Bt maize and the fall armyworm in Africa: DEBUNKING INDUSTRY CLAIMS

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Contents

On 7 April 2015 the African Centre for Biosafety officially changed its name to the African Centre for Biodiversity (ACB). This name change was agreed by consultation within the ACB to reflect the expanded scope of our work over the past few years. All ACB publications prior to this date will remain under our old name of African Centre for Biosafety and should continue to be referenced as such.

We remain committed to dismantling inequalities in the food and agriculture systems in Africa and our belief in people's right to healthy and culturally appropriate food, produced through ecologically sound and sustainable methods, and their right to define their own food and agricultural systems.

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The image in Figure 1 is reproduced with the permission of John Obermeyer, Purdue Extension Entomology, Purdue University, West Lafayette, Indiana, USA.

Acronyms and Abbreviations

ACB	African Centre for Biodiversity
AATF	African Agricultural Technology Foundation
CIMMYT	The International Maize and Wheat Improvement Center (known by its Spanish acronym CIMMYT for *Centro Internacional de Mejoramiento de Maíz y Trigo*)
DAFF	Department of Agriculture, Forestry and Fisheries
FAO	Food and Agriculture Organization of the UN
FAW	fall armyworm
GM	genetically modified
GMO	genetically modified organism
IITA	International Institute of Tropical Agriculture
ISAAA	International Service for the Acquisition of Agri-biotech Applications
KALRO	Kenya Agricultural and Livestock Research Organization
NARs	national agricultural research systems
UN	United Nations
USDA	United States Department of Agriculture
WEMA	Water Efficient Maize for Africa

Key findings

The fall armyworm (FAW) *Spodoptera frugiperda*, is a moth native to tropical and subtropical regions of the Americas and was first observed in the African continent in 2016, in Nigeria, São Tomé and Príncipe. It has since spread to most sub-Saharan countries. How it reached West Africa is subject to speculation though the identification of numerous genetic strains in West and Central Africa suggests that there were potentially multiple introductions.

The limited availability of official statistics (depending on the country) has made it difficult to ascertain the extent of infestation and the impacts of FAW attacks. However, reports from various countries suggest damages have varied from minimal to substantial, with Mozambique reporting crop losses of up to 65% in some regions, while other nations are reporting much reduced or even insignificant damage in 2018. Damage has lessened and yields seem to have improved in 2018 compared with 2017 due to a variety of factors, including the implementation of control strategies, increased farmer awareness and improved rainfall.

The introduction of the FAW has given proponents of genetic modification (GM) technologies renewed impetus to bring forth the commercialisation of GM crops—especially Bt maize—expressing insecticidal Bt toxins to combat the pest. Those representing the Water Efficient Maize for Africa (WEMA) project and other pro-GM organisations have claimed that Bt toxins expressed in GM maize being trialled for the WEMA project are showing partial to strong protection. However, requests from the African Centre for Biodiversity (ACB) for data to substantiate these claims have not thus far been provided. Nor have any such data been published in peer-reviewed studies or any other publicly available format that would allow for independent scrutiny by scientists and the public.

The data that does exist on the efficacy of Bt crops in dealing with the FAW derive from the experiences of dealing with the pest in Brazil and elsewhere in the Americas, where the pest originates from, and where GM crops have been widely deployed to combat it. In Brazil, the FAW has not only developed resistance to numerous chemical pesticides but, crucially, has developed resistance to all but one Bt toxin, sometimes after only a year of commercialisation. Laboratory data showing that resistance can also develop against the final Bt toxin effective in the field (Vip3AA20) suggest that it will likely not be effective for long. The FAW is thus far the only insect to have developed resistance to Bt toxins in multiple locations, and its biology appears to make it particularly adapted to developing and rapidly spreading resistance genes.

Currently, there is little information on whether or not Bt toxin resistance already in American populations is present in those that were introduced to Africa. Only one study of one genetic strain in Togo has assessed Bt toxin resistance to date. It also appears that this is not an active area of inquiry by those researching and pushing for the commercialisation of GM crops—a rather negligent approach, considering that Bt toxins expressed in crop plants may be ineffective if resistance is present. The high levels of resistance witnessed in Brazil serve as a warning for what is likely to be repeated in Africa. Even if resistance is not already present, Bt resistance is a natural evolutionary process and it is only a matter of time before it occurs.

Alternative solutions to GM and industrialised models of crop and food production are being implemented and researched. One such solution is the climate-adapted push-pull system that has been shown to decrease damage by over 80% across Kenyan, Ugandan and Tanzanian farms, and to significantly increase yields. Such agro-ecological practices can be immediately deployed, at little financial or biosafety risk to small-holder farmers. We strenuously urge governments to withstand the external pressures to introduce GM crops and to reject the unsubstantiated claims that they present a ‘panacea’ to FAW attacks.

About this paper

This research report is part of the ACB's wider research agenda of analysing the impacts of GM seed/crops on Africa's food systems.

