The Existence and Population Dynamic of New Fall Armyworm Species *Spodoptera frugiperda* J. E. Smith (Lepidoptera: Noctuidae) in Yogyakarta, Indonesia

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Abstract.
Fall Armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae) is a new pest in Indonesia that attacks corn plants. *S. frugiperda* larvae damage by eating the leaves to the growing point which can result in yield loss from 55 to 100%. This pest reportedly attacked corn plantations at the beginning of 2019 then spread almost throughout Indonesia. This study aims to study the distribution and population dynamic of *S. frugiperda* in Yogyakarta, Indonesia. Preliminary research was conducted in Sleman and Bantul regency covering all district in these areas, then the research was continued in six corn fields in Bantul regency (Kasihan, Pajangan, Sedayu) district. The result show that the *S. frugiperda* has been spread throughout Bantul and Sleman District. The populations of *S. frugiperda* are different in each location, the density of each larvae ranged from 0-1 larvae per plant. Larvae population increased by increasing the age of plants. Mortality of *S. frugiperda* larvae found in the field was relatively low. Mortality is caused by fungal infections, entomopathogenic bacteria, parasitoid insect Tachinidae sp.1 and predatory insects *Coccinella transversalis*. The population rate was influenced by the internal factors of *S. frugiperda* itself that is the life cycle.

Keywords: corn, distribution, fall armyworm, population, *Spodoptera frugiperda*.

1. Introduction
Corn (*Zea mays* L.) is one of the most widely cultivated food crop commodities in Indonesia. Corn plays a role as the second important food crop after rice, industrial raw material, and an important component in the manufacture of animal feed. Several regions also use corn as a staple food, substituting rice. Therefore, corn is annually grown in Indonesia [1].

In the corn farming system, the pest attack is one of the factors causing the decline and even loss of yields [2]. According to [3], several insect pests have been reported to attack corn crops. Several types of important pests in corn cropping are seed flies (*Atherigona* sp.), soil worms (*Agrothis* sp.), grubs (*Phyllophaga hellen*), corn stem borer (*Ostrinia furnacalis*), armyworms (*Spodoptera litura* and *Mythimna* sp.), cob borer (*Helicoverpa armigera*), and corn leafhoppers (*Peregrinus maydis*) [4]. One of the new types of the pests attacking corn in Indonesia is *S. frugiperda* [5].
Spodoptera frugiperda is a pest of corn that native to America. S. frugiperda can attack around 186 plant species [6]. The larvae of S. frugiperda damage the plants by eating the leaves including the growing point. The larval attack can be observed by the presence of their frass on plant. The yield loss due to S. frugiperda attack is estimated at 15% -75% if the plant population attacked is around 55-100% [5].

Spodoptera frugiperda has been spread in various countries including Indonesia. This pest is reported to have attacked corn in Indonesia, precisely in the Sumatra area in early 2019 [5]. In August, this insect was found in West Java such as in Bandung, Garut, and Sumedang [7]. Recently, S. frugiperda has been spread throughout Indonesia. However, the distribution of S. frugiperda in Yogyakarta remain unknown. As a preemptive control method, a survey to study the distribution and population dynamic of S. frugiperda in the field was carried out. This study needs to be conducted to identify the factors determining population dynamics of S. frugiperda in the field. This study provides a reference for the future control strategy.

2. Materials and Methods

2.1 Distribution of S. frugiperda
Initial field surveys were carried out as preliminary research in Sleman and Bantul regency covering all district in these area (Figure 1) during September – November 2019. Surveys were carried out in 17 district both in Sleman and Bantul regency. One to three corn field (1000 – 2500 m$^2$) in different village in each district was observed once. In total, 27 and 30 corn fields were observed in Bantul and Sleman regency respectively. The observed S. frugiperda larvae were recorded as population size data.

![Figure 1. Preliminary research sampling site](image)

2.2 Population dynamic of S. frugiperda larvae
The sampling of S. frugiperda larvae was carried out in the cornfield in Kasihan District, Sedayu District, and Pajangan District, Bantul Regency, Yogyakarta, Indonesia from December 2019 to March 2020. The location was determined based on the availability of cornfield and accessibility to the research location.

Two cornfield measuring ±500 m$^2$ were determined as the place for S. frugiperda sampling in each district. In total, six corn field was chosen for sampling activity. Each field was divided into five observation plots measuring ±30 m$^2$ (Figure 2). There were 15 plant samples in each plot, resulting in a total of 75 plant samples in each field. The sampling of S. frugiperda was carried out alternately between plants in a plot. The larvae were collected once a week for nine weeks of observation during a planting season.
The larvae of *S. frugiperda* obtained from the field were then reared in the laboratory using a transparent container (5 cm in diameter, 4 cm in high). The larvae were fed with corn leaves or baby corn. Meanwhile, the pupae of *S. frugiperda* were kept in Petri dishes (86 mm x 13 mm) placed in a rearing container in the form of a transparent cylindrical jar (15 cm in diameter, 30 cm in high).

