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# Status of the fall armyworm [*Spodoptera frugiperda* (J.E. Smith)] infestation on maize one year after detection in eastern Uganda

**Author's Details:**

***Frank Kagoda[1], Joel Amunaun[3], Paul Mufumbiro[3], Emmanuel Basena[1] and Stella Kabiri[2]**

[1]National Agricultural Research Organisation (NARO), Buginyanya Zonal Agricultural Research and Development Institute, P.O. Box 1356, Mbale, Uganda

[2]National Agricultural Research Organisation, Mukono Zonal Agricultural Research and Development Institute, Mukono, Uganda

[3] Busoga University, Faculty of Agriculture Science and Technology, Iganga, Uganda

***Corresponding author:** E-mail: fkagoda@gmail.com

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***Abstract***

*The fall armyworm (Spodoptera frugiperda), first observed in Uganda in mid 2016, has the potential to cause maize yield losses of 15 – 75%. The study was aimed at determining the fall armyworm (FAW) status on maize in eastern Uganda one year after detection. We interviewed 270 farmers from nine districts of eastern Uganda for this study. Key elements during interviews were: the maize varieties grown, maize grain yields, FAW awareness, symptoms and mitigation measures. Results showed that 41.5% of the farmers were still not aware of the FAW outbreak. The most common FAW symptom reported was the formation of holes on leaves. Majority (60.7%) of farmers were using pesticides, especially rocket 44EC, to control the FAW, whereas 11.9% relied on cultural methods and 26.7% did not apply any control measures. Under pesticide use, grain yields were much higher in the highlands especially Bukwo (5.1 – 7.5 t ha$^{-1}$) as reported by 80% of respondents, and lowest (< 1.25 t ha$^{-1}$) in the lowlands of Luuka, Pallisa and Butaleja as reported by 53.3-66.7% of the respondents. Varieties Longe 10H, Longe 5, Longe 7H and the landraces, registered the lowest grain yields (< 1.25 t ha$^{-1}$) under no pesticide use. Therefore, the FAW is more aggressive in the lowland than in the highland districts of Uganda. The poor agronomic practices in the lowland districts exacerbated the effect of the FAW.*

***Key words:*** *Awareness, districts, control, fall armyworm, landraces, rocket*

## 1 INTRODUCTION

The fall armyworm (FAW) is a new Lepidopteran, Noctuidae pest of maize first observed in Uganda between May and July 2016 (MAAIF, 2017). The pest is native to the Americas while in Africa it was first spotted in Nigeria and Togo in January 2016, but currently present in over 30 countries of Africa (Goergen *et al.,* 2016). In Uganda, it was first detected in the eastern districts of Bukedea and Kayunga, and the western district of Kasese, but it has now spread to almost all districts of Uganda. With a host range of nearly 100 plants, the pest inflicts most damage to staple cereal crops, non-cereal crops, and pasture grasses. According to MAAIF (2017), in the absence of proper control methods, the - FAW has the potential to cause maize yield losses of 15 – 75%. The destructive stage of the pest is the caterpillar, which feeds -relentlessly on most parts of the plant including the leaves, stems, maize cobs and tassels except the roots. Symptoms of its damage include leaf perforation, defoliation, perforated cobs and damaged kernels. This feeding damage results in a reduction in both yield and grain quality. The adult moths move in large swarms at night with each female laying up to 2000 eggs and the emerging caterpillars are aggressive feeders with the potential to destroy a hectare of maize within 72 hours in its later stages (Prassana *et al.,* 2018). The pest can be identified by its prominent white, inverted Y-shaped mark on the front of the head and four large spots towards the end of the abdomen. The FAW larvae vary from light tan or green to almost black (Bessin, 2003). It is not well understood how it came to Africa but it is suspected that the pest was carried across borders on exported plant material. The adult moths can also cross freely given their unusual excellent flying ability that enables them to migrate enormous distances. Major host plants are maize, sorghum, cotton, millet, peanut, rice, soybean, sugarcane, tobacco and wheat. Other crops sometimes injured are apple, grapes, oranges, pawpaws, peach, strawberry and a number of flowers and pasture species. The major cause for worry is that in much of Africa, especially where there is a bimodal rainfall pattern, the pest can persist throughout much of the year (Prassana *et al*., 2018). It is particularly hard to control, as the moths are strong flyers, capable of covering 2000 km per year. It is therefore a serious threat to the food and nutrition security and livelihoods of hundreds of millions of farming households in sub-Saharan Africa (SSA).

The month of July 2017 marked a whole year since FAW was detected in Uganda. Sensitization and awareness campaigns were immediately extended to stakeholders in agriculture spearheaded by the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) and other agencies. So far, a lot of chemicals are being sold out to farmers specifically to control the FAW. The study was conducted in eastern Uganda because the FAW was first detected in this part of the country. According to UBOS (2010), of the 3.95 million Ugandan agricultural households, 28.1% were from eastern Uganda and the second largest number of agricultural households after western Uganda. Eastern Uganda is also the biggest producer of maize (1,108,554 tons) in the country. The region is made up of the lowland (1000 – 1500 m asl) and highland (1600 – 3000 m asl) agro-ecological zones. It's worth noting that the maize varieties grown in the highland agro-ecological zone are different from those grown in the lowland agro-ecological zone because of the totally different climatic conditions. The major objective of the study was to determine how maize farmers have responded to the outbreak of the FAW in eastern Uganda a year after detection. The specific objectives were to (1) determine FAW prevalence in the different parts of eastern Uganda, (2) ascertain the damage and key symptoms due to FAW and (3) assess the effectiveness of the mitigation measures being deployed.

