INTEGRATED BIOLOGICAL TECHNOLOGY TO CONTROL MUNGBEAN
PESTS AND DISEASES

Integrisi 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 + SlNPV, T2 = Trichol + SBM, T3 = Trichol + SBM + SlNPV, T4 = Trichol + SBM + SlNPV + Bebas, T5 = Trichol + SBM + SlNPV + Bebas + EL, P6 = pestisida kimia, dan P7 = kontrol (tanpa pengendalian). Hasil penelitian menunjukkan bahwa efeksi tertinggi terjadi pada perlakuan P4 dan P5, karena dapat menyelamatan 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 kimia. 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 memburuk 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.

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

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 (Lamprosoema indicata), semiloopers (Chrysodeixis chalcites), whitefly (Bemisia tabaci), leaf sucker (Empoasca sp.), mite (Tetranychus urticae) and thrips. At generative phase, there were found pod sucking bugs (Riptortus linearius, Nezara viridula, Piezodorus hybneri), pod borer (Maruca testulalis), and pod feeder (Helicoverpa armigera) (Brier...
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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; Indiati et al. 2013; Indiati 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). Indiati et al. (2013) reported that the combination of Spodoptera litura Nuclear Polyhedrosis Virus (SiNPV) 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 1⁻¹), neem seed powder containing azadirachtin compounds

| Treatment | Kind of biological agents and application time (WAP*) |
|-----------|------------------------------------------------------|
| T1        | 0,2,3,4 NSP 3,4,5,6 BeBas - - - - - - |
| T2        | 0,2,3,4 - 3,4,5,6 - - - - - - |
| T3        | 0,2,3,4 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; SiNPV = Spodoptera litura Nuclear Polyhedrosis Virus; BeBas = Beauveria bassiana; GE = galangal extract.

Table 1. The kind of biological agents used for controlling the major mungbean pests and diseases.
to refuse insect to come to the plants, inhibit insect appetite and reduce insect vertility; (3) SNPV (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. SNPV 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 10\(^7\) 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. rolfsii) 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: \( LDI = \frac{\sum n_i \times v_i}{ZN} \times 100\% \), 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 m\(^2\) 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. rolfsii 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
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 SINPV 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, 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,
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.

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

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              |         |         |         |         |         |         |         |
| S. litura          | 11.5    | 5.5     | 4.5     | 3.5     | 4.0     | 14.5    | 19.5    |
| Empoasca sp.       | 11.0    | 10.5    | 9.5     | 10.0    | 9.5     | 2.5     | 15.0    |
| O. phaseoli        | 0.0     | 0.0     | 0.0     | 0.0     | 0.0     | 0.0     | 1.5     |
| Thrips sp.         | 8.5     | 10.0    | 5.5     | 4.5     | 7.0     | 3.0     | 11.5    |
| B. tabaci          | 31.5    | 29.5    | 25.5    | 24.0    | 20.0    | 24.5    | 46.0    |
| N. viridula        | 5.5     | 4.5     | 5.0     | 3.0     | 4.5     | 2.0     | 6.5     |
| M. testulalis      | 13.5    | 11.0    | 13.5    | 9.0     | 10.5    | 11.0    | 19.5    |
| Natural enemies    |         |         |         |         |         |         |         |
| Oxyopes sp.        | 11.0    | 3.0     | 4.5     | 7.0     | 9.5     | 1.5     | 12.5    |
| Paederus sp.       | 8.5     | 5.0     | 4.5     | 9.5     | 8.0     | 1.5     | 11.5    |
| Coccinella sp.     | 3.0     | 3.0     | 2.5     | 2.0     | 3.5     | 0.0     | 5.0     |
| Trichogramma sp.   | 3.5     | 6.0     | 4.5     | 3.0     | 3.0     | 0.0     | 17.0    |
| Telenomus sp.      | 63.5    | 61.0    | 49.5    | 39.0    | 23.0    | 3.5     | 72.5    |

