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# Leaf Litter Decomposition Rate by Utilizing Biological Agents to Improve Plant Growth of Red Chili

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**Abstract**

*Decreased yield and quality of chilies were mainly due to the attack of fruit flies and whiteflies as virus-carrying vectors. Until now, to control these pests, farmers still rely on the use of synthetic chemical pesticides that leave residues. Efforts to control pathogens and improve yield and quality of red chilies use biological agents Trichoderma sp., Mycorrhizal, and organic materials that have been completely decomposed. The objective of this research was to examine the effect of the level of decomposition of leaf litter in combination with the application of different biological control agents and NPK dosage on plant growth. This experiment was conducted at Experiental Garden, Condongcatur Campus, Depok, Sleman, Yogyakarta, from June until September 2020. The experiment was arranged according to Randomized Completely Block Design with two factors; each treatment consists of three replicates. The first factor was half decomposed of leaf litter with C/N ratio of 28.52 and fully decomposed of leaf litter with C/N ratio of 16.57. The second factor was NPK dosage and/or types of biological control agents with the following five treatments: 1) Only recommended NPK dosage (500 kg.ha$^{-1}$), 2) Combining Trichoderma and 50% recommended NPK dosage, 3) Combining Mycorrhiza and 50% recommended NPK dosage, 4) Combining PGPR and 50% recommended NPK dosage, 5) Pest control, 6) Stimulant. The data were subjected to analysis of variance followed by Duncan's Multiple Range Test. The result of the experiment showed that the decomposition of leaf litter with C/N ratio of 16.57significantly improved the plant height at 14, 28, and 42 days after transplanting and shoot dry weight in comparison with chili that was treated by decomposition of leaf litter with C/N ratio of 28.52. The use of decomposition of leaf litter with C/N ratio of 16.57 in combination with biological control agents + 50% recommended NPK dosage significantly increased the number of branches and had a faster flowering stage. However, there were no significant differences between the three types of biological control agents in affecting the number of branches and* the *flowering stage. The growth plants treated with NPK fertilizer only has the lowest plant growth compared to other treatments. It is suggested that to increase plant growth and accelerate the flowering stage, and chili can be treated with fully decomposed leaf litter combine with biocontrol agents and 50% recommended NPK.*

Keywords: biological control agents, chili, leaf litter decomposition, plant growth



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# I. INTRODUCTION

Chili (Capsicum annuum L.) is a horticultural commodity that has high economic value. Chili is consumed in fresh or processed form or as industrial raw material for medicines, dyes, and other uses (Fitria, 2019). Every 100 g of chili contains nutrients including Calories (31 calories), Protein (1g), Fat (0.3g), Carbohydrates (7.3g), Calcium (29 mg), Phosphorus (24 mg), Iron (0.5 mg), Vitamin A (470 SI), Vitamin C (18 mg), Vitamin B1 (0.1mg) and Edible Weight/ BBD (85%). The productivity of chili (quintal/ha) in Indonesia for the period 2011 - 2016 shows that there was a decrease in 2016, the productivity of chilies from 2012-2016 was 79.34 ku / ha, 81.61 ku / ha, 83.35 ku / ha, 86.49 ku / ha and 84.73 ku / ha, respectively (BPS, 2018; Fajar 2018). The main problem with chili crop failure is a curly disease (downy mildew) caused by the Gemini virus and Fusarium wilt caused by Fusarium fungus. The decline in yield and quality of chilies was also caused by fruit flies and whiteflies attack as virus-carrying vectors. To control these pests, farmers still rely on the use of synthetic chemical pesticides, which leave residues on products and the environment and disrupt human health as well as plants to become resistant to diseases attacks. Efforts to increase the productivity of Chili require a technological breakthrough.

