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ORIGINAL ARTICLE

Analysis of Fall armyworm infestations on rainy season crops under different cropping systems in two agroecological zones in Burkina Faso, West Africa

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Abstract

The Fall armyworm (FAW), *Spodoptera frugiperda,* was first reported in a few regions of Burkina Faso in 2017. Since then, it has continued to spread and damage maize crops in the country, thereby threatening food security. This study, conducted three years later, aimed to assess the pest status on major rainy season crops, and the effects of cropping systems, crop diversity, and phenology in 11 localities of Sudanian and Sudano-Sahelian zones in Burkina Faso. Two sampling periods, the first conducted at the beginning of the rainy season and the second at the end of the season, were considered. Maize was the most FAW-infested crop, mainly as monocrops (84–88% of surveyed fields). Sorghum, pearl millet, cowpeas, and peanuts were the secondary infested crops, more infested when intercropped with maize. Maize fields were more FAW-affected in the Sudanian zone, whereas the secondary infested crops were significantly more affected in the Sudano-Sahelian zone. The highest field infestation rates were recorded during the second survey period, coinciding in most cases (> 90%) with the flowering and post-flowering of maize. Then, FAW attacks were found in vegetative, flowering, and post-flowering cereal organs. Despite the technical recommendations, most farmers (57.30 ± 10.34 and 66.78 ± 6.74% in the Sudanian and Sudano-Sahelian zones, respectively) did not apply insecticide in infested maize fields. Thus, in 3 years, the FAW has become an important pest of cereals, specifically maize, in the main agricultural zones of Burkina Faso. These results should be taken into account to develop effective control actions against FAW.

Keywords *S. frugiperda* · Agroecosystems · Crop infestation · Pest management · Agroecological zones · Burkina Faso

Introduction

In West Africa, agriculture provides approximately 80% of the food needs of nearly 300 million people, employs an average of 60% of the working population, and contributes for 35% to gross domestic product (GDP) (FAO & AfDB, 2015). Unfortunately, this sector faces many challenges that compromise food security (Payne et al. 2011), while the population is growing exponentially in many countries of the continent (Bizimana et al. 2023).

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In Burkina Faso, staple food crops grown on approximately 83% of cultivated land (DGESS 2021) include mainly cereals (maize, sorghum, pearl millet, rice), grain legumes (cowpeas, bambara nuts, peanuts, soybeans), and tubers (sweet potatoes, potatoes, yams, and cassava). Maize is one of the key staple food crops produced in Burkina Faso. Indeed, it is a crop with a high growth potential that has spread rapidly over the past 15 years. The national maize production was estimated at 1,920,101 tons in 2021 or 37.07% of the total cereal production (Sanou et al. 2023). Despite its remarkable potential, the maize sector faces several abiotic (poor soils, and irregular and poorly distributed rainfall) and biotic constraints that significantly limit its production (Dao et al. 2015). Prior to 2017, major biotic constraints included weeds, diseases, and stem borers. Since 2017, these biotic constraints have been exacerbated by the introduction of *Spodoptera frugiperda* (FAW) J. E. Smith (Lepidoptera: Noctuidae) (MAAH/DGPV 2018; Sanou et al. 2023), an invasive insect pest associated with plants in the

Poaceae family and especially maize. This outbreak of FAW in Africa occurred in 2016 (Goergen et al. 2016; Cock et al. 2017) from the American continent.

Following this invasion, the pest spread rapidly in Burkina Faso, attacking crops in all agricultural regions during the subsequent rainy season (2018–2019). For example, in the first two years of FAW introduction, 58,000 and 100,000 ha of crops were infested, respectively, including 90% of the maize fields (MAAH/DGPV 2018). This is alarming because *S. frugiperda*, known for its great polyphagia (Montezano et al. 2018), can potentially attack several cereals produced in Burkina Faso, which would significantly reduce cereal production and cause food insecurity in a large part of the population. Most agricultural production is obtained during the rainy season in which diverse crop species are grown. The frequent association of maize with other crops in the country's agricultural landscapes (Dao et al. 2015) may increase risk of FAW infestation for these crops and subsequently exacerbate the situation. However, cropping systems can affect crop infestation and pest management in several ways (Pumarifio et al. 2015; Baudron et al. 2019). Specific studies covering different agro-ecological zones are therefore needed to better understand the consequences of the invasion and to guide relevant stakeholder groups and decision-makers (Koffi et al. 2022).

