

The effect of bokashi fertilizer from agricultural waste contain *Trichoderma* to improve soybean production, growth, and resistance against plant diseases

Gusnawaty HS^{1,*}, Muhammad Taufik¹ and Novita Pramahsari Putri²

¹ Department of Plant Protection, Faculty of Agriculture, Halu Oleo University, Kendari, Southeast Sulawesi, Indonesia.

² Department of Agroecotechnology, Faculty of Agriculture, Malikussaleh University, Aceh, Indonesia.

World Journal of Advanced Research and Reviews, 2023, 18(03), 645–657

Publication history: Received on 23 April 2023; revised on 02 June 2023; accepted on 04 June 2023

Article DOI: <https://doi.org/10.30574/wjarr.2023.18.3.0965>

Abstract

This study focus on the development agent of biological control based on technologies used *Trichoderma* mix with bokashi fertilizer from agricultural waste. This study arranged in a randomized block design (RBD) in a factorial pattern, factor I is a type of decomposer microorganism that consisted of three treatments (M1: EM4 decomposer, M2: *Trichoderma* decomposer, M3: EM4 decomposer and *Trichoderma*), and factor II is the type of agricultural waste, consisted of four treatments (L1: soybean plant waste, L2: rice crop waste, L3: corn plant waste, and L4: a mixture of various agricultural waste) so there were 12 combinations of treatments with three repetitions. The observations data have been analyzed used variance and continued with the Duncan multiple distance test (DMRT) at the 95% confidence level. The result showed the application of bokashi from agricultural waste using EM4 and *Trichoderma* can increase plant growth, plant production, and resistance from plant pathogenic both independently and interactively, especially for Cucumber Mozaic Virus (CMV) and Soybean Mozaic Virus (SMV). In the other hand, the experimental study confirms that the Legume agricultural waste (L1), EM4 decomposers, and *Trichoderma* (M3) are the best combination to increase the growth, production, and durability of soybean crops either by main-treatment or interaction treatment compared to other treatments.

Keywords: Agricultural waste; Bokashi fertilizer; CMV/SMV; Soybean plant; *Trichoderma*

1. Introduction

The soybean is one of the most important crops in the world and has extremely high social and economic value (Yu *et al.*, 2022). In Indonesia, soybean is the third crops rice and corn, it continues to increase as the population increases, but the production of national soybean not enough for that, so Indonesia still has to import to supply those consume needed. This fact is very ironic because Indonesia is known as an agricultural country with sufficient land area (Gusnawaty HS *et al.*, 2020).

The low productivity of soybeans in Indonesia caused by the kind of several pathogens that can infect the soybean during its planting process with high intensity (McCaghey *et al.*, 2018). According to Agrios that several types of pathogens that often infect soybean plants are *Phakospora pachyrhizi* that causes rust, *Sclerotium rolfsii* causes seedling, and rotten stems, *Xanthomonas axonopodis* pv. *glycines* causes of bacterial pustules, *Colletotrichum dematium* var. *truncatum* and *C. destructivum* causes of anthracnose disease, *Perenospora manshurica* causes of downy mildew, *Rhizoctania solani* causes of the blight of stem, pods, and seeds, and Mosaic Virus Disease (SMV) (Agrios, 2015). *P. pachyrhizi* can cause a loss of 10-90% of soybean yield, while *S. rolfsii* can result in 75-100% of yield loss (Semangun, 2010). Therefore, selecting a suitable control method is an effective way to overcome soybean diseases. Currently, the commonly used control methods include chemical control, screening disease-resistant soybean varieties,

* Corresponding author: Gusnawaty HS

and biological control (Rodriguez *et al.*, 2021; Willbur *at al.*, 2019). To increase soybean production, we focus on the development of biological control agents based on the technology. Biological control is a promising alternative method for plant pathogen control based on the use of antagonistic microorganisms, such as endophytic fungi *Trichoderma*, capable of protecting their hosts from the action of pathogens used, also aiming to maintain or increase agricultural production with a reduced application of chemical agents.

Trichoderma is a fungus that very easy to find and isolate from a plant's rhizosphere, easy to adapt, easily propagate, and easy to apply on growth medium or in the soil (Morais *et al.*, 2022). Many *Trichoderma* strains have been identified as having potential applications in biological control of soil-borne fungi such as *Armillaria*, *Fusarium*, *Phytophthora*, *Pythium*, *Rhizoctonia*, *Sclerotium*, and *Verticillium* (Taufik *et al.*, 2021) and have been tried as BCA and used as an alternative to synthetic pesticides to control a variety of plant diseases (Ma *et al.*, 2020). The biocontrol mechanisms of *Trichoderma* are based on the activation of multiple mechanisms, either indirectly, by competing for space and nutrients, promoting plant growth and plant defensive mechanisms, and antibiosis, or directly, by mycoparasitism (Inglis *et al.*, 2020). They are found in rhizospher and non-rhizospher soils, in addition to their endophytic relationships with many plants (Druzhinina *et al.*, 2011; Inglis *et al.*, 2020). Their biodiversity has been extensively investigated in various geographical locations, and their distribution varies with ecosystems (Ma *et al.*, 2020).

Trichoderma has the potential to be a bio decomposer of organic matter and bokashi. The utilizing of bokashi contain *Trichoderma* sp. can be used to reduce the use of chemical pesticides, it can increase plant growth and able to suppress the growth of plant pathogens while *Trichoderma* sp. can break down organic materials, produce growth hormones such as cytokinin and auxin, have antagonistic abilities against plant pathogens (Gusnawaty HS *et al.*, 2020).

