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Invasion, Population Development, and Attack Intensity of The Fall Armyworm (*Spodoptera frugiperda*) J.E Smith (Lepidoptera: Noctuidae) On Two Varieties Corn In Serongga Village, Gianyar Regency, Bali -Indonesia

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ABSTRACT— The Fall armyworm (FAW), Spodoptera frugiperda J.E Smith is an invasive pest that is now an important pest of maize crops in Indonesia and Bali in particular. This study aims to 1) determine the invasion process, 2) population development, and 3) the level of FAW pest attack on sweet corn and glutinous corn varieties in the Gianyar Regency, Bali. This study used a pair of plot design between plant varieties. A sampling of plants was carried out systematically randomly with a "U" shape. Furthermore, the sample plants were observed at intervals of one week. The results showed that the FAW invasion process had started since the plants were 1 week after planting (wap). Female moths prefer glutinous corn more strongly than sweet corn for the egg-laying process. The highest larval density was found at the age of 4 (wap) plants, respectively 30.6 larvae in glutinous corn and 26.0 larvae in sweet corn. The population development of FAW showed the same pattern in the two varieties of maize, namely the peak spawning occurred at the age of 2 (wap), while the peak population of larvae instar-1, -2, -3, -4, -5, and instar-6 respectively occurred at 2, 3, 4, 5, 6, and 7 (wap) respectively. The attack intensity of FAW showed the same tendency as the population density, which was heavier in glutinous corn, reaching 34.74% compared to sweet corn, which was 33.72%.

KEYWORDS: Invasive pests, Fall armyworm, Spodoptera fugiperda, corn varieties, food safety.

1. INTRODUCTION

The corn plant (Zea mays L.) originates from Central America and spreads to various tropical to sub-tropical regions of the world [1]. Efforts to increase maize production are still facing various obstacles that impact on the level of productivity of the corn commodity, which has not been able to meet national and international needs. The low yield of maize is caused by many factors including physical factors such as climate, soil type, and land, while biological factors such as varieties, pests, diseases, and weeds [2]. Pests and diseases become obstacles in increasing the productivity of corn commodities [3], [4]. [5] state that no less than 50 species of insects have attacked the maize crop in Indonesia. The fall armyworm (FAW), Spodoptera frugiperda (J.E. Smith) (Lepidoptera: Noctuidae) is an insect native to tropical, invasive spesies, and subtropical regions of the American continent [6], [7]. FAW has been reported to attack more than 100 host plants [8]. Based on a

literature review and additional surveys, [9] revealed that there were 353 host plants of S. frugiperda found in Brazil, from 76 families, mainly Poaceae, Asteraceae, and Fabaceae. This pest prefers maize as its host and is also commonly found in wheat, sorghum, and sugarcane and is also an important pest on cotton, soybeans, and vegetables [10], [11]. This insect native to tropical America has become a serious pest of maize crops in several countries [12], [13]. The losses incurred as a result of this pest attack on maize crops in African and European countries are between 8.3 and 20.6 million tonnes per year with an economic loss of between the US $ 2.5-6.2 billion per year [14]. In African countries, this pest was first detected in January 2016 [15]. Furthermore, this insect has spread to other countries such as India and Yemen in 2018 [16]. FAW was first reported in Indonesia in early 2019 attacking a cornfield in the northern part of Sumatra Island [17] and has now spread in several maize fields such as in Lampung and western Java and Sulawesi [18], [19]. There have not been many reports about the damage caused by FAW, S. frugiperda in Indonesia. Moreover, there are no reports of this FAW pest in Bali. Therefore, this study aims to see the response of invasive pests of FAW on sweet corn and glutinous corn varieties studied from invasion, population development, and intensity of FAW pest attack in the field.

2. Material and Methods

2.1 Study area

This research was conducted from March to May 2020. This research was conducted in the field, which is located in Serongga Village, Gianyar District, Gianyar Regency, Bali, with the coordinates of 8º 34'14" S 115º 20'23" E with a height of 69 meters above sea level (masl) (Figure 1).

