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Farmers' knowledge, perceptions, and management practices of the new invasive pest, fall armyworm (*Spodoptera frugiperda*) in Ethiopia and Kenya

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ABSTRACT
This paper reports for the first time on farmers' knowledge, perceptions and management practices of the fall armyworm (*Spodoptera frugiperda*) in Ethiopia and Kenya. A survey of 343 smallholder maize farmers was conducted. Most farmers in Ethiopia and Kenya had knowledge about fall armyworm; they could identify it mainly during its larval stage. Furthermore, most farmers in Ethiopia (93%) and Kenya (97%) encountered damage by fall armyworm in their farms. They estimated an average of 32% crop damage in Ethiopia and 47.3% of crop damage in Kenya, with an estimated yield reduction between 0.8 to 1 tonnes/ha. Nearly half of the farmers relied on chemical insecticides to control this pest. The majority (60%) of the farmers in Kenya perceived that insecticides were not effective in controlling fall armyworm as compared to most farmers (46%) in Ethiopia who perceived that chemical spray is effective for the control of fall armyworm. In Ethiopia, 26% of the farmers combined handpicking larvae with insecticide sprays, whilst 15% of the farmers practiced only handpicking. The present study highlights the need to develop management strategies for fall armyworm based on farmers' needs and priorities.

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1. Introduction

The genus *Spodoptera* (Lepidoptera: Noctuidae) consists of several species of moths that are important pests worldwide, including *S. littoralis* (Boisduval) (the Egyptian cotton leaf worm), *S. exempta* (Walker) (the African armyworm), *S. litura* (Fabricius) (the tobacco caterpillar), *S. exigua* (Hübner) (the beet armyworm), *S. ornithogalli* (Guenée) (the yellow striped armyworm), and *S. frugiperda* (J.E. Smith) (the fall armyworm) (Belay 2011). The fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) is native to the Americas and it is a key pest of maize (*Zea mays* L.) and many other crops throughout the Americas (Sparks 1979; Abrahams et al. 2017).

The fall armyworm has a migratory behaviour with a high dispersal capacity that allows the pest to quickly spread along the range of its host plants. The life cycle of fall armyworm varies according to the season. It completes its life cycle in about 30 days during the summer, in 60 days in the spring and autumn, and in 80–90 days during the winter (Belay 2011). The fall armyworm is described as the second most damaging agricultural pest, causing total losses ranging from \$39 to \$297 million annually (Sparks 1986). It is also reported that the fall armyworm is the major insect pest of maize in Brazil (Sena et al. 2003), causing annual losses of US \$400 million (Figueiredo et al. 2005)

The fall armyworm eggs are usually laid in mass on the upper surface of the leaves and the number of eggs per mass can vary from 100 to 200, with up to 1,000 total eggs production per female. There are usually six larval instars in fall armyworm. The first and second instars feed on one side of the leaf skeletonizing it, whilst the final instars feed on most plant parts causing considerable damage (Abrahams et al. 2017). Duration of the larval stage tends to be about 14 days during the summer and about 30 days during cool weather (Capinera 2014). The last instar drops to the ground and pupate in the soil for about eight to nine days during the summer or for about 20–30 days during the winter in Florida (Sparks 1979; Capinera 2014).

The fall armyworm has recently introduced to Africa; it was first reported in Nigeria in West Africa in early 2016. It soon spread in southern Africa in late 2016 and by early 2017 was confirmed in East Africa. Currently, the pest is ravaging crops in over 20 African countries. The fall armyworm attacks more than 80 different plant species, including maize, a major food staple in sub-Saharan Africa, upon which more than 300 million people depend (Abrahams et al. 2017; Cock et al. 2017).

Empirical information regarding subsistence farmers' perceptions, knowledge, and management of the fall armyworm has not been reported. We hypothesize

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that farmers could develop coping strategies in dealing with and managing the fall armyworm in a way that influences the status of this pest. Assessing farmers' perceptions, knowledge, and pest management strategies for the control of this pest is critically important for setting a research agenda, designing extension strategies, and formulating research that meet farmers' demands (Khan and Damalas 2015; Olaniran et al. 2015). Understanding farmers' socio-economic factors, their knowledge and perceptions, and their current management practices and potential constraints of the fall armyworm control are critical steps towards developing sustainable integrated management strategies for this pest.

There are no systematic studies carried out on the fall armyworm in Africa, except reports from affected countries and media outlets. The objective of the present study was to assess farmers' perceptions, knowledge, current management practices, and potential constraints in management practices of the fall armyworm among maize subsistence farmers in Ethiopia and Kenya.

