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Short Communication

An Update on the Fall Armyworm: Severity of Maize Damage and Susceptibility to Emamectine Benzoate and Chlorantraniliprole

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ABSTRACT

The damage area due to fall armyworm (FAW, *Spodoptera frugiperda*) in Indonesia decreased during the last three years (2021-2023) after the first outbreak in 2019. This insect continues to pose some risk for maize production with most reports documented the damage during the vegetative maize stage showing leave defoliation. This article provides an update on the high field population and the new type of damages caused by FAW by boring the stalks and feeding the cobs observed in the District of Grobogan, Central Java. The populations of egg masses, adults, and larvae were 0.4, 0.17, and 0.37 per plant of 27-day-old, respectively. The reproductive maize was heavily damaged by FAW with leave damage score of 9, 0.33 holes per stalk, and 75% of cobs damaged. The FAW larvae produced from the collected egg masses were still susceptible to emamectin benzoate and chlorantraniliprole. These findings prove that FAW can cause very seriuos damage leading to almost total yield loss. As maize becomes more important in Indonesia, proper management in compliance with the Integrated Pest Management (IPM) principles is mandatory to keep the population low and prevent large-scale outbreaks.

Keywords: Fall armyworm; Integrated Pest Management; stalk and cob damage; susceptibility

INTRODUCTION

Since the outbreak of Fall Armyworm (FAW), *Spodoptera frugiperda* J. E. Smith (Lepidoptera: Noctuidae), in African countries in 2016 that caused massive damage and economic losses (Goergen *et al.*, 2016; IITA, 2016), this insect has spread and created problems in many Asian countries and Australia (Rane *et al.*, 2023). In Indonesia, a report on the outbreak with noticeable damage was first published in 2019 (Trisyono *et al.*, 2019). To the best of our knowledge, there is no document recording and showing the exact arrival time of this insect in Indonesia, and FAW has occupied 28 out of 33 provinces by 2023 (Directorate of Food Crop Protection MOA; personal communication in December 2023).

Several researchers have published their research on FAW in different journals and proceedings (Mukkun *et al*., 2021; Sartiami *et al*., 2020; Vebryanti *et al*., 2023; Widhayasa *et al*., 2022); however, research to determine the damage and economic losses due to this insect is still lacking.

Our communications with the farmers, agricultural officers, and pesticide companies showed that the FAW problems weakened after 2020 and this observation was in agreement with the data on damage areas at the national level. The damaged area in 2020 was 114.6 thousand ha and it was the highest up to the present time. Since then, the damaged area declined to 28.7 thousand ha in 2023 (Directorate of Food Crop Protection MOA; personal communication in December 2023). There are several plausible explanations for this declining trend, such as the farmers and other stakeholders might have been successful in controlling FAW, the local natural enemies have contributed more due to their successful adaptation to the new host/prey, or the weather and climate that have not been conducive for this insect to grow and develop its population. These factors may contribute individually or in combination to cause the decline. Maize plant resistance to FAW has been developed but it has not been commercialized by now in Indonesia. This control measure has the potential to be effective and easily adopted by the farmers once it is commercially available.

FAW poses a continuous threat to maize farmers although the 2021–2023 situation was better than the first two years of the outbreak (2019–2020). In the origin countries, FAW has continuously become a main pest because of its biotic potential and its ability to adapt to the control technologies being applied in the form of resistance development to chemical insecticides (Carvalho *et al*., 2013; Muraro *et al*., 2022; Nascimento *et al*., 2016; Yu, 1991) and transgenic maize expressing *Bacillus thuringiensis* toxins (Boaventura *et al*., 2021; Gutierrez-Moreno *et al*., 2020; Yang *et al*., 2021). Monitoring becomes a priority to determine the shift of the population, and early detection of shifting would provide early warning and time for mitigation. In the same sense, this article documents and reports the reality of heavy damage and the high population of FAW in maize (potential field damage) in a couple of locations in the District of Grobogan, Central Java. This finding provides a precautionary understanding for all stakeholders on the potential damage and yield reduction caused by FAW, and insightful efforts in managing this pest to prevent further losses.

MATERIALS AND METHODS

Selected Locations

Field observation was carried out in the District of Grobogan, one of the maize production centers in the Province of Central Java. The sites of field observation were selected purposively with the criteria of maize heavily damaged and infested by FAW. Before the site selection, information regarding heavily damaged maize and high infestation was received from farmers and agricultural officers followed by a field survey to confirm the damage in several sites in the District of Grobogan, Central Java. The two selected sites for field observations were Sugihmanik, Sub-district of Tanggungharjo; 7°05'20.2"S 110°36'46.7"E, and Nampu, Sub-district of Karangrayung; 7°14'22.9"S 110°47'07.5"E. Sugihmanik represented lowland area with vegetative maize (27 days after planting [DAP]) infested by high population of FAW. Nampu represented a high land area with a reproductive stage (>60 DAP) and was heavily damaged by FAW.

