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Perception and Management Strategies of the Fall Armyworm, *Spodoptera frugiperda* J.E. Smith (1797) (Lepidoptera: Noctuidae) on Maize, Millet and Sorghum by Farmers in Western Burkina Faso

Innocent S. Yaméogo[1], Delphine Ouattara[2], Rémi Dabiré[2], Arthur Ki[3], Donatien Bationo[3], Lakpo Agboyi[4], Olivier Gnankiné[1], Marc Kenis[5], Souleymane Nacro[6]

[1]Science and Technology Doctoral School, Université Joseph Ki-Zerbo, Ouagadougou, Burkina Faso
[2]Centre Régional de Recherches Environnementales et Agricoles de l'Ouest, Bobo-Dioulasso, Burkina Faso
[3]Centre Agricole Polyvalent de Matourkou, Bobo Dioulasso, Burkina Faso
[4]Centre International d'Agriculture et de Biosciences (CABI), CSIR Campus, Cantonments, Ghana
[5]Centre International d'Agriculture et de Biosciences (CABI), Delémont, Switzerland
[6]Centre Régional de Recherches Environnementales, Agricoles et de Formation de Kamboinsé, Ouagadougou, Burkina Faso
Email: snacro2006@yahoo.fr

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Abstract

Since it was first detected in Africa in early 2016, the fall armyworm (FAW), *Spodoptera frugiperda* Smith (Lepidoptera: Noctuidae), has spread to over 50 African countries, including Burkina Faso. This insect pest attacks important cereals, such as maize, millet and sorghum, which are the staple food in Burkina Faso. Since the invasion of the FAW in Africa, data on farmers' knowledge and their perceptions of this insect's pest are scarce and fragmented in Burkina Faso. Although this issue has been already addressed in some African countries, farmers' perceptions of this invasive insect pest may differ from one country to another. This reality justifies our study, the main objective of which is to assess the perception and level of knowledge of farmers on this new invasive insect pest and the consequences of its damage to cereal production in western Burkina Faso. To do this, a stratified survey was conducted among 355 farmers in two important agricultural regions of Burkina Faso, namely the Hauts-Bassins and the Cascades. At the end of these surveys, it was found that the age of the people surveyed varied from 18 to 80 years. People between the ages of 41 and 50 and 31 and 40 were the most numerous, with 31.27% and 30.14% of the target population, respectively. In addition, the

majority of the farmers were male, 94.08% of them being men and 5.92% being women. More than half (50.42%) of this population was non-literate. Almost all of the farmers surveyed (97.46%) said they had heard of *S. frugiperda* and 80.85% of them said they could identify the insect pest. The date of appearance of the FAW was variously perceived by the farmers of the study area. According to these cereals growers, the years 2016, 2017, 2018, and 2019 were to be remembered in terms of the insect pest's appearance. While for sorghum and millet the change in yields from 2010 to 2019 seemed slight, it was quite remarkable for maize according to the farmers. The average maize yield in 2016 and 2017 was 1.95 and 1.83 t/ha, respectively. These values will increase slightly in 2018 and 2019 with 2.08 and 2.39 t/ha, respectively. In the field, several management methods were used by the farmers to control the insect pest's attacks. These include chemical, cultural, and physical control. Insecticide spray frequencies ranged from 1 to 4 and even more depending on the duration of the maize cycle.

Keywords

Spodoptera frugiperda, Cereals, Yield Losses, Burkina Faso

1. Introduction

In Burkina Faso, the primary sector, which includes agricultural activities in the broad sense (livestock, crop production, fishing and, forestry), employs approximately 86% of the active population [1]. However, this sector faces difficulties, including crop losses caused by well-known crop pests, such as locusts, granivorous birds, fruit flies, caterpillars, etc. [2]. In addition to these pests, the recent invasive insect pest, the fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith) is a new flea to the agriculture sector. This insect pest is highly polyphagous [3] feeding on a large number of over 80 plant species. Severe infestation is caused by its primary hosts, maize and sorghum and other monoculture crops, like soybean and cotton [4]. It causes severe damage to maize (*Zea mays* L.), sorghum (*Sorghum bicolor* L., Moench), rice (*Oryza sativa*), cotton (*Gossypium hirsutum* L.), potato (*Solanum tuberosum* L.), vegetables, as well as other cultivated and wild plant species [5]. Damage from infestations results in total or partial yield losses and reduces production quality [6]. According to [7], *S. frugiperda* would affect 50 African countries, including Burkina Faso, 116 countries in the Americas, 52 Asian countries, 1 European country, and 4 countries in Oceania. The problem of this insect pest in Sub-Sahara Africa is exacerbated because its preferred host plant, maize, is a staple food in the region [8]. In Burkina Faso, the presence of the FAW was first reported during the 2016-2017 agricultural cropping season in the Centre-North region [9]. This presence was confirmed in the 2017-2018 cropping season in all 13 administrative regions of the country. The infestation rates vary between 5 and 90% or even 100% inducing at

the same time, a decrease in yields and, therefore, agricultural production [10]. The FAW is, therefore, a threat to the food and nutritional security of the people of Burkina Faso. At the local level, farmers are aware of the new insect pest and are doing their best to cope with it.

To be able to efficiently implement management methods for a given insect pest, farmers must be able to morphologically identify the target pest and distinguish it from non-target organisms. In the case of FAW, which is an economically important and invasive pest, it is crucial to know how much farmers know about the pest, what control methods they have available to control it, and what their limitations are. Understanding these factors is important in setting a research agenda, designing extension strategies, and formulating research that meets farmers' demands [11] [12] [13]. In order to focus on the subject, we discuss the results of studies on the perception of FAW by farmers in some countries on the African continent.

