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Agroecological zones influence maize infestation and damage severity by the fall armyworm (*Spodoptera frugiperda* [J. E. Smith, 1797]) in southwestern Nigeria

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Agroecological zones influence maize infestation and damage severity by the fall armyworm (*Spodoptera frugiperda* [J. E. Smith, 1797]) in southwestern Nigeria

Abstract: The fall armyworm (*Spodoptera frugiperda*) is an invasive and highly destructive insect pest that has caused extensive damage to maize in Africa since its first report on the continent in 2016. Information on fall armyworm infestation and damage within African agroecologies is essential for the development of appropriate pest management strategies, but these are scant in Nigeria. Consequently, in this study, fall armyworm infestation levels and severity of damage to maize in the three major maize-growing agro-ecological zones (humid forest, derived savanna, and southern guinea savanna) of southwestern Nigeria was investigated using standard field sampling protocols. Results showed that maize infestation and damage severity varied across agroecological zones, with the humid forest being the most impacted. Information provided will enhance decision-making for effective management of the fall armyworm in southwestern Nigeria.

Key words: agroecology; foliar damage; larval infestation; *Spodoptera frugiperda*; farm sampling; humid forest; derived savanna; guinea savanna

Vpliv agroekoloških območij na okužbo in velikost poškodb koruze zaradi ameriške koruzne sovke (*Spodoptera frugiperda* [J. E. Smith, 1797]) v jugozadni Nigeriji

Izvleček: Ameriška koruzna sovka (*Spodoptera frugiperda*) je invazivna in zelo škodljiva žuželka, ki povzroča obsežne poškodbe koruze v Afriki od njenega prvega pojava na kontinentu leta 2016. Poznavanje okužb in poškodb zaradi te sovke v različnih agroekoloških območjih Afrike je bistveno za razvoj primernih strategij upravljanja, a to vedenje je zelo nezadostno v Nigeriji. V tej raziskavi sta bili s standardnimi metodami vzorčenja preučevani raven okužbe in jakost poškodb zaradi ameriške koruzne sovke v treh glavnih agroekoloških conah jugozahodne Nigerije in sicer v območju vlažnih gozdov, v prehodni savani in južni gvinejski savani. Rezultati so pokazali, da sta se raven okužbe in velikost poškodb koruze razlikovali v teh agroekoloških območjih s tem, da je bila koruza na območju vlažnih gozdov najbolj prizadeta. Pridobljeni podatki bodo pospešili sprejemanje odločitev za učinkovito upravljanje z ameriško koruzno sovko v jugozahodni Nigeriji.

Ključne besede: agroekologija; poškodbe listov; okužba z ličinkami; *Spodoptera frugiperda*; vzorčenje na kmetijah; vlažen gozd; prehodna savana; gvinejska savana

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1 INTRODUCTION

The fall armyworm, (*Spodoptera frugiperda* [J. E. Smith, 1797], Lepidoptera: Noctuidae), **is a**n invasive moth with its origin in the Americas (Sparks, 1979; Liu et al., 2020). It is a highly destructive insect pest of crops (Murúa et al., 2009) that was first reported on the African continent in 2016 (Goergen et al., 2016). The fall armyworm is polyphagous and is known to attack more than 350 plant species spread across 76 plant families (Montezano et al., 2018). In Africa, however, maize (*Zea mays* L.) is its primary host and the most damaged crop on the continent. In addition to causing extensive damage to maize leaves and whorls (CABI, 2020), fall armyworm larvae may feed on reproductive organs like tassels and kernels causing yield losses (Midega et al., 2018; Prasanna et al., 2018). According to ICIPE (2020), maize damage by the fall armyworm has caused yield losses of between 8 – 20 million tonnes in Africa. The fall armyworm thus poses an on-going regional threat to the cultivation of maize – a major staple food to millions of families in sub-Saharan Africa (Prasanna et al., 2018).

