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# Fall armyworm infestation and management practices on maize fields of smallholder farmers in Northern Tanzania

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## Abstract

Fall armyworm (FAW) is native to America and is currently affecting maize production in different parts of Africa, and recently reported in Tanzania. In the present study, FAW infestation levels and their associated management practices were investigated in 90 maize fields in the 18 villages in Arusha, Kilimanjaro and Manyara regions. Infestation levels were assessed using a scale of 0 (no damage) to 9 (100% damage), while the management practices information was collected through a survey and questionnaires from 210 maize growing farmers in the 18 villages. Results showed that all fields were infested by FAW at low (1-4) to moderate (5-7) damage levels. Arusha scored the highest (66.59% and 5.422) significant mean incidence and severity ($P<0.05$) respectively, followed by Kilimanjaro (52.96%, 4.756) and Manyara (52.64%, 3.989) regions. Variation in damage levels was also observed among villages, with means incidences ranging between 35.57% and 79.55%, and mean severity ranging between 2.333 and 7.267. Variation between regions and villages can be associated with farmer's knowledge and FAW management practices. About 84.3% of farmers reported synthetic pesticides as the main management option, although the majority did not effectively apply them. Farmer's recommendations include awareness creation on the FAW management, provision of effective pesticides and resistant maize varieties, and government intervention in the overall management of FAW. From the findings it is evident that sustainable integrated management strategies against FAW is urgent needed and this study serves as a stepping stone for the development of sustainable management options.

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## Introduction

Maize belong to family Poaceae and genus *Zea*, it ranks among the three most important cereal crops of the world (Sandhu *et al.*, 2006; Rouf Shah *et al.*, 2016). Maize provides food for human, fodder for livestock and poultry. It also serves as the source of carbohydrates, protein, minerals, vitamin, and irons (Suleiman and Rosentrater, 2015; Day *et al.*, 2017). In Africa, maize contributes to the country's economies for most of the African countries (Hailu *et al.*, 2018). It is an important food and cash crop for millions of smallholder farmers in Africa (Midega *et al.*, 2016; Day *et al.*, 2017). Maize consumption and demand is increasing year by year due to the increase in human population and this has accelerated the importance of expanding crop production to fit the need of the growing populations. The crop is grown in different agro-ecological zones from cold to hot temperature with varying soil types which provide opportunities to increase its production.

Tanzania has been ranked as the first and the forth major maize producer for East Africa and sub Saharan Africa respectively (Suleiman and Rosentrater, 2015). Regardless of the importance of maize to feed the increasing population in Africa and the word in general, its production is challenged with pest infestation among other factors (Suleiman and Rosentrater, 2015). Currently, the production is hampered with FAW (Spodoptera frugiperda) infestation which is a new invasive pest native to America (Goergen *et al.*, 2016; Abrahams *et al.*, 2017; Day *et al.*, 2017; Otim *et al.*, 2018). The pest is reported to cause massive crop damage in almost all African countries including Tanzania (Abrahams *et al.*, 2017; Bateman *et al.*, 2018, Kumela *et al.*, 2018). The pest was reported to cause crop loss of 32% and 60% in the United States and Nicaragua respectively (Belay *et al.*, 2012). In Africa, FAW is expected to cause crop loss of 40-45% (Day *et al.*, 2017), which could lead to a total crop loss if control actions are not taken. Preliminary assessments indicated that, the effect of fall armyworm damage can cause US$2.5 to 6.2 billion losses in maize growing countries in Africa (Day *et al.*, 2017; Hailu *et al.*, 2018). This level of crop damage and economic loss is huge enough to cause food and income insecurity as the majority of the population relies on maize for their livelihood. The level of pest infestation and crop damage varies between regions based on different management practices applied, maize varieties grown, planting season and geographical conditions.

