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A survey of cultivated and wild host plants for the invasive fall army worm (*Spodoptera frugiperda*) in Kenya

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Abstract

The fall army worm (FAW), *Spodoptera frugiperda* (J.E.Smith) invaded Kenya in 2017 and is known globally as polyphagous pest. This pest invaded and immediately spread in many regions including Western, Rift valley, Central and Eastern Kenya and has become an important economic pest, posing serious food security threat across the country. This study was carried out to determine the range of host plants (both cultivated crops and wild plants) of FAW and to confirm its occurrence in various regions of the country. The survey was conducted in 13 counties, located between 34° and 37° east longitude and latitude 0°42'N and 03°24'S and altitude range of 905-2500m a.s.l in February and March 2018. The fall army worm was observed on 18 plant species representing *Poaceae* and *Cyperacea* plant families. The frequency of occurrence of fall army worms was 45.8% for maize (*Zea mays* L.) followed by napier grass (*Pennisteum purpurea)* (9.7%) and crabgrass (*Digitaria spp)* (8.0%), sorghum (S*orghum bicolor)* (7.8%), Masai love grass (S*eteria verticillate)* (4.8%) and sudan grass *(Sorghum halapense)* (3.2%). Barn yard grass (*Echinocloa colona)*, Bermuda grass (*Cynodon dactylon)* and sedge grass (*Cyperus rotunda)* each had 2.4% of FAW leaf damage symptoms. The frequency of occurrence of fall army worm on wild finger millet *(Eleusine indica)* and cultivated millet (*Eleusine coracana)* was (2.3%). Fall army worm infestation was high for maize (1.9) followed by crabgrass (1.3) and masai love grass (0.1) compared with the other host plants. The proportion of egg masses (0.2) and number of caterpillars on plants (1 .6) was higher in Maize. More caterpillars were recorded on napier grass (0.4) and crab grass (0.3). The egg masses (0.3 and 0.3) and the numbers of caterpillars (2.2 and 1.6) on maize crop was more in the vegetative V7 and V9 growth stages respectively. Fall army worm infestation was highest in Meru (2.2), Machakos, (1.9), Makueni, Taita and Tharaka Nithi (1.8) and lowest in Narok (1.2), Trans-Nzoia (1.0) and Baringo counties. Mean egg masses was highest in Makueni (0.8), followed by Machakos, Nakuru and Taita (0.4) and was lowest in Tharaka-Nithi, Kakamega and Trans-Nzoia counties. The number of caterpillars in the host plants was highest in Kirinyaga (3.1) followed by Meru (2.3) and Machakos (2.1)

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counties and lowest in Nakuru (0.0) County. 76% of the farms surveyed used insecticide to control fall army worm, except in one farm in Nakuru where pheromone traps were used to manage the pest. Mean fall army worm infestation score (1.5), number of egg masses (0.1) and number of caterpillars (1.4) was higher on cultivated crops and grass weeds growing under irrigated farms compared to those under rain-fed farming systems in the surveyed areas. Different types of insecticides were used across the counties that included; *escort, cyclone duduthrin, profen, pentagon, coragen, actra, ranger* and *bestox*. The study provides important understanding of pest distribution and potential host plants that should be taken into consideration when developing integrated pest management strategies.

Keywords: Fall army worm, *Spodoptera frugiperda*, host plants, farming systems, infestation, IPM, Kenya

Introduction

The fall army worm (*Spodoptera frugiperda* (J. E. Smith) is a serious pest of cultivated plants throughout the world. It is a pest of cereals and many other host plants numbering close to 100 plant species worldwide (Progue, 2002, CABI, 2016). The FAW invaded Kenya possibly late 2016 but was first confirmed in farmer fields in March 2017 in Trans-Nzoia County. Since then, it has quickly spread throughout the country causing severe damage to cereals, particularly, maize and some fodder grass. Fall army worm is one of the prominent pests of cereal crops in East Africa, where the level of infestation can reach up to 100% and with potential of causing up to 50% annual crop loss. For example, farmers in Trans-Nzoia reported yield loss between 0.18 to 2.7 tonnes per acre (Omwoyo *et al.*, 2022). According to a survey conducted by Kumela *et al.* (2018), the pest has now spread and reached many parts and regions of Eastern Africa countries. In Kenya, the pest has spread into various regions including Western and Rift valley regions where much of the country's maize is grown and is becoming an important economic pest, posing serious food security threat.