Due to their peculiarities, agroecologies in African countries are expected to favour the occurrence, proliferation and development of fall armyworms (Day et al., 2017; Huesing et al., 2018; Chimweta et al., 2019). Consequently, studies that investigate maize infestation and damage by the fall armyworm in different African agroecologies must be undertaken if effective management strategies will be developed for the pest on the continent. The southwestern region of Nigeria, for instance, comprise three major maize-growing agroecological zones namely – humid forest, derived savanna, and southern guinea savanna zones (Onyeka et al., 2008; Olaniyan, 2015). However, information on the similarities or differences in fall armyworm infestations levels and severity of damage to maize in these maize-growing agroecological zones is scarce and remains unclear. This study was therefore carried out to investigate the influence of agrocology on maize infestation and damage severity by fall armyworm larvae in southwestern Nigeria. The specific objective of the study was to compare fall armyworm larval infestation and foliar damage severity on maize plants in the humid forest, derived savanna, and southern guinea agroecological zones of southwestern Nigeria.

2 MATERIALS AND METHODS

2.1 DESCRIPTION OF THE STUDY AREA

On-farm assessment of fall armyworm infestation and severity of damage to maize was conducted in the southwestern region of Nigeria which comprise six

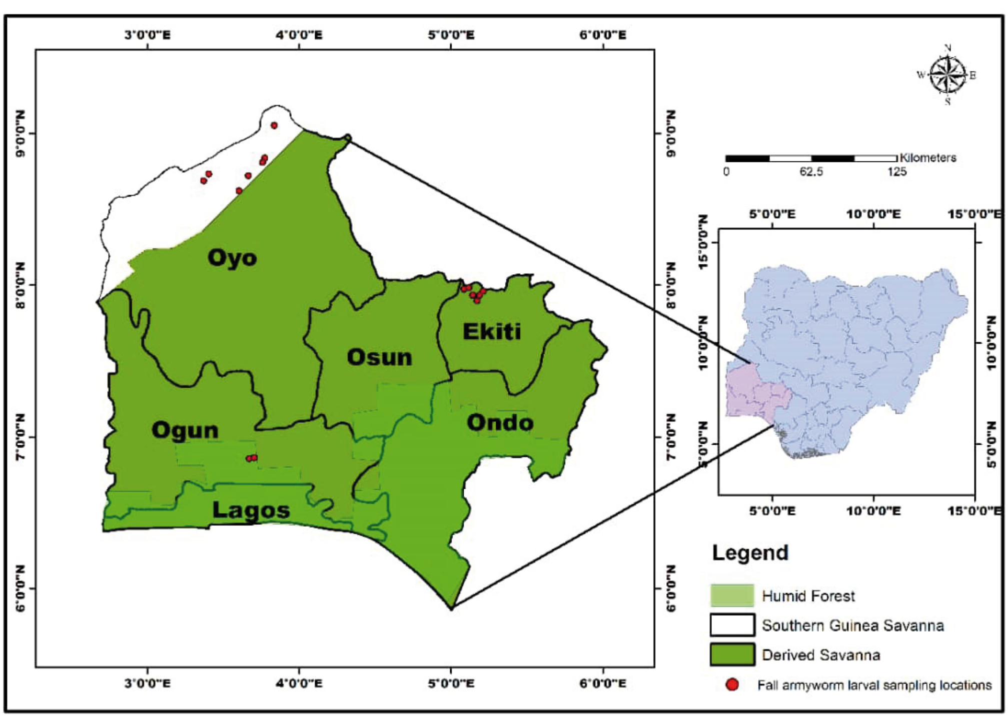

Fig. 1: Map of southwestern Nigeria showing the political states, agroecological zones and sampling location of fall armyworm larvae

geopolitical states – Lagos, Ogun, Ondo, Ekiti, Oyo and Osun states (Fig. 1). The humid forest agroecological zone in the region spreads across Lagos, Ondo, Ogun, and Osun states and is known to experience a relatively longer annual rainfall of at least 2000 mm (Oyenuga, 1967). On the other hand, the southern guinea savanna agroecological zone is characterized by an average annual rainfall of 1051.7 mm (Oyenuga, 1967), and occurs only in the northwestern part of Oyo state. The derived savanna transitional zone is the largest agroecological zone in southwestern Nigeria. It is reported to receive an average annual rainfall of 1314 mm (Sowunmi & Akintola, 2010), and can be found in all the states except in Lagos. All three agroecological zones experience a bimodal pattern of rainfall that peaks yearly in June and September (Aderolu et al., 2013).