![Sampling layout of *S. frugiperda* larvae in a plot (yellow square). Green plant indicating plants in a plot and white plant indicate plant samples](image)

*S. frugiperda* larvae were reared until the adult stage or the emergence of insect parasitoids. Obtained parasitoids and other natural enemies encountered during field observations were documented and identified. Mortality rate was calculated using this following formula:

\[ p = \frac{A}{B} \times 100\% \]

Remark:
- p : Mortality rate
- A : Number of dead larvae
- B : Total larvae

2.3 Data Analysis
The number of *S. frugiperda* larvae was analyzed using the Generalized Linear Model. Mean number of larvae population was separated using Tukey HSD test. The relationship between plant age and population size of *S. frugiperda* was analyzed using simple regression analysis. All analysis was performed using R Statistic ver 3.6.3.

3. Results and Discussion
From the previous study, *S. frugiperda* almost to be found in all research location. 16 out of 17 districts in Bantul had attacked by *S. frugiperda*. Meanwhile, 12 out of 17 districts in Sleman regency had attacked by *S. frugiperda* (Figure 3). The population density of *S. frugiperda* in each district is varied ranging from 0-98 larva per-field. This may occur because each observed corn field have different characteristics such as plant age which ranges from 10 – 35 days after planting. We then continue the research to study the population dynamic of *S. frugiperda* during a planting season.

The population density of *S. frugiperda* larvae were different in each location (*F* = 3.05; df = 5; *P* = 0.0267) (Table 1). The highest *S. frugiperda* population was in Pajangan 1, and the lowest was in Kasihan 2, while the population in Kasihan 1, Pajangan 2, and Sedayu 2 was...
relatively same. The differences in the population may be influenced by altitude, vegetation, the distribution of *S. frugiperda*, and the cultivation methods practiced by farmers. Vegetation is a factor that can affect pest populations due to the presence of trees, shrubs, and various weeds that can become host plants, refugia, and a source of nectar for adult insect [8]. The high population of *S. frugiperda* in Pajangan 1 was probably due to the large number of weeds around the sampling location. Montazeno et al. [9] stated that there were at least 353 host plants for *S. frugiperda*, in which most of the species were weeds.

![Distribution and population size of *S. frugiperda* in Bantul (a) and Sleman (b) regency](image)

Figure 3. Distribution and population size of *S. frugiperda* in Bantul (a) and Sleman (b) regency

The population density of *S. frugiperda* larvae at each observation location ranged from 7-13 larvae per 75 sample plants. It means that the population density of the larvae per plant ranged from 0-1 larvae. The presence of larvae in the sample plants was found with an uneven distribution. This result is in accordance with Maharani et al. [7] which revealed that *S. frugiperda* population found in several villages in Bandung and Garut, West Java was still at a low rate. Furthermore, Trisyono et al. [10] reported that the attack rate of *S. frugiperda* in Lampung Province reached 100%. However, there is only one larva was found per plant.

The population development of *S. frugiperda* based on plant development showed that the population of *S. frugiperda* larvae was significantly different at each stage of the plant's growth (*F* = 30.80, df = 8, *P* = 0.0001) (Table 2). The population of *S. frugiperda* larvae increased with the increasing age of the corn plant. This may occur because as plants get

| Location   | Population density (mean ± SE) |
|------------|--------------------------------|
| Kasihan 1  | 10.8 ± 1.59 ab                 |
| Kasihan 2  | 7.4 ± 0.87 b                   |
| Pajangan 1 | 13.8 ± 1.16 a                  |
| Pajangan 2 | 10.0 ± 1.04 ab                 |
| Sedayu 1   | 11.4 ± 1.02 ab                 |
| Sedayu 2   | 11.0 ± 1.30 ab                 |

Mean followed by the different letter in a column is significantly different using Tukey (HSD) test (α=5%)
older, they grow bigger so that plant biomass becomes an abundant source of food for pests [11]. However, the population found is still relatively low so that it does not cause significant damage.

## Table 2. Population density of *S. frugiperda* for different age of corn plants

| Plant age (week after planting) | Population density (mean ± SE) |
|----------------------------------|-------------------------------|
| 1                                | 0.00 ± 0.00 d                 |
| 2                                | 0.00 ± 0.00 d                 |
| 3                                | 0.00 ± 0.00 d                 |
| 4                                | 1.83 ± 0.91 cd                |
| 5                                | 7.50 ± 1.12 bc                |
| 6                                | 6.33 ± 1.30 bc                |
| 7                                | 5.33 ± 0.84 bcd               |
| 8                                | 10.00 ± 2.75 b                |
| 9                                | 22.67 ± 1.82 a                |

Mean followed by the different letter in a column is significantly different using Tukey (HSD) test (α=5%)
Spodoptera frugiperda started to appear at 4 weeks old plants in all sampling locations, and the population fluctuated and increased at 9 weeks old plants. No larval infestations were found at one, two, and three weeks old plants. This result is different from the research of Trisyono et al. [10] who reported that the attack of S. frugiperda larvae on corn plants in Lampung began at 2 weeks old plants. It could be due to the differences in research locations. As Hill [12] said that a pest can perform different effect on same plant in the different part of the world.