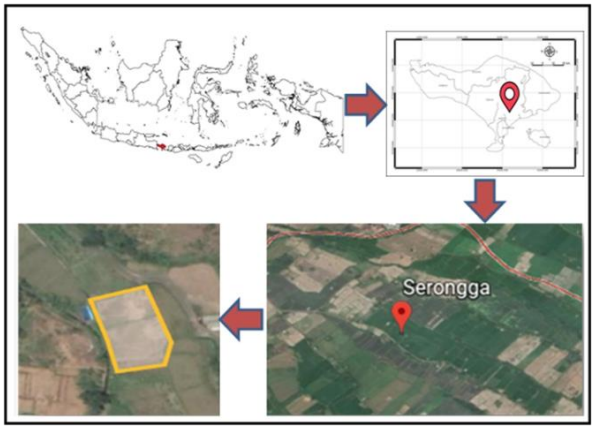

Figure 1. Research location

2.2 Research procedure

This study used a paired plot design with 2 treatments and 5 replications, the size of the treatment plot was 4 meters × 6 meters, with a distance between plants of 25 cm × 70 cm and a distance between treatments of 1 meter. The number of samples observed was 10 plants per treatment plot. Sampling was carried out systematically randomly with a "U" shape and then observed at intervals of 1 week. The variables observed in the study were:

A. Invasion

The FAW invasion was observed on egg groups laid by FAW imago. Prior to the observation, the samples were determined for each corn plant variety. The invasion observations were started when the maize plants were 1 and 2 weeks after planting (wap) and were recorded in every observation, which was once a week.

B. Population density

Observation of population density was carried out by counting the population of FAW larvae in the sample plants with an interval of observation every once a week. Population density observations were started when the plants were 1 (wap) to 8 (wap). The variables observed included the egg group, larvae 1 to larvae instar-6 in the sample plant, and then had been recorded.

C. Attack intensity

The attack intensity of FAW on maize was calculated using the attack intensity value. The method to calculate the intensity of the attack was done by counting the number of affected leaves in the plant sample which was determined based on the attack score [20].

$$IS(\%)=(\sum(ni\times vi))/(Z\times N)\times 100\%$$

Annotation:
IS (%) = The intensity of the attack
ni = Number of plants with i'th-scale value
vi = The scale value of each i'th-attack category
Z = The scale value of the highest attack category
N = Number of plants observed.

After the intensity of the affected plant was known, it would be rated into the attack intensity table (Table 1.) to determine the intensity of the attack.

Table 1. Intensity of FAW, S. frugiperda attack on sweet and glutinous corn plants commodities

No.	Attack intensity	Category
0	0%	Healty
1	>0 - ≤ 10%	Very low
2	>10 - ≤ 20%	Low
3	>20 - ≤ 40%	Moderate
4	>40 - ≤ 60%	High
5	>60 - ≤ 100%	Very High

Source: [35].

2.3 Data analysis

The invasion data were tabulated and presented in graphs and tables, the mean data for the egg group and larvae population of FAW, the population development of FAW were presented in the table. The data was tabulated to get an average, after the data was tabulated then were analyzed using the independent sample t-test with a 95% confidence interval using SPSS.20.0.

3. Result

3.1 Invasion and population development of FAW, Spodoptera frugiperda on sweet corn and glutinous corn varieties in Gianyar Regency, Bali

The invasion was characterized by the presence of FAW imago on sweet and glutinous corn plants, besides the invasion could be identified by observing the presence of FAW egg groups in the corn plants. The invasion of FAW was started 1 week after planting (wap) on both sweet corn and glutinous corn varieties (Figure 2). The presence of FAW egg groups was found from 1 - 4 wap observations both in sweet and glutinous corn.

At 5 - 8 wap observations, egg group populations were not found in the two varieties of corn plants. The average number of egg groups in sweet corn from 1 - 4 wap observations ranged from 0.4 - 2 eggs. Meanwhile, glutinous corn had an average value of 0.6 - 2.4 eggs.