2. Materials and methods

2.1. Study area description

The survey was conducted in three districts of Ethiopia and five sub-counties of Kenya (Figure 1). The sites in Ethiopia were Shabe Sombo (07°27.840'N 36°25.314'E), Dedo (07°36.812'N 36° 50.089'E) and Seka Chekorsa (07°33.879'N 36°38.786'E). The sites in Kenya were Tongaren (00°84.182'N 35°00.449'E), Webuye East (00°58.770'N34°75.557'E), Mt. Elgon (00°50.456'N 34°43.450'E), Kabuchai (00°36.023'N 34 °37.336'E), and Kipkelion East (00°12.409'S 35° 33.609'E). These areas are among the main maize-growing areas characterized by maize and common bean cropping systems integrated with livestock production.

2.2. Data collection

Both in Ethiopia and Kenya, the survey districts were purposively selected based on the report of occurrence of the fall armyworm through official organization websites and news channels. In each country farmers were randomly selected for interviews from sampling lists obtained from the agricultural office of each district and sub-counties. A total of 343 farmers were randomly selected for interviews, with 150 farmers from Ethiopia and 193 farmers from Kenya. Surveys were carried out from May to July 2017. A semi-structured questionnaire was administrated by trained agricultural enumerators after pre-testing the questionnaire for its validity. The pre-testing was conducted among selected farm households in the surveyed areas. Apart from verifying the validity of the questionnaire, the pre-testing was found to be useful for familiarizing the enumerators with the questionnaire as well as handling of the survey. The information collected included: farmers' socio-economic profiles, farm characteristics, knowledge, and perceptions of the fall armyworm, incidence of the pest, and management practices for its control. Farmers were interviewed in their local language (Afan Oromo) in Ethiopia and in Kiswahili in Kenya. The questionnaires were discussed during face-to-face interviews with individual farmers and addressed information on farmers' socio-economic profile (e.g. age, gender, education, and family size), farm size, maize production systems and purposes of production. Farmers were also asked to prioritize maize pests, their perceptions of the fall armyworm, estimated losses by this pest and management practices undertaken.

2.3. Data analysis

Survey data were summarized and descriptive statistics (means and percentages) were calculated using the Statistical Package for Social Sciences (SPSS). For each question, the percentage of farmers who gave similar responses was calculated for each site. Those who did not respond to certain questions were excluded from the calculations. In instances where a farmer indicated more than one reason regarding a given question, percentages were calculated for each group of similar responses. Percentages of farmers in the two countries who gave similar responses to a question were calculated based on the total number of farmers who responded to each question. Comparative statistical tools, such as Chi-square and one-way analysis of variance (ANOVA), were conducted to assess differences regarding socio-demographic and farm characteristics, knowledge and perceptions of fall armyworm and management practices. The level of significance was set at 0.05 and means were separated by Tukey's HSD (Honestly Significant Difference) test.

3. Results

3.1. Socio-economic profile

Most respondents (93%) surveyed in Ethiopia were male; however, in Kenya the majority were female (56%). The average household size of the farmers comprised about six individuals in Ethiopia, with an education average of 4.5 years, whilst the average household size of the farmers was seven individuals in Kenya, with an education average of 8.2 years. Farmers in Ethiopia owned an average of 2.5 ha total land, of which maize occupied about 1 ha; however, in Kenya, farmers held an average of 4.3 ha land, of which maize was allocated an average of 1.7 ha of land. The majority

