Impact of biopesticide inundation on the diversity of soybean pests and diseases

Y Prayogo, MSYI Bayu, GWA Susanto, SW Indiati
Indonesian Legumes and Tuber Crops Research Institute, Jl. Raya Kendalpayak KM 08, Po. Box 66, Malang 650101, East Java, Indonesia
E-mail: yusmani.prayogo@yahoo.com

Abstract. Soybean pests and diseases are quite abundant and have shown the resistance to chemical pesticides. Biopesticides are biological agents derived from plant metabolites and microorganisms. They are effective for controlling pests and diseases as well as suppress the resistance and resurgence. This research aimed to study the impact of biopesticide inundation on soybean pests and diseases. The study was conducted in Banyuwangi, East Java. Biopesticides applied were Trichoderma harzianum (Trichol 8), neem seed powder, entomopathogenic virus SINV (Virgra), entomopathogenic fungi Beauveria bassiana, and eugenol from clove oil. The results showed that biopesticide applied by inundation can suppress Sclerotium rolfsii, Phakopsora pachyrhizi, Xanthomonas axonopodis, and Spodoptera litura. The application of biopesticides by inundation is safer and can maintain the survival of natural enemies and can reduce yield losses. However, the application of chemical can kill natural enemies. Oxyopes sp., Coccinella sp., Sycanus sp., Andrallus sp., Rhynocoris sp., Paederus sp., Entomobrya sp., Aphidius sp., Binodoxys sp., Encarsia sp., Trichogramma sp., and Telenomus sp. which survived on field applied with biopesticides is quite abundant. Therefore, natural enemies have a great opportunity as biological agents for controlling soybean pests and diseases and as an alternative to replace the use of chemical.

1. Introduction
National soybean productivity is still relatively low, which is only 0.8-1.2 t/ha, meanwhile the potential yield from superior varieties can reach 3 t/ha. The key factor interfering the soybean yield is the presence of pests and diseases. There are numerous main pests of soybean that attack from early growth up to harvest. In the early growth, soybean was vulnerable to bean fly (Ophiomyia phaseoli), stem borer (Melanagromyza sojae), and shoot borer (M. dolichostigma) [1-2]. In vegetative phase, there are armyworm (Spodoptera litura), leaf-rollers (Lamprosema indicata), caterpillars (Chrysodeixis chalcites), and whitefly (Bemisia tabaci) [3-4]. Furthermore, during generative phase, there are pod sucking pests consisting of brown stink bugs (Riptortus linearis), green stink bugs (Nezara viridula), pale-green stink bugs (Piezodorus hybneri) [5], and pod borer (Etiella zinckenella) [6-7]. Soybean yield losses due to pests may reach 80% and even puso if there are not controlled [8].

Another biotic factor that plays a significant role in reducing soybean yield is pathogen infection. Important disease in the early growth of soybean is soil borne disease caused by fungi (Rhizoctonia solani and Sclerotium rolfsii). The symptoms of plants infected with R. solani and S. rolfsii are wilting and dying suddenly. The development of the disease in field is very fast, especially in high humidity condition through the spread of sclerotia and mycelium as infective organs [9-10]. The important
diseases in the vegetative to generative phases are leaf rust (Phakopsora pachyrhizi), downy mildew (Perenospora manshurica), and powdery mildew (Microsphaera diffusa) [11-12]. These three kinds of disease cause necrotic leaves. The severe attack causes leaves to be dry out and fall down prematurely [13-14]. Another disease that is no less important is the soybean mosaic virus (SMV), which is transmitted by B. tabaci or Aphis glycines [15]. Symptoms of SMV are curling leaves and stunted plants so that cause yield losses up to 80% and crop failure [16].

Generally, pest control technology applied by farmers is the intensive use of chemical pesticides, but the pest population in the field increased continuously. It occurred due to some kinds of pests build a resistance to most chemical pesticide formulations. This condition is triggered by increasing the intensive use of chemical pesticides with excessive dosages so that an insect will survive, build immunity and produce offspring with high tolerance [17-18]. In addition, the application of chemical pesticides with inappropriate doses and broad spectrum cause the resurgence or explosion of secondary pests and destroying all existing natural enemies [19]. The study by [20] indicated that chemical insecticides containing active ingredients chlorpirifos, indoxacarb and flubendiamide were more toxic to predators of the Coccinellidae family as compared with spinosad. The increase of the intense exploitation of chemical pesticides does not only seem to destroy the target pest, but also all natural enemies so that pest outbreak will occur.

An effort to prevent pest outbreak can be done with the alternative control, namely biopesticides [21-22]. Biopesticides are biological pesticides from plants, pathogens such as viruses and entomopathogenic fungi, and predators. Neem seed powder (Azadirachta indica), eugenol from clove oil (Syzygium aromaticum), entomopathogenic virus (Spodoptera litura nuclear polyhedrosis virus) (S/NPV), entomopathogenic fungi (Beauveria bassiana), and antagonistic fungi (Trichoderma harzianum) that applied by inundation was reported effectively suppress the population and inhibit the outbreak of major soybean pest and disease [13], [23-24]. In addition, other research also reported that the application of biopesticides is safer and environmentally friendly so that it can maintain the survival of beneficial insects, both predators and parasitoids [25-27]. Based on the reason above, this research aims to study the impact of biopesticides inundation on major soybean pest, pathogen and natural enemies disease populations.

