JPT: Jurnal Proteksi Tanaman (Journal of Plant Protection)
p-ISSN : 2580-0604, e-ISSN: 2621-3141
Accredited: Sinta 3
Publisher: Universitas Andalas, Website: http://jpt.faperta.unand.ac.id/index.php/jpt
Vol. 7 No.1 (2023): 55 – 64

The Environmentally IPM Package for Controlling Fall Armyworm (*Spodoptera frugiperda*) in Maize Field

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Received: 30 May 2023 | 1st Revised: 15 June 2023 | Accepted: 30 June 2023 | Published: 30 June 2023

Abstract

Integrated Pest Management (IPM) is a pest control method that combines several control techniques by considering ecological, economic, and sociological consequences. Management efforts with IPM principles can be conducted by cultivating healthy plants and entomopathogen application. This study examined the IPM package's success for controlling fall armyworm (*Spodoptera frugiperda*) in maize field. This research was conducted in a farmer's maize plantation in the West Pasaman District from August to December 2021. The study used a Randomized Block Design (RBD) which consisted of three treatments and five replications. The treatments were different cultivation techniques using IPM, Non-IPM, and control. The variables observed were the population of *S. frugiperda* (individual/plant), attack rate (%), attack intensity (%), cob weight (g/cob), and farming cost (IDR). The results showed that the IPM and Non-IPM maize cultivation techniques had no different effect on *S. frugiperda*, especially survival stage, attack rate, intensity, and yield. However, this effect was higher than the control. In addition, the economic benefits of cultivation with IPM were higher than non-IPM. Therefore, this IPM package can be recommended for controlling *S. frugiperda* because it is also economically profitable and environmentally friendly.

Keywords: Cob weight, corn, damage level, fall armyworm, farming cost

Introduction

Maize constitutes a primary carbohydrate source in Indonesia besides rice, and it has the opportunity to improve the economic level of the community. Maize contains fiber and is rich in essential nutrients for the body (Ariyani, 2013), producing macronutrients, minerals, and vitamins. The kernels contain carbohydrates, fats, vitamins, minerals, and protein (Saavoss et al., 2021, 2016). Maize has been utilized and developed as a raw material for processed food, feed, and industry. 51% of dry maize will be processed as feed, and 49% will be processed into food products such as flour (Herlina and Fitriani, 2017).

One problem faced during maize cultivation is fall armyworm attack (*Spodoptera frugiperda*, Lepidoptera: Noctuidae), which is a polyphagous insect (Baudron et al., 2019) and causes economic losses to more than 350-353 species of plants including maize, beans, and soybeans, and rice (Montezano et al., 2018; Kansiime et al., 2019). Its presence has been reported in many countries, such as Latin America, Africa, Europe, and Asia (Clark et al., 2007; Purwanto, 2008; Lee et al., 2020). According to Harahap (2019), this pest spread quickly from America in 2016, entered Africa, and spread across Asia to Thailand in 2018. In Indonesia, S. *frugiperda* was first reported in West Pasaman District, West Sumatra, with a larval population of 2-10 individuals per plant (Nonci et al., 2019). The larvae can attack all stages of the maize, vegetative and generative (Lubis et al., 2020), damaging all parts of the maize, such as the cob, flowers, leaves, and roots (Prasanna et al., 2018). The Center for Forecasting Plant Pest Organisms (BBPOPT, 2019) reported that the attack rate of *S. frugiperda* in Indonesia during 2019-2020 reached 14,133.6 ha. Meanwhile, Lubis et al. (2020) reported that the attack rate in Petir Village, Bogor District reached 60%.

Integrated pest management (IPM) is expected to be safe and environmentally friendly to control *S. frugiperda*. According to Metcalf and Luckmann (1982), IPM is a method of pest control in a compatible way that considers ecological, sociological, and economic principles. Two main concepts of IPM are healthy cultivation and using natural enemies.