Bokashi widely used in various Agriculture activities, and can increase soil fertility. Bokashi has a role in improving plant growth, production and protein content so that it can produce good quality seeds (Saro, 2007). Besides, being a source of nutrition, bokashi contains a lot of microorganisms that are beneficial for soil fertility because it can improve the physical, chemical and biological properties of soil so as to provide nutrients in increasing the growth and production of plant (Binardi, 2014). Bokashi is made by processing the organic matter with EM (Effective Microorganism). There are a lot of microorganisms in EM4. Here are 4 main EM4 microorganisms: (1) photosynthetic bacteria (phototropic bacteria), (2) lactic acid bacteria (*Lactobacillus* sp.), (3) yeast, and (4) *Actinomycetes* sp. (Umadi *et al.*, 2018). Therefore, the efforts to improve the growth, productivity, and resistance of soybeans must be a priority now. One alternative that can solve this problem in this research is by developing Bokashi fertilizer and *Trichoderma* as a biopesticide and biofertilizer that can help improve plant health and control the disease, additionally to increase soybean productivity. Bokashi from agricultural waste with *Trichoderma* is believed that has an essential role in improving the growth, productivity, and resistance of soybean plants against plant pathogenic.

2. Materials and Methods

This research was conducted in the Laboratory of Plant Protection, Faculty of Agriculture Halu Oleo University, and also in the Experimental Garden owned by UPTD Food Crop Protection Agency of Agricultural and Livestock Southeast Sulawesi Province.

2.1. Research and Observation

This research was arranged in a Randomized Block Design (RBD) in a factorial pattern namely factor I was a type of bio decomposer microorganism consisting of three treatments namely M1: EM4 decomposer, M2: *Trichoderma*, M3: EM4 decomposer, and *Trichoderma*, while Factor II was the type of agricultural waste, consisted of four treatments, namely L1: soybean waste, L2: rice crop waste, L3: corn plant waste, and L4: a mixture of various agricultural wastes, so there were 12 combinations of treatments. Each treatment repeated three times so that there were 36 research units in total.

2.2. Research Stages

2.2.1. Purification of *Trichoderma* spp.

The collection of local *Trichoderma* isolates was re-grown in Potato Dextrose Agar (PDA) media for up to seven Days After Inoculation (DAI).

2.2.2. Preparation of Agricultural Waste

Agricultural wastes such as rice straw, corn straw, and soybean straw were collected based on their species then cut into smaller sizes to be used as bokashi material.

2.2.3. Making Bokashi+Trichoderma

Each agricultural waste was put into a container and then mixed with manure to accelerate the decomposition of effective microorganisms (EM4), sugar solution and *Trichoderma* suspension, then tightly closed use a tarpaulin to bokashi prossed (with criteria such us black, odorless and not hot).

2.2.4. Soybean Seeds Provision

The soybean seeds used from the Central Seed Hall and Seed Certification of the Agriculture Service of Southeast Sulawesi Province.

2.2.5. Land Preparation for Planting

The land was cleaned and then processed entirely by using hoes to a depth of 20 cm, then made into plots as needed with the size of the map 3x5 m and the plot distance was 25 cm.

2.2.6. Bokashi Application and Basic Fertilizer

10 ton ha⁻¹ of bokashi was applied to the soil surface two weeks before planting and then mix well, while NPK fertilizer (with dose 90 kg N ha⁻¹, 180 kg P2O5, 60 kg K2O ha⁻¹) applied on the right and left plant (at the time of planting with a distance of approximately 10 cm from the plant).

2.3. Planting and Maintenance

Soybean seeds were planted with space 40x30 cm. Each planting hole was filled with two soybean seeds. Maintenance has done with watering and replanting (if there were dead plants), and fertilization (according to the recommendations of each type of plant).

2.4. Harvesting

Harvest was done when soybean has already shown signs that 80% of plants have shown physiological maturity (\pm 85 days after planting).

2.4.1. Observation variable:

Plant growth, includes plant height, leaf area, growth rate, assimilation rate, and carried out every week;

Crop yields such as number of productive branches, number of pods, number of pods containing, number of seeds per pod, and the weight of 100 grains, production. Observation of crop yields of seed weight after the drying process was carried out by drying the seeds in the drying tub for 3-7 days, and the water content was \pm 12%.

The level of disease incidence was carried out by calculating the number of disease plants divided by plant populations in each treatment, and the observations were observed every week.

2.5. Data analysis

The observation data were analyzed using analyzed variance and continued with the Duncan Multiple Distance Test (DMRT) with a 95% confidence level.

3. Results

The effectiveness of bokashi from the decomposition of bio decomposers and organic materials of agricultural waste on the growth, production, and health of soybean shows in Table 1.

Table 1 Recapitulation of the short effectiveness of decomposers and agricultural organic waste materials on the growth, production, and health of soybean

No	Observation	Decomposer (M)	Agriculture waste (L)	Interaction (M*L)
1.	Plant Growth			
	Plant height			
	2 WAP	ns	ns	ns
	4 WAP	ns	**	ns
	6 WAP	**	**	ns
	8 WAP	**	**	ns
	Number of leaves			
	2 WAP	ns	ns	ns
	4 WAP	ns	ns	ns
	6 WAP	ns	*	ns
	8 WAP	ns	*	ns
	Leaf area			
	2 WAP	ns	ns	ns
	4 WAP	*	*	ns
	6 WAP	*	*	ns
	8 WAP	ns	**	ns
	Growth rate			
	2 WAP	ns	**	ns
	4 WAP	ns	**	ns
	6 WAP	ns	**	ns
	Net Assimilation Rate			
	2 WAP	ns	ns	ns
	4 WAP	ns	**	ns
	6 WAP	ns	**	ns
2.	Production			
	Productive branches	ns	*	ns
	Number of all pods	**	**	*
	Number of intact pods	**	**	ns
	Weight of 100 seeds	ns	**	ns
	Production (Ton Ha ⁻¹)	**	**	**
3.	<i>Disease incidence</i>			
	<i>Disease incidence of CMV</i>			
	7 WAP	ns	**	ns
	8 WAP	ns	*	ns
	9 WAP	**	**	**
	10 WAP	**	**	**
	11 WAP	**	**	*
	<i>Disease incidence of SMV</i>			

7 WAP	**	**	**
8 WAP	**	**	**
9 WAP	**	**	**
10 WAP	**	**	**
11 WAP	**	**	**

Note; ns: not significant, **: very significant, *: significant, WAP: Week After Plant, CMV: Cucumber Mosaic Virus, SMV: Soybean Mosaic Virus.

