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Farmers' knowledge of biological control for sustainable management of fall armyworm in Western Burkina Faso

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Abstract
The recent invasion of the fall armyworm (FAW) is severely limiting cereal yields and the main method of controlling is the use of chemical insecticides, which unfortunately cause damage to human and environmental health. Alternative methods to insecticides include biological control, which is still little known by farmers. The aim of this study, carried out in the Hauts-Bassins and Cascades regions of Burkina Faso, was to assess, through surveys, the perceptions of 256 cereal crop farmers on biological control of FAW. During the interview, images of the main parasitoid species associated with FAW were shown to farmers to enable them to answer questions. Among these farmers, only 14% of them had received training in FAW management methods. The evaluation of knowledge's level on natural enemies showed that in the Cascades and Hauts-Bassins regions, 74% and 80.77% of farmers respectively were unaware of the existence of natural enemies against the FAW. It was only after showing parasitoids' images that 85% and 67% of farmers in the Cascades and the Hauts-Bassins regions respectively, recognized having encountered at least one of the four main parasitoid species in their fields. No farmer reported using natural enemies to control FAW. Farmers are therefore unaware of the existence of useful insects in the environment that help to control insect pests in general and FAW in particular. This study therefore highlights the urgent need to strengthen the technical skills of cereal Farmers in recognizing and preserving natural enemies in order to promote biological control in FAW.

Keywords: *Spodoptera frugiperda*, farmer perception, parasitoids, Burkina Faso

Introduction
The fall armyworm (FAW), *Spodoptera frugiperda* J. E. Smith (Lepidoptera: Noctuidae) is a voracious pest native to tropical and subtropical regions of America [1]. It first appeared in Africa in 2016 [2] and has been reported in several African countries, including Burkina Faso. *Spodoptera frugiperda* larvae preferentially attack maize, but can feed on 353 plant species belonging to 76 families [3, 4], causing damage to leaves, stems and cob kernels at the doughy stage of infested plants. According to [5], yield losses caused by *S. (Frugiperda* were 73% for maize, the cereal on which 208 million people in Africa depend, the equivalent of 9.8 billion US dollars.

Upon its introduction in Burkina Faso in 2016, the FAW spread to all the 13 regions of the country infesting and damaging more than 58,324 ha and 8,388 ha of crops, respectively with cereals including maize, millet and sorghum being the most affected [6]. The severity of its attacks has led to a drop in cereal production, and consequently in farmers' incomes. In most African countries, *S. frugiperda* management is done by several methods such as inert substances (Ash, sand), cultural, biological and physical controls but the main one remains synthetic insecticides, many of which are not yet registered for use against this pest [7, 8]. This practice poses a risk to human health and the environment, and increases the risk of the development of insecticide resistance in the pest, as was the case in America [9]. Sustainable management of *S. frugiperda* requires the development of sustainable, environmentally-friendly crop protection methods [10].

Biological control, which involves the use of parasitoids, bioinsecticides and predators, is becoming an alternative for the sustainable and effective management of *S. frugiperda*.

This method contributes to protecting human and environmental health and conserving biodiversity. As part of the implementation of this biological control, studies have been carried out in Burkina Faso and in several African countries to determine the indigenous parasitoid complex and assess parasitism rates of *S. frugiperda* [10–16]. In Burkina Faso, inventories of natural enemies have shown the presence of hymenopteran parasitoids *Chelonus* sp. (Braconidae), *Chelonus bifoveolatus* (Szépligeti) (Braconidae), *Coccygidium luteum (Brullé)* (Ichneuminidae) and *Telenomus remus* (Nixon) (Platygastridae)), dipteran parasitoids (*Drino* sp. (Tachinidae)), nematodes (Mermethidae) associated with FAW [17]. This wide range of parasitoids aroused our interest in using them for biological control of the FAW. For the successful use of these natural enemies in Burkina Faso, efforts must be combined at both researchers and farmers level to maintain the survival of these indigenous species. Research has shown the presence of several parasitoid species in Burkina Faso, but how well do farmers know these natural enemies? What are they doing to ensure the preservation of these natural enemies in the environment?

The present study was initiated, with the overall aim of assessing farmers' knowledge of biological control of FAW through the use of natural enemies in western Burkina Faso.