Numerous conventional pesticides have been applied for management of FAW in Africa including Tanzania (Day *et al.*, 2017; Kumela *et al.*, 2018; Prasanna *et al.*, 2018). However, information on the pesticides efficiency against FAW is limited which may accelerate the pest importance. Therefore, the perfect method to combat the maladies is to establish FAW infestation levels in different maize growing zones and management options being applied so that proper action to be taken immediately. For this purpose, assessing incidence and severity level on maize fields is pre-requisite to detect the level of infestation. Hence, the current research was conducted to determine the FAW infestation level and farmers management approaches applied in the farms in the study area.

## Material and methods

*Study area description*

Three regions of northern Tanzania namely, Arusha, Kilimanjaro and Manyara (Fig. 1), were sampled based on the consideration that they have a high potential for maize production while FAW infestation was reported as the main maize production constraints for the year 2017-2018.

*Data collection*

Incidence and severity data were collected in 270 plots from the purposefully selected villages of the three regions based on reports on fall armyworm occurrences as reported by the district Extension Officers from each of the surveyed regions. Five (5) fields were randomly selected per village, out of 18 villages of the three regions, and 3 plots of 3m x 3m were sampled as replicates in each field. The incidence rate was measured by the number of infected plants per plot divided by a total number of plants per plot times 100. Visual rating scale (0-9) reported by Wiseman *et al.*, (1984) described as 0 - no visible leaf damage; 1 - only pin-hole damage on leaves; 2 - pin-hole and shot hole damage to leaves; 3- small elongated lesions (5–10mm) on 1–3 leaves; 4 - midsized lesions (10–30mm) on 4–7 leaves; 5-large elongated lesions (>30mm) or small portions eaten on 3–5 leaves; 6- elongated lesions (>30mm) and large portions eaten on 3–5 leaves; 7- elongated lesions (>30mm) and large portions eaten on 50% of leaves; 8- elongated lesions (>30mm) and large portions eaten on 70% of leaves; and 9- leaves destroyed on 70% of leaves was adopted with minor modifications. The scale was further categorized as; 0, no visible damage, 1-4, minimum visible damage, 5-7, moderate damage and 8-9 high damage.