However, since 2017, when the pest was first detected in Burkina Faso, accurate data on attacked plant species by FAW in fields, infestation levels, and their dynamics in different agro-ecological zones and cropping systems are not available at the national level. Such information is essential for effective agricultural forecasting and the coherent planning of control actions. The current study, conducted 3 years after the first occurrence of FAW in Burkina Faso, aimed to contribute to fill this gap. The study was conducted on-farm in the main maize production areas of the country to determine infestation levels by crop, cropping system, phenological stage, and agro-ecological zone throughout the rainy season.

Material and methods

Study locations and sites

Burkina Faso comprises three agro-ecological zones: the Sahelian zone in the extreme North of the country, the Sudano-Sahelian zone, which is an intermediate zone covering East to West part of the country, and the Sudanian zone, which extends to the South and Southwest of the country. The study sites were included in the Sudano-Sahelian and Sudanian agro-ecological zones, which represent the main maize production areas (Fig. 1). The study covered 11 localities, six in the Sudano-Sahelian zone (Dédougou, Koudougou, Koupéla, Léo, Ouagadougou, and Yako), and five in the Sudanian zone (Banfora, Bobo-Dioulasso, Diébougou, Orodara, and Pô).

Surveys were conducted in four villages of each locality, for a total of 44 villages. For each village, four sampling areas located in four directions (East, West, South, and North) were identified and georeferenced. In each sampling area, the cereal fields and other crops encountered according to the main cropping systems (monocultures and/or intercrops) were considered. For this purpose, 5 sampling units of 5×2 m^2 each were previously delimited in each field at the 4 corners and in the middle of the field for an in-depth observation.

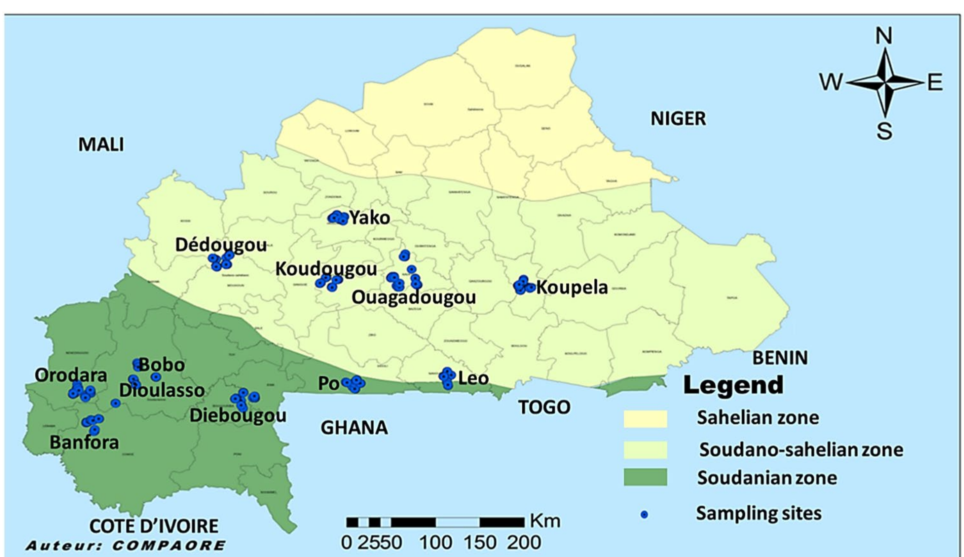

Fig. 1 Map of Burkina Faso illustrating the agro-ecological zones and the locations of sampling sites throughout the country

Inventory of FAW-infested crops and assessment of the infestation levels throughout the cropping season

This study was conducted during two periods of the rainy season to cover the pre-flowering (vegetative), flowering, and post-flowering stages of maize and other crops in the study area. During the first period, August 8–30, 2020, 95% of the maize crops were in the pre-flowering stage, whereas during the second period, i.e., September 17–October 11, 2020, more than 90% of the maize fields were in the flowering and post-flowering stages. In each sampled field, the sample units described above were thoroughly investigated to determine the following parameters:

- The total number of plants
- The number of plants infested by FAW
- The symptoms of FAW attacks on different plant organs

Since the FAW invasion, agricultural technical services recommended 1–3 insecticide applications (basically Emamectin benzoate-based insecticides) in infested maize fields during the vegetative stage only (Sanou et al. 2023). Thus, to assess the potential impact of these technical recommendations on FAW infestations, during the second survey, farmers were asked about insecticide treatments (number and active ingredients) carried out in infested maize fields.

The collected data were used to calculate infestation rates in relation to crop and cropping systems, sites, and sampling areas. According to the data on the FAW infestation level in the maize fields, 6 scales were formed and included the following levels: ≤ 5%; 6–20%; 21–40%; 41–60%; 61–80%; and 81–100%. The infestation levels were compared for the two sampling areas and the two data collection periods.

