The incidence of fall armyworm *Spodoptera frugiperda* J.E. Smith (FAW) (Lepidoptera: Pyralidae), a newly invasive corn pest in Indonesia

Septian Hary Kalqutny, Nurnina Nonci, and Amran Muis

Indonesian Cereals Research Institute, South Sulawesi, Indonesia

Email: amranmuis1@gmail.com

**Abstract.** *Spodoptera frugiperda* J.E. Smith (FAO) (Lepidoptera; Pyralidae), is one of a newly Invasive armyworms on corn in Indonesia has been quickly spreading recently. *S. frugiperda* attack in Indonesia was first discovered in March 2019, in West Sumatra and Lampung. These pests have caused major damage on corn in the United States, which has become one of the important invasive pests that are polyphagous, however, its main host is corn. This study aimed to determine the characteristics of eggs, larvae, pupae and its adults’ stage, as well as the attacks, and the distribution area of *Spodoptera frugiperda* in Indonesia. Observations and sampling were carried out at locations affected by *S. frugiperda* attack from March 2019 to May 2020. The characteristics of eggs and larvae were observed in the laboratory using a stereomicroscope (Olympus SZX 12) while pupae, and the adult stage was observed visually. The field observations were carried out on 50 plant samples at each location, using the scouting method, the data collected were the number of larvae and the percentage of attacks. The *S. frugiperda* was observed placing the eggs in groups under the surface of the leaf, sometimes the eggs are covered with fine hairs. The defining characteristics of *S. frugiperda* larvae are the inverted Y shape on its caput, and four black dots on the eighth abdominal segment, and the larvae consisting of 5 stages of instars. These characteristics were found at all observation sites (West Sumatra, Lampung, South Sulawesi, South Kalimantan, and East Java. Based on field observations, it is known that *S. frugiperda* has spread and attacked several regions in Indonesia, namely; Sumatra, Kalimantan, Java and South Sulawesi, with an average between 1.26 - 3 individuals/plant and an average percentage of attacks between 60.12 - 87.05%. In accordance with the development of FAW attacks in the field that are increasingly widespread, it is better to design and test to support a continuous FAW control program in accordance with IPM principles.

1. Introduction

Pests and diseases are one of the important factors efforts to increase corn production. Pest attacks occur at all stages of corn plant growth, ranging from plant growth to harvest, processing and even during transport. The types of pests that are commonly present in corn plantations are; seed flies (*Atherigona* sp.), stem borer (*Ostrinia furnacalis*), cob borer (*Helicoverpa armigera*), pink stem borer (*Sesamia inferens*), *Spodoptera litura*, *Mythimna Separata*, Grasshopper, *Aphis* sp. and corn plantopper (*Peregrinus maidis*) [1].

Stem borer, cob borer, grasshopper and aphis were commonly known corn pests among farmers [2]. While *Spodoptera frugiperda* armyworm is relatively new in Indonesia, this polyphagous pest has been well known to be one of the most damaging corn pests in [3]. The wide range of hosts causes this pest to be a major threat to the production of a wide range of plants [4], this polyphagous characteristic makes
the host for the pest is always available. *S. Frugiperda* is known to live on 353 plant species from 76 families [5]. [6] reported that *S. frugiperda* is also an important pest in sorghum in the southern part of the USA and is one of the limiting factors for production in tropical parts of America. Maruthadurai and [7] reported that corn is the most preferred host of *S. Frugiperda* giving them a faster life cycle compared to another plant host.

This pest is a native pest from the tropical and subtropical regions of America, namely South America and the Caribbean, also found in several southern states of the United States [8]. In winter, this pest is usually only found in South Florida and South Texas. In early 2016, this pest was first discovered in Central and West Africa (Benin, Nigeria, Sao Tome and Principe and Tago) [9]. Then, it has spread throughout Southern Africa, threatened the nearby countries in Africa and Europe. Sharanabasappa first reported *S. frugiperda* attacking maize in India in 2018 [3].