2. Methods
This research was conducted in Kedungasri Village, Tegallimo district, Banyuwangi, East Java, on March – July 2018. Banyuwangi was chosen as the location of this technology development because Banyuwangi is a soybean production center in East Java. In addition, the use of chemical pesticides carried out by farmers in these locations is very intensive, the application is done weekly even though the pest population was not dangerous. Therefore, most chemical pesticide formulations at the location were no longer effective for suppressing the pest population, and there were pest outbreaks in each growing season.

2.1 Experimental set-up
The total area used was 15 hectares of ex-paddy rice fields consisting of 10 ha area for control technology by using biopesticides. The biopesticides used were; (1) Trichol 8, biofungicide containing Trichoderma harzianum, (2) NSP, plant-based pesticide from neem seed powder, (3) Virgra, entomopathogenic virus containing S/NPV, (4) BeBas, entomopathogenic fungus (Beauveria bassiana), (5) Eugenol, a vegetable pesticide containing clove oil. In addition, an area of 5 ha was used for control technology using chemical pesticides from Benomyl (fungicide), Captan, Deltamethrin and Sipermenin (insecticide) (Table 1). Soybean varieties used were; (1) Anjasmoro (large seeds), (2) Argomulyo (large seeds), and (3) Martoloyo (Banyuwangi local varieties with small seeds). Ex-paddy rice fields without tillage (TOT) then made drainage channels in each 4 m plot. The width of drainage channel was 20 cm and depth of 25 cm. Soybean seeds were treated by using Trichol 8 in the biopesticide technology plot, while the seeds in the chemical pestlelicide technology plot was treated by using benomyl. Both seed treatments were used to suppress the infection of soil borne pathogen (S. rolfsii & R. solani). Seed was planted by inserting into a hole, the plant spacing used is 40 cm x 15 cm, with two seeds in each hole.
Table 1. Technology component of soybean cultivation by using biopesticides and chemical pesticides

| No. | Component       | Soybean cultivation technology                        | Chemical insecticide (5 ha) | Biopesticide (10 ha) |
|-----|-----------------|--------------------------------------------------------|----------------------------|----------------------|
| 1.  | Land Preparation| Herbicide before planting (non tillage/ minimum tillage) | Straw was burned before planting (non tillage) |
| 2.  | Drainage        | At each 4 m (width: 20 cm, depth: 25 cm)               | At each 4 m (width: 20 cm, depth: 25 cm) |
| 3.  | Seed            | High quality, vigor >80%                              | High quality, vigor >80%    |
| 4.  | Seed treatment  | captan & sipermethrin                                  | Trichol 8                  |
| 5.  | Variety         | Argomulyo, Anjasmo, Martoloyo (local)                 | Argomulyo, Anjasmo, Martoloyo (local) |
| 6.  | Plant method    | Tugal                                                  | Tugal                      |
| 7.  | Plant spacing   | 40 cm x 15 cm                                         | 40 cm x 15 cm              |
| 8.  | Organic fertilizer | 2 t/ha                                               | 2 t/ha                    |
| 9.  | Anorganic fertilizer | 200 kg Phonska + 100 kg SP 36/ha                      | 200 kg Phonska + 100 kg SP 36/ha |
| 10. | Liquid fertilizer | 5 ml/l (20, 40, 60 DAP)                               | 5 ml/l (20, 40, 60 DAP)    |
| 11. | Weeding         | Herbicide (15-20 DAP)                                  | Manual (15-20 DAP)         |
| 12. | Pest and disease control | Chemical pesticide (scheduled)                       | Biopesticide (Inundation) |
|     |                 | Benomyl, sipermethrin, deltamethrin                   | Virga, BeBas, Trichol 8, NSP, Eugenol |
| 13. | Harvesting time | Brown pods                                             | Brown pods                 |

Note: NSP (neem seed powder), Trichol 8 (*T. harzianum*), Virga (SNPV), BeBas (*B. bassiana*), eugenol (clove oil).

Weeds were sprayed using herbicides at 15-20 (DAP) and at 28-30 HST weeding was done manually. In addition, in biopesticide technology plot, straw were burned before planting and at 28-30 DAP, weeding was done manually. Pests and diseases controlled by using chemical pesticides made from Benomyl (fungicide), Deltamethrin, and Sipermetrin (insecticide) applied scheduled. However, biopesticide technology used were five kinds namely Trichol 8, NSP, Eugenol, Virga, and BeBas (Table 2).