Data analysis

The data were first subjected to a normality test and then transformed into "lnx + 1" before an analysis of variance (ANOVA) to compare infestation levels in each sampling area according to survey periods. When the ANOVA indicated significant differences, the means were separated using the Student–Newman–Keuls multiple comparison test. R software was used to determine the descriptive statistics and to perform the various statistical tests. In all cases, the analyses were considered significant at the 5% probability level.

Results

The plant species and cropping systems surveyed

During the two survey periods, 12 and 16 crop species, respectively, belonging to 9 plant families, were assessed for FAW infestations. Maize, sorghum, pearl millet, peanut, cowpea, and rice were the most representative (Table 1). Overall, 364 and 476 fields were surveyed at the first and second survey, respectively. The majority of the surveys

Table 1 Number of fields and crops surveyed in the two study periods, Burkina Faso

	Crops surveyed	Plant family	Number of fields per survey period	
			Period 1	*Period 2*
1	Bambara nut (*Vigna subterranea*)	Fabaceae	–	7
2	Cassava (*Manihot esculenta*)	Euphorbiaceae	1	1
3	Cotton (*Gossypium barbadense*)	Malvaceae	7	7
4	Cowpea (*Vigna unguiculata*)	Fabaceae	23	49
5	Fabirama (*Solenostemon rotundifolius*)	Lamiaceae	–	1
6	Ginger (*Zingiber officinale*)	Zingiberaceae	–	1
7	Maize (*Zea mays*)	Poaceae	176	184
8	Okra (*Abelmoschus esculentus*)	Malvaceae	12	11
9	Peanut (*Arachis hypogea*)	Fabaceae	39	52
10	Pearl millet (*Pennisetum glaucum*)	Poaceae	24	34
11	Rice (*Oryza sativa*)	Poaceae	15	23
12	Sesame (*Sesamum indicum*)	Pedaliaceae	4	16
13	Sorghum (*Sorghum bicolor*)	Poaceae	50	65
14	Soybean (*Glycine max*)	Fabaceae	12	15
15	Sweet potato (*Ipomea batatas*)	Convolvulaceae	–	8
16	Tomato (*Solanum lycopersicum*)	Solanaceae	1	2
	Total	**9**	**364**	**476**

Period 1: August 8 to 30, 2020; *Period 2*: September 17 to October 11, 2020

were conducted on maize monocrops, representing 45.6 and 35.2% of surveyed fields during sampling periods 1 and 2, respectively, (Fig. 2). The other crops surveyed, such as sorghum, pearl millet, cowpeas, and peanuts, were less represented either in monoculture or in association with maize (Fig. 2). All other plant species mentioned in Table 1 were studied because of their presence in plots located near the maize fields, but they were poorly representative.

The proportion of fields infested by FAW as a function of cropping systems and survey periods

Of all the plant species studied during both sampling periods, only maize, sorghum, pearl millet, cowpea, and peanut were infested by FAW. In the first sampling period, only maize and sorghum were infested in monocultures or in mixed sorghum–maize crops. However, pearl millet was only infested when intercropped with maize (Table 2). Overall, 88% of the maize fields, 8% of the sorghum fields, and 4% of the pearl millet fields intercropped with maize were infested (Fig. 3). In the second sampling period, maize, sorghum, pearl millet, and cowpea were infested in both monocrop and intercrop systems. Peanut infestations were only recorded when this crop was associated with maize (Table 2). Maize (84%) and sorghum (12%) were also the most infested crops in the second survey period (Fig. 3). Therefore, sorghum, pearl millet, cowpeas, and peanuts were more infested when grown in association with maize than monocrops.

The infestation levels of fields and plant organs damaged in relation with sampling localities and periods

Infestation levels were related to sampling localities during the two survey periods, but infestation seemed to be higher in Sudanian localities and during the second survey period