T1 (Trichol + NSP), T2 (Trichol + SINPV), T3 (Trichol + NSP + SINPV), T4 (Trichol + NSP + SINPV + BeBas), T5 (Trichol + NSP + SINPV + BeBas + GE), T6 (chemical pesticides), and T7 (control, no biological agent). Consult Table 1 for abbreviations of treatments.
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 from 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 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 *Phytophthora* spp. and putustar 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 ecdison hormone which functions for molting. Azadirachtin also has an impact on insect pests that are not attracted to the plants and reduces insect vertility so that the population of S. littura is low. Results of the study indicated that control technology innovations by using biological agents in an integrated manner, especially NSP, SlNPV and B. bassiana were more effective for suppressing S. littura 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 gossipii, Empoasca sp. and S. littura (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 + SlNPV + BeBas (T4) and Trichol + NSP + SlNPV + 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 + SlNPV + 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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REFERENCES

Ahmad, J.N., Mustagq, R., Ahmad, S.J.N., Maqsood, S., Ahuja, I. & Bones, A.M. (2018) Molecular identification and pathological characteristics of NPV isolated from spodoptera litura (Fabricius) in Pakistan. Pakistan Journal of Zoology. [Online] 50 (6), 2229–2237. Available from: doi:10.17582/journal.pjz.2018.50.6.2229.2237.

Bandara, K. A., Kumar, V., Ninkovic, V., Ahmed, E., Pettersson, J., Glinwood, R. 2009. Can leek interfere with bean plant-bean fly interaction? Test of ecological pest management in mixed cropping. Journal of Economic Entomology 102(3): 999-1008.

Bastakoti, S., Belbase, S., Manandhar, S. & Arjyal, C. (2017) Trichoderma species as Biocontrol Agent against Soil Borne Fungal Pathogens. Nepal Journal of Biotechnology. [Online] 5 (1), 39–45. Available from: doi:10.3126/njb.v5i1.18492.

Bedjo (2016) Effectiveness of Spodoptera litura Nuclear Polyhedrosis Virus JTM97C against Helicoverpa armigera larvae: In: Rahmianna, A.A., Sholihin, Nugraheni, N., Tautif, A., Suharsono, Saleh, N., Ginting, E., Rozi, F., Tastra, I.K., Hermanto, Yusnawan, E. & Harnowo, D. (eds.) Proceedings of National Seminar on Legumes and Tubers Crops Research Result. Malang, Indonesian Centre for Food Crops Research and Development.

Brier, H. (2010) Integrated pest management in Australian mungbean and soybeans, swings, roundabouts and conundrums.In: Proceedings of the 1st Australian summer grains conference, Gold Coast, Australia. 21st – 24th.

Das, G.P. & Islam, M.A. (1985) Maruca testulalis (Lepidoptera: Pyralidae): an important pest of country bean in Bangladesh. AGRIS Science. 10 (1), 57–66.

Dubey, S.C., Tripathi, A. & Singh, B. (2013) Integrated management of Fussarium wilt by combined soil application and seed dressing formulations of Trichoderma species to increase grain yield of chickpea. International Journal of Pest Management. [Online] 59 (1), 47–54. Available from: doi:10.1080/09676074.2012.744494.

Fei, M., Harvey, J.A., Yin, Y. & Gols, R. (2017) Oviposition Preference for Young Plants by the Large Cabbage Butterfly (Pieris brassicae) Does not Strongly Correlate with Caterpillar Performance. Journal of Chemical Ecology. [Online] 43 (6), 617–629. Available from: doi:10.1007/s10886-017-0853-9.

Indiati, S.W. (2014) Pengendalian hama thrips kacang hijau dengan insektisida nabati dan kimia. Buletin Palawija. [Online] 27, 39–51. Available from: doi:10.21082/bulpa.vn27.2014.p39-51.

Indiati, S.W., Suharsono & Bedjo (2013) NoEffect of application of neem seed powder, Spodoptera litura Nuclear Polyhedrosis Virus and resistant variety to the development of armyworms in soybeans. Journal of Agricultural Food Research. 32 (1), 43–49.

Jackai, L.E.N. (1995) The legume pod borers Maruca testulalis, and its principal host plant, Vigna unguiculata (L.) Walp. - use of selective insecticide sprays as an aid in the identification of useful levels of resistance. Crop Protection. [Online] 14 (4), 299–306. Available from: doi:10.1016/0261-2194(94)00021-Y.

Karel, A.K. (1985) Yield Losses from and Control of Bean Pod Borers, Maruca testulalis (Lepidoptera: Pyralidae) and Heliothis armigera (Lepidoptera: Noctuidae). Journal of Economic Entomology. [Online] 78 (6), 1323–1326. Available from: doi:10.1093/jee/78.6.1323.

