NEW INVASIVE PEST, *Spodoptera frugiperda* (J. E. Smith) (LEPIDOPTERA: NOCTUIDAE) ATTACKING CORN IN BENGKULU, INDONESIA

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ABSTRACT

Spodoptera frugiperda or Fall Armyworm (FAW) is one of the new pests that attack corn plantations in Indonesia. The pest outbreak was reported in America in 2016 and later spread to Africa and Asia, where it was first reported in Thailand in 2018. In March 2019, the first infestation of FAW in Indonesia was reported on corn in Pasaman, West Sumatra province. Losses due to this pest on corn plants in Africa were between 8.3-20.6 million tons per year or valued at 2.481-6.187 million US$/year. This study was aimed to evaluate the damage on of corn plants varieties due to *S. frugiperda* attacks in Bengkulu Province, Sumatra-Indonesia. The corn varieties involved in this study were Bisi 18, Skada, Paragon, Bima 20 and Nasa 29. The research method was a survey, sampling with a scouting system. The results showed that among the varieties of corn in Bengkulu, Bisi 18, Skada, and Nasa 29 were partially resistant, while the Paragon and Bima 20 varieties were susceptible to the attack of *S. frugiperda*. Natural enemies found in the cornfields were *S. frugiperda* multiple nucleopolyhedro virus(SfMNPV), *Nomura earileyi*, predators *Coleomegilla maculata* (Coleoptera: Coccinellidae), and parasitoids (Diptera: Tachinidae). It is expected that the results of this study could be used for further research to control *S. frugiperda*.

Keywords: Damage, natural enemies, *Spodoptera frugiperda*, varieties.

ABSTRAK

Spodoptera frugiperda atau *Fall Armyworm* (FAW) merupakan salah satu perosak baru yang menyerang tanaman jagung di Indonesia. Perosak tersebut tersebar dari benua Amerika pada tahun 2016, masuk ke benua Afrika dan tersebar di wilayah Asia hingga ke Thailand pada tahun 2018. FAW pertama kali dilaporkan di Indonesia pada Mac 2019 di Pasaman Barat (Sumatera Barat) pada tanaman jagung. Kerugian akibat serangan perosak ini pada tanaman jagung di Afrika antara 8.3-20.6 juta ton per tahun atau berkisar US$ 2.481-6.187 juta per tahun. Kajian ini bertujuan untuk menilai kerosakan tanaman jagung akibat serangan *S. frugiperda* di Bengkulu, pada pelbagai varieti di antaranya: Bisi 18, Skada, Paragon, Bima 20 dan Nasa 29. Kaedah yang digunakan adalah survei, pengambilan sampel dengan sistem *scouting*. Hasil kajian menunjukkan bahawa berdasarkan kerosakan daun oleh FAW pada variety Bisi 18, Skada, Nasa 29 tergolong sederhana rentan, sementara varieti Paragon dan Bima 20 tergolong rentan dari

menyerang *S. frugiperda*. Musuh semulajadi yang ditemui di lapangan adalah *S. frugiperda* multiple nucleopolyhedrovirus (SfMNPV), *Nomurae arileyi*, pemangsa *Coleomegilla maculata* (Coleoptera: Coccinellidae), dan parasitoid (Diptera: Tachinidae). Diharapkan hasil kajian ini dapat digunakan untuk kajian lanjutan untuk pengawalan spesies *S. frugiperda*.

Kata kunci: Kerosakan, musuh semulajadi, *Spodoptera frugiperda,* varieti.