Healthy cultivation is related to managing the cultivation from planting to harvest, including fertilizer, spacing, and intercropping. According to Hariono (2017), organic fertilizer in the form of cow manure contains macronutrients; nitrogen (28.1%), potassium (20%), and phosphorus (9.1%). This fertilizer is easily decomposed and can increase microorganism number in the soil (Risnandar, 2012). Applying 15 kg/plot of cow manure can improve maize growth better (Dewi et al., 2007).

Furthermore, Silaban et al. (2013) stated that adjusting spacing can increase yields and reduce competition to absorb nutrients, sunlight, and water. According to Yunita et al. (2017), narrow spacing will increase competition between plants. The spacing of 75 x 30 cm significantly affected the cob weight of maize compared to 75 x 25 cm or 70 x 20 cm. Based on Rahmansyah and Sudiarso (2018), a 2:1 *jajar legowo* (widened spacing) with a 30 x 70 cm spacing increased maize growth and high yields compared to other methods. In addition, intercropping cultivation of maize with legumes is also important in suppressing *the S. frugiperda* population. According to Hailu et al. (2018), the intercropping method can be an alternative in suppressing *S. frugiperda* up to 38%.

Besides that, entomopathogens are potential natural enemies that can control *S. frugiperda* (Abbas et al., 2022). According to Masyitah et al. (2017), there are three types of fungi that can be used: *Metharizum anisopliae, Lecanicillium lecanii,* and *Beauveria bassiana*. Wraight et al. (2000) stated that *B. bassiana* can control various pests, propagate quickly, and is environmentally safe. It can kill larvae of Coleoptera, Lepidoptera, Hemiptera, and Orthoptera (Riyatno dan Santosa, 1991), suppressing the population of *Leptinotarsa decemlineata* up to 76.6% (Poprawski et al., 1997) and *Bemisia argentifolii* up to 77% (Wraight et al., 2000). According to Soetopo and Indrayani (2007), *B. bassiana* causes white muscardine in insects because it produces white conidium and mycelium. There was no report on *S. frugiperda* management using the IPM package (fertilizer, spacing, intercropping, and entomo-pathogen). This study aimed to determine the success of controlling *S. frugiperda* using the environmental IPM package.

Methods

This study was carried out in August-December 2021 on maize field owned by farmers in Wonosari Village, West Pasaman

District, West Sumatra, with an altitude of 1,332 meters above sea level. The average daily temperature reached 26.18-28.1°C, and the humidity reached 76.5-85.1%.

Method

The study was conducted in a randomized block design (RBD) of three treatments and five replications. The treatments were in the form of different cultivation: IPM, Non-IPM, and control. All three treatments used the same seeds (Pioneer 32) to ensure that differences in growth only occurred due to the treatments. Petroganik is an organic fertilizer containing 15% C-organic with C/N ratio of 15-25. Cow manure used contained N-total of 1.191%, P-total of 56.36 ppm, and K-total of 1.97% (Table 1).

Table 1. The difference cultivation of IPM, Non-IPM, and control

Cultivation package	IPM	Non-IPM	Control
Variety	Pioneer P32	Pioneer P32	Pioneer P32
Fertilizer	Petroganik, cow manure	NPK mutiara, Phonska, Urea	-
Insecticide	Biopesticide: *B.bassiana*	Spinoteram 120 g/l (Endure)	-
Intercropping	Soybean	-	-
Spacing	30 x 70 cm, *jajar legowo*	30 x 50 cm	30 x 50 cm

Maize Cultivation

The field was divided into 15 plots, each measuring 4 x 5 m. Land preparation with turning the soil was done using a hoe. Two weeks after land preparation, planting holes were made in each plot, each filled with the seed of Pioneer 32. Briefly, the stages of cultivation activities are presented in the following table:

Table 2. Treatment was given to IPM, non-IPM in the maize field

	Treatment	
	IPM	Non-IPM
2 weeks before planting	Applying petroganik: 2,000 kg/ha	-
S. frugiperda present	Applying *B. bassiana*: 100 g in 10 liter of water (100 ml/plant)	Endure 7.05 ml/plant (250 ml/ha, water: 350-500 l/ha)
2 weeks after planting	Cow manure: 625 kg/ha (200 g/plant)	NPK compound: 100 kg/ha (15 g/plant)
3 weeks after planting	Cow manure: 625 kg/ha (200 g/plant)	Phonska: 100 kg/ha (15 g/plant) + urea 50 kg/ha (7.5 g/plant)
6 weeks after planting	Cow manure: 625 kg/ha (200 g/plant)	NPK compound: 50 kg/ha (7.5 g/plant) + Phonska 50 kg/ha (7.5 g/plant)
8 weeks after planting	Cow manure: 625 kg/ha (200 g/plant)	NPK compound: 50 kg/ha (7.5 g/plant)

Intercropping Planting

The intercropping technique between maize and soybean was carried out with a spacing of 20 x 40 cm, where two rows of soybean plants can be planted between the maize. Soybean plants were planted seven days after planting maize.

Preparing *Beauveria bassiana* isolate

B. bassiana isolate used was a collection from the Laboratory for Monitoring Pests and Diseases and Development of Biological Agents, Bukittinggi. The isolate was then propagated on rice media at the Biocontrol Laboratory, Faculty of Agriculture, Universitas Andalas. The media was protected from direct sunlight for one week before applied.

Variable Observed

***Spodoptera frugiperda* population**

Observation of *S. frugiperda* was done directly and using traps. Direct observations were made on 20 samples in each plot to obtain the number of eggs, larvae, pupae, and adults. Eggs were observed under and upper-side of the leaves. Larvae were observed in the circle of maize shoots. Pupae were observed in the soil around the roots at a 2-8 cm depth. Then, we put one light trap for collecting adults in each plot center.

Attack rate (%)

Attack rate was observed in 2-8 weeks, starting from 2 WAPs until no additional symptoms were found. Observations were made by observing 20 samples, counting the number of attacked plants, then calculated using the following equation:

$$P = \frac{a}{b} x100\% \quad (1)$$

Notes: P = Attack rate (%), a = the number of attacked plants, b = Total of samples

Attack Intensity (%)

Samples were observed once in 2-8 weeks, starting from 2 WAPs until no additional symptoms were found. Observations were made by categorizing damaged leaves into certain score (Table 3). Attack intensity can be calculated using the following equation:

$$I = \frac{\sum(ni.vi)}{N.V} x100\% \quad (2)$$

Notes: I = Attack intensity (%), ni = the number of plants in score-i, vi = the score, V = the highest score, N = Total of samples

Table 3. Criteria for the attack score of *Spodoptera frugiperda* on corn plants

Attack percentage	Score	Criteria
0%	0	No attacks
0<x<25%	1	low
25<x<50%	2	middle
50<x≤75%	3	heavy
x>75%	4	Very heavy

Cob weight

Cobs were harvested manually picking. The cobs among treatments were separated. The cobs were weighed one by one analytically by weighing equipment (g).

Farming cost

All costs incurred for the three cultivation techniques were calculated, then converted to hectares. The estimated costs related to land preparation, seeds, fertilizers, pesticides/ bio-pesticides, labor, maintenance, and harvesting. The yield of maize was weighed and multiplied by the selling price of 1 kg. The income obtained from the difference between the selling price and the costs incurred. Data on the profit was obtained by using the following formula:

$$L = P - B \quad (3)$$

Notes: L = Profits earned (IDR), P = selling price of harvest (IDR), B = Costs incurred starting from processing-harvesting

Data Analysis

The data on the population of *S. frugiperda*, the attack rate and intensity, and cob weight of maize were statistically analyzed by ANOVA, and the significant difference was tested under RBD design at probability level

0.05% using Statistic 8.0 program. Attack development for eight weeks of observation is displayed in the graphic. Furthermore, the farming cost during the research was conversed to hectare.

Results

Population of *S. frugiperda* (individual/plant)

S. frugiperda and its symptoms has been found in maize field that cultivated by different techniques (Figure 1). In fact, differences in cultivation have affected the number of larvae but not the number of egg mass, pupae, or adults. The number of larvae in the IPM and non-IPM was lower than in the control, but there was no difference was found in the IPM and non-IPM (Table 4).