In recent years, many African nations have been under renewed pressure to commercialise GM crops, and to weaken their biosafety laws in order to do so. Driven by the private-sector, with public partners, the WEMA project, an initiative that aims to develop drought-tolerant and insect-resistant maize using conventional breeding, marker-assisted breeding and genetic engineering, is exerting such pressure. It does so under the guise of philanthropic intentions to provide solutions to small-holder farmers facing the very real threat of climate change. Instead, the ACB has called out the project for promoting a privatised food system that will increase farmer costs, while making unsubstantiated claims of safety and efficacy.

Following the initial observations of the FAW, an American moth pest, in West Africa and its subsequent rapid spread across most countries in sub-Saharan Africa, GM proponents are now making additional claims that genetically modified organisms (GMOs), and specifically those being trialled under the WEMA project, are now not only a climate-change solution, but a solution for the FAW pest.

This research paper aims to document the many claims being made by GM proponents that GM maize will solve the FAW problem, and debunks those that are currently unsubstantiated with thorough, publicly available, peer-reviewed data. The ACB wrote to members of the WEMA project in order to access trial data that back up claims of efficacy, but to date have received no such data, only further unsubstantiated claims. The research paper also critiques these claims, analysing published data and reports from the Americas where it is a major pest, showing that GM crops have been far from a sure solution, but instead have become rapidly ineffective in many cases due to FAW resistance to GM traits. Finally, we document some of the alternative agro-ecological solutions currently being implemented or researched that may provide effective, sustainable, long-term strategies that can be immediately deployed with lower financial and biosafety risk to small-holder farming systems.

What is the fall armyworm and where did it originate?

The fall armyworm (FAW), *Spodoptera frugiperda*, is a moth native to the tropical and subtropical regions of the Americas. The FAW is a distinct species to the African armyworm (*Spodoptera exempta*), with the term 'armyworm' referring to a numerous species that share a marching behaviour when travelling to new feeding sites.

The FAW caterpillar or larva (Figure 1) is regarded as a pest due to their highly polyphagous behaviour, feeding on a recorded 100 plant species including its preferred plants: maize, rice and sorghum, as well as sugarcane, cotton, millet, groundnut, soybean, potato and other vegetable crops. They are highly migratory, with female moths travelling 100 km a night, allowing the pest to spread rapidly. Its remarkable dispersal capacity allows expansive territorial spread, from warmer parts of the Americas to as far as Canada in the north, and Chile and Argentina in the south during the summer months, though it cannot overwinter in temperatures below 10°C. These characteristics make them a significant risk to food crop production, with the ability to cause high yield losses if not well managed. It is considered the most important maize pest in Brazil, the third largest maize producer in the world, and is estimated to cost US$ 600 million in control strategies (Filho *et al*. 2010).

Figure 1: Fall armyworm

Source: Purdue Extension Entomology.

The FAW reproduces at a rate of up to several generations per year. In warmer climates/ seasons its life cycle can be completed in 30 days, but it can take 90 days during cooler temperatures. A female moth can lay 6–10 egg masses of 100–300 eggs each, totalling a maximum of 1 500–2 000 eggs in her two- to three-week lifetime. Eggs tend to be laid on the bottom of leaves near the base of the plant and after a few days they start to feed superficially, usually on the underside of the leaves. In maize plants, the caterpillars eventually reach the whorl of the plant where they do the most damage, punching holes in the plants at the growing point, preventing the development of new leaves. Feeding in the whorl of maize often produces a characteristic row of perforations in the leaves. Only one or two caterpillars tend to be found in the whorl, as they become cannibalistic when larger and eat each other to reduce competition for food. When the caterpillars are fully grown (about 14 days) they will drop to the ground to pupate after burying themselves in the soil, or under leaves, before emerging a further eight to nine days later as a moth.

It is generally considered that there are two strains of FAW in the Americas, a rice strain (R-strain) most consistently found in millet and grass species, and a corn strain (C-strain), which prefers corn and millet. Both strains occur across the Americas. According to recent studies the two strains are genetically distinct, representing two 'sister' species. Genetic studies have revealed that the C-strain can be further divided into two subgroups, the FL-type and TX-type, based on geographical and genetic (mitochondrial haplotype) differences. The TX-type is found in most of the Americas, while the FL-type is found in Florida and the Caribbean, as well as the east coast of the US, due to migrating populations from Florida. No subgroups for the R-strain have been identified. These strains have been found to hybridise in the field, but at low levels.

How did it come to be in the fields of farmers in Africa?

The first observations of the FAW on the African continent were made in January 2016 in the rainforest region of South West Nigeria and, very interestingly, in maize fields at the International Institute of Tropical Agriculture (IITA) at Ibadan and Ikenne, but damage was first attributed to the indigenous moth species of the genus *Spodoptera Guenée*, 1852 (Lepidoptera: Noctuidae) that is common in the region. However, later in the season, high FAW populations were observed in northern Nigeria, Benin and Togo. The Federal Government of Nigeria expressed alarm over the upsurges of the pest in Edo maize fields and surrounding areas. In April 2016, following distress calls by maize producers, the government of São Tomé and Príncipe called for assistance from the Food and Agriculture Organization (FAO) through its sub-regional office for Central Africa who expedited a technical mission to the country to assess the situation.