The development of the S. frugiperda population in each location was different (Figure 4). The emergence of S. frugiperda larvae on corn plants started at 4-5 weeks old plants. Larvae generally make holes and hide in young leaves that are still rolled up.

The population of larvae increased during two weeks of observation, then decreased. It happens because the larvae last only two weeks before they turn into pupa for about nine days and adults for 7-21 days [13]. Pitre & Hogg [14] said that the larval stage of S. frugiperda lasts about 14 days, and the stage of pupae lasts for nine days. After that, the pupae continue their life cycle to become adults. The number of female moth eggs ranges from 1500 to 2000 eggs with an egg incubation period of 2-3 days [15]. After that, the population of S. frugiperda larvae increased at 8 weeks old plant with the highest population at nine weeks old plant.

Simple regression analysis showed a strong relationship (R² = 0.7288) between S. frugiperda larval density and plant age. Plant age affected the density of S. frugiperda larvae by 72.88% (Figure 5). The insect population in the field is influenced by internal biological factors such as the life cycle. Furthermore, it also affected by the presence of natural enemies as external factors that can regulate the insect population in the field. These factors are important to identify so that manipulation of these factors can be carried out for control strategies purposes [16].

![Liner regression of larval population density vs plant age](image)

The mortality rate of S. frugiperda in the field was relatively low. The mortality rate is around 5% in Pajangan 1 and Sedayu 2. No mortality rate observed in other fields. Larval mortality was caused by an entomopathogenic fungi, entomopathogenic bacterial infection, as well as predatory insects and parasitoids. Rios-velasco et al. [17] reported two species of entomopathogenic fungi i.e., Beauveria bassiana (Balsamo) Vuilleimin and Nomuraea rileyi (Farlow) (Samson) and a nucleopolyhedrovirus (Baculoviridae) as pathogens for S. frugiperda in Chihuahua, Mexico. The infection of N. rileyi on S. frugiperda was also reported by Ginting et al. [18] in Bengkulu, Indonesia. Meanwhile, Maharani et al. [7] also reported an infection of entomopathogenic bacteri on S. frugiperda larvae in West Java that have not been identified yet.

The predatory insects found were Coccinella transversalis (Coleoptera: Coccinellidae). This predator was also reported by Sharanabasappa et al. [13] with another two predatory insects such as Forficula sp. (Dermaptera: Forficulidae) and Harmonia octomaculata.
Furthermore, the parasitoid insect found were the Tachinidae sp.1 fly (Figure 6) which was only found in one of all samples of *S. frugiperda* larvae. *Archyta marmoratus* (Diptera: Tachinidae) was reported as larval parasitoid of *S. frugiperda* larvae [7, 17]. Another Tachinid parasitoid of *S. frugiperda* larvae was *Exorista sorbillans* [13] and *Lespesia* sp. [17]. For Hymenoptera parasitoid, *Telenomus remus* was identified as a potential egg parasitoid of *S. frugiperda* in Africa [19], which also was found in China [20]. There has no report about the parasitism of *S. frugiperda* by *T. remus* in Indonesia, yet. However, *T. remus* was reported as potential biocontrol agent for controlling *S. frugiperda* in Indonesia [21]. Another Hymenoptera parasitoid of *S. frugiperda* are *Coccygidium melleum* (Hymenoptera: Braconidae), *Campoletis chlorideae*, *Eriborus* sp. (Hymenoptera: Ichneumonidae), *Odontepyris* sp. (Hymenoptera: Bethylidae) [13], *Chelonus insularis; Meteorus arizonensis* (Hymenoptera: Braconidae), *Campoletis sonorensis; Campoletis flavicincta; Pristomerus* sp. (Hymenoptera: Ichneumonidae), and *Euplectrus platyhyponae* (Hymenoptera: Eulophidae) [17].

![Figure 6. Parasitoid Tachinidae sp.01](image)

4. Conclusion

*Spodoptera frugiperda* has been spread throughout Bantul and Sleman regency. The population of *S. frugiperda* was influenced by location and by the age of corn plant. The population of *S. frugiperda* continued to increase with increasing plant age. The population rate of *S. frugiperda* found in the research locations was still relatively low. The population rate was influenced by the internal factors of *S. frugiperda* itself that is the life cycle. Further study needs to be carried out to understand more the development of *S. frugiperda* population dynamic in the field across the time.

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