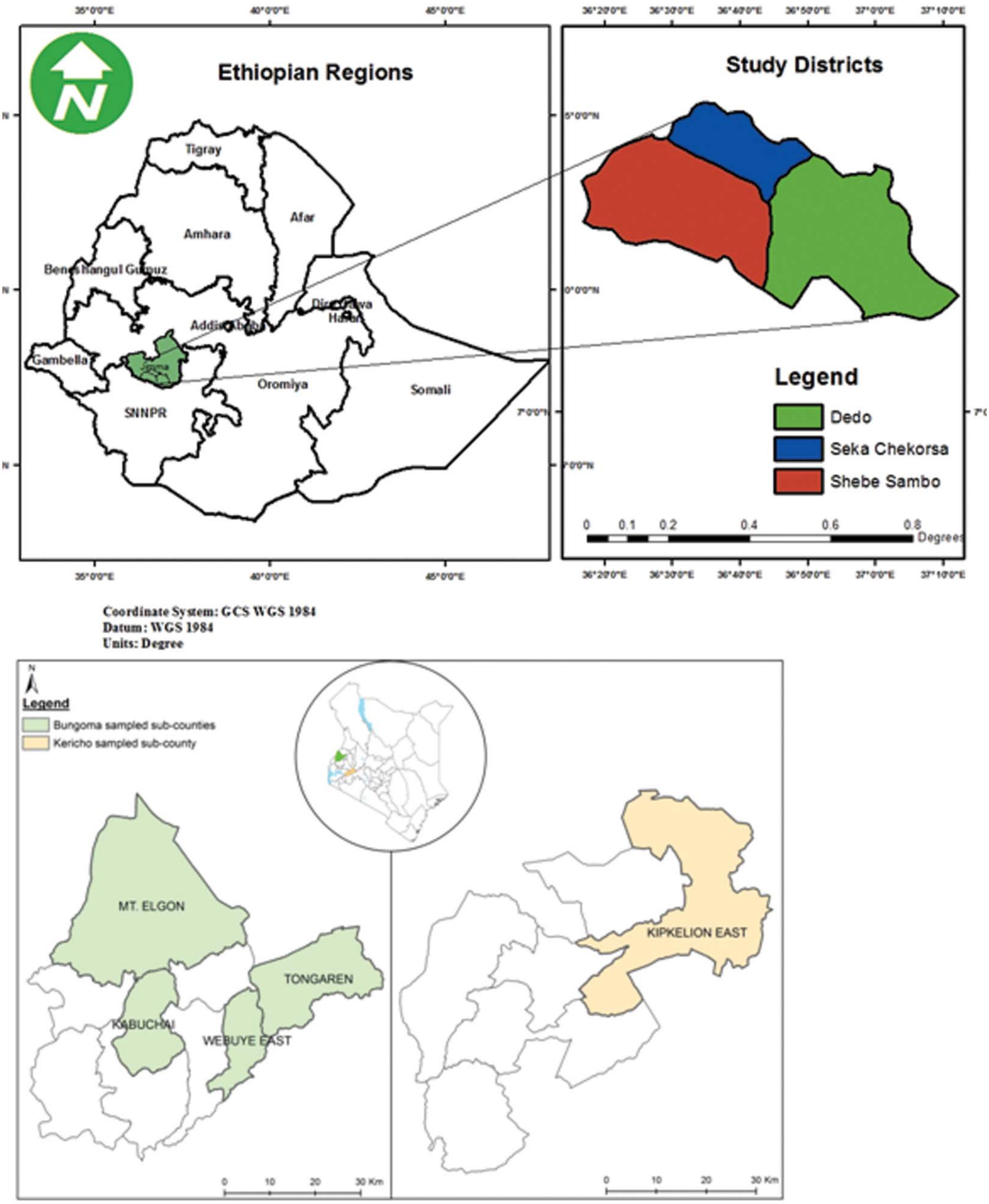

Figure 1. Map showing study districts in Ethiopia and Kenya.

of the farmers in Kenya (66%) grew maize for home consumption, while in Ethiopia 81% of the farmers grew maize both for home consumption and sell (Table 1).

Farmers in Ethiopia reported different types of maize farming systems. The majority of the farmers (69%) reported to grow maize as a rain-fed crop followed by maize in wetland areas (using residual moisture) and irrigated maize (19%) (Figure 2(A)). On the other hand, in Kenya, all farmers reported to grow maize as a rain-fed crop (Figure 2(B)). Most farmers (92%) reported maize as a main food crops grown in Ethiopia, followed by sorghum (3%) and rice (3%) (Figure 3(A)). In Kenya, all farmers reported to grow maize as a main food crop, followed by beans (68.3%) and groundnuts (22.5%) (Figure 3(B)). Farmers in Ethiopia (48%)

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Table 1. Socio-economic characteristics of the respondents in different districts of Ethiopia and Kenya.

Variable	Ethiopia						Kenya							
	Shebe Sombo *N* = 55	Dedo *N* = 50	Seka Chekorsa *N* = 45	Mean *N* = 150	χ^2	*F*-test	Tongaren *N* = 35	Webuye East *N* = 45	Mt. Elgon *N* = 8	Kabuchai *N* = 13	Kipkelion East *N* = 19	Mean *N* = 120	χ^2	*F*-test
Gender														
Male	92.7	94	93.3	93.3	0.068^{ns}		42.9	35.6	37.5	76.9	47.4	44.2	7.257^{ns}	
Female	7.3	6.0	6.7	6.7			57.1	64.4	62.5	23.1	52.6	55.8		
Age	43.4	41	41	41.9		0.589^{ns}	41.8	43.9	46.4	49.5	43.3	44		0.757^{ns}
Family size	5.9	5.7	6.8	6.2		2.886^{ns}	5.4	6.2	7.4	7.9	7.6	6.9		2.382^{ns}
Education level	4.6	3.9	4.8	4.5		1.429^{ns}	8.9	8.2	7.7	7.9	8.2	8.2		1.565^{ns}
Total land size	2.6	2.1	2.7	2.5		2.676^{ns}	4.2	2.0	4.3	5.9	5.3	4.3		4.032**
Land for maize production	1.1	0.9	1.3	1.1		2.364^{ns}	2.8	1.1	1.5	1.6	1.3	1.7		4.402**
Purpose of maize production														
Consumption	11	18	27	18	5.737^{ns}		48.6	74	87.5	76.9	42.4	65.9	17.506*	
For sell	1.8	0	0	0.7			2.9	9.0	0	7.7	4.8	4.9		
Both	87	82	73	81			48.6	17.8	12.5	15.4	52.6	31.7		
Willingness to pay														
High	45.5	16.0	43.2	34.9	14.801*		100	100	100	100	100	100		
Based on observation	52.7	82.0	54.5	63.1			0	0	0	0	0	0		
Indifferent	1.8	2.0	2.3	2.0			0	0	0	0	0	0		

Note: Statistically significant at $*P < 0.05$, $**P < 0.01$, $***P < 0.001$; ns = not significant.