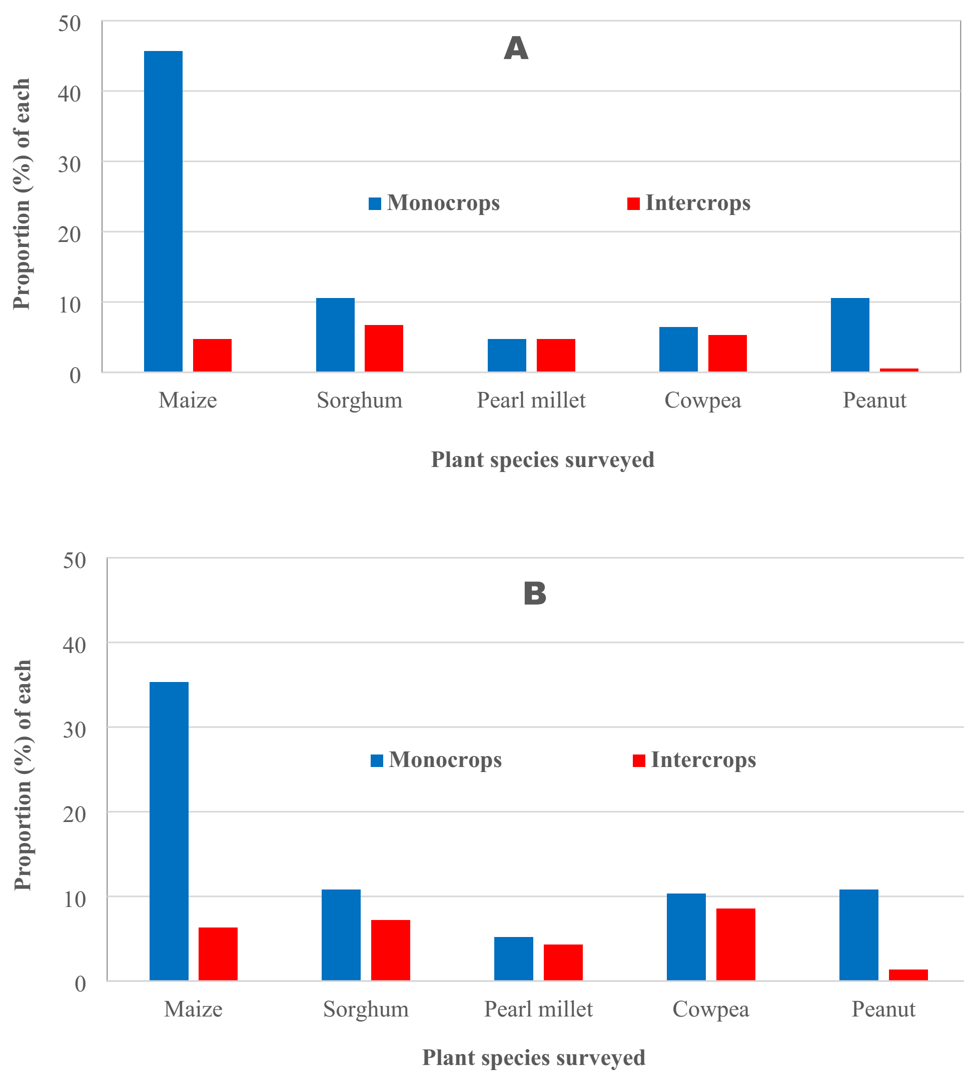

Fig. 2 The proportion (%) of main crop fields surveyed by cropping system in each of the two sampling periods. n = 359 and 445 fields sampled during *Periods 1 and 2,* respectively. A. *Period 1*: August 8 to 30, 2020; B. *Period 2*: September 17 to October 11, 2020

Table 2 Crops infested by FAW (%) according to cropping systems and survey periods, Burkina Faso

Crops	Zones	(%) crops infested by FAW/period			
		Period 1		Period 2	
		Monocrops	Intercrops (+Maize)	Monocrops	Intercrops (+Maize)
Maize	Sudanian	72.15	N/A	94.74	N/A
	Sudano-Sahelian	72.92	N/A	91.36	N/A
Sorghum	Sudanian	0.00	85.71	20.00	100.00
	Sudano-Sahelian	25.00	88.24	30.90	96.15
Pear millet	Sudanian	0.00	25.00	25.00	60.00
	Sudano-Sahelian	0.00	61.54	10.52	48.86
Cowpea	Sudanian	0.00	0.00	0.00	88.89
	Sudano-Sahelian	0.00	0.00	4.00	86.21
Peanut	Sudanian	0.00	0.00	0.00	33.33
	Sudano-Sahelian	0.00	0.00	0.00	0.00