The preferred hosts are graminaceous plants, including economically important crops such as maize, millet, sorghum, rice, wheat, and sugar cane. Other food sources include cowpeas, groundnuts, cotton, potatoes, soybeans, clover, alfalfa, sugar beet and tobacco (Goergen *et al*, 2016).

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Among vegetable crops, only sweet corn is regularly damaged, but other crops attacked occasionally include, tomatoes, pepper, cole, crucifers, apples, grapes, oranges, papaya, peach, strawberry and a number of flowers. Weeds known to serve as hosts include bent grass (*Agrostis* sp.) crabgrass (*Digitaria* spp.), Johnson grass (*Sorghum halepense*), morning glory (*Ipomoea* spp.), nutsedge (*Cyprus* spp.) pigweed (*Amaranthus* spp.) and sandspur (*Cenchrus tribuloides)* (Barlow and Kuhar, 2009). The year-long warm climate in most parts of the country is ideal for continuous reproduction and increase of FAW. This leads to overlapping generations and occurrence of multiple life stages at any one time. The pest is reported to be able to switch host plants depending on availability but prefers maize over other alternative host plants including grasses (Prasifka *et al*, 2009). Current control of the pest relies on use of insecticides directed against the larval stage of Fall army worm but high tolerance to insecticides, increased cost of production and associated environmental problems jeopardize their continued use (Green bug *et al*, 2002).

Despite their economic importance, little is still known about the alternative host plants in Kenya. This study aimed at determining the range of host plants for cultivated crops and wild plants and the occurrence of the pest in various regions of the country. This information is necessary and important pre-requisite for the development of appropriate control methods.

Materials and methods

Study sites

The survey sites included 13 counties transecting the main maize growing counties of Kenya from coastal to western areas. These regions vary in mean annual rainfall, temperature and evapotranspiration and have distinct agro-ecological zones (Jaetzold *et al*. 2009). The sampled fields included crops grown under both rain-fed and irrigation farming systems.

Fall army worm host is defined as plants on which egg masses and larval instars are present and capable of supporting complete life cycle and development of the insect. Based on the given definition, identification of alternative

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host plants of fall army worm was conducted from 19th to 23rd February 2018 (just before onset of rains) that covered Eastern, Central and coastal regions of the country. The survey for Western and Rift Valley regions was conducted from 19th to 23rd March 2018 (at the start of long rains). The surveyed counties were: Machakos Makueni, Kirinyaga, Tharaka, Meru, Taita, Nakuru, Narok, Bomet, Kakamega, Uasin Gishu, Trans-Nzoia and Baringo.

Sampling methods

Five farm fields were selected for sampling after a distance of every 3 to 5km along motorable roads in each county. In each field, observations were made on five random plants across diagonal transect walk and on the edges of the farms. Data collected included counts of egg masses, number of caterpillars and the level of infestation in each field.

Fall army worm damage or infestation was assessed by scoring for damage symptoms in the whole field on a scale of 1-3 where:

1= no damage or light infestation < 25% plants damaged or infested 2= Average damage and infestation > 25% and < 75% plants damaged or infested 3 = Severe damage and infestation >75 % of plant parts damaged or infested.

The plant samples were identified in the field and others were preserved in herbarium and were later transported to the laboratory where they were identified by the experts.

