BIOPESTICIDE EFFICACY AGAINST MAIN PESTS, DISEASES, AND NATURAL ENEMIES OF MUNGBEAN (*VIGNA RADIATA* L.)

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Abstract. Synthetic pesticides are not effectively controlling pests and diseases of mungbean in Indonesia. The objective of this study was to examine the inundation of various types of biopesticides in controlling the main pests and diseases, and their impact on natural enemies in mungbean. The study consisted of five treatments namely P1 = preventive biopesticide (*Trichoderma harzianum*, neem seed powder (*Azadirachta indica*), *Spodoptera litura* Nuclear Polyhedrosis Virus, *Beauveria bassiana*, and galangal rhizome extract) inundation, P2 = biopesticide application based on control threshold (CT), P3 = scheduled synthetic pesticide application, P4 = synthetic pesticide application based on CT, and P5 = without control. The results showed that P1 inundation reduced the population of 11 types of mungbean pests. The P1 treatment had the same efficacy as the P3 treatment. Scheduled and inundated application of biopesticides maintained the survival of natural enemies *Oxyopes* sp., *Paederus* sp., *Coccinella* sp., *Andrallus* sp., *Sycanus* sp. and the parasitoids *Trichogramma* sp., *Telenomus* sp., and *Apantheles* sp. Synthetic pesticides on schedule or based on control threshold killed the entire population of natural enemies. Preventive application of biopesticides could be recommended for controlling the main pests and diseases of mungbean as well as an alternative to synthetic pesticides.

Keywords: *synthetic pesticides, application, control, impact, preventive*

Introduction

Mungbean (*Vigna radiata* L.) production in Indonesia is still classified as low, only around 1-1.1 t/ha, meanwhile the opportunity for increasing productivity is quite large because the yield potential of several superior varieties that have been released can reach a productivity of 2 t/ha. One of the obstacles in increasing mungbean productivity is the occurrence of organisms harmful to plants which attack in them from early growth stages until just before harvest, even in storage areas. The main pests that attack at the beginning of growth are bean flies and shoot borer. Pests that attack in the vegetative phase are armyworms, leaf rollers, looper cutworm, whitefly, and leaf suckers. Meanwhile, pests that attack in the generative phase include pod sucking bug, pod borer, and pod feeder (Brier, 2010).

The types of diseases found on mungbean plants at the beginning of plant growth are soil borne pathogens which can cause yield losses ranging from 30-100% (Hall, 2005). Meanwhile, diseases in the vegetative phase are leaf spot and rust disease except viral disease caused by whitefly (Karthikeyan et al., 2014). Mungbean pest control technology applied by farmers is the application of synthetic pesticides because the results of this technology can be immediately determined. In addition, farmers do not have sufficient knowledge about other control technologies that can suppress pest populations and yields loss. However, it is not realized that the application of synthetic pesticides which are not in the right type, dose, time or method of application can lead

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to resistance and resurgence due to the killing of all natural enemies, both predators and parasitoids (Panizzi, 2013).

One of several ways to reduce resistance and resurgence is by suppressing the use of synthetic pesticides and developing the roles of various types of biological agents that can be used as biopesticides in pest control. Various advantages of biopesticides for controlling plant pests due to the fact that biopesticides: (1) have more specific host, (2) are easily degraded in nature so that they do not leave any residue, (3) the products obtained are organic so that improves the health of consumers, although the selling price of crop products become more expensive (which is good for the farmers) and, (4) are easy to breed in an easy way, (5) are not toxic to livestock, domestic animals and humans, as well as (6) do not pollute water sources or the environment (Gupta and Dikshit, 2010). The results of a recent study reported by Pacheco et al. (2018) that the antagonist fungus *T. harzianum* and several other species are very effective in suppressing the development of soil-borne diseases caused by the fungus *S. rolfsii*, even exceeding the efficacy of synthetic fungicides.

Biopesticide Virgra from *Spodoptera litura* Nuclear Polyhedrosis Virus (*Sl*NPV) is quite effective in controlling several types of pests, including toxic in killing armyworm *S. litura* larvae (Bedjo, 2004, 2012). *Sl*NPV is also able to kill leaf-folding caterpillars (*Chrysodeixis chalcites*) and leaf-rolling caterpillars (*Lamprosema indicata*) (Indiati and Bedjo, 2017). Biopesticides derived from botanical pesticides, neem seed powder (NSP), have been reported to be effective in refusing to eat the targeted insect by *O. phaseoli* bean flies, *S. litura* armyworms and several other pests (Indiati et al., 2013). Furthermore, BeBas biopesticide from the entomopathogenic fungus *Beauveria bassiana* can kill all pod sucking pests (*R. linearis, N. viridula, P. hybneri*) (Prayogo, 2013; Prayogo and Tantawizal, 2015).

Trichol 8 biopesticide from the antagonistic fungi, *T. harzianum*, was reported to be quite effective in suppressing the development of soil borne diseases of *S. rolfsii* and *R. solani* (Redda et al., 2018). Soil borne diseases reported by Handayani and Purwoko (2008) could also be controlled with extracts of galangal rhizome (*Alpinia galanga*) because they contain essential compounds that function against fungi and bacteria. Therefore, this study aims to test the inundation efficacy of various types of biopesticides to control mungbean pests and diseases.