INTRODUCTION

Spodoptera frugiperda (Lepidoptera: Noctuidae) is an economically significant pest for agricultural commodities and food crops most especially corn plants in Indonesia. The pest has a widespread in tropical and subtropical regions. The outbreak of FAW in Indonesia was first reported in March 2019 occurring on corn plants in Pasaman, West Sumatra province. FAW has a severe attack rate, with the larval population attacking between 2-10 larvae per plant (Ministry of Agriculture 2019). *Spodoptera frugiperda* pest is native to the tropical and subtropical regions of America. In 2016, it was reported for the first time in Africa (Nigeria, Sao Tomé, Benin and Togo) (IITA 2016), and the year 2018 it had attacked many crops in more than 30 countries of Africa (FAO 2018). It then reported to keep on attacking crops in other African countries and locations pus in other tropical or subtropical regions of the world. In 2018, *S. frugiperda* was reported to exist in Karnataka, India (ICAR-NBAIR 2018a; IITA 2018). It was later reported to be occurring in other areas including Bihar, Chhattisgarh, Gujarat, Maharashtra, Odisha, Tamil Nadu, Telangana, and West Bengal (EPPO 2019; ICAR-NBAIR 2018b). In 2019, *S. frugiperda* was reported in Bangladesh, China, Myanmar, Sri Lanka and Thailand (IPPC 2019; IPPC 2018). The FAW is poly fag, attacking more than 80 species of plants, including corn, rice, sorghum, barley, sugar cane, vegetables, and cotton. These pests are difficult to control because the adult larvae spreads quickly. Losses due to the attack of this pest on corn plants in 12 countries in Africa was 8.3-20.6 million tons per year or valued at 2.481-6.187 million US$/year (Shylesha et al. 2018). Infestation of FAW larval on corn could cause 15-73% yield loss, if the plant population attacked is 55-100% (Hruska & Gould 1997). The spread of *S. frugiperda* can occur through the trade of vegetables, fruits between countries (Harahap 2019). Maharani (2019) reported that *S. frugiperda* had attacked corn in Bandung and Garut. However, no information about the attack of *S. frugiperda* on varieties corn varieties in Bengkulu has been reported. Therefore, this study was aimed to ascertain and evaluate the damage due to the attack of new invasive pest of *S. frugiperda* on corn varieties in Bengkulu, Indonesia.

METERIALS AND METHODS

Survey of *S. frugiperda*

The survey of *S. frugiperda* attack on corn and its natural enemies was carried out from April to September 2019. The survey area covered Seluma District: Sidomulyo, and Napal sub-districts. Kepahiang Regency, Merigi District: Pulo Geto Baru Village, Taba Mulan Village, Bukit Barisan Village. Bengkulu City, Muara Bangka Hulu District, and Beringin Raya (Figure 1).

Figure 1. Map showing the survey areas (the yellow mark were the location of the riset).

Source: Map-Administration-Province-Bengkulu 2014.

Sampling and Identification of *S. frugiperda*

Insect sampling was carried out using a scouting system. Corn varieties observed were Bisi 18, Skada, Paragon, Bima 20, Nasa 29. The number of samples of corn plants in each location observed were 50. Each sample plant was observed for symptoms of attack by *S. frugiperda* and the number of larvae found. The larvae found were collected and taken to the plant protection Laboratory, University of Bengkulu to be reared until adult level and were morphologically identified.

Observation of Attack Symptoms and Larvae Population

Observation of symptoms of attack was carried out directly on the canopy of corn plants in each location. The symptoms identified were then confirmed by examining the larvae in the rolled leaves and then taking pictures (photographed). The larval population was observed by counting the number of larvae found.

The level of plant resistance based on leaves damaged by FAW

Leaf damage due to FAW feeding on each corn variety was assessed using a scoring system, on a scale of 1-9 (Davis & Williams 1992), where highly resistant plants were given a score of 1 and plants that were very susceptible to score 9 (Table 1).

Table 1. Scale for assessment of foliar damage due to FAW on corn.

Score	Damage symptoms/description	Response
1	No visible leaf-feeding damage	Highly resistant
2	Few pinholes on 1-2 older leaves	Resistant
3	Several shot-hole injuries on a few leaves (<5 leaves) and small circular hole damage to leaves	Resistant
4	Several shot-hole injuries on several leaves (6–8 leaves) or small lesions/pinholes, small circular lesions, and a few small elongated (rectangular-shaped) lesions of up to 1.3 cm in length present on whorl and furl leaves	Partially resistant
5	Elongated lesions (>2.5 cm long) on 8-10 leaves, plus a few small- to mid-sized uniform to irregular-shaped holes (basement membrane consumed) eaten from the whorl and/or furl leaves	Partially resistant
6	Several large elongated lesions present on several whorl and furl leaves and/or several large uniform to irregular-shaped holes eaten from furl and whorl leaves	Susceptible
7	Many elongated lesions of all sizes present on several whorl and furl leaves plus several large uniform to irregular-shaped holes eaten from the whorl and furl leaves	Susceptible
8	Many elongated lesions of all sizes present on most whorl and furl leaves plus many mid- to large-sized uniform to irregular-shaped holes eaten from the whorl and furl leaves	Highly susceptible
9	Whorl and furl leaves almost totally destroyed and plant dying as a result of extensive foliar damage	Highly susceptible

Observation of Natural Enemies (parasitoids, predators and pathogens)

Observation on natural enemies of FAW was carried out by collecting larvae which are attacked by insect pathogens. The collected larvae were taken to the laboratory for identification using Olympus microscope. The observations of parasitoids and predators on corn plants in the field were visually observed and recorded.