3.1. Plant Growth

3.1.1. Plant height

The average of main effect decomposer test and the main effect of agricultural organic waste materials on the slight effectiveness of decomposers and organic materials of agricultural waste in increase the height of soybean plant shows in Figures 1 and 2.

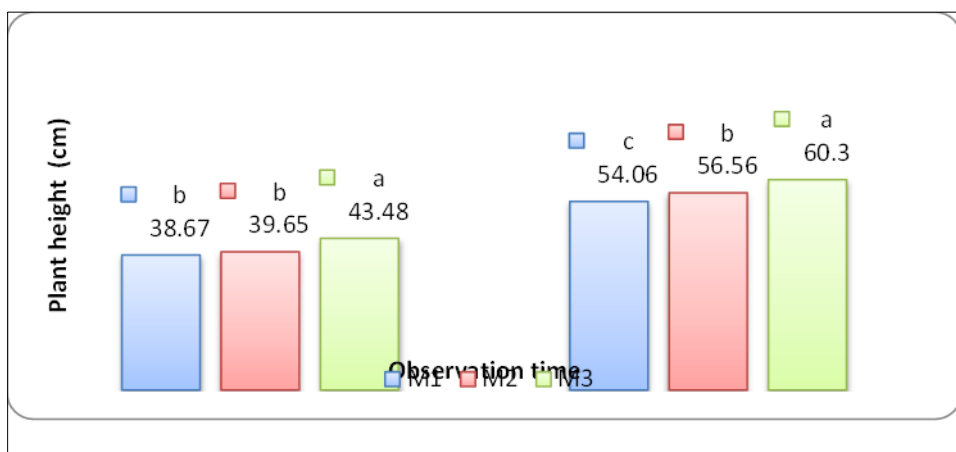


Figure 1 The effect of the main decomposer of soybean plant height on 6 and 8 weeks after plant

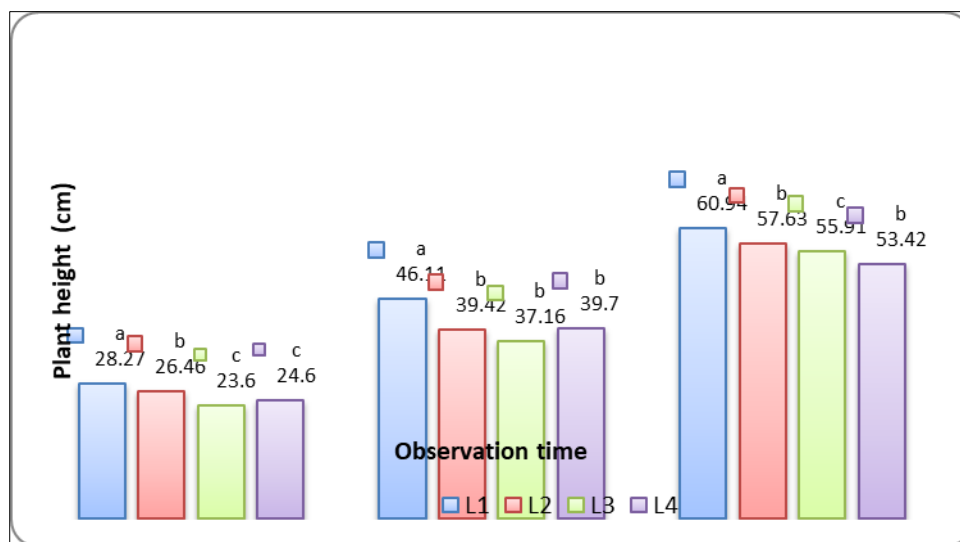


Figure 2 Effect of main organic matter from agricultural waste (L) of soybean plant height on 4, 6, and 8 weeks after plant

Figures 1 and 2 showed DMRT test results that decomposer main-treatment (M) and main-treatment of organic waste agricultural materials (L) affect the increase of plant height. Main-treatment of decomposer, consistently, M3 treatment showed the highest response of different plant height than other treatments on observations 6 and 8 weeks after plant. Main-treatment of organic materials from agricultural waste, consistently, the L1 treatment showed the highest

response on plant height and significantly different than the other treatments on observations 4, 6, and 8 weeks after the plant (Table 1).

3.1.2. Number of Leaves

The average test of main-effect of organic materials from agricultural waste on the effectiveness of decomposers and organic materials from agricultural waste in increasing the number of leaves of soybean plant shows in Figure 3.

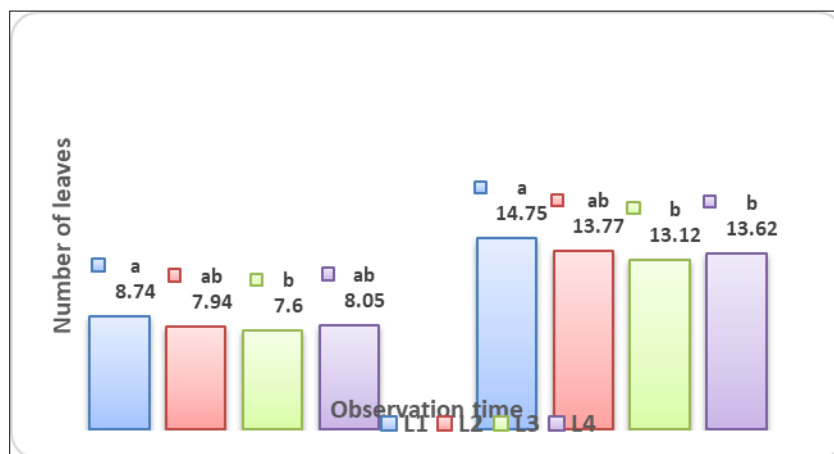


Figure 3 Main-effect of organic matter from agriculture waste (L) of soybean plant height on observations 4, 6, and 8 weeks after plant

Figure 3 showed the DMRT test of the main-treatment of organic materials from agricultural waste (L) affects the increase of the number of leaves. In the main-treatment of organic matter from agricultural waste, treatment of L1 was not significantly different than the treatment of L2 and L4 but significantly different than the L3 treatment on 6 weeks after plant, while treatment of L1 was not significantly different from the L2 but was significantly different than L3 and L4 treatments in 8 weeks after the plant (Table 1).