Materials and Methods

Presentation of study sites

The study was carried out in two regions of the Sudanian zone of Burkina Faso: the Hauts-Bassins region (in the municipalities of Bobo-Dioulasso (Nasso, Denderesso and Sonsogona), Bama and Koumbia) and the Cascades region in the municipality of Siniena and Tiéfora (Figure 1). The choice of these regions was based partly on the importance of cereal crop production (156,616 ha in the Cascades region and 472,524 ha in the Hauts-Bassins region), and partly on *S. frugiperda* pressure in the fields [18]. The Hauts-Bassins region is subject to a tropical climate of the North Sudanian type, with isohyets ranging from 800 mm to 1100 mm, and characterized by two (02) alternating seasons [19].The Cascades region has a South Sudan-type climate marked by two main seasons too. Average annual rainfall ranges from 800 to 1200 mm [20].

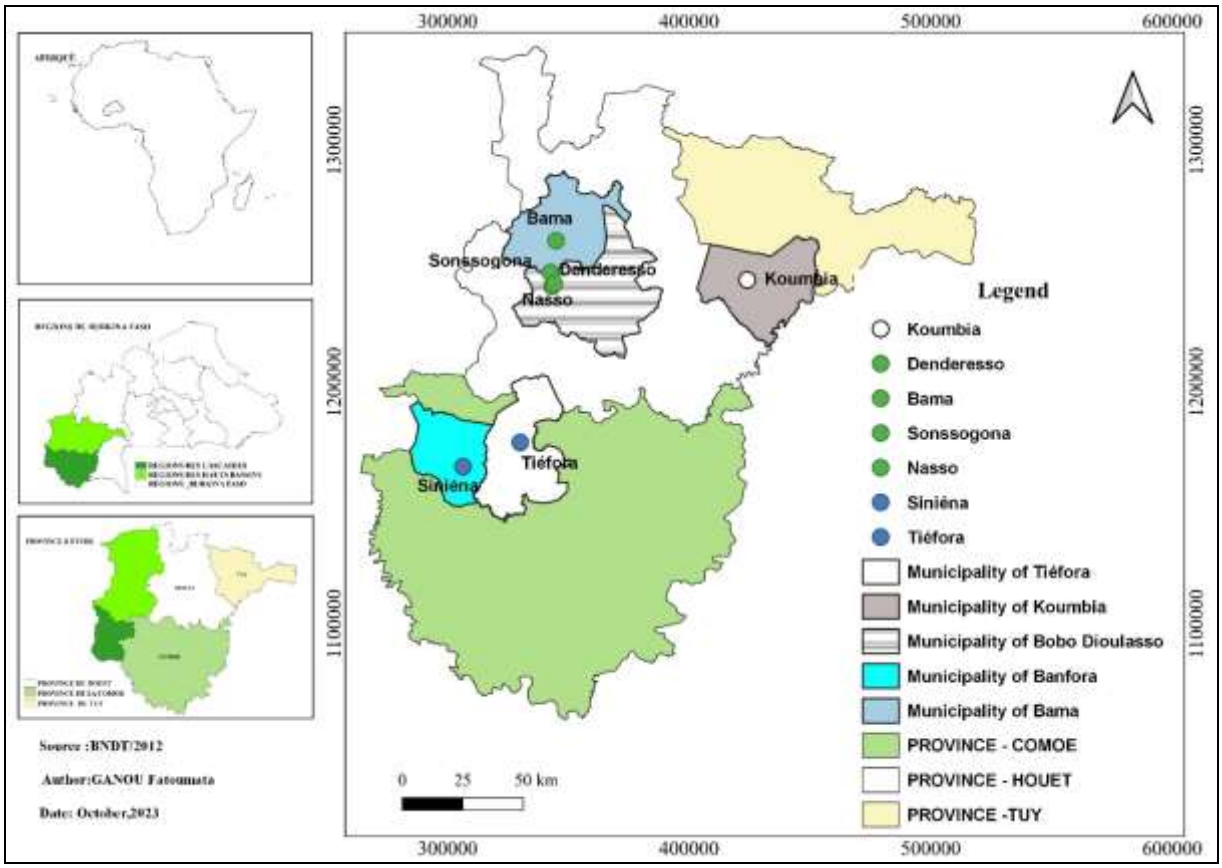


Fig 1: Localities where survey was carried out in Hauts-Bassins and Cascades regions