RESULTS

The FAW adult is characterized with two white spots on the front wing while the pupa is dark brown. The new larvae come out of eggs that are green and turn light brown to black. The larva has an inverted "Y" shaped head and 4 large spots (pinnacle) on the abdomen segment, which distinguishes it from other species (Figure 2).

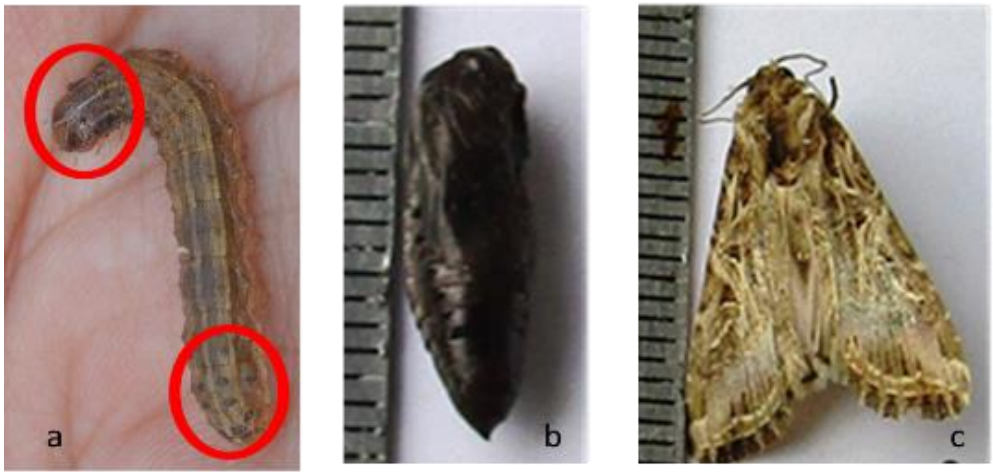

Figure 2. *Spodoptera frugiperda* (a) larvae, (b) pupae, (c) Adult.

The results of the FAW survey based on attack symptom on several varieties of corn plant in several areas in Bengkulu atthe vegetative stage indicated that the attack starts from the leaves that are still rolling where larvae feeding on epidermis from inside the roll, consequently, making holes and the edge of the leaf becomes tattered. Severe feeding activity by larvae can cut off the plant's growing point. The feedingactivities could be seen as sawdust around the feeding site. Cannibalistic behavior occurs at the larval stage, where larger larvae feed on smaller larvae and occur at the advanced instar (instar 3) (Figure3).

Figure 3. Symptoms of *S. frugiperda* attack (a, b) Bisi 18 variety, c. Pragon, d. Skada.

Screening resistance of corn varieties to FAW attacks was based on the level of crop damage. The response of plants and the level of damage to FAW attacks are influenced by the number of insects per plant, plant strength, plant age, and environmental factors such as temperature and humidity. The age of plants at the time of observation of the level of damage to plants in all varieties is 6 weeks, and only one larva per plant was observed. The results of the scoring were based on damage to the leaves of corn on various varieties included in scores 5 and 7, which were partially resistant and susceptible (Table 2).

Table 2. Score of leaf damages due to FAW attack on various corn varieties.

No	Corn varieties	Scoring	Description of damage	Response
1	Bisi 18	5	Elongated lesions (>2.5 cm long) on 8-10 leaves, plus a few small to mid-sized uniform to irregular-shaped holes (basement membrane consumed) eaten from the whorl and/or furl leaves	Partially resistant
2	Skada	5	Elongated lesions (>2.5 cm long) on 8-10 leaves, plus a few small to mid-sized uniform to irregular-shaped holes (basement membrane consumed) eaten from the whorl and/or furl leaves	Partially resistant
	Paragon	7	Many elongated lesions of all sizes present on several whorl and furl leaves plus several large uniform to irregular-shaped holes eaten from the whorl and furl leaves	Susceptible
	Paragon	7	Many elongated lesions of all sizes present on several whorl and furl leaves plus several large uniform to irregular-shaped holes eaten from the whorl and furl leaves	Susceptible
3	Bima 20	7	Many elongated lesions of all sizes present on several whorl and furl leaves plus several large uniform to irregular-shaped holes eaten from the whorl and furl leaves	Susceptible
	Nasa 29	5	Elongated lesions (>2.5 cm long) on 8-10 leaves, plus a few small- to mid-sized uniform to irregular-shaped holes (basement membrane consumed) eaten from the whorl and/or furl leaves	Partially resistant

Natural enemies are an important part of integrated pest control. Fall Armyworm has many natural enemies that act as biological control agents that can reduce the FAW population. FAW's natural enemies found in the field can be seen in Table 3.