Since the initial observations, presence of the FAW has been reported and confirmed in all of mainland southern Africa (except Lesotho), in Madagascar and Seychelles and throughout sub-Saharan Africa, except for Djibouti and Eritrea. Detection in Gabon, Equatorial Guinea and Republic of Congo was awaiting official confirmation, as of February 2018 (FAO 2018a).

How the armyworm came to the continent is subject to speculation. A number of possibilities have been suggested, including via anthropomorphic activities such as commercial flights, travellers, agricultural commodities, or by long-distance dispersal via wind patterns across the Atlantic.

Genetic analyses of various populations suggest the possibility of multiple introductions of the FAW. Analysis of the Nigerian and São Tomé populations, where the pest was first detected, revealed the presence of at least two maternal lineages (Goergen *et al*. 2016). More recent analyses of Ugandan populations found the additional presence of a third maternal lineage, two of the C-strain, as found in Nigeria, and one of the R-strain sister species (Otim *et al*. 2018). These findings prompted the researchers of the two studies to suggest that separate introductions may have occurred. Studies of Ghanaian populations also suggest the presence of both sister species (Cock *et al*. 2017). Another recent study, however, has questioned the presence of the R-strain and also discovered a supposedly novel genetic population yet to be identified in the western hemisphere, concluding that there was likely only a single introduction of the FAW originating from the Florida/Caribbean region (Nagoshi *et al*. 2018). Further work may be needed to clarify which strains are present, especially when looking at which crops may be targeted, and which strains are carrying existing resistance alleles to Bt crops if they are to be at all effective in dealing with the pest.

Infestation and impacts

The extent of infestation across African countries has been hard to estimate, depending on the level of monitoring and the publication of figures. Attaining accurate information is further clouded by predictive claims made across media outlets, many of which appear to be stating worst case scenarios painted prior to the implementation of control strategies, which in some cases seem to have staved off major crop losses. Information from major maize producers has been summarised below.

In Nigeria, where the infestations were first observed, the Nigerian Ministry of Agriculture confirmed the presence of the pest in 22 of the country's 36 states in February 2017 (*Premium Times* 2017). They also estimated that a sum of 2.98 million naira would be needed to curtail the infestation. Agricultural experts estimated projected losses at 15% for maize, if no control measures were put in place. Financial reports on maize outputs from February 2018, however, estimated a smaller drop in production of 7% attributable to FAW, but also reported reduced planting of the crop due to the pest as well as increased cheaper imports, with the result that farmers were switching to alternative crops. The US Department of Agriculture's (USDA) Foreign Agricultural Service, has reported a drop in the production of maize to a lesser extent, at 2% this year, or from 10.7 million tons in 2016/17 to 10.5 million tons in 2017/18 across 5.8 million hectares (1.81 tons per hectare). In 2015/16, the USDA reports that production was 7 million tons across 3.8 million hectares (1.84 tons per hectare). However, reports of more extreme losses have been made in certain regions. In the state of Jigawa, media reports from June 2017 state that they were harvesting five to six bags of maize from their farms, while previously they were harvesting 10 to 15 bags. Farmers have thus far deployed chemical pesticides to counter the problem and the FAO for national plant protection, extension experts and FFS practitioners (master trainers and facilitators) have conducted training in West Africa. The government also signed a technical cooperation agreement with the FAO to manage the issue (ReliefWeb 2017).

In Ghana, reports from the Ministry of Food and Agriculture in April 2018 stated that 249 000 hectares of maize fields have been affected this season, of which 234 807 recovered through the implementation of control measures such as early scouting, chemical pesticides and public awareness campaigns, while 14 247 were destroyed. The ministry also reported that early reports of FAW infestations in "Ashanti, Brong-Ahafo, Eastern, Volta and Western Regions had been blown out of proportion as it was a pre-season production infestation" (GhanaWeb 2018).

In East and southern Africa countries, predictions of major losses this year have been mitigated by the implementation of control measures as well as by above average rainfall, which boosted yields. Zimbabwe media outlets have recently reported a sharp reduction in damage this year, with the FAO confirming 15 000 hectares of farmland

during the 2017/18 season compared to more than 13 000 hectares the season before, a drop of 88% (*The Herald* 2018).

Similarly, in Kenya, the Ministry of Agriculture reported figures of 200 000 hectares being lost in 2017, with infestations occurring in 27 of the 47 counties (Dhahabu Kenya 2018). Reports from 2018 suggest that 160 000 hectares are currently affected—approximately 7% of maize land—but spanning more counties than in 2017, with 43 of the 47 counties affected (Bloomberg 2018). In May 2018 the FAO announced that infestations have been contained this year as pest management has now kicked in (FAO 2018b). The USDA's Foreign Agricultural Service 2018 Grain and Feed annual report also states that "Production is also expected to increase as the country rebounds from a nearly two-year period of erratic weather, the improved management of fall army worm (FAW), and the apparent containment of maize lethal necrosis (MLN)" (USDA 2018a). The government has thus far set aside KSh300 million, which will increase to KSh1 billion in the future to tackle the pest (Business Daily 2018).

