INNOVATION OF MAIN PEST AND DISEASE CONTROL TECHNOLOGY USING BIOPESTICIDES ON SOYBEAN(*GLYCINE MAX* L.)

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Abstract. The use of biopesticides is a control technology that can reduce the occurrence of resistanceand resurgence. The objective of the study was to determine the efficacy of Proposed technology (biopesticides) and Conventional technologies (synthetic pesticides) on soybean varieties. The study was conducted in an endemic location in Banyuwangi Regency, East Java Province, Indonesia, from April to September 2018. The results showed that the Proposed technology was able to suppress the development of stem rot disease (*Sclerotium rolfsii*) and blight (*Rhizoctonia solani*) by 54.18% and 47.84% in Martoloyo and Anjasmoro varieties, respectively, compared with Conventional technology. The Conventional technology was less effective in suppressing the development of rust disease (*Phakopsora pachyrhizi*), especially of Martoloyo and Anjasmoro varieties when compared to other varieties. The highest pest population occurred in the Proposed technology, namely the whitefly *Bemisia tabaci* followed by the leafminer *Liriomyza* sp. Predatory arthropods at the proposed technology obtained 13 species and nine types of parasitoids; both types of arthropods are potential as natural enemies but the population was very low at the conventional technology. Proposed technology has better prospects because it is eco-friendly, can suppress the occurrence of resistance and resurgence in endemic lands, and has no chemical pesticide residues.
Keywords: *conventional, chemical, efficacy, natural enemies, soybean*

Introduction

In Indonesia, the average soybean productivity is relatively low at around 1.20 t/ha. Meanwhile, the results of research using high-yielding varieties and appropriate cultivation technology can achieve productivity of 3.00 t/ha. One of the causes of the low increase in soybean productivity is the attack of plants by pests and diseases. Soybean yield loss due to pest and disease attacks is quite large (up to 80%), resulting even in harvest failure if it is not controlled properly (Arifin and Tengkano, 2011).

There are quite a lot of pests that attack soybean plants, from the early plant growth until harvest time. At the early plant growth, there are bean fly (*Ophiomyia phaseoli*), stem borer (*Melanagromyza sojae*), shoot borer (*M. dolichostiqma*) (Arnemann et al., 2016; Abdel-Raheem and Al-Keridis, 2017). Furthermore, in the vegetative phase there were armyworms (*Spodoptera litura*), leaf rollers (*Lamprosema indicata*), span caterpillars (*Chrysodeixis chalcites*), and whitefly (*Bemisia tabaci*) (Tengkano and Suharsono, 2005; Mansour et al., 2013; Biswa, 2013). In the generative phase, there are several types of sucking pests and pod borers (Baliadi et al., 2008; Kusuma, 2014). The pathogen that are often found in the field are soil borne diseases caused by fungi (*Rhizoctonia solani* and *Sclerotium rolfsii*). Major diseases in the vegetative

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to generative phases are leaf rust (*Phakopsora pachyrhizi*), downy mildew (*Perenospora manshurica*), and powdery mildew (*Microsphaera diffusa*) (Ribeiro et al., 2008; Hardaningsih, 2012).

The pest control technology applied by farmers is the application of synthetic pesticides on a weekly basis, but the pest population in the field continues to increase due to resistance to most synthetic pesticide formulations. This condition is triggered bythe increasingly intensive use of synthetic pesticides with application doses that are not as recommended so that individual insects that are able to survive will form immunity and produce offspring that have high tolerance (Kontsedalov et al., 2012; Tabasian et al., 2014). In addition, the application of synthetic pesticides with inappropriate doses and broad spectrum can trigger a resurgence or secondary pest explosion due to the killing of all existing natural enemies (Torres and Bueno, 2018). The research results of Nafikar et al. (2016) indicated that synthetic insecticides containing the active ingredients chlorpyrifos, indoxacarb and flubendiamide were more toxic to predators of the Coccinellidae family group than spinosad insecticides. The increasingly intensive exploitation of synthetic pesticides appears not only to kill the target insect pest, but also to destroy all existing natural enemies, so that the explosion of the pest will inevitably occur if it is not stopped.

Efforts to prevent pest explosions can be made by applying alternative control technologies using biopesticide applications (Ramasamy, 2012; Kumar et al., 2021). Biopesticides can consist of botanical pesticides, pathogens such as viruses and entomopathogenic fungi and predators. Vegetable pesticides neem seed powder (*Azadirachta indica*), eugenol from clove oil (*Syzygium aromaticum*), entomopathogenic virus *Spodoptera litura* nuclear polyhedrosis virus (*Sl*NPV), the entomopathogenic fungus *Beauveria bassiana*, and the antagonist fungus *Trichoderma harzianum* that were applied inundationally were reported to be able to suppress populations the occurrence of explosions of major soybean pests (Bedjo, 2004; Prayogo,2004; Hardaningsih, 2011; Indiati et al., 2013; Indiati, 2014; Sumartini, 2015). Another report states that the application of biopesticides is safer and environmentally friendly so that it can maintain the survival of useful insects, both predators and parasitoids (Raudonis et al., 2010; Arena et al., 2015; Ndakidemi et al., 2016; Murithi et al., 2016). It is necessary to develop technological Proposeds to control the main pests anddiseases of soybean in Indonesia. The objective of the study was to determine the efficacy of Proposed technology (biopesticides) and Conventional technologies(synthetic pesticides) on soybean varieties.

This site is 1,250 m above sea level and located at 60° 30’ S and – 107° 30’ E. Soil type in this location is mainly Andisol with the average pH of 5.0.

Methodology

The development of technological Proposeds for controlling soybean pests and main diseases using various types of biopesticides was carried out in Kedungasri Village, Tegaldlimo District, Banyuwangi Regency, East Java Province, Indonesia from April to September 2018. This site is 168 m above sea level and located at 8° 22′ 44.4″ S – 114° 8′ 45.6″ E. Soil type in this location is mainly light Entisol with the average pH of 6.2. The average temperature during the study ranged from 30-31 °C and humidity reached 88-91% because the condition of the land was given irrigation every week during the vegetative phase before generative (filling pods).

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The location selection was determined based on the following criteria; (1) Banyuwangi is one of the largest soybean production centers in East Java, (2) every soybean planting season there is always an outbreak of pests and major diseases, (3) the application of synthetic pesticides by farmers for pest control is very intensive so that it does not following control threshold values and recommended doses, (4) soybean varieties developed by farmers are local Banyuwangi (Martoloyo) were susceptible against major pests and diseases, and (5) major pests that have developed are resistant tomost synthetic pesticide formulations.

Research implementation

This activity to develop technological Proposeds for controlling soybean pests and main diseases used 15 hectares of irrigated paddy fields of former rice plants. Two technologies used as treatment, namely synthetic pesticides and biopesticides, while the number of farmers as replicates. Each treatment used replicates of 10 farmers who were members of the group.