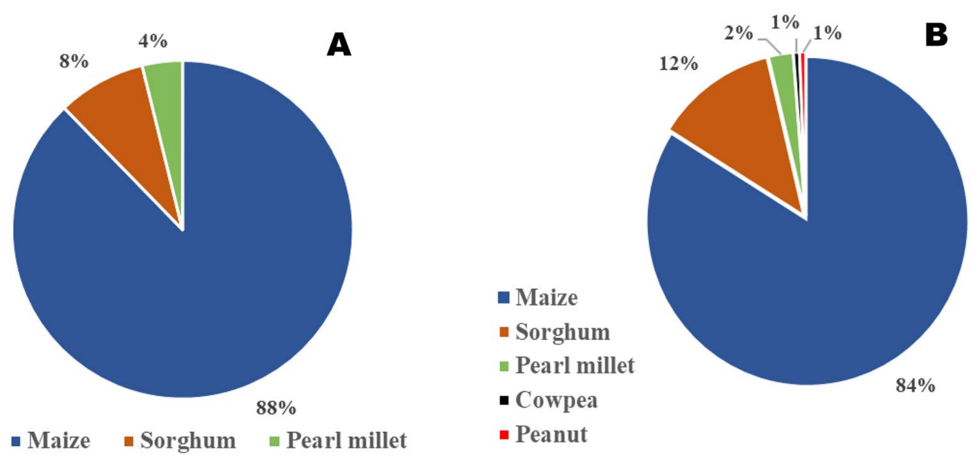

Fig. 3 Overall proportion (%) of each crop infested by FAW during the two study periods. n = 359 and 445 fields sampled during *Periods 1 and 2,* respectively. **A**, *Period 1*: August 8 to 30, 2020; **B**, *Period 2*: September 17 to October 11, 2020

(Table 3). However, the fields in the localities of Dédougou and Léo, located in the lower limit of the Sudano-Sahelian zone, have recorded particularly high infestation rates (Table 3).

The overall infestation levels also varied among crops and periods, but significantly increased during the second period. Pearl millet was only infested during the second period at the low rate of $4.36 \pm 2.86\%$ (Table 4). An overall analysis of crop infestation levels also revealed that the Sudanian zone was significantly more infested than the Sudano-Sahelian one (*ANOVA,* $P < 0.05$ for both periods). FAW infestations and damage were recorded in various plant organs (Fig. 4). Characteristic symptoms of FAW infestations were observed on the 3 main cereals (maize, sorghum, and pearl millet) which showed damage on the leaves, the leaf whorls, and in the funnels. Specifically, in maize, the infestations extended to stalks, male flowers, and cobs (Fig. 4). In contrast, pods and leaf organs were FAW-infested in cowpeas and peanuts, respectively.

A comparative analysis of the infestation levels of different plant organs (Table 5) indicated that leaves were always heavily attacked and 100% of infested plants had their leaves attacked regardless of the area and the period of survey. Next in order of importance were the cobs including female flowers (maize), funnels (maize, sorghum, pearl millet), male flowers (maize), and stalks (maize). Surprisingly, the maize cob infestation was particularly high in the second survey period ranging from 44.32 ± 16.27 to $76.56 \pm 15.76\%$ in Sudano-Sahelian and Sudanian zones, respectively (Table 5).

The distribution patterns of maize infestation levels by zones and sampling periods

The maize infestation levels followed different distribution patterns according to the sampling areas and periods. Thus, in the first period, the infestation level was recorded in the 6–20% range for the majority of infested fields, whereas in the second period, most of the infested fields were found in the 61–80% infestation range (Fig. 5). It should also be noted that during the latter period, almost 20% of the fields sampled had infestation levels in the 81–100% range. Moreover,

Table 3 Variations in mean (% ± SD[α]) field infestation levels (cereal crops) as a function of sampling localities and agroecological zones during the two sampling periods, Burkina Faso

	Period 1		Period 2	
Zones/localities	Infested fields (n)	Infestation level (%)	Infested fields (n)	Infestation level (%)
Sudanian Zone				
Diébougou	14	19.45 ± 4.22^{ab}	16	66.16 ± 5.92^{a}
Banfora	12	14.18 ± 2.46^{c}	11	56.76 ± 6.49^{ab}
Bobo-Dioulasso	13	20.99 ± 4.43^{ab}	17	65.93 ± 6.99^{ab}
Orodara	13	10.36 ± 1.79^{c}	14	49.80 ± 7.73^{b}
Pô	11	15.05 ± 3.59^{bc}	12	54.98 ± 8.37^{ab}
Whole zone	63	16.29 ± 1.63^{b}	70	59.44 ± 3.20^{ab}
Sudano-Sahelian Zone				
Koudougou	17	10.61 ± 1.88^{c}	15	35.78 ± 7.68^{bc}
Ouagadougou	15	15.81 ± 1.45^{b}	17	38.32 ± 6.75^{bc}
Koupéla	17	8.24 ± 1.32^{d}	12	49.38 ± 12.09^{bc}
Dédougou	12	9.52 ± 1.74^{cd}	17	63.42 ± 8.42^{a}
Yako	9	2.67 ± 0.71^{e}	15	30.80 ± 8.10^{c}
Léo	11	24.20 ± 2.92^{a}	15	60.89 ± 7.94^{a}
Whole zone	81	11.88 ± 0.98^{c}	91	46.53 ± 3.58^{b}
ANOVA and P	$F = 6.99$; $P < 0.0001$		$F = 2.49$; $P = 0.0087$	

