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SHORT COMMUNICATION

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First report of the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), natural enemies from Africa

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Abstract

The fall armyworm (FAW), *Spodoptera frugiperda*, is a major pest of maize in North and South America. It was first reported from Africa in 2016 and currently established as a major invasive pest of maize. A survey was conducted to explore for natural enemies of the fall armyworm in Ethiopia, Kenya and Tanzania in 2017. Smallholder maize farms were randomly selected and surveyed in the three countries. Five different species of parasitoids were recovered from fall armyworm eggs and larvae, including four within the Hymenoptera and one Dipteran. These species are new associations with FAW and were never reported before from Africa, North and South America. In Ethiopia, *Cotesia icipe* was the dominant larval parasitoid with parasitism ranging from 33.8% to 45.3%, while in Kenya, the tachinid fly, *Palexorista zonata*, was the primary parasitoid with 12.5% parasitism. *Charops ater* and *Coccygidium luteum* were the most common parasitoids in Kenya and Tanzania with parasitism ranging from 6 to 12%, and 4 to 8.3%, respectively. Although fall armyworm has rapidly spread throughout these three countries, we were encouraged to see a reasonable level of biological control in place. This study is of paramount importance in designing a biological control program for fall armyworm, either through conservation of native natural enemies or augmentative release.

KEYWORDS
diptera, hymenoptera, insect parasitism, maize, *Spodoptera frugiperda*

1 | INTRODUCTION

Maize is the most important staple food crop in Africa, where it is grown predominantly by smallholder farmers (FAOSTAT, 2017). Currently, however, the production of maize is threatened by the fall armyworm, *Spodoptera frugiperda* (J.E.Smith) (Lepidoptera: Noctuidae). The pest, which is indigenous in the Americas, is highly polyphagous, causing economic damage in various crops such as maize, sorghum, beans and cotton (Abrahams et al., 2017; Day et al., 2017). This invasive pest was first reported in West Africa in late 2016 (Goergen, Kumar, Sankung, Togola, & Tamo, 2016); by early 2017, the pest invaded Sub-Saharan Africa. Recent reports confirmed the occurrence of fall armyworm in 28 countries in Africa (Cock, Beseh, Buddie, Cafa, & Crozier, 2017; Day et al., 2017) indicating the rapid spread of the pest in the African continent, threatening the food security of millions of people. Recent studies conducted by Centre for Agriculture and Biosciences International in 12 maize-producing countries showed that, without control, fall armyworm can cause maize yield losses ranging from 8.3 m to 20.6 m tonnes per year (Day et al., 2017).

In North and South American countries where fall armyworm is a major problem, chemical insecticide use is a common practice.

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For example, in Brazil, an average of five insecticide sprays per maize cycle may be required (Ribeiro et al., 2014). Invasion of fall armyworm in Africa alarmed governments of different countries in Africa to apply different insecticides in maize fields as an emergency response to fall armyworm invasion (Kumela et al., 2018). Most smallholder farmers in Africa, however, cannot afford repeated insecticide sprayings. Furthermore, dependence on chemical insecticides results in the development of resistance to major classes of insecticide (e.g., Yu, Nguyen, & Abo-Elghar, 2003), increased risk to human health due to lack of appropriate safety precautions (Day et al., 2017), effects on nontarget organisms and risks for the environment. This highlights the need for the development of integrated pest management (IPM) strategies that are suitable to African smallholder farmers. Given the fact that fall armyworm is a new invasive pest in Africa, apart from reports on its occurrence, natural enemies associated with FAW are not documented for Africa. For IPM development for FAW, therefore, it is imperative to determine recruitment of local natural enemies. The objective of this study was, therefore, to assess association of new local parasitoids with the fall armyworm in Ethiopia, Kenya and Tanzania. This study reports for the first-time parasitoids associated with the fall armyworm in Africa.

2 | MATERIALS AND METHODS

2.1 | Study area description

Survey of fall armyworm natural parasitoids was conducted in major maize growing areas affected with the fall armyworms in Ethiopia, Kenya and Tanzania. The sites in Ethiopia were Hawassa (7°00.89′N 38°23.256E – 7°1.154′N 38°22.568′E), Jimma (7°27.855′N 36°25.32′E – 7°40.137′N 36°47.349′E) and Awash-Melkassa (8°24.842′N 39°19.355′E – 8°25.222′N 39°19.237′E). The study was conducted in five sites in Kenya: Taita Taveta (03°13.336′S 037°44.551′E – 03°81.853′S 037°44.017′E), Kwale (01°30.133′ S 036°53.966′E– 01°35.636′S 036°55.082′E), Homabay (04°19.612′S039°22.450′E–04°20.0101′S039°22.442′E), Machakos (01°07.593′S037°26.396′E–01°13.835′S037°27.363′E) and Transzoia (01°45.711′S037°28.840′E– 01°46.126′S 037°37.761′E). In Tanzania, the sites were Morogoro (S06°26.958′ E037°31.916′– S07°07.533′ E037°30.765′), Tanga (S05°08.100′ E038°55.776′– S 05°44.765′ E038°15.285′) and Pwani (S06°26.666′ E038°20.191′).