The land area used for Proposed control technology with biopesticides were 10 ha, while the Conventional technology (synthetic pesticides) were 5 ha. The croppingpattern developed by farmers is rice-soybean-soybean. The newly harvested former rice fields were then made into plots measuring 4 m, each plot making a drainage channel with an area of 20 cm width and 25 cm depth. Land preparation was conducted using a no tillage method with the aim of time efficiency of development implementation(*Table 1*). The soybean varieties used are Argomulyo, Devon, and Anjasmoro for large seed size (14-16 g/100 seeds), while Dering, Deja and Martoloyo varieties are small seed size (9-12 g/100 seeds). Each soybean seed before planting was given a seed treatment using the biofungicide *T. harzianum* at a dose of 50 g/10 kg of seed for technological Proposed. Meanwhile, for the Conventional technology, soybean seeds were immersed in the synthetic function of captan and prochloraz at a dose of 2 ml/L/kgof seed for 10 min.

The types of biopesticides used in the technological Proposeds were: (1) Trichol 8 containing the antagonist fungus *T. harzianum*, (2) neem seed powder (NSP), (3) Virgra, an entomopathogenic viruses containing *Spodoptera litura* Nuclear PolyhedrosisVirus (*Sl*NPV), (4) BeBas is a biopesticide formulation containing fungal conidia entomopathogenic *Beauveria bassiana*, (5) Bio-Lec is a biopesticide formulation containing conidia of the entomopathogenic fungus *Lecanicillium lecanii*, (6) Eugenol is a botanical pesticide made from clove oil, and (7) *Allium cepa* (Ac) is an extract from shallots. Meanwhile, the Conventional technology components consist of: (1) synthetic fungicides containing the active ingredients captan, prochloraz, chlorothalonyl and mankozeb, and (2) synthetic insecticides containing the active ingredients cypermethrin, amitraz, deltamethrin and cyhalothrin.

Soybean seeds of each variety were planted by inserting them into single holes (made by using a stick) according to their respective treatment plots. The spacing used was 40 cm × 15 cm, each hole was filled with two seeds according to each treatment plot. Maintenance carried out for weed control was sprayed using synthetic herbicides with the active ingredient glyphosate at 15-20 days after planting (DAP) and at 28-30 DAP on Conventional technology, while weeding for Proposed technology was only done manually. Maintenance for pest and disease control on Proposed technology is carried out by inundation application four times, while control on Conventional technology is carried out

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by application of each type of synthetic pesticide up to six applications. The function and efficacy of various types of biopesticides used in the development of technological Proposeds and synthetic pesticides for controlling soybean pests anddiseases as well as the time of application can be seen in *Table 2*.

The observed variables were: (1) the type and intensity of the disease was observed from the age of 14 DAP for soil borne diseases based on disease incidence, while for air borne diseases based on disease severity, (2) the types and populations of insect pests were observed directly in 10 clumps of plants, (3) the abundance of arthropods (predators and parasitoids) was taken by using an insect net (sweep net) five single swings at each of fifteen points taken diagonally for each control technology, and (4) seed weight per hectare (t/ha).

Table 1. *Components of technologies for controlling soybean pests and diseases using in Banyuwangi regency, East Java, Indonesia, 2018*

No.	Components of technology	Technology components for controlling soybean pests and diseases	
		Conventional	**Proposed**
1.	Land preparation	No tillage	No tillage
2.	Drainage channel	Every 4 m (20 cm width and 25 cm depth)	Every 4 m (20 cm width and 25 cm depth)
3.	Certificate seed quality	Plant growth > 80%	Plant growth > 80%
4.	Seed care	Benomyl & cypermethrin	Trichol 8
5.	Varieties	1. Dering 2. Deja 3. Martoloyo (local Banyuwangi)	1. Argomulyo 2. Devon 3. Anjasmoro
6.	Planting method	Manual: by using stick	Manual: by using stick
7.	Planting distance	40 cm × 15 cm	40 cm × 15 cm
8.	Organic fertilizer	2 t/ha	2 t/ha
9.	Inorganic fertilizer	200 kg Phonska + 100 kg SP 36/ha	200 kg Phonska + 100 kg SP 36/ha
10.	Liquid fertilizer (DAP)	5 ml/l (20, 40, and 60 DAP)	*Allium cepa* (Ac) 5 ml/l (20, 40, and 60 DAP)
11.	Weeding (DAP)	Herbicide (0, 15, and 35 DAP)	Manual (15 and 35 DAP)
12.	Pest control (DAP)	Synthetic pesticides (scheduled): • Captan, prochloraz (0, 7, 14, 21, 28, and 35 DAP) • Chlorothalonyl, mankozeb (35, 42,49, 56, 63, and 70 DAP) • Amitraz (28, 35, 42, 49, 56, 63 DAP) • Deltamethrin (35, 42, 49, 56, 63, and 70 DAP) • Cypermethrin (21, 28, 35, 42, 49, and 56 DAP) • Cyhalothrin (35, 42, 49, 56, 63, and 70 DAP)	Biopesticide (Inundation):* • Trichol 8 (0, 14, 21, and 28 DAP) • Virgra & NSP (14, 21, 28, and 35 DAP) • BeBas, Bio-Lec, (42, 49, 53, and 60 DAP) • Eugenol & *Allium cepa* (Ac) (45, 52, 59, and 66 DAP)

*Biopesticides: Neem seed powder (NSP), Trichol 8 (*T. harzianum*), Virgra (*Sl*NPV), BeBas (*B. bassiana*), Bio-Lec (*L. lecanii*), eugenol (clove oil), and *Allium cepa* (Ac)
DAP = days after planting

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Table 2. *Types of pests and diseases, synthetic pesticides, biopesticides and application time in the field*

No.	Types of pests and diseases	Technology components for controlling soybean pests and diseases	
		Conventional	**Proposed**
	Pests:		
1.	*S. litura, C. chalcites, L. indicata*	Cypermethrin (21, 28, 35, 42, 49, and 56 DAP)	NSP & Virga (21, 28, 35, and 42 DAP)
2.	*B. tabaci*	Amitraz (28, 35, 42, 49, 56, 63)	BeBas & NSP (28, 35, 42, 49 DAP)
3.	*R. linearis, N. viridula, P. hybneri*	Deltamethrin (35, 42, 49, 56, 63, 70 DAP)	Bio-Lec & BeBas (42, 49, 56, 63 DAP)
4.	*E. zinckenella, H. armigera*	Cyhalothrin (35, 42, 49, 56, 63, 70 DAP)	Virgra & Bebas (35, 42, 49, 56 DAP)
	Diseases:		
1.	*R. solani, S. rolfsii, Fusarium* sp.	Captan, prochloraz (0, 7, 14, 21, 28, 35 DAP)	Trichol 8 (0, 14, 21, 28 DAP)
2.	*P. pachyrhizi, M. diffusa, P. manshurica*	Chlorothalonyl, mankozeb (35, 42, 49, 56, 63, 70 DAP)	Eugenol & Ac (35, 42, 49, 56 DAP)

The types of pests and diseases listed in *Table 2* are the results of observations on soybean plants one season before development activities were carried out and the results of discussions with the coordinator of the Field Extension Officer (FEO) in the Tegaldlimo, Banyuwangi

Data collected were subjected to statistical analysis of variance (ANOVA) by using a computer program MSTATC. Least Significant Differences (LSD) Test at 5% probability level was applied to compare the differences among treatments means.