Methodology

Place and time of study

The research was conducted at the Ngale Agricultural Technology Research and Assessment Installation (ATRAI), Ngawi, East Java, Indonesia with an altitude of 50 meters above sea level at the coordinates of 7° 24′ 32.4″ and 111° 22′ 22.8″ East Longitude. The experiment was conducted during Dry Season (June-August) 2017. The field soil is classified as clay vertisol with pH 6.8, C-organik 1.2%, N Total 0.14, and climate type is C3 base on Oldeman system.

Research design

The study was arranged in a randomized block design (RBD) with five replications. The treatments tested were: P1 = preventive biopesticide inundation, P2 = biopesticide inundation based on control threshold (CT), P3 = scheduled synthetic pesticide application (weekly), P4 = synthetic pesticide application based on CT, and P5 = without control.

The types of biopesticides used were: (1) Trichol 8, a biofungicide containing the antagonistic fungi *T. harzianum;* (2) NSP, a botanical pesticide made from neem seed powder (NSP) (*Azadirachta indica*) containing azadirahtin compounds; (3) Virgra, an entomopathogenic virus containing particles of *S. litura* Nucear Polyhedrosis Virus (*Sl*NPV); (4) BeBas, a biopesticide containing the entomopathogenic fungal conidia *B. bassiana*; and (5) GE, a botanical pesticide made from galangal rhizome extract (*Alpinia galanga*).

Preventively inundation of biopesticides is the application in abundance amount with the expectation of reducing the pest population in a short time. Scheduled synthetic pesticide control was an application that was carried out every week regardless of the type or population of the pest. Control based on the control threshold (CT) value, namely the applications of both biopesticides and synthetic pesticide were adjusted with the control threshold value for each type of pest (*Table 1*).

Table 1. *Control threshold (CT) for each type of pest in mungbean and time of control*

No.	**Type of pest**	**Control threshold for each type of pest in mung beans and time of control**		
		Control threshold (CT)	**Biopesticide**	**Synthetic pesticide**
	Pests			
1.	*O. phaseoli*	1 adult/50 cluster, plant age of 5 DAP*	NSP** (7, 14, 21, 28 DAP)	Monocrotophos (7, 14, 21, 28 DAP)
2.	*S. litura* *L. indicata* *C. chalcites*	10 insects of instar 3/10 clump, plant flowering age; 13 insects /10 clump, pod filling stage	Virgra (28, 35, 42, 49 DAP)	Cyhalothrin (28, 35, 42, 49 DAP)
2.	*B. tabaci*	1 pair of adult/ 20 clump, plant age of 21 DAP	BeBas (21, 28, 35, 42 DAP)	Thiamethoxam (21, 28, 35, 42 DAP)
3.	*R. linearis* *N. viridula*	1 pair of adult/20 clump, plant age of 35 DAP	BeBas (35, 42, 49, 53 DAP)	Cypermethhrin (35, 42, 49, 53 DAP)
4.	*M. testulalis*	2 insects/20 clump, plant age of 42 DAP	Virgra (42, 49, 53 DAP)	Cypermethrin (42, 49, 53 DAP)
	Diseases			
1.	*S. rolfsii* *R. solani*	IP 10% at plant age of 7-35 DAP	Trichol 8 (seed maintenance, 7, 14, 21, 28, 35 DAP)	Captan (seed maintenance, 7, 14, 21, 28, 35 DAP)
2.	*E. polygoni* *C. canescens* *Uromyces* sp.	IP 35% at plant age of 35 DAP	GE (35, 42, 49, 53 DAP)	Benomyl (35, 42, 49, 53 DAP)

Land preparation

The soil was cultivated by plowing twice then adding organic fertilizer as much as 4 t/ha mixed with soil, then the plots were made with the size of 4 m × 5 m per plot as treatment units. The mungbean variety Vima 1 was planted in each plot with a plant spacing of 40 cm × 15 cm, 2 plants per hole. Inorganic fertilizers as much as 37.5 Kg N/ha, 73.5 Kg P_2O_5/ha, and 37.5 Kg K_2O/ha were all given at planting time by being distributed beside the planting hole. Weeding was done mechanically two times at the age of 14 and 28 days after planting (DAP).

Biopesticides preparation

Trichol 8 biofungicide was obtained from the IETRI Mycology Laboratory, then cultured on potato dextrose agar (PDA) growing media in a petri dish. At the age of 21 days after inoculation (DAI), each fungal culture in the cup was added with 10 ml of water/cup, then the fungal colony was scraped off using a soft brush to knock out the formed conidia. The conidia suspension was put into a beaker glass, then 2 ml/L of Tween 80 was added and shaken using a shaker until it was homogeneous for 60 min. Conidia suspension was calculated using a hemocytometer to obtain a conidia density of 2.5×10^7/ml, then the conidia suspension was mixed with the seeds as a seed treatment before planting. Trichol 8 biofungicide, also applied to the vegetative phase to suppress airborne diseases.