Sampling Method for Damage Assessment

The field assessment was conducted on January 27, 2024, for both selected locations. The site for sampling in Sugihmanik was a plot of 0.24 ha maize of 27 DAP. This plot was surrounded by >100 ha of reproductive maize (Figure 1A). Four sampling units with each unit consisting of 10 plants were selected randomly. The 10 maize plants were distributed in two adjacent rows, each consisting of five plants consecutively. The distance between each sampling unit was >10 m apart. In each plant sample, observation was made to determine the defoliation using Davis's scale (Davis *et al.*, 1992), population of larvae, adults, and egg masses. More than 100 egg masses were collected and brought to the laboratory for further assessment of the susceptibility of newly hatched larvae against two insecticides (emamectin benzoate and chlorantraniliprole). Based on the information from the owner, this plot has been sprayed two times with emamectin benzoate and chlorantraniliprole and applied once with carbofuran by pouring the granule formulation into the whorl.

Different from the Sugihmanik site, Nampu was the maize center production in the upland area surrounded by teak plantations. The sampling procedure for Nampu was similar to that of Sugihmanik. Two different plots were observed in Nampu for different purposes. These two plots were side by side separated by a village road. The first plot was used to observe the defoliation and stalk borer; while the second plot was used to observe the cob damage. Because of heavy defoliation and stalk damage (Figure 1B), this maize did not produce sufficient cobs for observations. Defoliation was scored using Davis's scale (Davis *et al.*, 1992), and stalk damage was assessed by counting the number of plants showing one or more holes caused by FAW. The holes made by larvae of FAW (Figure 2A) were different from those made by Asian corn borer (ACB), *Ostrinia furnacalis* (Figure 2B). Similar to stalk damage, the number of cobs damaged was counted in 10 plants per unit with a total of four sampling units (Figure 2C). This symptom was unique and different from cob damage due to three other Lepidopteran species often attacking the cobs: ACB, corn earworm *Helicoverpa armigera* (CEW), tobacco cutworm *Spodoptera litura* (TC).

Susceptibility of FAW Larvae to Insecticides

The newly hatched larvae from field-collected egg masses were tested for their susceptibility against the two commonly used insecticides for controlling FAW, emamectin benzoate (Emacel® 30 EC, Indonesia) and chlorantraniliprole (Prevathon® 50 SC, Indonesia) under laboratory conditions. Bioassays were carried out by dipping the artificial diet in the insecticide solutions for 10 seconds. The artificial diet (Y. Andi Trisyono, 2006, unpublished) has been used for rearing FAW since 2019. Three concentrations were examined for each insecticide: 3.75, 15, and 60 ppm for emamectin benzoate and 6.25, 25, and 100 ppm for chlorantraniliprole. These concentrations ranged from the possible lowest to the highest field recommendation rates. After dipping, the cube diets (1×1×1 cm) were air dried before placing them in the plastic cups (3.3 cm in diameter and 4.3 cm in height, one diet per cup). Ten newly hatched larvae were then transferred into a treated or control diet, and each treatment was replicated four times. Mortality in the control and treated diet was observed 4 days after treatment.

In addition, a mass susceptibility test was done by exposing >1000 newly hatched larvae from the field-collected egg masses into the diet (8x8x1 cm) treated with chlorantraniliprole (25 pm) in plastic jars (15 cm in diameter and 5.5 cm in height). Larval mortality was observed on the fourth day after treatment.

RESULTS AND DISCUSSION

Maize Damage

The maize in Sugihmanik received light defoliation by FAW with the score ranging from 2–3 on Davis's scale. However, the crops were heavily infested by the populations of egg masses with different stages starting from newly laid (Figure 3A) to early hatching (Figure 3B). In addition, adults (Figure 3C) were also found. The average populations for egg masses, adults, and larvae were 0.4, 0.17, and 0.37 per maize crop, respectively.

Very low damage in leaves was the result of intensive insecticide applications (three times within the span of 27-day-old-maize). The observed larvae were the survivors of these treatments. They may survive because they did not get enough exposure to insecticide applications or they may be able to resist the insecticides applied. Early reports showed that the seven populations of FAW in Central Java were still susceptible to emamectin benzoate, chlorantraniliprole, and spinetoram (Suryani *et al*., 2022). However, intensive application of insecticides in Grobogan may selected for resistance development. Further experiments are needed to determine whether the resistant population of FAW exists.