2.2 | Assessment of natural enemies of the fall armyworm

In the three countries surveyed, districts/counties were purposively selected based on the report of occurrence of fall armyworm through official country reports. A total of forty-four farms were randomly selected for the survey of natural enemies with 16 farms in Ethiopia, 15 farms in Kenya and 13 farms in Tanzania.

In Ethiopia, the survey was conducted from March to October in 2017. Surveys were conducted in Kenya during July 2017 to October 2017. In Tanzania, the survey was conducted from July to November 2017. Geographical data such as latitude, altitude and longitude were taken in each location. Damaged maize plants were assessed for fall armyworm egg masses, larvae, pupae and parasitoid cocoons, respectively. The egg masses were collected and placed in plastic cups with 5 grams of natural diet (fresh maize leaf). The larvae and pupae were collected and they were placed in rectangular plastic containers (4 cm height × 15 cm width × 21 cm length), covered on top with fine screen from which the parasitoids could not go through the mesh. The larvae were fed with pieces of fresh maize leaves, about 60 g, which were replaced every 48 hr until pupation. The eggs, larvae and pupae were kept in the laboratory at room temperature of 24–26°C, 50%–70% RH and a photoperiod of 12:12 (L:D) h until parasitoids emerged. No parasitoid emerged from pupae. The parasitoids that emerged from the eggs and larvae were recorded every 24 hr. For dead eggs or larvae where nothing emerged, no dissections were made to examine for dead parasitoids. Parasitoids were preserved in 70% ethanol and sent for identification to the Natural History Museum, UK. We did not find multiple parasitism in this study. Per cent of parasitism was calculated by dividing number of larvae parasitized by total number of larvae collected multiplied by 100 (Pair, Raulston, Sparks, & Martin, 1986).

2.3 | Statistical analysis

Per cent parasitism of natural enemies were summarized and descriptive statistics (means and percentages) were calculated using MINITAB 16 statistical software.

3 | RESULTS

In Ethiopia from the total sample of fall armyworm collected, three species of larval parasitoids emerged, that is, *Cotesia icipe* Fernandez-Triana & Fiobe, *Palexorista zonata* (Curran) and *Coccygidium luteum* (Brullé) (Table 1). *Cotesia icipe* was the most common parasitoid that emerged from all surveyed areas of Ethiopia with parasitism ranging from 33.8% in Awash-Melkasa to 45.3% in Jimma. On the other hand, parasitism by a tachinid fly *P. zonata* and *C. luteum* was relatively lower (<6.4%). Different species of egg and larval parasitoids emerged from fall armyworm egg and larvae collected in Kenya, among which the parasitic wasp *Charops ater* Szépligeti and *P. zonata* caused about 12% parasitism, while *Chelonus curvimaculatus* Cameron and *C. icipe* showed low levels of parasitism (<6%). Egg parasitism by *C. curvimaculatus* was quite low (4.8%). In Tanzania, *C. ater* was the dominant larval parasitoid with per cent parasitism of 10%. *C. luteum* caused 4% to 6% parasitism.

4 | DISCUSSION

In this study, five species of parasitoids were recorded from fall armyworm in all three East African countries sampled. Parasitism

TABLE 1 List of fall armyworm parasitoids collected from Ethiopia, Kenya and Tanzania in 2017

Country	Location	Parasitoids	Order: family	Host stages parasitized	% Parasitism	Number of farms
Ethiopia	Hawassa	*Cotesia icipe* Fernandez-Triana & Fiobe	Hymenoptera: Braconidae	Larva	33.8	7
		Palexorista zonata (Curran)	Diptera: Tachinidae	Larva	6.4	
	Jimma	*Coccygidium luteum* (Brullé)	Hymenoptera: Braconidae	Larva	4.6	4
		C. icipe	Hymenoptera: Braconidae	Larva	45.3	
	Awash-Melkasa	*C. icipe*	Hymenoptera: Braconidae	Larva	33.8	5
		P. zonata	Diptera: Tachinidae	Larva	5.7	
Kenya	Taita Taveta	*Charops ater* Szépligeti	Hymenoptera: Ichneumonidae	Larva	12.3	5
	Kwale	*C. luteum*	Hymenoptera: Braconidae	Larva	8.3	3
	Homabay	*P. zonata*	Diptera: Tachinidae	Larva	12.5	1
	Transnzoia	*Chelonus curvimaculatus* Cameron	Hymenoptera: Braconidae	Egg	4.8	2
	Machakos	*C. icipe*	Hymenoptera: Braconidae	Larva	5.6	4
Tanzania	Morogoro	*C. ater*	Hymenoptera: Ichneumonidae	Larva	7.0	3
	Tanga	*C. ater*	Hymenoptera: Ichneumonidae	Larva	10	6
	Tanga	*C. luteum*	Hymenoptera: Braconidae	Larva	6.0	2
	Pwani	*C. luteum*	Hymenoptera: Braconidae	Larva	4.0	2

