Potential Yield Reduction of Sweet and Glutinous Corn Varieties Damaged by The Invasive Pest *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae): Field Trial Scale

Anak Agung Ayu Agung Sri Sunari[1] , I Ketut Sumiartha[1] , I Wayan Supartha[1,*] , I G Febri Mahaputra[2] , I Kadek Wisma Yudha[3] , I Wayan Eka Karya Utama[3] , Putu Angga Wiradana[4]

[1] *Laboratory of Integrated Pest Management (IPMLab), Faculty of Agriculture, Udayana University, Denpasar City, Indonesia*
[2] *Graduate Program of Dryland Agriculture, Faculty of Agriculture, Udayana University, Denpasar City, Indonesia*
[3] *Doctoral student of Agriculture Science, Faculty of Agriculture, Udayana University, Denpasar City, Indonesia*
[4] *Study Program of Biology, Faculty of Health, Science and Technology, Universitas Dhyana Pura, Badung Regency, Bali Indonesia*
[*] *Corresponding author. Email: yansupartha@yahoo.com*

ABSTRACT
The aim of this study is to assess the extent of attack and the potential for decreased production of maize types in the field caused to *Spodoptera frugiperda*. This study was carried out on a large scale, with four treatments and six replications (10 systematic sample replications). Parameters observed include population development, attack rate, the potential for production decline. The results show that this pest attack began to be found in maize 2 weeks after planting (wap) with an average population of 5.37 individu on sweet corn and 6.53 individu on glutinous corn. Furthermore, the population continued to increase up to 5 wap and lowering again to 8 wap. The regression analysis revealed a positive relationship between the larval population and the *S. frugiperda* attack rate. Sweet corn production decreased by 28.08 percent and glutinous corn output decreased by 25.04 percent, respectively. Overall, our results showed that *S. frugiperda* attacks continued to increase in both maize varieties (glutinous and sweet), which was indicated by an increase in population and a decrease in production on a field trial scale.

Keywords: *new invasive pest, the fall armyworm, maize varieties, Bali Province.*

1. INTRODUCTION

Maize *(Zea mays* L.*)* originally came from Central America and then spread to various tropical and sub-tropical areas around the world [1]. With a total production of 18,511 tons in 2013, Indonesia is one of the Southeast Asian nations that produces the most maize among Asean member countries [2]. The use of maize plants in Indonesia apart from being a source of food for the community is also used as animal feed. Almost all parts of the maize plant can be used for various purposes, such as making fertilizer, firewood, and paper materials [3].

Spodoptera frugiperda, or Fall Armyworm J.E. Smith (Lepidoptera: Noctuidae) is a significant maize pest and a polyphagous insect pest that affects over 80 crops. S. frugiperda initially mainly attacked maize fields in subtropical places such as America, causing severe losses. This pest was discovered in Africa for the first time in January 2016. Furthermore, in 2018, this insects expanded to other nations such as India and Yemen [4]. This pest was reported in maize plants in Sumatra, Indonesia, in early 2019. The larval species of *S. frugiperda* caused 60 percent damage to sweet hybrid maize in Petir Village, Dramaga, Bogor Regency, East Java [5].

The losses recorded in African and European nations as a result of this insect invasion on maize crops varied from 8.3 to 20.6 million tons per year, with an economic loss value ranging from 2.5 to 6.2 billion US dollars per year. Therefore, this pest has received serious attention by developing countries in ASEAN and Asia-Pacific [6]. This pest attacks maize plants from a young age (vegetative) to the flowering phase (generative) [7]. Symptoms of attack on the shoots of the affected plant appear to be hollow, and there are many larval feces. Characteristics of attacks that appear on the leaves of corn, it will be clear that the damaged parts, holes, and generally the larvae are at the growing point of the corn plant [6].

Sweet corn is a popular horticultural commodity among the general public due to its sweet flavor [8]. However, national sweet corn productivity remains low, with an average of 8.31 tons/ha, despite the fact that the yield potential ranges between 14 and 18 tons/ha [9]. Furthermore, glutinous corn is one of the horticultural commodities that has a high amylopectin content and has a soft and fluffier texture [10]. Likewise, the productivity of glutinous corn is still low at 2 tons/ha [11].