In Uganda, there are similar reports of less-than-expected losses. An FAO report from February 2018 suggests that implementation measures have staved off worst case scenarios, with 'satisfactory' harvests reaped in the 2017 second-season harvest. The report states that "Fall Armyworm infestations were reported in mid-2017 in 60 of the country's 112 districts. However, crop losses are reported to be less significant than originally expected due to increased pest management and prevention measures." However, reduced maize production due to weather and fall armyworm attacks in the region of Karamoja were also mentioned in the same report (FAO 2018c).

In Tanzania, The Ministry of Agriculture posted data gathered from December 2017 to January 2018, reporting that 71 425.9 hectares of maize, sorghum and other crops (a little of coffee and cotton) have been attacked, as well as 34 034.2 hectares of grain cereals in the Singida, Lindi, Simiyu, Kagera, Mwanza, Geita, Iringa, Kilimanjaro, Mbeya, Pwani, Tabora, Shinyanga, Tanga and Ruvuma regions.

Ethiopia, a country that appears to have recently joined the WEMA project, has also reported significant infestations of 353 000 hectares of maize, though 30 000 has already been controlled with both "traditional methods and modern ones", according to the Chinese newspaper, *Xinhuanet* (*Xinhuanet* 2018). As of May 2018, control measurements were still required in order to halt potential impacts on the remaining 57 000 hectares. However, the USDA Foreign Agricultural Service reports that the impacts since March 2018 have been minimal:

> *At the same time, the impact of FAW on overall corn production was relatively minor because of various government and development partner-supported interventions, including manual removal, pesticide application, and other measures. In addition, the longer than expected rainy season (Meher) was also said to have suppressed the spread of the pest due to the cooler temperatures. (USDA 2018b)*

Mozambique's Ministry of Agriculture has reported more severe losses, with reports from April 2018 predicting a 50–60% loss in the production of maize. In Maputo, the armyworm has reportedly infested 42 000 hectares, though infestations across 33 000 hectares have since been brought under control. However, a member of the FAO has claimed that the impacts of the pest are "not yet alarming". The areas most affected are Niassa province, in the far north, with 65% losses in the zones hit by the pest, Maputo province in the south (56% losses) and Zambezia in the central region (46% losses) (AllAfrica 2018a).

Information on the affected areas in South Africa were sent by the Department of Agriculture, Forestry and Fisheries (DAFF) via email, following requests for information on the extent of infestation and whether or not transgenic maize has been effective in staving off attacks (Table 1). This information does not report the extent of crop losses, making it hard to estimate the damage caused by the pest. Their update published in February states: "The infestation level is less than the previous year (2017), since most of the farmers are using and/or spraying registered agrochemicals. There were more

Table 1: Areas affected by FAW infestation in South Africa, 2018

Province/Region	Districts affected	Area affected (hectares)
Gauteng	• City of Tshwane	394
	• Ekurhuleni	
	• West Rand	
Limpopo	• Capricorn	10 172
	• Mopani	
	• Vhembe	
	• Waterberg	
	• Sekhukhune	
Mpumalanga	• Ekangala	634.05
	• Ehlanzeni	
	• Gert Nsibande	
North West	• Bojanala (Brits area)	150
Free State	• Motheo	Trapping data only (only moth catches)
	• Lejweleputswa	
KwaZulu Natal	• uThukela	219.1
	• uMkhanyakude	
	• uMgungundlovu	
Eastern Cape	• Amathole	14
Northern Cape	• Pixley ka Seme	Trapping data only (only moth catches)
	• Frances Baard	
Western Cape	None	0

Source: Department of Agriculture, Forestry and Fisheries, email to author 17 May 2018.

chemicals registered during 2017 to control and manage the FAW. Therefore, there are more options to control the pest." With South Africa being the only nation on the continent to grow Bt crops such as MON89034 commercially, it is interesting that there is no mention of their use as part of the control measures being employed.

Industry myth making

The rapid spread of the fall armyworm has provided new impetus to the pro-GM industry's push for GM crop commercialisation across the continent and the liberalisation of biosafety laws in order to allow them in.

One narrative that is being widely disseminated is that the current trials conducted by the WEMA project on so-called drought-resistant and insect-resistant GM maize is showing efficacy against the FAW. The WEMA project is a public-private partnership coordinated by the African Agricultural Technology Foundation (AATF), also involving Monsanto and the International Maize and Wheat Improvement Center (CIMMYT), and rolled out in partnership with the national agricultural research systems (NARs) in Kenya, Mozambique, South Africa, Tanzania and Uganda. Recent media reports suggest Ethiopia has also recently joined the project. WEMA is funded by the Bill and Melinda Gates Foundation, the Howard G. Buffett Foundation and USAID. The ACB has been raising concerns about WEMA since its inception, vehemently disputing the claims that their transgenic techniques are successfully generating drought tolerance. The ACB has reported how, in reality, the project is being used to promote Monsanto's insecticidal maize varieties MON810 and MON89034 in Kenya, Uganda, Mozambique and Tanzania under the guise of water efficiency. MON810 has already failed in South Africa due to insect resistance, making the motivations for pushing these failed traits on other African nations somewhat questionable.

