

INTEGRATED BIOLOGICAL TECHNOLOGY TO CONTROL MUNGBEAN PESTS AND DISEASES

Integrasi Teknologi Pengendalian Biologi pada Hama dan Penyakit Tanaman Kacang Hijau

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ABSTRACT

The main constraints to increase mungbean production in Indonesia are pests and diseases. The application of integrated biological agents can improve the efficacy of controlling the mungbean pests and diseases. The study aimed to determine the efficacy of integrated biological agents to suppress mungbean pests and diseases. This field research was conducted from May to July 2018 using a randomized block design with seven treatments and four replicates. The treatments were: T1 = Trichol + NSP, T2 = Trichol + S/NPV, T3 = Trichol + NSP + S/NPV, T4 = Trichol + NSP + S/NPV + BeBas, T5 = Trichol + NSP + S/NPV + BeBas + GE, T6 = chemical pesticides, and T7 = control. The results showed that the highest efficacy occurred in T4 and T5 treatments which saved the yield loss from major pests and diseases attack, and did not differ significantly with chemical pesticides (T6). Treatments T4 was able to reduce the development of soil borne diseases by 3% and suppress *Spodoptera litura* attack by 9.8% as compared to chemical treatment. T4 was also more efficient than T5 because it uses less biological agents. The advantage of biological agents is compatible if they were used together with predators such as *Oxyopes* sp., *Paederus* sp. and *Coccinella* sp; and also *Telenomus* sp. and *Trichogramma* sp. parasitoids. On the other hand, the chemical pesticides (T6) killed all existing natural enemies. Therefore, T4 could be recommended for controlling mungbean pests and diseases.

[Keywords: biological agents, innovative technology, integrated pest control, mungbean]

ABSTRAK

Kendala utama dalam meningkatkan produksi kacang hijau di Indonesia ialah hama dan penyakit. Penggunaan beberapa jenis agen hayati secara terintegrasi dapat meningkatkan efektivitas pengendalian hama dan penyakit kacang hijau. Penelitian ini bertujuan untuk mengetahui efikasi agen biologi yang diaplikasikan secara terintegrasi untuk menekan populasi hama dan penyakit tanaman kacang hijau. Penelitian lapang dilaksanakan pada Mei sampai Juli 2018, menggunakan rancangan acak kelompok dengan tujuh perlakuan dan diulang empat kali. Perlakuan yang diuji yaitu P1 = Trichol + SBM,

P2 = Trichol + S/NPV, P3 = Trichol + SBM + S/NPV, P4 = Trichol + SBM + S/NPV + Bebas, P5 = Trichol + SBM + S/NPV + Bebas + EL, P6 = pestisida kimia, dan P7 = kontrol (tanpa pengendalian). Hasil penelitian menunjukkan bahwa efikasi tertinggi terjadi pada perlakuan P4 dan P5, karena dapat menyelamatkan hasil kacang hijau dari hama dan penyakit utama, dan tidak berbeda nyata dengan perlakuan pestisida kimia (P6). Perlakuan P4 mampu menurunkan perkembangan penyakit tular tanah sebesar 3% dan menekan serangan *Spodoptera litura* 9,8% dibandingkan dengan penggunaan insektisida kimiawi. Kelebihan dari agen biologi ialah kompatibel bila diaplikasikan bersama dengan predator *Oxyopes* sp., *Paederus* sp., dan *Coccinella* sp, serta parasitoid *Telenomus* sp. dan *Trichogramma* sp. Pengendalian secara konvensional dengan pestisida kimia (P6) dapat membunuh seluruh musuh alami. Selain efektif, P4 juga lebih efisien dibanding P5 karena lebih sedikit dalam menggunakan agen biologi. Oleh karena itu, P4 dapat diaplikasikan untuk mengendalikan hama dan penyakit pada tanaman kacang hijau.

[Kata kunci: agen biologi, kacang hijau, pengendalian hama terpadu, teknologi inovatif]

INTRODUCTION

Pests and diseases are one of the main obstacles to increase mungbean production in Indonesia. There are numerous kinds of pests and diseases that infested mungbean from the beginning of growth up to harvesting time. The kind of pests will be different between locations so that the control technology used is also different (Pande et al. 2009; Ryley et al. 2010). Pest at the juvenile stage is bean fly (*Ophiomyia phaseoli*). At vegetative phase, there are armyworm (*Spodoptera litura*), leaf roller (*Lamprosema indicata*), semilooper (*Chrysodeixis chalcites*), whitefly (*Bemisia tabaci*), leaf sucker (*Empoasca* sp.), mite (*Tetranychus urticae*) and thrips. At generative phase, there were found pod sucking bugs (*Riptortus linearis*, *Nezara viridula*, *Piezodorus hybneri*), pod borer (*Maruca testulalis*), and pod feeder (*Helicoverpa armigera*) (Brier