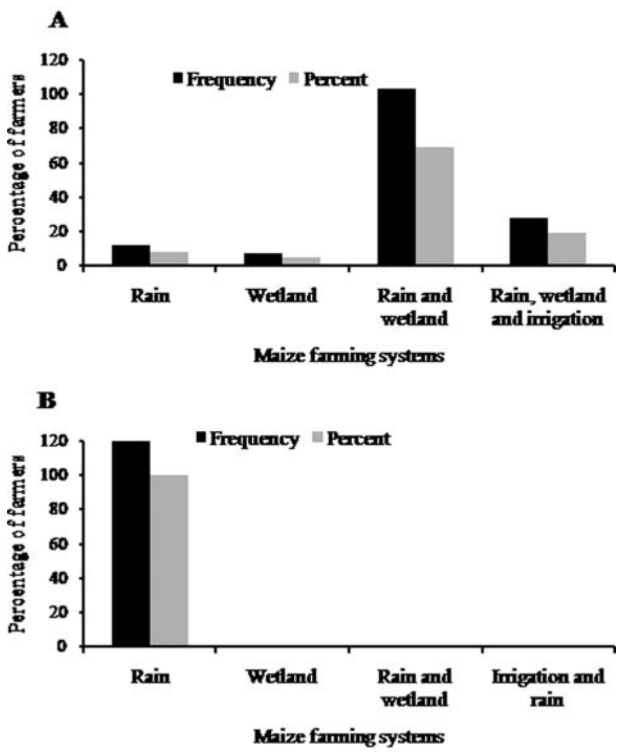

Figure 2. Types of maize farming systems in different districts of (A) Ethiopia and (B) Kenya.

mentioned coffee as the major cash crop followed by vegetables (20%) and maize (15%) (Figure 3(C)), while in Kenya most farmers (55%) mentioned maize as the major cash crop, followed by Irish potato (20.8%) and sugarcane (18.3%) (Figure 3(D)).

3.2. Farmers' knowledge and perceptions of FAW infestation

Most farmers (99%) in all districts of Ethiopia were aware of the fall armyworm (Table 2). Similarly, in Kenya all farmers had knowledge about the fall armyworm (Table 3). Farmers in Ethiopia reported that they had observed this pest for an average of 4 weeks, while in Kenya for 7.6 weeks. Most farmers in Ethiopia (95%) and Kenya (100%) encountered damage by the fall armyworm in their farms. Farmers in Ethiopia estimated maize infestation by the fall armyworm ranging from 24.1% to 39.4%, with an average of 32%, whereas farmers in Kenya estimated maize infestation ranging from 38% to 53.9%, with an average of 47.3%. Farmers in the two surveyed countries considered that damage by the fall armyworm could inflict an estimated maize yield reduction of about 934 kg/ha in Ethiopia and 1381 kg/ha in Kenya. Most farmers in Ethiopia (82%) and Kenya (97%) perceived an increasing trend of spread of the fall armyworm in their areas.