3.1.3. Leaf Area

The average test of main-effect decomposer agricultural waste on the effectiveness of decomposers and organic material from agricultural waste in increase soybean leaf area shows in Figures 4 and 5.

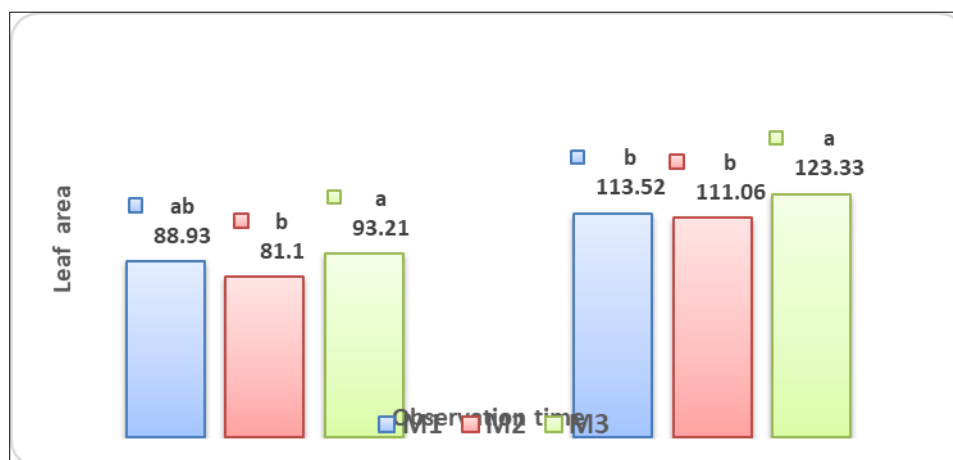


Figure 4 Main-effect of decomposer of leaf area on 4 and 6 weeks after plant

Figures 4 and 5 showed test results of DMRT for main-treatment of decomposer (M) and main-treatment of organic matter from agricultural waste (L) affect increase leaf area. M3 treatment showed the highest response of leaf area with not significantly different than M1 treatment, but significantly different than M2 treatment on 4 weeks after plant, while on 6 weeks after planting, M3 treatment showed the highest leaf area response and significantly different than M1 and

M2 treatments. Main-treatment of organic matter from agricultural waste, the L1 treatment showed the highest leaf area response and significantly different than other treatments on 4, 6, and 8 weeks after the plant (Table 1).

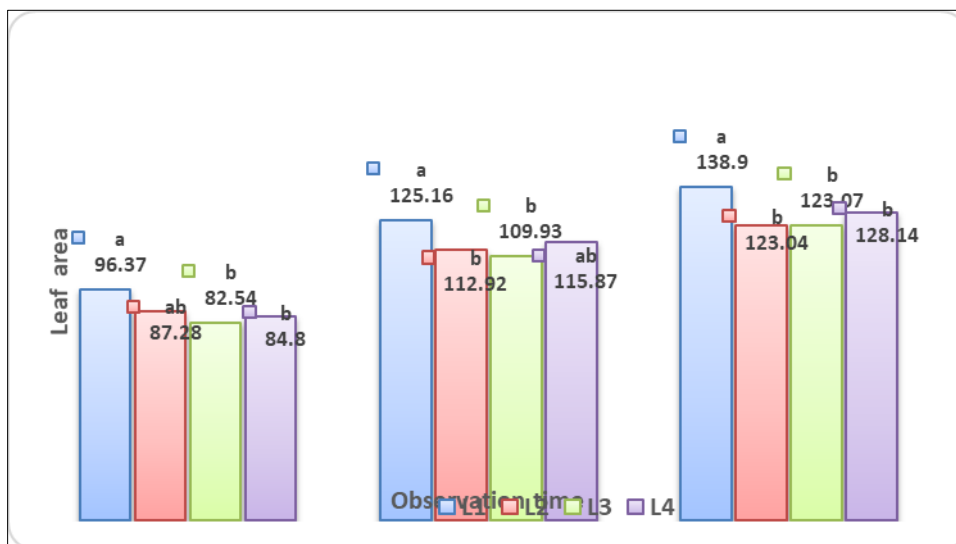


Figure 5 Main-effect of organic matter from agricultural waste (L) on leaf area on 4, 6, and 8 weeks after plant

3.1.4. Growth Rate and Net Assimilation Rate

The average test of the main-effect of organic materials from agricultural waste on the effectiveness of decomposers and organic materials from agricultural waste in increasing the Growth Rate and the Net Assimilation Rate of soybean plants shows in Table 2.

Table 2 Main-effect of organic material from agricultural waste on the effectiveness of decomposer and organic material from agricultural waste in increasing the Growth Rate and Net Assimilation Rate

Treatments	Growth rate ($\times 10^{-2} \text{ g}^{-1} \text{ cm}^{-2} \text{ days}^{-14}$)			Net Assimilation Rate ($\times 10^{-3} \text{ g}^{-1} \text{ cm}^{-2} \text{ days}^{-14}$)		
	14-28	28-42	42-56	14-28	28-42	42-56
L1	0,10a	0.39a	0.45a	ns	6.89a	29.65a
L2	0.07b	0.27b	0.29b	ns	5.57b	23.00b
L3	0.06b	0.27b	0.30b	ns	5.12b	22.65b
L4	0.07b	0.29b	0.30b	ns	5.65b	24.11b
DMRT _{0,05%}	2=0.0132	0.0693	0.0842	-	0.807	4.343
	3=0.0139	0.0728	0.0884	-	0.847	4.560
	4=0.0143	0.7508	0.0911	-	0.873	4.699

Numbers followed by the same letter are not significant in the DMRT test at the 95% confidence level.