The high population of adults and egg masses indicates that there had been adult migration coming from the surrounding areas which was dominated by reproductive maize. Our field observations in many provinces, including in Lampung in 2019 (Trisyono *et al*., 2019), showed that females preferred to lay eggs on the vegetative stage of maize approximately 1–2 weeks after planting and the most damage also occurred during the vegetative stage. This finding provides some insights related to FAW management, particularly in designing the planting seasons and crop rotations.

In Nampu, the reproductive maize was heavily damaged by FAW with 100% of the plants defoliated with an average damage score of 9 (the maximum score) (Figure 1B) and an average of holes of 0.33 holes per stalk (Figure 2B). In this plot, cobs were mostly not produced because of highly damaged maize before the cob formation. In another plot, the defoliation and stalk damage were less and the cobs were formed. Unfortunately, these cobs were also heavily damaged with an average of 75%. The damaged cobs were marked with one or more holes (Figure 4A), and these damaged cobs almost had no kernels inside (Figures 2C and 4B). The heavy damage in the reproductive stage was first publicly reported in Indonesia but these types of damage have already been reported in other countries (Rwomushana, 2019). This may suggest that heavy damage could occur anytime in any place if proper management is not in place.

Since the first outbreak in Sumatra Island was noticed in 2019 followed by an increase in spreading dan damage area in 2020, the damage areas tended to decrease at the national level during the last two years (2021 and 2022) (Directorate of Food Crop Protection MOA, 2023; personal communication). This trend was similar in other regions, including in African and Southeast Asian countries. This finding provides an early warning of how bad FAW could cause damage and very significantly reduce the yield. Continuous monitoring of this invasive species is a must and the development of Integrated Pest Management (IPM) for FAW could protect and prevent the damage and yield loss due to this insect reaching its maximum capacity.

Larval Susceptibility to Insecticides

All tested concentrations for both insecticides (emamectin benzoate and chlorantraniliprole) resulted in 100% mortality by the fourth day after treatment, no control mortality was observed. In addition, mass treatment of 25 ppm chlorantraniliprole yielded the same result. These suggest that the larvae hatching from the field-collected egg masses were still susceptible to these two insecticides. However, we also observed some larval survivors in the same field which had been sprayed with the same insecticides. At this point, we cannot conclude if these larvae were resistant to the insecticides and further experiments are needed to determine their status. The results from these laboratory bioassays should not be directly connected with the field situation because the females FAW that laid egg masses and used for these laboratory tests were different from those that laid egg masses earlier and produced the larvae that had been sprayed. In other words, the female populations may be two different genetic pools. Another possible explanation for the surviving larvae in the field was due to sublethal exposure because of misuse of insecticide application, such as applying at a lower rate, improper use of nozzle causing uneven coverage of leaves surface, missing the proper timing, or simply because the larvae escape temporarily from exposure.

This update should be treated as an awakening call that FAW continues to pose a threat to maize growers, and together with the ACB, the challenges increase. Improper use of insecticides may contribute to unintended impacts, such as reducing the role of local natural enemies and the development of resistance that will lead to control failure. As maize becomes more important from year to year in Indonesia, proper management in compliance with the IPM principles including the use of maize plant resistance, is mandatory to keep the population low and prevent large-scale outbreaks.

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APPENDIX

Figure 1. Vegetative maize (27-day-old plants) surrounded by reproductive maize and heavily populated by the Fall Armyworm (FAW), *Spodoptera frugiperda*, in Sugihmanik, Grobogan, Jawa Tengah (A) and reproductive maize heavily damaged by FAW in Nampu, Karangrayung, Grobogan (B)

