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Efficacy of Biofungicide with Active Ingredients *Trichoderma* sp. Against Late Blight Disease (*Phytophthora infestans*) in Potato Plants

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Abstract. The cultivation of potatoes in Indonesia faces challenges, particularly a decline in production attributed to the devastating impact of late blight caused by the fungus *P. infestans*. Traditional control methods involve the frequent use of chemical pesticides, which pose environmental and health risks. To address this, the research aimed to assess the efficacy of biofungicide containing *Trichoderma* sp. as a biological agent in controlling late blight on potatoes. The study, conducted in Sumberbrantas Village, Bumiaji District, Batu City, East Java, and the plant disease laboratory at Brawijaya University from January to April 2023, employed both in vivo and in vitro experiments. A Randomized Block Design (RBD) was used for in vivo research, while a Completely Randomized Design (CRD) was employed for in vitro studies, each comprising five concentration treatments with five repetitions. Parameters such as disease intensity, efficacy level, potato production, and biofungicide inhibition were observed. Analysis of variance and the Tukey Honestly Significant Difference (HSD) test were applied to the data and processed using Microsoft Excel. The results indicated that biofungicide with *Trichoderma* sp. concentrations of 6 ml/l, 4.5 ml/l, 3 ml/l, and 1.5 ml/l effectively reduced the intensity of late blight on potatoes, with efficacy levels exceeding 50%. The highest potato production occurred with a concentration of 6 ml/l, yielding 15.44 tons/ha, followed by 14.67 tons/ha for the 4.5 ml/l concentration. The biofungicide with a concentration of 6 ml/l exhibited the lowest disease intensity at 14.28% and the highest efficacy at 83.08%. Inhibition tests demonstrated that concentrations of 6 ml/l and 4.5 ml were highly effective, inhibiting *P. infestans* growth by an average of 62.04% and 59.90%, respectively. These findings highlight the potential of biofungicide with *Trichoderma* sp. in managing late blight on potatoes, providing a sustainable and environmentally friendly alternative to chemical pesticides.

Keywords: biofungicide; *Phytophthora infestans*; potato; *Trichoderma* sp.

INTRODUCTION

Plant Pest Organisms (OPT) such as leaf blight (*Phytophthora infestans*) are a major challenge in efforts to increase potato yields. This disease becomes a critical pathogen that can result in a decrease in potato production, especially in the rainy season. This disease is one of the main constraints during potato production because it can decrease potato yields by up to 45% in the Granola variety (Kusmana, 2003; Ambarwati, 2019) and reportedly can cause yield losses of up to 75% (Adiyoga, 2009).

Phytophthora infestans can attack various parts of potato plants, including leaves, stems, and tubers. The initial symptom is grayish-black spots on the leaves, which can expand rapidly and lead to death in severe infestations (Sastrahidayat, 1992). Environments with low temperatures and high humidity favor disease progression, accelerate the spread of *P. infestans* (Susetyo, 2023) and harm crop yields. To prevent the development of this pathogen, farmers generally control using chemical fungicides. One of those is the fungicide active ingredient Mancozeb 64% + Simoxanil 8% WP.

Although the use of fungicides provides quick and effective results, conventional farming of potatoes which relies on the use of chemicals in the long term can have negative impacts such as disease outbreaks, decreased land carrying capacity, decreased soil organic matter, impacts on the environment and non-target organisms (Wightwick *et al*., 2010). In addition, the excessive use of fungicides causes pathogen resistance to certain active ingredients, thereby increasing the use of recommended doses (Purwantisari *et al*., 2008).

Therefore, an innovative study of eco-friendly control of late blight disease needs to be carried out. Such as replacing chemical fungicides with the use of biological agents or biofungicides which have many advantages for the environment. Especially in

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the production center areas of potatoes in Batu City. *Trichoderma* sp. has been studied as an antagonistic agent which has been proven to control diseases in various types of cultivated plants.

Trichoderma sp. is able to produce cellulase enzymes, which are reported to damage the walls of pathogenic molds in the Pythiaceae group, such as *P. infestans* (Salma & Gunarto, 1999; Purwantisari *et al*., 2008). *Trichoderma* fungi have various modes of action in controlling pathogens there are competition, antibiosis, mycoparasites, and producing secondary metabolites that stimulate plant defense (Harman, 2006).