levels varied considerably among the surveyed farms. Ruíz-Nájera et al. (2007) and Hay-Roe, Meagher, Nagoshi, and Newman (2016) noted that variation in species occurrence and level of parasitism may vary due to differences in geographical locations, agronomic practices, crop type and stage. In Ethiopia, *C. icipe* was the most prevalent parasitoid that occurred in three locations with per cent parasitism ranging from 33.8% to 45.3%. It was also recorded from one location in Kenya, but with lower parasitism (5.6%). Recently Fiaboe, Fernández-Triana, Nyamu, and Agbodzavu (2017) described *C. icipe* which is a new species from eastern Africa and it was reared in Kenya as a solitary parasitoid from Lepidopteran pests *Spodoptera littoralis* (Boisduval, 1833) and *S. exigua* (Hübner, 1808). The authors also stated that this species has been recorded in Madagascar, Saudi Arabia, South Africa and Yemen. The tachinid fly *P. zonata* was the second most abundant larval parasitoid of fall armyworm in Ethiopia with 6.4% parasitism, while in Kenya, *C. ater* and *P. zonata* were the dominant parasitoids with 12% parasitism. *Charops ater* and *C. luteum* were the primary larval parasitoids recorded in Tanzania. From all surveyed sites, *C. curvimaculatus* was the only egg parasitoid found, recovered in Kenya. *Chelonus curvimaculatus* is an egg–larval parasitoid of Lepidoptera which has been recorded from many hosts, including potato tuber moth in South Africa (Broodryk, 1969), pink bollworm, *Pectinophora gossypiella* (Saunders) in US originally collected from Ethiopia and Australia (Hentz, Ellsworth, & Naranjo, 1997) and lepidopteran stem borers *Concofrontia* sp, *Sesamia calamistis* (Hampson) and *Chilo partellus* (Swinhoe) in Botswana (Mutamiswa et al., 2017). Parasitization by *Coccygidium luteum* ranged from 4.6% in Ethiopia to 8.3% in Kenya. This species is widely distributed in Africa including Kenya, Ethiopia, Tanzania, Uganda, Cameroon, Congo, Namibia, Niger, Nigeria, Senegal, etc. This species has been reported to be parasitoids of Lepidoptera such as *S. exempta*, *S. exigua*, *Condica capensis*, *Crypsotidia mesosema* and *Cydia ptychora* (Waspweb, 2018).

Recruitment of native parasitoids and reasonably high parasitism rates suggests the potential for biological control of the pest. *Charops ater*, the main parasitoid of fall armyworm recorded in this study was reported to parasitize African bollworm and other species in Kenya (Van den Berg & Cock, 2000). In addition, *P. zonata* was recorded from African armyworm, *Spodoptera exempta* (Rose, Dewhurst, & Page, 2000). Recruitment of native parasitoids to different invasive insect pests has been reported by several researchers (e.g., Matošević & Melika, 2013; Vercher, Costa-Comelles, Marzal, & Garcìa-Marì, 2005).

In North and South America, which is a native region for fall armyworm, surveys conducted in different countries documented several species of natural enemies. For example, in Mexico Hymenopteran (e.g., *Rogas vaughani* Muesebeck, *R. laphygmae* Viereck, *Chelonus insularis* Cresson) and Dipteran (e.g., *Archytas marmoratus* (Townsend), *Lespesia archippivora* (Riley) and *Archytas* sp.) parasitoids (Ruíz-Nájera et al., 2007); in Honduras, the Braconid *Aleiodes laphygmae* (Viereck) and the Ichneumonid

Campoletis sonorensis (Cameron) were identified as the main parasitoids (Wyckhuys & O'Neil, 2006); in the US *Cotesia marginiventris* (Cresson), *Chelonus texanus* (Cresson), *Chelonus insularis* and *Archytas marmoratus* (Townsend) (Meagher, Nuessly, Nagoshi, & Hay-Roe, 2016). Variation in species occurrence and level of parasitism may vary due to differences in geographical locations, agronomic practices, crop type and stage (Ruíz-Nájera et al., 2007). An inventory of fall armyworm natural enemies in the Americas and Caribbean documented a total of 150 species of parasitoids (Molina-Ochoa, Carpenter, Heinrichs, & Foster, 2003) indicating substantial natural enemy diversity and prospects for biological control.

The present study confirms new associations of several species of natural enemies with fall armyworm in Africa. Information on the occurrence and rates of parasitism of indigenous natural enemies is of paramount importance in designing a biological control program for fall armyworm, either through conservation of native natural enemies or the introduction of new species for augmentative release. The current blanket recommendation and indiscriminate use of pesticides against the fall armyworm may have a negative impact on natural enemies. It is, therefore, crucial to protect natural enemies from the adverse effects of insecticides and design more comprehensive IPM strategies for fall armyworm management in the region.

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AUTHOR CONTRIBUTION

Author 1, author 2, author 3, author 4 and author 5 collected the data. Author 7 and author 8 conceived the research. Author 6 and author 9 conceived the research and wrote the manuscript. All authors read and approved the manuscript.

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