Results and discussion

Types and intensity of soil-borne diseases

Observations of soil borne diseases carried out on plants aged 21 days after planting (DAP) obtained three types, namely: stem rot disease caused by the fungus *Sclerotium rolfsii*, root rot/blight caused by *Rhizoctonia solani* and sprouting caused by *Fusarium oxysporum* (*Figs. 1a, b, c*). The three types of disease are characterized by general symptoms, namely wilting of the leaves and then the plant dies, while at the base of the stem and roots there are white hyphae (mycelium). The characteristic symptom that distinguishes between *S. rolfsii* and *R. solani* is the presence of sclerotia in the form of small white to brown granules in *S. rolfsii* disease, while sclerotia in *R. solani* is in the form of brown flat plates. Both propagule structures are reproductive organs that are used to infect host plants or the resistant stadia of the fungus to defend themselves from the effects of unfavorable environmental conditions. Meanwhile, *F. oxysporum* disease only forms chlamydospores and the white mycelium is a resistant structure in the soil.

The highest disease intensity of *S. rolfsii* occurred in the Conventional technology in the small seed soybean variety (Martoloyo) reaching 12.55% followed by the large seed soybean variety (Anjasmoro) 11.80% and Devon 11.70%, then the small seed soybean (Dering) 6.75% then the large seed soybean variety (Argomulyo) 5.45%. Meanwhile, the lowest disease intensity of *S. rolfsii* occurred in the small seed variety (Deja) with disease

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incidence only below 5%. The highest mean intensity of *R. solani* root rot disease also occurred in the Conventional technology of large seed (Anjasmoro) and small seed (Martoloyo) soybean varieties by 10.90% and 10.45%, respectively. Meanwhile, the disease intensity of *R. solani* in Dering, Deja, Argomulyo and Devon varieties was low, only below 5%.

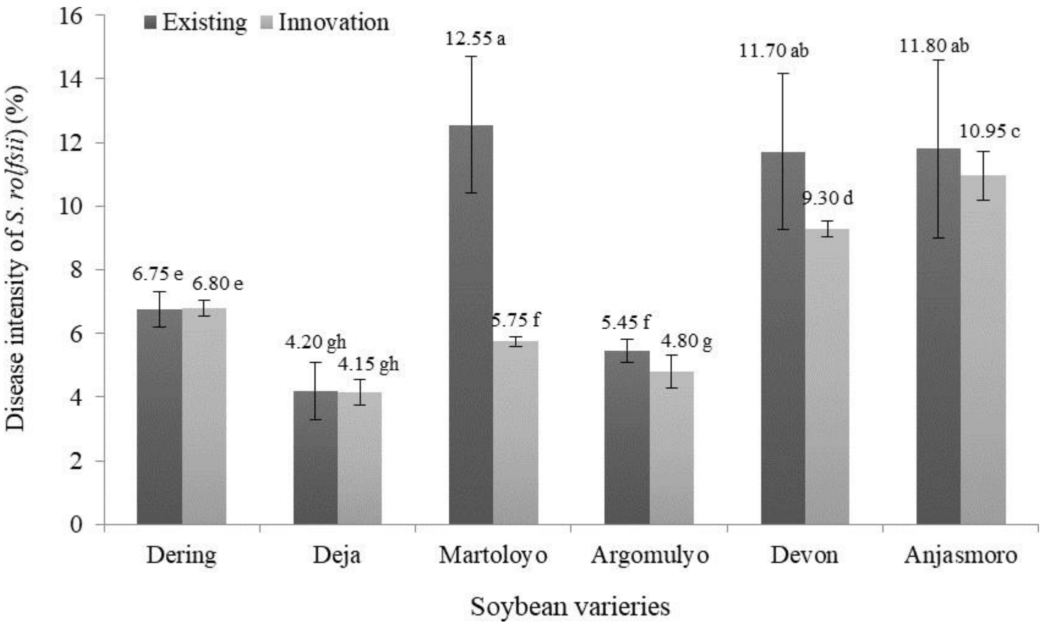

Figure 1a. *Average intensity of root rot disease (S. rolfsii) on soybeans varieties with large seed size (Argomulyo, Devon, and Anjasmoro) and small seed size (Dering, Deja, and Martoloyo) applied with synthetic pesticides and biopesticides (Tegaldlimo, Banyuwangi, 2018)*

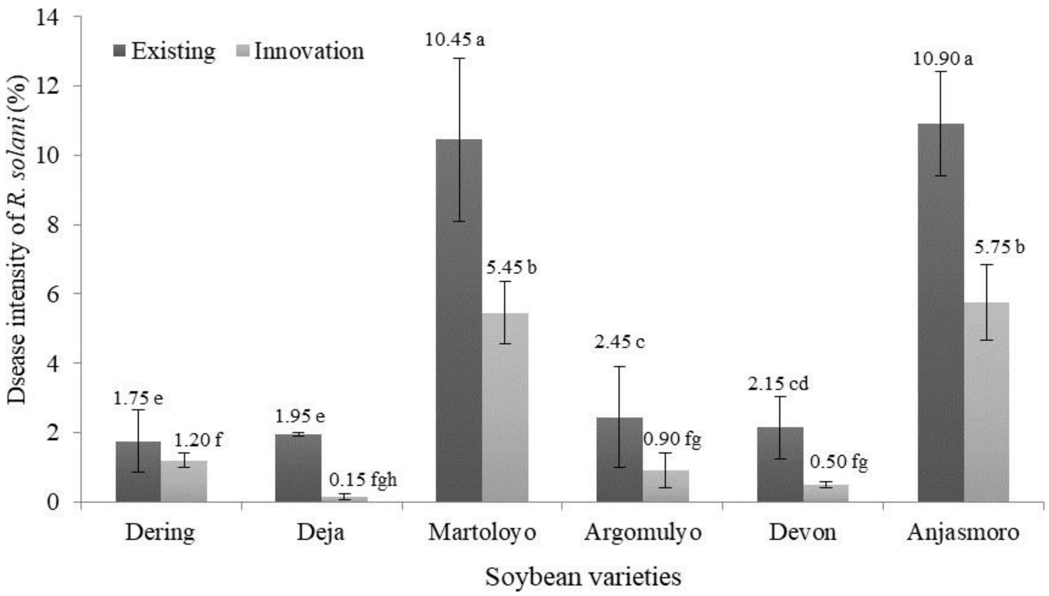

Figure 1b. *Average intensity of root blight (R. solani) on soybeans varieties with large seed size (Argomulyo, Devon, and Anjasmoro) and small seed size (Dering, Deja, and Martoloyo) applied with synthetic pesticides (Conventional) and biopesticides (Proposed) in Tegaldlimo, Banyuwangi, 2018*

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The results of this observation indicated that the Conventional technology for small-seeded soybeans of the Martoloyo and large-seeded varieties of Anjasmoro was less effective in suppressing the development of *S. rolfsii* and *R. solani* diseases when compared to innovative technologies. Meanwhile, the superiority of the efficacy of Proposed technology can be seen from the use of the biopesticide Trichol 8 from the antagonist fungus *T. harzianum* when compared with synthetic fungicides in suppressing the development of *S. rolfii* disease ranging from 7.20 to 20.51% in Anjasmoro, Devon and Argomulyo varieties. The efficacy of the use of the biopesticide Trichol 8 in innovative technology was also seen to be very significant in suppressing the development of *S. rolfsii* disease in the Martoloyo variety up to 54.18%. This phenomenon indicates that moisture at the base of the stem is one of the triggers for the less effective application of synthetic fungicides when compared to innovative technology. This condition was supported by the number of crowns on the Martoloyo and Anjasmoro varieties which were much more numerous and denser than other varieties.