New technological breakthroughs can be focused on the complete and balanced fertilization technology usage, the use of standardized organic fertilizers and lime as an element for soil improvement, integrated pest and disease control technology, and post-harvest handling. The main pests and diseases that attack chili crops are soil-borne pathogens, Gemini virus, Fusarium wilt, and whiteflies and fruit flies. Efforts to solve the problem and reduce the negative impact of using synthetic pesticides will be carried out by using biological control. The availability of biological agents in sufficient quantities with quality that can be accounted for as biological control agents is essential. One of the efforts to control pathogens and increase the yield and quality of red chilies is using biological agents and organic materials that have been completely decomposed. The use of Trichoderma sp. is an alternative in increasing the biological activity of micro soil organisms. Trichoderma herzianum is the most widely used antagonist fungus to control soil-borne pathogens (biological agents), decomposing organisms, and stimulating plant growth. According to Islami et al. (2019), T. herzianum application has a good effect on the growth and yield of soybean plants. The use of mycorrhizae can also increase yield and growth in maize (Astiko, 2016). The application of mycorrhizae helps increase plant growth and production by increasing the absorption of water and nutrients in the soil, especially phosphorus. Phosphorus is an essential nutrient needed by plants in large quantities (Powell & Bagyaraj, 1984). Plant Growth Promoting Rhizobacteria is beneficial for soil growth and health, and has the ability to control pests and diseases and has been considered important in sustainable agriculture (Sharma et al., 2017). In addition, it is also proven to accelerate the bioremediation and biodegradation process of toxic compounds found in soil, water, heavy metals, and organic pollutants (Srivastava & Singh. 2017).

The application of organic fertilizers can improve field quality because it plays a role in improving soil structure, as a source of nutrients, increasing the ability to hold water, increasing the soil cation exchange capacity (CEC) and as energy for microorganisms during decomposition (Hardjowigeno 2010). The process of decomposition of organic matter is a simple physical and chemical change matter by soil microorganisms, including bacteria, fungi, and other soil animals, into simple inorganic compounds (Susanti and Halwany, 2017). Microorganisms, including biological agents in the soil, play an important role because they can decompose organic matter, in this case, fresh leaf litter, and release nutrients into the soil into available form for plants (Choirul, 2010; Iskandar, 2014). Decomposition will run faster if there are additional microorganisms. Therefore, with the addition of a fungus to the leaf litter, the decomposition process is expected to be faster (Aisyah & Kuswytasari, 2014). The application of fresh leaf litter will reduce the quality of the soil because there are not many microorganisms available. The microbes require food sources in the soil to proliferate, so it becomes competitive in the early growth of the plant. Using biological agents will accelerate the decomposition process of organic matter.

Biological control by using Biological Control Agencies (BCA) is an alternative to anticipate the impact of disease attacks. This Biological Control agent is utilized because it can suppress the growth of pathogens for a longer time so that it does not leave residues and can accelerate the decomposition process of organic matter, so the balance of the ecosystem can be achieved (Ningsih, 2016). The use of microorganisms to control pathogen attacks and the use of organic fertilizers on chili plants have been widely studied. However, research on the use of a combination of biological agents, including PGPR, Trichoderma sp, and Mycorrhiza sp. has not much done. Based on the summary above, it is necessary to conduct research on the use of biological agents and the level of decomposition of leaf litter to increase yield and quality red chili. The aim of this study was to examine the effect of the decomposition level of leaf litter in combination with various biological control agents and NPK dosage on plant growth.

# II. LITERATURE REVIEW

**Chili plant morphology**

Chili is classified as an annual plant in the form of a shrub with a taproot. The trunk is upright with sections of woody undersides, with regular branches and fine hair. The height of the chili plant can reach 1.5 meters, has an oval leaf shape with alternating positions, is pinnate, and includes a single leaf. Perfectly flowering chilies androgynous, in the form of small white trumpets. The young fruit is green and bright red after ripe (Dermawan, 2010).