2010; Swaminathan et al. 2012). Moreover, mungbean diseases caused by fungi are quite a lot also, among others were soil-borne pathogens (*Rhizoctonia solani*, *Sclerotium rolfsii*, *Fusarium* sp., *Phytophthora* sp., *Phytium* sp.) which can cause yield losses from 30% to 100% (Ryley et al. 2010; Kaur et al. 2011).

Generally, farmers were rely on the efficacy of chemical pesticides to manage pest and disease population, but the optimal goal from this action has not been obtained because the populations in the field are still high and difficult to be controlled. This phenomenon occurred because several kinds of pests have experienced resistance to most chemical pesticide formulations thus they become difficult to be controlled. Therefore, an effective and efficient control technology which can reduce the occurrence of resistance and resurgence of the target pest is highly required.

The use of biological agents to control plant pest and disease have been reported by Sarwar (2015a & 2015b). The advantages of biological controls are (1) high efficacy in suppressing the development of pests and diseases, (2) easy to decompose in nature, (3) not cause resistance and resurgence, (4) safe for water sources, livestock, pets, humans or the environment, (5) available abundantly, (6) able to be produced using simple equipments, and (7) producing organic products which have a high value.

The study about biological control reported by Bastakoti et al. (2017) indicated that antagonistic fungus *Trichoderma* sp. was highly effective for suppressing the development of soil borne pathogens, *S. rolfsii* and *R. solani*. Moreover, the use of neem seed powder containing azadirachtin compound was effective for suppressing the development of *O. phaseoli* and *S. litura*. This azadirachtin compound is also capable for repelling *B. tabaci* infestation (Lynn et al. 2010; Indiaty et al. 2013; Indiaty 2014).

The research improvement in biological control was also reported by Prayogo (2013a & 2013b), that biological agents from entomopathogenic fungus *B. bassiana* were able to kill several kinds of pests including green stink bug (*N. viridula*). *B. bassiana* is able to parasitize the spores of several kinds of plant diseases including rust, downy

mildew and powdery mildew (Prayogo 2011a). Others, *B. bassiana* is compatible with such natural enemies (*Paederus fuscipes*, *Oxyopes javanus* and *Coccinella* sp.) (Prayogo 2011b). The use of entomopathogenic viruses containing polyhedral viruses has succeeded for killing *S. litura*, *C. chalcites*, *L. indicata*, and *Etiella zinckenella* (Bedjo 2016; Ahmad et al. 2018). Indiaty et al. (2013) reported that the combination of *Spodoptera litura* Nuclear Polyhedrosis Virus (S/NPV) and neem seed powder (NSP) was more effective for controlling *S. litura* as compared with single application. According to Srinivasan (2012), the application of several kinds of integrated biological agents can improve the efficacy of pests and diseases control. In addition, to reduce the resistance and resurgence, it is necessary to develop pest management technology by optimizing biopesticides through an integrated application (Koul 2011; Nawaz et al. 2016). Therefore, the objective of this research was to study the efficacy of various types of biological agents that were applied in an integrated manner to suppress the development of major mungbean pests and diseases.

MATERIALS AND METHODS

Field Experiment

This research was conducted at Ngale Experimental Station, Ngawi, East Java, Indonesia: 7°24'0"S, 111°20'0"E in May to July 2018. This research was arranged using randomized block design with seven treatments and four replications. Vima 1 mungbean variety was planted on area of 4 m x 5 m with a spacing of 40 x 15. The treatments were various kinds of biological agents to suppress pest population and infestation that were applied in an integrated manner (Table 1).

The kinds of biological agents and chemical pesticides used were (1) Trichol (50 g 10⁻¹ kg seed), an antagonistic fungus containing *Trichoderma harzianum* for controlling soil borne diseases, increasing resistance to insect pests, and as a decomposer; (2) NSP (50 g l⁻¹), neem seed powder containing azadirachtin compounds

Table 1. The kind of biological agents used for controlling the major mungbean pests and diseases.