This study aims to assess the effectiveness of the concentration of biofungicide made from active ingredients *Trichoderma* sp. on controlling potato late blight. The results of the study are expected to give recommendations for late blight disease management as well as it will be able to support sustainable agriculture for potato commodities in Batu City.

METHODS

Isolation of *Phytophthora infestans*

Isolation of the fungus *Phytophthora infestans* was carried out by cutting the leaves of potato plants that showed symptoms of late blight obtained from the land of Sumberbrantas Area, Bumiaji District, Batu City. Then the leaf pieces are sterilized with 70% alcohol/ ethanol with the chemical formula C_2H_5OH for 1 minute. The cut leaves are then rinsed with sterile aquades for 1 minute and repeated twice. After that, the pieces of leaves are dried on sterile wipes. Dried leaves can be planted on PDA and incubated (Purwantisari *et al*., 2016).

Biofungicide Assay

In biofungicide testing using *Trichoderma* sp., a biofungicide solution is taken and the concentration is adjusted using a micropipette, then mixed with sterile aquades in a beaker. Filter paper is soaked in the solution for 2 minutes, taken and dried. The prepared filter paper is planted on PDA media in a petri dish. Inhibition tests against the growth of *Phytophthora infestans* were carried out through the direct opposition method. *P. infestans* fungi and filter paper that have been soaked in the biofungicide *Trichoderma* sp. inoculated in a 9 cm diameter petri dish containing PDA media, placed opposite at a distance of 3 cm. This inhibitory power test uses a Complete Randomized Design (CRD) with 5 treatments and repeated 5 times. This inhibitory power test scheme is designed to evaluate the effectiveness of the biofungicide *Trichoderma* sp. against the growth of *Phytophthora infestans*.

In vivo testing, and application of biofungicide using knapsack sprayer was carried out once a week for six weeks, starting at plant age 70 days after planting (DAP), and the maximum limit of spraying was two weeks before harvest. The experimental design used was a Randomized Block Design (RBD) with 5 treatments and 5 repeats, covering a total of 25 treatment plots. Each treatment plot measures 1 m x 5 m, with a potato planting distance of 30 cm x 30 cm and one row of potato plants as a barrier between treatments. The number of sample plants in each treatment plot is 10 systematically determined plants, which are treated with the type and dose of fertilizer following local farmers during planting (organic manure ±20-30 tons/ha of organic manure, Urea ±250-300 kg/ha, KCl 200-250 kg/ha, and SP-36 450-550 kg/ha). The treatment involved four concentrations of biofungicide *Trichoderma* sp. (P1: 1.5 ml/l, P2: 3 ml/l, P3: 4.5 ml/l, P4: 6 ml/l) and one control without biofungicide. Based on Table 1, the biofungicide concentration of 6 ml/l (P4) is the recommended concentration from PT. Kayaku Petrochemicals. The observed modifiers were the intensity of disease attacks, the level of efficacy and potato production.

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Table 1. Biofungicide concentration treatment with active ingredients *Trichoderma sp.*

Code	Treatment
P1	Concentration : 1.5 ml/l
P2	Concentration: 3 ml/l
P3	Concentration: 4.5 ml/l
P4	Concentration: 6 ml/l*
P5	Control (without biofungicides)

*Concentration recommendations

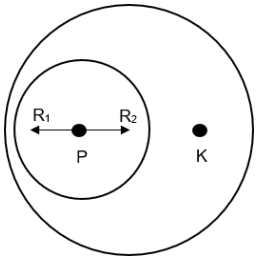

Figure 1. Biofunctional inhibitory power test scheme with active ingredients *Trichoderma* sp. against pathogenic fungus *P. infestans*

Remarks:
P = Pathogenic fungus *P. infestans*
K = Filter paper containing biofungicides made from the active fungus *Trichoderma* sp.
R1 = Radius of *P. infestans* colonies whose growth away from antagonistic fungi
R2 = Colony radius of *P. infestans* fungus whose growth direction is close to antagonistic fungus

Table 2. Biofungicide concentration treatment with active ingredients *Trichoderma* sp.