Data collection and analysis

All the data were subjected to analysis of variance (ANOVA) using General Linear Model, frequency and correlation procedures (SAS-UNIVERSITY ED). Data on infestation, number of egg masses and fall army worm caterpillars were transformed to ($\sqrt{X}$+ 0.5) prior to the analysis. The differences among the treatment means were tested using least significant differences (LSD) at 5% probability level.

Results

Distribution of the pest across counties surveyed

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The list of potential host plants (wild and cultivated) for fall army worm in the surveyed areas of the country (Table 1).

Table 1: Potential host plants of fall army worm in the surveyed regions of Kenya

Family	Common name	Scientific name	Sites
Poaceae	Sorghum	*Sorghum bicolor*	Makueni, Kirinyaga, Nakuru, Bomet, Uasin Gishu and Trans-Nzoia
Poaceae	Sudan grass	*Sorghum halapense*	Makueni, Nakuru, Baringo
Poaceae	Napier grass	*Pennisetum*	Makueni, Kirinyaga, Nakuru, Bomet, Uasin Gishu and Trans-Nzoia
Poaceae	Wheat	*Triticum aestivum*	Narok Uasin Gishu
Poaceae	Barnyard grass	*Echinocloa colona*	Makueni, Machakos, Taita
Cyperacea	Cyperus rotunda	*Sedge grass*	Machakos, Makueni, Baringo
Poaceae	Crab grass	*Digitaria spp*	Machakos, Taita, Nakuru Bomet, Uasin Gishu, Kakamega
Poaceae	Yard grass	*Eleusine indica*	Bomet, Makueni
Poaceae	Finger millet	*Eleusine coracana*	Bomet, Makueni
Poaceae	Signal grass	*Bracharia decumbens*	Bomet
Poaceae	Kikuyu grass	*Pennisetum clandestinum*	Bomet
Poaceae	Guinea grass	*Panicum spp*	Makueni
Poaceae	Love grass	*Eragrostis superba*	Machakos, Makueni
Poaceae	Bermuda grass	*Cynodon dactylon*	Taita, Nakuru, Narok
Poacea	Masai love grass	*Seteria verticillata*	Narok, Bomet, Machakos and Makueni

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Based on leaf damage symptoms, FAW was observed on 18 plant species belonging to *Poaceae* and *Cyperacea* plant families. The frequencies of occurrence of FAW were: Maize (45.8%), napier grass (9.7%), crabgrass (8.0%), sorghum (7.8%), Masai love grass (4.8%) and sudan grass (3.2%). Barn yard grass, bermuda grass and sedge grass each had 2.4% of FAW leaf damage symptoms. The frequencies of occurrence of FAW on wild finger millet and cultivated millet were 2.3%. The frequency of occurrence on the rest of the wild grass weeds and cultivated crops such as sugar cane and wheat (*Triticum aestivum)* in the farms was low. Sorghum, Finger millet, sugar cane, (*Saccharum officinarum)* and wheat were the only cultivated alternate host species from which FAW was observed.

Fall army worm inflict damage on various cultivated crops and wild plants. Its level of infestation varied significantly ($p<0.001$) among the different host plants. However, the proportion of egg masses laid and number of caterpillars in the host plants were not significantly different ($P>0.05$).

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Table 2: Mean fall army worm infestation, number of egg masses and caterpillars on different host plants during field survey conducted during long rains of 2018 Kenya