BeBas biopesticide from the entomopathogenic fungus *B. bassiana* was obtained from the ILETRI Biopesticide laboratory collection, then the fungus was cultured in a petri dish using potatoes dextrose agar (PDA) and chitin as growth media. At the age of 21 DAI, 10 ml of water/cup was added to the fungal culture in a petri dish, then the fungi colony was scraped off using a soft brush until all conidia formed were fall out. The conidia suspension was then put into a beaker glass and 2 ml/L of Tween 80 was added and shaken using a shaker for 60 min. Conidia suspension was calculated using a hemocytometer to obtain a conidia density of 10^7/ml before application in the field. The application of BeBas biopesticide was sprayed right on the integument of target insect for optimal control.

Virgra biopesticide containing *S. litura* Nuclear Polyhedrosis Virus (*Sl*NPV) was a JTM97C isolate obtained from the ILETRI Entomology Laboratory. *Sl*NPV isolates were reproduced in the larvae of *S. litura* as a result of rearing in the laboratory. The larvae of *S. litura* were fed with soy leaves every day, after the IV instar was formed. The larvae were fed with soybean leaves that have been sprayed with the *Sl*NPV suspension, then the *S. litura* larvae were maintained until they die. Every 20 dead *S. litura* larvae were crushed using a mortar or blender until smooth, then added with 1000 ml of water. Viral suspension was calculated using a hemocytometer to obtain a density of 10^{11} PIB/ml, then added with Tween 80 as much as 2 ml/L and shaken before being applied in the field. The application of biopesticides derived from entomopathogenic viruses were attached to all plant organs, especially the leaves and pods eaten by insect pests.

NSP biopesticides containing azadirachtin compounds from neem seed powder (*A. indica*) were obtained from the Indonesian Sweetener and Fiber Crops Research Institute (ISFCRI). Every 50 g/L of NSP formulation was first boiled to a boiling point with the aim that all azadirachtin compounds were decomposed and then deposited one night before application in the field. The SBM solution was mixed with 2 ml/L adhesive and then applied in the afternoon to the plant organs according to the predetermined schedule.

Botanical pesticides of galangal rhizome (*A. galangal*) obtained from the Gadang market (Malang) were cut into pieces and then dried. The application dose of galangal extract (GE) was 50 g/L. First GE was boiled to a boil point in order to break down the essential compounds and alicin. Furthermore, biopesticide was applied in the evening to avoid ultraviolet rays and winds that affect the efficacy of biopesticides.

Data observed

The observed variables were: (1) types and populations of pests through direct observation of 10 sample plants or using sweep nets on each treatment plot, (2) types of diseases that appear were visually observed in 10 sample plants in each treatment plot,

(3) leaf pest attack intensity, (4) pod pest attack intensity, (5) disease intensity observed in 10 sample plants by calculating the level of plant damage, (6) species and population of natural enemies were directly observed and harvested using insect nets in each treatment plot, and (7) seeds weight of determined 20 m^2 plot size.

Soil-borne disease intensity was observed based on disease incidence which referred to the van-Schoonhaven and Pastor-Carrales (1991) method with the following formula:

$$KjP = (A/B) \times 100\% \qquad (Eq.1)$$

where KjP = incidence of disease (%), A = number of disease infected plants, and B = number of plants observed.

Leaf disease intensity was observed based on disease severity using the method developed by Paplomatas et al. (1992) with the following formula:

$$KrP = \sum \frac{(nxv)}{N\,x\,V}\,x\ 100\% \qquad (Eq.2)$$

where KrP = disease severity (%), n = number of leaves from each attack category, v = score value for each attack category, N = number of all leaves observed, and V = the highest score of disease score. The type and population of arthropods were observed from an area of 20 m^2 by catching them using a sweep net and yellow trap, as done by Holcomb et al. (2011). Each catch obtained was taken to the laboratory and identified based on the key of determination, referring to the method developed by Gibb and Oseto (2020).

Data analysis

All observed data were analyzed using the Minitab 14 program. If there was a significant difference between treatments, it was followed by a multiple distance test (Duncan’s Multiple Range Test) at the real level α = 0.05.

Results and discussion

Soilborne disease

Soil-borne disease with wilting symptoms at the beginning of growth was caused by the fungus *S. rolfsii*. The results showed that the average incidence of wilt disease was 3-12% (*Fig. 1*). The lowest wilt disease intensity occurred in the inundation treatment of Trichol 8 (P1) by coating the seed before planting and continued application at the age of 14, 21, 28 and 35 DAP. The efficacy of Trichol 8 in suppressing soil borne diseases occured because the fungus of *T. harzianum* was antagonistic in addition to endophytes and decomposer so that it was able to remodel all litter into a source of nutrients that were more quickly available to plants. This resulted in the plants became more fertile and were able to increase plant resistance to pests and pathogenic infections.