Treatment	Kind of biological agents and application time (WAP*)					
	Trichol	NSP	SINPV	BeBas	GE	Chemical
T1	0,2,3,4	3,4,5,6	-	-	-	-
T2	0,2,3,4	-	3,4,5,6	-	-	-
T3	0,2,3,4	3,4,5,6	3,4,5,6	-	-	-
T4	0,2,3,4	3,4,5,6	3,4,5,6	4,5,6,7	-	-
T5	0,2,3,4	3,4,5,6	3,4,5,6	4,5,6,7	3,4,5,6	-
T6	-	-	-	-	-	0,2,3,4,5,6,7,8
T7	Control (no biological agents/pesticide was applied)					

*WAP = week after planting

NSP = neem seed powder; S/NPV = *Spodoptera litura* Nuclear Polyhedrosis Virus; BeBas = *Beauveria bassiana*; GE = galangal extract.

to refuse insect to come to the plants, inhibit insect appetite and reduce insect fertility; (3) *S/NPV* (2 g l⁻¹), an entomopathogenic virus containing *S. litura* Nuclear Polyhedrosis Virus for killing larva of the order of Lepidoptera; (4) BeBas (2 g l⁻¹), an entomopathogenic fungus containing *B. bassiana* conidia for controlling foliage insect and pod sucker as well as thwarting egg hatch; (5) GE (80 ml l⁻¹), galangal extract containing plant-based pesticides for controlling leaf diseases; (6) chemical pesticides (fungicides) containing active ingredients of kaptan to control soil borne diseases, benomyl to control leaf diseases, thiamethoxam to control leaf sucker and sipermethrin to control pod sucker and pod borer (2 ml l⁻¹), which were applied according to plant age and target pest; and (7) without any application.

Each biological agent was applied consecutively by inundation four times so that the population of the biological agent has been survived and abundant. Thus, each kind of pest was not interested for coming to the plants or pest that comes will be infected by biological agents.

Biological Agents Preparation

Trichol was obtained from phytopathology laboratory of the Indonesian Legumes and Tuber Crops Research Institute (ILETRI), Malang. Neem seed powder (NSP) was obtained from the Indonesian Sweetener and Fiber Crops Research Institute, Malang. NSP solution was made simply (immersion method) by dissolving 50 g of NSP in 1 l of water, then blend it for 5 minutes and soaked for overnight. After 24 hours, the solution was filtered with furing cloth and added 1 g of detergent, stirring evenly, and ready to use. *S/NPV* used was JTM97C isolate, powder formulations from entomology laboratory of ILETRI which has high virulence. The fungal isolate of *B. bassiana* which had the highest virulence in 2011 was cultured on potato dextrose agar (PDA) medium. At 21 days after inoculation (DAI), the formed conidia were grown on maize media in the laboratory. After the next 21 days, *B. bassiana* conidia formed were mixed with water, then the conidia density was counted using a haemocytometer to obtain 10⁷ ml⁻¹ conidia density. Conidia suspension of *B. bassiana* was added with 2 ml of Tween 80 as an adhesive before field application. Galangal extract was made simply by cleaning and thinly cutting the galangal rhizome then blending and filtering. Every 100 g of galangal rhizome were added 4 l of water.

Observation and Data Analysis

Soil borne diseases (*S. rolfii*) were observed by calculating disease incidence in each plot followed a

formula: $DI = \frac{A}{B} \times 100\%$, in which DI = disease incidence (%), A = the number of plants affected by the disease, and B = total number of plants observed (Kone et al. 2017). The intensity of leaf disease (powdery mildew caused by *E. polygoni*) was observed based on the severity of the disease followed a formula: $LDI = \frac{\sum \frac{n_i \times v_i}{ZN}}{V} \times 100\%$, in which LDI = leaf disease intensity (%), n = number of leaves from each attack category, v = score of each attack category, N = total number of leaves observed, V = highest score of disease (Li et al. 1989 in Zhang et al. 2014).

Moreover, the kind and population of insects were observed visually by taking 10 samples of plant from each plot or by collecting the insects using a sweep net in a five single swing. The attack intensity of foliage pest (*S. litura* and *B. tabaci*) was observed in 10 samples in each plot. The attack intensity of pod sucking pest (*N. viridula*) and pod borer (*M. testulalis*) were observed by taking 20 pods randomly in each plot at harvesting time. The kind and population of natural enemies (*Oxyopes* sp., *Paederus* sp., *Coccinella* sp., *Trichogramma* sp. and *Telenomus* sp.) were observed visually by collecting them using a sweep net then be brought to the laboratory and observed under binocular microscope followed the insect identification key. Seed weight taken from 20 m² areas was measured by digital scale at harvesting time (57 days after planting).