Table 2 showed DMRT's test result of main-treatment of organic material from agricultural waste affects in increasing the growth rate and the rate of net assimilation of soybean plants. L1 treatment showed the highest response consistently and significantly different than L2, L3, and L4 treatments on 14-56 days after planting.

3.2. Plant Production

The average test of main-effect of organic material from agricultural waste in increasing the Number of Productive Branches (NPB), Number of Intact Pod (NIP), and Weight of 100 Seeds shows in Figure 6. The main-effect of decomposer on the Number of Intact Pod (NIP) shows in Figure 7. The effect of interaction between decomposers and organic material from agricultural waste in increasing the number of pods in total and production (Ton/Ha) of soybean shows in Table 3.

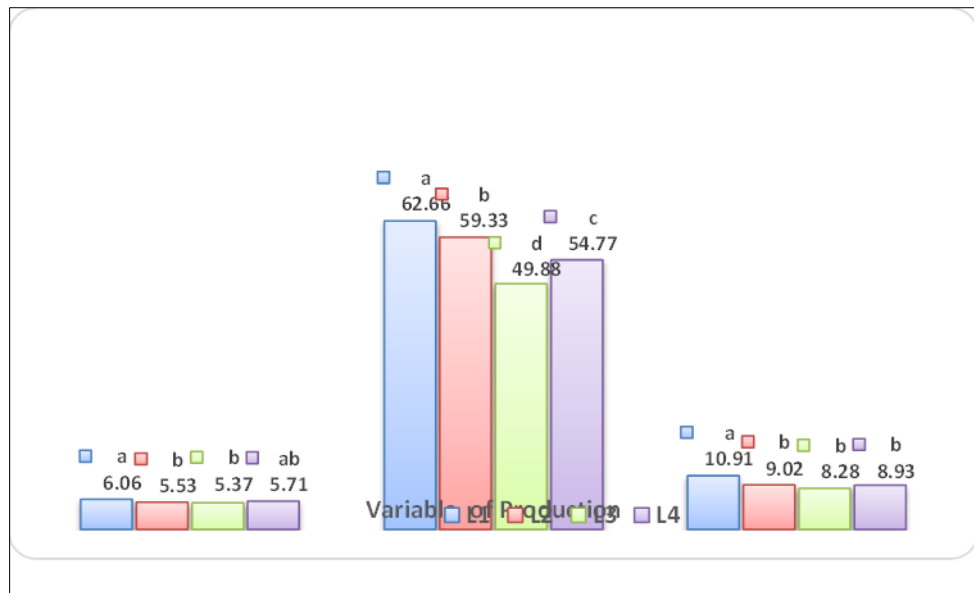


Figure 6 Main-effect of organic matter from agricultural waste (L) in increasing the Number of Productive Branches (NPB), Number of Intact Pod (NIP), and Weight of 100 Seeds

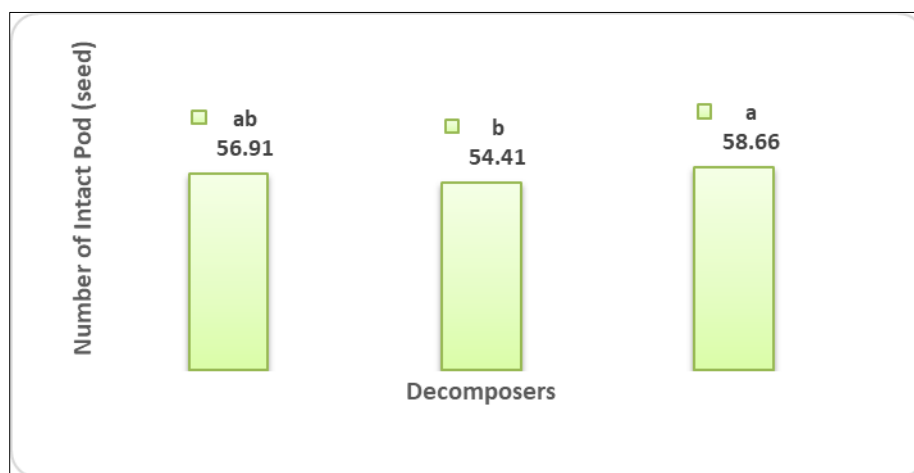


Figure 7 Main-effect of decomposer on Number of Intact Pod (NIP)

Figure 6. showed DMRT test results of the main-effect of organic material from agricultural waste in Number of Productive Branches (NPB), Number of Intact Pod (NIP), and Weight of 100 Seeds. Observation of Number of Productive Branches (NPB), the L1 treatment showed the best treatment and not significantly different than L4 treatment, but significantly different than L2 and L3 treatments, while in Number of Intact Pod (NIP), the L1 treatment showed the best treatment than treatments of L2, L4, and L3. On observation main-treatment of the weight of 100 seeds, the L1 treatment showed the best treatment and significantly different than L2, L4, and L3 treatments.

Table 3 Effect of interaction decomposers and organic materials from agricultural waste in increasing the number of pods in total and production (Ton/Ha)

Variable Observation	Treatments	L1	L2	L3	L3	DMRT 0,05
Number of Total Pods	M1	219.00	a	215.00	ab	2=6.56
		Q		P		
	M2	212.00	a	210.00	ab	3=6.89

		R		Q		P		Q		
	M3	243.00	a	217.00	b	191.00	b	199.00	c	4=7.09
		P		P		P		Q		
Production (Ton/Ha)	M1	3.21	a	2.79	b	2.23	d	2.60	c	2=0.138
		Q		P		Q		P		
	M2	3.07	a	2.77	b	2.39	d	2.58	c	3=0.145
		Q		Q		P		P		
	M3	3.80	a	2.70	b	2.50	c	2.66	bc	4=0.149
		P		Q		P		P		

Table 3 showed DMRT's test results of treatment between the interaction of decomposers and organic material from agricultural waste that can increase the Number of Total Pods and production (Ton/Ha) of soybean plants. In the observation, M3L1 treatments shows the best treatment combination compared to other treatments.