The incidence of *R. solani* disease was also seen to be higher in the Conventional technology for large and small seed soybeans, namely the Anjasmoro and Martoloyo varieties at 10.90% and 10.45%, respectively. Judging from the control efficacy, Proposed technology is more effective in suppressing the development of *R. solani* disease when compared to Conventional technology because the control efficacy reaches 47.84% in small seed soybean varieties (Martoloyo) and 47.24% in large seed soybeans (Anjasmoro). The results of this development activity support the research conducted by Mahmud and Hossain (2017) and Najera et al. (2018), that the application of biopesticides from the antagonist fungus *T. harzianum* was better in suppressing the development of *S. rolfsii* and *R. solani* diseases when compared to the efficacy of synthetic fungicides with the active ingredients of carbendazim and prochloraz.

The low intensity of soil-borne diseases caused by the fungus *S. rolfsii* and *R. solani* in innovative technology is due to the main factor being that the seed treatment to be planted has previously been given the biopesticide Trichol 8 which contains *T. harzianum* which can function as an antagonist against the fungus causes of root and stem rot. In addition, the fungus T. harzianum also functions as a decomposer in used straw from the previous rice plant which was spread on the soil surface so that it can be directly converted into organic fertilizer which becomes more quickly available to plants to increase plant resistance to pathogen infection (Sharma et al., 2017; Kushwaha et al., 2018).

This study showed significant results by treating seeds using the biopesticide Trichol 8 containing conidia of the fungus *T. harzianum* because it was able to suppress the development of wilt disease in areas that were declared endemic. This phenomenon is supported by the results of research by Hirpara et al. (2017) that the fungus *T. harzianum* is able to produce hydrolytic enzymes chitinase and glucanase, causing lysis of the cell wall structure of *R. solani* and *S. rolfsii* by means of mycoparasites. Thus, technological Proposeds for control using biofungicides, especially the antagonist fungus *T. harzianum*, can be recommended as biological control agents against wilt disease caused by *S. rolfsii* and *R. solani*.

The intensity of *F. oxysporum* sprouting disease was very low, especially in the Conventional technology, which occurred in all soybean varieties from small seeds to large seeds because it was only 2% (*Fig. 1c*). Meanwhile, the intensity of disease in the Proposed technology appears to be higher when compared to the Conventional technology although the difference in efficacy levels is also less significant. The low

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incidence of germination disease is thought to be due to the lack of growth of the pathogen when compared to *S. rolfii* and *R. solani*. Based on the results of personal communication with the coordinator of PPL Tegaldlimo (Surati, SP) that two types of soil-borne diseases that are endemic in that location are *S. rolfsii* and *R. solani* with disease incidence reaching above 20% in dry season-1 after rice cultivation. The results of this study also showed that the application of the fungus antagonist *T. harzianum* to the Proposed technology was less effective than the synthetic fungicides captan and prochloraz in suppressing the development of *F. oxysporum* sprouting disease because these pathogens did not develop optimally. The results of this study were also supportedby testing of several types of synthetic fungicides, especially prochloraz in addition to caneconazole and propiconazole which were more significant in suppressing *F. oxysporum* wilt disease by up to 80% when compared to the efficacy of the fungal antagonist *T. harzianum* (Mondani et al., 2021).

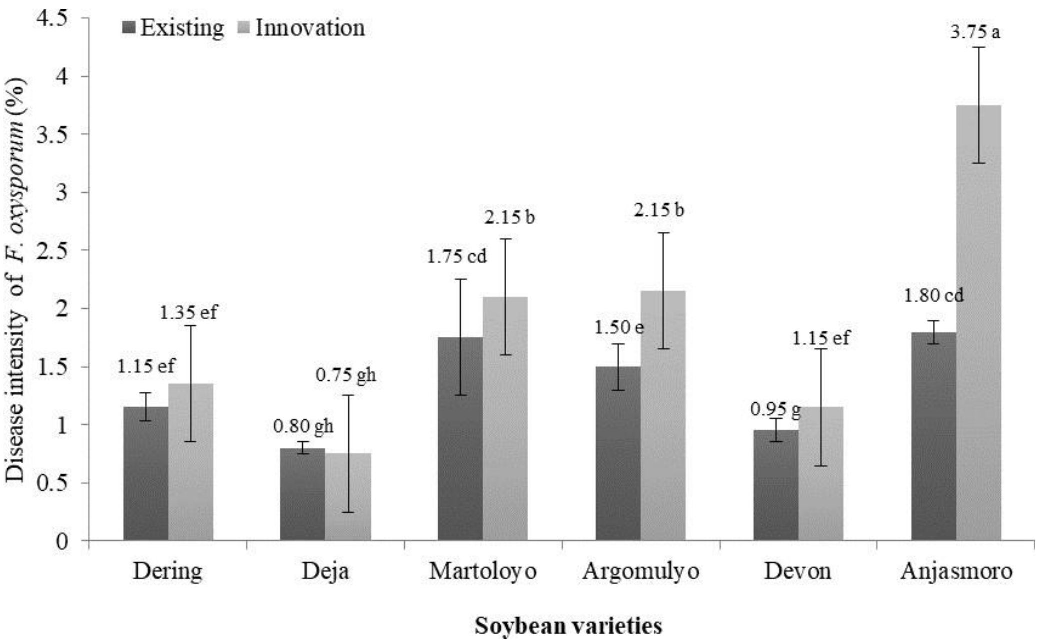

Figure 1c. *The mean intensity of germination disease (F. oxysporum) on soybeans varieties with large seed size (Argomulyo, Devon, and Anjasmoro) and small seed size (Dering, Deja, and Martoloyo) applied with synthetic pesticides (Conventional) and biopesticides (Proposed) in Tegaldlimo, Banyuwangi, 2018*

Bacterial pustule disease intensity

In addition to soil-borne diseases, leaf diseases were also found, namely bacterial pustules caused by *Xanthomonas axonopodis*, especially in Conventional technology. Symptoms of pustule disease are characterized by small patches or boils, initially pale green patches then turn brown. The hallmark of a pustule is that in the center of the spot there is a brownish stain with the edges of the spot being pale to yellowish in color, irregular in shape, and dead cell tissue (necrosis). Spots that are located close together, can coalesce to produce spots with a much larger size that can cause yellowing of the leaves (chlorosis) and is often followed by early leaf fall this interferes with pod filling.

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This condition is due to the symptoms of bacterial pustules which generally occur in the flowering phase around the age of 40 DAP, especially on young leaves which are more susceptible to infection. The bacteria not only infect leaves, but also infect soybean pods and seeds (*Fig. 2*).