The highest incidence of wilt disease was found in the treatment without control (P5) with an intensity of 12.60% and this intensity of the disease was not significantly different from the application of biopesticides or synthetic pesticides based on CT (P2 and P4 treatments). The results of this study indicated that Trichol 8 inundation and the application of chemical fungicides based on CT were not effective in suppressing the development of soil borne diseases. It was suspected that the *S. rolfsii* in the research location was tolerant to synthetic fungicides containing the captan active ingredient.

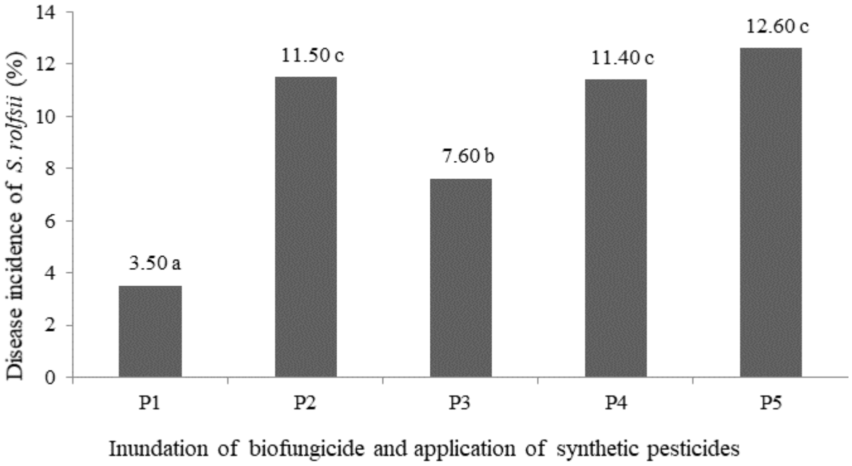

Figure 1. *Inundation of Trichol 8 biofungicide and synthetic pesticides against the incidence of S. rolfsii disease. The treatments: P1 = preventive biopesticide inundation, P2 = biopesticide inundation based on control threshold (CT), P3 = scheduled synthetic pesticide application (weekly), P4 = synthetic pesticide application based on CT, and P5 = without control*

Powdery mildew

The observation results showed that the average powdery mildew disease intensity ranged from 15-37% (*Fig. 2*). The lowest powdery mildew disease intensity occurred in the treatment of botanical pesticide application of galangal GE by inundation which was only 15.50% and the synthetic fungicide scheduled basis, namely 16.75%.

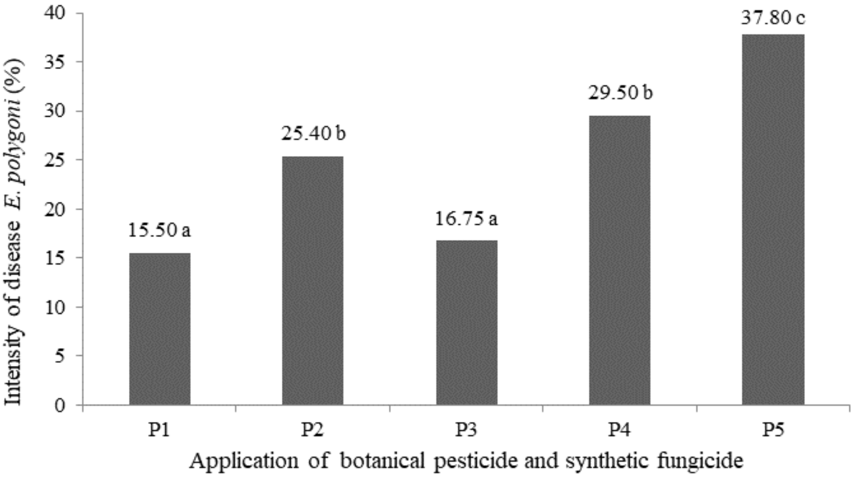

Figure 2. *Efficacy of galangal extract (GE) botanical pesticides and synthetic fungicides in suppressing the development of E. polygoni. The treatments: P1 = preventive biopesticide inundation, P2 = biopesticide inundation based on control threshold (CT), P3 = scheduled synthetic pesticide application (weekly), P4 = synthetic pesticide application based on CT, and P5 = without control*

The results of observations on the application of botanical pesticides from GE (P2) and synthetic fungicides based on CT (P4) were not able to reduce the progression rate of powdery mildew showed by the disease intensities of the two P2 and P4 treatments were 25.40% and 29.50%, respectively. This condition occurred because the rate of disease progression was very fast which was supported by the dry season and the severe wind so that the spores of *E. polygoni* could easily spread and infect other plant organs. Therefore, mung bean leaves that were heavily infected by *E. polygoni* on the entire leaf surface appeared white, covered by mycelium and fungal spores. Leaves heavily infected by powdery mildew turned slightly dark in color and eventually the leaves dried out and fell prematurely (*Fig. 3*).

