the treatment of Biocon-NP and *T. harzianum* did not have a significant effect on leaf colour. Based on the observation of the leaf colour of chilli plants, these values correspond to the colour gradation on the Leaf Colour Chart (Figure 1), where scale 2 indicates light green, scale 3 indicates medium green, scale 4 indicates slightly dark green and scale 5 indicates dark green. The higher the LCC value, the darker the leaf colour, which generally indicates better nitrogen availability. At 91 DAP, the control treatment and the combination of Biocon-NP and *T. harzianum* had the highest average value of leaf colour at 4, but statistical analysis showed no significant effect.

The analysis results show that treating Biocon-NP and *T. harzianum* did not significantly affect the number of leaves (Table 2). Statistical analysis indicated that there was no significant effect of the three treatments. However, at 91 DAP, the Biocon-NP and *Trichoderma harzianum* treatments produced the highest number of flowers, averaging 2 per plant. In contrast, the control and Biocon-NP treatments each produced one flower. These results indicate that although there is a tendency to increase the number of flowers in specific treatments, their effect on the growth of chilli plant flowers cannot be considered significant.

Based on data on the number of fruits per plant sample in the second generative period, the treatment of Biocon-NP and Trichoderma harzianum biofertiliser combination showed a significant effect, which can be seen in Table 2. The analysis of the number of chilli plant fruits shows that the control treatment and Biocon-NP each have an average of 1 fruit. At the same time, the combination of Biocon-NP with *Trichoderma harzianum* produces a higher average of 3 fruits (Table 2). Based on this, it indicates that the Biocon-NP and *Trichoderma harzianum* treatments significantly increased the number of fruits of chilli plants, which is in line with the theory that fertilisation with microbes and organic nutrients can increase agricultural yields through improved plant health and increased physiological processes (Sarijaya and Agustiyani, 2021).

DISCUSSION

Based on the observations made, it shows that the cultivation of cayenne pepper plants treated with Biocon-NP biofertilisation and *Trichoderma harzianum*, each treatment shows different results on the research parameters, namely plant height (cm), number of leaves (strands), leaf width (cm), leaf colour, number of fruits, and number of flowers. The growth response of chilli plants on the leaf width parameter can be seen in Table 2, which shows the average leaf width of all treatments. Table 2 shows that the width of the leaves of chilli plants at the age of 91 DAP was significantly different. According to Chairunnisak (2023), nitrogen increases plant growth, chlorophyll, and protein content. High chlorophyll levels affect leaf width, especially in photosynthesis, where leaves that have more chlorophyll can more effectively capture sunlight and produce more ATP for growth and cell division (Rizal and Barokah, 2024).

This increase can be explained by the focus on vegetative development in the early phase of chilli plant growth and the optimal activity of microorganisms that support early growth. Microorganisms in biofertilisers actively colonise the rhizosphere or root zone during the early vegetative growth phase, promoting root growth and absorbing nutrients that affect the growth of the upper part of the plant (Wardiman *et al*., 2024). Chilli plants show a faster response to nutrient uptake in the resource acquisition phase needed to build the basic structure of the plant. Trichoderma acts as an important component in increasing iron uptake and the production of the hormone auxin, which has various physiological effects on plants, including cell enlargement, abscission, inhibition of lateral buds, root growth, and cambium activity (Debitama *et al*., 2022).

Biocon-NP and *Trichoderma harzianum* treatments recorded the highest average number of leaves at the age of 91 DAP. The availability of nutrients and environmental conditions greatly affects the number of plant leaves. An optimal environment can support plant growth and increase leaf production. Adequate nutrient availability facilitates plant metabolism and increases leaf production. Nitrogen elements contained in *Trichoderma* sp. and *Azotobacter* sp. play a role in binding nitrogen from the atmosphere. Sugianti (2024) revealed that the nitrogen element in liquid organic fertiliser from lamtoro leaves can stimulate the growth of photosynthetic organs, including leaves. Nitrogen availability plays a role in accelerating growth and increasing plant yields, as well as encouraging vegetative growth, such as leaves, stems, and roots, that are important for overall plant development.