Figure 2. *Symptoms of bacterial pustule disease (X. axonopodis) on local soybean variety Martoloyo which was applied with synthetic fungicide (Conventional, Left) and biopesticides (Proposed, Right) in Tegaldlimo, Banyuwangi, 2018*

The intensity of bacterial pustules ranged from 0-15.25% and the severity of the disease tended to be found in the Conventional technology, especially the Martoloyo variety (*Fig. 3*). The results of this observation indicate that the Martoloyo variety on the Conventional technology appears to be more susceptible to *X. axonopodis* infection with an intensity of up to 15.25%. Meanwhile, the Dering, Deja, Argomulyo, Devon and Anjasmoro varieties on the Conventional technology only ranged from 0.15-1.55% even though they had been applied using synthetic fungicides compared to the Dering and Deja varieties, which were only 1.55% and 1, respectively. 25%. Meanwhile, the intensity of bacterial pustules in the Proposed technology was seen much lower, only 0.15-0.50% and there were no signs of infection in the three varieties Argomulyo, Devon and Anjasmoro.

In terms of the varieties used, the Martoloyo variety does appear to be more susceptible to bacterial pustule infection when compared to the Dering, Deja, Argomulyo, Devon and Anjasmoro varieties. This condition can also be seen from the intensity of bacterial pustule disease in the Proposed technology of 5.25%, but the useof biopesticide *T. harzianum* makes plant performance better coupled with the application of botanical pesticides eugenol and Shallot extract (SE) so that the pathogenis less able to develop properly. Plant tolerance to this bacterial pustule disease is thought to have a significant effect on the antagonist fungus *T. harzianum* given before planting for seed treatment so as to produce metabolites that can suppress the development of pathogens because plant vigor appears to be better (Lorito et al., 2010; Leylaie and Zafari, 2018). Another report states that the fungus *Trichoderma sp*. capable of producing phytohormones jasmonic acid and salicylic acid so that it can affect the development of bacterial pustule disease (*X. axonopodis*) although its performance is lower than *Pseudomonas fluorescens* bacteria (Giri et al., 2008; Jagtap etal., 2012). Furthermore, Chowdappa et al. (2018) explained that clove oil can suppress the development of bacterial pustules caused by *X. axonopodis*.

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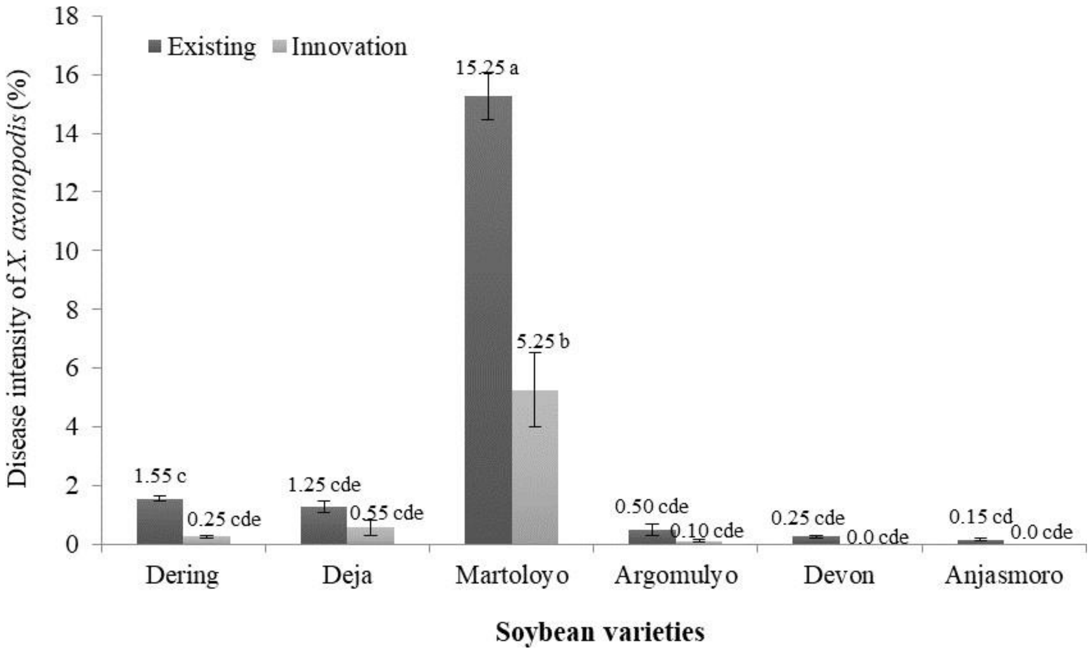

Figure 3. *Intensity of bacterial pustules (X. axonopodis) on soybeans varieties with large seed size (Argomulyo, Devon, and Anjasmoro) and small seed size (Dering, Deja, and Martoloyo) applied with synthetic pesticides (Conventional) and biopesticides (Proposed) in Tegaldlimo, Banyuwangi, 2018*

Intensity of rust disease (Phakopsora pachyrhizi)

Rust disease (*P. pachyrhizi*) also occurred in Conventional and innovativetechnologies with disease intensity ranging from 5.45-26.75% in the six soybean varietiesdeveloped (*Fig. 4*). In general, the results showed that the intensity of leaf rust disease inthe Conventional technology seemed to be higher than the Proposed technology, especially in the Martoloyo, Argomulyo and Deja varieties. Meanwhile, the intensity of leaf rust on the Anjasmoro, Devon and Dering varieties showed a higher disease intensity in the innovative technology, although the difference in disease intensity was not too striking, only about 1%. The intensity of rust disease on the Martoloyo variety on the Conventional technology which was applied with the synthetic fungicide chlorotalonyl and mankozeb showed the highest intensity of leaf rust disease up to 26.75% when compared to other soybean varieties. Meanwhile, the Proposed technology applied with the bipesticide Trichol 8 followed by the application of eugenol and *A. cepa* (Ac) showeda lower disease intensity of 23.15% or there was a control efficacy on the Proposed technology of 13.45% compared to the Conventional technology.

The intensity of rust disease on the Anjasmoro variety with the treatment of innovative technology appeared to be higher at 16.85% or 0.10% when compared to the intensity of rust disease in the Conventional technology, which was only 16.75%. However, the innovative technology by relying on botanical pesticides from eugenoland *A. cepa* is almost comparable to the efficacy of synthetic fungicides with the active ingredients of chlorotalonyl and mancozeb. The Anjasmoro variety is quite tolerant of rust disease infection caused by *P. pachyrhizi*, however, this variety still has a high chance of infection if environmental conditions support the development of the pathogen (Paul et al., 2011; Sumartini and Kuswantoro, 2014).