Figure 3. *Mungbean leaves infected by E. polygoni (P1) which was applied preventive galangal extract (GE) (a) and P5 without control (b)*

Leaf spot and rust disease

Other leaf diseases found were leaf spot, namely *C. canescens* and *Uromyces* sp. with a disease intensity of less than 11% (*Fig. 4*). The intensity of rust disease appeared to be higher than the intensity of leaf spot disease. Inundation of GE preventively (P1) and scheduled synthetic fungicide application (P3) were able to suppress the development of spotting and leaf rust, which were showed by the intensity of the disease appeared to be lower when compared to control based on CT on P2 and P4 treatments. The intensity of leaf spot disease in P1 and P3 was only below 3%. This condition was due to the efficacy of GE and synthetic fungicides that were applied early, which could make pathogens difficult to develop.

Pests population

The results observation obtained 11 types of pests, namely; bean flies (*O. phaseoli*), armyworms (*S. litura*), *Empoasca* sp., *Megalurothrips usitatus*, leafminer (*Liriomyza* sp.), whitefly (*B. tabaci*), brown stink bug (*R. linearis*), green stink bug (*N. viridula*), pale green stink bug (*P. hybneri*), pod borer (*M. testulalis*) and pod feeder (*H. armigera*) (*Table 2*). The population of *S. litura* in the P1 and P3 treatments were 5.9 and 17.5 insect bodies, respectively was lower when compared to P4 (19 insect bodies) and P5 (26.5 insect bodies). The low population in the P1 was due to the Virgra containing *Sl*NPV being able to kill *S. litura* larvae.

Table 2 shows that the populations of *B. tabaci* and *M. usitatus* pests was higher in all treatments except for P3, even if the populations of the two types of pests were uncontrolled, they reached 42.10 and 92.30 insect bodies, respectively. The preventive application of biopesticide (P1) was still found 19 nymphs and adult of *B. tabaci*, while

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34.60 insect bodies of *B. tabaci* were found in P2. Scheduled application of synthetic insecticide thiamethoxam (P3) was found in the nymphs and adult *B. tabaci* with a higher population of 46 insect bodies and an increase in population to 66.90 insect bodies in P4. The results of this study as reported by Fang et al. (2018) which informed that the application of synthetic insecticides that were not in the right dose and target could trigger the explosion of the *B. tabaci* population, apart being caused by all existing natural enemies were killed due to the efficacy of synthetic insecticides in P4 treatment.

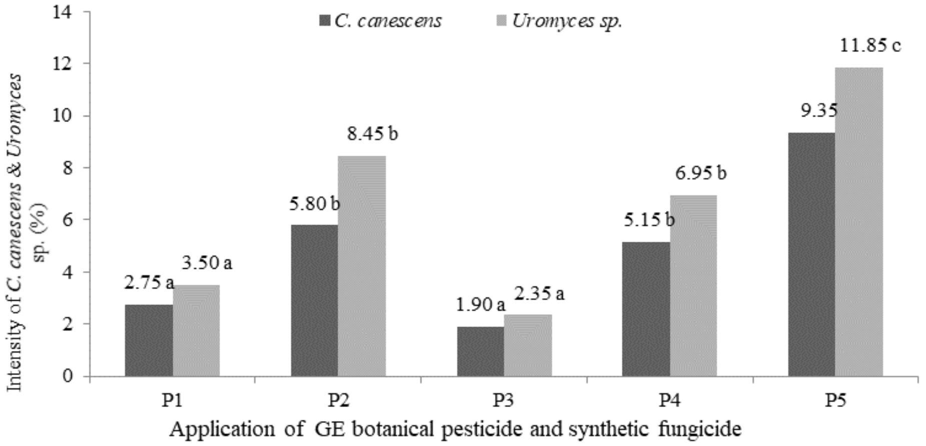

Figure 4. *Efficacy of botanical pesticides GE and synthetic fungicides against mung bean leaf spot and leaf rust. The treatments: P1 = preventive biopesticide inundation, P2 = biopesticide inundation based on control threshold (CT), P3 = scheduled synthetic pesticide application (weekly), P4 = synthetic pesticide application based on CT, and P5 = without control*

Table 2. *Pest populations per plot land of mung bean applied using biopesticides and synthetic pesticides*

No.	**Type of arthropod**	**Pest populations (insect bodies) per plot at 49 DAP ***				
		P1	**P2**	**P3**	**P4**	**P5**
1.	*O. phaseoli*	2.7 bc	4.1 b	2.6 bc	6.4 a	7.5 a
2.	*S. litura*	5.9 cd	0.9 c	17.5 b	19.0 b	24.5 a
3.	*Empoasca* sp.	7.1 d	23.1 b	12.4 d	21.4 bc	57.3 a
4.	*Liriomyza* sp.	3.5 a	2.4 ab	1.5 b	2.5 ab	3.1 a
5.	*M. usitatus.*	11.7 d	23.1 bc	4.5 e	29.0 b	42.1 a
6.	*B. tabaci*	19.0 e	34.6 cd	46.8 c	66.9 b	92.3 a
7.	*R. linearis*	2.4 d	9.7 bc	0.5 d	11.0 b	22.5 a
8.	*N. viridula*	1.7 d	6.1 bc	1.0 d	10.9 b	21.0 a
9.	*P. hybneri*	2.4 cd	3.7 c	2.0 cd	11.7 b	20.9 a
10.	*M. testulalis*	9.9 bc	15.1 ab	4.1 d	12.5 b	20.0 a
11.	*H. armigera*	2.5 b	7.4 a	2.4 b	6.5 a	6.9 a