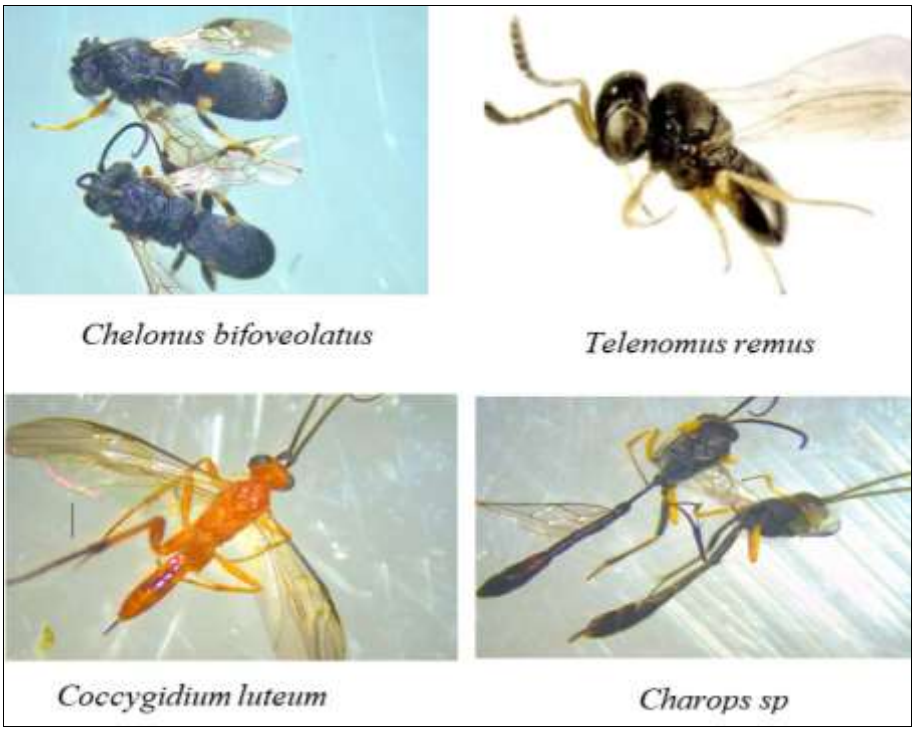
Survey process and data collection

The survey involved Farmers selected with the support of the zone chiefs of each municipality from the Provincial Direction of Agriculture and Animal Resource and the president of the village development council of each village according to the following criteria: (i) Be a resident in the village for at least 10 years, (ii) Be a cereal Farmer, (iii) Be a member of the local Farmers' group.

The exchange consisted of an individual interview using a questionnaire (Table 1) recorded on the Kobotoolbox mobile platform. A sheet containing images (Figure 2) of the four parasitoid species already identified in Burkina Faso was made available to the farmers surveyed, so that they could learn about the existence of parasitoids on the one hand, and identify those commonly encountered in the ields on the other hand. The survey took place from June 13 to 25, 2023 with 50 cereal Farmers in each commune, i.e. a total of 256 registered participants (Table 2).

Table 1: Survey questionnaire on farmers' knowledge of biological control for sustainable management of fall armyworm in western Burkina Faso

Respondent identification
How many years have you been producing cereals?
Have you ever received training in maize production?
Do you know the fall armyworm (FAW)? (Show a picture)
What is its local name?
Have you ever received training/awareness on FAW?
What do you do in case of the presence of the FAW in your field?
Do you think that the use of insecticides for FAW control is effective?
Are you aware that there are natural enemies that consume the eggs and/or larvae of the FAW?
Have you ever seen these insects in your field? (show photos of parasitoids)
Which of these natural enemies are most common in your field (Show photos of parasitoids) *Chelonus bifoveolatus Coccygidium luteum Charops sp Telonumus remus* Others
Have you ever used these natural enemies against the FAW?



(*Source*: Author)

Fig 2: Photos of parasitoids presented to farmers during the survey

Table 2: Number of farmers surveyed by village in Hauts-Bassins and Cascades regions

Regions	Provinces	Municipality	Villages	Number of farmes surveyed
Hauts-Bassins	Houet	Bama	Bama	54
		Bobo-Dioulasso	Nasso	12
			Dinderesso	13
			Sonsogona	27
	Tuy	Koumbia	Koumbia	50
Cascades	Comoé	Banfora	Siniena	50
		Tiéfora	Tiefora	50

Statistical analysis

Data collected on the Kobocollect mobile application, were exported to Microsoft Excel Software 2013 and processed using IBM SPSS Statistics 27 for descriptive statistics. Tables and graphs were constructed using Excel 2013.

Results

Farmer socio-demographic characteristics

The characteristics of the farmers surveyed in the two regions are recorded in Table 3. It can be seen that the proportion of men (82.81%) was higher than that of women (16.80%) in our study conditions. The most active population was observed in the following age brackets [26]. In the Cascades region, more than half of the respondents were Karabôrô ethnic group (51%), followed by Goin (46%) while in the Hauts-Bassins region, 57.05% of them were Mossi, followed by Bôbô (24.36%) ethnic group. In terms of education, 46.09% of farmers had not attended school, 21.48% hold primary education level and only 0.78% of farmers experienced tertiary education level. It can be seen that farming was the main occupation of 98.83% of the farmers in the study area.