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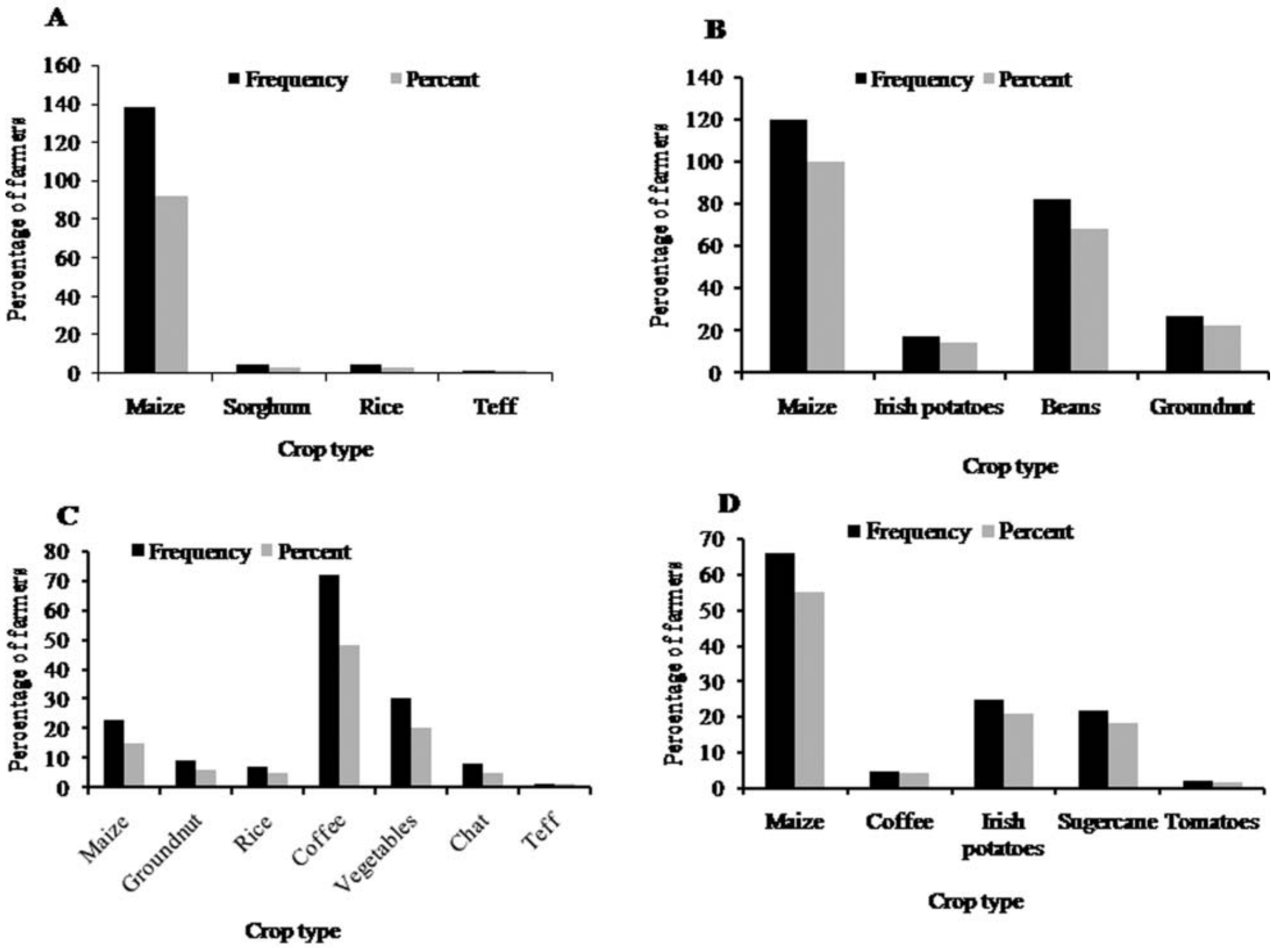

Figure 3. Major food crops grown in (A) Ethiopia and (B) Kenya, and major cash crops in (C) Ethiopia and (D) Kenya.

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Table 2. Farmers' knowledge and perceptions of FAW in Ethiopia.

	Districts					
Variable	Shebe Sombo $N = 55$	Dedo $N = 50$	Seka Chekors $N = 45$	Mean $N = 150$	χ^2	*F*-test
Know FAW	100	98.0	100	99.3	2.013^{ns}	
Time observed FAW (weeks)	3.8	4.4	3.8	4		2.522^{ns}
Encountered FAW damage (Yes %)	98.2	98.0	88.9	95	6.003*	
Maize plants damaged by FAW (%)	39.4	33.8	24.1	32		6.984**
Expected maize yield (kg/ha)						
If no damage by FAW	2440	1688	1834	2008		3.638*
Infested by FAW	1105	1018	1097	1074		0.160^{ns}
Extent of spread of FAW						
Increasing	98.2	88	60	82	30.109***	
Remain the same	1.8	10	29	13		
Decreasing	0	2	11	4		
Pest control method						
Chemical spray	52.7	42	50	48.3	40.972***	
Chemical and Pick-off by hand	38.2	12	27.2	25.8		
Pick-off by hand	5.5	36	2.3	14.6		
No control	3.6	10	20.5	11.3		
Types of insecticide used						
Ethiolathion	78.2	54	88.6	74	43.429***	
Dursban 48%EC	21.4	46	11.4	26		
Effectiveness of sprayed chemicals						
Effective	41.8	42	55.6	46	18.086*	
Fair	27.3	20	18.9	22		
Not effective	30.9	38	25.1	32		
Drawback of chemicals						
Affect human health	12.7	12	18.7	14	17.481**	
Kills bees	5.5	10	18.9	11		
Deformed shape of maize	1.8	2	2	2		

Note: Statistically significant at *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$; ns = not significant.

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Table 3. Farmers' knowledge and perceptions of FAW in Kenya.