The observed variables are: (1) Kind of pest and population, observed visually in 10 plants and catching insects by sweep net in a single swing for five times, as many as five points diagonally per plot; (2) Kinds and diseases intensity, observed based on diseases incidence for soil borne diseases and diseases severity for air borne diseases; (3) plant growth, (4) yield components (number of filled and hollow pods), (5) seed weight per hectare (t/ha); and (6) abundance of insects as natural enemies (predators and parasitoids).
Table 2. Kind of pests, economic threshold, kinds and application time of chemical pesticides and biopesticides

| No. | Kind of pests and diseases | Economic threshold | Application time (DAP) | Chemical pesticide | Biopesticide |
|-----|---------------------------|------------------|------------------------|-------------------|--------------|
| Pest |                          |                  |                        |                   |              |
| 1.  | *S. litura, C. chalcites,* | 10 individuals   | Cyhalotrin (21, 28, 35, | SBM + Virga (28,  |
|     | *L. indicata*             | instar III/10    | 42, 49)                | 35, 42)           |              |
|     |                           | plant at flowering phase |                        |                   |              |
|     |                           | 13 individuals/10 |                        |                   |              |
|     |                           | plants as pod filling |                        |                   |              |
| 2.  | *B. tabaci*               | 1 pair of adult/100 plants at 28 DAP | Amitraz (28, 35, 42, 49, 56) | BeBas (35, 42, 49) |              |
| 3.  | *R. linearis, N. viridula, P. hybneri* | 1 pair of adult/20 plants at 35 DAP | Sipermethrin (42, 49, 56, 63, 70) | BeBas (42, 49, 56) |              |
| 4.  | *E. zinckenella, H. Armigera* | 2 individuals/plant at 42 DAP | Sipermethrin (42, 49, 56, 63, 70) | Virgra+BeBas (42, 49, 56) |              |
| Disease |                          |                  |                        |                   |              |
| 1.  | *R. solani, S. rolfsii*   | DS=10%           | Captan (*seed treatment*) | Trichol 8 (*seed treatment*) |
|     |                           |                  | Mankozeb (7, 14, 21, 28, 35) | Trichol (14, 21, 28) |
| 2.  | *P. pachyrhizi*           | DS=35%           | Benomyol (35, 42, 49, 56, 63, 70) | Eugenol (35, 42, 49) |

2.2 Data analysis
Data were subjected to analysis of variance (ANOVA) and mean values were compared using Tukey’s test when significant F values were obtained (α = 0.05; SPSS ver. 22).

3. Results and discussion

3.1 Pests population
Based on visual observations and catching the insect by using sweep net, several kinds of orders were obtained including Homoptera, Hemiptera, Orthoptera, Diptera and Lepidoptera (Table 3). The highest population was *B. tabaci*, both in soybean plants that are applied with biopesticides and chemical pesticides. The population of *B. tabaci* at 49 DAP in the biopesticides plot was lower (43.10 individuals), while in the chemicals plot it reached 80.40 individuals. However, at 63 DAP, the population of *B. tabaci* in the biopesticide plot was higher (154 individuals), while the population of *B. tabaci* on the chemical pesticides plot was 96 individuals.

Another pest from the order Hemoptera obtained was *Empoasca* sp. with the highest population in the biopesticide plot 2.60 individuals at 49 DAP and 11 individuals at 63 DAP. However, in the chemical pesticide plot only 2.30 were found at 49 and 63 DAP. The Hemiptera insect caught were *R. linearis* with a low population (0.10-1.50 individual). *M. sojae* and *M. dolichostigma* were also successfully caught using sweep net in large population, especially *M. dolichostigma* (17 individuals) in biopesticide plot at 63 HST. The population of *M. dolichostigma* in the chemical pesticide plot was also quite high (10.60 individuals). However, the population of *M. sojae* caught was 4.80 individuals.
on chemical pesticide plot at 63 DAP. The pests from the order of Lepidoptera caught were *S. litura*, *L. indicata*, and *E. zinckenella*. The population of these three types of insects is quite low based on visual observation on 10 clumps of plants.

| No. | Kind of arthropods | Population average at the DAP (individual) |
|-----|--------------------|------------------------------------------|
|     |                    | Biopesticide | Chemical pesticide |
| 1.  | *Empoasca* sp. (Homoptera: Cicadellidae) | 2.6          | 11.0             |
| 2.  | *B. tabaci* (Homoptera: Aleyrodidae) | 43.1         | 154.0            |
| 3.  | *R. linearis* (Hemiptera: Alydidae) | 0.1          | 1.5              |
| 4.  | *Valanga* sp. (Orthoptera: Acrididae) | 1.4          | 1.0              |
| 5.  | *M. sojae* (Diptera: Agromyzidae) | 0.1          | 0.0              |
| 6.  | *M. dolichostigma* (Diptera: Agromyzidae) | 0.3         | 17.6             |
| 7.  | *S. litura* (Lepidoptera: Noctuidae) | 2.3          | 0.0              |
| 8.  | *L. indicata* (Lepidoptera: Noctuidae) | 0.9          | 1.5              |
| 9.  | *E. zinckenella* (Lepidoptera: Pyralidae) | 0.0         | 0.9              |

### 3.2 Pest attack intensity

The observations on three varieties showed that the symptoms of armyworm attack appeared with very low intensity (1.5-5%), both in the biopesticides plot and chemical pesticides plot (Figure 2). The performance of the plants was quite good, there was no significant damage (Figure 3). The intensity of *S. litura* attack was very low, still below the economic threshold, which is 10 larvae of third instar / 10 clumps at flowering time and 13 larvae / 10 clumps during pod filling.

The highest intensity of *B. tabaci* attack was found in the plot that applied with biopesticides, namely Anjasmor (9.50%), Argomulyo (9%), and Martoloyo (6.50%). However, the intensity of *B. tabaci* attacks on plot that applied using chemical pesticides was lower about 3-5% (Figure 4).