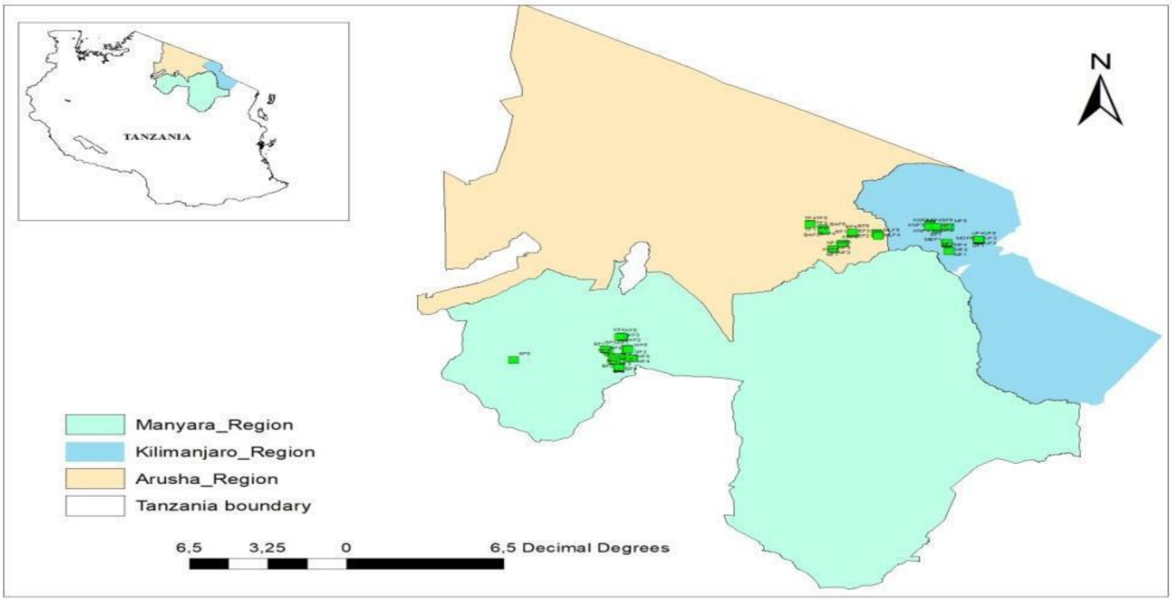


**Fig. 1.** Map of the study area; Arusha, Kilimanjaro and Manyara.

Information on farmer's management practices was obtained through interviews of smallholder farmers who were growing maize and old enough (minimum 18 years old), and focus group discussions (FGD). Focus group discussions were conducted through smallholder farmers organized meetings including smallholder farmers who are responsible for handling the farm and they can provide information on the pest in their areas. Guiding questions were asked to prompt discussion and generate information on the key aspects of FAW knowledge, maize production, maize varieties grown, FAW management practices, challenges, and recommendation. All of the survey questions were 'open', in order to avoid limiting smallholder farmers' responses, and each meeting took approximately 2 hr. The information obtained from FGDs was confirmed through key informants interviews which were conducted in the average of 30mins. Key informants of this survey included; experienced farmers, farmer organization representatives, extension officers, Ward Executive Officers (WEO), Village executive officers (VEO) and private sectors making.

*Data analysis*

Data collected were analyzed by GenStat software (Student-Newmann-Keuls test) and SPSS version 21. Least significant difference (LSD) test at 5% probability level was applied to compare the treatment means. Various variables were subjected to basic descriptive statistics and multiple responses to obtain the frequency of responses.

## Results

*Social economic factors and farm characteristics*

Smallholder farmers that participated in the survey were both males and females. In all regions, males formed 76.2% while the females made up the remaining 23.8%. About 42.9% of smallholder farmers that participated in the survey aged between 36-51 years with high experience of farming in their area. The majority (85.7%) of the respondents had some formal educations which were measured as the skills of understanding the communication. Among them; 64.8% had attended primary education, 15.7% had attended secondary level education, 5. 2% had attained tertiary level of education and only 14.3% of farmers with no formal education.

Farm size for maize cultivation; majority of the smallholder farmers that were interviewed (52.4%) are cultivating an average of 1-2 acres followed by 28.6% cultivating 3-4 acres, 13.3% cultivating less than one (1) acre, and the least group 5.7% cultivating more than (4) acres. Maize was cultivated in all regions mainly for food and small portion is sold to cater for family needs. Other crops grown in the study area for food and income included; beans (28.7%), vegetable (19.1%), pigeon peas (12.7%), sorghum (12.2%), sunflower (6.7%), sweet potato (4.9%) groundnuts (4.5%), rice (3.3%), green gram (3.3%), irish potato (2.4%) and sesame (2.2%), although their cultivation varies among regions.

*Evaluation of FAW infestation level on maize fields of the study area*

The results on the infestation level show that all the fields were infested by the FAW in the study area. However, the infestation levels varied among regions (Table 1). Arusha region had the highest level of incidence (*p*=0.001) at 0.05 level followed by Kilimanjaro and last by Manyara (Table 1). The severity of the damage was slightly minimum in Kilimanjaro and Manyara except in Arusha where it was moderate. Based on the survey data, severity was significant different (*p*= 0.05) between regions which ranged from low (1-4) to moderate (5-7) damage as scored following the (Wiseman *et al.*, 1984) visual rating scale.

Moreover, the infestation results among villages which are given in Table 2 show that Malula (79.55%) had the highest infestation level followed by Timbolo (76.55%) and Kikwe (76.10%) with the least infestation recorded in Embasen (35.57%) and these villages are in Arusha region. However, the severity of FAW damage was low throughout the fourteen villages except for Malula, Timbolo, Kikwe and Mtakuja where it was moderate.