## 2 MATERIALS AND METHODS

### 2.1 Study area, sampling size and design

The study was conducted between the months of July and September 2017. It targeted both small and large-scale maize farmers in nine districts of eastern Uganda, namely in the lowland districts of Bugiri, Butaleja, Pallisa, Luuka, Manafwa, Sironko and Mayuge, and the highland districts of Bukwo and Kapchorwa. A descriptive cross-sectional survey design using quantitative methods of data collection and analysis was adopted. However, it was supported by qualitative information obtained from key informants and document reviews. A three-stage cluster sampling technique was used to select the 270 households based on existing reports on the presence of FAW in these districts. In the first stage of clustering, the nine districts as listed above were purposively selected out of 24 districts of south eastern Uganda. The nine districts are the leading producers of maize in eastern Uganda but also rank highest in maize production in the whole country. In the second stage of sampling, two sub-counties were purposively selected from each district where cases of the disease were evident. The third stage involved random selection of 270 households from within the group villages (smallest unit of local government especially in a rural setting) in each sub-county (sub-division within a district comprising at least 4-5 villages). Only households involved in maize cultivation at that time (2017) and the previous year (2016) were selected. On average, 30 farmers were interviewed from each of the nine districts.

### 2.2 Methods and procedure of data collection

The interview method supplemented by documentary review was used. The interview approach involved administering a structured questionnaire of both closed and open-ended questions to the respondents. The questionnaire was preferred because it is a quick way of data collection and it is easy to categorize, quantify and generalize the information. The questionnaire was pre-tested on ten households outside the randomly selected villages to ensure reliability and validity. The major elements during interviews were: (1) maize pests with emphasis on the FAW, (2) maize varieties grown and the source of seed, (3) estimated maize grain yield and yield losses attributed to FAW (4) FAW symptoms and mitigation measures. Relevant documents with related information to the study at district and sub-county production offices were reviewed. These mainly comprised copies of reports submitted to the Ministry of Animal Industries and Fisheries (MAAIF).

### 2.3 Data analysis

Qualitative data were coded and analysed using SPSS version 20 (SPSS, 2011). Chi-squared tests were used to compare performance between locations. Cramer's V, which ranges between 0 and 1, was used to measure the strength of the association between variables. When V is closer to one, it implies that the marginals are more equal, therefore a strong association, and the reverse is true. The SPSS was also used to provide summaries of the farmer household's maize production characteristics such as frequencies and means.

## 3 RESULTS

### 3.1 Farmers' awareness of the FAW, sources of information and the observed symptoms

Only 58.5% of the farmers were aware of the FAW outbreak, although there were high significant differences ($P < 0.001$) in the level of awareness across locations (Fig. 1). The most informed farmers about the FAW were those from Manafwa (80%), Bugiri (73%) and Butaleja (73%) while the least informed were from Kapchorwa (40%) and Mayuge districts (26.7%).

There were significant differences ($V = 0.271$; $\chi2 = 59.24$; $P < 0.001$) among farmers on the source of information about FAW (Fig. 2). About 44% of the farmers, especially in Mayuge (73.3%) and Kapchorwa (60%), discovered on their own about the FAW. The least source of information (2.2%) were the extension agents such as the sub-county Extension Officers, National Agricultural Advisory Services (NAADs) and many Non-Government Organisations (NGOs) such as World Vision, Lutheran World Federation (LWF) and International Centre of Insect physiology and Ecology (ICIPE). Other important sources of information were the media (22.4%) e.g. radios, TVs and newspapers, and neighbours and friends (31.3%), especially in Manafwa (60%) and Bugiri (50%). There were significant differences ($V = 0.33$, $\chi2 = 117.9$, $P < 0.001$) in the symptom distribution across locations (Fig. 3).

Most farmers (60.7%) however reported formation of holes on leaves as the major symptom they observed in maize as a result of damage by the FAW. This was mainly in the districts of Kapchorwa, Bukwo, Pallisa and Luuka. Other key symptoms were window pane feeding injury on leaves and formation of powdery substances on the affected plant area. The least observed symptom was formation of tunnels on the stems. This was reported by only 1.5% of farmers, and only in Bugiri district.

### 3.2 Mitigation measures against the FAW

Mitigation measures being used against the FAW were significantly different ($P < 0.001$) across locations (Table 1). Chemical spray was the most commonly used method (60.7%), and was reported as such in all districts though more commonly in Bukwo (93.3%) and least in Luuka (26.6%). At least in every district, a section of farmers reported not having taken any measures to control the FAW with highest incidences in Luuka (60%) and Pallisa (46.7%), and least incidences in Bukwo (6.7%). Cultural methods such as roguing, applying ash, applying cooking oil on leaves, early planting, fertilisation with foliar fertiliser, intercropping with other crops not maize, were more popular in Bugiri (26.7%) and Kapchorwa (33.3%). Manual methods, characterised by hand picking the larvae of the FAW and killing it, were only reported by 6.7% of respondents in Pallisa district.