Examples of such claims include those made in the recent guide on FAW management by Feed the Future, produced by CIMMYT in collaboration with USAID and CGAIR, stating that alongside other pest control strategies,

> *[d]eploying transgenic or genetically modified (GM) crop varieties that express lepidopteran resistance genes is another strategy to effectively control FAW damage in maize...Several different cry genes are available – e.g., cry1A, cry1Ab, and cry1F – and have been deployed in commercial Bt maize varieties globally for over 20 years. (Feed The Future 2018, p.49)*

The guide later adds:

> - *The MON810 event, which is intended to control stem borer but also confers partial resistance to FAW, has been cultivated in South Africa since 1997; and*
> - *The MON89034 event, which has demonstrated efficacy for control of both FAW and stem borer, has been cultivated in South Africa since 2010. MON89034 is particularly recommended for FAW control due to its high efficacy against the pest, as well as anticipated durability of control over time due to its incorporation of "stacked" or "pyramided" insect-resistance traits.*
>
> *WEMA's emerging results are consistent with the performance of Bt maize in other countries: When introduced into locally preferred African maize varieties, the MON810 event is demonstrating strong control of stem borers and partial control of FAW in Kenya, Mozambique, and Uganda. An application for approval of MON810 in Kenya is pending finalization, and applications for approvals in other WEMA partner countries are expected to be ready for submission in 2018 – giving African biosafety regulatory agencies the opportunity to evaluate the technology themselves and decide on the safety, efficacy, and performance of Bt maize in African environments. (Feed The Future 2018, p.49)*

WEMA scientists have been quoted in various articles repeating similar claims. An article appearing in the Kenyan *Standard Digital* newspaper on 14 March 2017, quotes Dr Sylvester Oikeh, a WEMA project manager and other associates:

> *"Every effort to approve Bt maize in East Africa including Kenya will give farmers some protection against this new pest," Oikeh said. Though Kenya and Uganda have conducted numerous tests on Bt maize, they are yet to commercialise it due to policy requirements. According to Dr Murenga Mwimali, a maize breeder at Kenya Agricultural and Livestock Research Organisation, fall armyworm is capable of destroying an entire maize field in a couple of days. Dr Anani Bruce, an entomologist at CIMMYT in Nairobi says that although chemical sprays control the pest, researchers insist that Bt maize is a sure solution against fall armyworm invasion. (Standard Media 2017).*

Articles published by Cornell University's Alliance for Science website, funded by the Bill and Melinda Gates Foundation and partners of the Monsanto/industry-funded International Service for the Acquisition of Agri-biotech Applications (ISAAA), have also joined in the drive to bring forth the commercialisation of WEMA crops for FAW management, and to even extend the crops beyond those nations taking part in the WEMA project, such as Nigeria and Ghana. In September 2017, an article stated that agricultural industry stakeholders were "pushing for the application of innovative technology", in the face of resistance to chemical pesticides that are also harmful to health. The article quoted various scientists from Ghana and Nigeria, including Dr

Rose Gidado from the Nigerian National Biotechnology Development Agency: "… genetically modified varieties will have natural resistance to the armyworm, there will be no need to spray chemicals as expected" (Cornell Alliance for Science 2017).

In March this year, the Cornell Alliance for Science published an article on the trials conducted in Uganda. Written by a British pro-GM campaigner who is now a visiting fellow at the Alliance, it states that:

> *Although the WEMA maize being developed at Namulonge was developed primarily for drought tolerance in order to help maize farmers cope with climate change, it also carries an insect-resistant Bt gene that protects against two primary maize pests: stem borer and fall armyworm. Addition of the Bt gene should allow Ugandan farmers to dramatically improve yields with less need for expensive and environmentally toxic pesticides, according to Asea. (Cornell Alliance for Science 2018a)*

Dr Godrey Asea, director of the National Crops Resources Research Institute in Uganda, went further, stating that the WEMA hybrids show "strong protection" against both the fall armyworm and stem borers, and expressing frustration at the delays in passing the biosafety bill that would facilitate the commercialisation of GMOs in the country.

The latest article, published in April 2018, states that the Mozambique trials showed "unexpected benefits…that despite them being genetically modified to withstand drought and the vicious stem borer pest, they're also showing promising resistance to the destructive fall armyworm pest" (The Cornell Alliance for Science 2018b). This article seems to have framed the results as some sort of new serendipitous result, despite statements by other members of the WEMA project, such as CIMMYT, that MON89034 has "demonstrated efficacy against the FAW" (as highlighted above). Monsanto's website also quotes their Director of Collaboration from Developing Countries, Mark Edge, who earlier this year asserted that "Bt maize helps protect that genetic potential and minimizes the negative impact of insects like Fall Armyworm. It would be an excellent addition to the crop protection toolbox for farmers in Africa" (Monsanto 2018). Claims of WEMA traits working against the FAW specifically in Mozambique trials were also published many months before the "unexpected benefits" were declared by the Alliance for Science, such as an October 2017 article in Zimbabwe's The Herald newspaper, which reported that the AATF had confirmed "on a scale of one to nine, based on the Bt maize trials in Uganda, the damage from the armyworm was three for the Bt genetically modified variety and six on the local checks or the popularly grown varieties. Similarly, Bt maize trials in Mozambique have shown that on a scale of one to nine, the damage was on 1.5 on Bt maize and seven on popularly grown varieties" (*The Herald* 2017).