Kaur, L., Singh, P. & Sirari, A. (2011) Biplot analysis for locating multiple disease resistant diversity in mungbean germplasm. Plant Disease Research. 26, 55–60.

Kone, N., Asare-Bediako, E., Silue, S., Kone, D., Koita, O., Menzel, W. & Winter, S. (2017) Influence of planting date on incidence and severity of viral disease on cucurbits under field condition. Annals of Agricultural Sciences. [Online] 62 (1), 99–104. Available from: doi:10.1016/j.aoas.2017.05.005.

Koul, O. (2011) Microbial biopesticides: Opportunities and challenges. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources. [Online] 6, 1–26. Available from: doi:10.1079/PAVSNNR20116056.

Lynn, O.M., Song, W.G., Shim, J.K., Kim, J.E. & Lee, K.Y. (2010) Effects of azadirachtin and neem-based formulations for the control of sweetpotato whitefly and root-knot nematode. Journal of Applied Biological Chemistry. [Online] 53 (5), 598–604. Available from: doi:10.3839/jksabe.2010.092.

Menhito, J.T., Atachi, P., Kpindon, O.K.D. & Tamo, M. (2014) Pathogenicity of entomopathogenic fungi Metarhizium anisopliae and Beauveria bassiana on larvae of the legume pod borers Maruca vitrata (Lepidoptera: Crambidae). ARPN Journal of Agricultural and Biological Science. 9 (2), 55–64.

Nawaz, M., Ibrahim Mahbubu, J., Hua, H. & Muhammad Nawaz, C. (2016) Current status and advancement of biopesticides: Microbial and botanical pesticides. Journal of Entomology and Zoology Studies. 4 (2), 241–246.

Oliveira de Freitas Bueno, R.C., Carneiro, T.R., de Freitas Bueno, A., Prattisoli, D., Fernandes, O.A. & Vieira, S.S. (2010) Parasitism capacity of Telenomus remus Nicon (Hymenoptera: Scelionidae) on Spodoptera frugiperda (Smith) (Lepidoptera: Noctuidae) eggs. Brazilian Archives of Biology and Technology. [Online] 53 (1), 133–139. Available from: doi:10.1590/S1516-89132010000100017.

Omomowo, I.O., Fadiji, A.E. & Omomowo, O.I. (2018) Assessment of bio-efficacy of Glomus versiforme and Trichoderma harzianum in inhibiting powdery mildew disease and enhancing the growth of cowpea. Annals of Agricultural Sciences. [Online] 63 (1), 9–17. Available from: doi:10.1016/j.aaos.2018.03.001.

Owney, B.H., Griffin, M.R., Klingeman, W.E., Gwinn, K.D., Moulton, J.K., Pereira, R.M. 2008. Integrated foliar diseases management of legumes. Indian Society of Pulses Research and Development. 143 – 160.

Permatasar, Y.C. (2019) Effectiveness of Trichoderma spp. as biofungicides and inducers of maize plant resistance to downy mildew. Lampung University.

Prajapati, B.K., Patel, J.K. & Patil, R.K. (2015) Bioefficacy of Trichoderma spp. against Scelenterium rolfsii Sacc; an incitant of collar rot of chick pea in vitro. The Biocon. 10 (4), 1745–1748.

Prayogo, Y. (2011a) Impact of the application of Beauveria bassiana on Coccinella sp., Paederus sp., and Oxyopes sp. Malang.

Prayogo, Y. (2013a) Pathogenicity of entomopathogenic fungi Beauveria bassiana (Deuteromycotina: Hyphomycetes) in various
stage of green stink bug (Nezara viridula L.). Journal of Tropical Plant Pests. 13 (1), 76–75.

Prayogo, Y. (2011b) The level of parasitize of entomopathogenic fungi Beauveria bassiana in three kinds of soybean leaf disease caused by leaf rust (Phakopsora pachyrhizi), downy mildew (Peronospora mansyraca), and powdery mildew (Microsphaera diffusa). Malang.

Prayogo, Y. (2013b) The toxicity of Beauveria bassiana Vuill. (Balsamo) against stink bug (Nezara viridula). In: Proceeding of National Seminary on Legumes and Tuber Crops Research Result. Indonesian Centre for Food Crops Research and Development, Malang, 19 Mei 2015.