Data were subjected to analysis of variance (ANOVA). Mean values were compared using Tukey's test when significant F values were obtained ($\alpha = 0.05$; SPSS ver. 22).

RESULTS AND DISCUSSION

Soil Borne Disease Intensity

The highest intensity of soil borne disease caused by *S. rolfii* occurred in T7, which was 39.15% (Figure 1). The lowest incidence of the disease occurred in T4, which was 8.30%. The incidence of disease in T3, T5, and T2 were 8.90%, 8.90%, and 8.95%, respectively. However, the intensity of soil borne diseases in T1 was higher than that in T2, T3, T4 and T5, but the damage was not significantly different. The incidence of soil borne diseases in T6 (application of chemical fungicide) by using active ingredients (kaptan) was 11.75%, higher than that in T1, T2, T3, T4 and T5 in which an application was done by using biological agents.

The intensity of powdery mildew caused by *E. polygoni* ranged from 27.20% to 58.75% in which the lowest intensity occurred in T6 with kaptan active ingredient (27.20%) (Figure 2). However, the efficacy of the chemical fungicide for controlling powdery mildew was not significantly different from the efficacy

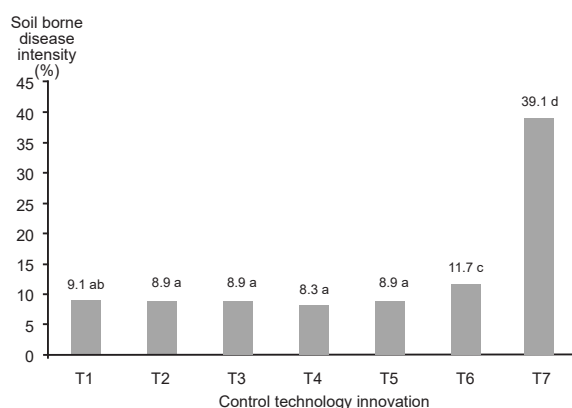


Fig. 1. Soil borne disease intensity controlled by biological agents and chemical pesticides. T1 = Trichol + NSP, T2 = Trichol + S/NPV, T3 = Trichol + NSP + S/NPV, T4 = Trichol + NSP + S/NPV + BeBas, T5 = Trichol + NSP + S/NPV + BeBas + GE, T6 = chemical pesticides, and T7 = control, no biological agent. Consult Table 1 for abbreviation of treatments.

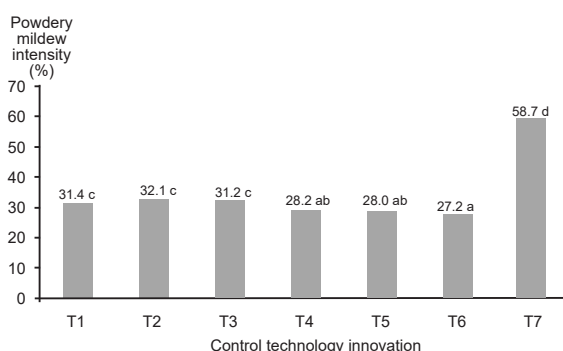


Fig. 2. Powdery mildew intensity controlled by biological agents and chemical pesticides. T1 = Trichol + NSP, T2 = Trichol + S/NPV, T3 = Trichol + NSP + S/NPV, T4 = Trichol + NSP + S/NPV + BeBas, T5 = Trichol + NSP + S/NPV + BeBas + GE, T6 = chemical pesticides, and T7 = control, no biological agent. Consult Table 1 for abbreviation of treatments.

of biological agents in T4 and T5. The intensity of powdery mildew in T1, T2 and T3 were low (31–32%), but the intensity was higher than that in T4, T5 and T6. The severity of powdery mildew was getting heavier if it was not controlled (T7), which caused plant damage up to 58.75%. Almost the entire surface of the leaves was covered by mycelium and white-colored flour dew spores (Figure 3).

Foliage Pest Intensity

Foliage pests found in mungbean field were *S. litura* and *B. tabaci*. The attack intensity of *S. litura* was not too high, especially in the treatment using S/NPV which were T2 (8.80%), T3 (8.50%), T4 (7.10%), and T5 (7.05%) (Figure 4). The attack intensity of *S. litura* in T6 was higher (16.90%) than that in T2, T3, T4 and T5. However,



Fig. 3. Mungbean leaves infected by powdery mildew in an uncontrolled plot (A) and controlled plot by chemical fungicide (B).

the intensity of leaf damage in T6 did not differ significantly from T1. Meanwhile, the intensity of leaf damage due to *S. litura* was high in T7 (21.35%).

