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Farmers' knowledge and management practices of the fall armyworm (*Spodoptera frugiperda* Smith) in Burkina Faso

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Description of the subject. The fall armyworm *Spodoptera frugiperda* Smith has recently invaded sub-Saharan African countries where it causes significant losses to maize since 2016.

Objectives. In this study, we examined farmers' knowledge of the fall armyworm, changes in pest management practices, and the safety of insecticide use by farmers since the recent invasion of the pest in Burkina Faso.

Method. Data were collected through a survey of 197 maize farmers.

Results. The majority of the farmers (96%) had experienced the fall armyworm invasion, mainly on maize, but also on sorghum and rice. Almost none of them (7%) used chemical insecticides to control maize pests before the arrival of the pest. Since then, 84% have used chemical insecticides, but various measures have also been implemented: cultural practices (48%) such as early planting, crop associations and fertilization; physical control (29%, *i.e*, handpicking, application of sand and ash) and applications of aqueous extracts of *Azadirachta indica* and *Khaya senegalensis* (12%). Most farmers do not use protective equipment when handling insecticides. Although they can name several natural enemies of the fall armyworm based on the photographs presented to them, they are generally unable to describe their beneficial role.

Conclusions. We recommend evaluating the effectiveness of alternatives to chemical insecticides, publishing information on locally available insecticides that effectively control fall armyworm, and training farmers on proper pesticide application methods and natural enemy recognition.

Keywords. Invasive species, communication, pest control, maize, Indigenous Peoples' knowledge, botanical insecticides.

Connaissances des producteurs et méthodes de gestion de la chenille légionnaire d'automne (*Spodoptera frugiperda* Smith) au Burkina Faso

Description du sujet. La chenille légionnaire d'automne *Spodoptera frugiperda* Smith a récemment envahi les pays d'Afrique subsaharienne où elle cause des pertes importantes au maïs depuis 2016.

Objectifs. Dans cette étude, nous avons examiné les connaissances des agriculteurs sur la chenille légionnaire d'automne, les modifications de pratiques de gestion des bioagresseurs et la sécurité liée à l'utilisation des insecticides que les agriculteurs utilisent depuis l'invasion récente du ravageur au Burkina Faso.

Méthode. Les données ont été collectées au travers d'une large enquête menée auprès de 197 producteurs de maïs.

Résultats. La majorité des agriculteurs (96 %) ont été victimes de l'invasion de la chenille légionnaire d'automne, principalement sur le maïs, mais également sur le sorgho et le riz. Très peu (7 %) utilisaient des insecticides dans cette culture avant l'arrivée du ravageur. Depuis, 84 % d'entre eux utilisent des insecticides chimiques, mais des mesures variées ont également été mises en place : des pratiques culturales (48 %) telles que les semis précoces, associations culturales et fertilisation ; la lutte physique (29 %, écrasement des larves, application de sable et cendre de bois) et des applications d'extraits aqueux d'*Azadirachta indica* et *Khaya senegalensis* (12 %). La plupart des agriculteurs n'utilisent pas d'équipement de protection individuelle lors de la manipulation des insecticides. Bien qu'ils puissent nommer plusieurs ennemis naturels de la chenille légionnaire d'automne sur la base des photographies qui leur sont présentées, ils sont généralement incapables de décrire leur rôle bénéfique.

Conclusions. Nous recommandons d'évaluer l'efficacité des alternatives aux insecticides chimiques, de publier des informations sur les substances disponibles localement qui contrôlent efficacement la chenille légionnaire d'automne, et de former les agriculteurs aux bonnes méthodes d'application des insecticides et à la reconnaissance des ennemis naturels.
Mots-clés. Espèce envahissante, communication, lutte antiravageur, maïs, savoirs autochtones, insecticide d'origine végétale.

1. INTRODUCTION

The fall armyworm *Spodoptera frugiperda* Smith (Lepidoptera: Noctuidae) was first reported in 2016 in Africa (Goergen et al., 2016). The pest is native to America and has been reported to feed on more than 350 host plants belonging to 76 plant families (Montezano et al., 2018). Since then, the fall armyworm has become the most damaging pest, especially affecting maize production (Goergen et al., 2016; Rwomushana et al., 2018). To mitigate the impact of this invasive species, most national governments have made synthetic insecticides accessible to their farmers (Sisay et al., 2019; Tambo et al., 2020). In Burkina Faso, US$ 397,000 were allocated for the supply of insecticides, education and protective clothing, and more than 12,000 liters of synthetic insecticides were sprayed on 14,000 ha of fall armyworm infested fields, during the 2018–2019 crop season (MAAH, 2018). Given that the fall armyworm is new to Africa, it is essential to conduct species-targeted research to generate the necessary knowledge to develop context-specific management strategies. While some recent studies have investigated farmers' perceptions and management practices of fall armyworm in Kenya, Uganda, Tanzania (Midega et al., 2018), Zambia (Kansiime et al., 2019), Zimbabwe (Chimweta et al., 2020), Benin (Houngbo et al., 2020) and Ghana (Asare-Nuamah, 2020), there is no such information from Burkina Faso. This study aims to fill this gap.