2.2 SAMPLING OF MAIZE FARMS

In each of the three major maize-growing agroecological zones, 50 % of existing local government areas (LGA) was purposively sampled (Table 1). Thereafter, two towns were randomly sampled in each LGA. Finally, a maize farm was selected for assessment in each town. Farms selected for fall armyworm infestation and damage assessment were owned by smallholders and typically between 1–5 ha in size; were cultivated solely to maize; had only plants between two and four weeks old; and had not been sprayed with insecticides. Information on plant age and insecticide application was obtained from farm owners through resident agricultural extension officers working in each LGA. In all, a total of 18 farms (four in the humid zone; six in the derived savanna zone and eight in the southern guinea savanna zone) were sampled in the study area in July 2019 (Table 1).

2.3 ASSESSMENT OF FALL ARMYWORM INFESTATION AND DAMAGE TO MAIZE

On each selected maize farm, 20 maize plants were randomly selected for assessment using the 'W' sampling method described by McGrath et al. (2018). The method comprise the random sampling of four plants each at five different locations on the farm (away from the border) while following a 'W' pattern of movement. All sampled plants were assessed for the presence or absence of fall armyworm larval infestation by gently turning the leaves and carefully unfurling whorls. Plants with one or more

Table 1: Location of farms in southwestern Nigeria sampled for on-farm assessment of maize infestation and damage by the fall armyworm

Agroecological zone	Local Government Area	Town	Geolocation Information
Humid Forest	Sagamu	Sagamu	6°51'16"N 3°40'13"E
		Sagamu	6°51'19"N 3°40'17"E
	Ikenne	Ikenne	6°51'43"N 3°42'10"E
		Ikenne	6°51'46"N 3°42'13"E
Derived Savanna	Ilejemeje	Ewu Ekiti	7°55'49"N 5°11'16"E
		Ijesamodu Ekiti	7°57'39"N 5°12'40"E
	Moba	Osun Ekiti	7°58'15"N 5°05'12"E
		Otun Ekiti	7°58'49"N 5°07'02"E
	Ido-Osi	Aiyetoro Ekiti	7°56'01"N 5°08'32"E
		Usi Ekiti	7°53'55"N 5°10'07"E
Southern Guinea Savanna	Saki West	Saki	8°44'12"N 3°24'11"E
		Saki	8°41'19"N 3°22'11"E
	Saki East	Ago-Amodu	8°38'16"N 3°39'26"E
		Sepeteri	8°37'24"N 3°36'13"E
	Irepo	Igboho	8°50'29"N 3°46'21"E
		Igboho	8°48'37"N 3°45'33"E
	Orelope	Kisi	9°03'12"N 3°50'11"E
		Kisi	9°03'12"N 3°50'03"E

actively feeding larva were taken as infested, and allocated a score of one (1). On the other hand, plants without larval infestation were scored zero (0). Characteristic larval foliar feeding damage symptoms on plants (whether or not infested with larvae) was visually assessed and scored based on severity using the five-point rating scale described by Dal Pogetto et al. (2012) for fall armyworm damage to field maize. Based on the scale, plants without damage were scored 0; plants with erasure leaves were scored 1; plants with pin holes or shot holes due to larval feeding were scored 2; plants with significant number of holes and some whorl damage were scored 3; plants with the whorl completely eaten off or destroyed were scored 4; and a score of 5 was awarded to dead plants**.**

2.4 DATA ANALYSIS

The number of plants infested with fall armyworm on each farm was converted to percentages. Percentage infestation and damage severity data were then summarized with means in Microsoft Excel (Microsoft Office Excel, 2019). Thereafter, data on percentage fall armyworm infestation and foliar damage severity scores recorded in each agroecology and LGA were submitted to a one-way Analysis of Variance (ANOVA) test using a Generalized Linear Model. Where necessary, means were separated using the Tukey's Honestly Significant Difference (HSD) test at 5% level of significance in IBM SPSS statistics software (2011).

3 RESULTS

3.1 FALL ARMYWORM INFESTATION ON MAIZE

Infestation of fall armyworm larvae on maize was highest (86.25 ± 3.88 %) in the humid forest and lowest (56.88 ± 3.93 %) in the southern guinea savanna agroecological zones (Fig. 2). The derived savanna zone, however, had an intermediate level of infestation (71.67 ± 4.13 %). Infestation level of fall armyworm larvae in the humid forest was significantly higher ($p < 0.05$) than in the southern guinea savanna. Similarly, infestation was observed, to varying degrees, in all LGA where maize farms were sampled and assessed (Fig. 3). The top three LGA with high fall armyworm infestation were Ikenne in the humid forest zone (92.5 ± 4.22 %), Ido-Osi in the derived savanna zone (85.0 ± 5.72 %), and Sagamu in the humid forest zone (80.0 ± 6.41 %). In contrast, the lowest infestation levels were recorded in Orelope (47.5 ± 8.00 %); Saki West LGA (50.0 ± 8.01 %), and Irepo (55.0 ± 7.97 %) all in the southern guinea savanna agroecological zone. Significant differences ($p < 0.05$) were observed between the LGA with highest and lowest larval infestation levels.