The attack intensity of *B. tabaci* was higher than that of *S. litura*. The lowest attack intensity of *B. tabaci* occurred in T6, which was 9.60%, and the highest attack intensity was in T7, which was 25.1%. (Figure 5). The application of T1, T2, T3, T4, and T5 was not significantly different to minimize the attack intensity of *B. tabaci*.

The Number of Empty Pods and Damaged Pods

The results showed that pod pests consisted of pod sucking bug (*N. viridula*) and pod borer (*M. testulalis*). The intensity of pod sucking bug was measured by the number of empty pods, which ranged from 0.6 to 1.8 pods per plant (Figure 6). The lowest attack intensity of pod sucking bug occurred in T6 and T5, which were 0.6 pods. The number of empty pods in T1 was higher (1.3 pods) than that in T2, T3 and T4 (0.7–0.8 pods).

Pod damaged caused by pod borer ranged from 0.5 to 2.2 pods. The lowest intensity occurred in T4 and T5,

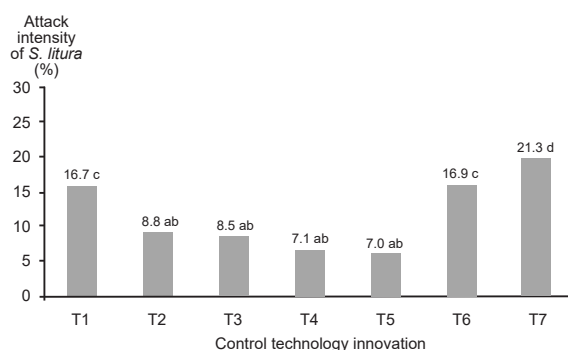


Fig. 4. Attack intensity of *Spodoptera litura* controlled by biological agents and chemical pesticides. T1 = Trichol + NSP, T2 = Trichol + S/NPV, T3 = Trichol + NSP + S/NPV, T4 = Trichol + NSP + S/NPV + BeBas, T5 = Trichol + NSP + S/NPV + BeBas + GE, T6 = chemical pesticides, and T7 = control, no biological agent. Consult Table 1 for abbreviation of treatments.

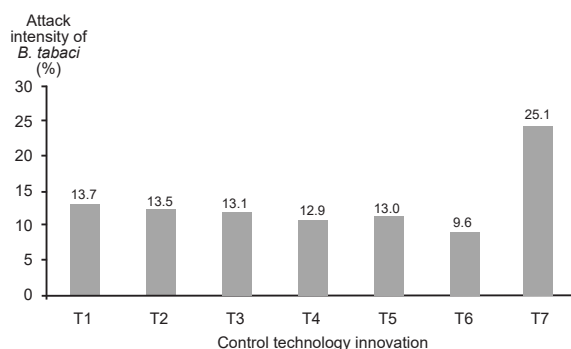


Fig. 5. Attack intensity of *Bemisia tabaci* controlled by biological agents and chemical pesticides. T1 = Trichol + NSP, T2 = Trichol + S/NPV, T3 = Trichol + NSP + S/NPV, T4 = Trichol + NSP + S/NPV + BeBas, T5 = Trichol + NSP + S/NPV + BeBas + GE, T6 = chemical pesticides, and T7 = control, no biological agent. Consult Table 1 for abbreviation of treatments.

which was 0.5 pods and it was lower than that in T6 (0.6 pods). Pod damaged in T1 and T2 was higher (0.8 pods) than that in T3, T4, T5 or T6. Meanwhile, the pod damaged in uncontrolled plot (T7) was 2.2 pods (Figure 6).

Kind and Population of Arthropods

The results showed that arthropods captured through sweep net were pests and natural enemies. Arthropods identified as pests were *S. litura*, *Empoasca* sp., *O. phaseoli*, *Thrips* sp., *B. tabaci*, *N. viridula* and *M. testulalis* (Table 2) and those as natural enemies were *Oxyopes* sp., *Paederus* sp., *Coccinella* sp., *Trichogramma* sp. and *Telenomus* sp. Population of *S. litura* at 42 DAP varied from 3 to 19 individuals per 20 plants per plot. The lowest population of *S. litura* was found in T4 (3.50 individuals) and the highest was in T7 (19.50 individuals). The bean fly, *O. phaseoli*, was only found one individual in an uncontrolled plot (T7) and was not found in another plots.