**Decomposition of organic matters**

The decomposition process starts from the crushing process carried out by small insects to plants and the rest of the dead organic matter into smaller sizes. Then proceed with the biological process carried out by bacteria and fungi to decompose organic particles (Sunarto, 2010). The level of decomposition is affected by environmental factors, the type and number of microorganisms, and the activity of the decomposers. Environmental factors, include climate such as rainfall, humidity, light intensity, and air temperature, affect the decomposition process. Water temperature, pH, water salinity, oxygen content, organic nutrient content also determine the decomposition process (Setrorini, 2014). The rate of the litter decomposition at different growth phases was correlated with different litter quality indexes. The rate of litter decomposition correlated positively with litter N concentration at the early stage of growth but negatively correlated with litter N and P concentrations at the final phase. The response of litter decomposition to the availability of soil nutrients is different from one to another species. The quality of litter and the addition of nutrients in the processing of the decomposition affects the availability of soil nutrients and the acquisition of carbon (C) as a source of nutrition for microorganisms (Lu-Jun Li *et al.*, 2011).

**Biological Agents to Control Plant Pest Organisms**
Biological agents are a means of controlling pests that are already available in an ecosystem, but often their presence at an inadequate level, this causes the pest population tends to increase. The availability of adequate biological control agents in an ecosystem greatly determines the success of pest control efforts (Sunarno 2016). Several types of biological agents that play a role in controlling pathogens are:

1. Plant Growth Promoting Rhizobacteria (PGPR)

Giving bacteria can increase plant growth and production. Bacteria that can stimulate plant growth and production have a role as Plant Growth Promoting Rhizobacteria (PGPR), a group of beneficial soil microorganisms. PGPR is a group of bacteria that live and develop well in soil rich in organic matter. PGPR is a soil bacteria found in the atmosphere around plant roots. There are two groups of Rhizobacteria, which are symbiotic and non-symbiotic. Some examples of Rhizobacteria include *Bacillus, Pseudomonas, Serratia, Burkholderia, Arthrobacter, Micrococcus, Agrobacterium, Flavobacterium, Azospirillum, Azotobacter, Rhizobium, and Bradyrhizobium*. PGPR produces antibacterial-effective plant pathogens that attack certain plants (Ashrafuzzaman, 2009).

2. *Trichoderma* sp

*Trichoderma* sp. is a soil fungus that plays a role in breaking down complex organic compounds such as hemicellulose and cellulose to form several components such as N, P, S, and Mg and other nutrients needed by plants for growth. *Trichoderma* functions to break down organic materials used by plants to stimulate growth above the ground, especially plant height and the formation of green on leaves (Marinah, 2013).

3. Arbuscular Vascular Mycorrhiza

Mycorrhizae are fungi that form symbiotic mutualism between fungal species and plant roots. Both of them get benefits for their lives (Madjid, 2009). Host plants obtain various nutrients, water, biological protection, and others, while fungi obtain photosynthate as a carbon source (Moose, 1981). The use of 15 g/plant mycorrhizae had a very significant effect on the number of fruits, fruit weight, number of productive branches, and the percentage of roots infected with AMF (Abdurrahman, 2015). The benefits of mycorrhizae for plant development are increasing the absorption of the nutrients from the soil; functioning as a biological block against root pathogen infections, improving host resistance to drought; ensuring the implementation of biochemical activity; and improving growth-regulating hormones (Madjid, 2009).

# III. RESEARCH METHODOLOGY

This research was carried out at Experiental Garden, Condongcatur Campus, Depok, Sleman, Yogyakarta, from June until September 2020. The research was arranged according to Randomized Complete Block Design with two factors, and each treatment consists of three replications. The first factor was the decomposition of leaf litter with C/N ratio of 28.52 (half decomposed) and decomposition of leaf litter with C/N ratio of 16.57 (Fully decomposed). The second factor was NPK with/without various types of biological control agents with the following five treatments: 1) Only recommended NPK dosage (500 $kg.ha^{-1}$), 2) Combination of Trichoderma and 50% recommended NPK dosage, 3) Combination of Mycorrhizae and 50% recommended NPK dosage, 4) Combination of PGPR and 50% recommended NPK dosage, 5) Pest control, 6) Stimulant. Plants height was measured every two weeks until 42 days after transplanting (DAT), a number of branches were assessed at 42 DAT, flowering age, shoot dry weight, and root dry weight was assessed at 35 DAT from three plant samples.