![Figure 2](image-url) The intensity of *S. litura* attack on three soybean varieties on plot applied by biopesticides and chemical pesticides.
Figure 3. Performance of soybean plants applied with biopesticides (left) and chemical pesticides (right).

Figure 4. The intensity of B. tabaci attack on three soybean varieties on plot applied by biopesticides and chemical pesticides

3.3 Kinds and disease intensity
Observation of soil borne diseases were carried out on plants at 21 DAP. The identified soil borne diseases are caused by Sclerotium rolfsii which can be found on plot applied with biopesticides and chemical pesticides with intensities about 1.80 to 6.70% (Figure 4). The highest intensity occurred in the Martoloyo variety in plot applied with captan (6.70%), while the lowest intensity occurred in plot applied with Trichol 8. There was wilting symptom about 6.70% on seed treatment by using captan, it was higher than the treatment by using biofungicides.
Figure 5. The intensity of soil borne diseases (S. rolfsii) and bacterial pustules (X. axonopodis) in the biopesticide and chemical pesticides plot.

Bacterial pustules caused by X. axonopodis was also found in plot that applied with biopesticides and chemical pesticides. The average of disease severity that occurs in plot applied with chemical pesticides was high (9.15%) which found on Martoloyo. However, the average of disease severity of X. axonopodis on Anjasmoro and Argomulyo in the plot applied with biopesticides was only 2.5%. Symptoms of bacterial pustules are small, yellowish green spots with a slightly protruding in the middle, larger patches developing in the middle, light brown bumps on the lower surface. This protrusions caused by hypertrophy and hyperplasis (Figure 5). The intensity of X. axonopodis disease in both varieties (Anjasmoro & Argomulyo) was much lower than that of Martoloyo.

Figure 6. Symptoms of bacterial pustules (X. axonopodis) in Martoloyo variety applied using Trichol 8 (left) and chemical fungicides (right).

3.4 The intensity of rush disease (P. pachyrhizi)

The intensity of rust disease was very low, the intensity of this disease in the plots applied with biopesticides was only 2.20% while, in the plots applied with chemical fungicides was about 6.70%. However, the intensity of rust disease on farmer’s field around the research site that were not controlled reached 27.50% (Figure 7).
The average intensity of rust disease (*P. pachyrhizi*) in plots applied with biofungicides, chemical fungicides, and without control (farmer's field).

### 3.5 Seed Weight

The highest seed weight was obtained on Anjasmoro which were applied using biopesticide (2.98 t/ha), while the seed weight in the chemical pesticide plots was 2.89 t/ha (Figure 8). Martoloyo variety can produce seed weight up to 2.81 t/ha on plots applied using chemical pesticides, while in biopesticide plots, seed weight was low (2.65 t/ha). Seed weight obtained from the Argomulyo appears to be lower than Anjasmoro and Martoloyo, which was 2.45 t/ha in chemical pesticides plots and 2.37 t/ha in biopesticides plots.

Anjasmoro produced higher seed weight as compared to the other two varieties, Argomulyo and Martoloyo (Table 4). This condition related with the number of node in Anjasmoro was also greater (21.10) than Argomulyo (16.16) and Martoloyo (18.50). The seed weight of Argomulyo was lower than Anjasmoro and Martoloyo, but Argomulyo contains half of total number of filled pods from Martoloyo and Anjasmoro. This incident can be proven from the number of pods on Martoloyo (84 pods), but the number of pods on Argomulyo was only 43 pods. The size of seeds on Argomulyo (16 g) was much larger than Anjasmoro (14.8-15.3 g) and Martoloyo (10.7 g) [28].

![Figure 7. The average intensity of rust disease (*P. pachyrhizi*) in plots applied with biofungicides, chemical fungicides, and without control (farmer's field).](image)

![Figure 8. Seeds weight of Anjasmoro, Argomulyo, and Martoloyo from plot applied with biopesticide and chemical pesticide](image)
Table 4. Plant height, number of node, filled pods, and empty pods of three soybean varieties on plot applied with biopesticides and chemical pesticides

| Varieties | Plant height | Number of node | Filled pod | Empty pod |
|-----------|--------------|----------------|------------|-----------|
|           | Biopesticide | Chemical       | Biopesticide | Chemical       | Biopesticide | Chemical       |
| Anjasmooro| 66.40        | 71.81          | 21.10      | 22.54     | 81.40        | 83.90          | 0.70         | 1.40      |
| Argomulyo | 69.53        | 67.35          | 16.16      | 17.54     | 43.61        | 31.54          | 1.14         | 1.18      |
| Martoloyo | 83.16        | 71.76          | 18.00      | 16.43     | 84.84        | 85.53          | 1.57         | 2.23      |

3.6 Abundance of natural enemies

Many natural enemies was still found on the plot applied with biopesticides, both predators and parasitoids. There were *Oxyopes* sp., *Coccinella* sp., *Andrallus* sp., *Rhynocoris* sp., *Sycanus* sp., *Paederus* sp., and *Entomobrya* sp. (Figure 9). Predators *Coccinella* sp., *Sycanus* sp., *Andrallus* sp., and *Rhynocoris* sp. inhabit plant canopy and they have high ability to predict insect pests that attack the soybean canopy. However, *Oxyopes* sp. and *Paederus* sp. are predators that inhabit soil surface and also plant canopy, while predators *Entomobrya* sp. only inhabit soil surface. The population of predator on plots applied with biopesticides, especially *Entomobrya* sp., *Oxyopes* sp., and *Paederus* sp. were quite high at 49 to 63 DAP. However, in plots applied with chemical pesticides, no predators was found to be survived, except *Paederus* sp. and *Entomobrya* sp. with very low populations.