Table 3. Natural enemies found in varieties of corn.

No	Location	Altitude	Coordinate	Corn Variety	Number of larvae	Natural enemies
1	Seluma, Sidomulyo	0 m	-4^{o}6’18”S 102^{o}33’35” 172^{o}	Bisi 18	7	Entomopathogenic fungus, SfMNPV, Parasitoid: Diptera (Tachinidae) Predator: *Coleomegilla maculata*
	Selumaselatan (Napal)	44 m	-4^{o}5’57,64171”S 102^{o}33’43,61933”E	Bisi 18	35	-
2	Kepahiang, Merigi, Pulo Geto Baru	617 m	-3^{o}30’53,76042’S 102^{o}31’2,91328”E	Skada	31	8 Entomopathogenic fungus, 2 SfMNPV Diptera

						(Tachinidae) Predator: *Coleomegilla maculata*
	Merigi, Taba Mulan	610 m	-3°29'52,15229"S 102°30'23,7793E	Paragon	19	Entomopathogenic fungus, Predator *Coleomegilla maculata*
	Merigi, Bukit Barisan	619 m	-3°30'16,25029"S 102°30'23,7793E	Paragon	10	38: Entomopathogenic fungus, 1 SfMNPV *Coleomegilla maculata*
3	Bengkulu, Muara Bangka Hulu, Beringinraya	9.3 m	-3°44'43,45076"S 102°15'38,36779"E	Bima 20	37	SfMNPV, predator *Coleomegilla maculata*
	Beringinraya	14.2m	-3°44'43,83604"S 102°15'38,42532"E	Nasa 29	31	4: SfMNPV Predator *Coleomegilla maculata*

Based on the symptoms, natural enemies that attacked *S. frugiperda* larvae were entomopathogenic fungi and *S. frugiperda* Multiple Nucleopolyhedrovirus (SfMNPV) (Figure 4).

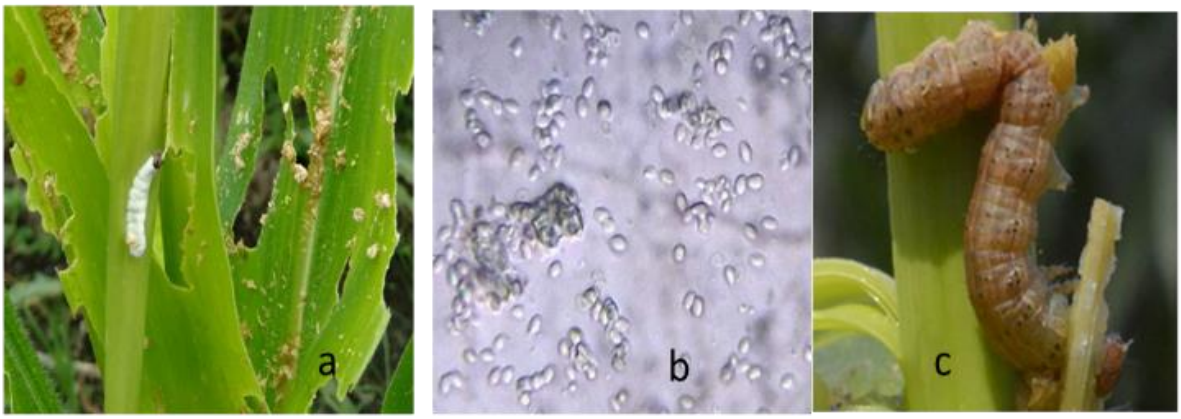

Figure 4. Natural enemies a. *S. frugiperda larvae* attacked by entomopathogenic fungi *N. rileyi*, b. conidia c. *S. frugiperda* larvae affected by the entomopathogenic virus (SfMNPV).

Microscopic observation of entomopathogenic fungi that infected *S. frugiperda* larvae in cornfields was *Noumeria* sp. The number of larvae infected by entomopathogenic fungi in the Merigi was higher compared to other regions. This was likely to be influenced by the altitude, i.e. Merigi is on a higher altitude compared to other areas i.e. 610-619 m above sea level. Also, the low number of larvae infected with pathogens and other natural enemies in the Seluma and Bengkulu city is due to high application of insecticides by farmers. The parasitoid and predator

found in the field were (Diptera: Tachinidae) and *Coleomegilla maculata* (Coleoptera: Coccinellidae) (Figure 5 & 6).