3.2.1. Disease Incidence

The average test of the effect between the interaction of decomposers and organic material from the agricultural waste of the incidence of the disease of Cucumber Mosaic Virus (CMV) and Soybean Mosaic Virus (SMV) on 11 weeks after plant shows in Table 4 and the main-effect of organic waste of CMV disease incidence shows in Figure 8.

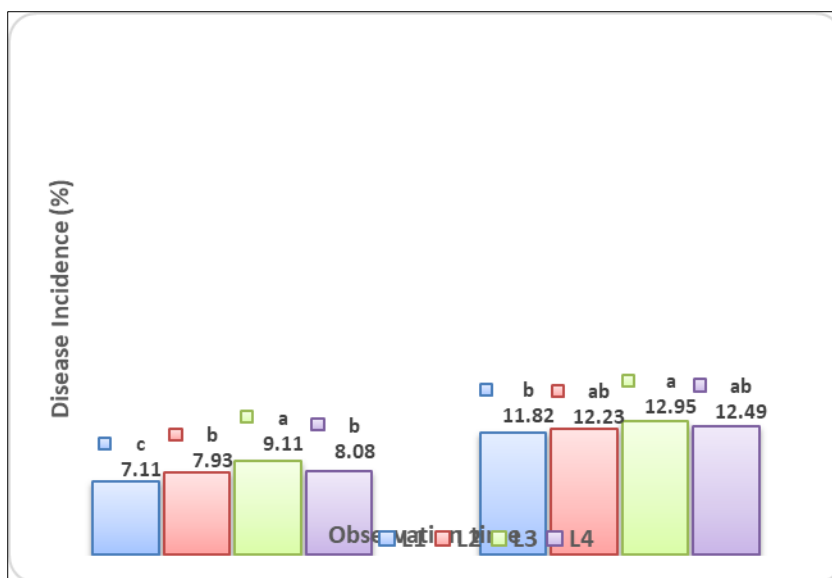


Figure 8 Main-effect of organic material from agricultural waste on the disease incidence of CMV on 7 and 8 weeks after plant.

Table 4 Effect of interaction decomposers and organic material from agricultural waste on the incidence of the disease of CMV and SMV on 11 weeks after the plant

Variable of Observation	Observation Time	Treatments	L1		L2		L3		L4		DMRT 0,05
CMV	11 WAP	M1	72.35	b	73.73	b	84.33	a	73.27	b	2=2.75
			P		R		Q		R		
		M2	74.65	b	89.40	a	90.32	a	88.94	a	3=2.89
			P		Q		P		P		

			P		P		P		P		
		M3	69.59	d	83.41	b	86.18	a	78.80	c	4=2.97
			Q		Q		Q		Q		
SMV	11 WAP	M1	106.45	d	179.72	a	182.95	a	123.96	bc	2=11.73
			Q		P		P		P		
		M2	119.35	b	123.96	a	129.49	a	134.10	a	3=12.33
			P		Q		Q		P		
		M3	96.31	c	118.43	b	141.01	a	133.64	a	4=12.69
			Q		Q		Q		P		

Table 4 showed DMRT test results of treatments, M3L1 treatment showed the best treatment combination than other combinations of treatments.

4. Discussion

In the ecosystem, decomposer organisms of organic material play an important role because the organic remains decomposed into elements returned to the soil such as N, P, K, Ca, Mg, etc., and atmosphere (CH₄ or CO₂) as nutrients that can be reused by plants, therefore, the nutrient cycle in the soil runs as it should.

The results of this study showed that the application of organic material from agricultural waste combine with EM4 and *Trichoderma*, both main-treatment nor interaction treatment was able to increase soybean crop growth, production, and plant resistance to pathogens, especially for CMV and SMV. The combinations of agricultural waste from the legume (L1) with EM4 and *Trichoderma* (M3) are the best combination of all observation variables than other treatments. The compatibility of legume, EM4, and *Trichoderma* are thought to accelerate the decomposition process of organic matter, therefore, be able to give the best effect to soybean plant. According to Wijanarko et al., the addition of organic matter to the soil would increase the activity of microorganisms in the organic matter. Legume has a lower C/N ratio than the type of non-legume organic material. The content of the C/N ratio affects the rate of decomposition of organic matter by microbial decomposers (Wijanarko *et al.*, 2012). Isrun (2010) also stated that legume plants are both uses as organic materials because they have a low C/N ratio when compared to non-legume plants with a much higher C/N ratio. Furthermore, a high C/N ratio causes more extended compositions and nutrient mineralization processes slower than legume plants. In addition to the factor C/N ratio of organic matter, another factor that affects the ho fast decomposition process of organic matter is the ability of decomposer microorganisms. In this study, the best decomposer treatment is a combination of EM4 and *Trichoderma* (M3). This combination can accelerate the decomposition process of organic matter from legume litter (L1).

Composting is the process of reforming or decomposition of organic materials by utilizing the role or activity of microorganisms. Through this process, organic materials will be converted into compost fertilizer, which is rich in both macro and micronutrients required by plants (Isrun, 2010). Decomposition of the dead bodies of living things and organic matter is part of the nutritional cycle that starts from the decay process until the mineralization process and will be absorbed by plants to compose plant biomass until its death, then, the decomposition cycle will continue repeatedly.