The AATF blog further quotes Dr Rose Gidado claiming:

> *The lasting solution to army worm infestation on maize is the use of genetic modification technology to develop a maize variety that would be resistant to the pest, that gives a permanent solution…There is already a variety of maize called Water Efficient Maize Variety for Africa that has proven to be resistant to army worm, it has not yet been deployed to Nigeria but we are making plans. (AATF 2017a)*

The AATF has also made general statements about the efficacy of both MON810 and MON89034 in WEMA trials in their 2017 newsletter:

> *The ability for Bt maize to contribute towards controlling the FAW has further been demonstrated in the Water Efficient Maize for Africa (WEMA) Project confined field trials in Uganda and South Africa with Bt maize (MON810) and GM maize stacked for drought tolerance and insect resistance (MON89034). (AATF 2017b)*

The pro-biotech organisation ISAAA has published a string of articles on the issue, with claims in a January article for example, that Kenyans are on "the brink of starvation", alongside quotes from Kenyan WEMA scientist at the Kenya Agricultural and Livestock Research Organization (KALRO), Dr

Murenga Mwimali, that Bt maize is able to control for the FAW (ISAAA 2018). Emails to ISAAA requesting evidence to back up claims made in their articles were not answered.

The ACB wrote to WEMA members requesting scientific data to substantiate the above claims, though none has thus far been provided. One response was received from Dr Sylvester Oikeh (see Annex I for the full written response and attached photo), who elaborated the above claims, writing that GM varieties in Mozambique provided "9–98% better yield than isogenic hybrids depending on levels of infestation" under natural infestation of both stem borers and FAW; in Kenya GM maize conferred "partial but significant protection against FAW (see attached photos from Uganda)" with "15–27 % higher yields" in TELA® hybrids. The photo provided (Figure 2 in Annex 1) is somewhat confusing, considering that it appears that the main difference between the GM and non-GM control is growth rates, an effect that one would not expect to be associated with insect damage. More importantly, the control non-GM lines do not appear to have been badly affected by insect damage. These questions were again raised in a follow-up email with Dr Oikeh and other members of WEMA, but a response is yet to be received. The Mozambique Ministry of Agriculture and Food Security's Agricultural Research Institute Of Mozambique (IIAM) echoes the claims in a recent response to requests from civil society organisations for information on the WEMA trial, which states that there was a "lower intensity of attacks" on GM varieties during the trials but, again, no supporting data were provided (MASA 2018).

Requests for information were also made on a second issue—whether or not the populations of FAW that arrived from the Americas came with existing resistance to Bt toxins and whether or not this is being actively assessed—a vital question to answer before commercialisation considering that resistance is common in the Americas. The response from Dr Oikeh (Annex 1) was as follows:

> *Fall Armyworm is a new pest to Africa. It is rather too early to speculate about FAW developing resistance on Bt crops, or even on Bt sprays commonly used by organic farmers in Africa. At this stage, we should advocate for the immediate use of all available technologies in an integrated pest management approach to protect farmers' crops from huge losses caused by the pest.*

This could be considered a rather negligent approach since, as expanded below, that resistance is rendering Bt crops futile in Brazil where GM maize is widely grown.

The Feed the Future guide also discusses the issue of resistance, referencing what appears to be the only study to date to be published on Bt toxin resistance in African FAW populations. The study (Nagoshi *et al*. 2017) looked for a Cry1Fa resistance allele that is present in the FL-type of C-strain populations present in Togo.

The WEMA project is shrouded in secrecy, as has been previously stated by ACB in an open letter to the project's leaders (ACB 2017). This secrecy is now extending to the issue of the FAW where again, absolutely no data is presented to support the claims that the WEMA project, originally sold as the best solution for Africa's climate change issues, is now also the "sure solution" for FAW control.

The propaganda drive is also circulating in the Global North, with media articles regurgitating the worn-out narrative that African farmers need technology from the North to progress and modernise. A recent article in the UK's *The Economist* suggests:

> *Better still would be to copy America's commercial farmers, who plant GM crops that are largely resistant to the worm. Almost all African countries apart from South Africa have formally or informally banned GM crops, following iffy advice from ecowarriors. Lifting these restrictions would lead to fewer hungry caterpillars and fewer hungry people.*
> *(*The Economist *2018)*

It also rather patronisingly states that the FAW is a major issue in Africa partly because farming is "done by smallholders who use outdated techniques and whose yields are already low", reflecting a tired attitude that foreign interventions are needed in order to successfully deal with the issue.

A similar article from the *Financial Times* in the UK concluded that "one of the ways the US has been able to mitigate the armyworm's impact is through the use of genetically modified maize, but this is rarely planted in sub-Saharan Africa, where there is widespread opposition to such crops" (*Financial Times* 2017).