The number of egg mass in the non-IPM field was higher than IPM and controls. The egg mass was laid for the first time in the second week for non-IPM, it was no longer found in the 6-8th week of observation. Larvae were found from the 2^{nd} to 5^{th} week of observation. The number of larvae in the Control was higher than IPM and non-IPM. The larvae were first found in the 2^{nd} week for control.

Table 4. The number of egg mass, larvae, pupae, and adults of *S. frugiperda* found on maize plants with different cultivation

Treatment	Egg mass ± SD		Larvae ± SD		Pupae ± SD		Adult ± SD	
IPM	0.0417±0.072	a	0.125±0.125	a	0	a	0	a
Non IPM	0.125±0.000	a	0.041±0.07	a	0	a	0.417±0.072	a
Control	0.0417±0.072	a	1.541±0.36	b	0.417±0.072	a	0	a

Note: The number is followed by small letter is significantly different according to LSD test at 5% significance level

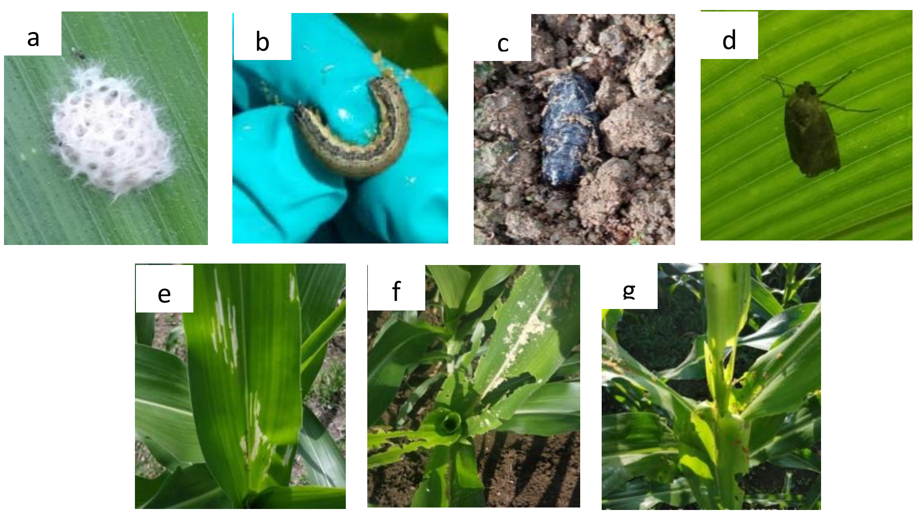

Figure 1. Life stages of *Spodoptera frugiperda* found in the maize field and the attack symptoms: (a) egg mass, (b) larvae, (c) pupae, (d) adult, (e) damage on the epidermis, (f) damage to the leaf shoots, (g) leaves became torn and broken bones.

The presence of larvae was not found again in the 7th-8th week of observation. Furthermore, pupae were not found in IPM and Non-IPM fields from the beginning. Pupae were only found in the fourth week for Control. The presence of pupae was not seen again in the 6th-8th week of the observation. The adult was found in the fourth week of IPM. The presence of adults was not found in IPM and Control. The adult was no longer found in the 6-8th week of observation on non-IPM (see Figure 2).