Table 3: Socio-demographics characteristics of farmers surveyed in Hauts-Bassins and Cascades regions

Characteristics	Variables (%)	Cascades	Hauts-Bassins	All Regions
Gender	F	34.00	5.77	16.80
	M	66.00	93.59	82.81
Age	[15-25]	11.00	6.41	8.20
	[26-35]	31.00	25.00	27.34
	[36-45]	33.00	25.00	28.13
	[46-55]	19.00	23.72	21.88
	[56-65]	6.00	14.74	11.33
	[65 and+[	0.00	5.13	3.13
Ethnic group	Bôbô	0.00	24.36	14.84
	Bwaba	0.00	0.64	0.39
	Dafing	0.00	1.92	1.17
	Goin	46.00	0.00	17.97
	Karabôrô	51.00	0.00	19.92
	Mossi	0.00	57.05	34.77
	Senoufo	1.00	2.56	1.95
	Toussian	1.00	0.00	0.39
	Others (Dioula. Dogossin. Peulh.Sambla. Samo,Tiefo. Waala)	1.00	13.46	8.59
Marital status	Single	15.00	11.54	12.89
	Married	82.00	88.46	85.94
	Widowed	3.00	0.00	1.17
Education level	Koranic	0.00	30.77	18.75
	None	69.00	31.41	46.09
	Primary	13.00	26.92	21.48
	Secondary	17.00	10.26	12.89
	Higher	1.00	0.64	0.78
Main occupation	Farmer	100.00	98.08	98.83
	Breeder	0.00	1.28	0.78
	Official	0.00	0.64	0.39
Household size	[1-25]	78.00	92.95	87.11
	[26-50]	17.00	6.41	10.55
	[51-75]	3.00	0.64	1.56
	[76-100]	2.00	0.00	0.78

Farm's characteristics

Among the respondents, 52.34% had 1 to 25 years' experience in cereal production; 47.27% had 26 to 50 years' experience and 0.39% had more than 50 years' experience. Regarding the area exploited, 78.13% of respondents owned at least 2ha of land, of which 69.92% devoted at least 1ha to cereal production (Table 4). Of these farmers, 73.83% had never received any training in cereal production, and 95.70% were familiar with the FAW or "Tantalan" in Bôbô, "Kaba toumou" in Dioula, "Kamane Zouigna" in Mooré, "Fian" in Karabôrô or "Djièm" in Goin (Table 5).

Table 4: Structural characteristics of farms in selected regions of Burkina Faso

Characteristics	Variables (%)	Cascades	Hauts-Bassins	All regions
Number of years of practice	[1-25]	53	51.92	52.34
	[26-50]	47	47.44	47.27
	[51-75]	0	0.64	0.39
Surface area	[1-2ha [	3	27.56	17.97
	<1ha	0	6.41	3.91
	> 2 ha	97	66.03	78.13
Area occupied by cereals	[0.5-1ha [	5	26.92	18.36
	[0.25-0.5ha [	2	13.46	8.98
	< 0.25ha	0	4.49	2.73
	> 1 ha	93	55.13	69.92
Training on cereal production	No	58	83.97	73.83
	Yes	42	16.03	26.17
Crop rotation	No	3	31.41	20.31
	Yes	97	68.59	79.69
Knowledge of the FAW	No	3	5.13	4.30
	Yes	97	94.87	95.70

Table 5: Name attributed to fall armyworm (FAW) in five local languages in selected regions of Burkina Faso

Ethnic groups	Bôbô	Dioula	Moore	Karabôrô	Goin
Name of FAW	Tantalan Tintanli Cimi Chimia Douma	Kaba toumou	Kamane-Zouigna Kamane-zounre Zounri	Fian Fientouhou Fihanre Fimore Koncre	Djièm Guihahou Faledjianhou Nantogolo Tounle

Farmers' level of awareness of fall armyworm management methods

Only 18% of farmers in Cascades region and 11% in Hauts-Bassins region were trained or made aware on the control methods against fall armyworm, and (figure 3).