A variety of chili used in this experiment was a hybrid variety Tropy F1. The seedlings were planted in 35 cm-sized polybags filled with soil mixed with compost in 1: 1 ratio. NPK fertilizers, biological control agents, pest control, stimulant formulation, according to treatment, were given twice at 14 and 28 days after transplanting (DAT). The obtained data were then analyzed using Analysis of Variance (ANOVA, α = 5%) and further tested by Duncan's Multiple Range Test (α = 5%) in SPSS for Windows version 15.

# IV. FINDING AND DISCUSSION

## Plants height

The application of leaf litter decomposition with C/N ratio of 16.57 significantly improved the plant height at 14, 28, and 42 days after transplanting, compared with chili that was treated with leaf litter decomposition with C/N ratio of 28.52 (Table 1). The decomposition of leaf litter, which has a C / N ratio of 10-20, increases organic matter, which further increases the Cation Exchange Capacity and as a source of energy for microorganisms (Harjowigeno, 2010). The decomposition of organic matter is an occurrence of physical and chemical changes by soil microorganisms, including bacteria, fungi, and other soil fauna, into simple inorganic compounds (Susanti dan Halwany, 2017). Increased nutrient availability, followed by increased nutrient uptake, spurred nutrient adequacy for plant growth, which indicated by a significant increase to the plant height.

Table 1. Plant height at 14, 28, 42 days after transplanting (DAT)

| Treatments | Plant height (cm) | | |
|---|---|---|---|
| | 14 DAT | 28 DAT | 42 DAT |
| Decomposition rate ( S ) | | | |
| Decomposition of leaf litter with C/N ratio of 28.52 ($S_1$) | 22.89 q | 47.39 q | 76.56 q |
| Decomposition of leaf litter with C/N ratio of 16.57 ($S_2$) | 24.30 p | 51.44 p | 82.56 p |
| Types of biological control agents (A) | | | |
| Only recommended NPK dosage ($A_0$) | 22.82 a | 48.83 a | 74.17 a |
| Combation of Trichoderma + 50% recommended NPK dosage ($A_1$) | 24.50 a | 49.67 a | 77.83 a |
| Combination of Mycorrhizae + 50% recommended NPK dosage ($A_2$) | 24.17 a | 48.17 a | 80.80 a |
| Combination of PGPR+50% recommended NPK dosage ($A_3$) | 22.33 a | 47.33 a | 80.33 a |
| Pest control ($A_4$) | 22.67 a | 49.17 a | 81.33 a |
| Stimulant ($A_5$) | 25.17 a | 53.33 a | 91.67 b |

Note: Means followed by the same letter within a column are not significantly different from one another at P≤ 0.05 (DMRT)

## Number of branches

Application of leaf litter decomposition with C/N ratio of 16.57 and combination of biological agents and 50% recommended NPK dosage such as Mycorrhizae, PGPR and stimulant significantly improved the number of the branch at 42 days after transplanting in comparison with chili that was treated with leaf litter decomposition with C/N ratio of 28.52 and combination of Trichoderma and 50% recommended NPK dosage, pest control and only recommended NPK dosage (Table 2).

