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First report of fall armyworm, *Spodoptera Frugiperda* (Lepidoptera: Noctuidae) incidence on oil palm and coconut and its interactive effect on maize-coconut intercrop system at Kusi in Ghana

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Abstract
Oil palm and coconut are essential crops in Ghana, but they are vulnerable to various pests. This study reports the first occurrence of fall armyworm (FAW) feeding on oil palm and coconut seedlings at the CSIR-Oil Palm Research Institute in Kade. It also evaluates the interactive effect of FAW on cropping patterns. A phytosanitary survey of oil palm and coconut seedlings at the nursery revealed signs of FAW caterpillar feeding, similar to those seen in maize. A confirmation test identified the pest as FAW, which the Ministry of Food and Agriculture later validated in partnership with CABI-Ghana. Incidence and severity tests showed a 90% infestation rate on oil palm and coconut seedlings. Three cropping patterns were tested to explore intercropping effects: sole coconut (control), sole maize, and coconut-maize combinations over a 0.4ha area each from September 2022 to February 2023. FAW activity on coconut and maize was monitored weekly, focusing on damage assessments, presence or absence of pests, and activities of non-target organisms. The ANOVA results showed no significant difference in fall armyworm populations among the different cropping systems; $F(2,18) = 1.340$, $p = 0.287$. The data indicated that FAW populations were lowest in sole coconut (0), higher in coconut-maize (24), and highest in sole maize (44). Feeding was mainly observed on maize, with no damage to coconut. Monthly data showed peak FAW populations from October to January, followed by declines in February and March, with a total of 7,017 recorded non-target organisms, including pests and predators. The study confirmed FAW's first occurrence on oil palm and coconut seedlings and suggests that intercropping maize with coconut does not harm transplanted coconut.

Keywords: Fall armyworm, coconut, oil palm, pests, predators

Introduction

The oil palm, *Elaeis guineensis*, and the coconut (*Cocos nucifera*) are the most extensively grown and widely used palms in the world [1]. However, their production has been significantly impacted by the infestation of several arthropod pests. Until recently, the fall armyworm, an invasive pest, had not been reported to infest oil palm and coconut in Ghana. The fall armyworm is recognized as a highly destructive, polyphagous pest that targets over 350 host plant species, with a particular focus on maize [2]. It originated in the Americas and has caused devastating impacts on various food crops, including rice, sorghum, maize, and sugarcane, with maize serving as its primary host [3, 4, 5]. The first invasion of the fall armyworm (FAW) was detected in Central and Western Africa in early 2016, starting in Nigeria in January 2016 [6] and spreading to Ghana in April 2016. Since then, it has rapidly invaded 47 African countries and 18 Asian countries [6, 7], and as of today, FAW has spread from the Americas to more than 80 countries [8]. Female adults lay eggs in clusters on host plants, which hatch into larvae that undergo six instars. These larvae feed voraciously on foliage, leading to substantial crop damage [9]. The larvae, also known as caterpillars, primarily affect maize and sorghum, causing severe damage in monoculture crops [3, 4, 10, 11]. Initial estimates suggest that maize losses in 12 major African countries could range between US$2.5 billion and US$6.2 billion [12].

Until recently, there has been no information about the infestation of fall armyworms on oil palm and coconut seedlings in Ghana since their invasion of Africa. Previous research has identified both major and minor pests affecting oil palms and coconuts throughout their growth stages: nursery, young, and adult. However, there is little knowledge regarding the polyphagous pest, the fall armyworm, and its impact on coconuts and oil palms in Ghana. Notably, a significant outbreak of this pest occurred in 2020, damaging coconut and oil palm seedlings by up to 90% at the CSIR-Oil Palm Research Institute in Kusi. This infestation raised concerns among all stakeholders. Phytosanitary surveillance identified this polyphagous pest infesting oil and coconut seedlings. The rapid spread of the infestation was alarming, calling for swift management strategies. An observational report indicated that the source of the FAW infestation was maize farms around the nursery. In the absence of the main host, maize, the pest turned to the coconut and oil palm seedlings as alternative hosts. There was a ban on maize and other cereals in and around the nursery until a verification survey was conducted; hence, there was a need to intercrop maize with coconut.