**Table 1.** Incidence and severity of fall armyworm in Northern Tanzania.

| District | Incidence (%) | Severity level |
|---|---|---|
| Arusha | 66.59 a | 5.422 a |
| Kilimanjaro | 52.96 b | 4.756 b |
| Manyara | 52.64 b | 3.989 c |
| P value | 0.001 | 0.001 |
| Grand mean | 57.4 | 4.72 |
| LSD (*p*=0.05) | 6.12 | 0.578 |

Means with the same letter(s) down the column are not significantly different (*p*= 0.05) based on Student-Newman-Keuls test, severity score based on a visual rating scale of 0-9.

**Table 2.** Mean Incidence and mean severity of the fall armyworm in the selected villages of the three regions.

| Village Name | Mean Incidence% | Mean severity |
|---|---|---|
| Malula | 79.55 a | 7.267 a |
| Timbolo | 76.55 a | 6.600 ab |
| Kikwe | 76.10 a | 6.667 ab |
| Mtakuja | 72.39 ab | 6.733 ab |
| Nduruma | 69.46 abc | 5.067 cd |
| Mabogini | 62.94 abcd | 5.667 bc |
| Bangata | 62.30 abcd | 4.600 cde |
| Signo | 59.86 abcd | 4.533 cde |
| Halla | 54.71 bcde | 3.867 cdef |
| Mabungo | 52.25 cde | 4.867 cde |
| Nakwa | 51.92 cde | 4.200 cde |
| Wangwaray | 51.58 cde | 3.067 ef |
| Bonga | 51.28 cde | 4.533 cde |
| Uchira | 49.66 cde | 4.600 cde |
| Kiongozi | 46.48 de | 3.733 def |
| Kindi | 41.81 de | 3.533 def |
| Sambaray | 38.70 e | 3.133 ef |
| Embasen | 35.57 e | 2.333 f |
| Mean | 57.4 | 4.722 |
| P value | 0.001 | 0.001 |
| LSD (*p* =0.05) | 12.99 | 1.1355 |

Means with the same letter(s) down the column are not significantly different (*p* = 0.05) based on Student-Newman-Keuls test, severity score based on a visual rating scale of 0-9

*Farmer's FAW management practices*

In the present study, two main types of management practices were identified including; synthetic pesticides and nonchemical methods applied by 86% and 11.2% of the respondents respectively. However, only 2.8% of the respondents reported having done nothing against the pest. Sixteen (16) different types of pesticides were reported to be used by smallholder farmers in the study area as shown in Table 3. Chemical pesticides like Duduba 450 EC was the mostly (23.7%) used type of synthetic pesticides across regions, followed by Duduall 450 EC (10.5%) and Supercron 500 EC (9.7%). Other types of chemical pesticides their applications were restricted to certain regions or villages due to their availability and smallholder farmer's experience.

**Table 3.** Chemical formulations used for management of FAW in the study area.

| Trade Name | Common Name | Frequency | Percentage (%) |
|---|---|---|---|
| Duduall 450EC | Cypermethrin150g/L +Chlorpyrifos 300g/L | 67 | 10.5 |
| Duduba 450 EC | Cypermethrin 100g/l +Chlorpyrifos 350g/l | 152 | 23.7 |
| Spidex 2.15EC | Emamectin Benzoate 21.5g/L | 30 | 4.7 |
| Laraforce 25EC | Lambdacyhalothrin 25g/L | 12 | 1.9 |
| Belt 480SC | Flubendiamide 480g/L | 42 | 6.5 |
| Selecron 720EC | Profenofos 720g/l | 23 | 3.6 |
| Boneforce | - | 14 | 2.2 |
| Supercron 500EC | Profenofos 500g/l | 62 | 9.7 |
| Karate 5EC/5SC | Lambda cyhalothrin 50g/l | 24 | 3.7 |
| Dudumectin1 1.2%EC | Emamectin 4.8%+Acetamiprid 6.4% | 26 | 4.1 |
| Profecron 720EC | Profenofos 720g/l | 31 | 4.8 |
| Prosper 720EC | Cypermethrin120g/L +Profenofos 600g/L | 18 | 2.8 |
| Libarate | Emamectin Benzoate 40g/L+ Indoxacarb 160g/L | 39 | 6.1 |
| Snow super 20%EC | Abamectin10% + Emamectin Benzoate 10% | 27 | 4.2 |
| Ninja 5EC | Lambdacyhalothrin 50g/l | 27 | 4.2 |
| Multi-Alfplus150 EC | Emamectin Benzoate 50g/l +Alphacypermethrin 100g/l | 12 | 1.9 |
| Soap | - | 35 | 5.4 |