In Mozambique, a study on farmers' knowledge, perception and management practices regarding *S. frugiperda* was conducted in 2019 in four districts including Macate, Manica, Sussundenga and Vanduzi [14]. Of a total of 200 smallholder farmers with maize growing experience interviewed, most (from 93.9% in Vanduzi to 98.0% in Manica) were unable to morphologically identify the FAW. Most farmers (from 92% in Macate to 98.0% in Manica) experienced FAW damage on their farms. With the exception of Vanduzi where 65.3% of farmers apply insecticides, most farmers (from 60.8% in Macate to 88.0% in Manica and Sussundenga, respectively) in the other districts did not use any method to control the FAW [14]. In Benin, in a national survey of 1237 maize growers, 91.8% of farmers recognized damage caused by *S. frugiperda*, 78.9% were able to identify its larvae and 93.9% of maize fields were infested [15]. Similar studies were also conducted in Kenya [13], Uganda, Tanzania [16], Zambia [17], Zimbabwe [18] and Ghana [19] to understand the actual situation of the insect pest in these different areas and fall armyworm management practices used by farmers. Thus, to counter the incidence of insect pests, farmers rely on chemical pesticides, which have harmful consequences for humans, the environment and animals [20]. In addition to chemical control methods, farmers use other simple and accessible means, such as botanical pesticides, cultural practices and physical control. Farmers have various forms of indigenous knowledge to deal with pest problems, but this knowledge is often overlooked [12]. Farmers' knowledge and practices in pest management are important because they can highlight the need to train farmers in pest identification and debunk misconceptions about pest management [11]. In Burkina Faso, a study was conducted on farmers' knowledge and management of *Spodoptera frugiperda* on maize [21]. This study focused only on maize and did not take into account other cereals, such as millet and sorghum, which are also significant pest threats. Thus, data on the perception of producers and their management of FAW are still insufficient in the country and particularly in the Cascades and Hauts-Bassins regions. Therefore, it is important

to have data that integrate the main crops attacked by FAW, notably maize, sorghum and millet, in order to consider management methods that could be holistic.

It is in this context that the present study was conducted and aimed at establishing the state of knowledge of farmers in the Cascades and Hauts-Bassins regions of Burkina Faso on the FAW and the means they use to deal with it.

2. Material and Methods

2.1. Presentation of the Study Area

The study was conducted in the west of Burkina Faso, specifically in the Hauts-Bassins region (11˚15' north, 4˚30' west) and the Cascades region (10˚15' north, 4˚30') (**Map 1**) and concerned corn, sorghum and millet farmers. These regions border Mali to the west and Côte d'Ivoire to the south. They have a tropical North Sudanian and South Sudanian climate and are marked by two main seasons: a wet season lasting six to seven months (May to October/November) and a dry season lasting five to six months (November/December to April). The relatively abundant rainfall in these regions is between 800 and 1200 mm. Average annual temperatures range from 17˚C to 36˚C.

The vegetation of the area is essentially a savanna with all subtypes from wooded savanna to grassy savanna [22]. It has 30 classified forests (16 for the Hauts-Bassins and 14 for the Cascades), with fairly rich plant biodiversity compared to the rest of the country. The fauna of the area is quite rich and varied due to the existence of several classified forests. In general, the soils in the study area are suitable for agriculture.

The choice of this area to host the study was based on the importance of agricultural production, particularly cereal production (maize, millet and sorghum) in this part of Burkina Faso.

In addition, this choice is explained by the importance of caterpillar infestations observed in the Cascades, South-West, Hauts-Bassins, Boucle du Mouhoun and Centre-West regions [23] during the 2018-2019 agricultural cropping season.

The study was conducted in 19 villages of 8 communes, namely Bama, Bobo-Dioulasso, Karangasso-Sambla, Kanrangasso-Vigué, Lèna, Satiri, Koumbia in two provinces of the Hauts-Bassins region and 12 villages of 6 communes namely Banfora, Niangoloko, Soubakagnèdougou, Tiéfora, Dakoro and Dounain the two provinces of the Cascades region.

2.2. Methodology of the Survey

2.2.1. Type of Study, Study Population and Inclusion Criteria

The study was a cross-sectional descriptive study of maize, sorghum and millet farmers in the study area, *i.e.* the Hauts-Bassins and Cascades. The plant material consists of cereal varieties (maize, sorghum and millet) planted by the farmers

whose farms were surveyed.

The inclusion criteria were as follows:

- Be a farmer;
- Reside in the study area;
- Produce at least one of the cereals considered (maize, sorghum, millet) for the study.

The list of villages and individual farmers in the villages covered by the study was obtained with the support of the field extension network of the Regional Directorates of Agriculture and Hydro-Agricultural Development and Mechanization of the Hauts-Bassins and Cascades regions.

2.2.2. Sample Size

The sample size was determined by considering the number of farmers in the Hauts-Bassins and Cascades. Thus, by estimating the number of farmers in the two regions to be between 100,000 and 1,000,000 [24] and adopting a margin of error of 5% and a confidence interval of 95%, a questionnaire was developed and administered to respondents in both regions. The questionnaire contained closed, semi-closed and open-ended questions. A total of 384 farmers were surveyed. This sample was obtained by applying the method described by [25] [26]. It consisted of conducting a preliminary survey of a randomly selected sample of farmers in the area. The 97% of respondents who answered yes to the question "Have you ever heard of army worm?" was used to determine the sample of farmers to be surveyed. The sample size is determined according to the following formula [24] [25]:

$$n = \frac{t_p^2 \times P(1-P) \times N}{t_p^2 \times P(1-P) + (N-1) \times y^2}$$

- n: Sample size;
- N: Size of the target population (number of households, users, etc.), actual or estimated. (N = 1,000,000);
- P: Expected proportion of a population response or actual proportion. P = 0.5;
- t_p: Sampling confidence interval. For a 95% confidence interval, the associated t_p value is 1.96;
- y: Margin of sampling error. y = 5%.