The moths of *S. frugiperda* were characterized with dark brown front wings and greyish-white back wings [10]. Female moths lay eggs in groups on the upper and lower surfaces of corn leaves [11]. After the eggs hatched, instar 1 (neonates) will scatter to find shelter and places to eat [12]. *S. frugiperda* larvae consist of 5 stadia instars, the larvae damaging the corn plant by eating the leaf [13]. FAO [8] reported that the 5th (final) instar larvae can cause severe damage which often leaves only fractions of the leaves. Furthermore, FAO and CABI[10] reported that with an average larvae density of 0.2 - 0.8 larvae per plant can reduce the yield of 5.20%.

Currently, the geographical spread of this pest includes the Americas, Africa, Europe and Asia [14]. *S. frugiperda* is predicted to spread more widely to all parts of the world [8]. This pest is a transboundary highly destructive pest that will continue to spread because it has unique biological characteristics, its high migration and reproductive ability [15]. The temperature factor is known to influence the level of development of *S. frugiperda*, the higher temperature tends to increase the reproduction rate [16]. In Indonesia, Nonci reported that in West Pasaman Regency, West Sumatra, *S. frugiperda* was found to damage the corn plants, covering an area of 4 hectares, with a heavy attack rate, larval populations between 2-10 individuals/plant. In the same month, this pest was also found in corn plants in South and East Lampung [17]. The report of this new invasive species in Indonesia is limited. Thus, it is necessary to determine the characteristics of *S. frugiperda* as a new pest in Indonesia, both the distribution area, its characteristics and the level of attack.

2. Materials and Methods

Observations were made at the sites where there was a report on *S. frugiperda* attacks, the data collected namely: the number of eggs, larval populations and the percentage of *S. frugiperda* attacks. The characteristics of eggs, larvae, pupae, and the adult were observed in the laboratory. Observation activities took place from March 2019 to May 2020.

2.1. Morphological Characters Observation

The characteristics of eggs, larvae, pupae and the moth of *S. frugiperda* were observed from the samples collected from the field. 10 groups of eggs and 50 larvae were taken to the laboratory. The characteristics of eggs, larvae were seen under a stereomicroscope (Olympus SZX 12). The pupae and the adult (moth) were observed visually. The larvae were immobilized by using ethanol 70% and observed under the Olympus SZX 12 microscope.

2.2. Field Observations

The observations were made according to FAO’s recommended method of scouting [8]. A total of 50 sample plants were observed, and the number of eggs, larval population and percentage of *S. frugiperda* attacks were recorded. The number of eggs and larval populations were counted directly while the percentage of attacks were scored based on the scale of the leaf damage according to Davis et al. (1992) [18] in Table 1 as follows:
Table 1. Visual rating scales for leaf damage assessment (Davis et al. 1992).

| Scale | Description |
|-------|-------------|
| 0     | No visible leaf damage |
| 1     | Only pinhole damage on leaves |
| 2     | Pinhole and shot hole damage to the leaf |
| 3     | Small elongated lesions (5–10 mm) on 1–3 leaves |
| 4     | Midsized lesions (10–30 mm) on 4–7 leaves |
| 5     | Large elongated lesions (>30 mm) or small portions have eaten on 3–5 leaves |
| 6     | Elongated lesions (>30 mm) and large portions have eaten on 3–5 leaves |
| 7     | Elongated lesions (>30 cm) and 50% of leaf eaten |
| 8     | Elongated lesions (30 cm) and large portions have eaten on 70% of leaves |
| 9     | Most leaves with long lesions and complete defoliation observed |

The recorded scores were transformed by using this following formula:

$$I = \frac{\sum(n \times v)}{Z \times N} \times 100\%$$

Remarks:

$I$ = Attack intensities
$n$ = number of the damaged plant
$v$ = damage scores
$Z$ = highest scores
$N$ = Number of plants observed

3. Results and Discussions

In Indonesia, the first attack of S. frugiperda reported in West Sumatra and Lampung in March 2019. The attack in the vegetative phase of corn plants was quite high. Up until May 2020, these pests have spread throughout Indonesia.