Despite the intense use of pesticides, smallholder farmers have reported; ineffectiveness of the pesticides (40.9%), high cost of pesticides (38%), limited FAW management knowledge (11.6%), limited knowledge on FAW biology and behavior (5.3%) and limited technical FAW expertise (4.2%) as the main constraints for effective management in the study area. On the other hand, nonchemical methods were also used in the study area to manage FAW and application of these methods was reported by 11.2% of the respondents. Whereby these methods were applied in the field followed by application of synthetic pesticides or applied simultaneously. Nonchemical methods applied in the study area are presented in Table 4.

**Table 4.** Non-chemical methods used for management of FAW.

| Name | Frequency | Frequency | Percentage (%) |
|---|---|---|---|
| Cultural | Ash | 23 | 27.7 |
| | soil/sand | 18 | 21.7 |
| Biological | - | 0 | 0 |
| Botanical | *Tephrosia vogelii* | 9 | 10.8 |
| | *Azadiracta indica* | 9 | 10.8 |
| | *Zingiber officinale* | 9 | 10.8 |
| | *Solanum incanum* | 4 | 4.9 |
| | *Capsicum annuum* | 11 | 13.3 |
| Resistant variety | - | 0 | 0 |

In this study, farmers have also pointed out some factors to be considered in managing FAW. This included; identification and provision of effective pesticides (28.3%), reduced costs and timely provision of pesticides (20.6%), enhanced awareness on FAW (16.7%), provision of training on proper use and handling of pesticides (12.9%), provision of maize resistant varieties (10%), availability and frequent visit by agricultural extension officers (6.6%) and Government intervention (public pesticides spraying) (4.9%).

## Discussion

Fall armyworm is the major constraint in maize production responsible for massive crop damage. FAW is known to cause massive economic loss due to yield loss and high cost for its management (Prasanna *et al.*, 2018). Among other factors, the level of crop damage depends on pest population density and the growth stage of the crop (Wiseman *et al.*, 1984). FAW larva affects all stages of maize growth, though the level of damage is more serious at the early growth stages of the plants (Goergen *et al.*, 2016; Kumela *et al.*, 2018). In the current study, the level of fall armyworm infestation and crop damage varies between regions with mean infestation level of above fifth two percent (52%) in all regions. The variation was observed between villages, and eighty-three percent (83%) of the villages have mean infestation level of more than fifty percent (50%). The most likely cause of variation between villages could be due to farmer's knowledge on the pest, different management practices and difference in planting dates. In this study, variation in planting time was observed between regions whereas farmers in Manyara region planted maize early in the season followed by Kilimanjaro and Arusha. The variation in planting date influenced the variation of pest infestation and crop damage, although the damage was observed in all maize stages. Thus, results from the current study is similar to results previously reported by other authors that planting maize early in the season reduces chances of pest infestation (Goergen *et al*., 2016; Abrahams *et al*., 2017).

In the current study, majority of farmers in the study area are smallholder farmers who depend on agriculture for food and income generation. Their average farm size is 1-2 acres, where they cultivate maize and other food and cash crop. One of the challenges that these farmers are facing is the limited ability to control fall armyworm due to the high expenses of dealing with this pest. FAW is a polyphagorous insect and can also affect other crops grown in the area such as sorghum and rice. This adds more stress to farmers who are struggling to manage FAW on their maize field. In this study two main management practices applied by smallholder farmers in managing fall armyworm were identified, which include synthetic chemical and non- synthetic chemical methods.