Common name	Scientific name	Infestation Scale (1-3)	Number of egg masses/plant	Number of caterpillars/plant
Maize	*Zea mays*	1.9	0.2	1.6
Napier	*Pennisteum purpurea*	1.0	0.1	0.4
Star grass	*Digitaria spp*	1.0	0.0	0.0
Sedge grass	*Cyperus rotunda*	1.0	0.0	0.0
Signal grass	*Echinocloa colona*	1.0	0.0	0.0
Love grass	*Eragrostis superba*	1.0	0.0	0.0
Finger millet	*Eleusine coracana*	1.0	0.0	0.0
Wild finger millet	*Eleusine indica*	1.0	0.0	0.0
Sudan grass	*Sorghum halapense*	1.0	0.0	0.0
Sorghum	*Sorghum bicolor*	1.0	0.0	0.2
Guinea grass	*Panicum spp*	1.0	0.0	0.0
Crabgrass	*Cynodon dactylon*	1.3	0.0	0.3
Wheat	*Triticum aestivum*	1.0	0.0	0.0
Kikuyu grass	*Pennisetum spp*	1.0	0.0	0.0
Signal grass	*Bracharia spp*	1.0	0.0	0.0
Masai love grass	*Seteria verticillata*	1.2	0.0	0.1
LSD		0.4	ns	ns

Fall army worm infestation scale: 1 *1ess than 25% of plant infested; 2,> 25% and <75% of plant infested and 3, above 75% infested*

Among the many host plants surveyed, maize (1.9) followed by crab grass (1.3) had higher levels of infestation than the other alterative host plants (Table 2). The proportion of egg masses laid (0.2) and number of caterpillars in plants (1.6) was similarly higher for Maize although not significantly different from the rest of the host plants. Napier grass (0.4) and crab grass (0.3) were the only grass species with fall army worm caterpillars. (Table 2).

Crop age significantly ($p<0.001$) influenced fall army worm infestation,

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oviposition in terms of egg masses laid and the number of caterpillars found in plants ($p< 0.0322$). The intensity of fall army worm infestation was higher in V12 (3.0), R4 (3.0) and R5 (2.0) which are the reproductive or flowering growth stages for maize. The egg masses (0.3 and 0.3) and the numbers of caterpillars (2.2 and 1.6) was more abundant in the vegetative V7 and V9 maize growth stages respectively (Figure 1).

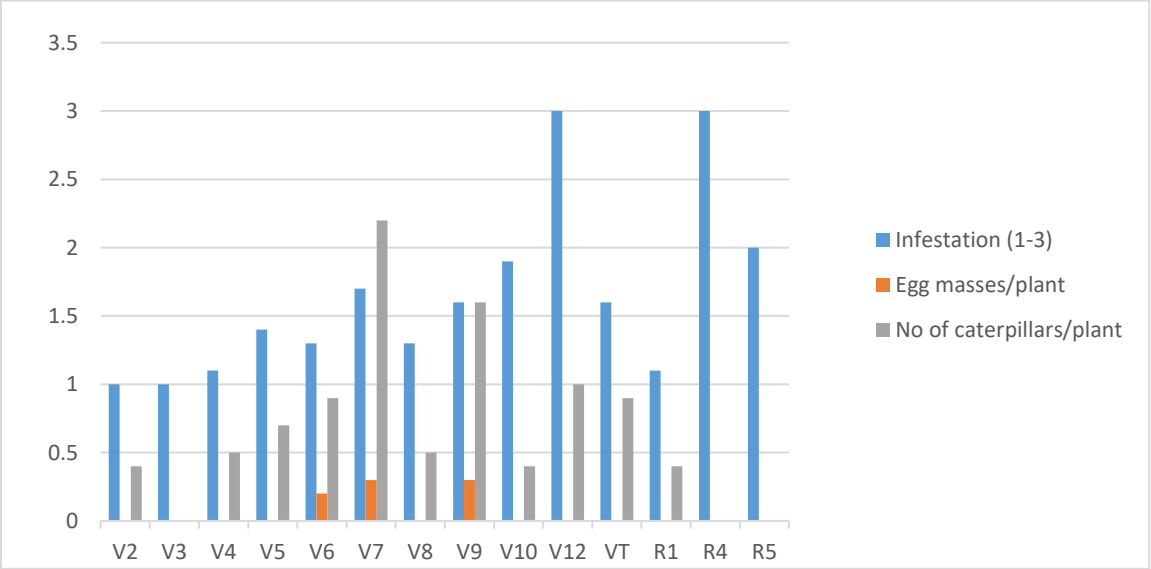

Figure 1: Mean infestation level, number of egg masses and caterpillars per plant at different maize plant growth stages in Kenya