	Districts							
Variable	Tongaren *N* = 35	Webuye East *N* = 45	Mt. Elgon *N* = 8	Kabuchai *N* = 13	Kipkelion East *N* = 19	Mean *N* = 120	χ^2	F-test
Know FAW	100	100	100	100	100	100		
Time observed FAW (weeks)	10.5	10	6	8	3.6	7.6		26.445***
Encountered FAW damage (Yes %)	100	100	100	85	100	97	10.719*	
Maize plant damaged by FAW (%)	38	54	40.6	50	53.9	47.3		4.783**
Expected maize yield (kg/ha)								
If no damage by FAW	5036	2634	2824	2456	4416	3610		1.030^{ns}
Infested by FAW	2335	1074	1581	1277	1406	2229		8.393***
Extent of spread of FAW								
Increasing	100	48	100	100	100	97.6	40.551***	
Remain the same	0	0	0	0	0	0		
Decreasing	0	12	0	0	0	2.4		
Pest control method								
Chemical spray	35	74	37.5	30.8	63.2	48.1	24.491**	
Traditional methods	58	13	37.5	69.2	21.0	39.8		
Pick-off by hand	0	0	2.4	0	0	0.5		
No control	7	13	25	0	15.8	12.2		
Types of insecticide used								
Duduthrin	43.3	35	0	50	33.3	32.3		
Pentagon	16.7	0	0	0	0	3.3		
Match	16.7	0	0	0	0	3.3		
Karate	0	0	0	0	8.3	1.7		
Rocket	0	0	30	0	0	6		
Albaz	0	0	0	0	8.3	1.7		
Jackpot	0	0	30	0	0	6		
Not sure the insecticide used	23.3	65	30	50	28.2	39.3		
Effectiveness of sprayed chemicals								
Effective	10	10	0	0	8.3	5.7	52.732***	
Fair	40	39	25	25	41.7	34.1		
Not effective	50	51	75	75	50	60.2		
Drawback of chemicals								
Affect human health	0	0	0	0	0	0	67.115***	
Kills bees	0	0	0	0	0	0		
Deformed shape of maize	0	0	30	0	33	12.6		

Note: Statistically significant at *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$; ns = not significant.

3.3. *Farmers' knowledge of the stages of fall armyworm, indicators of damage and level of severity*

When farmers were asked to compare the levels of damage caused by the fall armyworm and stem borer, the common pest of maize in Africa, most farmers in all surveyed districts in Ethiopia and Kenya perceived the fall armyworm as a serious pest causing higher level of damage compared to stem borer (Table 4). Most farmers were able to differentiate the fall armyworm and the stemborer based on larval color, eating habit, head orientation, and faecal excretion on maize leaves (Figure 4(A, C)). The majority of the farmers in Ethiopia and Kenya reported that they had observed the larvae of the fall armyworm on infested maize plant, while very few farmers observed eggs and adult stages of the insect (Figure 4(B, D)). Extension agents and media were the main information sources of farmers about the fall armyworm (Figure 5(A, B)).

3.4. *FAW control practices*

Farmers in Ethiopia and Kenya applied different pest control methods to mitigate the fall armyworm damage, with chemical sprays being the main control method reported by most farmers (48%) in Ethiopia and Kenya (Tables 2 and 3). In Ethiopia, about a quarter of the farmers reported combined use of chemical spray and

Table 4. Farmers' perceptions of severity of FAW and stemborer in Ethiopia and Kenya

			% Response	
Country	District	Level of damage	FAW	Stemborer
Ethiopia	Shebe Sombo	High	82	0
		Medium	14	36
		Low	0	56
		No	4	8
	Dedo	High	52	0
		Medium	42	32
		Low	4	62
		No	2	6
	Seka Ckekorsa	High	71	0
		Medium	9	67
		Low	9	22
		No	11	11
	χ^2		14.361**	17.523**
Kenya	Tongaren	High	90	0
		Medium	10	0
		Low	0	100
		No	0	0
	Webuye Eas	High	100	0
		Medium	0	0
		Low	0	79
		No	0	21
	Mt. Elgon	High	100	0
		Medium	0	10
		Low	0	85
		No	0	5
	Kipkelion East	High	100	0
		Medium	0	0
		Low	0	100
		No	0	0
	Kericho	High	100	0
		Medium	0	32
		Low	0	62
		No	0	6
	χ^2		4.939^{ns}	42.297***

Note: Statistically significant at *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$; ns = not significant.