*Means, in the same columns, followed by different alphabetic letters are significantly different according to the Student–Newman–Keuls test at the probability level of 5%

[α]SD, standard deviation

Table 4 Variations in mean FAW infestation levels (% ± SD[α]) in maize, sorghum, and pearl millet fields according to survey periods, Burkina Faso

	Period 1		Period 2		ANOVA and P
Crops	Infested fields (*n*)	Mean infestation level (%)	Infested fields (n)	Mean infestation level (%)	
Maize	131	$14.41 \pm 0.97^{Aa*}$	137	58.4 ± 2.44^{Ab}	$F = 273.4$; $P < 0.0001$
Sorghum	13	7.51 ± 1.91^{Ba}	20	16.73 ± 5.13^{Ba}	$F = 1.69$; $P = 0.2045$
Pearl millet	0	–	4	4.36 ± 2.86^{C}	
ANOVA and P	$F = 5.58$; $P = 0.0047$		$F = 26.02$; $P < 0.0001$		

*Means followed by different alphabetic letters are significantly different according to the Student–Newman–Keuls test at the probability level of 5%. Lower case letters are used to compare means within a row, while upper case letters are used to compare means across columns

[α]SD, standard deviation; Period 1: August 8 to 30, 2020; Period 2: September 17 to October 11, 2020

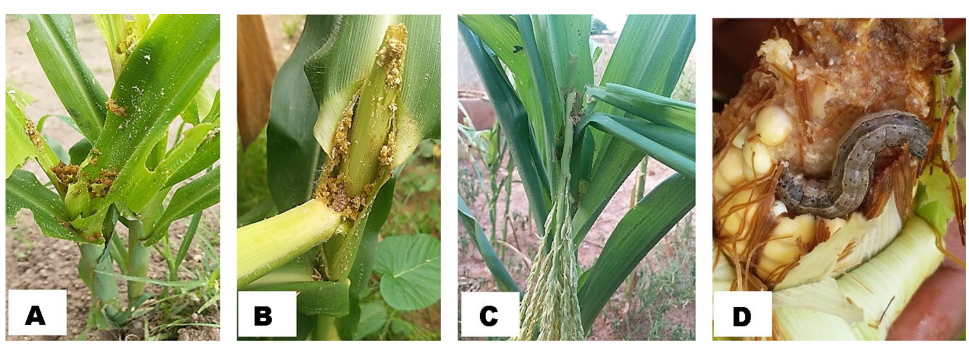

Fig. 4 Characteristic symptoms of FAW infestations on different organs of maize plants whatever the sampling zones and periods infested leaves, whorls, and funnels (**A**); broken stalk (**B**); damaged male flowers (**C**), and damaged cob (**D**)

Table 5 Average attack rates* (% ± SD$^{\alpha}$) on plant organs following FAW infestations in Sudanian and Sudano-Sahelian zones during the two study periods, Burkina Faso

Periods and zones	% attack on cereal plant organs				
	Leaves (Maize, Sorghum, Millet)	Funnels (Maize, Sorghum, Millet)	Stalks (Maize)	Male flowers (Maize)	Cobs (Maize)
Period 1 (n = 144)					
Sudan	100 ± 0.00	71.43 ± 22.80	1.59 ± 3.44	–	3.17 ± 40.7
Sudano-Sahelian	100 ± 0.00	71.60 ± 13.08	1.23 ± 2.72	–	0 ± 0.00
Both zones	100 ± 0.00	71.53 ± 17.13	1.41 ± 2.91	–	1.59 ± 3.00
Period 2 (n = 161)					
Sudan	100 ± 0.00	17.19 ± 16.21	1.56 ± 4.07	14.06 ± 12.82	76.56 ± 15.76
Sudano-Sahelian	100 ± 0.00	34.09 ± 10.17	11.36 ± 11.60	23.86 ± 4.67	44.32 ± 16.27
Both zones	100 ± 0.00	25.64 ± 15.14	6.46 ± 9.93	18.96 ± 9.90	60.44 ± 22.85

*Means calculated from data of sampling localities of each zone; several organs may be attacked at the same time

$^{\alpha}$SD, standard deviation; *Period 1*: August 8 to 30, 2020; *Period 2*: September 17 to October 11, 2020