*The numbers in the row followed by the same notation are not significantly different among treatments in the 0.05 DMRT test

The treatments: P1 = preventive biopesticide inundation, P2 = biopesticide inundation based on control threshold (CT), P3 = scheduled synthetic pesticide application (weekly), P4 = synthetic pesticide application based on CT, and P5 = without control

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The pod pests found were borers caused by *M. testulalis* (Lepidoptera: Crambidae). The lowest pod borer population occurred in the scheduled synthetic insecticide application treatment (P3), namely 4.1 insect bodies followed by preventive biopesticide inundation treatment (P1), namely 9.9 insect bodies. The application of biopesticides and synthetic pesticides based on CT had not been able to suppress pod borer attack because it was found that the pest population was higher than P3 and P1. The population of pod borer larvae continued to increase if do no control was applied (P5), which reached 20 insect bodies.

The results of this study indicated that scheduled control using synthetic insecticides (P3) and preventive inundation of biopesticides (P1) could be more effective in suppressing the mung bean pod borer population. The efficacy of P1 treatment was thought to be due to the impact of the accumulated application of *Sl*NPV, NSP, and BeBas so that the pod borer population could not develop. Subhasree (2013) reported that the fungus *B. bassiana* and NSP was effective enough to kill pod borer, causing mortality to reach 79%.

Abundance of natural enemies

Insects as natural enemies that were observed, namely five types of predators and three types of parasitoid and other species of parasitoids that had not been identified. Five types of predators were found, namely; *Oxyopes* sp., *Paederus* sp., *Coccinella* sp., *Andrallus* sp., and *Sycanus* sp. (*Table 3*).

Table 3. *Population abundance of natural enemies (predators and parasitoids) per plot of mung beans applied with biopesticides and synthetic pesticides*

Type of natural enemies	**Population of natural enemies (insect bodies) per plot at 49 DAP ***				
	P1	**P2**	**P3**	**P4**	**P5**
Predator					
1. *Oxyopes* sp.	4.8 b	12.9 a	0.5 c	0.8 c	13.9 a
2. *Paederus* sp	10.2 c	18.5 ab	0.4 d	0.7 d	19.5 a
3. *Coccinella* sp.	4.9 c	13.5 b	0.0 d	1.2 cd	20.4 a
4. *Andrallus* sp.	2.1 a	1.8 ab	0.0 c	0.1 c	1.9 ab
5. *Sycanus* sp.	2.0 a	1.9 a	0.0 c	0.0 c	1.6 ab
Parasitoid					
1. *Trichogramma* sp.	27.8 b	23.5 bc	0.9 d	1.0 d	38.7 a
2. *Telenomus* sp.	21.6 c	31.2 b	1.5 d	0.3 d	41.5 a
3. *Apantheles* sp.	19.5 a	11.5 b	0.5 c	0.9 c	21.9 a
Other species	17.5 ab	21.8 a	2.1 c	2.1 c	23.8 a

*The numbers in the row followed by the same notation are not significantly different between treatments in the 0.05 DMRT test

The treatments: P1 = preventive biopesticide inundation, P2 = biopesticide inundation based on control threshold (CT), P3 = scheduled synthetic pesticide application (weekly), P4 = synthetic pesticide application based on CT, and P5 = without control

There were three types of parasitoid insects identified, namely: *Trichogramma* sp., *Telenomus* sp. and *Apantheles* sp. and there were other species that had not been identified. The populations of these three types of parasitoids were abundant at P5, P2 and P1 (*Table 3*). The population of *Telenomus* sp. was the highest until it reached 41 insect bodies, namely at P5 then followed by P2, namely 31 insect bodies and P1 as many as 21 insect bodies. The population of *Trichogramma* sp. The highest also occurred in P5, reaching 38 insect bodies, then P1, namely 27 insect bodies and P2 with 23 insect bodies. Meanwhile, P3 and P4 treatments were applied with synthetic pesticides and on a regular basis, it appeared that the parasitoid population was very limited and even almost extinct. This condition was caused by parasitoid insects more susceptible to synthetic pesticides than insect pests. These three types of parasitoids were generally effective in parasitizing eggs and larvae of *S. litura*. Therefore, the population of *S. litura* was lower in treatment P1 and P2 when compared to P5.

Pod damaged

The results of the observation showed that the highest number of empty pods reached 5.5 pods per plant hill that occurred in treatment P5 (without control) (*Fig. 5*). The number of empty pods in P2 and P4 treatments was also quite large, namely 4.5-4.8 pods per plant hill which was not significantly different from the number of pods in P5. The lowest number of empty pods was only 2.5 pods per plants hill which occurred in the scheduled insecticide application treatment (P3) and the number of empty pods was not significantly different from the P1 treatment, namely 3.1 pods per hill.