3.2 FALL ARMYWORM DAMAGE SEVERITY ON MAIZE

Foliar damage ratings were higher (2.63 ± 0.14) in the humid forest agroecological zone, with most maize

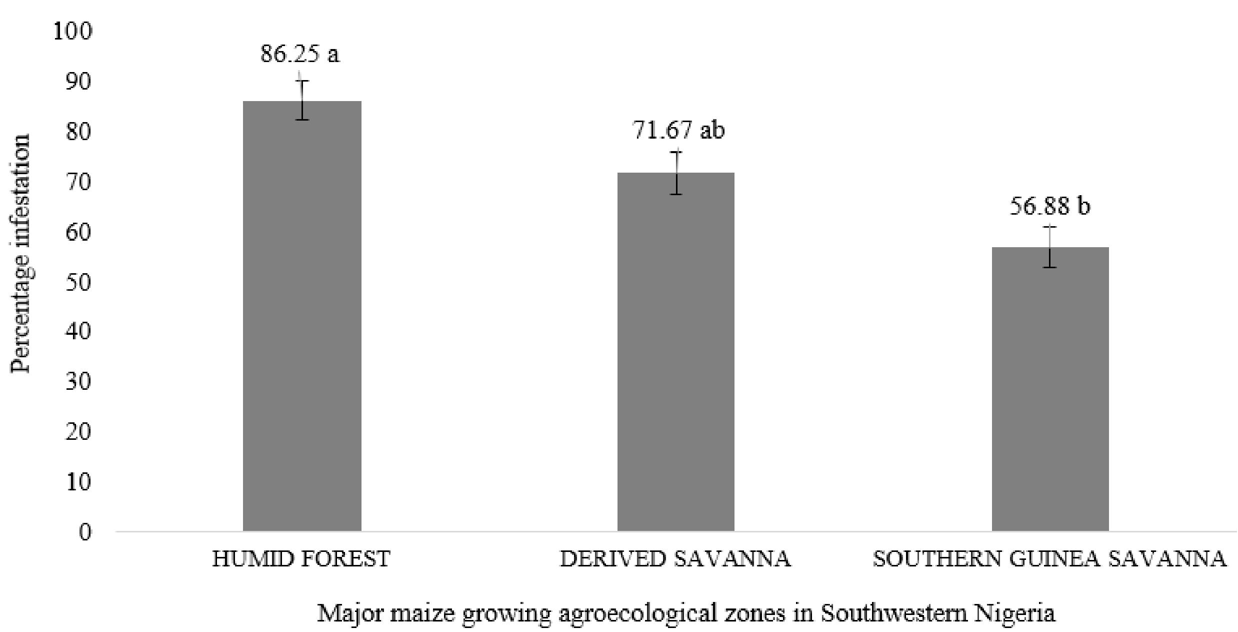

Figure 2: Fall armyworm infestation on maize in the major maize-growing agroecological zones of southwestern Nigeria. Mean values on bars followed by the same letter are not significantly different at $p = 0.05$