Glutinous and sweet corn varieties have great potential to be produced, especially in the province of Bali. However, problems caused by *S. frugiperda* are still being experienced in the planting of this local corn variety in Bali [12,13]. Therefore, it is necessary to carry out a series of field-scale studies to evaluate the level of attack and the potential loss of yield as a result of this *S. frugiperda* attack. So that the results of this study provide information about the impact of these pests and can make decisions in controlling them wisely.

2. MATERIALS AND METHODS

2.1. Study area

This research was conducted on a field-scale located in Gianyar Regency, Bali. The corn land used belongs to local farmers with an area of 10 ha.

2.2. Research design

This study used 4 treatments and 6 replications with 10 samples/replications that were systematically determined. The plot units are 3 × 3 m in size with a distance between the plots of 1 m. The maize used were sweet and glutinous maize varieties with a spacing of 25 cm × 65 cm with one perforated plant.

Table 1. Treatment in this study

Treatment	Remarks
V1P1	Sweet corn without *S. frugiperda* attack
V1P2	Sweet corn is attacked by *S. frugiperda*
V2P1	Glutinous without *S. frugiperda* attack
V2P2	Glutinous corn is attacked by *S. frugiperda*

U1	U2	U3	U4	U5	U6
V1P1	V1P2	V2P1	V2P2	V1P1	V1P2
V2P2	V1P1	V1P2	V2P1	V2P2	V1P1
V2P1	V2P2	V1P1	V1P2	V2P1	V2P2
V1P2	V2P1	V2P2	V1P1	V1P2	V2P1

Figure 1. Treatment plan

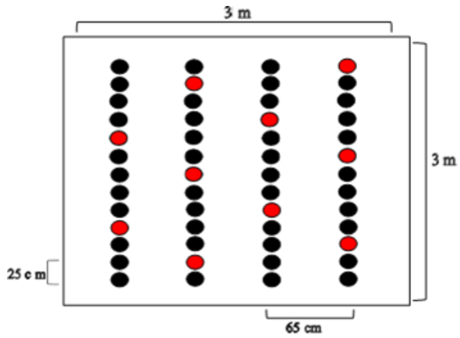

Figure 2. Observed sample scheme

2.3. Observation method

Observations were made once a week by directly observing the presence of *S. frugiperda* pests in each sample of the maize plant. The variables observed in this study are:

2.3.1. Population development & attack rate

The number of *S. frugiperda* populations present in the sample plants was counted once a week to observe population development, and the findings were averaged. Observation of the level of attack was carried out by determining the attack rate (%) using the equation [14], namely:

$$P = \frac{a}{a+b} \times 100 \quad (1)$$

Note:
P = the percentage of plants affected (%)
a = the number of plants attacked
b = the number of plants observed

Furthermore, after knowing the percentage of plants attacked, it is then compared with the attack criteria table in Table 2.

Table 2. Attack level criteria

No.	Attack percentage	Criteria
1	0%	Healthy
2	>0 - 10%	Very low
3	>10 - 20%	Low
4	>20 - 40%	Moderate
5	>40 - 60%	High
6	>60 - 100%	Very high

Source: Moekasan et al. [15]

2.3.2. Decreased production

Observation of the decline in production was carried out by taking a sample plant that was observed in each treatment plot and weighing it then converting it to hectares and comparing the results from plots of corn plants that were not attacked by *S. frugiperda* with the plots of plants that were attacked by *S. frugiperda* with the formula:

$$H = \frac{a - b}{a} \times 100\% \quad (2)$$

Note:
H = Decreased production (%)
a = Results from plots that were not attacked by *S. frugiperda*
b = Results from plots infested with *S. frugiperda*

2.4. Data analysis

To determine the differences in each treatment, data were analyzed using SPSS 23.0 version software (IBM, USA) and then analyzed using the T-Test and a 5% confidence interval.Data is displayed in the form of graphs, figures, and tables.