Figure 5. Parasitoid (Diptera: Tachinidae) found in corn plants a. *Winthemia trinitatis* b. *Archytas marmoratus.*

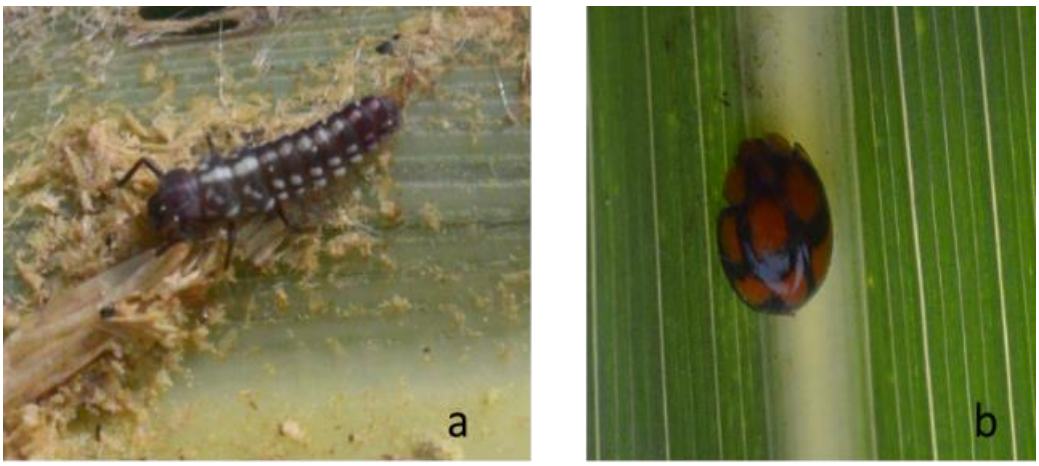

Figure 6. Predators found in corn plants a. Larvae *Coleomegilla maculata* (Coleoptera: Coccinellidae), b. Adult.

DISCUSSION

Spodoptera frugiperda is a polyphagic insect belonging to the order Lepidoptera and family Noctuidae. It is an invasive and important corn pest which comes out to eat and mate at night. The adultof *S. frugiperda*is characterized by two white spots on the front wing. Females lay their eggs under the leaves on the upper side of the leaf covered by a layer of hairy scales. Their pupas are dark brown, while their new larvae come out of eggs that are green and turn light brown to black. The larva has an inverted "Y" shaped head**,** which distinguishes it from other species. The identification results are in accordance with the results of Sharanabasappa et al. (2018).

Symptoms of *S. frugiperda* attack include dry leaves caused due to random feeding by neonatal larvae, leaf fronds and veins caused by severe feeding on leaves by larvae which making holed and causing tattered corn leaves, dry leaf lamina, and dead plant growing points if feeding is severe. Also, damage due to feeding leaves can cause defoliation which results in yield loss. Young larvae feed on plant tops. The first instar feeds in groups on the underside of young leaves which have a characteristic skeletonizing or windowing effect, and the growth point can be killed. Larger larvae are cannibalistic in behavior where by the larger larvae feed on smaller ones during food shortages. As a result, there are only one or two larvae per plant (Shylesha et al. 2018).

The plant's resistance to damage by pest attacks is usually influenced by the plant's genetics. Mechanisms of plant resistance to FAW attacks have also been developed in maize plants by developing plants that have thicker leaf epidermis (Davis & Williams 1995). Development of transgenic plants or genetically engineered plants is a strategy used to control FAW damage in corn with the expression of genes resistant to Lepidoptera. The first FAW resistant corn varieties were developed using the insecticidal (cry) crystal protein gene isolated from *Bacillus thuringiensis* (Bt). The cry protein is very deadly to Lepidoptera species, including FAW. Some cry genes including, cry1A, cry1Ab, and cry1F have been used in corn varieties. Besides, Bt produces Lepidoptera specific proteins called Vegetative Insecticidal Proteins (VIP), which is encoded by the VIP gene like VIP3A, the most famous is the VIP3A gene which is used for FAW resistance. Several hybrids of corn, comprising of a combination of Cry and VIP genes, have been cultivated with Bt corn in Brazil and North America (Horikoshi et al. 2016). The level of resistance of this kind of maize to FAW compared to 32 conventional hybrids of maize against three transgenic Bt hybrids that expressed the toxin Cry1F and Cry1A.105 + Cry2Ab2 (2B707Hx, AG8088PRO, and DK390PRO), the best six conventional hybrids have scores based on Davis ranging from 2.8 to 4.1, while the three Bt hybrids show a score of 1. In contrast, susceptible hybrid control shows a score of 7 (Viana et al. 2016). The varieties of corn observed in Bengkulu are conventional hybrids of maize, and so that they are still susceptible to FAW attacks. Therefore, it is necessary to develop or plant corn varieties that are resistant to FAW attacks.