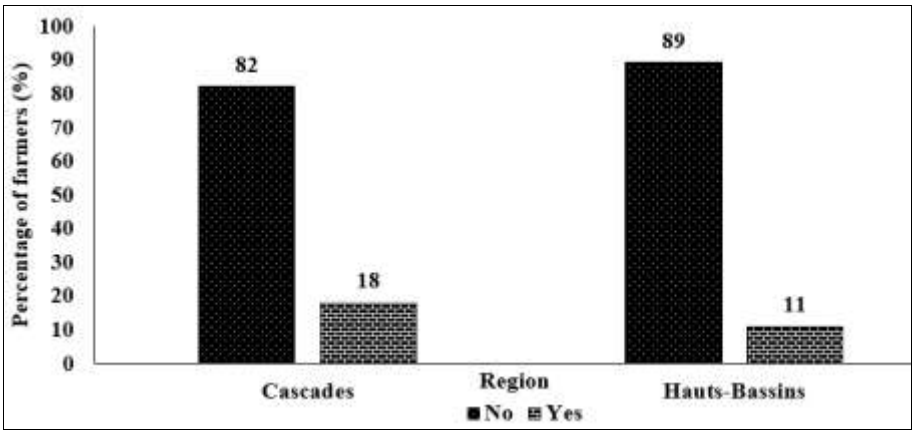


Fig 3: Proportion of farmer awareness of fall armyworm management in selected regions of Burkina Faso

Fall armyworm management methods used by farmers

The different control methods used by farmers against the fall armyworm are chemical insecticides, biopesticides, combine chemical insecticides and biopesticides, cultural methods (figure 4). In the Hauts-Bassins and Cascades regions, 94.23% and 84% of farmers respectively use only chemical insecticides to control the FAW; 2.56% and 4% combine chemical insecticides and biopesticides; 0.64% and 7% use only biopesticides; 1.92% and 3% use cultural methods.

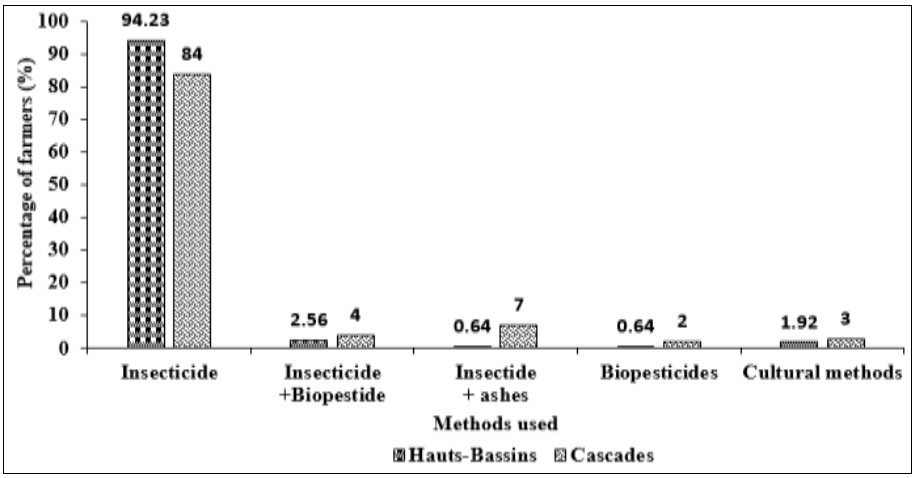


Fig 4: Proportion of farmers using different methods to control fall armyworm in selected regions of Burkina Faso

Farmers' perception on insecticide efficacy

Evaluating farmers' perceptions of the effectiveness of insecticides against the FAW showed that in the Cascades region, 56% of those surveyed thought that insecticides were not effective in controlling the FAW, while in the Hauts-Bassins region, 72% of farmers noticed that insecticides were effective against the FAW (Figure 5).

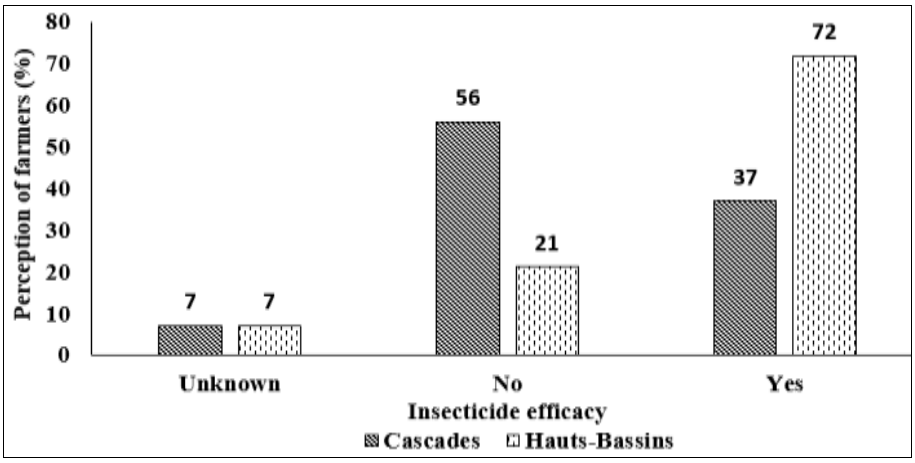


Fig 5: Knowledge of insecticide efficacy against fall armyworm in selected regions of Burkina Faso

Assessment of farmers' knowledge of natural enemies associated with fall armyworm

The proportion of farmers regarding their knowledge of the existence of natural enemies associated with fall armyworm are different through the regions (figure 6). In the Cascades and Hauts-Bassins regions, 74% and 80.77% of farmers respectively were unaware of the existence of natural enemies of the fall armyworm.