3. RESULT AND DISCUSSION

3.1. Population development of S. frugiperda

The results of our observations showed that in the treatment of sweet corn (V1P2) and glutinous corn (V2P2) which were attacked by *S. frugiperda*, the population began to be found in plants 2 weeks after planting (wap) (Fig 3). The population average was 5.37 on sweet corn and 6.53 on glutinous corn. The population continues to increase and the peak occurs at 5 wap with a population of 13.87 on sweet corn and 15.24 on glutinous corn. Furthermore, the larvae population decreased until the maize plant was 8 wap. Furthermore, at the age of 9 wap corn, no further *S. frugiperda* population development was found in the treatment of sweet corn (V1P1) and glutinous maize (V2P1). The maize variety sampling activity is shown in Fig 3.

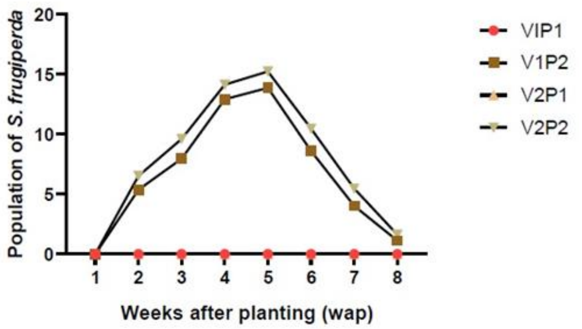

Figure 3. Population development of *S. frugiperda* in sweet and glutinous corn in field-scale trials.

The decline in the larvae population can be caused by various obstacles. According to Wahyuni et al. [16], food sufficiency, climate, competition, and natural enemies are environmental factors that significantly influence population growth and development, which in turn affects the natural decline in insect pest populations. Nutrient sources in the form of nectar or pollen can act as carbohydrates that can improve the fitness and reproductive output of adult Lepidoptera including *S. frugiperda* [17].

The life cycle of insect pests is another environmental element that influences their growth, development, and population density [18]. According to study, *S. frugiperda* has a high reproductive capability at 34°C and a high population expansion [19]. The population of *S. frugiperda* can develop well at an altitude of about 700-850 masl (metres above sea-level) [5].

Figure 4. Sampling of *S. frugiperda* pests on maize plantations (Figure source: Authors)

3.2. The correlation of population and S. frugiperda attack rate

The results showed that the treatment of sweet corn (V1P2) and glutinous maize (V2P2) was attacked by S. frugiperda, the attack began to appear on plants aged 2 WAP with an average low attack rate of 16.93% in sweet corn and 17.09 % on glutinous corn. The attack rate increases and peaks at 5 weeks after planting (wap) with a high attack rate of 46.73% for sweet corn and 49.79% for glutinous corn. Then, the attack decreases until the corn plant is 8 (wap) with an average attack rate of 31.15. % in sweet corn and 33.65% in glutinous corn (Fig. 5). Crop damage caused by armyworms, according to Arifin [20], can be impacted by population density and insect pest stages. *S. frugiperda* causes more severe plant damage during the vegetative period [21].

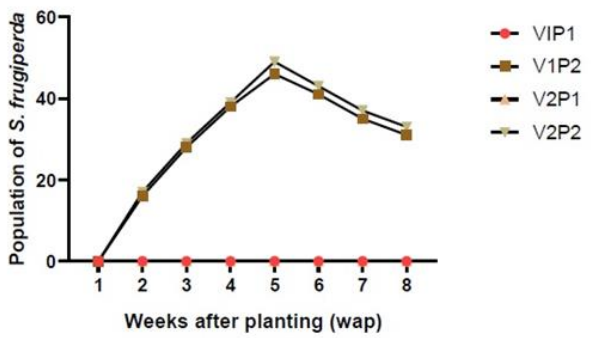

Figure 5. The level of attack rate on sweet and glutinous maize

The regression analysis results showed a relationship between the larval population and the attack rate of *S. frugiperda* and the relationship follows the following equation: *y = 1.4122x + 22,657* with a correlation coefficient *(R2)* of 0.4115 (Fig. 6). In our cases indicates, that each addition of the 1.4 larvae population of *S. frugiperda* can cause an increase in the attack rate by 22.65%. The greater the pest population density, the greater the harm. The capacity to control pests can also have an impact on crop damage severity [22].