Increased organic matter derived from completely decomposed leaf litter (C / N ratio 16.57 and organic material 78.86%) will supply macro and micronutrients for plants and provide ideal soil environments for the growth of all microbes. Microbes will decompose leaf litter by altering the size of organic matters from big size into a smaller size. The enzyme protease is produced by *Bacillus* sp during the decomposition; Sugars is decomposed into format acid, ethanol, and $CO_2$ and lactic acid by lactic acid bacteria. Yeast is utilized for the fermentation process, and it converts sugar into ethyl alcohol and CO2 (Kosit, 2011). Biological agents consist of beneficial microbes, including 1) the main microbes that deliver N, P, K elements available to plants through biosynthetic, bio-enzymatic, and fixation; 2) secondary microbes that provide a food source for the propagation of all microbes in the biotic consortium (Ngrembakatingkir.blogspot.com. 2011). The uptake and efficiency of micronutrients like Zn, Cu, Fe, and Mg can be increased by fungi (Suresh *et al*., 2011). The metabolic processes carried out by these microbes produce macro and micronutrients. Besides that, plant hormones are also an important component in increasing plant growth. Adequate nutrients and plant hormones help to produce maximum branches and as an indicator of the formation of flowers and fruit.

Table 2. Number of branches at 42 days after transplanting

| Treatments | Decomposition of leaf litter | | Average |
|---|---|---|---|
| | C/N ratio 28.52 ($S_1$) | C/N ratio 16.57 ($S_2$) | |
| Only recommended NPK dosage ($A_0$) | 15.67 e | 16.33 e | 16.00 |
| Combination of Trichoderma + 50% recommended NPK dosage ($A_1$) | 20.00 c | 18.33 d | 19.17 |
| Combination of Mycorrhizae + 50% recommended NPK dosage ($A_2$) | 19.33 cd | 24.00 a | 21.67 |
| Combination of PGPR +50% recommended NPK dosage ($A_3$) | 20.67 c | 22.63 ab | 21.65 |
| Pest control ($A_4$) | 16 e | 16.00 e | 18.50 |
| Stimulant ($A_5$) | 21.00 bc | 23.00 ab | 19.50 |
| Average | 18.44 | 19.50 | |

Note: Means followed by the same letter within a column are not significantly different from one another at P≤ 0.05 (DMRT)

## Flowering stage

The flowering stage of chili that was treated with leaf litter decomposition with C/N ratio of 16.57 with a combination of biological agents + 50% recommended NPK dosage were significantly start earlier from those treated with the decomposition of leaf litter C/N ratio of 28.52 and combination of biological agents+50% recommended NPK dosage. The flowering stage of chili that was treated with biological agents such as *Trichoderma* sp., Mycorrhizae, and PGPR did not significantly different from one to another (Table 3).

Table 3. Flowering stage (days)

| Treatments | Decomposition of leaf litter | | Average |
|---|---|---|---|
| | C/N ratio 28.52 ($S_1$) | C/N ratio 16.57 ($S_2$) | |
| Only recommended NPK dosage ($A_0$) | 32.00 b | 32.00 b | 32.00 |
| Combination of *Trichoderma sp.* and 50% recommended NPK dosage ($A_1$) | 32.00 b | 30.00 c | 31.00 |
| Combination of Mycorrhizae and 50% recommended NPK dosage ($A_2$) | 34.67 a | 30.00 c | 32.33 |
| Combination of PGPR and 50% recommended NPK dosage, ($A_3$) | 32.67 b | 30.00 c | 31.33 |
| Pest control ($A_4$) | 31.33 bc | 30.00 c | 30.67 |
| Stimulant ($A_5$) | 32.00 b | 32.00 b | 32.00 |
| Average | 32.44 | 30.67 | |

Note: Means followed by the same letter within a column are not significantly different from one another at P≤ 0.05 (DMRT)

The decomposition of organic matter can take place faster by utilizing microorganisms such as PGPR, Mycorrhizae, and *Trichoderma sp.* Plant Growth Promoting Rhizobacteria is beneficial for plant growth and soil quality, pests, and disease control and has been considered important in sustainable agriculture (Sharma *et al.*, 2017). Besides that, it is also proven to accelerate the bioremediation and biodegradation process of toxic compounds found in soil, water, heavy metals, and organic pollutants (Srivastava and Singh. 2017). Microorganisms that are classified as biological agents live in the soil and play an important role because they can break down organic matter, for example, fresh leaf litter, so it can release nutrients into the soil and make them are available to plants (Choirul, 2010; Iskandar, 2014). Although the application of biological agents has not shown an increase in plant height, it was able to increase the number of branches and accelerate the flowering age (Tables 2 and 3). Adequate nutrients and an optimal photosynthetic net accelerate the distribution of photosynthate from "sink" to "source". Maximum assimilates can be translocated into the generative growth, especially for flowering.