3.1. Morphological Characters Observation of Eggs, Larvae, Pupae and the Moth of S. frugiperda

As much as 1-3 eggs groups in the single plant were found in several samples, even 2-4 egg groups in one clump of the plant. The eggs are clear white to pale green when newly placed, then later turn brownish-green (Figure 1a), sometimes covered with fine hairs (Figure 1b).

Figure 1. Egg mass of fall armyworm on corn leaf (original)
Figure 2. Neonate larvae of fall armyworm (original)

Figure 3. FAW damaged corn plants and damage on-ear (original)
The 5th instar larva will form pupae in the ground. Pupae is dark brown and rarely found in the corn plant. The pupae will become a moth, with the front wings dark brown and the back wings greyish-white (Figure 4).

![Image of FAW pupae and adult moth](image)

**Figure 4.** FAW pupae (left) and adult (right) (original)

The characteristics of *S. frugiperda* larvae are the caput (head) with an inverted Y shape (Figure 5), and four black dots on the eighth abdominal segment (Figure 5).

![Image of S. frugiperda 5th instar](image)

**Figure 5.** The characteristics of *S. frugiperda* 5th instar (original)

From the observation of the morphology of the larvae under a microscope SZX 12, at the head, there are ecdysal line, epicranial notch, epicranial sutures, adfrontal suture, the adfrontal suture connected with eps forming an inverted Y shape (Figure 6a). In the thorax the prespiracular setae group in the first leg is bisotose (there are two setae (Figure 6b). Larvae have 4 pairs of prolegs in the 3rd to 6th segments of the abdomen (Figure 6c), and the crochet in the proleg is arranged in uniordinal mesoseries (Figure 6d). The L1 and L2 setae were also seen separated in the first and second segments in the abdomen of the larvae (Figure 6f). In the eighth segment of the abdomen, there are four large black dots (pinacula) (Figure 6e). The Identification was carried out based on the description of the morphological characteristics of the larvae described by Crumb [19], the dichotomous key and figures by OEPP/EPPO [20].
Figure 6. Morphological characteristics of S. frugiperda Fall Armyworm larvae from several locations. (original). Remarks: a. el = ecdysial line; en= epicranial notch; eps= epicranial suture; afs= adfrontal suture. The afs connected to eps formed an inverted Y shape; b. prespiracular setae group in the first leg is bisotose; c. 4 pairs of prolegs in the 3rd to 6th segments of the abdomen; d. crochet in the proleg is arranged in uniordinal mesories; e. four large black dots (pinacula) in the eighth segment of the abdomen; f. The L1 and L2 setae
3.2. Field Observations

The average percentage of attacks was 74.60% (Table 1). In Kinali District (West Pasaman Regency, West Sumatra) the \textit{S. frugiperda} found were 1-3 individuals/plant with an average of 1.26 individuals/plant. The average percentage of attacks was 67.51% (Table 1).

In South Lampung, Jati Agung District, in July 2019, \textit{S. frugiperda} attacked 0.3ha of corn cultivation. The number of individuals found in each plant was between 1-4 individuals/plant (3\textsuperscript{rd}-5\textsuperscript{th} instar) with an average of 1.43 individuals/plant. The average attack percentage is 60.12 %. During observations in East Lampung, Batangharinuban Districts, in October 2019 we found no larvae because insecticide has been applied several times. However, the symptoms of \textit{S. frugiperda} attacks were still apparent (63.60%).

In July 2019, \textit{S. frugiperda} was found damaging corn plants in South Sulawesi, precisely in Takalar Regency, Sanrobone District, with larvae ranging from 1-3 individuals/plant with an average of 1.38, and an average attack percentage of 75.04%. in Gowa Regency, Bajeng District, precisely in the Bajeng experimental farm of ICERI, the corn cultivations were attacked by \textit{S. frugiperda} in August 2019, with an average of 1.3 individuals/plant and an average attack percentage of 80.22% (Table 2). In Bone Regency, District: Kahu, in October 2019, \textit{S. frugiperda} attacked with a percentage of 70.86%. No \textit{S. frugiperda} larvae were found because insecticide was sprayed several times before the observation. In November 2019, in Maros experimental farm of ICERI, Maros Regency, \textit{S. frugiperda}, had highly damaged the corn plants with an average of 1.29 individuals/plant, and percentage of attacks of 82.23%.