![Figure 9. Kind and predators population on three soybean varieties on plot applied with biopesticides and chemical pesticides](image)

The kind of parasitoids that can be found in plot applied with biopesticides were *Aphidius* sp., (Hymenoptera: Braconidae), *Binodoxys* sp. (Hymenoptera: Braconidae), *Trichogramma* sp. (Hymenoptera: Trichogrammatidae), *Encarsia* sp. (Hymenoptera: Aphelenidae), and *Telenomus* sp. (Hymenoptera: Scelionidae). The population of this four kind of parasitoids was quite high at 49 DAP, which is 8, 10, 5, and 21 individuals, respectively. The population of this four parasitoids at 62 DAP increased significantly, especially *Telenomus* sp. (82 individuals), *Trichogramma* sp. (42 individuals), *Aphidius* sp. (21 individuals), and *Encarsia* sp. (11 individuals) (Figure 10).
10.

B. tabaci population at 63 DAP was higher in plots applied with biopesticides as compared to the plots applied with chemical pesticides. This condition occurs due to the migration of B. tabaci from plots applied with chemical pesticide to plots applied with biopesticides because of wind. According to [29], wind speed is one of the environmental factors that cause B. tabaci migration to other places, besides plant age and plant height. [30] mentioned that wind speed has a positive correlation with B. tabaci migration.

In both plots were also found M. soyae and M. dolichostigma with high numbers of population. It is suspected that the abundance of these pests impact on the eggs laid by adult on the plant but the age of the plant is not appropriate so they only fly over the plant surface. The low population of foliage pest and pod borer found in plots that applied with biopesticides was due to the use of Virgra. Virgra contains the active ingredient of the entomopathogenic virus S/ NPV so that the larval stage of the armyworm can be killed due to the virus infection. [31] reported that Virgra is an entomopathogenic virus formulated from JTM97C isolates and it is very effective for controlling S. litura larval with a mortality rate of up to 99%. [32] also explained that the control of S. litura was very effective by using bioinsecticides from S/NPV.

The low intensity of S. litura attacks on plots applied with chemical pesticides because the scheduled application, farmers also apply chemical insecticides outside the established schedule. This activity is carried out by farmers based on the reason that cultivated of soybean does not occur damage even though it must take excessive input to buy chemical pesticides. S/NPV biopesticide system requires a minimum of 3-4 days after feed insects (leaves) have been sprayed with a suspension of virus particles. Thus, larvae still eat soybean leaves, causing damage even though the intensity of the damaged was only about 5%. In addition, biopesticide plots was also applied with NSP containing azadirachtin compounds. These compounds originated from vegetable pesticides that plays function to inhibit the appetite of insects, refuse insects to come to the plants, and thwart the process of moulting.

The low intensity of soil borne diseases in plots applied with Trichol 8 through seed treatment due to the biofungicide functions as an antagonist, causing root and stem rot. In addition, T. harzianum plays role as a decomposer so that the litter above the soil surface can immediately be overlaid into organic fertilizer and can increase plant growth [33-34]. Withering was a major obstacle at the early growth in soybean production center in Banyuwangi. Seed treatment by using Trichol 8 is able to suppress wilting in endemic areas, so that control technology innovations by using biofungicides can be recommended to control S. rolfsii.

The intensity of X. axonopodis disease in both varieties (Anjasmoro & Argomulyo) was much lower than that in Martoloyo. This condition is likely due to the impact of the application of T. harzianum biofungicide that given before planting and the application was done at 21, 28, 35 DAP. This activity caused pathogens to be not able to develop due to better plant vigor [35-36].
The low intensity of the application of biofungicides (eugenol). It was carried out four times at 28, 35, 42 and 49 DAP so can kill P. pachyrhizzi spores, as a result, the disease was unable to develop. [37] reported that eugenol from clove oil is able to damage the uredospora cell wall so that the spores undergo lysis eventually dry and die. Further, the spores cannot develop. In addition, the application of NSP can also negatively influence the development of leaf rust as reported by [38] and [39], who mentioned that the application of azadirachtin compounds from neem seed powder can reduce the severity of P. pachyrhizzi rust disease up to 83%.

In case of seed weight, it appears that soybean pest control technology by using chemical pesticides can produce higher seed weight as compared with biopesticides. This phenomenon occurs because the application of chemical pesticides is scheduled, and it is able to kill all pests in a very fast time without pay attention to the pest population. Therefore, there is no chance for these organisms to damage plants, especially pods. Meanwhile, the efficacy of biopesticides which are applied in a slower inundation which takes a minimum of 3-4 days so that the insect still doing activities to damage the plant.