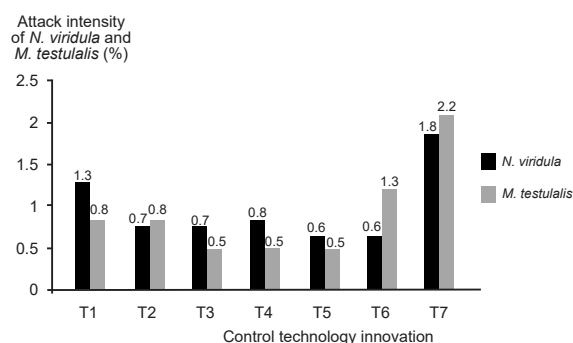


Fig. 6. Attack intensity of *Nezara viridula* and *M. testulalis* controlled by biological agents and chemical insecticide. T1 = Trichol + NSP, T2 = Trichol + S/NPV, T3 = Trichol + NSP + S/NPV, T4 = Trichol + NSP + S/NPV + BeBas, T5 = Trichol + NSP + S/NPV + BeBas + GE, T6 = chemical pesticides, and T7 = control, no biological agent. Consult Table 1 for abbreviation of treatments.

Table 2. Kind and population of arthropods found on mungbean at 42 DAP treated with biological agents and chemical insecticide.

Arthropods	Population of arthropods (individuals/20 plant)						
	T1	T2	T3	T4	T5	T6	T7
Pests							
<i>S. litura</i>	11.5	5.5	4.5	3.5	4.0	14.5	19.5
<i>Empoasca</i> sp.	11.0	10.5	9.5	10.0	9.5	2.5	15.0
<i>O. phaseoli</i>	0.0	0.0	0.0	0.0	0.0	0.0	1.5
<i>Thrips</i> sp.	8.5	10.0	5.5	4.5	7.0	3.0	11.5
<i>B. tabaci</i>	31.5	29.5	25.5	24.0	20.0	24.5	46.0
<i>N. viridula</i>	5.5	4.5	5.0	3.0	4.5	2.0	6.5
<i>M. testulalis</i>	13.5	11.0	13.5	9.0	10.5	11.0	19.5
Natural enemies							
<i>Oxyopes</i> sp.	11.0	3.0	4.5	7.0	9.5	1.5	12.5
<i>Paederus</i> sp.	8.5	5.0	4.5	9.5	8.0	1.5	11.5
<i>Coccinella</i> sp.	3.0	3.0	2.5	2.0	3.5	0.0	5.0
<i>Trichogramma</i> sp.	3.5	6.0	4.5	3.0	3.0	0.0	17.0
<i>Telenomus</i> sp.	63.5	61.0	49.5	39.0	23.0	3.5	72.5

T1 (Trichol + NSP), T2 (Trichol + S/NPV), T3 (Trichol + NSP + S/NPV), T4 (Trichol + NSP + S/NPV + BeBas), T5 (Trichol + NSP + S/NPV + BeBas + GE), T6 (chemical pesticides), and T7 (control, no biological agent). Consult Table 1 for abbreviation of treatments.

Leaf sucker, *Empoasca* sp. was found 2–15 individuals per 20 plants, but the symptoms did not significantly appear. The population of *Thrips* sp. and *N. viridula* were also lower than that of *B. tabaci* so that the damage caused by *Thrips* sp. was also not significant. The population of *B. tabaci* was 20–46 individuals per 20 plants, the highest population occurred in T7. Meanwhile, the population of *M. testulalis* was 9–19 individuals per 20 plants, but has a great chance to reduce mungbean yield.

Natural enemies from predator group found on mungbean were *Oxyopes* sp., *Paederus* sp. and *Coccinella* sp., while those from parasitoid group were

Trichogramma sp. and *Telenomus* sp. The result showed that the population of the three kinds of predators in T1, T2, T3, T4 and T5 did not differ significantly with T7. The population of *Oxyopes* sp., *Paederus* sp. and *Coccinella* sp. were lower in T6 than these in T1, T2, T3, T4 and T5, even though *Coccinella* sp. was not found in T6.

The population of *Trichogramma* sp. and *Telenomus* sp. in all treatments by using biological agents were almost same as those in uncontrolled plot. *Telenomus* sp. was abundant in all treatments by using biological agents, ranged from 23 to 63 individuals, which was almost comparable to the uncontrolled plot (T7) (73 individuals). Meanwhile, the population of *Telenomus* sp. in T6 was only three individuals.