Farmers using rocket pesticide (92.4%) to control the FAW were significantly higher ($V = 0.409$, $\chi2 = 88.4$, $P < 0.001$)) across the nine districts than farmers using other means (data not shown). Other pesticides were only reported in Bugiri (Ambush and striker), Kapchorwa (Super cyper) and Sironko (Ambush), but still not as popular as rocket. Use of an array of pesticides was commonest in Bugiri followed by Sironko and Kapchorwa, unlike in Butaleja, Pallisa, Luuka, Manafwa, Mayuge and Bukwo where farmers only reported using rocket pesticide. Notably, all farmers (100%) who used a combination of rocket and super cyper reported success in controlling the FAW.

Most respondents reported applying pesticides two times (38.6%), especially where Rocket and Ambush were used ($V = 0.556$, $\chi 2 = 163.5$; $P < 0.001$). This was followed by single applications (30.1%), which comprised Supercyper and Rocket again. Only 5.1% of respondents reported applying a chemical (striker and Rocket) more than five times. It is therefore worth noting that rocket was the most common and probably most misused pesticide since it appears at every level of application.

There were significant differences ($\chi 2 = 22.416$; df = 4; $P < 0.001$) in the number of sprays under monocropping and mixed cropping systems. Under monocropping system, most farmers (43.6%) sprayed their maize only once against the FAW. Under mixed cropping, spraying was conducted mostly two times by majority of the farmers (51%). Generally, spraying against the FAW was conducted between once and three times by majority of farmers (92.6%).

The four pesticides found with the farmers were significantly different ($P < 0.001$) in terms of action against the FAW across locations. Specifically, rocket was ranked as 'excellent', whereas super cyper was ranked as 'good'. Ambush and striker were both ranked as poor, meaning that they did not control the FAW to the contentment of the farmers. A number of farmers from Bugiri (16%) and Bukwo districts (16%) had doubts on the performance of some pesticides. Remarkably, these two districts (Bugiri and Bukwo) were the most affected by the FAW among the nine districts visited. Very few farmers from Luuka district (4.5%) criticized the performance of the pesticides against the FAW.

### *3.3* Maize grain yields amidst FAW infestations

Where pesticides were applied against the FAW, few farmers (29.8%) received yields below 1.25 t $ha^{-1}$ unlike where pesticide were not used (49.6%) (Table 2). Correspondingly, slightly more farmers (4.6%) obtained very high yields (6.26 - 7.5 t $ha^{-1}$) under pesticides application but only a few (0.8%) when pesticides were not used. Most farmers who planted Longe 5 and the landraces confessed obtaining much lower yields with or without pesticides. On the contrary, varieties like Longe 4, H614D and H624 performed much better under pesticide application, with grain yields between 5.1 - 6.25 t $ha^{-1}$, but quite poorly when no pesticides were applied. The varieties Longe 10H, Longe 5, Longe 7H and the landraces performed poorly (< 1.25 t $ha^{-1}$) when no pesticides against the FAW were applied.

With no pesticides applied against the FAW across locations and varieties, many farmers (49.6%) obtained grain yields below 1.25 t $ha^{-1}$ (Table 3). On the contrary, when pesticides were applied, few farmers (29.8%) obtained yields below 1.25 t $ha^{-1}$. Highest grain yields following pesticide application were realized in Bukwo (5.1 – 7.5 t $ha^{-1}$) followed by Kapchorwa (5.0 - 6.25 t $ha^{-1}$) as reported by 80% and 53.3% of farmers, respectively. In all the locations surveyed, farmers reported increase in grain yield whenever pesticides were used to spray against the FAW. However, a few farmers in Pallisa (6.7%) and Bukwo (33.4%) reported getting higher yields (5.1 – 7.5 t $ha^{-1}$) despite no pesticide use unlike in the rest of the locations which had 3.76-5.0 t $ha^{-1}$ as the highest yield without any pesticides used.

No significant differences were observed ($\chi 2 = 8.942$; df = 40; $P > 0.05$) in grain yields under monocropping and mixed cropping systems whether under pesticide application or not (data not shown). Planting dates were reported to result into significant differences ($P < 0.001$) in grain yield both where pesticides were used against the FAW and where they were not used (Table 4). Specifically, the farmers who planted in mid March (11.8%)

and late March (37.7%) and went ahead to apply pesticides obtained significantly higher grain yields (5.1 – 7.5 t $ha^{-1}$) compared to those who planted very early in February or very late in April. It was reported by 47.1-69.7% of respondents that even with very early planted maize (before mid March), pesticide application against the FAW was necessary in order to realize substantial yields.