Additionally, the implications of intercropping oil palm and coconut with maize, the fall armyworm's preferred host, have yet to be studied in Ghana. This intercropping could potentially offer several benefits, including higher yields, pest control, soil erosion reduction, and increased biodiversity [13]. However, stakeholders are concerned about detecting fall armyworms on oil palm and coconut seedlings, as well as the larger effect on transplanted seedlings. This study aimed to report the first occurrence of fall armyworm attacks on oil palm and coconut, examine how these pests affect maize-coconut intercropping, and evaluate non-target organism biodiversity in Ghana.

Materials and Methods

1. Field description

The research was conducted at the CSIR-Oil Palm Research Station at Kusi in the Eastern region of Ghana (6°10'N 0°30'W). The data collection took place at the nursery in 2020/2021, and intercropping was conducted on a three-year transplanted coconut field from August 2022 to the 2024 cropping season.

2. First report of the incidence of fall armyworm on oil palm and coconut.

The first report of fall armyworm infestation in oil palm and coconut seedlings was noted at the CSIR-Oil Palm Research Institute in Kusi during the 2020/2021 cropping season, significantly damaging the crops. During a phytosanitary survey conducted at the institute's nursery in December 2021, signs of FAW feeding activities were observed on oil palm and coconut seedlings. The incidence of FAW infestation was calculated using the formulae below;

$$Incidence\,(\%) = \frac{Number\ of\ infested\ plants}{Total\ number\ of\ palms\ sampled} \times 100$$

3. Evaluating the interactive impact of the Fall Armyworm on coconut-maize intercropping.

The study was conducted on a 1.2-ha plot of two-year-old transplanted coconut seedlings, with each treatment occupying 0.4ha. The treatments included: intercropped maize and coconut on 0.4 ha, maize only on 0.4ha, and coconut only on 0.4 ha. Methods used by [7] and [8] for visual assessments and scores of fall armyworm interactions within the different cropping systems were adopted and recorded. Observations survey centered on the presence or absence of fall armyworm and their feeding behavior on coconut fronds, trunks, and axils, as well as the maize using method outlined by [14]. Additionally, the feeding activities of fall armyworms on maize leaves and whorls were documented.

4. Coconut-Maize intercrop

Maize was planted within a 0.4 ha coconut plantation, and sampling was conducted in this maize-coconut intercrop. The herbicide glyphosate was applied to prepare the field before sowing the maize. The coconut trees were arranged in a triangular pattern, spaced 9 meters apart, resulting in a total of 60 trees per 0.4 ha. Maize was planted with a spacing of 90 centimeters by 60 centimeters, with three seeds planted per hill between the coconuts. Planting took place at the end of August during the rainy season. For data collection during sampling, a total of 52 coconut trees were selected. In Figure 1 below, four maize plants were chosen near each coconut tree, arranged in a square formation. Overall, 208 maize plants were examined in the maize field, along with 52 coconut trees. We closely inspected all parts of the coconut trees, including the fronds and stems, as well as the leaves and stems of the maize plants, to check for the presence of fall armyworms and other non-target organisms. Our findings were documented every week.

Fig 1. Planting distance of maize from coconut plants and data collection of fall armyworm

5. Sole Coconut

An 18-meter buffer zone was established between the coconut-maize intercrop and the sole coconut plot. Within a 0.4ha sole coconut plot, 52 coconut trees were sampled for data collection. Each tree was monitored closely every week to check for fall armyworm infestations.

6. Sole Maize

The plot designated for the sole maize crop was treated with herbicide before planting. Maize was cultivated on a 0.4ha plot, with a planting distance of 90 cm by 60 cm, placing three plants per hill. A total of 208 maize plants were randomly selected to assess the presence or absence of fall armyworm infestation and another non-target organism.