Treatment	Treatment Code	Concentration (ml/l)
Biofungicide	P1	1.5
Biofungicide	P2	3
Biofungicide	P3	4.5
Biofungicide	P4	6
Control	P5	0

Observations were made on sample plants in each treatment plot. Observations were carried out once a week by calculating the intensity of damage to the leaves of potato plants caused by blight attacks. According to Ambarwati *et al*. (2016) the assessment of the degree of plant damage due to late blight is calculated using the formula 1.

$$I = \frac{\Sigma\ (n\ x\ v)}{N\ x\ Z}\ x\ 100\%\ \ldots.\ 1)$$

Remarks:
I = Crop damage rate (%)
n = Number of plant leaves in each attack category
v = Scale value for each attack category
N = Number of leaves observed
Z = Scale value of the highest attack category
Attack scale value:
0 = No damage
1 = Percentage of damage to leaves between 0-10%
2 = The percentage of damage to the leaves is between 10-20%
3 = Percentage of damage to leaves between 20-30%
4 = Percentage of damage to leaves ±50%
5 = The percentage of damage to the leaves is between 50-75%
6 = Percentage of damage to leaves >75%

The efficacy criteria of a biofungicide formulation can be said to be effective if at the last observation the efficacy rate (TE)

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value is at least 50%, provided that the intensity of the treatment attack differs markedly from the control. Based on the Direktorat Jendral Prasarana dan Sarana Pertanian (2013) the efficacy rate can be calculated using the formula 2.

$$TE = \frac{(ISK-ISP)}{ISP}\ x\ 100\% \ldots. 2)$$

Remarks:
TE = Efficacy level
ISK = Intensity of disease attack on control (without biofungicides)
ISP = Intensity of disease attack on treatment (biofungicide application)

The production of potato crops is known through the yield of potato tubers. The implementation of potato harvesting is carried out at 120 DAP. Potato harvesting is carried out by taking sample crop potato tubers per treatment plot. The harvest is then weighed using digital scales.

Data Analysis

The data obtained from the observations were analyzed statistically using Analysis of Variance. If the results of the analysis differ markedly, then proceed with the Tukey Honestly Significant Difference (HSD) at the level of 5%. All data is processed using Microsoft Excel application.

RESULTS AND DISCUSSION

Inhibitory Test of *Trichoderma* sp. as Biofungicide Against Pathogenic Fungus *P. infestans*

The inhibitory power test was carried out to determine the ability of biofungicide made from the active ingredient *Trichoderma* sp. in inhibiting the growth of pathogenic fungi *P. infestans* in vitro. In addition, the inhibitory power test can also be known as the concentration treatment of biofungicides that are best in inhibiting *P. infestans* in vitro. Observation of the inhibitory power test is carried out every day, with a total of seven observation days. The average percentage of biofungicide inhibitory power against *P. infestans* fungi is presented in Table 3.

Table 3. Average percentage of inhibition of biofungicide with active ingredients *Trichoderma* sp. against *P. infestans* pathogens

Treatment	Average Drag (%)						
	1 DAI	2 DAI	3 DAI	4 DAI	5 DAI	6 DAI	7 DAI
Biofungicide 1.5 ml/l (P1)	3,93^{b}	10.23^{bc}	13.22^{b}	16.23^{b}	24.45^{b}	24.92^{b}	25.97^{b}
Biofungicide 3 ml/l (P2)	4,17^{b}	8.52^{b}	16.08^{b}	25.26^{c}	31.77^{c}	36.57^{c}	36.84^{c}
Biofungicide 4.5 ml/l (P3)	5,46^{c}	12.35^{cd}	21.54^{c}	37.33^{d}	48.14^{d}	56.08^{d}	59.90^{d}
Biofungicide 6 ml/l (P4)	4.78^{bc}	13.03^{d}	29.39^{d}	38.69^{d}	51.28^{d}	58.07^{d}	62.04^{d}
Control (P5)	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}

Remarks: Numbers accompanied by the same letter in the same column are declared not significantly different based on the 5% HSD test

On preliminary observations, Table 3 reflected that the average inhibitory power on the first day was still below 10% for all treatments, due to the limitation of inhibition of *Trichoderma* sp. rom biofungicides against *P. infestans* fungi. However, observations on the second day showed a significant improvement in biofungicide treatment with concentrations of 1.5 ml/l, 4.5 ml/l, and 6 ml/l, where the average inhibitory power reached or exceeded 10%. This phenomenon is accompanied by an increase in antagonistic activity of *Trichoderma* sp., seen from the growth of dominant colonies and the ability

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to inhibit the growth of *P. infestans*. The best results were recorded at a concentration of 6 ml/l, reaching a peak inhibitory value of 62.04% on day 7. Lontsi *et al*. (2020) said that the lower concentration of biofungicide makes the lower inhibitory power of *Trichoderma* sp., indicating the importance of concentration in determining the effectiveness of biofungicide against the pathogens. According to Otten *et al*. (2004) in Ali and Samosir (2021), fungi that have an inhibitory power of up to 50% are potentially effective as a biological agents for controlling pathogenic fungi in the field.