Table 2. The average number of individuals/plant and the average attack percentage of \textit{S. frugiperda} attacks in Indonesia. From March 2019 to May 2020.

| Location (Province, Town/Regency, Districts) | Date of observation | Number of individuals/plant | Attack percentage (%) |
|---------------------------------------------|---------------------|-----------------------------|-----------------------|
| West Sumatra, West Pasaman Regency, Pasaman District | March 2019 | 3.00 | 74.60 |
| West Sumatra, West Pasaman Regency, Kinali District | March 2019 | 1.26 | 67.51 |
| Lampung, East Lampung Regency, Batangharinuban District | October 2019 | - | 63.60 |
| Lampung, South Lampung Regency, Jati Agung District | July 2019 | 1.43 | 60.12 |
| South Sulawesi, Takalar Regency, Sanrobone District | July 2019 | 1.38 | 75.04 |
| South Sulawesi, Gowa Regency, Bajeng District | August 2019 | 1.30 | 80.22 |
| South Sulawesi, Bone Regency, Kahu District | October 2019 | - | 70.86 |
| South Sulawesi, Maros Regency, Lau District | November 2019 | 1.29 | 82.23 |
| South Sulawesi, Sidrap Regency, Tellulimpoe District | March 2020 | 1.54 | 70.12 |
| South Kalimantan, Tanah Laut Regency, Palaihari District | October 2019 | 1.46 | 70.82 |
| East Java, Tuban Regency, Jatirogo District, Pasean Village | October 2019 | 1.30 | 78.75 |
| East Java, Kediri Regency, Semandang | August 2019 | 0.74 | 58.31 |
In March 2020, in Sidrap, Tellulimpoe *S. frugiperda* attacked young corn plants with an average of 1.54 individuals/plant, and an average attack percentage of 70.12% (Table 2). 2-3 groups of eggs were found on the same leaf. There are even 1-4 groups of eggs/clumps of plants. In October 2019, in South Kalimantan, Tanah Laut, Pelaihari, *S. frugiperda* had damaged corn plants with an average of 1.46 individuals/plant and an attack percentage of 70.82%. In East Java, Tuban, Jatirogo, observations were made in two sites. In Pasean Village the number of larvae found was between 1-2 individuals/plants with an average of 1.3 individuals/plants (Table 2), the majority of the larvae that were found were 4th and 5th instar with the percentage of attacks of 78.75%. In Kebun Harjo Village, an average of 1.50 individuals/plant with an attack percentage of 87.05%. In Kediri Regency, Semandang Village in August 2019, the average number of individuals were 0.74 individuals/plant, and the percentage of attacks was 87.05%.

*S. frugiperda* eggs were placed in groups generally on the lower surface of the leaf but sometimes placed on the upper surface of the leaves. From the observation in the field, about 2% of the eggs were placed on the upper surface of the leaves, the rest is placed in lower the surface of the leaves. The eggs will hatch into larval instar 1 (neonates) after 3-4 days, after 3-4 hours the neonates will be scattered to find shelter and a place to eat (Figure 2). The larvae will spread throughout the surrounding corn plants, so the attacks are distributed quickly throughout the plantation. Symptoms of the attack on young plants damaged by young larvae (larvae instar 1-3) are leaves with a clear hole leaving only the epidermal tissues (Figure 3).

Babu et al. (2019) [21] stated that the characteristics present in *S. frugiperda* larvae are the adfrontal suture that connects with the epicranial notch form an inverted Y on the head (caput) of and four pinacula that form a square in the eighth segment. The characteristics shown in the head, abdomen, and limbs from all observation sites (West Sumatra, Lampung, South Sulawesi, South Kalimantan, and East Java) are identical as the descriptions of *S. Frugiperda*. Maharani [22] reported that *S. frugiperda* with specific characteristics of an inverted "Y" on the head and a four of black dots on the abdomen damaged the corn plants in West Java.