# 4 DISCUSSION

## 4.1 Farmers' awareness of the FAW and the observed symptoms

The FAW outbreak is now a known fact in majority of the districts of Uganda and Africa as a whole. In this survey, it is implied that the respondents (41.5%) who were not aware of the FAW outbreak were those who do not plant maize regularly, they have a distant neighbourhood and are quite reserved, and are without audio and visual media like radio and television, respectively. This was mainly in the districts of Mayuge and Kapchorwa in south eastern Uganda. Whereas most sub-counties in Uganda have public and private agricultural extension agents, only a few farmers (2.2%) reported having got information about the FAW from such personnel. This indicates that there is a big gap between the farmers and the extension agents. However, the most reliable information source for the maize farmers was indeed the fellow farmers who included the neighbours and friends. Therefore, farmers feel comfortable learning from each other than from strangers or people who are not of their social class. According to Wilkinson & Elvitch (1998), some farmers fear criticism from strangers, therefore prefer learning from fellow farmers.

The survey revealed that the most common symptom of the FAW on maize in eastern Uganda is the formation of holes on leaves as a result of their feeding. These begin as few pinholes and lesions on older leaves to several large uniform to irregular-shaped holes eaten from furl and whorl leaves (Plantwise, 2017). Other key symptoms observed were window pane feeding injury on young leaves, formation of powdery substances (frass) especially on the tassels and ears, and the damaged kernels. The lesions or scrappings on the leaves is a result of feeding by young (first instar) larvae of the FAW especially when the maize is still young (3 – 4 weeks) (Luginbill, 1928; Bessin, 2003). Young larvae initially eat leaf tissue from one side, leaving the opposite epidermal layer intact (window pane feeding) hence the whitish lesions. The frass, normally yellowish brown, is a combination of the pest excreta and the leftovers as it feeds. According to Swayamjit *et al.* (2015), caterpillars leave the frass in order to trick the plant that it is being attacked by fungal pathogens and mounting a defence against them, thereby suppressing the plant's defence against herbivores.

Rarely did farmers observe tunnels on the stems of maize attacked by the FAW. Similarly, other authors have reported observing most damage by the FAW on the leaves and ears and not the stem (Luginbill, 1928; Bessin, 2003). In fact, according to Bohnenblust (2012), whereas the European corn borer larvae will bore into the stalk of maize, the fall armyworm larvae feeds on the foliage making larger ragged holes.

## 4.2 Mitigation measures against the FAW

The commonest mitigation measure against the FAW across all districts surveyed was reported as being pesticide sprays. The fact that Bukwo emerged the greatest user of pesticides (93.3%) to control the FAW can be attributed to the commercially oriented farming system in Bukwo unlike in other districts like Luuka, Pallisa and Bugiri. However, Bessin (2003) advises on the use of pesticides only in extreme situations, e.g., when 100% of the plants are infested and they are less than 30 inches high. Captivatingly, quite a number of farmers tried different cultural methods other than pesticides to control the FAW. For example, roguing, applying ash, applying cooking oil on leaves, early planting, fertilisation with foliar fertiliser, intercropping with other crops and the manual approach of hand picking the larvae of the FAW and killing it. However, it was observed that the cultural and manual approaches require a lot of labour to implement, and are therefore not completely without a cost. This corroborates with reports by Prasanna *et al.* (2018) that there is a labour cost involved in cultural methods of FAW control.

This study has revealed that majority of farmers (92.4%) in eastern Uganda are using pesticides especially rocket to control the FAW. These pesticides are applied utmost three times though Sullivan *et al.* (1999) found two applications as the most ideal. However, what is important is the continuous scouting, such that any spray recommendation only comes at 25% damage or when egg masses are observed on 5% of the plants (Bessin, 2003). It should also be noted that it is not of any economic benefit to treat against FAW when the plants have initiated their reproductive phase (Agrihome, 2018).

Prasanna *et al.* (2018) advises farmers to always look for opportunities not to spray chemical pesticides against FAW, which is not yet an adapted concept in eastern Uganda. Even under pesticide use, chemicals with different modes of action need to be rotated every 30 days. This is not the case in eastern Uganda since farmers tend to stick to only one pesticide which works well for them and can easily be accessed. Farmers therefore need to be sensitized on pesticide safety and the use of pre-harvest intervals associated with specific insecticides of FAW as reported by Prasanna *et al.* (2018). The survey revealed that more sprays were conducted under mixed cropping system (a system of growing two or more crops simultaneously on the same piece of land, also referred to as intercropping) compared to monocropping system (only one crop grown on a piece of land in a given season) of maize production. This was mainly because conducting a thorough spray under mixed cropping was quite hard given the congestion of crops in the field. Nevertheless, intercropping maize with beans (*Phaseolus vulgaris*) has been reported to reduce fall armyworm infestations by 20 to 30% compared to maize planted as a monocrop (CIMMYT, 2017). Additionally, climate-adapted push-pull technology developed for control of cereal stem borers and striga weed (Khan *et al.,* 2010) has been reported to effectively control FAW in smallholder farming systems in East Africa (Midega *et al.,* 2018). It involves intercropping maize with greenleaf desmodium, *Desmodium intortum* (Mill.) Urb., and planting *Brachiaria* cv Mulato II as a border crop around this intercrop. Protection to maize is provided by semiochemicals that are emitted by the intercrop that repel (push) stem borer moths while those released by the border crop attract (pull) them. Therefore, lack of more frequent intercropping might have exacerbated the FAW incidence observed in Bukwo and Bugiri in comparison to the other seven districts visited.