Seed Weight

The results showed that the seed weight ranged from 0.9 to 1.4 t ha⁻¹. The highest seed weight was obtained in T6 (1.4 t ha⁻¹) (Figure 7). Seed weight in T5 was 1.4 t ha⁻¹ and in T4 was 1.4 t ha⁻¹, both treatments were not significantly different from that in T6. Seed weight in T1, T2, and T3 seemed not significantly different among each others even though there were different biological agents applied. In uncontrolled plot, the seed weight was very low (0.9 t ha⁻¹).

Discussion

Soil borne disease in the research area showed wilting symptoms and there was a white mycelium and brown sclerotia in a small round shape at the stem base. This soil borne disease was caused by *S. rolfsii*, especially on the area with high humidity. The incidence of soil borne disease was quite high especially in block III which has the lowest level so that the water flows into the plot and increases soil moisture even though it have been anticipated by drying channels. According to Raghavendra et al. (2018), soil borne diseases develop rapidly in the area with high humidity. Result of the study showed that biological control of soil borne diseases by using *T. harzianum* was more effective than that by chemical fungicides if it is applied in a right way. Results of the study was supported by Prajapati et al. (2015) who recommended to control soil borne diseases by using *Trichoderma* sp. Dubey et al. (2013) also confirmed that *T. harzianum* is more effective than chemical fungicides for suppressing the development of soil borne diseases caused by *S. rolfsii*.

The efficacy of T4 (Trichol + NSP + S/NPV + BeBas) and T5 (Trichol + NSP + S/NPV + BeBas + GE) against powdery mildew was due to the activity of endophytic

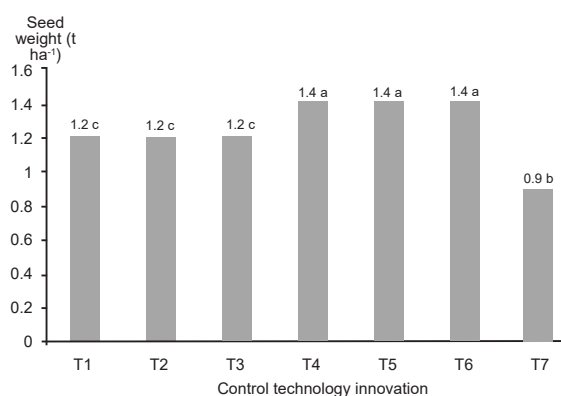


Fig. 7. Seed weight of mungbean applied by biological agents and chemical pesticides. T1 = Trichol + NSP, T2 = Trichol + S/NPV, T3 = Trichol + NSP + S/NPV, T4 = Trichol + NSP + S/NPV + BeBas, T5 = Trichol + NSP + S/NPV + BeBas + GE, T6 = chemical pesticides, and T7 = control, no biological agent. Consult Table 1 for abbreviation of treatments.

fungi, both *T. harzianum* and *B. bassiana*, as well as the galangal extract. Endophytic fungi play a role in producing metabolite compounds or toxins that can suppress the development of disease. *T. harzianum* is an antagonistic fungus and plays a role as an endophytic fungus that was able to suppress the incidence of downy mildew caused by *Peronosclerospora maydis* on maize (Permatasari 2019). Furthermore, Sarief et al. (2014) reported that the antagonistic fungus *Trichoderma* spp. is effective for controlling rust disease on peanut leaves (*Puccinia arachidis*) through its activity as mycoparasites. Meanwhile, Omomowo et al. (2018) also explained that endophytic fungus *Trichoderma* spp. is effective for suppressing powdery mildew in legumes. The study by Ownley et al. (2008) indicated that entomopathogenic fungus *B. bassiana* which was able to be endophytic could colonize plant tissue and inhibit the development of wilting disease caused by *Phytium* spp. and pustular bacteria (*Xanthomonas axonopodis*). Moreover, Rahardjo and Suhardi (2008) explained that galangal extract was effective for controlling powdery mildew on rose plants. Galangal extract produces compounds namely cineol, acetoxychavicol or acetoxyeugenol, which are antimicrobial (Subramanian and Nishan 2015). The results showed that in T1, T2 and T3, the activity of *B. bassiana* and galangal extract had a significant role in suppressing the development of powdery mildew.

The effectiveness of T2, T3, T4, and T5 for controlling *S. litura* was due to the effect of S/NPV which was able to kill all the larval stages of *S. litura* with a fairly high mortality. In addition, it was

suspected that the activity of the azadirachtin contained in NSP can block the nerve producing the ecdysone hormone which functions for molting. Azadirachtin also has an impact on insect pests that are not attracted to the plants and reduces insect fertility so that the population of *S. litura* is low. Results of the study indicated that control technology innovations by using biological agents in an integrated manner, especially NSP, *S/NPV* and *B. bassiana* were more effective for suppressing *S. litura* population as compared to conventional control (chemical insecticides).