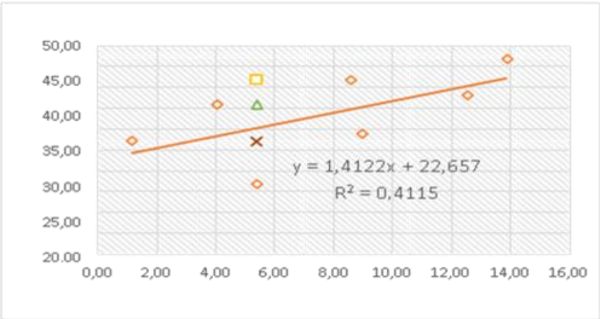

Figure 6. Population correlation with attack rate of *S. frugiperda*

3.3. Potential decrease production of maize varieties in this study

The analysis showed that the production of sweet corn that was not attacked by *S. frugiperda* (V1P1) was significantly different from that of sweet corn that was attacked by *S. frugiperda* (V1P2). The amount of yield decrease caused by *S. frugiperda* attack on sweet corn was 28.08%. There were also significant differences in the treatment of glutinous maize that was not affected and glutinous corn that was attacked by *S. frugiperda*. The infection of *S. frugiperda* on glutinous maize resulted in a 25.04 percent yield decrease. A total population of 0.2-0.8 larvae per plant drastically reduces productivity by 5-20% [12].

Table 3. The decrease in yield was caused by *S. frugiperda* attack on sweet and glutinous corn

Sweet Corn			Glutinous corn		
Treatment	**Wet Weight (ton/Ha)**	**Decreased yield (%)**	**Treatment**	**Wet Weight (ton/Ha)**	**Decreased yield (%)**
V1P1	19.66 [a]	28.08	V1P1	6.95 [a]	25.04
V1P2	14.14 [b]		V1P2	5.21 [b]	

Note: the numbers followed by different letters in the same column show a significant difference at the 5% level.

According to recent research, the amount of damage produced by *S. frugiperda* in 126 cornfields in ten districts of Karnataka during the wet season with a distributed equal infestation ranged from 44 to 100 percent [23]. Interestingly, the old larvae of *S. frugiperda* also have an affinity for cabbage which causes economic losses in China [24].

4. CONCLUSIONS

Treatment of sweet corn (V1P2) and glutinous maize (V2P2) which were attacked by *S. frugiperda*, the population began to be found in plants aged 2 (wap), the average population was 5.37 on sweet corn and 6.53 on glutinous corn. The population continues to increase and peaks at 5 (wap) with a population of 13.87 in sweet corn and 15.24 in glutinous corn, then the larva population decreases until the maize plant is 8 mst. 2. The regression analysis shows the relationship between the larval population and the *S. frugiperda* attack rate, that is, each addition of 1.4 *S. frugiperda* larvae population causes an increase in the attack rate of 22.65%. The yield decrease caused by S. frugiperda attack on sweet corn was 28.08% while it was 25.04% for glutinous corn.

Future research is still needed, especially information about the distribution of hosts from Family Gramineae and also the possibility of horticultural commodities, especially in the Province of Bali. Monitoring the presence of natural enemies associated with *S. frugiperda* is also very necessary for the integrated and environmentally friendly management of this pest [25]. In Bali Province, intensive field monitoring of *S. frugiperda* and ecological research is still needed [26].

AUTHORS' CONTRIBUTIONS

AAAASS, IKS, and IWS: conceived and developed the experiment, as well as managed and received financing for the research. IGFM, IKWY, and IWEKU carried out the experiment and analyzed the results. The paper was written by PAW. The published version of the work has been reviewed and approved by all authors.

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