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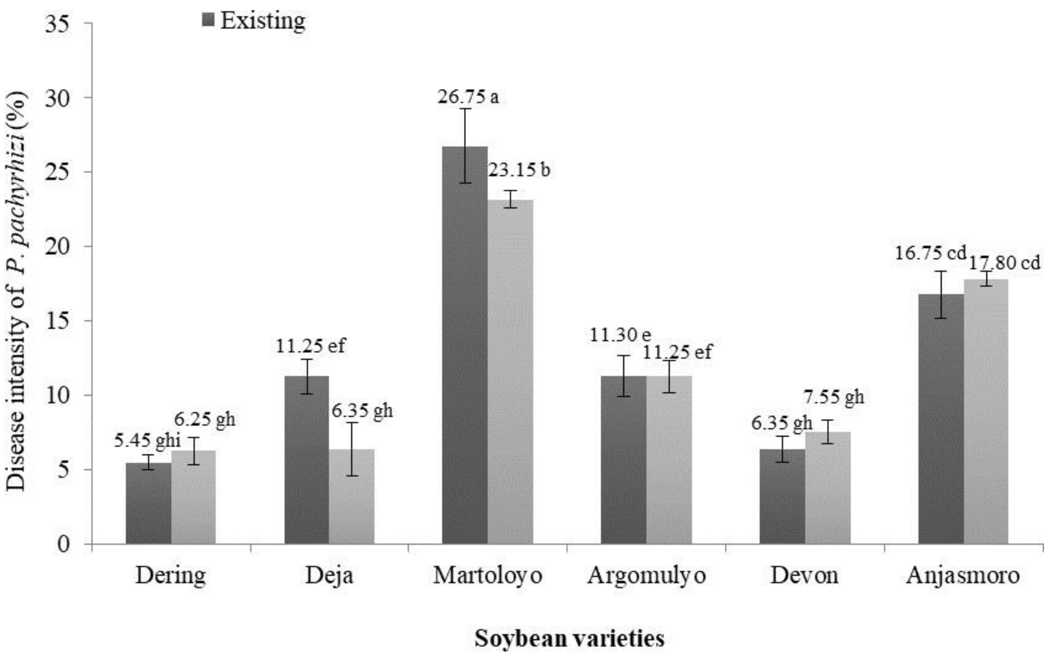

Figure 4. *The average intensity of rust disease (P. pachyrhizi) on soybeans varieties with large seed size (Argomulyo, Devon, and Anjasmoro) and small seed size (Dering, Deja, and Martoloyo) applied with synthetic pesticides (Conventional) and biopesticides (Proposed) in Tegaldlimo, Banyuwangi, 2018*

The intensity of leaf rust on conventional and innovative technologies on Deja and Argomulyo varieties is lower than Anjasmoro and Martoloyo varieties. Meanwhile, the lowest leaf rust intensity occurred in the Conventional technology of the Dering and Devon varieties, respectively 5.45% and 6.35%. The efficacy of synthetic fungicides chlorothalonyl and mankozeb were superior when compared to innovative technologies using botanical pesticides eugenol and *A. cepa* because the intensity of disease in the two varieties were 6.25% and 7.55%, respectively. However, if viewed from the difference in the intensity of the disease seen, there is also no significant difference because it is only about 1%, in addition to increasing the control efficacy, it is recommended to increase the frequency of biopesticide applications. The results of this study indicate that the innovative technology is also comparable to the efficacy of synthetic fungicides in suppressing the development of leaf rust disease. In addition, the two types of soybean varieties (Dering and Devon) are the result of crosses from parents who have better resistance to leaf rust disease when compared to the Deja, Argomulyo, Anjasmoro and Martoloyo varieties (Balitbangtan, 2012; Suhartina et al., 2013).

The low intensity of rust disease in innovative technology was caused by spraying plants using botanical pesticides containing eugenol compounds four times starting at 28 DAP. The results of the Sumartini report (2015) indicated that clove oil containing eugenol compounds was able to damage the cell wall (uredospore) so that the spores were lysed and eventually dried and died so that the spores could not develop. Another report also explained that the application of Neem seed powder (NSP) containing the metabolite azadirachtin was able to suppress the severity of rust disease (Devaraj et al., 2013; Angele et al., 2018). The results of the research of Shabana et al. (2017) also indicated that the application of azadirachtin compound could suppress *P. pachyrhizi* rust disease severity up

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to 83%. Leaf diseases other than *P. pachyrhizi* and downy mildew *P. manshurica* were not found in either the Proposed or Conventional technology, presumably due to the presence of underdeveloped pathogens in dry season-1 so that it was added with preventive cultivation management using various types of biopesticides (Proposeds) and synthetic fungicides (Conventional). the plants can be protected from pest attacks.

Pest population

Observations showed about 14 types of leaf and pod pests belonging to 3 orders of Diptera, 4 orders of Lepidoptera, 2 orders of Homoptera, 3 orders of Hemiptera, 1 order of Orthoptera, and 1 order of Coleoptera (*Table 3*). The highest pest population was whitefly (*Bemisia tabaci*) up to 114 individuals, especially at the age of 63 DAPon the Proposed technology but almost the same as the population on the Conventional technology, which was 96 individuals. Next, it was followed by a population of *Liriomyza sp*. and shoot borer *M. dolichostigma*, the number of which was almost the same between the Conventional and innovative technologies. Meanwhile, the population of pod sucking pests *R. linearis* and *P. hybneri* was seen to be much higher in the Conventional technology when compared to the Proposed technology. The high population of *B. tabaci* in innovative technology was caused by the migration of nymphs and imagos of *B. tabaci* carried by the wind from the Conventional plots. According to Khalid et al. (2006), wind speed is one of the main factors that can cause *B. tabaci* migration to other places. Zeshan et al. (2015) also confirmed that wind speed has a positive correlation with the incidence of *B. tabaci* migration in tomato plants.

Table 3. *Arthropod populations as pests on soybean plantations applied with synthetic pesticides and biopesticides*

No.	Predator types	Predator population in two control technologies DAP (individuals)			
		Conventional		Proposed	
		49	63	49	63
1.	*M. sojae* (Diptera: Agromyzidae)	0.10	0.00	1.50	4.80
2.	*M. dolichostigma* (Diptera: Agromyzidae)	0.30	17.60	1.40	10.60
3.	*S. litura* (Lepidoptera: Noctuidae)	2.30	0.00	2.10	0.00
4.	*L. indicata* (Lepidoptera: Noctuidae)	0.90	1.50	0.00	0.50
5.	*Empoasca* sp. (Homoptera: Cicadelidae)	2.60	11.00	2.30	2.30
6.	*P. inclusa* (Coleoptera: Chrysomelidae)	0.90	3.10	1.80	2.50
7.	*B. tabaci* (Homoptera: Aleyrodidae)	43.10	114.00	80.40	96.00
8.	*Liriomyza* sp. (Diptera: Agromyzidae)	11.80	24.15	39.50	25.70
9.	*Grasshopper* (Orthoptera: Acrididae)	1.40	1.00	0.60	4.00
10.	*R. linearis* (Hemiptera: Alydidae)	2.10	2.50	10.20	21.50
11.	*P. hybneri* (Hemiptera: Alydidae)	1.40	2.40	1.50	14.30
12.	*N. viridula* (Hemiptera: Alydidae)	1.50	2.20	1.40	3.20
13.	*H. armigera* (Lepidoptera: Noctuidae)	0.90	1.80	0.90	1.90
14.	*E. zinckenella* (Lepidoptera: Pyralidae)	0.00	0.90	0.00	0.50

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Populations of leaf-eating pests *S. litura* and *L. indicata* and pod-eating *H. armigera* and *E. zinckenella* were classified as low on the innovative technology or not significantly different from the population on the Conventional technology. This condition was caused by innovative technology using the biopesticide Virgra which contains an entomopathogenic virus so that all larval stages of the pest were killed dueto infection with the virus. Bedjo (2004) reported that the entomopathogenic virus isolate JTM97C as the active ingredient of the Virga formulation was very effective in killing armyworm and pod-eating larval stages with a mortality of up to 99%. Arifin (2012) also explained that the control of armyworms was very effective using bioinsecticides from *Spodoptera litura* Nuclear Polyhedrosis Virus (*Sl*NPV).