Plot applied by Trichol + NSP (T1) showed the highest number of empty pods causing by pod sucking bug. It was occurred because *Trichoderma* spp. and NSP were applied only during vegetative phase thus pod sucking bug was able to infest the plant as the pod sucker only comes to the plant at generative stage. Beside pod sucking bug, pod borer can also damage mungbean seed. The attack intensity of pod borer was characterized by hollow pod so that the seeds cannot be saved because seeds are crushed by *M. testulalis*. The population of *M. testulalis* below 20 individuals per 20 plant or equivalent with one individual per plant has a great potential to reduce mungbean yield. This condition may be due to larval of *M. testulalis* being the most damaging stage on mungbean pods and they spent all the time during this stage into the pod and damaged the seed (Das and Islam 1985). This study showed that the higher number of pods indicated the lower yield obtained. *M. testulalis* is the major pest that causes yield losses in mungbean (Karel 1985). Jackai (1995) suggested control measures by applying systemic chemical insecticides to save mungbean pods from *M. testulalis* attack. However, the biological control by using *B. bassiana* and *Metarhizium anisopliae* was more effective and environmentally friendly as compared to chemical insecticides (Menhito et al. 2014; Tumuhaise et al. 2015).

The bean fly, *O. phaseoli*, population was very low and only found in an uncontrolled plot. This phenomenon is likely because the presence of bean flies is not in accordance with mungbean growth phase so that female is not interested for laying their eggs in plant. Fei et al. (2017) explained that female of *Pieris brassicae* (Lepidoptera: Noctuidae) will lay their eggs on young plants or during juvenile phase. Moreover, Bandara et al. (2009) reported that female of *O. phaseoli* was not interested for laying their eggs on legume plants in the generative phase which produced metabolite compounds.

From the case of natural enemies population, biological control is relatively safer for the survival of natural enemies than chemical insecticide. *Oxyopes* sp. appears more abundant when compared with *Paederus* sp. and *Coccinella* sp. *Oxyopes* sp. is a generalist predator that

quite active in the soil and plant surfaces to prey various kinds of pests. *Coccinella* sp. was not found in plot applied by chemical insecticide. This condition was likely because the major population of *Coccinella* sp. during the observation is in larval stages, in which they move very slowly on the leaf surface. Chemical insecticide applied on the plant surface directly hits the body of predators thus many of them dead. Meanwhile, the potential of these three predators (*Oxyopes* sp., *Paederus* sp., *Coccinella* sp.) is quite high for preying *B. tabaci*, *Aphis gossypii*, *Empoasca* sp. and *S. litura* (Suastika et al. 2005; Udiarto et al. 2012; Riaz and Naqvi 2014). Therefore, the presence of these predators needs to be maintained because they have a significant role in biological control.

Population of *Trichogramma* sp. was lower than the population of *Telenomus* sp., both status are parasitoids. Biological agent applications were known to be relatively safe for maintaining the survival of these parasitoids. The application of chemical insecticide adversely affected the survival of *Trichogramma* sp. because there was no *Trichogramma* sp. found in this treatment. This phenomenon indicated that chemical insecticide adversely affects the survival of natural enemies, both predators and parasitoids. According to (Oliveira de Freitas Bueno et al. 2010), the parasitoid *T. remus* Nixon (Hymenoptera: Scleionidae) had a fairly high level of parasitism on the egg stages of pests from the order of Lepidoptera, Coleoptera, Homoptera, and Hemiptera.

Based on seed weight, there were no significant differences between combination of Trichol + NSP + *S/NPV* + BeBas (T4) and Trichol + NSP + *S/NPV* + BeBas + GE (T5) with a single application of chemical insecticide (T6), in which seed weight was 1.4 t ha⁻¹. However, based on the environmentally friendly aspect, T4 and T5 were safer than T6. T4 was also more efficient as compared with T5 because the treatment used less biological agents and could maintain the yield.

CONCLUSION

Biological agent consisting of combination of Trichol + NSP + *S/NPV* + BeBas was effective in suppressing the development and infestation of major mungbean pests and diseases. This biological control combination was able to maintain the mungbean yield, which is the same as chemical insecticide application, and safe for natural pest enemies. The integration of various components of biological agents could be used as a technological innovation in mungbean cultivation, as an alternative over chemical pesticides.

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