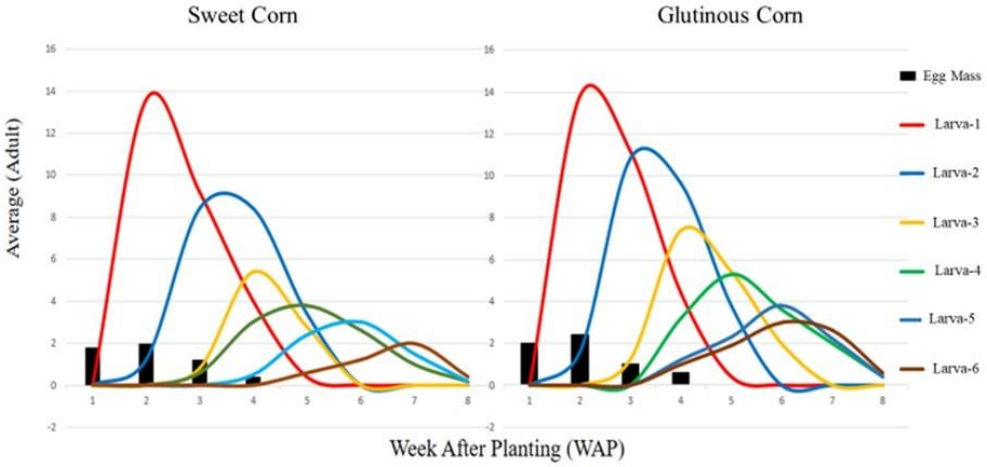

Figure 2. The FAW, S. frugiperda invasion on sweet and glutinous corn plants

After the egg group colony formation process occurred, it would be followed by the process of forming a larvae colony. FAW larvae began to appear on crop plants from the age of 2 wap in both sweet and glutinous corn. The average population of FAW larvae from 2-8 wap observations of instar-1 on sweet corn were 0.4 - 13.6 larvae, instar-2; 3,4 - 8,4 larvae, instar-3; 0.8 - 5.4 larvae, instar-4; 0.2 - 3.8 larvae, instar-5; 0.2 - 3 larvae and instar-6 were 0.2 - 2 larvae. Whereas in glutinous maize the average population of instar-1 larvae were 0.4 - 13.8 larvae, instar-2; 1.6 - 10.8 larvae, instar-3; 1.2-7.4 larvae, instar-4; 0.4-3.6 larvae, instar-5; 0.4-3.8 larvae, and instar-6 were 0.6-3 larvae.

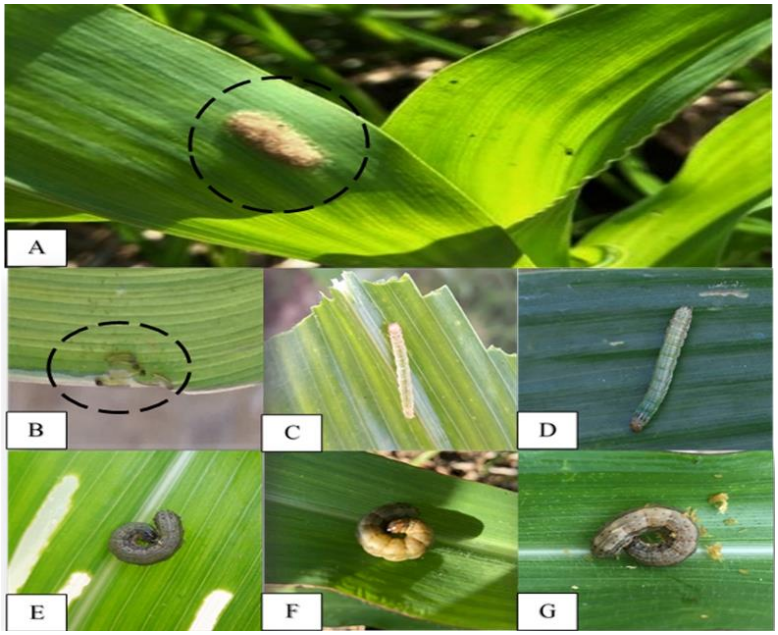

Figure 3. The development of FAW, S. frugiperda. (A) S. frugiperda eggs, (B) Instar-1 larvae, (C) Instar-2 larvae, (D) Instar-3 larvae, (E) Instar-4 larvae, (F) Instar-5 larvae and (G) Instar-6 larvae.

The average number of egg groups and larval populations of FAW instar-1 to instar-3 are presented in Table 2. The results showed significantly different results between sweet and glutinous corn varieties. The average

number of FAW egg groups in sweet corn was 0.67 while glutinous corn was 0.75 egg. The average population of instar-1 larvae in sweet corn was 3.40 larvae, while for glutinous corn it was 3.72 larvae. Instar-2 larvae in sweet corn were 2.76 larvae, glutinous corn was 3.22 larvae and instar-3 larvae in sweet corn was 1.42 larvae, while glutinous corn was 1.75 larvae. From the results of the analysis of the average larval population of FAW instar-4, 5, and 6 the results were not significantly different. The average population of instar-4 larvae in sweet corn was 1.02, and glutinous corn was 1.37. Instar-5 larvae in sweet corn were 1.00, on glutinous corn were 1.30 larvae. Instar-6 larvae in sweet corn were 0.62 larvae and on glutinous corn were 0.85 larvae.