Raghavendra, B., Srinivases, T. & Padmodaya, B. (2018) Influence of soil ph and moisture on the viability of sclerotia of S. rolfsii. International Journal of Current Microbiology and Applied Sciences. [Online] 7 (8), 92–100. Available from: doi:10.20546/ijcmas.2018.708.011.

Rahardjo, I.B. & Suhardi (2008) Pengaruh beberapa ekstrak tanaman terhadap berca hitam dan embun tepung pada tanaman mawar Varietas Pertiwi. Jurnal Hortikultura. [Online] 18 (4), 430–434.

Riaz, M., Atif, S. & Naqvi, H. (2014) Predation potential of foliage spiders and estimates of utilization curve, niche breadth and overlap in cotton filed from Punjab, Pakistan. Journal of Biodiversity and Environmental Sciences. 5 (3), 364–375.

Ryley, M., Douglas, C., Ryan, M., Tatnell, J., Martin, W., King, K. & Keller, L. (2010) Integrated management of foliar pathogens of mungbean in Australia. In: Proceedings of the 1st Australian Summer Grains Conference, Gold Coast, AConference, Gold Coast, Australia 21st – 24th June 2010. Gold Coast.

Sarwan, M. (2015a) Biopesticides: An effective and environmental friendly insect-pests inhibitor line of action. International Journal of Engineering and Advance Research Technology. [Online] 1 (2), 123–128. Available from: https://www.ijeart.com/download_data/IJEART01108.pdf.

Sarwan, M. (2015b) The killer chemicals for control of agriculture insect pests: The botanical insecticides. International Journal of Chemical and Biomolecular Science. [Online] 1 (3), 123–128. Available from: http://files.aiscience.org/journal/article/html/70420032.html.

Srinivasan, R. (2012) Integrating biopesticides in pest management strategies for tropical vegetable production. Journal of Biopesticide. 5, 36–45.

Suastika, I.B.K., Rauf, A., Hindayana, D. & Winasa, W. (2005) Paederus fuscipes (Coleoptera: Staphylinidae) and studies of predation on armyworm. Agritrop. 24 (2), 58–66.

Subramanian, P. & Nishan, M. (2015) Biological activities of greater galangal Alpinia galanga: A review. Research & Reviews: Journal of Botanical Science. [Online] 15–19. Available from: https://www.roij.com/open-access/biological-activities-of-greater-galangal-alpinia-galanga--a-review.pdf.

Swaminathan, R., Singh, K. & Nepali, V. (2012) Insect pests of green Gram Vigna radiata (L.) Wilczek and their management. In: Aflakpui, G. (ed.) Agricultural Science. [Online] 197–222. Available from: doi:10.5772/35176.

Syarief, M., Prahisatari, E. & Wardana, R. (2018) Efikasi agensia hayati Trichoderma sp. terhadap karat daun (Puccinia arachidis) pada kacang tanah. Agriprima : Journal of Applied Agricultural Sciences. [Online] 2 (2), 126–134. Available from: doi:10.25047/agriprima.v2i2.104.

Tumuhaise, V., Ekesi, S., Mohamed, S.A., Ndegwa, P.N., Irungu, L.W., Srinivasa, R. & Maniania, N.K. (2015) Pathogenicity and performance of two candidate isolates of Metarhizium anisopliae and Beauveria bassiana (Hypocreales: Clavicipitaceae) in four liquid culture media for the management of the legume pod borer Maruca vitrata (Lepidoptera: Crambidae). International Journal of Tropical Insect Science. [Online] 35 (1), 34–47. Available from: doi:10.1017/S1742758414000605.

Udiarto, B.K., Hidayat, P., Rauf, A., Pudjianto & Hidayat, S.H. (2012) Kajian potensi Predator Coccinellidae untuk pengendalian Bemisia tabaci (Gennadius) pada cabai merah. Jurnal Hortikultura. [Online] 22 (1), 85. Available from: doi:10.21082/jhort.v22n1.2012.p76-84.

Zhang, J., Pu, R., Yuan, L., Wang, J., Huang, W. & Yang, G. (2014) Monitoring powdery mildew of winter wheat by using moderate resolution multi-temporal satellite imagery. PLoS ONE. [Online] 9 (4), e93107. Available from: doi:10.1371/journal.pone.0093107.