**Shoot root dry weight**

Shoot dry weight chilies treated with leaf litter decomposition with C/N ratio of 16.57 was significantly higher than those treated with leaf litter decomposition with C/N ratio of 28.52. However, the decomposition rate of leaf litter did not significantly affect root dry weight. Plants dry weight of chili treated with a combination of biological control agents+50% recommended NPK dosage, pest control was not significantly different from one to another (Table 4).

Compost contains different types of microbes, including fungi, mikoflora, bacteria, actinomycetes, and protozoa. Each microbe has a specific role. The microbes play an important role in supporting plants growth by providing nutrients (e.g. Nitrogen-fixing microbes, and Phosphat-solubilizing microbes), improving the absorption of the nutrients (e.g. mycorrhizal arbuscular vascular), stimulating the growth of plant, and suppressing pests and diseases (e.g. antibiotic-producing microbes, antipathogen) (Kosit, 2011). This various macro and micronutrients, phytohormone, and biopesticides that are produced by microbes from leaf litter decomposition will be able to meet most of the nutrients required for plant growth and development. Leaf litter that fully decomposed (C/N ratio of 16.57) provides more nutrients for plant growth than half decomposed leaf litter (C/N ratio of 28.52). Thus the resulted in higher shoot dry weight.

Table 4. Dry weight of plant (g) at 35 days after transplanting (DAT)

| Treatments | Dry weight of plant (g) | |
|---|---|---|
| | shoot | root |
| Decomposition rate ( S ) | | |
| Decomposition of leaf litter with C/N ratio of 28.52 ($S_1$) | 5.48 q | 3.34 p |
| Decomposition of leaf litter with C/N ratio of 16.57 ($S_2$) | 8.91 p | 3.33 p |
| Types of biological control agents (A) | | |
| Only recommended NPK dosage ($A_0$) | 6.50 a | 3.56 a |
| Combination of *Trichoderma sp* + 50% recommended NPK dosage ($A_1$) | 7.60 a | 4.23 a |
| Combination of Mycorrhizae + 50% recommended NPK dosage ($A_2$) | 6.92 a | 2.98 a |
| Combination of PGPR + 50% recommended NPK dosage ($A_3$) | 6.87 a | 3.26 a |
| Pest control ($A_4$) | 6.33 a | 2.52 a |
| Stimulant ($A_5$) | 8.96 a | 2.86 a |

Note: Means followed by the same letter within a column are not significantly different from one another at P≤ 0.05 (DMRT)

# CONCLUSION

The result of the research showed that the decomposition of leaf litter with C/N ratio of 16.57 significantly improved the plant height at 14, 28, and 42 days after transplanting and shoot dry weight in comparison with chili that was treated by decomposition of leaf litter with C/N ratio of 28.52. The decomposition of leaf litter with C/N ratio of 16.57 and a combination of biological control agents and 50% recommended NPK dosage significantly increase the number of branches and have earlier flowering age. However, there was no significant difference between the three types of biological control agents. Plants treated with NPK fertilizer has the lowest plant growth compared to other treatments. This research showed that the use of a fully decomposed leaf litter (C/N ratio of 16.57) can reduce the usage of NPK if combined with the application of biological agents. The implication of this study would suggest that for chili cultivation, it is best to use fully decomposed leaf litter in combination with half dosage of recommended NPK+biological agent.

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