The sample size (n) was 384 for the two regions, 259 for the Hauts-Bassins and 125 for the Cascades (**Table 1**). The number of farms to be surveyed per crop and per region was determined according to the relative size of the area sown to each crop.

2.2.3. Technique for Sampling Farmers

Based on the data from the N farmers in the maize, sorghum and millet production sites in the Hauts-Bassins and Cascades regions, the 384 farmers were selected at random using the random number table according to the following procedure.

The survey was conducted in 19 villages in 8 districts in two provinces of the Hauts-Bassins region and 12 villages in six districts in two provinces of the Cascades region (Map 1).

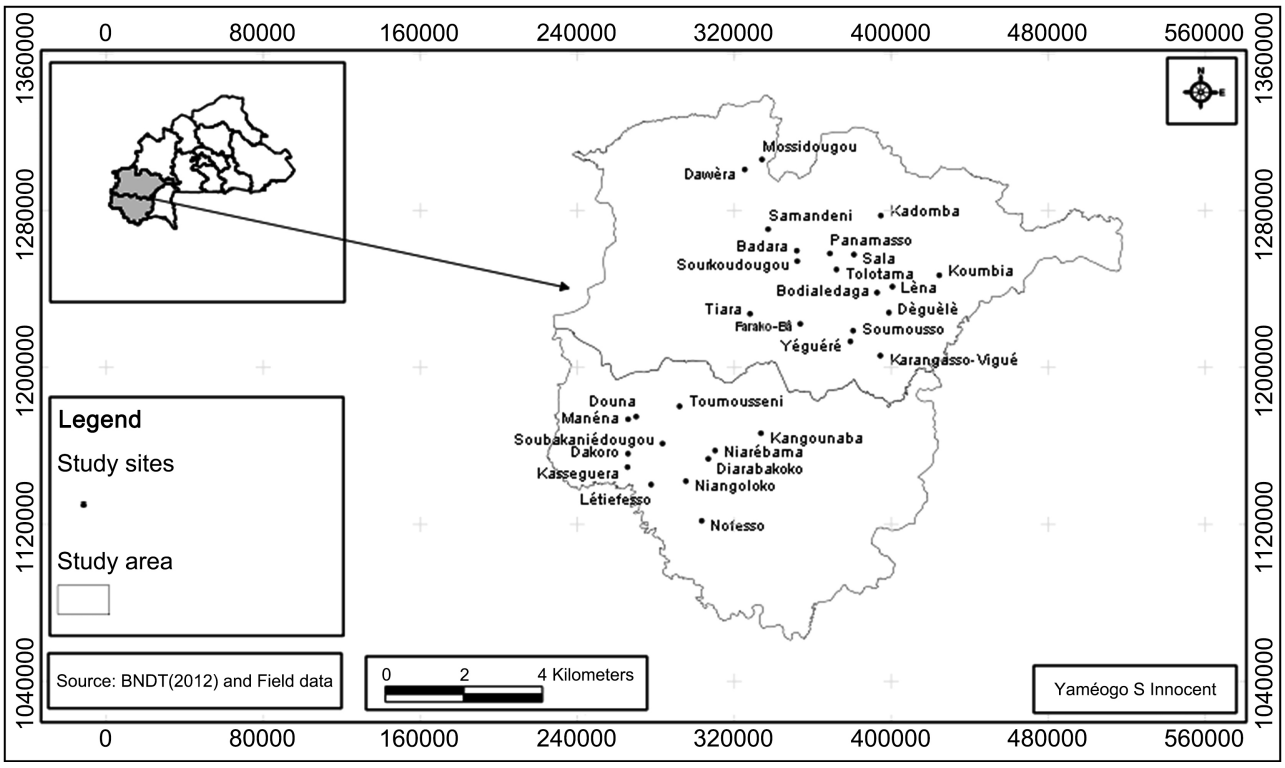
The quota of the different cereals (maize, sorghum and millet) was calculated according to the size of the crop plantings. For a sample village, an average of 10 farms was involved in our study.

2.2.4. Farmers' Surveys

The questionnaire administration phase took place during late June to early July 2020 simultaneously in the two regions covered by the study. A questionnaire developed by using Sphinx Plus2-V5 software was used for data collection. This questionnaire included three main parts. The first part deals with the identification of the respondent and the socio-demographic characteristics of the farms;

Table 1. Crop distribution in the study area.

Crops	Number of farmers Hauts-Bassins	Number of farmers Cascades	**Total**
Maize	130	63	**193**
Sorghum	78	37	**115**
Millet	51	25	**76**
Total	**259**	**125**	**384**



Map 1. Location of sampled sites in the study area.

the second part is related to the evaluation of the extent of the damage and the respondent's knowledge of *S. frugiperda*; finally, the third part deals with the management methods used by farmers and the estimation of the yields of the cereals sown during the last four wet agricultural cropping seasons.

2.2.5. Data Processing and Analysis Method

This stage consisted of the tabulation, statistical processing and analysis of the data collected in the field. The information collected during the survey was first transcribed into code in order to facilitate computer processing. After this coding, a database was created using Excel 2010 software.

Data were summarized per region, province, district and village. Descriptive statistics such as means and percentages were calculated through Excel 2010. In some cases, the percentage of farmers was determined based on the total number of farmers who gave a particular response.

Data processing was also carried out with Excel 2010 and consisted of extracting descriptive statistics from the database in the form of tables and graphs.