The effectiveness of microorganism4 (EM4) is a microorganism decomposer or bacteria decomposition that can eliminate odors, increase microbial content in the soil, improve soil quality and fertility, and accelerate composting (decay). EM4 contains selected species of lactic acid bacteria, yeast, photosynthetic bacteria, actinomycetes, and other types of bacteria (Higa and Parr, 1994). Umadi *et al.* (2018) state that the use of *Trichoderma* sp. as a biological agent combines with bokashi fertilizer can support green agriculture. Green agriculture currently becomes a trend for consumption patterns in the community because they start to care about their health. Green agriculture makes the balance of ecosystems in the soil and can be maintained. Combinations between bokashi and *Trichoderma* can improve the quality of seed yields.

According to Widyastuti, *Trichoderma* spp. is known as fungi, which can grow in various soil conditions and play an important role in the process of decomposition of organic matter (Widyastuti, 2007). Schmidt reported that

Trichoderma is a cellulolytic fungus that has the potential to decompose cellulose and hemicellulose compared to lignin (Schmidt, 2006). Samangan also reported that *Trichoderma harzianum* was able to decompose cellulose higher than lignin (Samangan, 2009). Composted straw which is immersed in soil has a good nutrient content for the soil and also plants, namely the C-organic content of 40-43%, N 0.5 - 0.8%, P 0.07 - 0.12%, K 1,2 - 7%, Ca 0.6%, Mg 0.2%, Si 4–7%, and S 0.10% (Simarmata and Joy, 2010).

Organic materials from agricultural waste such as legume litter can have a positive impact on the sustainability of microorganism decomposers because the organic material can be used as a source of nutrition for microorganisms. Haris reports that organic fertilizer has advantages that can improve soil structure, increase the content of topsoil, improve the growth of microorganisms in the soil, and improve the quality of agricultural products (Haris and Adam, 2000). Organic materials in the form of plant litter, compost, and manure are significant for microbial life (Moral *et al.*, 2009). With this condition, it strongly suspected that the organic matter produced from the legume decomposition process have high N content by microorganism decomposer that can improve other capabilities of the other microorganisms.

Trichoderma sp. has able to increase plant resistance from plant pathogen infections. Bailey and Lazarovits stated that the addition of organic materials with high N levels has the potential to suppress the attack of the soilborne pathogen by releasing allelochemicals (Bailey and Lazarovits, 2003). Also, *Trichoderma* sp. has the mechanism of antagonism, namely mycoparasitic (Verma *et al.*, 2007), space and nutritional competition, antibiosis, secondary metabolites (Wen *et al.*, 2005), and produce cellulase enzymes (cellulose degradation) (Wen *et al.*, 2005), and *Trichoderma* sp. can induce plant resistance.

The results of disease incidence showed that the interaction between short decomposer M3 (EM4 and *Trichoderma*) and bokashi legume litter shows the lowest incidence of disease because there is an active mechanism that occurs as a result of decomposer activity from *Trichoderma* sp. by inducing the resistance of soybean plants. One indicator of induction of a plant is seen from its physiological activity, namely the enzyme peroxidase. Peroxidase enzyme is one of the PR-proteins that play a role in plant resistance against plant pathogen that caused disease. Murphy *et al.* reported that the peroxidase enzyme is a transduction signal that can activate PR-protein. With the ability of *Trichoderma* sp. strongly suspected (Murphy *et al.*, 2001).

This research has been applied in Lamomea Village, Konda District, Kendari, Southeast Sulawesi, Indonesia, and will be applied to other soybean plant centers in Southeast Sulawesi.

5. Conclusion

Bokashi fertilizer from agricultural waste using EM4 and *Trichoderma* decomposers can increase plant growth, production, and resistance against plant pathogenic infections both main-treatment nor interactively. Agricultural waste from the legume (L1), EM4, and *Trichoderma* (M3) decomposers are the best combination compared to other treatments and they can increase the growth, production, and resistance of soybean.

Significance Statement

This research discovers the possible development of agricultural waste as bokashi fertilizer and suitable for increasing plant growth and production, and an additional suitable for disease management without give negative effects in ecosystem.

Compliance with ethical standards

Acknowledgments

Thanks to the Ministry of Research and Technology/National Research and Innovation Agency; Ministry of Education and Culture and the Institute for Research and Community Service (LPPM) Halu Oleo University for funding this research.

Disclosure of conflict of interest

The authors have declared that no competing interest exists.

Author Contribution

Name of the author	Types of contribution
Gusnawaty HS.	Head Project Manager, plant pathologist, biological control, plant production, agronomy, collected sample, research paper editor
Muhammad Taufik	Plant pathologist, mycologist, collected sample, observation of plant growth, research paper editor
Novita Pramahsari Putri	Plant pathologist, research paper editor