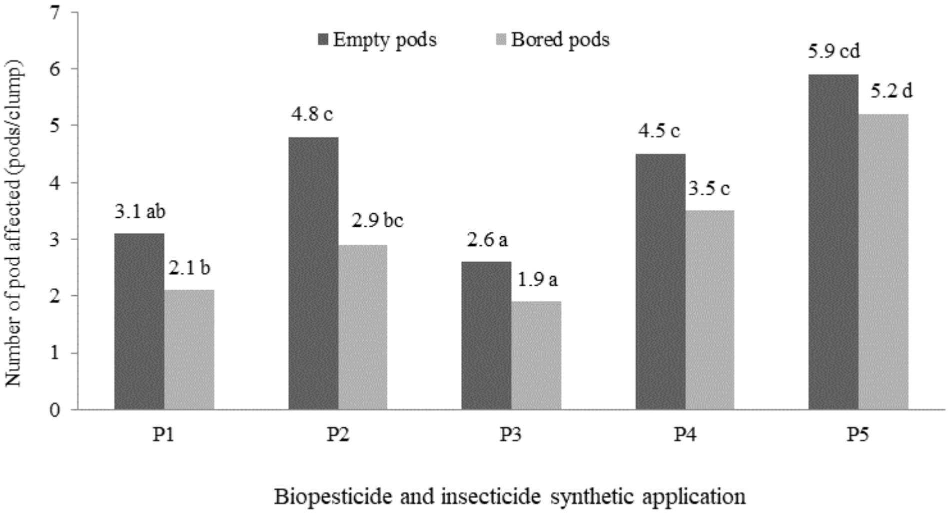

Figure 5. *Number of empty pods and bored pods on mung bean fields applied with biopesticides and synthetic pesticides. The treatments: P1 = preventive biopesticide inundation, P2 = biopesticide inundation based on control threshold (CT), P3 = scheduled synthetic pesticide application (weekly), P4 = synthetic pesticide application based on CT, and P5 = without control*

The results of the observation showed that the number of pods bored by *M. testulalis* was quite low at P1, P2, and P3, which ranged from only 1.8-2.0 pods per plant. The control efficacy in P1 and P2 was due to the use of the biopesticide Virgra and BeBas, which had the ability to kill all insect stages. The highest number of bored pods was found in the uncontrolled treatment (P5), namely up to 5 pods per plant, the number of pods was not significantly different from the application treatment using the insecticide cypermethrin based on CT (P4). Thus, the application of cypermethrin based on CT had not been able to suppress pod damage. This condition was due to the larvae of *M. testulalis* developing in the pods so that the synthetic insecticide application was unable to reach the target insects. In addition, the CT value for pod borer caused by *M. testulalis* larvae need to be reviewed so that the control technology set was accurate so that it did not cause losses. Indiati et al. (2021) reported that *M. testulalis* attacks with control application reduced pod damage of mungbean by 48.5% and increased mung bean seed yield by 25% compared to without control.

Seed weight

The research results showed that the average seed weight obtained ranged from 0.71 to 1.03 t/ha (*Fig. 6*). The highest seed weight was obtained from P3, which reached 1.03 t/ha and the weight of the seeds of this treatment was not significantly different from P1, namely 1.02 t/ha. The P2 and P4 treatments, namely the application of biopesticides and synthetic pesticides based on CT, obtained lower seed weight when compared to P1 and P3. Control based on CT, either using biopesticides or synthetic pesticides, had not been able to defend the pods from pests and diseases. This condition occurred, especially the applied biopesticide was unable to kill the pest in a short time, in addition, the application of synthetic pesticides was not able to reach the borer larvae in the pods so that the pests continue to damage the pods.

Seed weight occurred at P5 (without control) was only 0.71 t/ha, by which this condition was caused by many seeds that were empty due to pod sucking bug and being bored by *M. testulalis*. In addition, in the P5 treatment, there were also many whitefly populations whitefly and *M. usitatus* besides *S. litura* armyworm pests.

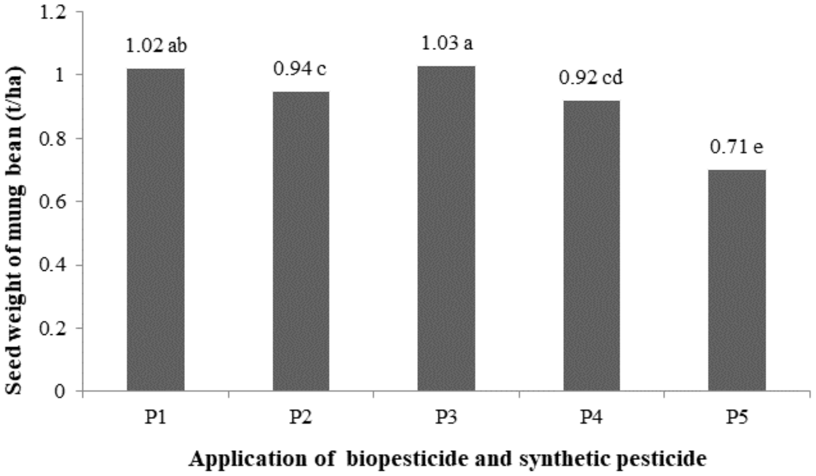

Figure 6. *Average mungbean seed weight (t/ha) applied using biopesticides and synthetic pesticides. The treatments: P1 = preventive biopesticide inundation, P2 = biopesticide inundation based on control threshold (CT), P3 = scheduled synthetic pesticide application (weekly), P4 = synthetic pesticide application based on CT, and P5 = without control*