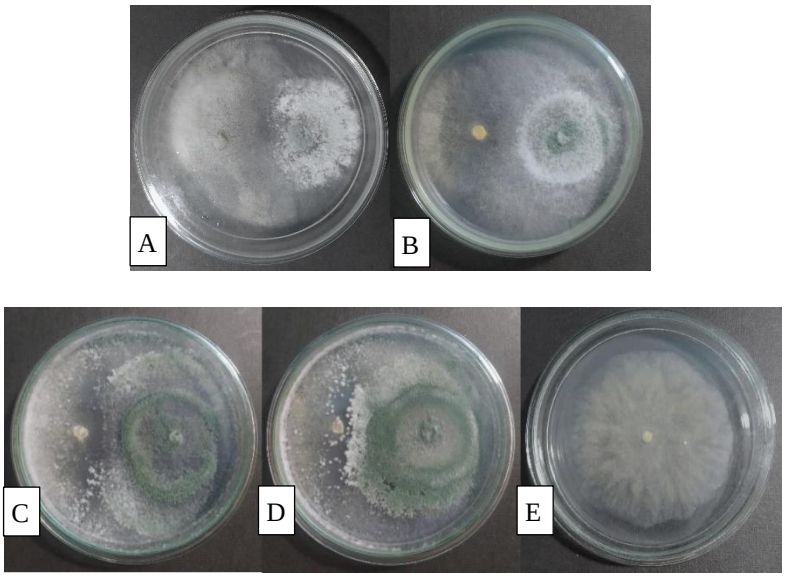

Figure 2. *Trichoderma* sp. activity as biofungicide against *P. infestans*. (A) biofungicide treatment 1.5 ml/l, (B) biofungicide treatment 3 ml/l, (C) biofungicide treatment 4.5 ml/l, (D) biofungicide treatment 6 ml/l, (E) control treatment

In the context of visualization through Figure 2, biofungicide treatment with a concentration of 1.5 ml/l showed low inhibitory power, while concentrations of 4.5 ml/l and 6 ml/l highlighted the ability of *Trichoderma* sp. to dominate and inhibit the growth of *P. infestans*. The growth speed of *Trichoderma* sp. is key, with a concentration of 6 ml/l showing rapid growth and optimal inhibition. These results provide insight that biofungicide concentrations have a significant effect on the antagonism activity of *Trichoderma* sp. against *P. infestans*, with the implication that selection of appropriate concentrations is a key factor in maximizing the effectiveness of biofungicides as biological control against plant pathogens (Kumar *et al*., 2020).

High growth speed causes *Trichoderma* sp. to be able to compete with pathogens in space control and food acquisition, so as to inhibit the growth of pathogenic fungi (Kaunang *et al*., 2018). In addition to growing speed, the fungus *Trichoderma* sp. also has an antagonistic mechanism that plays a role in inhibiting the growth of pathogenic fungi. The antagonistic mechanisms of *Trichoderma* sp. these are competition, parasitism, lysis, and antibiosis (Pandawani *et al*., 2020). The competition mechanism of *Trichoderma* sp. is characterized by the rapid growth of antagonistic fungi so that they are able to master the growing space and obtain more nutrients, which causes pathogenic fungi to be stunted in growth due to being unable to compete with antagonistic fungi. Mycoparasitism, namely *Trichoderma* sp. hyphae entangle pathogenic hyphae, degrade the cell wall of pathogenic fungi with the help of chitinase and glucanase enzymes, then penetrate into the cell wall and take the contents of pathogenic fungal hyphae as a food source (Cikita *et al*., 2016). The antibiotic mechanism of *Trichoderma* sp. is

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characterized by the formation of a clear zone between the colony of *Trichoderma* sp. fungi and pathogenic fungi (Gusnawaty *et al*., 2014) which can be interpreted as inhibiting pathogen by the metabolite compounds that are produced (Pandawani *et al*., 2020). The clear zone that is not clearly visible between *Trichoderma* sp. and pathogenic fungi can be caused by fast-growing antagonistic fungi so that the surface of the culture medium is quickly covered by colonies of *Trichoderma* sp. fungi (Molebila *et al*., 2020).