Results

1. Incidence and damage by fall armyworm on coconut and oil palm seedlings

The overall incidence of FAW (Fall Armyworm) was found to be 90.25%. This incidence was higher in coconut

seedlings, which showed a rate of 94%, compared to an 86.5% incidence in oil palm, based on 200 samples collected from each group (see Table 1). Adult moths were observed, along with large clusters of eggs laid beneath the

axils and on newly opened fronds (refer to Figures 2a and 2b). Some hatched larvae were seen feeding on the fronds while hidden in the folded sections of the new spear. As the larvae mature, they migrate to the base of the spear to continue feeding, often covering themselves with frass. In some instances, the spear is cut at the base (see Figure 2c). The first signs of larval presence are the holes they create on the fronds as they feed (see Figure 2d). The fronds were inspected down to the base of the new spear, with particular attention paid to the folded fronds, especially in coconut seedlings.

Table 1: FAW incidence at CSIR-OPRI nursery

S/n	Crop(s)	Total sample plants	No. infested	% incidence
1	Oil palm seedlings	200	173	86.5
2	Coconut seedlings	200	188	94.0
	Total	400	361	90.25

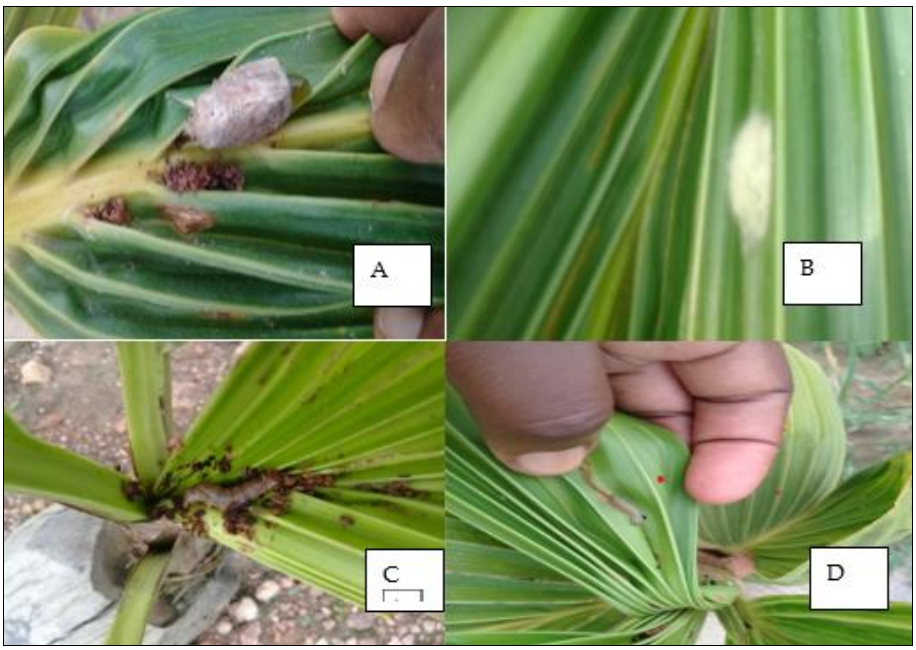

Fig 2: Symptoms of damage caused by FAW on oil palm and coconut seedlings at the Nursery. (A)Adult FAW laying eggs on fronds. (B) Clusters of egg masses of FAW. (C) Larvae of FAW feeding. (D)Larvae of FAW hide in folded fronds

2. Confirmation test

A confirmation test was conducted to ascertain whether it was a fall armyworm. A total of ten larvae were collected into vials and sent to the CSIR-OPRI entomology laboratory for rearing and identification. The larvae were placed in petri dishes and provided with maize leaves as a substrate for feeding during rearing. Out of the ten larvae, one survived, pupated, and developed into a moth (Figure 3c). The life cycle from the larvae to the adult showed that it took 13 days for the fall armyworm larvae to develop into a pupa. It took 8 days for the pupa to develop into an adult. The identification key developed by Goergen *et al.* (2016) [19] was used for identification, which was then confirmed by the Ministry of Food and Agriculture (MOFA), Ghana, and CABI-Ghana.