Emails were also written to Grain SA in South Africa, the only nation on the continent to grow Bt maize varieties commercially, to request official information on whether or not control from Bt maize in South Africa was effective, and whether or not resistance of FAW to the Bt traits was also being observed. A member of Grain SA stated that "feedback from our members are that especially the new Bt trait shows good resistance" (email to author, 1 May 2018). This new trait was later confirmed in a separate email to be MON89034.

In summary, we are being faced with inconsistent claims that Bt maize provides either 'partial' or 'strong' protection, that such successful results were 'unexpected', from a technology that is a 'sure solution' with 'demonstrated efficacy' in the Americas. More crucially, we are yet to see data to corroborate which, if any, of these claims are in fact based on sound scientific protocols and results, with regard to trials taking place in WEMA member countries.

Debunking the industry myths

Unfortunately, claims of Bt maize efficacy for FAW control in Africa, either in WEMA trials or in the commercialised fields of South Africa, have not been corroborated by any available scientific data, despite numerous requests to members of the WEMA team as described above.

The limited information from South Africa suggests that full resistance is not being observed, as despite the vast majority of maize being transgenic, maize crops are still affected. In email correspondence, a member of DAFF also informed ACB that they "did notice that those farmers who planted Bt maize (particularly in Free State province) had less infestation compared to normal maize not to say it was completely resistant".

Not only does the lack of data deny full and proper public participation in the approval process for commercialisation of GM crops, as stipulated in the UN Cartagena Protocol for Biosafety to which all WEMA countries are signatories, it also questions the scientific rigour and ethics of the project in its application of science for the sake of small-holder farmers across the region. Without such data, the potential efficacy of Bt maize to control the pest in Africa can only be extrapolated from the experiences in the Americas.

When assessing the current situation in American nations, the deployment of Bt maize looks far from a sure solution, with for example Brazil and Puerto Rico, as well as other parts of the US and Argentina, suffering from significant FAW resistance to Bt traits. Recent studies reported Cry1F resistance allele frequencies in Florida, Louisiana, and North Carolina at between 10 and 29%, suggesting widespread regional establishment of the resistance trait at a substantial frequency (Huang *et al*. 2014; Vélez *et al*. 2013).

In Brazil, the situation is even worse, where numerous Bt maize products have been commercialised since 2008. The country is already witnessing resistance to all but one Bt toxin, Vip3Aa20, as highlighted in a recent review by Fatoretto *et al*. (2017) (see Table 2). These crops were deployed following the development of resistance to synthetic pesticides, only for resistance to have now also developed to all of the Bt toxins used, except for the Vip3Aa20 toxin. As shown in Table 2, field failures of Bt maize occurred within four years of commercial approval. For two stacked events, MON-89034-3 x DAS-01507-1 x MON-00603-6 and DAS-01507-1 x MON-00810-6 x MON-00603-6, field failures were seen after only one year of market approval. These two events each include MON810 and MON89034, the two crops being touted as the solution for African FAW populations.

The resistance mutations noted by Fatoretto *et al*. (2017) as having occurred in Brazil also appear to be dominant, making the

Table 2: List of fall armyworm resistance to Bt GM crop traits in Brazil

Company	Traits	Event name	Trade name	Approval year	Field failure started
Syngenta	Cry1Ab	SYN-BT011-1	Agrisure TL	2008	2011
	Vip3Aa20	SYN-IR162-4	Agrisure Viptera	2009	NF
	Cry1Ab + Vip3Aa20 + Gli	SYN-BT011-1 x SYN-IR162-4 x MON-00021-9	Agrisure Viptera3	2010	NF
Monsanto	Cry1Ab	MON-00810-6	YieldGard	2008	2011
	Cry1A.105 + Cry2Ab2	MON-89034-3	YieldGard VT Pro	2009	2013
Dow Agrosciences	Cry1F	DAS-01507-1	Herculex I	2008	2011
	Cry1A.105 + Cry2Ab2 + Cry1F	MON-89034-3 x DAS-01507-1 x MON-00603-6	PowerCore	2013	2014
DuPont	Cry1F	DAS-01507-1 x MON-00603-6	Herculex I	2009	2011
	Cry1F + Cry1Ab	DAS-01507-1 x MON-00810-6 x MON-00603-6	Optimum Intrasect	2011	2012
	Cry1F + Cry1Ab + Vip3Aa20 + Gli + Glu	DAS-01507-1 x MON-00810-6 x SYN-IR162-4xMON-00603-6	Leptra	2015	NF

Source: Reproduced from Fatoretto *et al*. 2017, p.3.

deployment of integrated management practices, such as the use of 'refuges' of non-Bt maize adjacent to the GM maize fields ineffective as a means of delaying the development of resistance. Another genetic characteristic of the FAW resistance noted by Fatoretto *et al*. is the apparent lack of fitness costs associated with the resistance alleles.

Despite the Vip3Aa20 Bt toxin still showing efficacy in Brazil, laboratory studies have shown the development of resistance to this protein in both Agricusure Vipteral maize (expresses Vip3Aa20) and Agrisure Viptera 3 maize (expresses Vip3Aa20 and Cry1Ab), suggesting that it is only a matter of time before it will be observed in Brazilian fields.