Based on the result of previous research (Purwantisari *et al*., 2016) regarding to the inhibition of the *P. infestans* growth by several *Trichoderma* species, the inhibitory power ranged from 28.1 to 68.6% at 8 days after inoculation (DAI) and was proven to have mechanisms of competition for space and nutrients, antibiosis and also a combination of both. In addition, these antagonistic fungi also produce volatile and non-volatile antibiotic compounds that can inhibit the functional system of pathogen cells.

Disease Intensity of *P. infestans*

The intensity of pathogen attack indicates the percentage of plant tissue affected by the pathogen, out of the total area observed. The purpose of measuring the intensity of pathogen attack is to determine the severity of the disease in plants (Brugman *et al*., 2017). The attack of the pathogen *P. infestans* that causes late blight on potato plants was observed and the intensity of the attack was calculated every week until harvest time. In total there were 6 observations of the intensity of late blight disease carried out in the field. The results of observations in the form of the average intensity of *P. infestans* attacks on potato plants are presented in Table 4.

Table 4. Average intensity of *P. infestans* attacks on potato plants

Treatment	Average Intensity of *P. infestans* Attacks (%)					
	69 DAP	76 DAP	83 DAP	90 DAP	97 DAP	104 DAP
Biofungiside 1.5 ml/l (P1)	1.71^{c}	7.93^{c}	12.14^{b}	16.29^{d}	22.37^{b}	28.71^{c}
Biofungiside 3 ml/l (P2)	1.33^{bc}	5.92^{b}	11.40^{b}	13.36^{c}	21.25^{b}	27.91^{c}
Biofungiside 4.5 ml/l (P3)	0.88^{ab}	5.36^{ab}	5.42^{a}	9.16^{b}	10.60^{a}	16.09^{b}
Biofungiside 6 ml/l (P4)	0.65^{a}	4.89^{a}	5.01^{a}	5.38^{a}	8.84^{a}	14.28^{a}
Control (P5)	3.94^{d}	16.34^{d}	23.35^{c}	39.11^{e}	59.14^{c}	84.41^{d}

Remarks: Numbers accompanied by the same letter in the same column are declared not significantly different based on the 5% HSD test

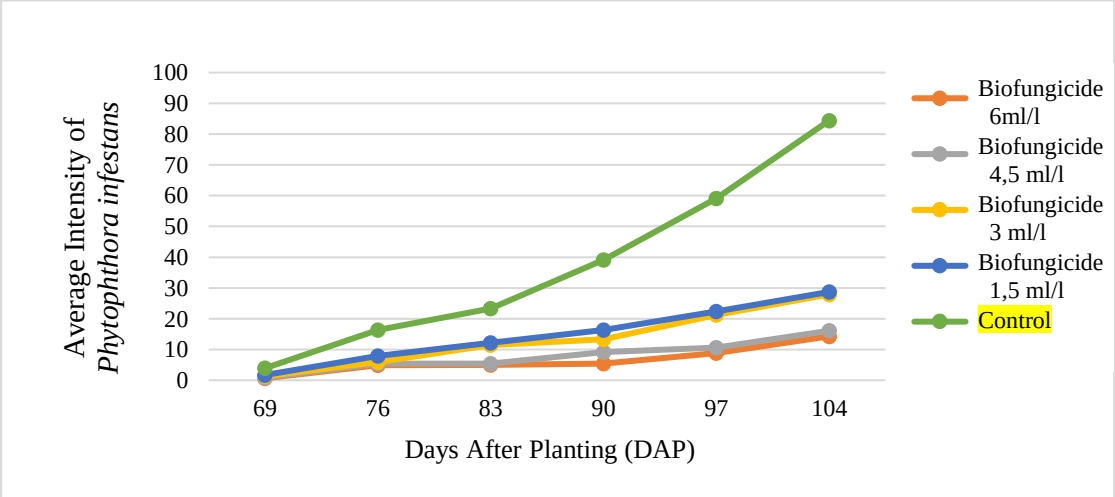

Figure 3. Rate of disease progression

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Based on the analysis of Table 4, there is an increase in *P. infestans* attacks every week. Biofungicides with a concentration of 6 ml/l stood out with the lowest average attack intensity throughout the observations, while controls showed the highest average attack intensity. The 5% HSD test showed that all biofungicide concentrations had a significant effect on the intensity of *P. infestans* attack on control. Biofungicide with the active ingredient *Trichoderma* sp. at all concentrations gave a lower average attack intensity than controls, showing an inhibitory effect on pathogen attack on potato plants. This is related with research that conducted by (Purwantisari *et al*., 2015), the damage caused on control plants due to the pathogen *P. infestans* was more severe than to plants treated with the antagonistic fungus *Trichoderma* sp. with a spore density of 3.7 x 10^8 conidia/ml.