3. Results

3.1. Socio-Demographic Characteristics of the Respondents

3.1.1. Distribution of Farmers According to Sex and Age

The age of those surveyed ranged from 18 to 80 years (Table 2). Farmers between 41 and 50 years of age were the most numerous in the survey sample, followed by those between 31 and 40 years of age with 31.27% and 30.14%, respectively. The age groups of 51 to 60, 18 to 30 and 61 to 80 represented 18.87%, 11.55% and 8.17% of the people surveyed, respectively. In addition, the majority of farmers were men, 94.08% of them against 5.92% of women.

3.1.2. Framers' Education Level

The level of education of the farmers surveyed is illustrated in Figure 1. Just over half of the respondents (50.42%) were illiterate, compared to 9.58% who were literate. Farmers with Koranic school education represented 10.14% of the

Table 2. Distribution of survey farmers by age and gender.

Age group	Men	Women	Total	Percentage (%)
18 to 30 years	39	2	41	11.55
31 to 40 years	95	12	107	30.14
41 to 50 years	106	5	111	31.27
51 to 60 years	65	2	67	18.87
61 to 80 years	29	0	29	8.17
Total (number)	**334**	**21**	**355**	**100**
Total (%)	**94.08**	**5.92**	**100**	

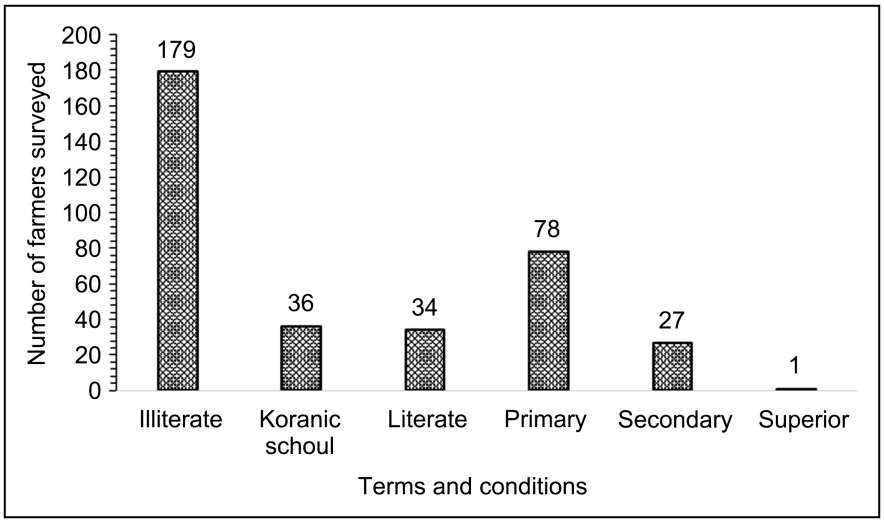


Figure 1. Educational level of sampled farmers in western Burkina Faso, sample size n = 355.

total; 21.97% of farmers had primary school education, 7.61% had secondary school education, and only 0.28% had higher education. In total, 92.11% of the farmers had an education level of primary school or less.

3.2. Farmers' Knowledge of *Spodoptera frugiperda*

3.2.1. Recognition and Identification of *Spodoptera frugiperda* by Farmers

Almost all (97.46%) of the farmers surveyed said they had heard of *S. frugiperda*. However, 80.85% of the farmers surveyed claimed to be able to identify the insect pest as opposed to 19.15% who said they were unable to do so (**Figure 2**). Farmers used several criteria to identify the FAW. These criteria include FAW color (36.42%), leaf damage (22.34%), pest droppings (22%), inverted Y on the head (8.25%), four dots on the tip of the abdomen (7.21%), and head color (3.78%) (**Figure 3**).

3.2.2. Year of Occurrence of *Spodoptera frugiperda*

The date of appearance of the fall armyworm is variously rated by the farmers in the study area. According to them, the years 2016, 2017, 2018, and 2019 are to be remembered with respect to the appearance of the insect pest (**Table 3**). If for the majority of the respondents (60%), 2017 is the date of appearance of the insect pest, a small proportion (1.41%) claims to have encountered it well before 2016. In addition, some farmers (4.23%) do not actually know the year the insect pest appeared in their area.

3.2.3. Assessment of Crop Production Losses Associated with *Spodoptera frugiperda*

The average yields of the three cereals, namely maize, sorghum and millet, have varied differently over the past four years according to farmers of Hauts-Bassins and Cascades regions estimates and perceptions. While for sorghum and millet

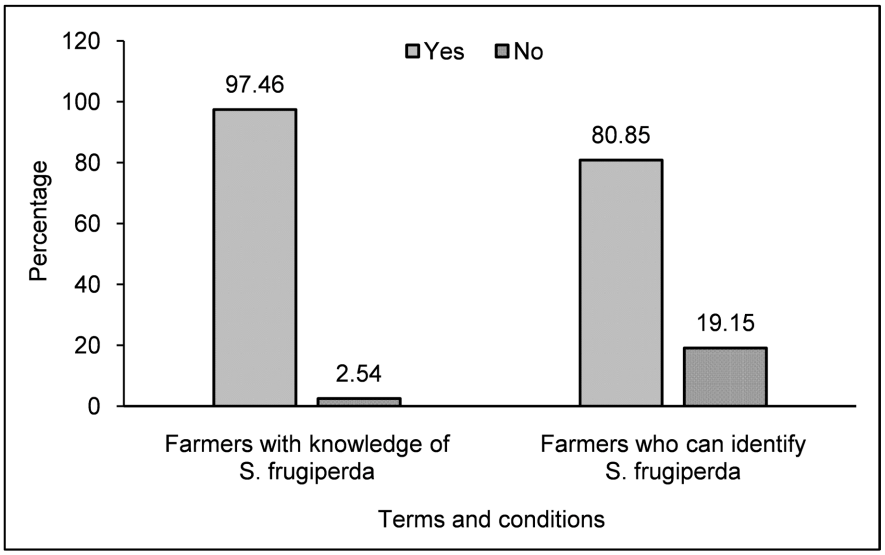


Figure 2. Farmers' knowledge and identification of *S. frugiperda* in western Burkina Faso.