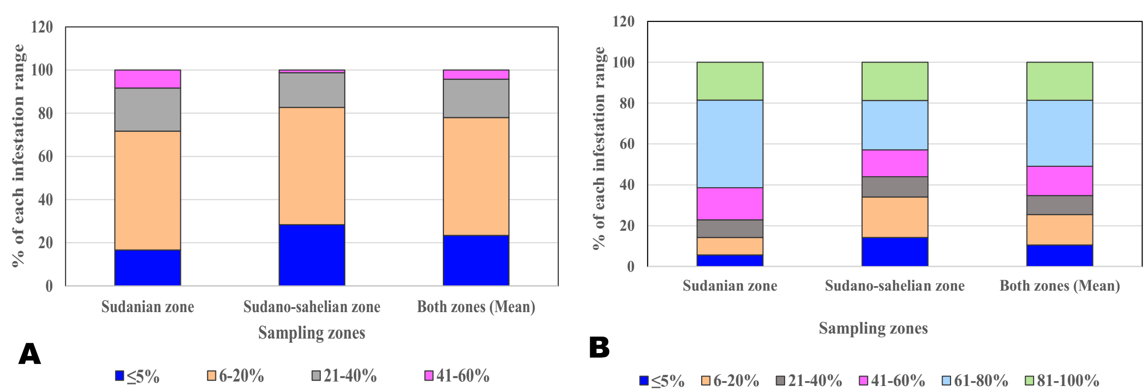

Fig. 5 Distribution patterns of maize infestation levels in relation to sampling zones and periods. **A**: *Period 1*; **B**: *Period 2*. *Period 1*: August 8 to 30, 2020; *Period 2*: September 17 to October 11, 2020

Table 6 Farmers' insecticide applications practices in maize infested fields in the two agroecological zones, Burkina Faso

Number of insecticide applications	Mean proportion (% ± SD*) of respondents in	
	Sudanian zone (*n* = 131)	Sudano-Sahelian zone (*n* = 137)
0	57.30 ± 10.34	66.78 ± 6.74
1	31.24 ± 10.91	20.74 ± 4.71
2	8.12 ± 2.66	3.82 ± 2.76
3	3.33 ± 3.33	2.78 ± 2.78
> 3	0.00	0.00

*SD standard deviation

40 to 60% of infested fields in Sudano-Sahelian and Sudanian zones, respectively, recorded over 61% infestation levels. Therefore, the dynamics of FAW infestation increased with the growth stage of the crop over time, regardless of sampling area (Fig. 5).

The insecticide application frequencies in maize fields infested by FAW

The majority of farmers interviewed (> 57%) did not spray their maize fields despite the infestation, with no significant difference between the two agroecological zones (Table 6). However, 31.24% and 20.74% of farmers sprayed their fields only once in the Sudanian and Sudano-Sahelian zones, respectively. The proportions of farmers having carried out 2 (8.12% and 3.82%, respectively) or 3 (3.33% and 2.78%, respectively) insecticide applications were low in both zones. Regarding the active ingredients used, in the Sudanian zone, more than half of the insecticides used were unknown to the producers and could not be identified, whereas in the Sudano-Sahelian zone, the farmers were more specific. The main known cited insecticides included Decis (Deltamethrin) and Emacot (Emamectin benzoate) in the Sudanian zone. Caiman B (Emamectin benzoate), Emacot (Emamectin benzoate), and Acarius (Abamectin) were cited for the Sudano-Sahelian zone.

Discussion

This study, carried out 3 years after the occurrence of *S. frugiperda* in Burkina Faso, is the first country-wide study providing information on infestation levels and dynamics in the rainfed crops during the main agricultural season. In general, the results indicate the presence of this insect pest in all maize production areas both at the beginning and at the end of the growing season, confirming the rapid expansion of *S. frugiperda* reported in several African countries (Day et al. 2017; Prasanna et al. 2018; Koffi et al. 2022) and worldwide (Capinera 2001; Babu et al. 2019; Kumar et al. 2020).

Among the 16 plant species sampled, only maize, sorghum, pearl millet, cowpea, and peanut showed signs of infestation, despite the significant sampling effort made by surveying 364 and 476 fields during the first (pre-flowering maize) and second (post-flowering maize) periods of the study, respectively. These infested plants belong to only 2 botanical families (Poaceae and Fabaceae) out of the 9 sampled. This relatively low number of attacked plant species/families is explained not only by the fact that the study mainly targeted maize fields, this crop being the main host plant of FAW (Lima et al. 2010), but also by the predominance of sorghum and pearl millet among the other cereal crops of the country (DGESS 2021). However, these results are surprising when considering the known high polyphagy of FAW (Cock et al. 2017; CABI 2018; Montezano et al. 2018), which is reportedly able to feed on 186–355 plant species belonging to 42–76 different botanical families (Early et al. 2018; Montezano et al. 2018).