The importance of biofungicide application in suppressing *P. infestans* attacks is reinforced by *Trichoderma* sp.'s ability to colonize dead tissue and play a key role in reducing disease progression. The results showed that treatment with a concentration of 6 ml/l of biofungicide achieved the lowest average attack intensity, while treatment with a concentration of 1.5 ml/l reached the highest average. This indicates that the concentration of biofungicides may affect the effectiveness of *Trichoderma* sp. in suppressing the growth of *P. infestans*, with high concentrations giving better results.

Further analysis showed that biofungicide treatment with a concentration of 6 ml/l, identified as a recommendation, effectively suppressed late blight disease infestation. Although treatments with lower concentrations (1.5 ml/l, 3 ml/l, and 4.5 ml/l) were also effective, concentrations of 6 ml/l gave the best results in reducing the average intensity of attacks. The decrease in disease attacks can be attributed to good population growth of *Trichoderma* sp. after biofungicide application, where optimal adaptation supports the ability of *Trichoderma* sp. in inhibiting pathogen growth (Yuen, 2021).

The calculation of the rate of development of the intensity of *P. infestans* attacks on potato plants provides a further picture. Control treatment showed a very high rate of development, while treatment with a biofungicide concentration of 6 ml/l had a low development rate, indicating plant resistance to disease attack. In conclusion, the application of biofungicides with a concentration of 6 ml/l, supported by optimal adaptation and antagonistic activity of *Trichoderma* sp., is effective in suppressing the attack of late blight on potato plants.

Efficacy Rate of Biofungicide Against *P. infestans* Attack Intensity

Efficacy test on biofungicides are carried out to determine the effectiveness of biofungicides used in controlling certain pathogen attacks (Direktorat Jendral Prasarana dan Sarana Pertanian, 2013). The calculation of the efficacy rate of biofungicides is based on the intensity of *P. infestans* attacks on treatment plots using biofungicides which are then compared to control plots (without biofungicide application). The concentration of biofungicide can be said to be effective if it has an efficacy rate value of ≥ 50%. The degree of efficacy of biofungicides against the intensity of *P. infestans* attacks is presented in Table 5.

Table 5. Efficacy rate of biofungicide against *P. infestans* attack intensity

Treatment	Efficacy Rate (%)
Biofungiside 1.5 ml/l (P1)	65.99
Biofungiside 3 ml/l (P2)	66.94
Biofungiside 4.5 ml/l (P3)	80.94
Biofungiside 6 ml/l (P4)	83.08
Control (P5)	-

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Based on the calculation results, it can be seen that the efficacy level of all biofungicide treatments contained in Table 5 is greater than 50%. These results showed that all biofungicide concentration treatments were made from the active ingredient *Trichoderma* sp. tested were effective in suppressing late blight attacks on potato plants. This is supported by Alfia and Haryadi (2022) statement that an efficacy value of ≤ 50% indicates the application of biofungicides made from the active ingredient *Trichoderma* sp. has poor effectiveness, while the efficacy value of ≥ 50% indicates the application of biofungicides made from active ingredients *Trichoderma* sp. has good effectiveness in suppressing the intensity of pathogen attacks.

The highest level of efficacy was found in the biofungicide treatment concentration of 6 ml/l which was 83.08% (Table 5). So it can be said that biofungicide treatment with a concentration of 6 ml/l is the best in inhibiting the development of *P. infestans* pathogen attacks in the field. This is supported by Alfia and Haryadi (2022) statement that the antagonistic ability of *Trichoderma* sp. is getting better with the increasing concentration used, so as to reduce disease attacks on plants. Then added with a statement from Elfina *et al*. (2017) that the higher the concentration of biofungicides, the greater the number of antagonistic fungal populations contained in the biofungicide. The population density of antagonistic fungi is getting higher in biofungicides, causing spores and hyphae produced to be more numerous. This causes an increase in the ability of antagonistic fungi to suppress pathogen attacks so that it can inhibit the development of diseases in plants in the field.