In plots applied with chemical pesticides, there were no predators found and survived, except Paederus sp. and Entomobrya sp. even though the population is very low. This condition occurred due to the habitat of these two predators are in soil surface. Paederus sp. has fairly high mobility so that the application of chemical pesticides does not have a negative impact on the behavior of these predators. Predator Rhynocoris sp. has a high predation rate of S. litura up to 20 individuals/day [40]. While, predators Sycanus sp. if they prey on S. litura larvae, they have a life span up to 88 days [41]. Predator Oxyopes sp. has the ability to prey on several kinds of major soybean pests such as B. tabaci, A. gossypii, Empoasca sp., and Nezara viridula [42]. The ability of P. fuscipes is also very high for preying on Helicoverpa armigera [43]. Meanwhile, these two predators (Oxyopes sp. and Paederus sp.) have the ability to prey the major soybeans pest up to 11 individuals/day [44-45]. Predator Entomobrya sp. is a predator that inhabit soil surface. Entomobrya sp. also play role as a decomposer insect that is effective in overhauling all soil litter. It is very useful to provide nutrients for the plant quickly [30], [46]. The abundance of various species of predator that survived on plots applied with biopesticides have considerable potential as biological agents to prey soybean pests.

Each parasitoid has a high level of parasitization against major soybean pests such as B. tabaci, A. craccivora, A. gossypii, and S. litura [47-50]. The increasing in parasitoid populations in plots applied with biopesticides was not followed in plots applied with chemical pesticides because most of the parasitoids were killed. This phenomenon occurs because natural enemies, especially parasitoids, are more susceptible to chemical insecticides than the pest, while parasitoids act as natural controllers. According to [51], insecticides containing active ingredients tiametoksam, lamda sialotrin, chlorpyrifos, or chlorphenapy can kill all parasitoids in soybean fields. [52] and [53] stated that the parasitoid Trichogramma pretiosum and Telenomus remus will be killed by the application of chemical insecticides. These result indicate that the use of biopesticides derived from microorganisms and plant-based pesticides is more environmentally friendly, because it can maintain the survival of natural enemies while being able to suppress the existing pest populations.

4. Conclusions
From this study, we concluded that biopesticides consisting of T. harzianum, SINPV, NSP, B. bassiana, and eugenol applied by inundation can suppress the development of pest and disease populations almost comparable to the efficacy of chemical pesticides. Soybean pest control by using various kinds of biopesticides by inundation is safer and can maintain the survival of useful insects, especially predators and parasitoids. It can maintain soybean yield almost comparable to the efficacy of chemical pesticides. Scheduled application of chemical pesticides can kill almost all existing natural enemies, both predators and parasitoids. Biopesticides applied by inundation can potentially be used as alternatives to the efficacy of chemical pesticides.
References

[1] Arnemann J A, Tay W T, Walsh T K, Brier H, Gordon K, Hickmann F, Ugalde G and Guedes J V C 2016 Soybean stem fly, *Melanagromyza sojae* (Diptera: Agromyzidae) in the new world: Detection of high genetic diversity from soybean field in Brazil *Genetic and Molecular Research* **15** 1-13.

[2] Abdel Raheem M A and Al-Keridis L A 2017 Virulence of three entomopathogenic fungi against whitefly *Bemisia tabaci* (Gennadius) (Homoptera: Alydidae) in tomato crop. *Journal of Entomology* **14** 155-159.

[3] Mansour S A A, Raff M N M, Khalid A S, Ismail A and Idris A G 2013 Population abundance of whitefly *Bemisia tabaci* (Genn.) on chilli an other vegetable crops under glass house conditions. *Journal Tropical Agriculture and Food Science* **41** 149-157.

[4] Biswas G C 2013 Insect pest of soybean (*Glycine max* L.) their nature of damage and succession with the crop stages. *Journal Asia Society Bangladesh Science* **39** 1-8.

[5] Kusuma M 2014 Kajian aspek ketahanan beberapa genotipe kedelai terhadap hama pengisap polong *Riptortus linearis* F (Hemiptera: Alydidae) [Thesis] Universitas Gadjah Mada Yogyakarta.

[6] Melo M and Silveira E P 1998 Pod borer *Etiella zinckenella* (Treit.) (lepidoptera: Pyralidae) damage to common bean *Anais da Sociedade Entomologica do Brasil* **27** 477-479

[7] Apriyanto D, Ogie H Y and Mulyadi A 2009 Performance of soybean pod borer, *Etiella zinckenella* treischke (Lepidoptera: Pyralidae), and host preference on soybean and groundnut *Akta Agrosia* **12** 62-67

[8] Arifin M and Tengkano W 2011 Tingkat kerusakan ekonomi hama kepik cokelat pada kedelai. *Jurnal Penelitian Pertanian Tanaman Pangan* **27** 47-54.

[9] Pinheiro Vd R, Seixas C D S, Godoy C V, Soares R M, MCNde O and Almeida A M R 2010 Development of *Sclerotium rolfsii* sclerotia on soybean, corn, and wheat straw, under different soil temperatures and moisture contents. *Pesq Agropec Brasilia* **45** 332-334.

[10] Kator L, Hasea Z H and Oche O D 2015 *Sclerotium rolfsii*: causative organism of Southern blight, stem rot, white mold and sclerotia rot diseases. *Annual of Biology Research* **6** 78-89.

[11] Hardaningsih S 2011 Jenis penyakit kedelai dan efektivitas jamur antagonis yang berasal dari Kalimantan Selatan terhadap *Sclerotium rolfsii* di laboratorium. (SUPERMAN) *Suara Perlindungan Tanaman* **1** 23-25.