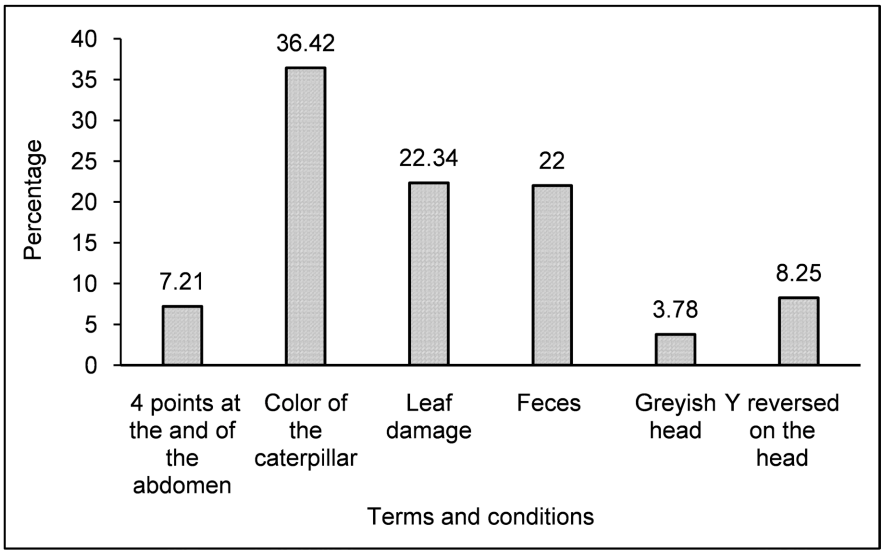


Figure 3. Criteria for identification of *S. frugiperda* by farmers in western Burkina Faso.

Table 3. Year of appearance of *Spodoptera frugiperda* according to farmers.

Year	Number of farmers	Percentage (%)
Before 2016	5	1.41
2016	32	9.01
2017	213	60
2018	77	21.69
2019	12	3.66
No response	15	4.23

this variation in average yields from 2010 to 2019 seemed slight, it was quite remarkable for maize. The average maize yield from 2010 to 2015 was continuously increasing in the study area and was 1.69 t/ha in 2010 and 2.27 t/ha in 2015. This continuous increase over the years will experience a remarkable drop in 2016 (1.95 t/ha) and especially in 2017 (1.83 t/ha).

These values will increased slightly in 2018 and 2019 with 2.08 and 2.39 t/ha, respectively (DGSS 2020) (Figure 4).