Predatory arthropod population

The abundance of the population of arthropods that act as predators was obtained as many as 13 species consisting of; 2 orders Orthoptera, 3 orders Araneida, 4 orders Coleoptera, 1 order Mantodea, 1 order Collembola, and 3 orders Hemiptera which are quite abundant in innovative technology when compared to Conventional technology (*Table 4*). Predators caught as potential predators of pests on the surface of the plant crown and soil surface, especially the order Collembola. The canopy-dwelling predators of the orders Orthoptera, Araneida, Coleoptera and Hemiptera are generally gregarious predators, especially *Paederus* sp., *Oxyopes* sp., and *M. sexmaculatus*. which is able to prey on leaf and pod pests so that the pest population in the Proposed technology is not too high when compared to the Conventional population in the Conventional technology.

Table 4. *Arthropod populations as predators in soybean plantations applied with synthetic pesticides and biopesticides*

No.	Predator types	Predator population in two control technologies DAP (individuals)			
		Conventional		Proposed	
		49	63	49	63
1.	*Metioche vittaticolis* (Orthoptera: Grylidae)	3.50	3.90	0.90	0.10
2.	*Conocephalus longipennis* (Orthoptera: Grylidae)	2.90	2.80	0.50	0.50
3.	*Heirodula formosana* (Mantodea: Mantidae)	2.50	1.90	1.20	0.00
4.	*Oxyopes* sp. (Araneida: Oxyopidae)	14.30	7.60	0.00	0.00
5.	*Pardosa pseudoannulata* (Araneida: Lycosidae)	2.40	2.90	1.00	0.50
6.	*Pardosa birmanica* (Araneida: Lycosidae)	1.90	1.80	0.50	0.00
7.	*Menochilus sexmaculatus* (Coleoptera: Coccinellidae)	17.20	22.50	0.00	0.00
8.	*Micraspis inops* (Coleoptera: Coccinellidae)	11.50	23.60	1.30	1.50
9.	*Sycanus* sp. (Hemiptera: Reduviidae)	2.50	1.50	0.00	0.00
10.	*Andrallus* sp. (Hemiptera: Reduviidae)	1.80	1.50	0.00	0.00
11.	*Rhynocoris* sp. (Hemiptera: Reduviidae)	1.50	2.50	0.00	0.00
12.	*Paederus* sp. (Coleoptera: Staphylinidae)	13.80	19.50	1.30	0.50
13.	*Entomobrya* sp. (Collembola: Entomobryidae)	47.50	63.90	12.50	9.10

The results of this study indicate that the application of synthetic pesticides can significantly suppress the growth of natural enemies, especially predators that inhabit

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the plant canopy (*Fig. 5*). The results of the study by Taulu and Polakitan (2010) explained that the dominant predator on the soybean canopy was the *Paederus* sp. (Coleoptera: Staphylinidae), crickets *A. longipennis* (Orthoptera: Gryllidae), spiders *Pardosa* sp. (Araneae: Lycosidae), *M. sexmaculatus* and *M. inops* (Coleoptera: Coccinellidae) as potential predators of soybean leaf and pod pests, especially the Anjasmoro variety, which has a denser canopy so that these predators are prime candidates for biological control in soybean plantations.

Figure 5. *The canopy-dwelling predator Coccinella sp. (left) and predators that inhabit the soil surface and plant canopy Oxyopes sp. (right) on technology proposed*

Arthropod (parasitoid) population

The abundance of the parasitoid population was obtained from the average results of Proposed technology and Conventional technology. The results showed that the parasitoid population in the Proposed technology caught was nine species, all of which were from the order Hymenoptera and the families Eupelmidae, Encyrtidae Scelionidae, Braconidae Aphelinidae and Trichogrammatoidae (*Table 5*). Meanwhile, the number of parasitoids in the Conventional technology found only four species from the families Eupelmidae, Encyrtidae and Scelionidae with very low populations. The population of all types of parasitoids in the Proposed technology was quite high starting at 49 DAP, namely; 4.9 tails; 3.5 tails; 5.4 tails; 3.2 tails; 8.5 tails; 3.5 tails; 5 tails; 10 tails and 21.5 tails. The population of eight types of parasitoids increased with increasing plant age at 62 DAP except for the parasitoid *O. malayanensis*. The increase in the population of parasitoids, especially *Trichogramma* sp. and *Telenomus* sp. quite significant, which were 42 and 82 individuals, respectively. Meanwhile, the population increase of *Aphidius* sp., *Binodoxys* sp., and *Encarsia* sp. respectively 21.5, 17.50 and 11 individuals. Several reports indicate that each type of parasitoid has a fairly high levelof parasitization against major soybean pests such as *B. tabaci*, *A. craccivora*, *A.gossypii*, and *S. litura* (Malik and Karut, 2012; Khan and Wan, 2015). Meanwhile, Trisawa et al. (2010) and Arsyi (2021) confirmed that the parasitoids *A. dasyni*, *O. malayanensis* and *T. japonicus* were parasitoids of eggs and nymphs of pod-sucking pests, especially *R. linearis* and *N. viridula*, so that the population of these pests appeared relatively lower in innovative technology.

The increase in the parasitoid population in the Proposed technology was not followed by the Conventional technology, the parasitoids in the Conventional land that were sprayed using synthetic insecticides on a regular basis almost no individuals were found because

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there were no living parasitoids, except for *Telenomus* sp. only 5 tails. This phenomenon occurs because natural enemies, especially parasitoids, are moresusceptible to synthetic insecticides than the main pests, while parasitoids act as natural controllers. According to de-Paiva et al. (2018) that synthetic insecticides with theactive ingredients of tiamethoxam, lambda cyhalothrin, chlorpyrifos, and chlorpyrophoscan kill all types of parasitoids in soybean fields. Bueno et al. (2012) also stated that the parasitoids *Trichogramma pretiosum* and *Telenomus remus* would be killed by theapplication of synthetic insecticides. Therefore, Zhao et al. (2012) and Cheng et al. (2021) suggested that to maintain the survival of natural enemies, especially parasitoids, synthetic insecticides should be used which are more selective. These observations indicate that the use of biopesticides derived from microorganisms or botanical pesticides is more environmentally friendly, because it can maintain the viability of natural enemies in addition to suppressing the Conventional pest population.