[12] Hardaningsih S 2012 Penyakit kacang-kacangan pada lahan kering masam di propinsi Lampung. (SUPERMAN) *Suara Perlindungan Tanaman* **2** 22-26.

[13] Murithi H M, Beed F, Tukamuhawba P, Thomma B P H J and Joosten M H A J 2016 Soybean production in eastern and southern Africa and threat of yield loss du to soybean rust caused by *Phakopsora pachyrhizi*. Plant Pathology **5** 176-188.

[14] Tuong H M, Truong T T, Lien T T P, Ha C H and Son L V 2016 Analysis of powdery mildew resistant characteristic and genetic relationship of cultivated soybean, *Glycine max* in Vietnam for parental selection. *International Journal of Bioscience Biochemical and Bioinformation* **6** 105-113.

[15] Burrows M E L, Boerbloom M C and Gaska J M 2015 The relationship between *Aphis glycines* and soybean mosaic virus incidence in different pest management systems. *Plant Disease* **89** 926-924.

[16] Mandhare V K and Gawade S B 2010 Effect of seed borne soybean mosaic virus infection on quality and yield parameters in soybean. Agricultural Research Communication Centre. *Legume Research* **33** 43-43.

[17] Kontsedalov S, Abu-Moch F, Labedev G, Czosnek H, Horowitz A R and Ghanim M 2012 *Bemisia tabaci* biotype dynamics and resistance to insecticides in Israel during the years 2008-2010. *Journal of Integrative Agriculture* **11** 312-320.

[18] Tabasian H, Ravan S, Bandani A R and Siahsar B A 2014 The effect of esterase activity in resistance of *Aphis gossypii* to selective insecticides. *Science and Technology* **8** 1128-1112.

[19] Ndkidemi B, Mtei K and Ndkidemi P 2016 Impacts of synthetic and botanical pesticides on beneficial insects *Agricultural Sciences* **07** 364-372.
[20] Natikar P K, Vinod M, Mallapur and Balikai R A 2016 Effect of newer insecticides on population of natural enemies and yield of soybean. Journal Exp. Zoology India 19 492-497.

[21] Oguh C E, Ogechi O C, Ubani C S and Okekeaji U 2019 Natural peptidic insecticides (Biopesticides) and uses in pest management- a critical review Environmental Toxicology 2 1-18

[22] Mnif I, Ghribi D 2015 Potential of bacterial derived biopesticides in pest management. Crop Protection 77 52-64.

[23] Indiati S W 2014 The use of sugar apple and neem extract to control leaf-eating pest on soybean. Journal of Exp Biology and Agriculture Science (JEBAS) 2 208-214

[24] Sumartini 2015 CEKA, Fungisida nabati untuk pengendalian penyakit karat pada daun kedelai. Info Teknologi, Balai Penelitian Tanaman Aneka Kacang dan Umbi.

[25] Landis D, Wratten S D and Gurr G 2000 Habitat management to conserve natural enemies of arthropod pests in agriculture Annual Review of Entomology 45 175-201

[26] Arena S, Palacios S M, Fenoglio M S and Defago M T 2015 Effects of Melia azedarach extract on natural enemies of Aphids. Biopesticides International 11 1-11.

[27] Ndakidemi B, Mtel K and Ndakidemi K A 2016 Impacts of synthetic and botanical pesticides on beneficial insects. Agricultural Science 7 364-372.

[28] [BALITTKABI] Balai Penelitian Tanaman Aneka Kacang dan Umbi 2012 Deskripsi varietas unggul kacang-kacangan dan umbi-umbian. Badan Penelitian dan Pengembangan Pertanian, Kementerian Pertanian.

[29] Khalid S A N, Noor M R M, Touhidor M R and Ghani I A 2006 Effect of plant height, maturity and climatic factors on the population of whitefly (Bemisia tabaci) on chilli J. Trop. Agric. And Fc. Sc. 34 195-206

[30] Zeshan M A, Khan M A, Ali S and Arshad M 2015 Correlation of conductive environmental conditions for the development of whitefly Bemisia tabaci population in different tomato genotypes. Pakistan Journal Zoology 47 1511-1515.

[31] Bedjo 2004 Pemanfaatan Spodoptera litura Nuclear Polyhedrosis Virus (SnNPV) untuk pengendalian ulat grayak (Spodoptera litura Fabricius) pada tanaman kedelai. Bulletin Palawija 7-8 1-9.

[32] Samsudin S 2017 Prospek pengembangan bioinsektisida Nucleopolyhedrovirus (NPV) untuk pengendalian/prospek of development of Nucleopolyhedrovirus (NPV) bioinsecticide against Perspektif 15 18

[33] Sharma B L, Sharma M L and Singh S P 2017 Bio-degradation of crop residues by Trichoderma species vis-a-vis nutrient quality of the preparat compost. Sugar Technology 14 174-180.

[34] Kushwaha S K, Kumar S and Chaudhary B 2018 Efficacy of Trichoderma against Sclerotium rolfsii causing collar rot disease of lentil under in vitro conditions. J of Appl & Nat Sci 10 307-312.