Potato Crop Production

Harvesting of tomato crops is carried out 116 DAP (Days After Planting). There is a treatment of biofungicide with active ingredients *Trichoderma* sp. on potato plants in an effort to control late blight, then related to being able to determine the effect of biofungicide application on potato plant yields. The average potato yield is presented in Table 6.

Table 6. Average potato production

Treatment	Average Potato Production	
	Potato tuber weight (kg)	Potato Weight per Plot (Kg)
Biofungiside 1.5 ml/l (P1)	1,09[b]	60,06[b]
Biofungiside 3 ml/l (P2)	1.14[b]	62.92[b]
Biofungiside 4.5 ml/l (P3)	1.32[c]	72.60[c]
Biofungiside 6 ml/l (P4)	1.45[c]	79.97[c]
Control (P5)	0.91[a]	49.94[a]

Remarks: Numbers accompanied by the same letter in the same column are declared not significantly different based on the 5% HSD test

Based on the data in Table 6, it is known that potato production in P1, P2, P3, and P4 treatments is significantly different from controls. The control treatment had the lowest average production value, namely the average weight of potato tubers of 0.91 kg and the weight of potatoes per plot of 49.94 kg. Low yields in the control treatment can be caused by the high rate of damage to the leaves of potato plants, along with the high intensity of leaf blight attacks in the treatment. This is because the leaves become an important part of the plant to carry out the process of photosynthesis and greatly affect the formation of potato tubers. Leaves become a part of the plant body that has an important influence on the yield and growth of potato plants. The low rate of leaf growth causes the photosynthesis process to be inhibited, so this condition will have an impact on inhibiting the formation of potato tubers (Sa'diyah *et al*., 2017). The average yield will be greatly influenced by the magnitude of the intensity of the attack on the

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crop before harvest. This is because the damage that occurs to plant leaves will affect the function of leaves as a place for photosynthesis (Purwantisari *et al*., 2016). So, the damage to the leaves of potato plants can cause a reduction in potato tube yields.

Meanwhile, the average production with the highest value of potato tuber weight and potato weight per plot was found in biofunction treatment concentrations of 6 ml/l of 1.45 kg and 79.97 kg, then followed by the results of biofungicide treatment concentration of 4.5 ml/l with potato tuber weight of 1.32 kg and potato weight per plot of 72.60 kg. Overall, the biofungicide treatment had a greater weight value than the control. Higher production of potato tubers in biofungicide treatment can be attributed to the intensity of disease attacks which is also low in biofungicide treatment, thus showing more healthy leaves and less blight disease than in controls. The leaves become part of the plant that plays an important role in carrying out the process of photosynthesis, so that a lot of healthy plant leaves will affect the production of potato tubers. The higher the intensity of blight, the lower the number of healthy leaves, causing low potato tuber production. Conversely, the lower the intensity of leaf blight attacks, the more healthy leaves so that potato tuber production is better (Baihaqi *et al*., 2013).

The research results of Wattimury *et al*. (2021) shows that the use of Trichoderma sp. 75 g per plant can increase vegetative growth of tomato plants and fruit yield. Besides the damage plant caused by *P. infestans*, also because this fungus is a decomposer. This accelerates the decomposition of soil organic matter and makes the soil more prolific and stimulates plant growth. In addition, *Trichoderma* sp. applied to plants can also directly trigger plant growth and development because it can produce growth regulators (ZPT). The hormone produced by this fungus is the hormone auxin/IAA (Indole Acetic Acid) which can make root elongation and causes the range of nutrient uptake to expand. Therefore, the use of *Trichoderma* sp. can provide sufficient plant nutrition so that production is higher.

CONCLUSION

The results showed that biofungicide made from *Trichoderma* sp. with concentrations of 6 ml/l, 4.5 ml/l, 3 ml/l, and 1.5 ml/l effectively suppressed the intensity of late blight attacks caused by *P. infestans* on potato plants. This biofungicide treatment also has a positive impact on potato yields. In particular, biofungicide with concentrations of 6 ml/l and 4.5 ml/l stand out with the highest percentage of inhibitory power, able to inhibit the growth of *P. infestans* very well. These results indicate that the application of biofungicide made from the active ingredient *Trichoderma* sp., especially at optimal concentrations, can be an effective strategy in disease control in potato plants. These conclusions make an important contribution to the development of sustainable and environmentally friendly agricultural practices, with the potential to increase the productivity of potato crops through the use of effective biological agents that positively affect crop yields.

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