Table 5. *Arthropod populations as parasitoids in soybean plantations applied with synthetic pesticides and biopesticides*

No.	Predator types	Predator population in two control technologies DAP (individuals)			
		Conventional		Proposed	
		49	63	49	63
1.	*Anastatus dasyni* (Hymenoptera: Eupelmidae)	4.90	5.50	0.80	0.10
2.	*Ooencyrtus malayanensis* (Hymenoptera: Encyrtidae)	3.50	2.40	0.50	0.00
3.	*Trissolcus japonicus* (Hymenoptera: Scelionidae)	5.40	6.40	0.00	0.00
4.	*Gryon japonicum* (Hymenoptera: Scolionidae)	3.20	4.30	0.10	0.10
5.	*Aphidius* sp. (Hymenoptera: Braconidae)	8.50	21.50	0.00	0.00
6.	*Binodoxys* sp. (Hymenoptera: Braconidae)	3.50	17.50	0.00	0.00
7.	*Encarsia* sp. (Hymenoptera: Aphelinidae)	5.00	11.00	0.00	0.00
8.	*Trichogramma* sp. (Hymenoptera: Trichogrammatoidae)	10.00	42.50	0.00	0.00
9.	*Telenomus* sp. (Hymenoptera: Scelionidae)	21.50	82.00	0.50	5.50

Soybean seed weight

Harvest was obtained from the results of tiling on plants that were physiologically ripe and the pods are brown. Tiles from the plant were 14.4 m^2 (6 m × 6 rows), then the pods are dried to a seed moisture content of about 10%. The average soybean seed weight yield ranged from 1.98-2.98 t/ha (*Fig. 6*) and in general the seed weight yield of the Conventional technology was higher than that of the innovative technology. The highest average seed weight was obtained for the large-seeded soybean variety (Anjasmoro) on the Conventional technology, which was 2.98 t/ha, while the average seed weight for the innovative technology was 2.89 t/ha. Furthermore, the average weight of soybean seeds was 2.81 t/ha, meanwhile the average weight of soybean seeds in the Proposed technology reached 2.65 t/ha so that there was a difference in seed weight of about 0.16 t/ha. The average weight of large-seed soybeans was superior, especially to the Devon and Argomulyo varieties with the application of Conventional technology, which were 2.67 t/ha and 2.45 t/ha, respectively. The difference in the weight difference of soybeans in the Conventional technology and in Proposed technology was 0.08 t/ha in the Argomulyo variety and 0.24 t/ha in the Devon variety. The lowest average soybean seed weight occurred in Deja and

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Dering soybean varieties on Proposed technology, respectively 1.98 t/ha and 2.10 t/ha, when viewed from the average seed weight that occurred in Conventional technology and Proposed technology, there were differences seed weight ranges from only 0.11-0.12 t/ha.

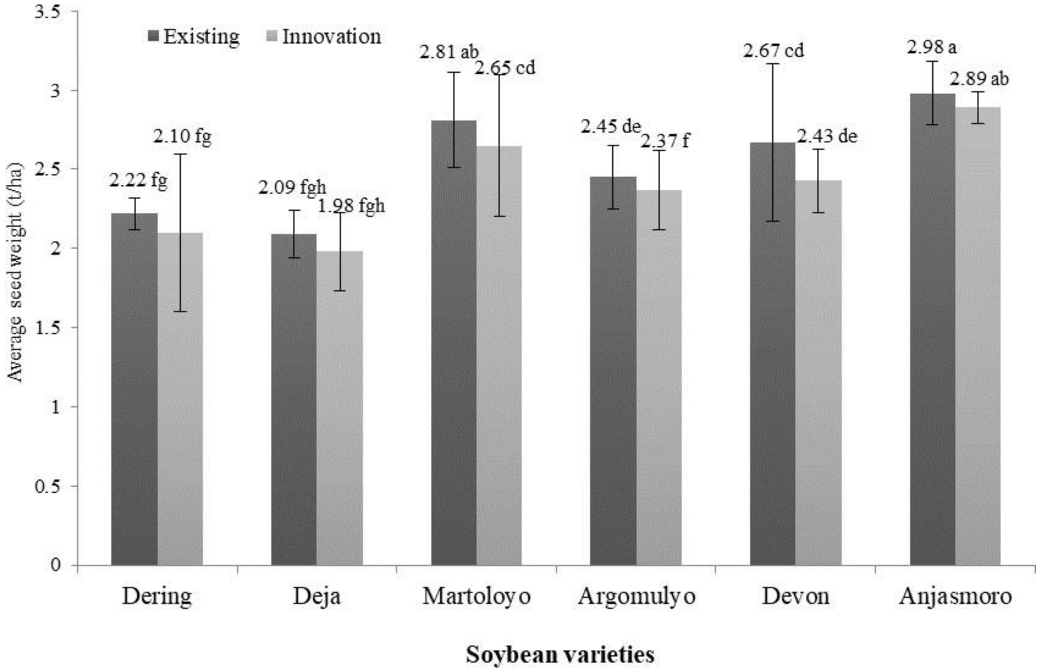

Figure 6. *The average weight of soybean seeds (t/ha) with large seed size (Argomulyo, Devon, and Anjasmoro) and small seed size (Dering, Deja, and Martoloyo) on Conventional technologyand Proposed technology, in Tegaldlimo, Banyuwangi, 2018*

The average weight of soybean seeds obtained shows that the Conventional technology that relies on the application of synthetic pesticides is superior to the weight of soybean seeds in the innovative technology that utilizes various types ofbiopesticides that are applied inundated. This phenomenon occurs because the scheduled application of synthetic pesticides is six times more effective and able to kill all Conventional pests without taking into account the pest population in a relatively short time. Therefore, the pest does not have the opportunity to damage the plant, especially the pods. Meanwhile, the application of biopesticides is only four times basedon the control threshold value for each type of pest so that these organisms can still damage plants because the performance of biopesticides is relatively slower than synthetic pesticides. Therefore, to obtain soybean yields as in the Conventional technology and yield losses can be kept/reduced as low as possible, the number and frequency of biopesticide applications must be increased. However, several advantages that can be obtained from innovative technology by using various types of biopesticides are: (1) can suppress the explosion of pests that are already resistant to several types of synthetic pesticide formulations, (2) inhibit the occurrence of resistance and resurgence in endemic lands, (3) are relatively safer in maintaining the survival of natural enemies, especially predators and parasitoids, (4) does not cause pollution or environmentalpollution and can even reduce poisoning and various negative impacts due to synthetic pesticide residues, (5) the product is more organic so it has the opportunity to have a much higher selling value compared to conventional products (Samada and Tambunan, 2020; Fenibo et al., 2021).

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Conclusions

Innovative technology with the application of various types of biopesticides consisting of; Trichol 8, Virgra, SBM, BeBas, Bio-Lec, eugenol and EBM can suppress the development of major soybean pest and disease populations and can suppress the occurrence of resistance and resurgence in endemic lands. Innovative technology with the application of various types of biopesticides can maintain the survival of useful insects, especially predators and parasitoids, while the Conventional technology with the scheduled application of synthetic pesticides can kill almost all Conventional natural enemies. The average yield of soybean seed weight in the Proposed technology is slightly lower than the Conventional technology although the difference is not significant. Innovative technology with the application of various types of biopesticides has better prospects and can suppress the occurrence of resistance and resurgence in endemic land, is environmentally friendly so that it does not leave synthetic pesticide residues and the product obtained is more organic and has a higher selling price. The number and frequency of application of biopesticides need to be increased and inundation is recommended in order to reduce yield losses such as the efficacy of synthetic pesticides.

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