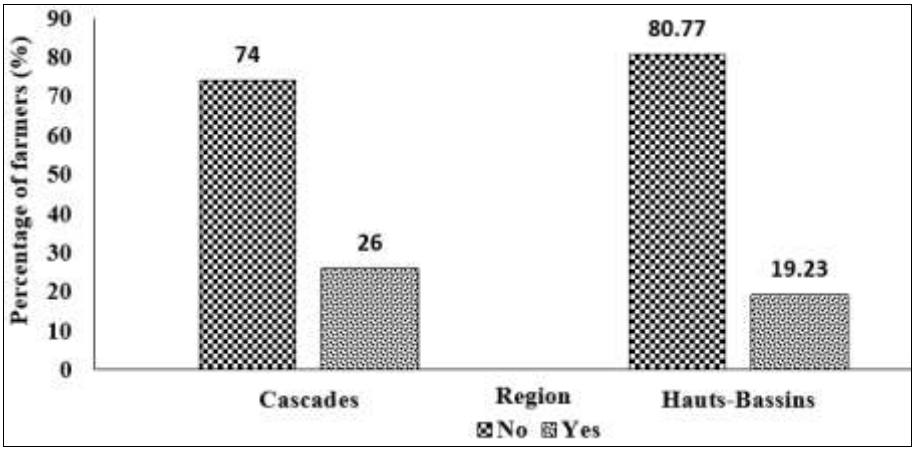


Fig 6: Knowledge of fall armyworm natural enemies amongst cereal farmers in selected regions of Burkina Faso

In both regions, the majority of farmers did not know examples of natural enemies of the fall armyworm, i.e. 87% of farmers in the Cascades region and 95% in the Hauts-Bassins. The natural enemies known by farmers during the survey were mainly predators including spiders, beef pick and toads (figure 7).

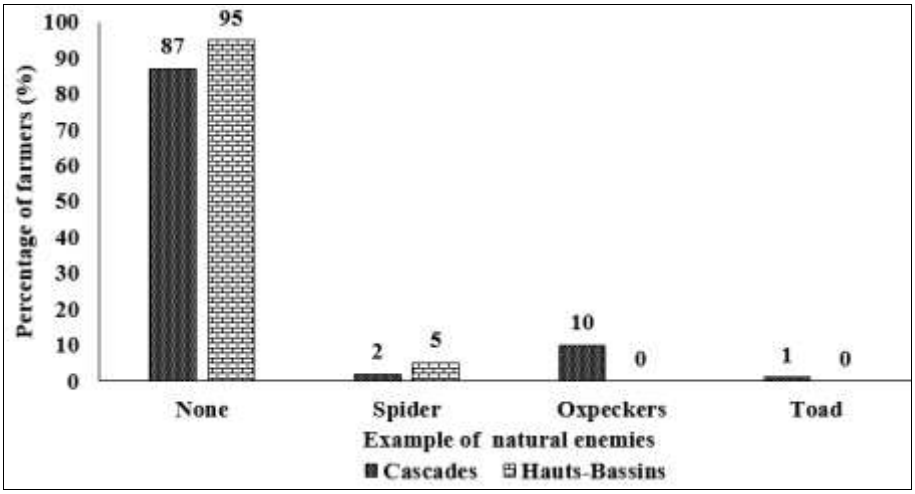


Fig 7: Proportion of farmers with knowledge of recorded natural enemies in selected regions of Burkina Faso

Results shown that 85% of farmers in the Cascades and 67% of farmers in the Hauts-Bassins had encountered at least one of the four main parasitoid species shown in images during the survey, in their fields (Figure 8).