Observation of the *S. frugiperda* attack in Pasaman Districts, West Pasaman Regency, West Sumatra, *S. Frugiperda* attacked 4 ha of the corn field, with a fairly high and evenly distributed attack on all plants. No *S. frugiperda* larvae were found in several locations because insecticide was sprayed several times before the observation. *S. Frugiperda* destroys the corn plants by eating the leaves, young larvae mainly feed on leaf tissue leaving only white epidermal tissue (Figure 3). The number of larvae found was 1-10 individuals/plants with an average of 3 individuals/plants (Table 2). The larvae found were 3rd-5th instar. This is interesting because *S. frugiperda* larvae are known to have cannibalistic behaviour [23], which usually begin from 3rd instar larvae [24].

4. Conclusion
*S. frugiperda* had first entered Indonesia in March 2019 and has spread quickly throughout Indonesia. These pests were found in West Sumatra, Lampung, South Sulawesi, South Kalimantan and East Java. The eggs are placed in groups mainly under the surface of the leaf, sometimes covered with fine hair. The defining characteristics of *S. frugiperda* larvae are the inverted Y shape on its caput, four black dots on the eighth abdominal segment, and the larvae consisting of 5 stages of instars. The pupae were dark brownish and the moths of *S. frugiperda* were characterized with dark brown front wings and greyish-white back wings.

In all sampling locations, the average number of *S. frugiperda* larvae ranged from 0.74 to 3.00 individuals/plant with an average attack percentage of 60.12 - 87.05%.
To deal with FAW attacks that have spread in Indonesia, it is recommended to control them with insecticides that are effective, efficient, and friendly to the environment and health. Biological and vegetable control is very possible considering the many natural enemies that are available in nature. Furthermore, it is necessary to look for varieties that are resistant to FAW.

References

[1] CABI. 2019. Invasive Species Compendium.

[2] Nurmin Nonci. 2013. Hama-hama tanaman jagung di beberapa sentra produksi jagung Semin. Nas. Serealia p. 411–419.

[3] Sharanabasappa, C.M. Kalleshwaraswamy M S M & H B P. 2018. Biology of invasive fall armyworm Spodoptera frugiperda (J.E. Smith) (Lepidoptera: Noctuidae) on maize Indian J. Entomol. 80, 3 p. 540–543.

[4] da Silva, D.M, Bueno, A.F., Andrade, K., Stecca, C.S., Neves, P.M.O.J., & de Oliveira M C N. 2017. Biology and nutrition of Spodoptera frugiperda (Lepidoptera: Noctuidae) fed on different food sources Sci. Agric. 74, 1 p. 18–31.

[5] Montezano D G et al., Sep. 2018. Host Plants of Spodoptera frugiperda (Lepidoptera: Noctuidae) in the Americas African Entomol. 26, 2 p. 286–300.

[6] Teetes, G.L., Seshu Reddy, K.V., Leuschner, K. and House L R. 1983. Sorghum insect identification handbook. ICRISAT. Patancheru, A. P. India. Information Bull 12.

[7] Maruthadurai R and Ramesh R. 2020. Occurrence, damage pattern and biology of fall armyworm, Spodoptera frugiperda (J.E. smith) (Lepidoptera: Noctuidae) on fodder crops and green amaranth in Goa, India Phytoparasitica 48, 1 p. 15–23.

[8] FAO. 2018. Integrated Management of Fall Armyworm on Maize. A Guide for Farmer Field Schools in Africa.

[9] Goergen G, Kumar PL, Sankung SB, Togola A T M. 2016. First Report of Outbreaks of the Fall Armyworm Spodoptera frugiperda (J E Smith) (Lepidoptera, Noctuidae), a New Alien Invasive Pest in West and Central Africa. PLoS One 11, 10 p. e0165632.

[10] FAO and CABI. 2019. Community-Based Fall Armyworm (Spodoptera frugiperda) Monitoring, Early warning and Management, Training of Trainers Manual First Edit Licence: CC BY-NC-SA 3.0 IGO.