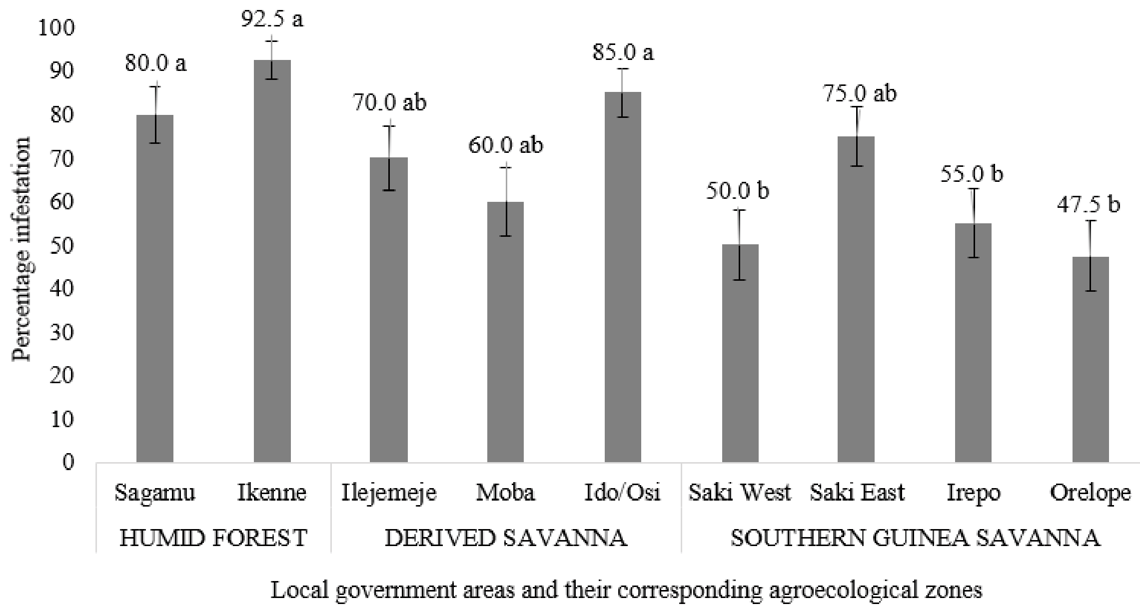

Figure 3: Fall armyworm infestation on maize at representative local government areas in the major maize-growing agroecological zones of southwestern Nigeria. Mean values on bars, in any of the three agroecological zones, followed by the same letter are not significantly different at $p = 0.05$

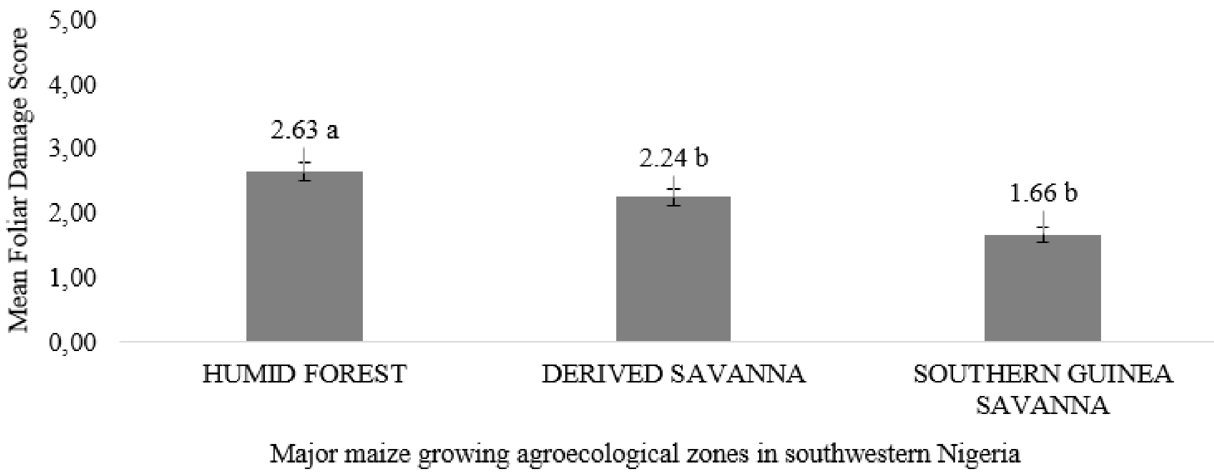

Figure 4: Fall armyworm foliar damage severity on maize in the major maize-growing agroecological zones of southwestern Nigeria. Mean values on bars followed by the same letter are not significantly different at $p = 0.05$

plants having larval feeding holes in leaves and whorls (Fig. 4). On the other hand, foliar damage ratings of 2.24 ± 0.14 and 1.66 ± 0.12 were respectively recorded in the derived savanna and southern guinea savanna zones, indicating the presence of relatively lower fall armyworm damage to plants. Foliar damage was significantly more severe ($p < 0.05$) in the humid forest zone than in the derived savanna or southern guinea savanna zones. In contrast, no significant difference ($p > 0.05$) was observed in the severity of foliar damage recorded between the derived savanna and southern guinea savanna agroecological zones. With respect to foliar damage severity ratings in LGA, maize plants were more severely damaged ($p < 0.05$) at Ikenne (3.05 ± 0.18) and Ido-Osi (2.78 ± 0.21) than in other seven LGA (Fig. 5).