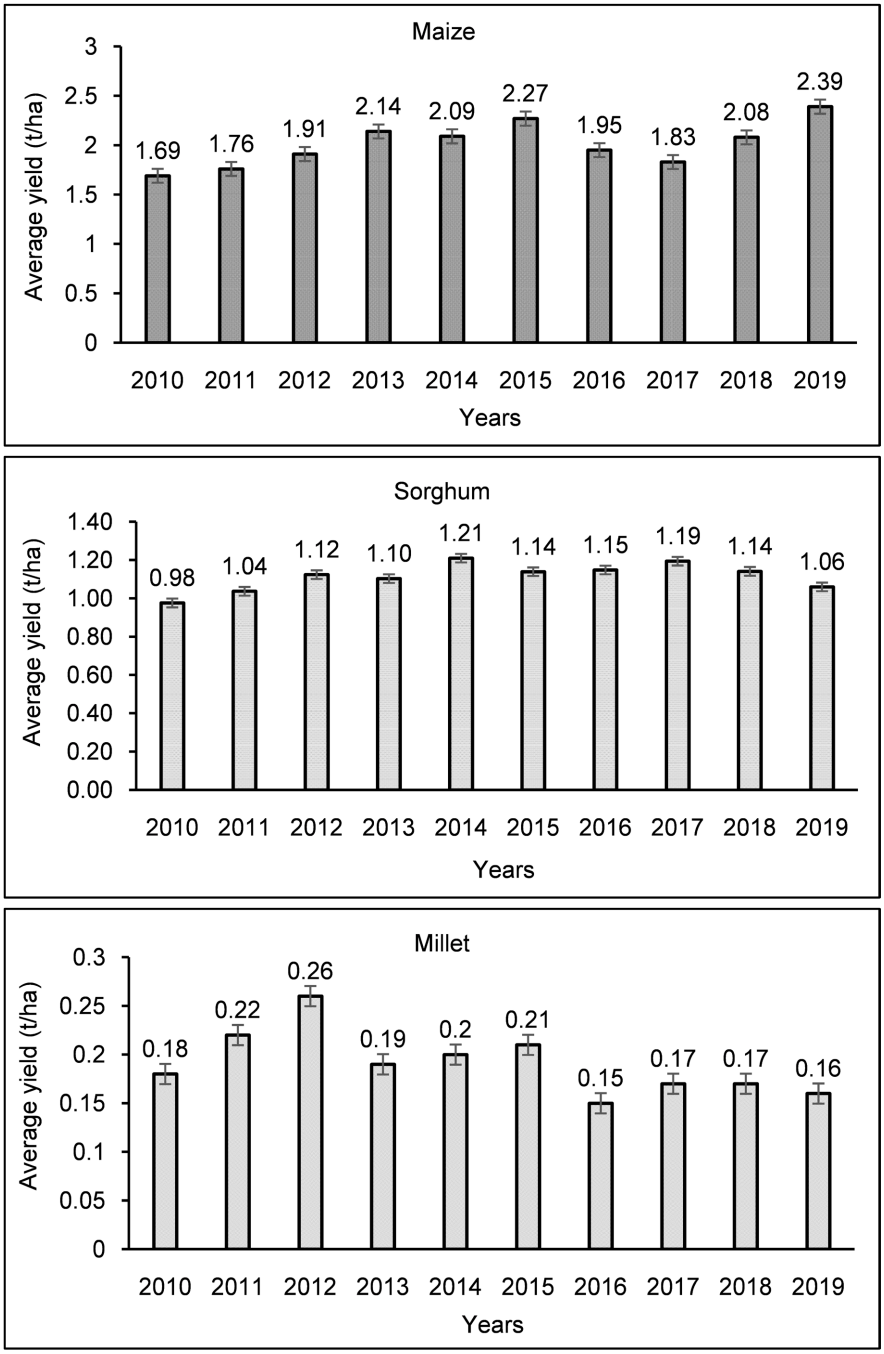


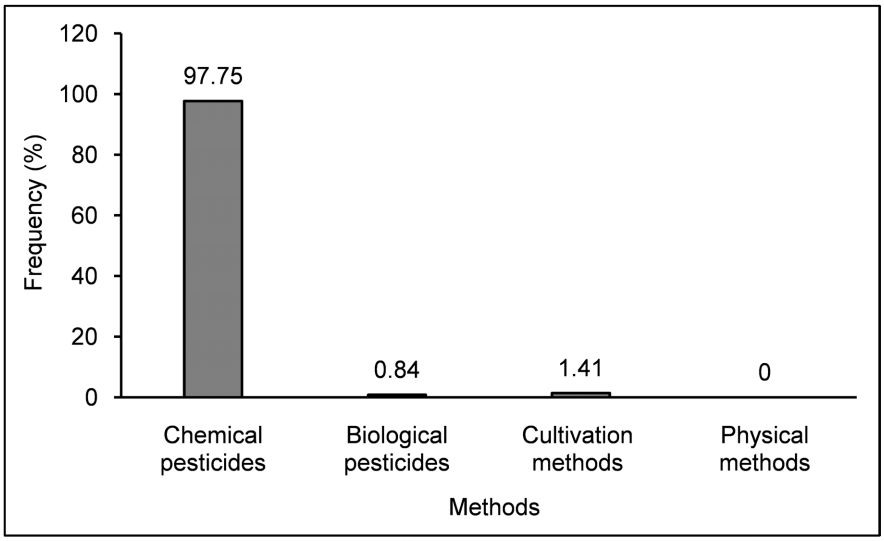
Figure 4. Evolution of the average yield of maize, sorghum and, millet from 2010 to 2019 of western Burkina Faso.

3.2.4. Management of *Spodoptera frugiperda* by Farmers

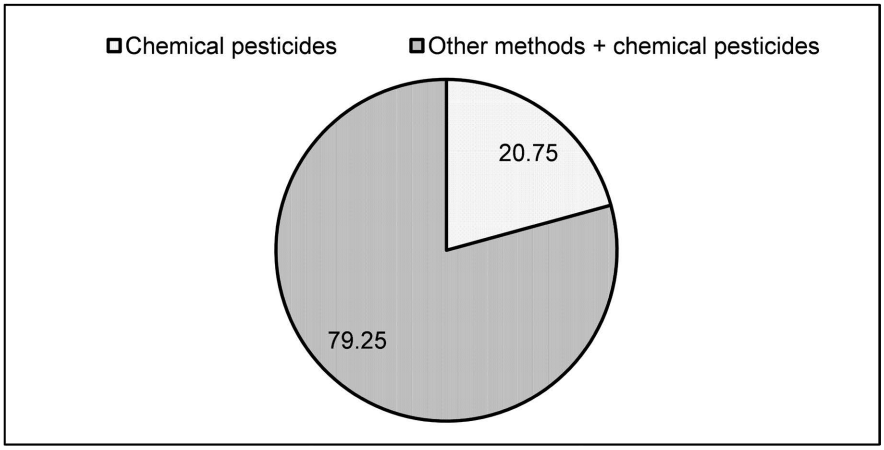
The protection of cereals (maize, sorghum and millet) is done in a discriminating manner by farmers in the study area. Maize is the crop that receives the most phytosanitary treatment. Thus, 82.20% of the farmers surveyed protect their maize fields against the insect pest with insecticides. As for sorghum, a few farmers (3.39%) stated that they had used an insecticide to protect it against the insect pest. None of the farmers surveyed used an insecticide to protect millet against the fall armyworm.

In fact, farmers in Burkina Faso do not usually protect sorghum and millet crops from pest attacks. Only maize fields benefit from such protection.

In the field, several management methods are used by farmers to counter FAW attacks. These control methods can be grouped into categories. For farmers who exclusively use one of these FAW management methods (Figure 5(a)), these are:



(a)



(b)

Figure 5. Control methods against *Spodoptera frugiperda.* (a) Exclusive use of one of the control methods; (b) Use of chemical pesticides and other control methods.

- The agro chemical control methods, which incidentally remains the most dominant (97.75%);
- The use of botanicals or bio-pesticides (0.84%);
- Cultural control methods including crop associations, early sowing, agro-ecology, etc. (1.41%);
- Physical control methods including manual crushing of larvae and eggs of the insect pest, application of ash and fine sand in the whorls of the attacked crops in order to suffocate the larvae (0%). No farmer uses this last pest management method without combining other control methods.