2. MATERIALS AND METHODS

2.1. Study area

This study was conducted between August and November 2020 among 197 maize producers in three communes located in two agro-ecological zones of Burkina Faso: Bobo-Dioulasso (Sudanian zone), Ouahigouya and Ziniaré (Sudano-Sahelian zone) (**Figure 1**).

2.2. Questionnaire development and delivery

A semi-structured questionnaire was provided to trained interviewers (the complete list of questions can be found as supplementary material). Interviews were conducted in the local language of the community during face-to-face interactions between the farmer and the interviewer. The basic information collected included farmer's name, gender, age, educational level, training in plant protection. The farmer's knowledge about the fall armyworm and perception to how they consider the pest problem, and the effectiveness of the available control measures were assessed. Farmer's knowledge was evaluated using photographs of the different stages of the fall armyworm, damage, as well as natural enemies. We also questioned on the actions that farmers undertake to control the fall armyworm. Additional information was requested for those who used insecticides: trademarks (the packaging was checked during the interview), active ingredient, number of applications per crop cycle, measures undertaken in case of ineffectiveness, management safety of pesticides, potential health side effects. To determine whether the insecticides were registered or not, the latest lists provided by the Sahelian Pesticides Committee (CSP) were used (CSP, 2018, 2019).

3. RESULTS

Table 1 summarizes the profiles of the farmers, their knowledge and perceptions of the fall armyworm and the control methods implemented. Although the fall armyworm is a new pest for Africa, the majority (96.0%) of respondents could correctly identify the larval stage based on pictures (unlike eggs and adult moths). The fall armyworm attacks mainly maize with infestation rates of 10-70% mostly. Farmers also reported other crops affected such as sorghum, rice and tomato.

Farmers' knowledge of the natural enemies of the fall armyworm was found to be limited to a few predatory birds (26.2%). Concerning other predators such as earwigs, ants, spiders and coccinellids, they were mainly observed by the producers in maize fields. They are barely never identified as beneficials and in some cases, they are considered as pests that also need to be eliminated.

More than 92.8% of farmers were not using any synthetic insecticides to control insect pests in maize production before the arrival of the fall armyworm in Burkina Faso. The most common measure was the application of synthetic insecticides (84.3%), followed by cultural practices (47.9%), physical control (28.8%) and botanical insecticides (11.7%). Most farmers