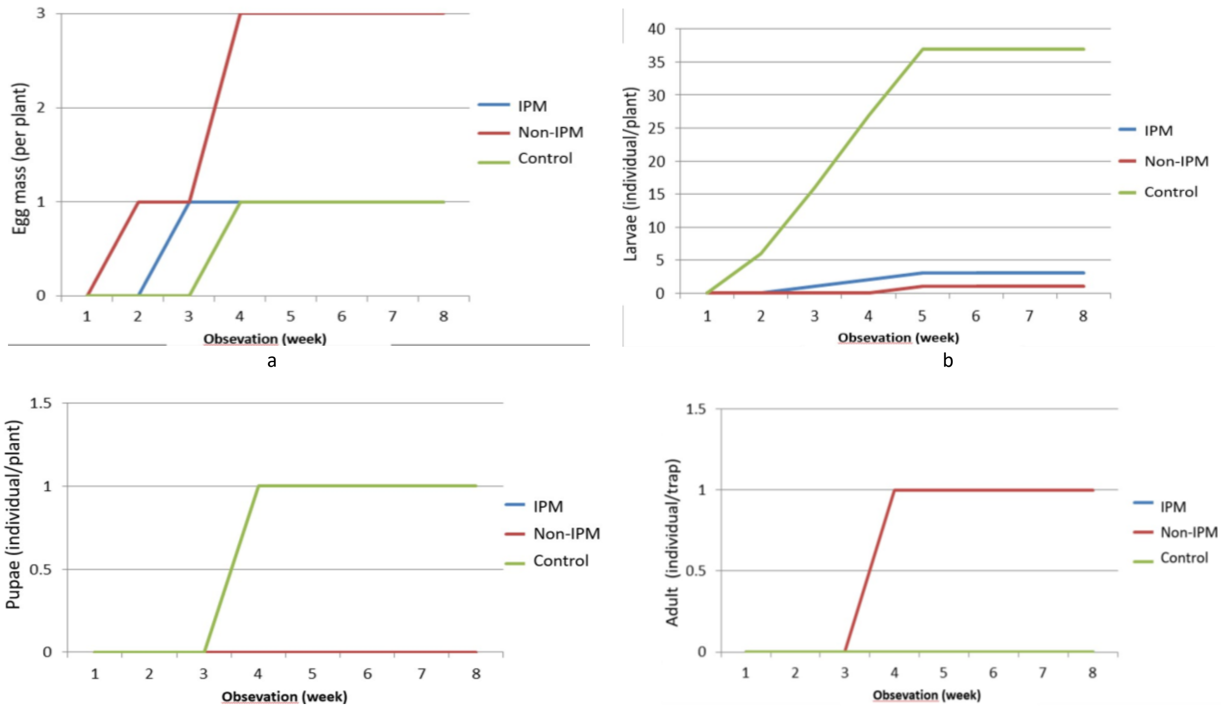

Figure 2. Number of *Spodoptera frugiperda* found in the field (a) egg mass, (b) larvae, (c) pupae, (d) adult.

Attack and Cob Weight

Differences in cultivation techniques have affected the attack rate, attack intensity of *S. frugiperda* and cob weight of maize. There was no difference in maize that cultivated under IPM and non-IPM techniques, but the attack rate and attack intensity was lower than the control. Conversely, cob weight was higher under IPM and non-IPM (Table 5).

Table 5. Attack rate, intensity and cob weight found in different cultivation

Treatment	Attack rate ± SD		Attack intensity ± SD		Cob weight ± SD	
IPM	6.25 ± 2.50	a	1.67 ± 0.65	a	207.6 ± 30.25	a
Non IPM	5.83 ± 2.60	a	1.77 ± 0.65	a	193.13 ± 4.80	a
Control	31.66 ± 6.29	b	17.60 ± 3.60	b	89.26 ± 11.20	b

Note: The number is followed by small letter is significantly different according to LSD test at 5% significance level

Farming Cost Analysis (ha)

The profit obtained by IPM cultivation was higher than non-IPM cultivation, almost two times compared to controls. Meanwhile, the cost of farming from planting to harvesting was lower in IPM cultivation (Table 8).

Table 8. Analysis of maize farming cost with different cultivation techniques (IDR/ha)

Cost (IDR)	IPM	Non-IPM	Control
A. Farming cost	6,035,000	17,815,000	5,315,000
B. Selling cost of maize	41,465,600	54,940,000	25,215,450
C. Selling cost of soybean	3,029,250	0	0
D. Profit = (B+C) - A	38,495,850	37,125,000	19,900,450

Discussion

S. frugiperda has been found in maize cultivated by different techniques (Figure 1). IPM and Non-IPM cultivations did not affect the number of eggs, pupae, and adults, but the larvae population in both techniques was lower than control (Table 4). Furthermore, IPM and Non-IPM cultivation reduced the attack rate and intensity compared to the control. The cob weight in the IPM and Non-IPM was also higher than the control (Table 5). These differences are caused by differences in the inputs given such as fertilizer, spacing, inter-cropping, and *B.bassiana* application.