[11] Beserra E B Dias C T D S and Parra J R P. 2002. DISTRIBUTION AND NATURAL PARASITISM OF SPODOPTERA FRUGIPERDA (LEPIDOPTERA: NOCTUIDAE) EGGS AT DIFFERENT PHENOLOGICAL STAGES OF CORN Florida Entomol. 85, 4 p. 588–593.

[12] Baudron F Zaman-Allah M A Chaipa I Chari N and Chinwada P. 2019. Understanding the factors influencing fall armyworm (Spodoptera frugiperda J.E. Smith) damage in African smallholder maize fields and quantifying its impact on yield. A case study in Eastern Zimbabwe Crop Prot. 120 p. 141–150.

[13] Trisyono, Y.A., Suputa, S., Aryuwandari, V.E.F., Hartaman, M., & Jumari J. 2019. Occurrence of Heavy Infestation by the Fall Armyworm Spodoptera frugiperda, a New Alien Invasive Pest, in Corn Lampung Indonesia J. Perlindungan Tanam. 23, 1 p. 156.

[14] Wang R et al. 2020. Potential distribution of Spodoptera frugiperda (J.E. Smith) in China and the major factors influencing distribution Glob. Ecol. Conserv. 21 p. e00865.

[15] Baloch M N Fan J Haseeb M and Zhang R. 2020. Mapping Potential Distribution of Spodoptera frugiperda (Lepidoptera: Noctuidae) in Central Asia, Insects, 11, 3. .

[16] Schlemmer M. 2018. Effect of Temperature on Development and Reproduction of Spodoptera frugiperda (Lepidoptera: Noctuidae) in Central Asia, Insects, 11, 3. .

[17] Nonci, N, Kalqutny, S.H., Mirmam, H., Muis, A., Azrai, M., Aqil M. 2019. Pengenaalan Fall Armyworm (Spodoptera Frugiperda J.E. Smith). Hama Baru pada Tanaman Jagung di Indonesia. Jakarta: Badan Penelitian dan Pengembangan Pertanian. Balai Penelitian Tanaman Serealia. Kementrian Pertanian.
[18] Davis F M Ng S S and Williams W P. 1992. Visual rating scales for screening whorl-stage corn for resistance to fall armyworm Tech. Bull. - Mississippi Agric. For. Exp. Station. 186 p. 9.

[19] SE. Crumb. 1956. The larvae of the Phalaenidae US Dep. Agric. Tech. Bull. 1135.

[20] OEPP/EPPO.2015. PM 7/124 (1) Spodoptera littoralis, Spodoptera litura, Spodoptera frugiperda, Spodoptera eridania. EPPO Bull. 45, 3 p. 410–444.

[21] Babu S R Kalyan R Joshi S Balai C Mahla M and Rokadia P. 2019. Report of An Exotic Invasive Pest The Fall Armyworm, Spodoptera frugiperda (J.E. Smith) on Maize in Southern Rajasthan J. Entomol. Zool. Stud. 7, 3 p. 1296–1300.

[22] Maharani, Y., Dewi, V.K., Puspa, L.T., Rizkie, L., Hidayat, Y., Dono D. 2019. Cases of fall armyworm Spodoptera frugiperda J. E. Smith (Lepidoptera: Noctuidae) attack on maize in Bandung, Garut and Sumedang District, West Java. J. Crop. 2, 1 p. 38–46.

[23] Valicente F H Tuelher E S Pena R C Andreazza R and Guimarães M R F. 2013. Cannibalism and Virus Production in Spodoptera frugiperda (J.E. Smith) (Lepidoptera: Noctuidae) Larvae Fed with Two Leaf Substrates Inoculated with Baculovirus spodoptera Neotrop. Entomol. 42, 2 p. 191–199.

[24] Chapman J W Williams T Escribano A Caballero P Cave R D and Goulson D. 1999. Fitness consequences of cannibalism in the fall armyworm, Spodoptera frugiperda Behav. Ecol. 10, 3 p. 298–303.