The results also showed the importance of cropping systems on the infestation of fields by FAW. Nearly 90% of the infestations were found in maize monocrops, probably due to its status of preferred host plant. However, sorghum, pearl millet, cowpeas, and peanuts were more infested when grown in association with maize. These results confirm our hypothesis that maize-based cropping systems increase the risk of infestation for the other crops associated with maize. In this context, cowpea and peanut, which are among the most widespread leguminous species and frequently associated with cereals, especially maize (Sawadogo et al. 2022) in Burkina Faso agrosystems, would therefore be more exposed to FAW infestation. However, some previous studies have shown that the association of leguminous (cowpea, mungbean) and oilseeds (sesame) with maize reduced the infestation of maize by FAW (FAO 2018; Baghat et al. 2022) without indicating the effects on these leguminous plants. The positive effects of crop diversification on at least one of the associated plant species include the introduction of a physical barrier that reduces pest mobility, the non-concentration of resources, and the mobilization of natural enemies to improve natural control (Pumarifio et al. 2015). Based on these findings, we recommend that cropping systems are analyzed in the context of the FAW outbreak to better understand the interactions in maize-other crop combinations, to optimize their contribution to pest management following the example of the push–pull technology (Hailu et al. 2018).

In line with previous observations, the FAW attacks were recorded on young cereal plants (maize, sorghum, pearl millet) during vegetative growth (Babu et al. 2019) with dramatic effects on leaves. Leaves and pods were also infested for peanuts and cowpeas, respectively. However, attacks on maize cobs can initially lead to significant yield losses, which could threaten food security (Koffi et al. 2022). In addition, these attacks can also increase the risk of aflatoxin infection, which affects maize quality (Setamou et al. 1998; Hell et al. 2000). These results highlight the need for more precise studies to determine the quantitative and qualitative impacts of FAW attacks on maize cobs. Indeed, due to the relatively recent invasion of the African continent by the pest, the impacts and implications are still relatively unknown (Koffi et al. 2022).

Infestation rates varied among localities, agroecological zones, crops, and sampling periods. Thus, the number of infested plant species increased from the first to the second sampling period, indicating an expansion of infestation around maize fields. Moreover, cowpeas and peanuts were only found attacked during the second sampling period (post-flowering of maize) probably because these two crops are often planted later and some of the attacked phenological stages, such as cowpea pods, are only available later in the season. Regardless of the localities sampled, the Sudanian zone seemed to have been the most infested, probably because this wetter zone is the main maize growing area in Burkina Faso (Dao et al. 2015). However, a greater diversity of plants was attacked in the Sudano-Sahelian zone, probably due to the lower availability of maize in this area, which could favor the selection of other host plant species by the pest. Nevertheless, these results show that complex factors are involved in the development and invasive behavior of the pest (He et al. 2019). Previous results have shown a decrease in *S. frugiperda* populations when relative humidity was high and rainfall abundant, whereas an increase in temperature would favor the insect's growth (Kumar et al. 2020). In all cases and within the limits of this study, it appears that the climatic conditions and the crops of the Sudanian zone favor the infestation of FAW.

The in-depth analysis of the distribution of FAW infestation levels clearly showed that infestation increased over time during the rainy season, becoming more important at the end of the season (second sampling period) independent of the agro-ecological zones. These results can be explained by an increase in pest population over time, together with the availability of host plants. It is also possible that the pest populations were transferred from early sown fields to later sown ones. Our results also showed that the technical recommendations in case of infestation were not well implemented and the number of insecticide applications actually performed was too low to control the pest populations (Sanou et al. 2023). The choice of insecticides used by farmers is also problematic, as is often the case when farmers feel powerless against an invasive pest (Drabo et al. 2022). Moreover, the majority of insecticide treatments occurred during the pre-flowering period of maize, whereas flowering and post-flowering were also highly infested phenological stages. These findings demonstrate the need for an accurate determination of losses due to FAW attacks (Koffi et al. 2022), as well as an effective control strategy. Many mechanical, cultural, genetic, ecological, biological, and chemical control options (Bateman et al. 2018; Day et al. 2017; Feldmann et al. 2019; Shingirayi et al., 2022; Mendesil et al. 2023) have often been reported but require further investigation to adapt them to different African contexts. Future research will be directed in this way, with a view to developing a global strategy for the integrated management of FAW in Burkina Faso and elsewhere in West Africa.

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Author contributions All authors contributed to the research and to the paper writing. IC and MRS carried out the experiment and collected the data. AB, LKA, and AS designed and supervised the experiment, and statistical analysis was performed by IC. All authors read and approved the final manuscript.

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Data availability The data and material of this manuscript are available from the corresponding author's institution on reasonable request.

Declarations

Conflict of interest The authors declare that they have no competing interests.

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