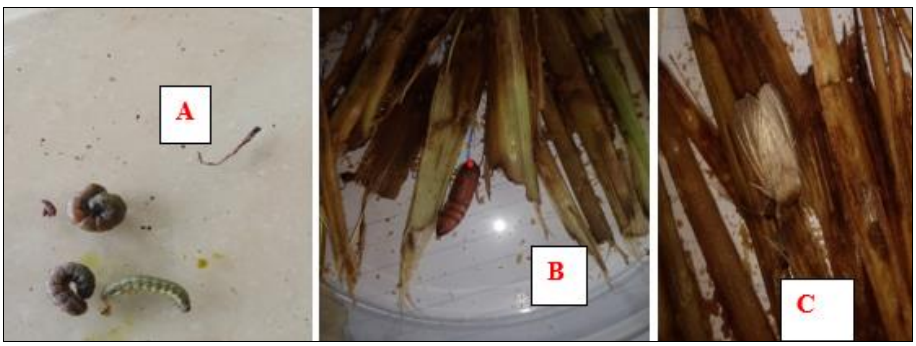

Fig 3: Life stages of the Fall Armyworm (FAW) confirmed in the laboratory: (A) Larval stages observed in a petri dish, (B) pupae stage, and (C) adult moth

3. **Management strategies adopted:** The outbreak of Fall Armyworm (FAW) was reported to the Ministry of Food and Agriculture (MOFA) for immediate action. MOFA worked with the Council for Scientific and

Industrial Research - Oil Palm Research Institute (CSIR-OPRI) to develop management strategies for controlling FAW in the nursery. A biopesticide containing the *Pieris rapae* granulosis virus and *Bacillus thuringiensis* was recommended for use against the pest. The biopesticide was applied using a knapsack sprayer on designated plots of oil palm and coconut nurseries. Results showed high pest mortality within 48 hours. A second application was made two weeks later to target newly hatched larvae, along with ongoing phytosanitary surveillance. It was suspected that pests had migrated from infested local maize farms to the nursery, resulting in a complete ban on cereal cultivation in and around the area.

4. The interactive effect of FAW on cropping systems.

An observational study identified varying populations of fall armyworms across different farming systems. A total of 68 fall armyworms were observed in maize-coconut intercrop, sole coconut, and sole maize systems, with the highest count (44) in the sole maize system, followed by 24 in the intercrop. The ANOVA results showed no significant difference in fall armyworm populations among the different cropping systems; $F(2,18) = 1.340$, $p=0.287$. No fall armyworms were found on coconuts or in sole coconut systems. These findings suggest that fall armyworms are more prevalent in sole maize and maize-coconut intercrops. The FAW larvae were first observed feeding on maize whorls when the maize was three to four weeks old in early October, mainly on maize rather than coconut (Figure 4). The highest concentration of fall armyworms was recorded from October to January, with a sharp decline after harvest, resulting in nearly no presence by September, February, or March (Figure 5). Visible damage to maize included leaf defoliation and signs resembling sawdust on the leaves (Figure 4).