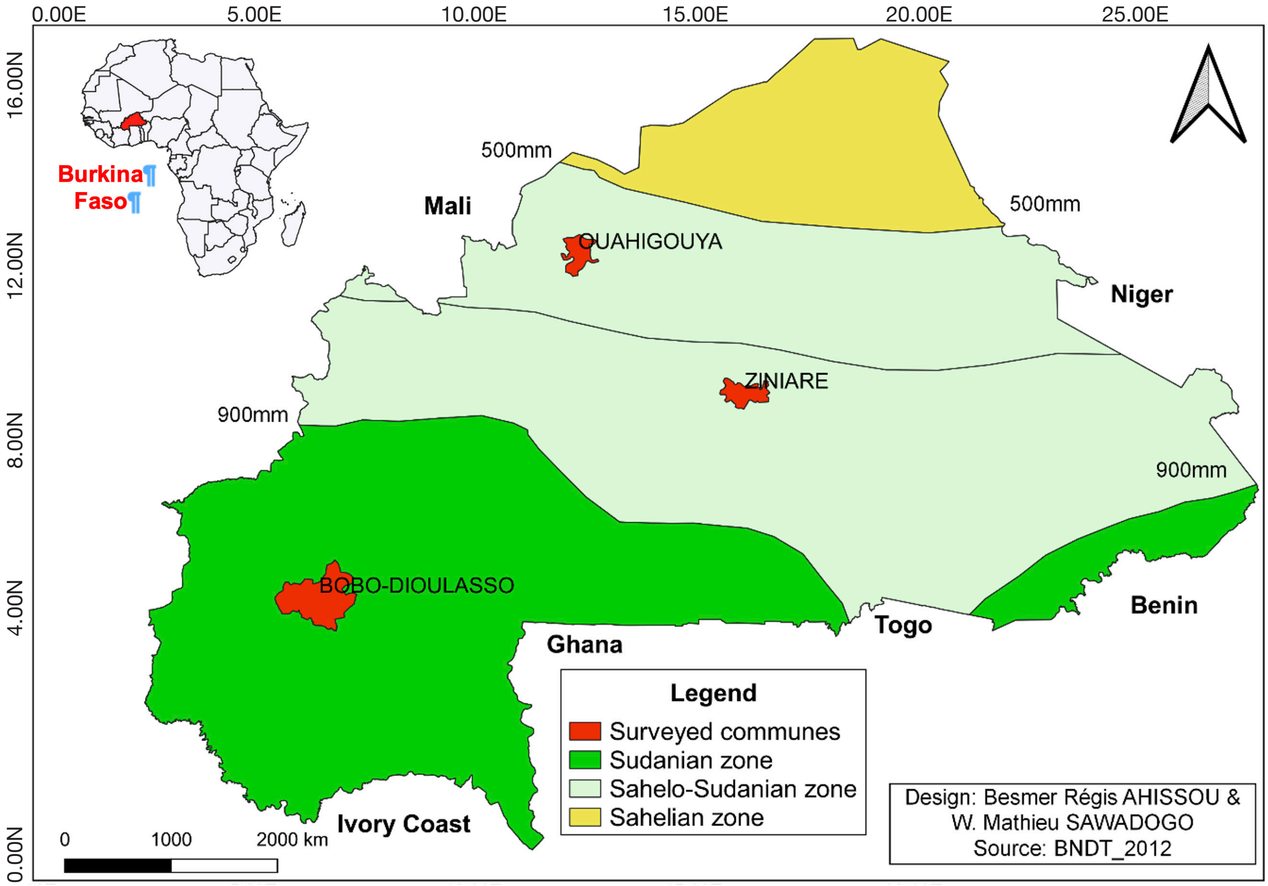

Figure 1. Map showing the location of the surveyed communes in Burkina Faso — *Carte montrant la localisation au Burkina Faso des communes étudiées*.

applied insecticides twice (28.5%) or three times (35.4%) without any specific timing.

At the time the survey was conducted, there were no registered chemical insecticides recommended for fall armyworm management in Burkina Faso and other member countries of the CSP. Among the 21 insecticides used by the interviewed farmers, three insecticides (Duel, Kapaas and Lambda Power) were not registered by CSP. All insecticides are formulated from 14 active ingredients and are available as single (15), binary (5) or ternary (1) formulations (**Table 2**). The most popular active ingredients used were: emamectin benzoate (62.4%), lambda-cyhalothrin (19.4%), abamectin (18.2%) and deltamethrin (10.9%). However, this study showed that the majority of maize producers (96.5%) did not use protective gear, even though they were aware of the harmful effects of chemical pesticides.

4. DISCUSSION

Similarly to previous studies conducted in Zambia (Kansiime et al., 2019) and Benin (Houngbo et al., 2020), the majority of the farmers could identify the fall armyworm larvae despite its new pest status. According to farmers' observations, the pest was present in Burkina Faso at least 1 or 2 years before it was officially reported. It is probable that the insect was present, but that its damage became significant and noticeable later. Apart from maize (the main crop attacked in all zones), sorghum and rice are particularly attacked by the fall armyworm in their main production zones, Ziniaré and Bobo-Dioulasso respectively.

Like most other African farmers, they did not apply insecticides to maize for pest control before the first detection of the fall armyworm (Caniço et al., 2020). They had to quickly implement new control methods, which mainly include synthetic insecticides (Tambo et al., 2020). They are easily accessible for farmers (Houngbo et al., 2020) and have been freely distributed in affected areas by African governments, including Burkina Faso (MAAH, 2018). Due to treatment failures associated with the use of certain molecules (lambda-cyhalothrin, abamectin and deltamethrin), we recommend proper communication on locally available insecticides that effectively control fall armyworm (Ahissou et al., 2021a, 2022).

Table 1. Farmers' characteristics, knowledge and perceptions of fall armyworm and control methods — *Caractéristiques, connaissance et perceptions de la chenille légionnaires d'automne par les agriculteurs et méthodes de contrôle*.