4 DISCUSSION

Many countries in Africa have agroecological conditions that are expected to favour the occurrence, development, and damage severity of fall armyworms (Day

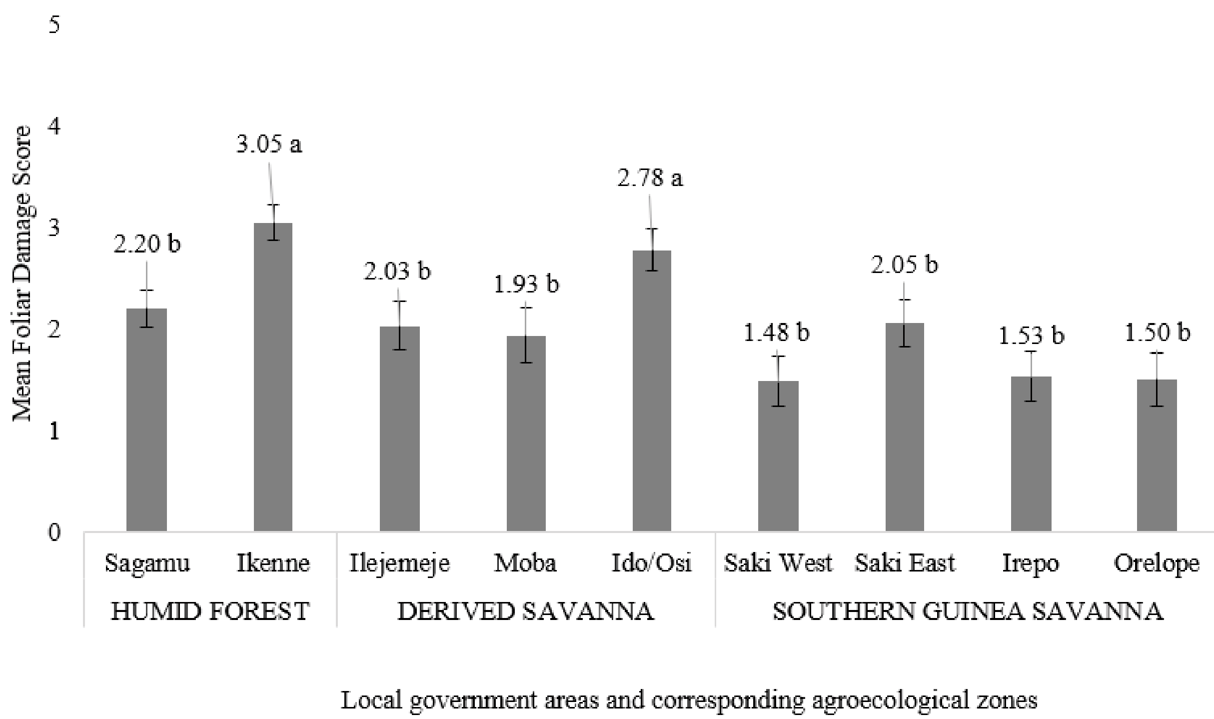

Figure 5: Fall armyworm foliar damage severity on maize at representative local government areas in the major maize-growing agroecological zones of southwestern Nigeria. Mean values on bars, in any of the three agroecological zones, followed by the same letter are not significantly different at $p = 0.05$