Fig 4: Symptoms of damage caused by fall armyworm on maize in the study area

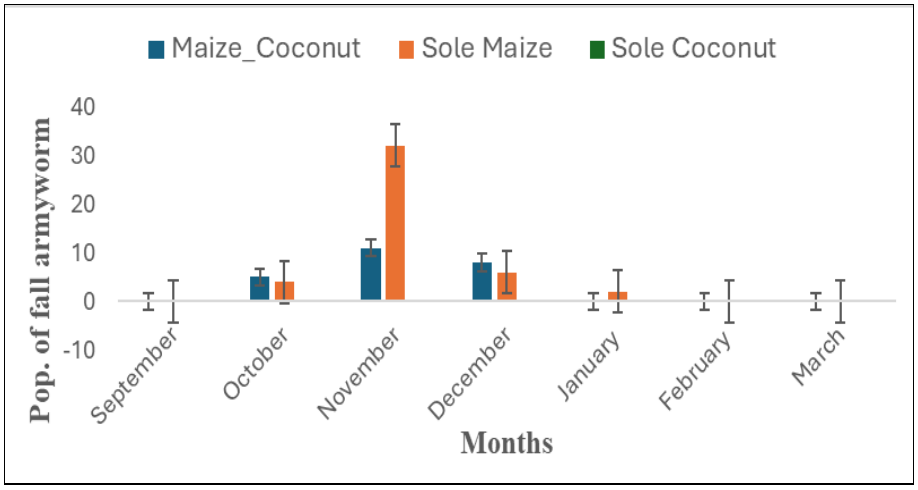

Fig 5: Population trends of fall armyworm on farming systems in the study are

Biodiversity of non-target organisms

The survey revealed a total of 7,017 non-target organisms on maize and coconut plants across sole coconut, sole maize, and maize-coconut systems, as shown in Table 2 below. Both predators and pests interacted positively and negatively during the observation. Organisms included predators such as ants, spiders, and ladybird beetles, and pests like grasshoppers and termites. The diversity of organisms was highest in the maize-coconut intercrop, while the sole coconut had the least. Ants dominated the population, with parasitic wasps being the least common, and pests outnumbered predators overall.

Table 2. Diversity of non-target organisms on maize and coconut in the study area

Other arthropods	Cropping systems			
	Maize-Coconut	Sole maize	Sole Coconut	Economic status
Grasshopper	96	75	36	Pest
Ants	3112	1521	302	Predators
Rhinoceros beetle	2	0	6	Pest
Spider	13	32	8	Predators
Earwig	92	45	49	Predator

Termite	13	52	11	Pest
Snails	56	31	17	Pest
Ladybird beetle	35	21	10	Predators
Cricket	145	253	12	Pest
Aphids	152	310	7	Pest
Assassin bug	32	73	9	Predator
Housefly	9	12	23	Pest
Moth	22	15	27	Pest
Flea beetle	102	98	74	Pest
Parasitic wasp	2	1	4	Predator
Total	3883	2539	595	

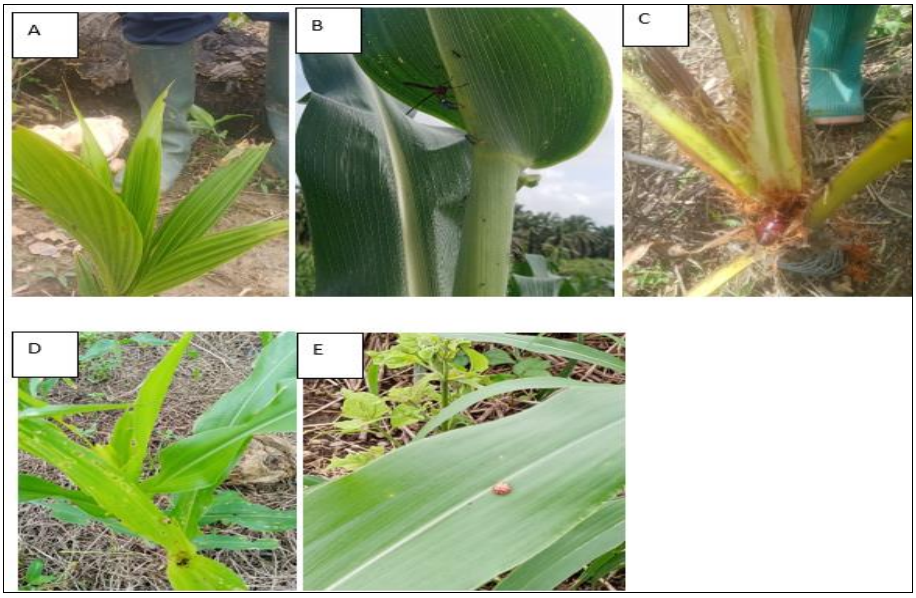

Fig 6. Pests and predators on coconut and maize in the study area. A- Grasshopper, B-Parasitic wasp, C-Rhinoceros beetle, D-Aphids, and E-Ladybird beetle