Variables	**Bobo-Dioulasso (N = 73)**	**Ziniaré (N = 64)**	**Ouahigouya (N = 60)**	**Mean N = 197)**
Gender (%)				
Male	87.7	89.1	86.7	87.8
Female	12.3	10.9	13.3	12.2
Age (years)	44.5 ± 9.9	44.1 ± 10.3	43.5 ± 11.9	44.1 ± 10.7
Education (%)				
No formal education	35.6	33.3	43.3	37.4
Literacy	31.5	25.4	15.0	24.0
Primary school	24.7	33.3	33.3	30.4
Secondary school	8.2	4.8	8.3	7.1
Tertiary education	0.0	3.2	0.0	1.1
Years of farming experience (%)				
< 5	6.9	9.4	6.7	7.7
5 - 10	12.3	18.8	33.3	21.5
10 -15	26.0	18.8	20.0	21.6
> 15	54.8	53.1	40.0	49.3
Maize field size (ha)	1.7 ± 2.1	1.2 ± 0.9	1.4 ± 1.2	1.5 ± 1.5
Training in crop pest management (%)	26.4	21.9	18.3	22.2
Known fall armyworm larval stage (%)	94.5	98.4	95.0	96.0
First attacks of the fall armyworm (%)				
2015	5.6	6.2	5.1	5.6
2016	48.6	50.0	33.9	44.2
2017	41.7	37.5	54.2	44.5
2018	4.2	3.1	6.9	4.7
Major crops attacked (%)				
Maize	100	100	98.3	99.4
Sorghum	17.8	31.2	13.6	20.9
Rice	15.1	1.7	3.4	6.7
Tomato	8.2	7.9	5.1	7.1
Cowpea	4.1	10.9	5.1	6.7
Infestation levels in maize fields (%)				
< 10%	29.2	15.6	13.6	19.5
10 – 40%	22.2	28.1	40.7	30.3
40 - 70%	36.1	53.1	35.6	41.6
> 70%	12.5	3.1	10.1	8.6
Know fall armyworm natural enemies				
No knowledge	57.5	54.7	40.0	50.7
Birds	12.3	28.1	38.3	26.2
Insecticide before the invasion (No)	94.5	93.8	90.0	92.8
Pest control methods (%)				
Synthetic insecticides	90.3	82.8	79.7	84.3
Cultural practices				
Fertilization	16.7	21.9	50.0	29.5
Early planting	5.6	12.5	13.3	10.5
Intercropping and rotation	1.4	17.2	5.0	7.9
Physical control (%)				
Handpicking	15.3	18.8	23.3	19.1
Ash and sand	4.2	3.2	8.3	5.2
Soaps or liquid detergents	5.6	6.2	1.7	4.5
Botanical insecticides* (%)	11.1	17.2	6.7	11.7

Table 1 (continued). Farmers' characteristics, knowledge and perceptions of fall armyworm and control methods — *Caractéristiques, connaissance et perceptions de la chenille légionnaires d'automne par les agriculteurs et méthodes de contrôle*.

Variables	Bobo-Dioulasso (N = 73)	Ziniaré (N = 64)	Ouahigouya (N = 60)	Mean N = 197)
Reponses to chemical insecticide inefficacy (%)				
Increase treatment frequency	75.4	58.5	43.5	59.1
Increase pesticide dose	32.3	49.1	54.3	45.2
Change insecticides	10.8	24.5	8.7	14.7
Mix insecticides	7.7	13.2	13.0	11.3
Nothing	9.2	5.7	10.9	8.6
Number of insecticide applications (%)				
Once	16.9	30.2	14.9	20.7
Two times	27.7	15.1	42.6	28.5
Three times	36.9	41.5	27.7	35.4
Four times and more	18.5	13.2	14.9	15.5
Insecticide selection (%)				
Pesticide vendor's advice	46.2	39.6	21.3	35.7
Personal experience	15.4	35.8	51.1	34.1
Agriculture officer's advice	24.6	13.2	12.8	16.9
Another producer's advice	33.8	32.1	14.9	26.9
Combination of methods (%)				
Insecticides + cultural practices	19.2	28.1	50.0	32.4
Insecticides + physical control	17.8	21.9	18.3	19.3
Insecticides + botanical insecticides	12.3	15.6	6.7	11.5
Security of pesticide management (%)				
Protective gear	1.4	3.4	5.8	3.5
Nose mask	66.2	71.2	78.8	72.1
Gumboots	36.6	37.3	44.2	39.4
Gloves	28.2	35.6	38.5	34.1
Reported side effects of insecticide (%)				
Eyes or skin irritation	62.3	41.4	60.8	54.8
Headaches	52.2	29.3	33.3	38.3
Tiredness	11.6	13.8	5.9	10.4

* *Azadirachta indica* A.Juss and *Khaya senegalensis* A.Juss

Some farmers have implemented alternative methods, including the use of ash, sand and aqueous extracts of neem and African mahogany (Kansiime et al., 2019; Babendreier et al., 2020). In West Africa, based on the recommended rates, chemical insecticides cost about 4,000-10,000 FCFA per hectare, while neem-based products can cost 14,000-20,000 FCFA. It is therefore very unlikely that resourceless farmers can afford anything other than cheap chemicals. However, increased use of bioinsecticides such as neem and Bt products could be achieved through a national policy to subsidize and recommend their use as in Ghana (Rwomushana et al., 2018).