Synthetic chemical formulations have been applied as the major option for the management of FAW infestation in the area. The same results have been presented in other regions of Africa that the use of synthetic chemical pesticides in pest management is a common practice in Africa (Abrahams *et al*., 2017; Day *et al*., 2017; Prasanna *et al*., 2018). However, the application of synthetic chemical pesticides formulation by farmers depends on its availability, farmer's knowledge and purchasing power of the farmers (Midega *et al*., 2018). The effectiveness of pesticides in managing fall armyworm depended on the type of pesticides applied, application time, dose and frequency (Hardke *et al*., 2011; DalPogetto *et al*., 2012; Kumela *et al*., 2018; Sisay, 2018). Thus, in this study we observed that majority of the farmer did not effectively apply the pesticides due to poor knowledge of the pest and pesticides. Chemical pesticide formulations used in the study area fall under organophosphates, pyrethroids and abermectin class of compounds. Some of chemicals of these classes of compounds are known to impact human health and environment in general (Abrahams *et al*., 2017; Togola *et al*., 2018). Also fall armyworm has developed resistance against some chemicals in these classes of compounds (Al-Sarar *et al*., 2006, Hardke *et al*., 2015, Abrahams *et al*., 2017). Previous study reported the improved efficiency of chemical pesticides after several applications (Belay *et al*., 2012; DalPogetto *et al*., 2012, Gutierrez-moreno, 2017; Togola *et al*., 2018). Therefore, the foremost probable solution for improved pesticides efficacy is the ideal time, frequent and rotational application of pesticides

Non-chemical methods were the other option used by smallholder farmers in managing fall armyworm. It is most likely that the high cost and low efficacy of chemical pesticides have caused smallholder farmers to use non-chemical method in managing FAW. Application of nonchemical methods is based on smallholder farmer's experience of using the same in managing other crop pests. The efficiency of this method is difficult to be established as there are no formal application instructions. Smallholder farmers applied the non-chemical methods alone or in combination with chemical pesticides. The similar approach has been used by smallholder farmers against FAW in Ethiopia and Kenya (Kumela *et al*., 2018). The method is affordable to smallholder farmers although, the method alone is not adequate to control the pest but can reduce the level of pest infestation (Abrahams *et al*., 2017). Despite the application of various management approaches and perceived significant loss of maize production, effective and sustainable management option is still limited.

Based on the infestation and management practices findings, the study reveals that the type of management applied has an influence on the level of fall armyworm infestation. The relation between pesticides application and infestation is by random chance because in some villages pesticides where applied prior to FAW infestation which reduced the chance of the pest to infect their fields. Moreover, the combination of different management approaches has most likely affected the level of infestation among regions. Infestation level was low in the region where different management approach was applied. This result is in line with another study that, combined management approaches (IPM) improve the efficiency in managing fall armyworm as compared to a single approach (Molina-ochoa *et al.*, 1999, Michelotto *et al.*, 2017). For instance, combining Bt hybrids and insecticides proved a good strategy in reducing leaf damage. Thus from the above findings, IPM remains the best option for management of fall armyworm by smallholder farmers in Africa. In developing the IPM strategy, farmer's interests and priorities highlighted in the previous section needs to be considered.

**Conclusion**

This study was designed to determine the level of fall armyworm infestation on maize fields and farmers management practices in Tanzania. Fall armyworm was identified as a serious and challenging pest of maize in the study area that may also reflect or interpolate to other maize growing areas. Fall armyworm management option was different depending on the accessibility and availability, although chemical pesticide formulations and nonchemical methods were the main types. Based on the known drawbacks of pesticides application in pest management, it is important to establish the pest biology and behavior in Africa which will help to identify an effective method for its control. Also, factors with an influence on infestation levels such as management options, maize seeds varieties and farmers knowledge need to be established to reduce crop damage. Moreover researchers should think of developing sustainable alternative methods which will be economical and environmentally friendly. Thus, IPM strategies based on smallholder farmer's knowledge will be the best option in reducing farmer's exposure to pesticides while reducing pest infestation and increasing maize production.

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