Among the farmers who use agro chemicals to control *S. frugiperda*, it appears from the surveys that 79.25% of them use it exclusively against 20.75% who combine it with other control methods (either with bio-pesticides, with cultural control or with physical control methods) (**Figure 5(b)**). **Table 4** presents the list of agro chemicals used by farmers in the Hauts-Bassins and Cascades regions to control the FAW usually in corn fields.

In these two regions of agricultural importance in Burkina Faso, synthetic chemical pesticides are in the forefront in the fight against CLA. Thus, Emamectin benzoate of the trade name Emacot is the most used by farmers with a percentage of use of 50.70% followed by Lambda-cyalothrin + Acetamiprid of the trade name Pacha at 32.96%. The biological pesticides are not widely used, the most common being Azadirachtin based on Neem extract with a percentage of use of about 1.69%.

Table 4. Pesticides used by farmers to control *Spodoptera frugiperda* in western Burkina Faso.

Tradename	Active ingredient	Group	Class (WHO)	Type of pesticides	Statut (CSP)	Percentage of users (%)
Neem extract	Azadirachtin	Bio-pesticide	-	Insecticide	-	1.69
Avaunt	Indoxacarb (150 g/l)	Oxadiazin	III	Insecticide	Yes	1.97
Calthio	Thiram (250 g/kg) Chlorpyrifos-ethyl (250 g/kg)	Pyrethrinoid + organophosphous	II	Insecticide	Yes	1.69
Savahaler	Methomyl 250 g wp	Oxime of carbamate	II	Insecticide	Yes	1.41
Decis	Deltametrin (25 g/l)	Pyrethrinoid	II	Insecticide+ fongicide	No	0.85
Emacot	Emamectin benzoate (50 g/Kg)	Avermectin	II	Insecticide	Yes	50.70
K-optimal	Acetamiprid (15 g/l)	Pyrethrinoid	II	Insecticide	Yes	5.91
Pacha	Lambda-cyalothrin (15 g/l)/Acetamiprid (10 g/l)	Pyrethrinoid	II	Insecticide	Yes	32.96
Sunpyriphos	Chlorpyrifos-ethyl 480 g/l	Organophosphorous	III	Insecticide	Yes	1.69
Others	-	-	-	-		1.13

3.2.5. Period and Frequency of Insecticide Applications by Farmers

The timing and frequency of insecticide applications are unevenly distributed over time at the discretion of each farmer. Applications frequencies range from 1 to 4 or more depending on the development cycle of the maize (Figure 6). The majority of the farmers make their unique application at the time of the bolting (33.72%). However, few of them (2.31%) make 4 applications at periods corresponding to the emergence, the bolting, the flowering and the heading. On the other hand, a good number of farmers started applications as soon as they observed the insect pest attacks on their crops (29.97).

4. Discussion

This survey identified the predominant age group of farmers in the study area. It falls between two age groups, namely 41 and 50 years on the one hand and 31 and 40 on the other. The male sex is overwhelmingly represented in the sampled population against only for the female sex.

This situation could conceal the fundamental problem of women's access to land, which is still very low in Burkina Faso, despite the primary role they play in family farming. This situation could conceal the fundamental problem of women's access to land, which remains very low in Burkina Faso despite the primary role they play in family farming [27]. In Burkina Faso, the exclusion of women from control of land management is one of the major characteristics of customary rights [28]. In still largely dominant traditional land tenure systems, women only precarious use rights and generally degraded land [29]. The absence or very low level of education of farmers was clearly highlighted during

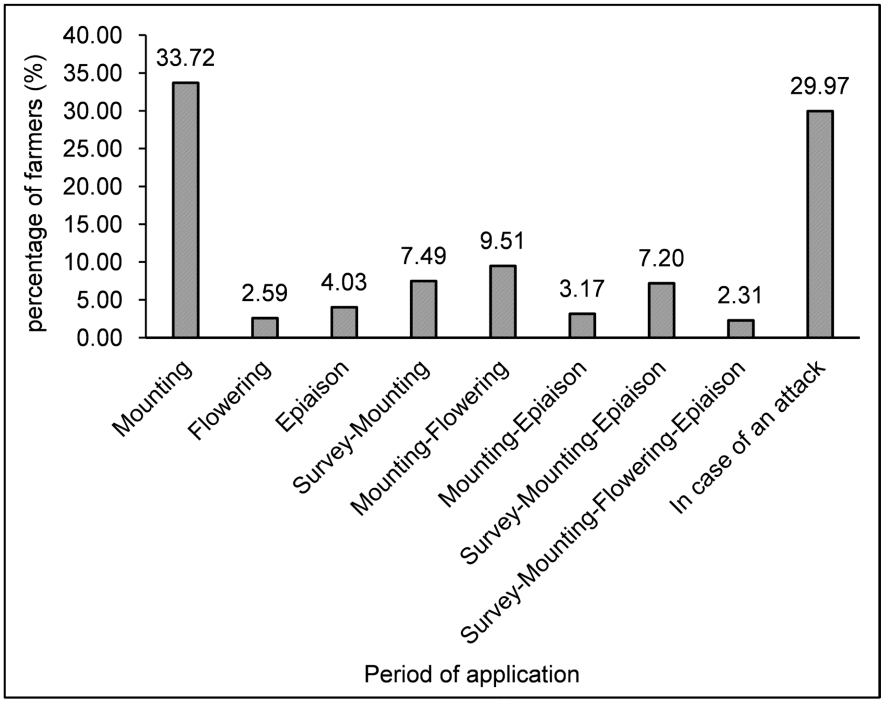


Figure 6. Timing and frequency of chemical insecticides application against FAW.