The application of Biocon-NP and *Trichoderma harzianum* showed varying effects on the leaf colour of chilli plants at different growth stages. The combination significantly improved leaf colour compared to the control, possibly due to the biostimulant properties of *Trichoderma* that enhance nutrient uptake and stress tolerance, resulting in better leaf quality (Guinan *et al*., 2021). This is due to the colonisation of microorganisms in biofertilisers in the root zone, which increases the absorption of nutrients, especially nitrogen (N) for protein synthesis. According to Bima (2024), increased nitrogen absorption at the beginning of growth makes the colour of the leaves greener. These microorganisms also stimulate the production of hormones such as auxins and cytokinins that play a role in leaf growth and increase chlorophyll content (Sugianti *et al*., 2024).

The higher average leaf colour at 35 HST and 91 HST was due to the adequate supply of nutrients from the control treatment and the optimal work of microorganisms in biofertilisers, thus increasing the absorption of nutrients by plants. *Trichoderma* sp. is known to produce growth regulators (ZPT) and protect organic matter in the soil that contains important nutrients, such as N, P, S, and Mg, which are needed for plant growth (Zani and Anhar, 2021). Biofertilisers play a role in increasing yield and plant growth. In addition, combining biofertilisers with a 50% reduction in NPK fertiliser dosage resulted in higher fruit yields, as well as higher wet and dry fruit weights, compared to using 100% NPK fertiliser (Trovicana *et al*., 2024). This fungus plays a role in breaking down complex nitrogen compounds so that plants can absorb them. This is because at 91 HST, chilli plants have reached the stage of hormone regulation and physiological processes needed for fruit formation. Microorganisms in biofertilisers create nutrient availability and optimal environmental conditions around the roots so that nutrient absorption can occur properly. Optimal nutrient absorption can stimulate the production of growth hormones such as auxins, cytokinins, and gibberellins, which are important in regulating flower formation (Mokoginta *et al*., 2022).

The results of the growth analysis of cayenne pepper (*Capsicum frutescens* L.) var. San Marino showed a significant effect of Biocon-NP fertiliser and *Trichoderma harzianum* on the number of flowers. Table 2 shows that the average number of flowers is highest in the treatment of Biocon-NP and *Trichoderma harzianum*. The test results show that the number of fruits in these treatments is significantly different compared to the control and Biocon-NP treatments, which is due to the number of leaves on the plant. According to Huda & Machfudz (2019), fruit wet weight is influenced by the content of carbohydrates and water formed during photosynthesis, which depends on the number of leaves and light intensity. Rosalina *et al*. (2020) added that increasing photosynthetic yields can increase food reserves for fruit weight. In addition, Sole *et al*. (2022) emphasised the importance of phosphorus

(P) and potassium (K) nutrients in generative growth and fruit formation, while growth hormones such as gibberellin and ethylene play a role in flower development and fruit ripening.

From all the research parameters, it can be observed that the application of Biocon-NP and *Trichoderma harzianum* significantly affects the growth of cayenne pepper plants from the vegetative phase to the generative phase - various nutrients affect plant growth in it. One of them is the role of nitrogen and phosphate in plants that can affect the process of leaf formation (Simatupang *et al*., 2016). If nitrogen nutrient needs are met, plants can produce protoplasm in greater quantities, so as to increase the fresh weight of plants and the net weight of plant products that can be consumed (Muliandini, 2022).

CONCLUSION

Based on the research done, it can be concluded that the application of a biological fertiliser combination of Biocon-NP and *T. harzianum* had a significant effect on the growth of cayenne pepper (*Capsicum frutescens* L.) var. San Marino on the parameters of leaf width (6.28 cm) and number of fruits (3.00 fruits) at 91 Days After Planting.

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CONFLICT OF INTEREST

There is no conflict of interest.

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