[35] Srivastava M, Vipul K, Mohammad S and Pandey S 2016 Trichoderma-a potential and effective bio fungicide and alternative source against notable phytopathogens: A revie African Journal of Agriculture Research 11 310-316

[36] Amaria W , Harni R and Wardiana E 2018 Pengaruh dosis dan frekuensi aplikasi biofungisisida trichoderma terhadap infeksi Rigidopus microporus pada benih karet Jurnal Tanaman Industri dan Penyebar 5 49

[37] Sumartini 2010 Penyakit karat pada kedelai dan cara pengendaliannya yang ramah lingkungan. Jurnal Penelitian dan Pengembangan Pertanian 29 107-112.

[38] Jahagirdar S, Patil P V, Patil R H, Bohra B and Vyas B N 2010 Integrated management of Asian soybean rust caused by Phakopsora pachyrhizi India. International Journal of Plant Protection 3 289-292.

[39] Shabana Y M, Abdalla M E, Shahin A A, El-Sawy M M, Draz I S and Youssif A W 2017 Efficacy of plant extracts in controlling wheat rust disease caused by Puccinia tricinia. Egyptian Journal of Basic and Applied Science 4 67-73.

[40] Ullah M I, Altaf N, Afzal M, Ashad M, Mehmoon N, Riaz M, Majeed S, Ali S and Abdullah A 2020 Effect of entomopathogenic fungi on the biology of Spodoptera litura (Lepidoptera: Lasiocampidae: Noctuinae). Journal of Environmental and Biological Sciences 10 20-25.

[41] El-Sawy M, Patil P V, Patil R H, Bohra B and Vyas B N 2010 Integrated management of Asian soybean rust caused by Phakopsora pachyrhizi India. International Journal of Plant Protection 3 289-292.
and its reduviid predator, *Rynocoris marginatus* (Heteroptera: Reduviidae) *International J. of Insect Science** 11** 11-19.

[41] Sahid A 2019 Aspek biologi *Sycanus annulicornis* Dohn. (Herniptera: Reduviidae) yang dipelihara dengan pakan alternative larva *Alphitobius diaperinus* Panzer (Coleoptera: Tenebrionidae) *Jurnal Agroekoteknologi Tropikal Lembab* 2 50-54.

[42] Ghavani S 2008 The potential of predatory spiders as biological control agents of cotton pests in Tehran Provinces of Iran. *Asian Journal Experimental Science** 22** 303-306.

[43] Winasa I W, Hindayana D and Santoso S 2007 Pelepasan dan pemangsaan kumbang jelajah *Paederus fuscipes* (Coleoptera: Staphylinidae) terhadap telur dan larva *Helicoverma armigera* (Lepidoptera: Noctuidae) pada tanaman kedelai. *Jurnal Ilmu Pertanian Indonesia* 3 147-153.

[44] Udiarto B K, Hidayat P, Rauf A, Pujianto and Hidayat S H 2012 Kajian potensi predator Coccinellidae untuk pengendalian *Bemisia tabaci* (Gennadius) pada cabai merah. *Journal Horticulture* 22 76-84.

[45] Riaz M and Naqvi S A H 2014 Predation potential of foliage spider and estimates of utilization curve, niche breadth and overlap in cotton filed from Punjab, Pakistan. *Journal of Biodiversity & Environmental Science** 5** 364-375.

[46] Ernesto M V, Liberal C N, Ferreira A S, Alves A C F, Zeppelini D, Martins C F, Pereira-Colavite A and Creau-Duare A J 2018 Hexapoda decomposers of serra de Santa Catarina, Baraiba, Brazil: an area with high potential for the conservation of caatinga biodiversity. *Biota Neotropica* 18 1-13.

[47] Malik A A Y and Karut K 2012 Parasitism status *Bemisia tabaci* (Gennadius 1889) (Homoptera: Aleyrodidae) on different host plants in the Cukurova region of Turkey. *Turky Entomology Den* 36 59-67.

[48] Hu J S, Gelman D B and Blackbum M B 2015 Age-specific interaction between the parasitoid *Encarsia formosa* and its host the silverleaf whitefly *Bemisia tabaci* (Strain B). *Journal Insect Science* 2 1-10.

[49] Khan I A and Wan F H 2015 Prey consumption of *Encarsia formosa* Gahan (Hymenoptera: Aphelinidae) un-parasitized and parasitized *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) biotype B prey by *Coccinella septempunctata* L. (Coleoptera: Coccinellidae) predator. *Journal of Entomology and Zoology Studies* 3 223-228.

[50] Oliveira R de, Oliveira G M, de Sauza M D S, Burba M A, Vedruscolo J, Nunes E da S, Nascimento I N and Batista Jd L 2016 Development and parasitism of *Encarsia hispida* (Hymenoptera: Aphelinidae) on *Bemisia tabaci* biotype B in cotton. *Academic Journal* 11 2266-2270.

[51] Fernandes F L, Bacci L and Fernandes M S 2020 Impact and selectivity of insecticide to predators and parasitoids *Entomobrasis* 3 1-10

[52] Car EL, Bueno A and Bueno R C O 2010 Pesticide selectivity for the egg parasitoid *Telenomus remus*. *BioControl* 55 455-464.

[53] Bueno R C O deF, Parra J R and Bueno A deF 2012 *Trichogramma pretiosum* parasitism and dispersal capacity: a basis for developing biological control programs for soybean caterpillars. *Bulletin of Entomological Research* 102 1-8.