Fall army worm infestation, the proportion of egg masses laid and the number of caterpillars in maize plants also varied significantly ($p<0.001$) among the different regions and altitudes that were surveyed. Mean fall armyworm infestation of the host plants was significantly high in Meru (2.2), Machakos, (1.9), Makueni, Taita and Tharak-Nithi (each 1.8). However, low infestation was recorded in Narok (1.2), Trans-Nzoia (1.0) and Baringo (1.0) compared to the rest of the regions (Table 3). Mean proportion of egg masses laid on plants was highest in Makueni (0.8), followed by Machakos, Nakuru and Taita counties (0.4) and was lowest in Tharaka-Nithi, Kakamega

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and Trans-Nzoia counties, where there were no eggs found on the sampled plants. Mean number of caterpillars in the host plants was highest in Kirinyaga (3.1) followed by Meru (2.3) and Machakos (2.1) counties. However lowest number of caterpillars was recorded in Nakuru County, where fall army caterpillars were observed in one maize field (Table 3).

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Table 3: Mean infestation, number of egg masses and caterpillars in different counties during field survey conducted during long rains.

County	Number of egg masses/ plant	Number of caterpillars/ plant	Infestation Scale (1-3)
Meru	0.1	2.3	2.2
Machakos	0.4	2.1	1.9
Makueni	0.8	0.6	1.8
Taita	0.4	0.9	1.8
Tharaka Nithi	0.0	1.9	1.8
Kirinyaga	0.3	3.1	1.7
Kakamega	0.0	0.4	1.7
Bomet	0.2	0.3	1.5
Nakuru	0.4	0.1	1.3
Narok	0.2	0.2	1.2
Trans Nzoia	0.0	0.2	1.0
Baringo	0.3	0.2	1.0
Uasin Ngishu	-	-	-
LSD	0.2	1.2	0.3

Fall army worm infestation scale: 1, *1ess than 25% of plant infested; 2,> 25% and <75% of plant infested and 3, above 75% infested*

Mean fall army infestation score (1.3), the proportion of egg masses laid (0.3) and the numbers of caterpillars in plants (0.2) was lower in cooler higher altitude (>1700 m above sea level) compared to warmer lower midland areas such as Makueni and Taita Taveta counties that in contrast had higher infestation, proportion of egg masses laid and numbers of caterpillars on plants (Table 4).

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Table 4: Mean percent infestation, number of egg masses and caterpillar on host plants at different altitude ranges of the surveyed regions.

Altitude range (m above sea level) scale	Infestation Scale (1-3)	Number of egg masses/ plant	Number of caterpillars/ plant
900-1399	1.8	0.6	1.5
1400-1700	1.8	0.3	0.9
>1700	1.3	0.3	0.2
LSD	0.2	0.1	0.6

Fall army worm infestation (r=-0.3, p<0.0001), proportion of egg masses r=-0.3, p<0.0001) and the number of caterpillars on plants (r= -0.2, p< 0.0001) were negatively correlated to altitude.

There was significant variation between cultivated and wild host plants growing under rain fed and irrigated conditions in the levels of fall army worm infestation (p=0.0130), the proportion of egg masses laid and number of caterpillars in plants (p<0.0001).

Table 5: Mean percent infestation, number of egg masses and caterpillar on host plants under rain fed and irrigated farming systems in the surveyed regions

Farming system	Infestation Scale (1-3)	Number of egg masses/plant	Number of caterpillars/plant
Rain fed	1.4	0.0	0.2
Irrigated	1.5	0.1	1.4
LSD	0.1	0.1	0.5

Fall army worm infestation scale: *1,1ess than 25% of plant infested, 2,> 25% and <75% of plant infested and 3, above 75% infested*

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Mean fall army worm infestation score (1.5), number of egg masses (0.1) and number of caterpillars (1.4) was higher on cultivated crops and grass weeds growing under irrigated compared to those under rain -ed farming systems in the surveyed areas (Table 5).