References

- [1] Agrios, G.N. 2005. Plant Pathology. 5th ed. Elsevier Academic Press. San Diego, California, USA.
- [2] Bailey, K.L. and Lazarovits, G., 2003. Suppressing Soil-Borne Diseases With Residue Management and Organic Amendments. *Soil and Tillage Research*. 72: 169-180. DOI: [https://doi.org/10.1016/S0167-1987\(03\)00086-2](https://doi.org/10.1016/S0167-1987(03)00086-2)
- [3] Central Bureau of Statistics, 2010. Agriculture Survey: Production of Vegetables and Fruits in Indonesia. Jakarta.
- [4] Central Bureau of Statistics, 2011. Agriculture Survey: Production of Vegetables and Fruits in Indonesia. Jakarta.
- [5] Central Bureau of Statistics, 2013. Agriculture Survey: Production of Vegetables and Fruits in Indonesia. Jakarta.
- [6] Directorate General of Food Crops, 2011. Food Crop Seed Policy. National Seminar: Role of Seeds in Agricultural Revitalization. Cooperation between the Department of Agriculture and the Faculty of Agriculture. Institut Pertanian Bogor. Bogor.
- [7] Gusnawaty HS, Taufik M, Bande LOS, Satrah VN, Putri NP, Mariadi, Rahman A and Asniah. 2020. Potential of Dosage of Bokashi from Agricultural Waste and Biodecomposer *Trichoderma asperellum* on growth of Three Varieties of Soybean, and Disease Incidence of Stem Rot Caused by *Sclerotium rolfsii*. *Journal of Agriculture and Veterinary Science (IOSR-JAVS)*, 13(6): 42-50.
- [8] Gusnawaty HS, Taufik M, Satrah VN, Putri NP and Asniah. 2020. In-Vitro Biocontrol Potential and Mechanism of Inhibition of Indigenous *Trichoderma* Isolates From Southeast Sulawesi Province of Indonesia Against *Sclerotium rolfsii*. *Plant Protection*, 4(3): 109-115.
- [9] Haris, A. and Adnan, A. M., 2000. Mycorrhiza and Its Benefits. Research Institute for Cereal Plants. Prosiding Scientific Seminar and Annual Meeting PEI dan PFI XVI Komda Sul-sel.
- [10] Irun, I., 2010. Changes in maize nitrogen uptake and Al-dd levels due to the application of legume and non-legume compost to napu inceptisols. *J. Agroland*, 17(1):23-29. <http://jurnal.untad.ac.id/jurnal/index.php/agroland/article/view/275>
- [11] Lopez-mondejar, R., Ros, M. and Pascual, J. A., 2011. Mycoparasitism-Related Genes Expression of *Trichoderma Harzianum* Isolates to Evaluate Their Efficacy as Biological Control Agent. *Biological Control*, Volume 56, Issue 1, January 2011. DOI: <http://dx.doi.org/10.1016/j.biocontrol.2010.10.003>.
- [12] Moral, R., Paredes, C., Bustamante, M. A., Marhuenda-Egea, F. and Bernal, M.P., 2009. Utilization of Manure Composts by High-Value Crops: Safety and Environmental Challenges. *Bioresource Technology*, 100(22). DOI: 10.1016/j.biortech.2008.12.007
- [13] Morais EM, Silva AA.R, Sousa FWAd, Azevedo IMBd, Silva HF, Santos AMG, 2022. Endophytic *Trichoderma* strains isolated from forest species of the Cerrado-Caatinga ecotone are potential biocontrol agents against crop pathogenic fungi. *PLoS ONE* 17(4): e0265824
- [14] Murphy, A. M., Gilliland, A., Wong, C. E., West, J., Singh, D. P. and Carr, J. P., 2001. Signal Transduction In Resistance to Plant Viruses. *Euro. J. Plant Pathol.* 107:121-128. DOI: <http://doi.org/10.1023/A:100873212>
- [15] Rodriguez, M. C. H., Evans, H. C., de Abreu, L. M., Macedo, D. M., Ndacnou, M. K., Bekele, B. K., 2021. New species and records of *Trichoderma* isolated as mycoparasites and endophytes from cultivated and wild coffee in Africa. *Sci. Rep.* 11, 5671–5630. doi: 10.1038/s41598-021-84111-1

- [16] Schmidt, O., 2006. Wood and Tree Fungi, Biology, Damage, Protection and Use. Springe. DOI: 10.1007/3-540-32139-X
- [17] Samingan, 2009. Fungal Succession and Decomposition of Acacia Mangium Willd Leaf Litter concerning the Presence of Ganoderma and Trichoderma on the Floor of Acacia Forest (Dissertation). Sekolah Pascasarjana Institut Pertanian Bogor. Bogor.
- [18] Simarmata, T. and Joy, B., 2010. Technology for Restoring Health of Rice Fields and Increasing Productivity of Rice Based on Straw Compost and Biodecomposers in a Sustainable manner in Indonesia. Fakultas Pertanian. Universitas Padjadjaran, Bandung.
- [19] Semangun, H., 2010. Plantation Plant Diseases in Indonesia. Gadjah Mada University Press, Yogyakarta. 808p.
- [20] Taufik M, Gusnawaty HS, Mariadi, Asniah, Wahab A, Mallarangeng R and Putri NP. 2021. Bacillus and Trichoderma Isolate Combination to Supress *Rigidoporus lignosus* White Root Rot Disease on Cashew Seedling. IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS), 14(2): 37-42.
- [21] Verma, M., Satinder, K., Brar, R.D., Tyagi, Surampalli, R.Y. and Valero, J. R., 2007. Antagonistic Fungi, Trichoderma spp.: Panoply of Biological Control. Biochemical Engineering Journal, 37(1):1-20. DOI: <http://doi.org/10.1016/j/bej.2007.05.012>
- [22] Wen, Z., Liao, W., and Chen, S., 2005. Production of Cellulase by Trichoderma reesei from Dairy Manure. Bioresource Technology. 96(4):491-499. DOI: <http://doi.org/10.1016/j.biortech.2004.05.021>
- [23] Widyastuti, S. M., 2007. The role of Trichoderma spp. In Forest Revitalization In Indonesia. Gadjah Mada University Press. Yogyakarta.
- [24] Wijanarko, A. Heru, B. Purwanto, Shiddieq, D. and Indradewa, D. 2012. Effect of organic matter quality and soil fertility on nitrogen mineralization and N uptake by cassava plants in Ultisols. J. Perkebunan & Lahan Tropika, 2(2). <http://jurnal.untan.ac.id/index.php/perkebunan/article/view/3484/3519>
- [25] Yurmiati, H. and Hidayati, Y. A., 2008. Evaluation of Production and Depreciation of Compost from Rabbit Feces on Smallholder Farms. Jurnal Seminar Nasional Teknologi Peternakan dan Veteriner. Pustaka Universitas Padjajaran. Bandung. <http://pustaka.unpad.ac.id/wp-content/upload/2015/02/evaluasi-produksi-dan-penyusutan-kompos.pdf>
- [26] Zakaria, A.K., 2010. Soybean Agribusiness Development Program to Increase Farmers' Production and Income. Center for Socio-Economic Analysis and Agricultural Policy, Bogor. Jurnal Litbang Pertanian. 29(4):147-153. DOI: <http://dx.doi.org/10.21082/jp3.v29n4.2010.p147-153>