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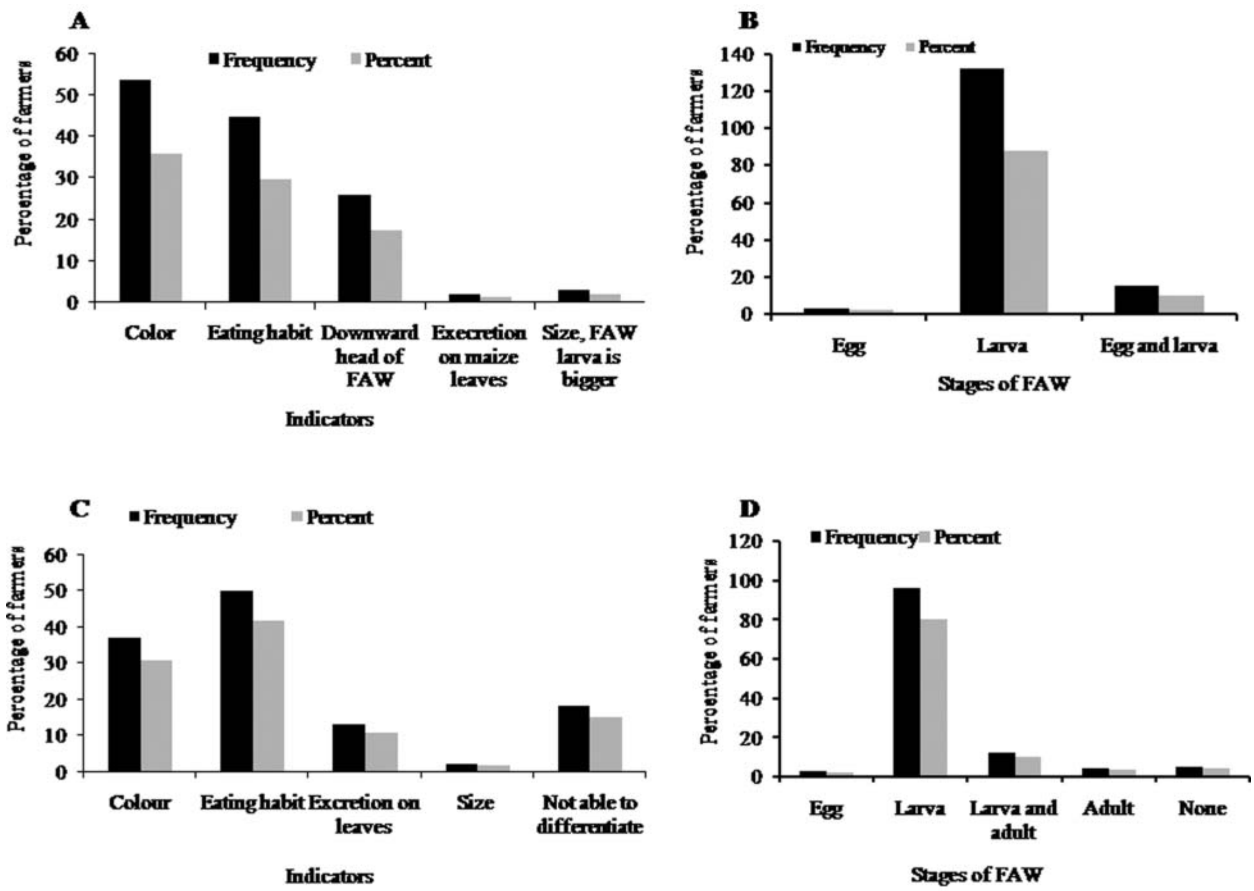

Figure 4. Indicators of differences between FAW and stem borer by farmers in (A) Ethiopia and (C) Kenya, and stages of FAW damage observed by farmers in (B) Ethiopia and Kenya (D).

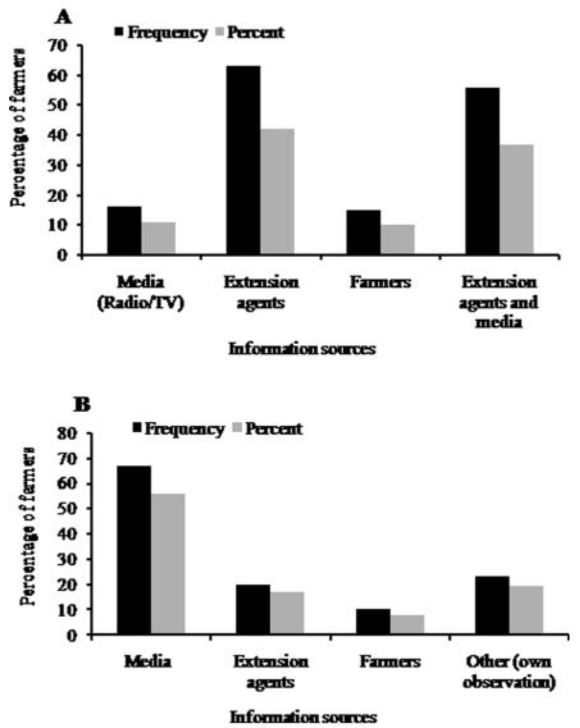

Figure 5. Main information sources of farmers regarding FAW in (A) Ethiopia and (B) Kenya.

handpicking, whereas about 14% of the farmers mentioned using handpicking only. In Kenya, about 39% of the farmers mentioned traditional control methods (such as adding soil to plant whorl, drenching tobacco extracts to damage plants) and only farmers in Mt. Elgon County reported handpicking. Most farmers (48%) in Ethiopia used Ethiolathion 50% EC (malathion) and Dursban 48% EC (chlorpyrifos), while in Kenya farmers used seven insecticides with Duduthrin (Lambda-cyhalothrin) being reported by most farmers (32%). Most of the farmers in Ethiopia (46%) perceived that chemical sprays were effective for the control of the fall armyworm, while 60% of farmers in Kenya perceived that sprayed insecticides were not effective. When farmers were asked about the drawbacks of chemical insecticides, few of them in Ethiopia mentioned that insecticides affect human health (14%) and kill bees (11%), whereas in Kenya deformed shape of maize was reported by about 12% of the farmers as the only drawback of insecticides.