The application of Petroganik fertilizer and cow manure can affect the nutrients in the soil. Nutrient availability affects plant production; maize with adequate nutrition will produce better. Optimal absorption of nutrients can occur if plants' nutrients have sufficient and balanced (Setyanto and Subagyono, 2006). According to Dewi et al. (2017), applying cow manure as much as 15 kg/plot can improve maize growth. Analysis of cow manure showed a total N of 1.191%, a total P of 56.36 ppm, and a total K of 1.971%. This revealed that the content of N, P, and K values in manure equals SNI organic fertilizer, where the minimum standard for N is 0.40%, P is 0.10%, and K is 0.20%.

Adjusting the spacing using the *jajar legowo* (widened spacing) technique also affects the level of maize production in the IPM. Planting with the *jajar legowo* will reduce competition for nutrients. Yunita et al. (2017) stated that narrow spacing would increase compete-tion between maize plants. The use of a spacing of 70 x 30 cm significantly affected the spacing of 70 x 25 cm and 70 x 20 cm on cob weight.

The low attack intensity in the IPM and non-IPM treatments was caused by applying biopesticides of *B. bassiana* and Spinetoram. Entomopathogenic fungi can infect several pests from Lepidoptera, Hemiptera, and Coleoptera (Prayogo, 2006). According to Sari (2021), applying *B. bassiana* to *S. frugiperda* eggs inhibited pupae formation and adults. *B. bassiana* was able to cause mortality of up to 100% in 2nd instar and 87% in 4th instar larvae (Ramos et al. 2020). *B. bassiana* decreased the survival of *S. frugiperda* larvae significantly (Russo et al., 2021). Mardiana et al. (2015) found that the toxin compound possessed by *B. bassiana* could eliminate the larvae's appetite, so the toxin reduced the ability of the larvae to eat and move normally.

Endure 120 SC also effectively suppressed the *S. frugiperda* population in non-IPM field because it has the ingredient of Spinetoram. Spinetoram can attack the nervous system causing continuous muscle movements and spasms until paralyzed (Astuti, 2014). Spinetoram has a relatively high insecticidal activity in all stages of insects. According to Shimokawatoko et al. (2012), the application of Spinetoram to *Plutella xylostella* for eggs, larvae, and adult caused a mortality of 88.2%, 100%, and 100%. According to Monicha (2020), spinetoram has a high level of toxicity in killing *S. frugiperda*.

Based on the farming cost analysis, the costs incurred for IPM were lower than non-IPM cultivation but provided higher profits. The higher cost of farming in the non-IPM was because of the price of synthetic fertilizer. This showed that maize cultivation using the IPM package is more profitable economically than non-IPM; more beneficial because it is safe for consumers and the environment. According to Sopialena (2018) and Sopialena et al. (2020), the advantages of biological control are lower costs and there is no negative impact on humans and the environment.

Conclusion

In general, the IPM and Non-IPM maize cultivation techniques had no different effect on *S. frugiperda*, especially survival stage, attack rate, intensity, and yield, but this effect was higher than the control. In addition, the economic benefits of cultivation with IPM were higher than non-IPM. Therefore, this IPM package can be recommended for the control of *S. frugiperda* because it is also economically profitable and environmentally friendly.

Declaration

Author contribution

Nova Yurina is the researcher and contributor for this paper. My Syahrawati is the main contributor and corresponding author. Arneti is the co-author. All authors read and approved the final paper.

Funding statement

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for profit sectors.

Competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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How to cite: Yurina N, M Syahrawati, Arneti, M. Busniah. 2023. The Environmentally IPM Package for Controlling Fall Armyworm (*Spodoptera frugiperda*) in Maize Plants. JPT: Jurnal Proteksi Tanaman (Journal of Plant Protection) 7(1): 55-64.