Differences in the effectiveness of pesticides against the FAW is not a surprise since different chemicals have different active ingredients, viz. (1) Super Cyper – an active synthetic pyrethroid with Cypermethrin 10% EC as active ingredient. It is a non-systemic, contact and stomach insecticide; (2) Striker 247 SC – a pyrethroid with Lambda-cyhalothrin (106g/l) as the active ingredient. It is a contact and stomach insecticide; (3) Ambush 2EC – also a pyrethroid with permethrin as the active ingredient, a stomach and contact insecticide; (4) Rocket – a non-systemic insecticide with Profenofos 40% and Cypermethrin 4% as the active ingredients. It has contact and stomach action. Worth noting is the fact that successful FAW control usually necessitates the use of insecticides at the upper range of their labelled rates as also reported by Adamczyk and Sumerford (2000).

Farmers reported rocket and super cyper as the most efficient pesticides used to control the FAW. Both of these pesticides have their active ingredient as profenophos and cypermethrin, which so far are the two most efficient chemical combinations against the FAW (Kinyua, 2017). It therefore implies that any chemical with profenophos and cypermethrin as the active ingredient should be efficient in FAW control. Such chemicals include Rocket 44EC (20 – 35 ml), Profecron 44EC (20 – 35 ml), Supa profenophos 44EC (20 – 35 ml), Agro-cypro 440EC (20 – 35 ml), Hitcel 44EC (20 – 35 ml), Procyper, Cypercal P720, Twigafos combi (Telton-C-425EC), Socket plus and Dudu-fenos (20 – 35 ml). However, according to Souza et al. (2013), lambda-cyhalothrin/thiamethoxam equally reduces parasitism capacity of FAW. Examples of chemicals which are a combination of lambda-cyhalothrin and thiamethoxam include striker (5 – 10 ml) and Engeo 247SC. The other effective chemical is Chlorpyrifos e.g. Troban 48EC applied at 40 – 60 ml. It is advisable to use such chemicals in rotation in order to avoid build up of resistance by the FAW (Dal Pogetto *et al.,* 2012). Also important to note is the fact that maize treated with these pesticides remains safe for consumption and the producers may not get any serious risk of contamination from the chemical control of the FAW (Togola *et al.,* 2018).

However, several authors have reported the FAW having developed resistance to several classes of insecticides, including pyrethroids (cypermethrin, fenvalerate, fluvalinate, and permethrin), organophosphates (chlorpyrifos, methyl parathion, diazinon, malathion, and trichlorfon), carbamates (methomyl, carbaryl, and thiodicarb) (Wood *et al.,* 1981; Yu, 1992; Adamczyk *et al*., 1999; Al-Sarar *et al*., 2006; Whalon *et al*., 2008). It is probably for this reason that a combination of chemicals, and at high concentrations, is more efficient than an individual chemical.

In this study, some maize varieties responded well to pesticide application against the FAW, such as Longe 4, H614D and H624, but not Longe 5. This implies that even the genetic constitution of a crop may influence its response to the FAW, and gives breeders a chance to develop varieties with resistance to the FAW. Similar reports of some varieties, especially the wild ancestors (*Balsas teosinte*) and Bt maize, being resistant to FAW have been reported (Bernal *et al*., 2015; Prasanna *et al*., 2018). It is also worth noting that Longe 5 is the most cultivated and recycled variety in Uganda, yet according to Bernal *et al.* (2015), direct and indirect defences of maize against *S. frugiperda* larvae tend to weaken with domestication.

This study also provides evidence of more maize production per unit area in the highland areas of Uganda than the lowland areas. For example, the grain yields were much higher in Bukwo (5.1 – 7.5 t $ha^{-1}$) and Kapchorwa (5.0 - 6.25 t $ha^{-1}$) when pesticides were utilized as reported by 80% and 53.3% of farmers, respectively. The good yields reported in the highland areas (for hybrids H614D and H624) compared to the lowland areas (for Longe 7H, Longe10H hybrids and OPVs) can be attributed to the fact that H614D and H624 are bred for adaptability to the harsh highland environments, therefore have more tough tissue compared to the mid altitude cultivars of Longe 7H and Longe 10H. Several authors (Williams *et al*., 1989; Widstrom et al. 1992, Widstrom *et al.,* 1993, Williams *et al*., 1995) have reported the genetic base of resistance to FAW to be of quantitative nature and the variation is due mainly to additive genetic effects. Probably it is for this reason that some OPVs and many landraces have not succumbed to the FAW compared to many improved hybrid cultivars.

## 5 CONCLUSION AND RECOMMENDATION

There was generally increased awareness and use of pesticides against the FAW, one year after detection. However, the lowland areas of Luuka, Pallisa and Butaleja had more FAW and much lower maize yields (< 1.25 t $ha^{-1}$) than the highland areas of Bukwo and Kapchorwa (5.1 – 7.5 t $ha^{-1}$). The most common FAW symptom was the formation of holes on leaves. The most common pesticide among farmers was rocket 44EC. Notably, 26.7% of farmers did not apply any control measures against the FAW. Maize cultivar Longe 5 was the most recycled and most cultivated therefore more associated with the FAW. We recommend that more efforts be made in creating awareness about the FAW. Secondly, since there are no resistant maize cultivars to the FAW as yet, farmers need to enhance the available maize intensification technologies (e.g. early planting, intercropping and adequate plant population) with the use of pesticides in order to realise adequate grain yield.