Table 2. The average egg group and larvae population of FAW, S. frudiperda

***S. frugiperda* (pest)**	**Corn varieties**	**The average egg mass and larvae**
egg mass	Sweet Corn	0.67 ± 0.30 a
	Glutinous Corn	0.75 ± 0.34 b
L-1	Sweet Corn	3.40 ± 1.85 a
	Glutinous Corn	3.72 ± 2.00 b
L-2	Sweet Corn	2.67 ± 1.31 a
	Glutinous Corn	3.22 ± 1.59 b
L-3	Sweet Corn	1.42 ± 0.53 a
	Glutinous Corn	1.75 ± 0.59 b
L-4	Sweet Corn	1.02 ± 0.45 a
	Glutinous Corn	1.37 ± 0.59 a
L-5	Sweet Corn	1.00 ± 0,66 a
	Glutinous Corn	1.30 ± 0.80 a
L-6	Sweet Corn	0.62 ± 0.34 a
	Glutinous Corn	0.85 ± 0.46 a

Note: Numbers followed by the same letter indicate an insignificant difference based on the Independent T-test for Difference at 5%. L-1 = instar-1 larvae; L-2 = instar-2 larvae; L-3 = instar-3 larvae; L-4 = instar-4 larvae; L-5 = instar-5 larvae; L-6 = instar-6 larvae.

3.2 Population density of FAW larvae on sweet and glutinous corn varieties in Gianyar Regency, Bali

The average population density of FAW larvae began to appear at 2 (wap) observations. The analysis showed a significant difference between sweet corn and glutinous corn. The average population density of FAW larvae in sweet corn was 14.80 larvae and glutinous corn was 15.40 larvae. The results of the analysis from observation 3 - 8 (wap) did not show significant differences between sweet corn and glutinous corn. The highest average population density was in the 4th observation of the wap with a population of 26.00 larvae of sweet corn and 30.60 larvae of glutinous corn. The population density of FAW was found at 8 (wap) observations with a population mean of 0.40 larvae in sweet corn and 0.60 larvae in glutinous corn (Table 3).

Table 3. Average population density of FAW, S. frugiperda larvae in sweet and glutinous corn varieties

Corn varieties	**Observation (wap)**							
	1	2	3	4	5	6	7	8
Sweet corn	0.0 ± 0.0a	14.80 ± 1,39 a	19.60 ± 1.36 a	26.00 ± 1.92 a	13.20 ± 0.86 a	5.80 ± 0.58 a	1.60 ± 0.24 a	0.40 ± 0.24 a
Glutinous corn	0.0 ± 0.0 a	15.40 ± 0.67 b	25.00 ± 2.07 b	30.60 ± 1.50 a	15.80 ± 0.96 a	7.60 ± 0.74 a	2.80 ± 0.37 a	0.60 ± 0.24 a

Note: Numbers followed by the same letter indicate an insignificant difference based on the Independent T-test for Difference at 5%. (wap): week after planting.

3.3 Attack intensity of FAW on corn varieties

The attack of FAW had a special characteristic, marked by initial damage to the maize shoots, causing holes and fractures in plant leaves (Figure 4). The results of this research were the intensity of FAW attacks starting from the age of the plants 2 to 8 (wap). The results of the analysis of the intensity of FAW attack on sweet and glutinous corn showed no significant difference. The intensity of the attack was found from the age of 2 (wap) plants and experienced the highest attack intensity at 5 (wap) with a value of 33.72% for sweet corn and 34.74% for glutinous corn. At 6 (wap) observation, the attack intensity began to decrease to 8 (wap) (Table 4).