Discussion

Oil palm and coconut play a crucial role in the economies of many countries, primarily through the export of palm oil and its various applications in products such as sauces, soap, wine, fertilizers (derived from ashes), roofing (using leaves), building materials (from the trunk), medicines (from roots), and ornamental items [1]. Farmers and researchers face challenges in oil palm and coconut cultivation worldwide, particularly in Ghana, where pests and diseases significantly reduce crop yields by competing for nutrients and causing damage to the trees [15]. The primary pests affecting oil palm and coconut include insects, mites, nematodes, rodents, birds, and other animals that can intermittently cause problems [16]. Globally, oil palm is affected by 58 notable insect species, all of which can be destructive at different developmental stages [17]. The coconut tree is also attacked by more than 900 insect pest species, including rhinoceros beetles, red palm weevils, coconut mites, and coconut black-headed caterpillars, which are the four major insect pests of coconut with national significance [18]. A particularly concerning pest is the polyphagous FAW, which feeds on over 350 host species and inflicts significant damage on economically important crops [2, 19, 20]. Since it invaded the African continent in 2016, its preferred hosts include graminaceous plants such as maize, millet, sorghum, rice, wheat, and sugarcane. Feeding damage has also been observed on other major crops, including cowpea, groundnut, potato, soybean, and cotton [19, 21]. The economic consequences of the establishment of FAW in Africa extend beyond its direct impact on agricultural production; it also has the potential to adversely affect access to foreign markets [19]. Recently, the discovery of FAW infestations in oil palm and coconut has marked the first report of its kind since it invaded the African continent. Initial observations of armyworms in coconut and oil palm nurseries were originally attributed to major pests affecting those plants until a thorough phytosanitary inspection revealed the true identity of the pests. Field assessments showed up to 90% damage to oil palm and coconut seedlings at the CSIR Oil Palm Research Institute in Ghana. During the recent discovery of FAW infestations in oil palm and coconut seedlings, it was suspected that the pests migrated from infested maize farms to the nursery. A phytosanitary inspection of the nursery revealed adult moths along with large clusters of eggs laid beneath the axils and on newly opened fronds. Some hatched larvae/caterpillars were observed feeding on the fronds while concealed in the folded sections of the new spear. As the larvae matured, they moved down to the base of the spear and continued to feed, covering themselves with frass and, in some cases, the spear was cut at the base. The presence of the larvae was first noticed by the holes they created on the fronds due to their feeding activities. The fronds were inspected down to the base of the new spear, with careful examination of the folded fronds, especially in coconut seedlings. The damage caused to the coconut and oil palm seedlings was comparable to that described by [19] and [22] on maize and rice. There is significant concern among stakeholders following a confirmation test that identified FAW as the cause of the attacks on coconut and

oil palm seedlings by the Ministry of Food and Agriculture (MOFA) and CABI-Ghana. The immediate solution to the infestation involved implementing integrated pest management strategies to control the FAW in the nursery. This included using a biopesticide that contains the *Pieris rapae* granulosis virus and *Bacillus thuringiensis*, conducting phytosanitary inspections, and imposing a ban on maize cultivation in and around the institute. The biopesticide led to a significant mortality rate of the fall armyworm (FAW) within 48 hours. Additionally, the ban on maize cultivation in and around the nursery contributed to a reduction in infestation levels. Observational research was conducted to examine the impact of FAW on maize-coconut intercropping in a newly established plantation. These measures aim to further investigate the interactive effects of intercropping maize with coconut and oil palm.