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Table 1: Farmers' response (%) on the mitigation measures being applied against the FAW in maize across districts in eastern Uganda

| Location | Spraying with pesticide chemicals | None | Cultural methods | Manual or mechanical method |
|---|---|---|---|---|
| Bugiri | 60.0 | 13.3 | 26.7 | 0.0 |
| Butaleja | 53.3 | 26.7 | 20.0 | 0.0 |
| Pallisa | 40.0 | 46.7 | 6.7 | 6.7 |
| Luuka | 26.7 | 60.0 | 13.3 | 0.0 |
| Kapchorwa | 40.0 | 26.7 | 33.3 | 0.0 |
| Manafwa | 80.0 | 13.3 | 6.7 | 0.0 |
| Sironko | 73.3 | 26.7 | 0.0 | 0.0 |
| Mayuge | 80.0 | 20.0 | 0.0 | 0.0 |
| Bukwo | 93.3 | 6.7 | 0.0 | 0.0 |
| Mean | 60.7 | 26.7 | 11.9 | 0.7 |
| Cramer's V | 0.33 | | | |
| $\chi 2$ (df = 32) | 92.95 | | | |
| P | < 0.001 | | | |

*Only those farmers who were aware of FAW were subjected to this question

Table 2: Farmers' response (%) on grain yield of different maize varieties under no pesticides and with pesticides applied against the FAW (N = 262)

| Treatment | Maize variety | Grain yield (t ha$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|---|
| | | < 1.25 | 1.25-2.5 | 2.51-3.75 | 3.76-5.0 | 5.1-6.25 | 6.26-7.5 |
| Pesticides applied | Longe 10H | 25.5 | 27.5 | 25.5 | 13.7 | 5.9 | 2.0 |
| | Longe 4 | 16.7 | 0.0 | 16.7 | 16.7 | 50.0 | 0.0 |
| | Longe 5 | 43.8 | 31.2 | 18.8 | 0.0 | 6.2 | 0.0 |
| | Longe 7H | 33.3 | 33.3 | 0.0 | 33.3 | 0.0 | 0.0 |
| | Landrace | 61.5 | 15.4 | 15.4 | 7.7 | 0.0 | 0.0 |
| | H614D | 0.0 | 10.0 | 20.0 | 20.0 | 40.0 | 10.0 |
| | H624 | 0.0 | 0.0 | 0.0 | 14.3 | 85.7 | 0.0 |
| | Others | 36.0 | 16.0 | 4.0 | 12.0 | 16.0 | 16.0 |
| | Mean | 29.8 | 20.6 | 16.8 | 12.2 | 16.0 | 4.6 |
| | Cramer's V | 0.337 | | | | | |
| | $\chi 2$ (df = 35) | 148.880 | | | | | |
| | P | < 0.001 | | | | | |
| No pesticides | Longe 10H | 52.9 | 25.5 | 15.7 | 3.9 | 2.0 | 0.0 |
| | Longe 4 | 16.7 | 16.7 | 16.7 | 50.0 | 0.0 | 0.0 |
| | Longe 5 | 75.0 | 18.8 | 6.2 | 0.0 | 0.0 | 0.0 |
| | Longe 7H | 66.7 | 0.0 | 33.3 | 0.0 | 0.0 | 0.0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Landrace | 76.9 | 15.4 | 7.7 | 0.0 | 0.0 | 0.0 |
| | H614D | 10.0 | 20.0 | 10.0 | 50.0 | 10.0 | 0.0 |
| | H624 | 0.0 | 0.0 | 28.6 | 71.4 | 0.0 | 0.0 |
| | Others | 48.0 | 8.0 | 12.0 | 16.0 | 12.0 | 4.0 |
| | Mean | 49.6 | 17.6 | 13.7 | 14.5 | 3.8 | 0.8 |
| | Cramer's V | 0.328 | | | | | |
| | $\chi2$ (df = 35) | 141.01 | | | | | |
| | P | < 0.001 | | | | | |

Table 3: Farmers' response on grain yields across different locations under no pesticides and with pesticides applied against the FAW (N = 262)