The parasitoid and predator found in the field were *Winthemia trinitatis*, *Archytas marmoratus* (Diptera: Tachinidae) and *Coleomegilla maculata* (Coleoptera: Coccinellidae). The results of the study were in line with Prasanna et al. (2018) which states that, there were several natural enemies of FAW that have been found. FAW parasitoid include; *Trichogramma pretiosum, T. armigera, Campoletis sonorensis, Cotesiaicipe, Winthemia trinitatis, Archytas marmoratus, Lespesia archippivora*. Pupa parasitoid *Diapetimorpha introit, Cryptus albitarsis, Ichneumon promissorius, Ichneumon ambulatorius,* and *Vulgicheneumon brevicinctor, Brachymeria ovate, B. robusta*; and *Trichospilus pupivora*. FAW Predators: *Hippodamia convergens, Olla vnigrum, Cycloneda sanguinea, Dorulu teipes, Euborellia annulipes, Zelus longipes, Zelus leucogrammus, Zelus armillatus, Geocoris punctipes, Orius insidiosus, Nubus rugosus, Podisus maculiventos, Calzorus granulus*. Entomopathogenic viruses Granulovirus (SfGV), (Beta baculovirus) and multiple nucleopolyhedroviruses (SfMNPV) (Alpha baculovirus). Among the microbial control agents, virus-based insecticides, the Baculovirus group, have the highest potential for the development of bio insecticides because of host specificity, high virulence, and safety for vertebrates (Barrera et al.2011). Two types of Baculovirus have been studied for controlling *S. frugiperda,* namely the granulovirus (SfGV) (Beta baculovirus) and multiple nucleopolyhedrovirus (SfMNPV) (Alpha baculovirus). However, SfMNPV has greater potential for use in FAW management (Behle & Popham 2012; Gómez et al. 2013; Haaseet al. 2015).

Entomopathogenic fungi have a broad spectrum with the ability to infect several different species of insects and stadia, causing epizootics under natural conditions. Fungal spores infect through integuments, multiply in various tissues in the insect's body, and kill insects due to tissue damage caused by toxins. Epizootic induction depends on climatic factors such as wind, rain, or frequency of contact between insects. The sick insects stop feeding, change color (beige, green, reddish, or brown), and eventually die, colonized by the fungus. Moisture is very important for the success of fungi as biological control agents. *Beauveria bassiana*, *Metarhizium anisopliae*, and *Nomura earileyi* are fungi commonly used for pest control. *N. rileyi* has the potential to use *S. frugiperda*, after 15 days of spraying it reduces the damage to the leaves of the leaves by 62.50 to 73.05 percent (Mallapuret al. 2018).

Biological control uses natural enemies using parasitoids, predators and pathogens to control pest populations which is more friendly environmental compared the chemical insecticides (Halim et al. 2017). To increase the effectiveness of natural enemies in the field, environmental conservation must be maintained so that natural enemies can develop properly. Practicing of intercropping patterns with plants that are not hosts for FAW is also a very good for increasing their biodiversity. Also, the parasitoid and predators need to be planted by host plants (refugia) in the vicinity of corn plants, as well as appropriate application of insecticides.

CONCLUSIONS

The Bisi 18, Skada and Nasa 29 corn varieties are partially resistant to the attack by *S. frugiperda*, while the Paragon and Bima 20 corn varieties are susceptible to attack. Corn varieties planted in Bengkulu are conventional hybrid varieties of corn that are not resistant to FAW attacks. Therefore, there is a necessity to develop corn varieties that are resistant to FAW attacks. Natural enemies found in the field were *S. frugiperda* Multiple Nucleopolyhedro virus (SfMNPV), *Nomuraea* sp., predators *Coleomegilla maculata* (Coleoptera:Coccinellidae) and parasitoids (Diptera: Tachinidae).

ACKNOWLEDGMENTS

We would like to thank the students of real work, lecture at the University of Bengkulu during the academic year 2019, for their tremendous contribution in carrying out of the survey in the studied areas.

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