In Ghana, many farmers commonly intercrop maize with coconut and oil palm during the first four to five years after planting. This practice is economically beneficial. However, the recent discovery of the FAW affecting coconut and oil palm has raised significant concerns about the sustainability of this intercropping practice. Various studies have demonstrated that intercropping can reduce pest infestations, including FAW, in the United States, and also increase the presence of beneficial arthropods [23, 24]. The concept of intercropping stems from push-pull technology, which uses no chemical deterrents or toxins but relies on repellent plants to deter pests from the main crop. During an observational study, findings indicated a high prevalence of Fall Armyworm (FAW) in sole maize systems, followed by maize-coconut intercropping, with no presence of FAW observed in sole coconut systems. The damage caused by FAW was primarily seen on maize plants, both in intercrop settings and in sole maize cultivation. During data collection, evidence of feeding activity, as described by [22], was evident (see Figure 5). This suggests that FAW was attracted to its main host plant, maize, which inhibited it from feeding on the transplanted coconut. Monthly observations revealed fluctuations in the FAW population across different treatments. The highest concentrations of FAW were recorded from October to January, followed by a sharp decline after the maize harvest. By September, February, and March, nearly no FAW were present (Figure 6). Continuous monitoring for potential damage to coconut plants from FAW was conducted after the maize harvest. Nwanze *et al.* (2021) [13] conducted similar research aimed at generating baseline information on the population dynamics of FAW in cassava-maize intercropping for management techniques in Abuja, Nigeria. They concluded that intercropping maize with cassava could lead to an increase in FAW bionomics due to the availability of abundant hosts, which may heighten the peak period of infestation. The presence of cassava in the maize-cassava cropping pattern encourages the feeding and oviposition of FAW on maize plants; thus, it is advisable to promote alternative cropping patterns in the region. Similarly, research at the Oil Palm Research Institute included a trial involving the intercropping of oil palm and cocoa conducted by [25], which revealed a greater number of beneficial insects in the intercropped system compared to the monocrops. Bawa *et al*. (2011) [25] concluded that the two crops did not share common insect pests, meaning that their association would not exacerbate pest problems for either crop. In the surveyed intercrops, various non-target organisms were observed and categorized as either predators or pests (see Table 2). Both groups interacted positively and negatively throughout the observation period. Predators included ants, spiders, and ladybird beetles, while pests consisted of grasshoppers and termites. The highest diversity of organisms was found in the maize-coconut intercrop, whereas the sole coconut crop exhibited the lowest diversity. Ants were the most dominant species in the population, while parasitic wasps were the least common. Overall, pests outnumbered the predators. These results align with similar findings by [26], which suggest that intercropping promotes the development of natural enemies. The study identified several common ant species, including *Oecophylla* sp., *Crematogaster* sp., *Camponotus* sp., and *Tetramorium* sp., in both solitary maize and the maize-coconut intercrop. The abundance of ants can be attributed to the presence of aphids on the maize plants, as ants have a mutualistic relationship with aphids; the aphids produce honeydew, which attracts the ants. However, it is important to note that ants are also predators of many insect pests [27]. Their predation was observed on FAW and other maize and coconut pests. Additionally, two significant pests that damage coconuts, the Rhinoceros beetle and the variegated grasshopper, were observed feeding on coconut plants (Figure 6c). The intercropping of maize with coconut also provides better protection of maize from FAW due to the diversity of predators that attack them. The first reported incidence of fall armyworm (FAW) on oil palm and coconut seedlings in the nursery caused 90% damage, which was a worry to all stakeholders in Ghana. In addition, stakeholders are concerned about the long-term effects that fall armyworm infestations may have on the yield and health of oil palm and coconut crops in Ghana. However, the survey on intercropping maize and coconut demonstrated that FAW has less impact on coconut. This study did not assess the differences in yield, so further research is necessary to determine the impact. However, intercropping maize with coconut is expected to provide significant economic benefits for farmers. Additionally, this study suggests that intercropping maize with coconut can serve as an effective alternative approach for managing Fall Armyworm (FAW), especially when combined with one or more integrated management strategies.

Conclusion

This study presents the first documented instance of fall armyworm feeding and damage to oil palm and coconut seedlings in a nursery setting. Confirmation tests identified the pest as the fall armyworm. An assessment of the damage revealed a 90% economic loss to the crops during a phytosanitary inspection, showing diverse feeding activities consistent with established symptoms. Potential sources of infestation were traced to maize farms in and around the institute. Additionally, further observational assessments indicated that intercropping maize with coconut in transplanted coconut fields did not adversely affect the growth of the coconut plants.

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Data availability statement: All data that supports the findings of this study are included within the article.

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Conflicts of Interest: The authors declare that there is no conflict of interest regarding the publication of the manuscript.

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