this work. Indeed, 92.11% of the farmers surveyed had a level of education lower than or equal to primary school. People with a low level of education have difficulty finding employment in the formal sector, which partly justifies their high representation in the agricultural sector where the activity does not require specific skills. In Burkina Faso, of the 3,335,848 workers in the informal sector, 52.2% are women. Nearly six out of ten people working in the informal sector are young people under the age of 35. Informal sector workers have a relatively low average number of years of education (2 years) nationwide [30]. Despite this low level of education, almost all the farmers of the survey areas were well informed about the threat caused by the fall armyworm. Better still, about of them said they could identify the insect pest against only who were unable to do so. This situation shows that the farmers have integrated the presence of the insect pest in their daily life, considering the importance of the attacks of this pest in the field. This rapid familiarization with the insect pest can also be explained by the contribution of the TCP/FAO/3606 project, which provided training from 2018 to 2019 for several dozen farmers on the sustainable management of the fall armyworm in the two study regions [31]. In addition to this, several agricultural extension officers and those from the Plant Protection Directorate (DPVC) conducted awareness campaigns for farmers on the fall armyworm in all 13 regions of Burkina Faso from 2017 to 2019. As a result, farmers gathered knowledge to identify the insect pest. These results contradict [32] and [6] who reported that in many African countries, farmers' knowledge of the fall armyworm is currently low.

Because *S. frugiperda* is a new insect pest, it can be easily confused with other caterpillars, especially those belonging to the same family [33] FAO and CABI, 2019). However, [34] emphasized the fact that even if farmers are not trained by extension officers in FAW identification and management, they will, over time, learn through their own experiences.

This may be true when farmers have no education on the insect pest. This is reportedly changing in the field due to the high infestations recorded every year since the pest appeared in 2016. In addition, dozens of farmers in the Cascades received training on the pest in 2018 thanks to an FAO-funded project, and most of the Ministry of Agriculture's supervisory extension officers in the field received information/training on the pest's bioecology and had to share it with farmers. While farmers recognize the armyworm, the date of appearance of the pest is not unanimously agreed upon in the study area. Indeed, according to the farmers, the period of appearance of the pest is between 2016 and 2019. If for the majority of the respondents 2017 is the date of appearance of the pest, a minority claims to have encountered it well before 2016. Finally, some farmers did not know the year of the pest's appearance in the study area. This reaction of the farmers could be attributed on the one hand to the low level of education of the majority of them and on the other hand to the fact that the production areas covered by our study did not record the first attacks of the pest during the same

period, not to mention the important variability of the infestations of the pest according to the agricultural production areas. Finally, it is possible that the fall armyworm is mistaken for one of the native species of the genus Spodoptera such as *Spodoptera exempta*. In any case, farmers' suggestions regarding the date of the pest's appearance in this region of Burkina Faso are within the range suggested by [5] and [35], who report that January 2016 was the first time the pest was reported on the African continent. To protect crops from fall armyworm attacks, farmers primarily resort to the use of chemical insecticides. Other control methods are also used by the population. On the one hand, these are cultural methods that consist of early sowing, the use of organo-mineral fertilizer, and the agrofeoretry and, on the other hand, physical control methods, in particular, the manual crushing of the pest larvae. These results are comparable to those reported by [35] and [6], who observed the same practices in Kenya, South Africa and Zimbabwe. However, cereals such as sorghum and millet receive little or no insecticde spays. This situation could be culturally explained, on the one hand, by the fact that sorghum and millet are indigenous cereals that have been that are produced with low or no inputs like fertilizers and pesticides. For example, before the invasion of the FAW, farmers did not spray the three cereals studied here. On the other hand, this could be associated with farmers' poverty in general. In Mozambique, farmers also reported that lack of financial resources was the main constraint, followed by inadequate resources [18]. A similar situation was reported in Ethiopia, where the main problems affecting management efforts are lack of financial and equipment resources [36]. Depending on the context, smallholders may have limitations that will define their pest management options [37]. Maize remains the crop that receives the most insecticide sprays. Maize is the preferred host plant of *S. frugiperda* [32], so there is a strong case for chemical protection of this plant. Various pesticides are used to control *S. frugiperda* but Emamectin benzoate remains the most used by farmers followed by Lambda-cyhalothrin + Acetamiprid.

Our results confirm those of [38] who reported that Emamectin benzoate is the most used insecticide against the pest in Sissili province with more than 36% of users. The choice of this product by farmers is explained by the fact that it has proven to be the most effective against various caterpillars before the appearance of *S. frugiperda*. In addition, the 2018 FAO-organized farmer field schools (FFS) in Sissili province demonstrated that Emamectin benzoate was the most effective insecticide against the caterpillar. Lambda-cyhalothrin + Acetamiprid is a foliar systemic insecticide with a broad spectrum activity. It can be used as a preventative or curative treatment. Despite the efforts of farmers to protect their crops, the damage inflicted by the pest on crops is not significantly reduced.

There is good potential for the implementation of an IPM strategy for the FAW in Burkina Faso. Apart from cultural control, the use of *Telenomus remus* Nixon (1937) (Hymenoptera: Platygastridae), an egg parasitoïd of *S. frugiperda* was found to be an indigenous natural enemy of the insect pest.

5. Conclusions

This study showed that since the FAW invasion in 2016, the government of Burkina Faso and its partners have not stopped supporting small-scale farmers through training and the provision of synthetic insecticides. In addition to synthetic insecticides, farmers use other more accessible control methods, such as botanicals and cultural or physical methods. The study confirms that farmers' knowledge of the insect pest is an important factor that influences their management decision. Further research is needed to refine and standardize management practices deemed effective by farmers and analyze farmers' willingness to incorporate improved management practices.

Overall, FAW appears to be under control thanks to the resilience of farmers and the readiness of the Burkina Faso government to act.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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