| | Location | < 1.25 t $ha^{-1}$ | 1.25-2.5 t $ha^{-1}$ | 2.51-3.75 t $ha^{-1}$ | 3.76-5.0 t $ha^{-1}$ | 5.1-6.25 t $ha^{-1}$ | 6.26-7.5 t $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| Pesticides applied | Bugiri | 41.7 | 33.3 | 8.3 | 16.7 | 0.0 | 0.0 |
| | Butaleja | 53.3 | 20.0 | 6.7 | 6.7 | 13.3 | 0.0 |
| | Pallisa | 60.0 | 13.3 | 20.0 | 0.0 | 0.0 | 6.7 |
| | Luuka | 66.7 | 26.7 | 6.7 | 0.0 | 0.0 | 0.0 |
| | Kapchorwa | 0.0 | 0.0 | 20.0 | 26.7 | 53.3 | 0.0 |
| | Manafwa | 21.4 | 28.6 | 14.3 | 21.4 | 14.3 | 0.0 |
| | Sironko | 0.0 | 33.3 | 40 | 20 | 6.7 | 0.0 |
| | Mayuge | 26.7 | 33.3 | 26.7 | 6.7 | 6.7 | 0.0 |
| | Bukwo | 0.0 | 0.0 | 6.7 | 13.3 | 46.7 | 33.3 |
| | Mean | 29.8 | 20.6 | 16.8 | 12.2 | 16.0 | 4.6 |
| | Cramer's V | 0.427 | | | | | |
| | $\chi2$ (df = 40) | 238.75 | | | | | |
| | P | < 0.001 | | | | | |
| No pesticides | Bugiri | 75.0 | 8.3 | 16.7 | 0.0 | 0.0 | 0.0 |
| | Butaleja | 73.3 | 6.7 | 6.7 | 13.3 | 0.0 | 0.0 |
| | Pallisa | 73.3 | 20.0 | 0.0 | 0.0 | 6.7 | 0.0 |
| | Luuka | 80.0 | 6.7 | 13.3 | 0.0 | 0.0 | 0.0 |
| | Kapchorwa | 0.0 | 20.0 | 20.0 | 60.0 | 0.0 | 0.0 |
| | Manafwa | 50.0 | 21.4 | 21.4 | 7.1 | 0.0 | 0.0 |
| | Sironko | 33.3 | 40.0 | 20.0 | 6.7 | 0.0 | 0.0 |
| | Mayuge | 66.7 | 26.7 | 6.7 | 0.0 | 0.0 | 0.0 |
| | Bukwo | 0.0 | 6.7 | 20.0 | 40.0 | 26.7 | 6.7 |
| | Mean | 49.6 | 17.6 | 13.7 | 14.5 | 3.8 | 0.8 |
| | Cramer's V | 0.407 | | | | | |
| | $\chi2$ (df = 40) | 216.6 | | | | | |
| | P | < 0.001 | | | | | |

Table 4: Farmers' responses on grain yields at different dates of planting following pesticides and no pesticides application against the FAW (N = 262)

| | Location | < 1.25 t $ha^{-1}$ | 1.25-2.5 t $ha^{-1}$ | 2.51-3.75 t $ha^{-1}$ | 3.76-5.0 t $ha^{-1}$ | 5.1-6.25 t $ha^{-1}$ | 6.26-7.5 t $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| Pesticides applied | Late Feb. | 33.3 | 29.6 | 18.5 | 7.4 | 11.1 | 0.0 |
| | Early Mar. | 42.4 | 27.3 | 15.2 | 9.1 | 6.1 | 0.0 |
| | Mid Mar. | 47.1 | 11.8 | 17.6 | 11.8 | 5.9 | 5.9 |
| | Late Mar. | 15.1 | 15.1 | 17.0 | 15.1 | 28.3 | 9.4 |
| | Early Apr. | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 |
| | Mean | 29.8 | 20.6 | 16.8 | 12.2 | 16.0 | 4.6 |
| | Cramer's V | 0.251 | | | | | |
| | $\chi2$ (df = 40) | 66.262 | | | | | |
| | P | < 0.001 | | | | | |
| No pesticides | Late Feb. | 63.0 | 22.2 | 7.4 | 7.4 | 0.0 | 0.0 |
| | Early Mar. | 69.7 | 18.2 | 9.1 | 3.0 | 0.0 | 0.0 |
| | Mid Mar. | 47.1 | 17.6 | 23.5 | 5.9 | 5.9 | 0.0 |
| | Late Mar. | 32.1 | 15.1 | 15.1 | 28.3 | 7.5 | 1.9 |
| | Early Apr. | 0.0 | 0.0 | 100.0 | 0.0 | 0.0 | 0.0 |
| | Mean | 49.6 | 17.6 | 13.7 | 14.5 | 3.8 | 0.8 |
| | Cramer's V | 0.255 | | | | | |
| | $\chi2$ (df = 40) | 67.928 | | | | | |
| | P | < 0.001 | | | | | |