4. Discussion

The present study showed that the recent invasion of the fall armyworm in Africa threatens the production of maize, which is a stable food crop for many people in the region. Farmers in Ethiopia and Kenya

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estimated maize yield reduction between 0.77 to 1 tonnes/ha due to damage by the fall armyworm. Although this pest was detected in East Africa recently (Abrahams et al. 2017), the present study demonstrated that apart from Mt. Elgon region of Kenya, most farmers in the surveyed districts of Ethiopia and Kenya had knowledge about the fall armyworm. This might be attributed to the information disseminated by the media and the extension agents in the region since the first detection of this invasive insect pest in Africa (FAO 2017; KARLO 2017).

Farmers in Ethiopia and Kenya mentioned that they had observed the fall armyworm in their farm nearly for about two months and most farmers experienced damage by this pest with estimated percent infestation ranging from 32% to 47%. The fall armyworm coupled with native lepidopteran maize stem borers in the region (Midega et al. 2015) are serious threats to food security and contribute to losses of income for smallholder farmers. Farmers were also able to recognize the fall armyworm based on different indicators, and the majority of them observed larvae attacking maize plants. The larvae caused severe damage at all maize crop growth stages; however, the damage was more serious at early growth stages of the plants (vegetative stage) (Goergen et al. 2016). The first and second larval instars feed on leaf tissue from one side by skeletonizing the leaf surface; the third and above larval instars make holes in the leaves from all sides by perforating the leaves leading their way to the leaf whorl. Holes are formed due to feeding of folded leaves and when the leaves grow out, a row of three or four small to large holes are seen across the leaf (Belay 2011; Abrahams et al. 2017). Late-instar larvae damage the growing points of the plants causing defoliation and dead hearts (death of the growing tip). Furthermore, older larvae burrow into maize tassels and ears, causing extensive damage (Abrahams et al. 2017; Capinera 2017).

Although there are no registered pesticides for the control of the fall armyworm both in Ethiopia and Kenya, farmers in the surveyed districts reported that they had sprayed different types of pesticides. However, the majority of the farmers in Kenya perceived that sprayed insecticides were not effective in controlling this pest. Insecticide spray targeted at the larval stage may not be effective, unless spraying is done in early or late time of the day, as the larvae are relatively inactive during the day. In addition, contact pesticides are not effective for older larvae, unless applied when the larvae are young (Goergen et al. 2016; Abrahams et al. 2017). Insecticides are widely used in Latin America for the control of the fall armyworm (Andrew 1988). As it is true in many other insect pest species, insecticides are important management options in the fall armyworm control. Repeated applications of insecticides may be necessary; for example in Brazil, on average five sprays were required for the fall armyworm control in maize (Ribeiro et al. 2014), and often in daily basis in the south-eastern United States during the silking stage of sweet corn (Capinera 2017).

As an emergency response, governments in Africa, including Kenya and Ethiopia, deployed massive use of pesticides to the affected areas to rescue the crops and halt further expansion of the pest. The invasive nature of the pest and the lengthy process of pesticide registration forced farmers to use non-registered pesticides for the fall armyworm control. This highlights the need for emergency registration of pesticides in exceptional cases. Most subsistence farmers in Africa do not apply pesticides to maize to control pests; nevertheless, they do practice cultural control methods which deter or kill pests, such as maize intercropping with common beans, handpicking and killing of caterpillars, application of tobacco extracts, wood ashes and soils to leaf whorls (Abate et al. 2000). Following the sudden invasion of the fall armyworm, farmers were supplied with pesticides by governments, often for free, to spray this pest without proper training and adequate spray equipment. However, besides supplying pesticides, it is important to train farmers on the proper methods of pesticide application to circumvent inefficacy of pesticides, health risks, and cases of resistance development.

At the time of this study in May to July 2017, the fall armyworm was reported from about 25 African countries in less than 6 months. This calls for rapid action, immense awareness creation, and technological innovation, along with national, regional, and international collaborations to tackle the danger of the fall armyworm and avoid heavy economic losses among smallholder farmers across Africa. Crucial concerted efforts from international research centres, national research and extension programs, international development organizations, policy makers, and donor communities in Africa are required to develop and deploy an effective integrated pest management strategy, which can provide sustainable solutions for effectively tackling the adverse effects of the fall armyworm.

The fall armyworm is a regional threat to food security; hence, it requires a sustainable and effective integrated pest management strategy. The present study showed that subsistence farmers' knowledge and perceptions of the fall armyworm management varied between Ethiopia and Kenya. This suggests the need to develop management strategies for this pest based on farmers' needs and priorities. In conclusion, innovations designed to control fall armyworm in maize under subsistence farming in Africa should consider farmers' knowledge of the pest, socioeconomic circumstances, and current pest management practices.

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