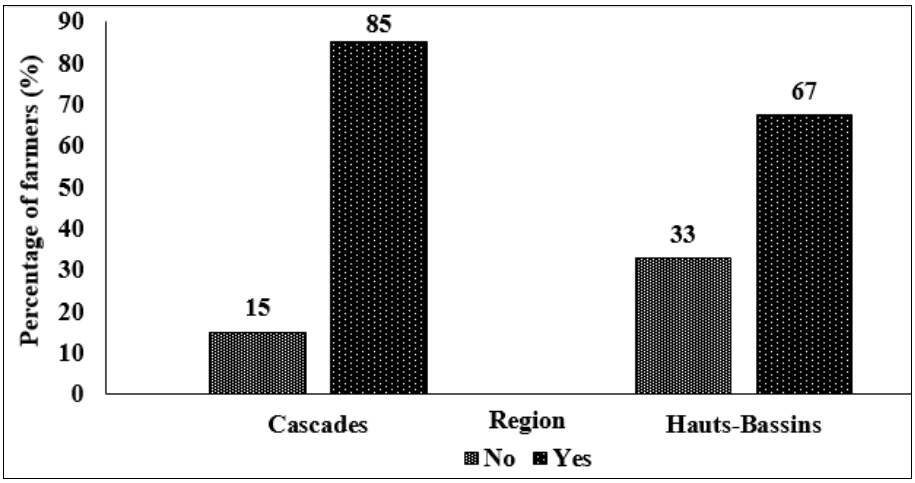


Fig 8: Proportion of farmers with knowledge of fall armyworm parasitoids in selected regions of Burkina Faso

Farmers' recognition of parasitoids identified during the surveys

Some farmers encountered at least one of the four parasitoids in their fields (Figure 9). In the municipality of Bobo-Dioulasso, Siniena and Tiéfora, more than half of farmers reported the presence of at least one of the four parasitoids in their fields. Based on farmers' observations, the most abundant parasitoid species were *Chelonus bifoveolatus* and *Coccygidium luteum*. In the municipality of Bama, the most abundant parasitoid species were *Charops* sp. and *Coccygidium luteum*. In the municipality of Koumbia, only a minority of farmers reported the presence of parasitoids in their fields. In both regions, no farmer uses these natural enemies to control fall armyworm.

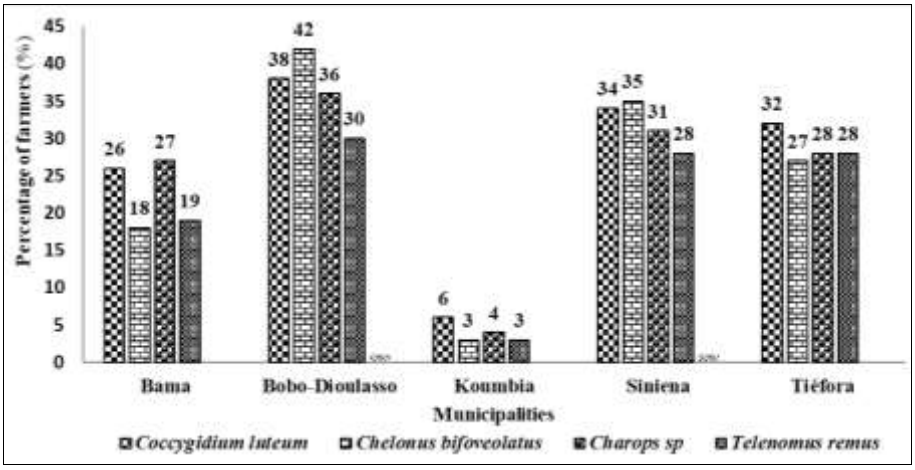


Fig 9: Parasitoid species reported by farmers in selected regions of Burkina Faso

Discussion

Investigations carried out among farmers in the Hauts-Bassins and Cascades region made it possible to identify the social characteristics of the farmers, the management methods used and their level of knowledge of natural enemies, mainly parasitoids. The farmer surveys revealed that very few women were involved in cereal crop production in our study area. This could be explained by the fact that women have limited access to land, and only 8% of farmlands is exploited by them [21]. The most active population was between 26 and 45 years old in both regions; the level of education of these farmers was relatively low, with agriculture as their main occupation. These results are similar to those obtained by [22] and [23], who respectively noted that agricultural practice was highly gender dependent in Africa and men were the most represented, the majority of whom were between 31-60 years old. These socio-demographic characteristics of the farmers are similar to those reported in Burkina Faso by [24] who had conducted surveys on the emergency response to the *Spodoptera frugiperda* invasion in Africa in nine regions of Burkina Faso. The same findings are reported by [25], who conducted surveys on the perception and management strategy of *S. frugiperda* on maize, millet and sorghum by farmers in western Burkina Faso.

Among farmers surveyed, 95.70% said they were familiar with the fall armyworm (FAW). Our results corroborate those of [26-28] who reported that 91.80% of growers in Benin, 93% in Ethiopia and 97% in Kenya and Togo recognized *S. frugiperda*. Among them only 26% had never received training in cereal crop production, while only 14% had been made aware of the various methods of managing the FAW. The low level of education of the cereal farmers could lead to non-compliance with pesticide application doses, protective measures on pesticide use, as well as pre-harvest intervals, potentially resulting in cases of intoxication of Farmers and consumers [29, 30].