The intensity of powdery mildew in the two treatments was able to reduce the rate of disease progression because it was lower than the CT value, which was 21% at the time of flowering (Sing et al., 2013). The efficacy of GE occured because the botanical pesticide contained various types of metabolite compounds, such as cineol, acetoxychavicol and acetoxyeugenol which function as antimicrobials (Subramanian and Nishan, 2015). Meanwhile, Simarmata (2017) stated that galangal rhizome extract (GE) could suppress the development of rust disease (*Phakopsora euvitis*) up to 70% and anthracnose (*Colletotrichum gloeosporioides*) up to 100%, such as the efficacy of the fungicide Mankozeb.

The low intensity of leaf spot and rust disease was also caused by the role of the Trichol 8, which was an endophytic agent that could suppress the development of leaf disease. This incident was also reported by Shultana et al. (2009) who indicated that the endophytic fungus *T. harzianum* was able to inhibit the development of leaf spot and rust disease. In addition, the effect of the application of NSP which contained azadirahtin, nimbin and salanin compounds functions as a food repellent, affected nerves that produce ecdisone hormone for the moulting process of insects, and reduced insect vertility so that egg production was very limited (Malik et al., 2017).

Empoasca sp. insect was also found with quite high population which was occurred in almost all control treatments. Scheduled preventive inundations of biopesticide (P1) and synthetic insecticide (P3) found the population of *Empoasca* sp. of 7.1 and 12.4 insect bodies, respectively. Meanwhile, the P2 and P4 treatments found the population of *Empoasca* sp. higher than P1 and P3. These insects are quite important leaf-sucking pests because they function as virus vectors in various types of plants (Acosta et al., 2017).

The five types of predators were generalist species that have the ability to prey on various types of major pests. *Oxyopes* sp. and *Paederus* sp. were the predator that occupied the surface of the soil and plant canopy so that the two types of predators had a fairly wide range of prey (pests). Predator *Coccinella* sp., *Andrallus* sp., and *Sycanus* sp. were plant canopy inhabitants that prey on pests that develop on the crown such as *B. tabaci*, *Aphis* sp., *S. litura*, *Empoasca* sp., and other pests (Udiarto et al., 2012). Meanwhile, *Oxyopes* sp. has a fairly high predation capacity in preying on almost all types of pests in the order Diptera, Orthoptera, Coleoptera, Hemiptera, Homoptera, and Lepidoptera (Riaz et al., 2014). Khan and Wan (2015) reported that the predator *C. septempunctata* was able to predict the nymphs and adult of *B. tabaci* up to 11 insect bodies/day. Furthermore, Ali et al. (2020) informed that the predator *Paederus* sp., *Coccinella* sp., *Oxyopes* sp. also had the ability to predict insect pests from pod sucker groups up to 9 insect bodies/day.

Abundant predator populations were found in the P5, P2 and P1 treatments, especially the *Paederus* sp. whereas the predator population at P3 and P4 was relatively low even for *Andrallus* sp. and *Sycanus* sp. were not found. Abundance population of the predator *Paederus* sp. due to the predators, the inhabitants of the canopy and the soil surface were very fast moving and immediately fall to the ground if there were vibration or disturbance so that the activity of biopesticide application did not have a negative effect on its survival. The results of the research by Sajap et al. (2001) indicated that the biopesticide from the entomopathogenic virus *Sl*NPV did not affect the survival of the *S. leucomesus* predator, unless the predator had preyed on the host (eggs/larvae) that had been infected with the entomopathogenic virus.

The application of biopesticide BeBas by inundation was able to suppress pod sucking pests as well as the efficacy of the pesticide cypermethrin which was applied regularly. The efficacy of the biopesticide *B. bassiana* is because it can kill all pod sucking bug, both *R. linearis* and *N. viridula*, with a mortality of up to 80% (Prayogo and Tantawizal, 2015).

Conclusions

Inundation of Trichol 8, SNP, Virgra, BeBas and GE biopesticides which were applied in an integrated preventive manner reduced the attack of major pests in mung beans equivalent to the efficacy of synthetic pesticides which were applied regularly. The application of biopesticides by inundation sustained the survival of predators and parasitoids, while the application of synthetic pesticides destroyed the entire population of natural enemies. The authors recommend for future studies that the control threshold of each pest organism in mungbean needs to be further investigated so that the control time is not too late in order to avoid high yield losses.

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