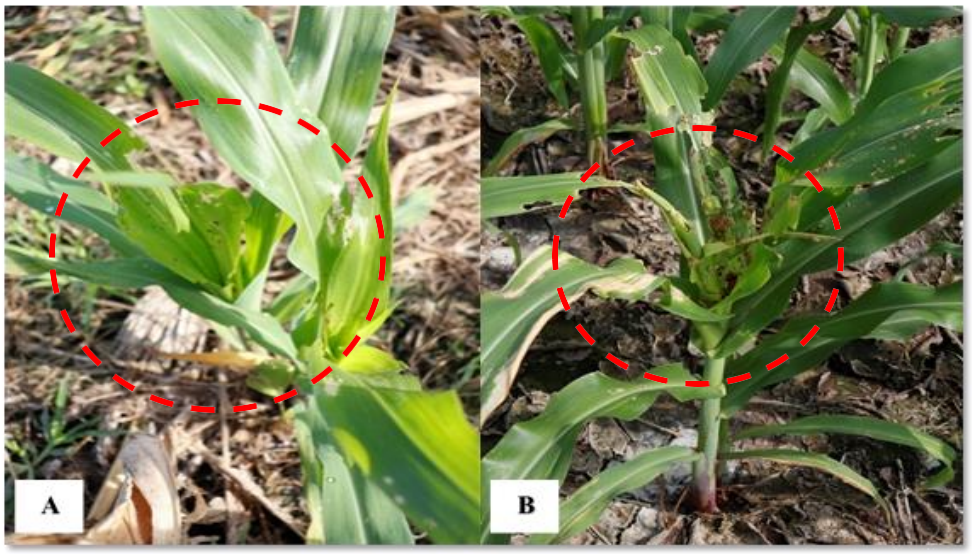

Figure 4. Description of symptoms of FAW on corn varieties. A) Symptoms of FAW damage on sweet corn; B) Symptoms of FAW damage on glutinous corn.

Table 4. Attack intensity (%) of S. frugiperda

Corn varieties	Observation (wap)							
	1	2	3	4	5	6	7	8
Sweet corn	0.0 ± 0.0 a	6.89 ± 0.53 a	14.75 ± 0.73 a	24.00 ± 0.72 a	33.72 ± 0.96 a	26.21 ± 0.32 a	14.32 ± 0.53 a	5.94 ± 0.70 a
Glutinous corn	0.0 ± 0.0 a	7.31 ± 0.46 a	15.94 ± 0.59 a	25.56 ± 0.45 a	34.74 ± 0.83 a	26.74 ± 0.33 a	14.61 ± 0.45 a	6.20 ± 0.72 a

Note: Numbers followed by the same letter and same column indicate an insignificant difference based on the Independent T-test for Difference at 5%. (wap): week after planting.

4. Discussion

The S. frugiperda pest has a population development from eggs, larvae instar-1, 2, 3, 4, 5, and 6 (Figure 3). The population development of FAW in sweet and glutinous corn was strictly influenced by extrinsic and intrinsic factors. Extrinsic factors such as environmental factors include adequate food, climate, space, competition, and natural enemies [21], [22]. [23] also stated that the factors that influence population growth, development, and density are the availability of resources such as food and living space as well as resource accessibility and the ability of individuals in the process of distribution, dispersal, and the ability to forage

and find partners. Intrinsic factors such as high fertility as well as short life cycles also greatly affect the population of insect pests [24]. Imago of FAW will fly to find a suitable place for laying eggs for larval development. The FAW pest has a high dispersal capacity, which allows the pest to quickly spread to its host plants [25]. The development, abundance, and population growth of FAW larvae are influenced by several factors such as rainfall, temperature, humidity, and wind direction which affect population development from insect pests to death [26]. The reproductive development of FAW is more efficient in tropical and subtropical areas [27]. The density of FAW depends on the preferred host plant because the nutrient content of the host plant is suitable for the growth and development of these insects [28]. Some Lepidoptera larvae prefer young plants to older plants [29]. The abiotic and biotic factors that influence the growth and development of insects according to [30] include: abiotic (physical) factors are temperature, light, humidity, rainfall, while biotic factors are all factors that are basically are alive and play a role in the balance of the pest population. Biotic factors include parasites, predators, competition, and plant resistance [22]. Planting using resistant varieties is able to control the pest of FAW [31]. The high intensity of FAW attacks is due to the early larvae instar FAW being on the lower surface of the leaves and preferring to attack the plants in groups, the larvae damage the leaves of the maize plants leaving the top of the leaf epidermis, which results in the plant leaves becoming transparent and leaving bones of the leaves alone [32] and according to [19] stated that the intensity of FAW attack was higher in young maize plants. [33] and [19] stated that the FAW pest attacked maize from the vegetative phase to the generative phase and the highest level of damage was found in the vegetative phase. The damage caused by FAW did not cause the corn crop to die, but it did cause significant damage to the maize plant with a percentage of damage to 28% of the crop at 1 (wap) [34].

5. Conclusion

1. The Fall armyworm (FAW), S. frugiperda invasion had been started since the plants were 1 week after planting (wap). Female imago was stronger in choosing glutinous corn than sweet corn for the egg-laying process. The highest larval population density was found at the age of 4 (wap), every 30.6 larvae on glutinous corn and 26.0 larvae on sweet corn.
2. The population development of FAW showed the same pattern in the two varieties of corn, namely the spawning peak occurred at 2 (wap) of the plant, while the peak population of larvae was instar-1, -2, -3, -4, -5, and instar- 6 each occurred at 2, 3, 4, 5, 6, and 7 (wap).
3. The intensity of FAW attacks showed the same tendency as the population density, namely heavier in glutinous corn, which reached 34.74% compared to sweet corn, which reached 33.72% with moderate attack category.

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