et al., 2017; Huesing et al., 2018; Chimweta et al., 2019), necessitating agroecology-based studies on the continent. In the present study, fall armyworm larval infestations increased southwards, that is, from the southern guinea savanna to the humid forest agroecological zone in southwestern Nigeria. In other words, larval infestation was generally higher and foliar damage more severe in the humid forest than in the derived or southern guinea savanna agroecological zones. This is in line with the findings of Odeyemi et al. (2020) who also reported higher fall armyworm damage severity in the humid forest zone than in the derived savanna zone in southwestern Nigeria. The humid forest zone of southwestern Nigeria experiences stable rains as early as March or April, enhancing early and higher maize cultivation. Thus, in a typical year, the humid forest receives up to 1000 mm more rainfall than the southern guinea savanna (Oyenuga, 1967). According to Chimweta et al. (2019), agroecological zones with abundant rainfall and high maize cultivation support multiple and overlapping cropping of maize, which in turn make host plants available all season for fall armyworm. De Groote et al. (2020) and Mutyambai et al. (2022) also reported that hot and wet weather conditions as well as presence of two growing seasons in the coastal lowland agroecological zone of Kenya enhance fall armyworm infestation and damage to on-farm maize compared to the high altitude highland zone of the country. Findings in the present study suggest that the humid forest agroecological zone in southwestern Nigeria favours more maize infestation and damage by the fall armyworm than any of the other two agroecological zones assessed. Nevertheless, it is apparent that all three agroecologies are suitable for fall armyworm reproduction and development.

Apart from weather conditions and number of maize cropping seasons, fall armyworm infestation and severity of damage to on-farm maize in an agroecology may be influenced by other factors like plant growth stage, cropping system, soil type, maize variety type, weeding frequency, and land tillage practice (Koffi et al., 2020; Mutyambai et al., 2022; Ojumoola et al. 2022).

The considerable level of fall armyworm larval infestation and foliar damage observed in the different agroecologies in the present study may be due to the fact that all the maize plants assessed were at the early vegetative growth phase and not more than four weeks old. Fall armyworm larvae are capable of inflicting extensive damage to maize reproductive parts including tassels, silks, and kernels (Midega et al., 2018; Chimweta et al., 2019; Odeyemi et al., 2020). Nevertheless, they are primarily known to be defoliators that tatter and fill leaves, whorls and stems with holes and wet frass, especially between the second and sixth week after planting (Prasanna et al., 2019; CABI, 2020; Odeyemi et al., 2020).

Cropping methods such as intercropping that increase the diversity of plant species on farmer's fields have been posited to be effective and sustainable fall armyworm management tactics in maize systems (FAO, 2018). Intercropping is known to reduce the infestation and damage caused by insects pests like thrips (Trdan et al., 2006) and stem weevils (Cadoux et al., 2015) by disrupting their ability to detect the visual and olfactory cues of host plants (Finch and Collier, 2012), or by increasing the diversity and abundance of natural enemies (FAO, 2018). In Uganda, Hailu et al. (2018) reported significantly lower fall armyworm infestation in maize intercropped with common beans, soybeans, or groundnuts compared with sole maize, especially in the early and late vegetative growth stages. In the present study, maize was planted as a sole crop on all the farms assessed. This might also explain why considerable infestation and damage were observed in all the three maize-growing agroecological zones.

Unlike in more compact soils, loose sandy soils enhance successful soil pupation of fall armyworms, and by extension, higher infestations and damage of the maize crops growing in them (Sims, 2008; Mutyambai et al., 2022). Furthermore, due to differences in morphology and constitutive phytochemical compounds, different maize varieties often have different resistance and tolerance levels to fall armyworm infestation and damage (Morales et al 2021; Ojumoola et al. 2022). In addition, frequent weeding using mechanical methods reduce fall armyworm infestation and damage by destroying the soil dwelling pupa stage and the shelter or food sources provided by reservoir weed hosts (Hay-Roe et al., 2016; Moraes et al., 2020; Mutyambai et al., 2022). Similarly, land tillage practices like conservation tillage or zero tillage, which cause little to no disturbance to the soil, promote higher populations of generalist predators of the immature stages of fall armyworm thus reducing seasonal infestations and damage of maize (Clark et al., 1993; Landis et al., 2000; Rivers et al., 2016; Baudron et al., 2019).

Nevertheless, the potential of the foregoing agronomic factors in reducing or preventing fall armyworm infestation and damage on maize in the humid forest, guinea savanna and southern guinea savanna agroecologies of southwestern Nigeria will require further investigations.

5 CONCLUSIONS

Fall armyworm larval infestation and foliar damage to maize has been shown in this study to be more prevalent in the humid forest agroecological zone than in the guinea savanna or southern guinea savanna agroecological zones of southwestern Nigeria. Notwithstanding, maize plants in all three major maize-growing agroecological zones are susceptible to fall armyworm attack and damage. The study recommends that further studies be conducted to develop suitable agroecology-specific management strategies for fall armyworm in southwestern Nigeria.

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