In the present survey, farmers' knowledge of the natural enemies was limited to birds. However, fall armyworm predators were observed, including Forficulidae (*Diaperasticus erythrocephalus* Olivier and *Forficula senegalensis* Serville), Coccinellidae (*Cheilomenes sulphurea* Olivier) and Formicidae (*Pheidole megacephala* Fabricius) (Ahissou et al., 2021b). Considering their performance, it is important to train farmers on the recognition, preservation of natural enemies and the implementation of cultural practices that promote their action.

A low level of education correlated with a lack of training favors the misuse of pesticides, increasing the health risk. The situation was similar in Ghana, Rwanda, Uganda, Zambia and Zimbabwe, where low use of protective clothing among smallholders was reported (Tambo et al., 2020). The farmers' reported adverse health effects show the importance of protective equipment when handling pesticides.

Table 2. Insecticides used by maize farmers for fall armyworm control in Burkina Faso — *Insecticides utilisés par les cultivateurs de maïs pour le contrôle de la chenille légionnaire d'automne au Burkina Faso*.

Trade name	Active ingredient	%[a]	WHO Class[b]	Recommended crop
Abalone 18 EC	Abamectin 18 g·l^{-1}	4.2	II	Tomato
Acarius	Abamectin 18 g·l^{-1}	7.3	II	Tomato
Bio K 16	*Bacillus thuringiensis* 16 000 UI·mg^{-1}	5.5	U	Gardening crop
Bomec 18 EC	Abamectin 18 g·l^{-1}	1.2	II	Tomato
Caiman B19	Emamectin benzoate 19.2 g·l^{-1}	6.7	II	Cotton, tomato
Conquest C 176 EC	Acetamiprid 32 g·l^{-1} + cypermethrin 144 g·l^{-1}	4.8	II	
Cypercal 50 EC	Cypermethrin 50 g·l^{-1}	6.1	III	Cotton, tomato
Décis 25 EC	Deltamethrin 25 g·l^{-1}	1.2	II	Tomato
Duel CP 186 EC	Cypermethrin 36 g·l^{-1} + profenofos 150 g·l^{-1}	4.2	II	Cotton
Emacot 019 EC	Emamectin benzoate 19 g·l^{-1}	24.8	II	Cotton
Emacot 050 WG	Emamectin benzoate 50 g·kg^{-1}	30.9	II	Cotton
Emapyr	Emamectin benzoate 20 g·l^{-1} + Pyriproxyphen 60 g·l^{-1}	5.5	III	Cotton
Kapaas	Emamectin benzoate + abamectin + acetamiprid	5.5	II	Cotton
K-Optimal	Lambda-cyhalothrin 15 g·l^{-1} + acetamiprid 20 g·l^{-1}	1.2	II	Cotton
Lambda Power	Lambda-cyhalothrin 25 g·l^{-1}	3.6	II	Cotton, gardening crop
Laser 480 SC	Spinosad	1.8	III	Cotton, tomato, cabbage
Radiant 120 SC	Spinetoram	1.2	III	Tomato
Savahaler	Methomyl 250 g·kg^{-1}	6.1	II	Cabbage
Sunhalotrin 2,5% EC	Lambda-cyhalothrin 25 g·l^{-1}	14.5	III	Tomato
Tamega	Deltamethrin 25 g·l^{-1}	9.7	II	Tomato, sweet pepper
Thunder 145 O- TEQ	Imidacloprid 100 g·l^{-1} + betacyfluthrin 45 g·l^{-1}	0.6	II	Cotton

[a] Percentages are based on farmers that used insecticides for fall armyworm control — *les pourcentages se basent sur les agriculteurs qui utilisaient des insecticides pour le contrôle de la chenille légionnaire d'automne*; [b] II: moderately hazardous — *modérément dangereux*; III: slightly hazardous — *légèrement dangereux*; U: unlikely to present acute hazard in normal use — *peu susceptible de présenter un danger aigu dans des conditions normales d'utilisation*.

5. CONCLUSIONS

Farmers' continuous training on the proper use of chemical pesticides and the recognition and preservation of natural enemies is crucial. Several alternatives of pest control also need to be scientifically evaluated for scaling up and then properly communicated.

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