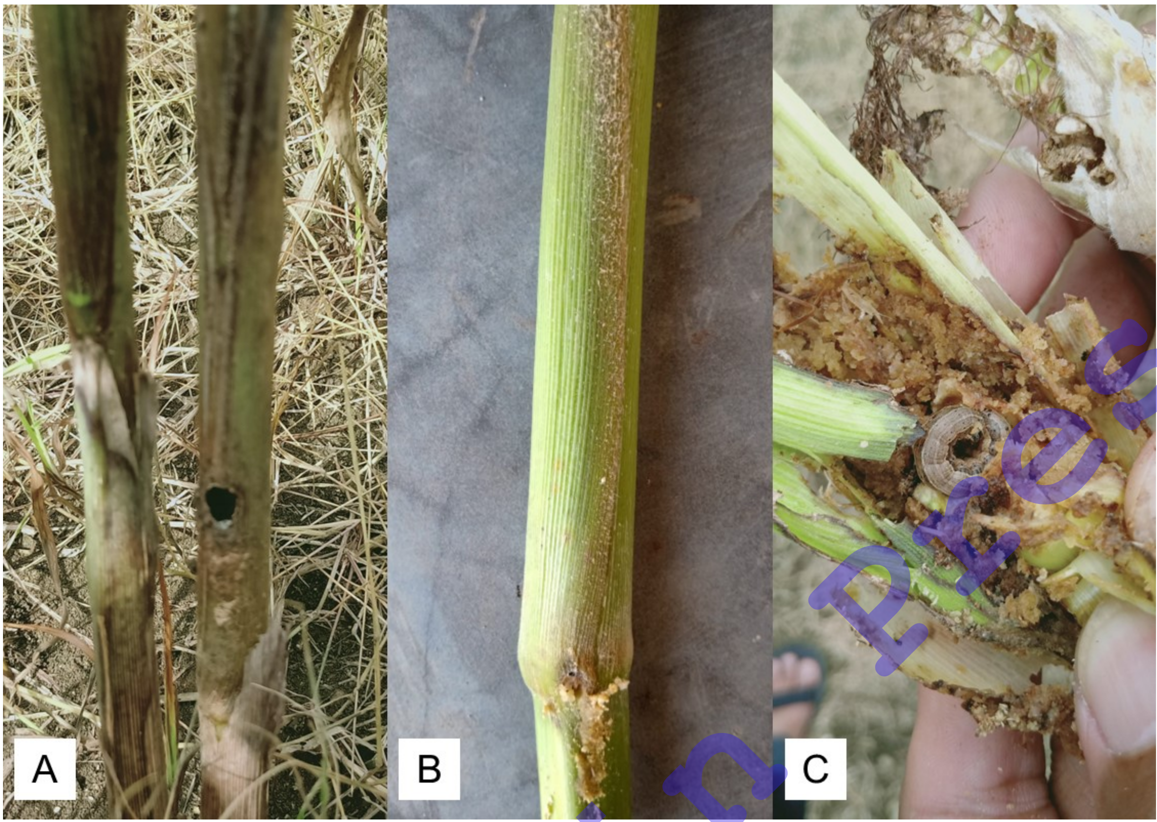

Figure 2. A hole in the maize stalk bored by a larva of the Fall Armyworm (FAW), *Spodoptera frugiperda* (A), the Asian corn borer, *Ostrinia furnacalis* (B), and a cob damaged by FAW (C)

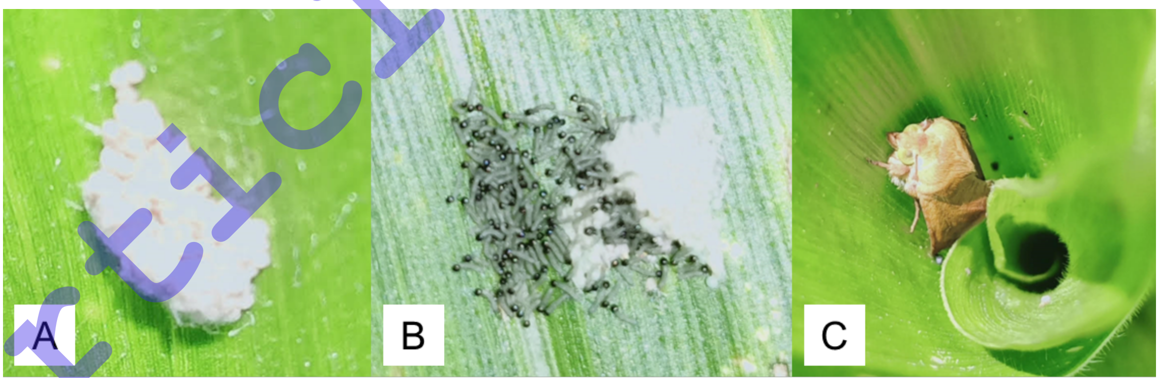

Figure 3. Newly laid egg mass (A), egg hatching (B), and adult (C) of the Fall Armyworm (FAW), *Spodoptera frugiperda* observed in maize on the same day (January 27, 2024) in Sugihmanik, Grobogan, Jawa Tengah

Figure 4. A cob with holes made the Fall Armyworm (FAW), *Spodoptera frugiperda* (A), and the more developed and heavily damaged cob FAW (B).