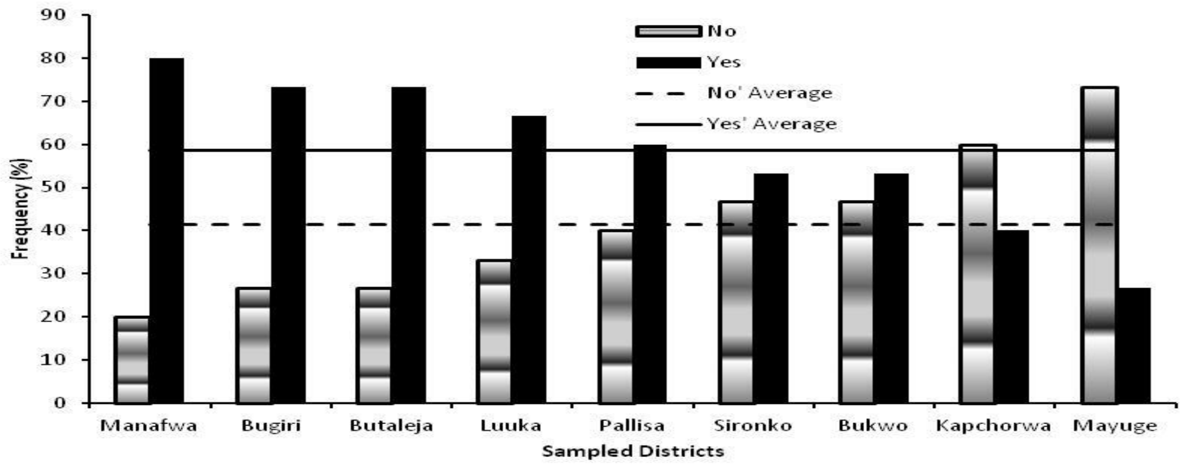


Fig. 1: Farmers' response on awareness of the FAW, their effects and mitigation measures (N = 270). No = not aware. Yes = very much aware.

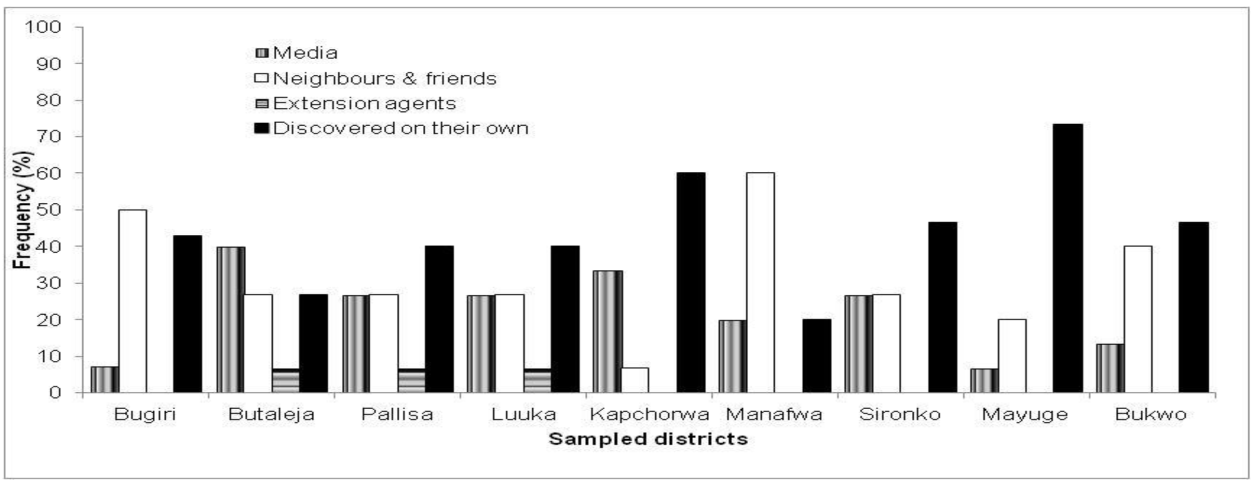


Fig. 2: Farmers' response (%) on source of information about the FAW

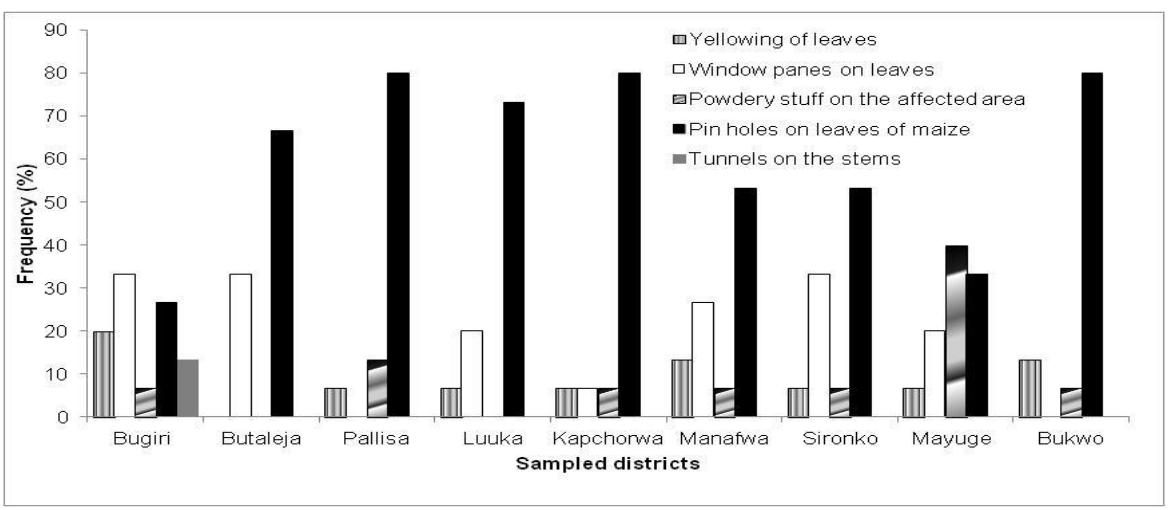


Fig. 3: Number of respondents (%) who observed FAW damage symptoms on their maize in nine districts of eastern Uganda (N = 270)