Discussions

Determining the distribution and non-crop host plants for FAW is an important step in improving pest management programs because it can help to reduce infestation of nearby cereal crops. The present study shows that FAW has spread to many regions of the country threatening food production and security. Our results have confirmed its occurrence in several areas and have identified counties with high infestations. The present study found fall army worm attacking various cultivated crops and wild alternative host plants such as wild grass weeds although maize was the preferred host plant for feeding by the caterpillars. Maize, followed by crabgrass had higher levels of infestation than the other alternative host plants. The proportion of egg masses laid on plants and number of caterpillars was similarly higher for Maize. Napier grass and crabgrass were the only grass species attractive to FAW caterpillars. The presence and abundance of non-crop host plants in the habitat may increase FAW population. When non-host plants are available in the immediate surrounding habitat near the farm fields, FAW can have more food sources and refuge for larvae when the crops in the fields are sprayed with insecticides thus contributing to build up of the population and high infestation of the newly planted cultivated cereal crops.

Fall army worm intensity of infestation, proportion of eggs laid on plants and the number of caterpillars was higher on cultivated crops and grass weeds under irrigated than under rain-fed farming systems. This suggests that some farming practices like growing crops under irrigation, leads to availability of several alternative host plants for feeding and continuous reproduction of fall army worm. Furthermore, most of the irrigated farming system areas are found in warm and dry areas of the country. These factors especially high temperature and relative humidity in

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irrigated areas and availability of different alternative food sources for fall army worm probably explains the high population and infestation levels observed in these areas. This has serious implications in the management of the invasive insect pests that must be given serious considerations when developing integrated pest management strategies in the country.

It has been shown that variation in environmental conditions influence severity of pest and disease intensity on crops (Mugo *et al.*, 2011; Ogecha *et al.*, 2012). Ogecha *et al.*, (2012) reported variation in bean stem maggot infestation and grain yield between the two locations and seasons recording higher bean stem maggot infestation and grain yield in Kisii compared to Kabete. This was attributed to variation in soil fertility and farming practices. Mugo *et al.*, (2011) similarly reported variation in thrip abundance in different environments of Kenya. The results showed more prevalence of coffee thrips, *Diarthrothrips Coffeae* (Williams) in upper midland zones, compared to lower mid-land agro-ecological zones. The present results show that the level of FAW infestation, egg masses and the number of caterpillars were high in Makueni, Machakos, Nakuru and Taita and lowest in Tharaka-Nithi, Kakamega and Trans-Nzoia counties. These results corroborate earlier reports by Kumela *et al.* (2018) and further confirms that FAW has spread in many parts of the country including Meru, Kirinyaga, Narok and Baringo counties and that urgent actions are required to manage the insect pest. Different agro-ecological zones and altitudes have varying farming practices, population densities, soil types, relative humidity, temperature and rainfall regimes (Jaetzoldt *et al.*, 2009). These factors especially rainfall and temperature affect population increase and subsequent damage by insect pests.

About 76% of the farms surveyed used insecticides to control FAW, except in one farm in Nakuru where pheromone traps were used to monitor and manage the pest. Different types of insecticides were used across the counties that included, escort, cyclone duduthrin, profen, pentagon, coragen, actra, ranger and bestox. The high proportion of farmers using insecticides and also

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use of sex pheromone lure traps can be attributed to coordinated regional efforts by FAW chemical control and trap provision initiative supported by FAO and USAID in the country during the said period.

The information presented in this study provides important understanding of vast range of wild alternative host plants necessary for the survival of the FAW throughout the year. Efforts should be made to manage grass weeds within and around the farm edges and also to ensure that they are also covered while spraying against FAW on cultivated crops.

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