Several methods were used alone or in combination by farmers, and the main strategy used (84-94%) was application of synthetic insecticide. This may be explained by the accessibility of chemical insecticides and their acquisition costs, on the one hand, and by the effectiveness of insecticides compared with other pest control methods, on the other. These results corroborate those of [25], who observed that 97.75% of farmers used only chemical insecticides in FAW control [23]. In Ethiopia [28]; in Togo [26], in Kenya and Ethiopia also noted that *S. frugiperda* was mainly managed by chemical control. A minority of farmers (2% and 3% respectively) used only bio-insecticides and cultural methods in the Cascades region. Our results are similar to those obtained by the [5] during a study on the impact of the FAW on maize production, livelihoods and food security in the Centre-Ouest, Haut-Bassins and Sud-Ouest regions, which showed that none of the farmers surveyed used practices such as push-pull, pheromone traps or bio-control. The low use of cultural methods could be due to the fact that most of the farmers surveyed had not been made aware of the various methods of managing the FAW, and particularly of the cultural methods (Detection and destruction of eggs, detection of the first larval stages on plants) that could help reduce the rate of FAW infestation in the fields.

With regard to their perception of the effectiveness of insecticides, opinions diverged in the two regions; in the Cascades region, 56% of farmers thought that insecticides were not effective, compared with 21% of farmers in the Hauts-Bassins This variation can be explained by a number of factors, including non-compliance with insecticide application rates, frequency of application, source of supply, product quality, education level, age and gender of the grower. Our results corroborate those of [31], who showed that pesticide efficacy was influenced by the user's level of education. In the search for alternative methods to chemical control, studies in Burkina Faso and several other African countries have identified numerous indigenous parasitoids associated with *S. frugiperda* [10, 15, 17, 32]. However, in Burkina Faso, the majority of farmers had no idea of their existence, only few of them recognized spiders, oxpeckers and toads as examples of caterpillar predators. Our results are similar to those obtained by [33], who noted in their survey on the evaluation of farmers'

knowledge of the diversity of the entomofauna of sorghum and groundnut in Burkina Faso that farmers' knowledge of natural enemies was limited to a few predators, including spiders, praying mantises, wasps, forficulae and predatory red ants, and none of the people surveyed mentioned parasitoids. Such a situation could be explained by the fact that farmers have a low level of education, and few of them have received training in FAW management methods.

Most farmers in both regions recognized having encountered at least one of the parasitoid species presented to them in images and identified during our studies of the FAW parasitic complex. The parasitoid species most frequently encountered in the fields by farmers were *Coccygidium luteum*, *Chelonus bifoveolatus*, *Charops* sp. and *Telonumus remus*. Farmers' limited knowledge of natural enemies is a real constraint, limiting their contribution to pest management. This lack of awareness of natural enemies leads farmers to consider them as crop pests, which are also sprayed during field treatments. This situation could be explained by the fact that there is ignorance of the use of biological pest control, hence the low awareness of farmers in recognizing and maintaining the survival of beneficial insects. According to [33] educational measures need to be taken to help farmers improve their ability to differentiate between natural enemies and insect pests in their fields, and also to develop their reflex to preserve natural enemies by reducing the use of chemical insecticides and adopting more environmentally-friendly control methods, such as the use of resistant varieties and appropriate cultural practices. Very few data exist on producers' knowledge of natural enemies and efforts must be made at national level to develop large-scale awareness-raising programs for farmers on the usefulness and recognition of natural enemies in order to guarantee the success of biological control against *S. frugiperda*. The fall armyworm remains a real threat to cereal production in Africa, and chemical control alone is not the solution. What is needed is integrated management against this pest, in which biological control plays a very important role, guaranteeing the health of producers, consumers and the environment, and conserving biodiversity.

Conclusion

This study shows that since its invasion in Burkina Faso, chemical insecticides remain the main tools used in the management of the fall armyworm. Biological control using natural enemies, remains little known by farmers. In both study regions, most farmers were unaware of the existence of natural enemies, and considered all insects encountered in their fields to be crop pests. As a result, none of the farmers used natural enemies to control the fall armyworm. Biological control being an important component of integrated pest management, farmers need to be made aware of the existence, recognition, importance and preservation of natural enemies. Preserving them means preserving the environment by reducing the frequency with which chemical insecticides are used.

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Conflict of Interests

The authors have confirmed that there is no conflict of interests associated with this publication.

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