Laboratory studies have also indicated the resistance of FAW to YieldGard VT PRO maize, which expresses Cry1A.105/Cry2Ab212,16; PowerCore maize, which expresses Cry1A.105/Cry2Ab2/Cry1F20; and Agrisure Viptera and Agrisure Viptera 3 maize, which express Vip3Aa20 and Vip3Aa20/Cry1Ab21, respectively (Horikoshi *et al*. 2016). The laboratory selection of these resistant strains from field populations of FAW is indicative of the presence of resistance alleles in the field.

Fatoretto *et al*. (2017) have noted that the fall armyworm's high rates of rapid resistance in Brazil may be due to a number of issues including innate biological factors associated with the species, such as its high reproductive output, its complex detoxification system that may promote the breakdown of Bt toxins and its high dispersal levels, as well as agrosystem issues such as the tropical climate that allows for overlapping crop cycles and thus continuous presence of its host plants, and lack of proper adoption of insect resistance management strategies, such as refuge compliance.

Cross-resistance to multiple Bt toxins is also an issue. Among the several available commercial Bt maize and cotton varieties, most express Bt proteins from the Cry1 group, with some proteins showing cross-resistance (Bernadi *et al.* 2015), including Cry1F with Cry1A.105 and Cry1Ab. Additionally, cases of cross-resistance between Bt toxins and non-Bt conventional insecticides were reported in the diamondback moth *Plutella xylostella* (i.e. pyrethroids and Cry1Ac toxin) and in *S. frugiperda* (i.e. organophosphates and Cry1F toxin) (Sayyed *et al*. 2008; Alvi *et al*. 2012; Bird *et al*. 2014; Zhu *et al*. 2015).

In a 2018 study, even Monsanto admit that resistance is a major issue limiting their long-term sustainability:

> *The evolution of insect resistance to these crops is a major threat to their sustainability. Indeed, in two decades of Bt crop cultivation, several insect species have developed resistance resulting in field control failures. S. frugiperda is one such insect. It has developed resistance to Bt maize expressing the Cry1Fa protein in Puerto Rico, the US mainland, and Brazil, with cross-resistance to Cry1A.105. (Flagel* et al. *2018).*

They further admit, in a study co-authored by a Monsanto employee, that "Up to date, S. frugiperda is the only target pest that has developed field resistance to Bt crops in multiple locations across different countries and continents" (Niu *et al*. 2016, p.1).

They also note that the resistance mutation reported in their 2018 paper (Flagel *et al*. 2018), which confers resistance to Cry1Fa and Cry1A.105 detected in resistant Puerto Rican populations, is not present in resistant Brazilian populations (therefore the Brazilian mutation is a different one) and conclude that "[t]ogether these results suggest that Cry1Fa and Cry1A.105 resistance in S. frugiperda may develop repeatedly in local populations, rather than infrequently and spread to new areas via long distance migration". This undermines the durability of MON89034, a stacked event that expresses Cry2Ab2 and Cry1A.105, which is a fusion protein that comprises Cry1Ab, Cry1F and Cry1Ac.

They also state that "there are likely a large number of mutations that can render SfABCC2 nonfunctional as a Bt receptor, so it is not surprising to have new resistance alleles being created at a steady rate in nature". So, even if the populations that arrived in Africa are not currently resistant, it is only a matter of time before such mutations will likely occur.

The issue of widespread resistance in the Americas also raises the obvious question as to whether or not the populations that arrived in Africa brought resistance alleles with them. This is a question that ACB put to WEMA members, as well as DAFF employees. As stated above, Dr Oikeh's response shows that this is not an active inquiry being pursued by the project. Only one study on resistance has been performed on the Togo population, independent of the WEMA project, and it reported a lack of resistance mutations to Cry1F, as is common in the FL-strain (Nagoshi *et al*. 2017). However, it is still unclear how many separate introductions of the FAW there have been across the continent, with studies to date suggesting multiple introductions. Nonetheless, the Feed the Future guide, for example, has used the single Togo study to claim that the African FAW populations do not show resistance, a presumptuous conclusion that simplifies the issue and promotes a false impression that Bt resistance is not yet an issue for Africa.

A second concern with regards to the deployment of MON810 specifically, is the reported limited efficacy of Cry1Ab in killing the FAW. Studies indicate that Cry1Ab degrades in the midgut of the FAW five times faster than other susceptible organisms (Miranda *et al*. 2001) and hence does not offer full control of the pest. A recent Monsanto study admits the limited efficacy of Cry1Ab, stating that it works "to a lesser extent" than other Bt toxins. Though the CIMMYT guide admits that MON810 offers "partial control", the guide seems to support its commercialisation in Africa, as stated in the previous section.

Solutions

It is considered unlikely that the pest will be eliminated from the continent and, as such, sustainable approaches suitable for small-holder farmers across the region are needed, especially in times of climate change.

It appears that the measures being implemented by governments and farmers thus far have already significantly reduced 2018 crop losses in many regions, in comparison to last year. Measures taken include the use of chemical pesticides, as well as local pest control measures that include plant-based and natural products, mechanical methods and monitoring strategies. However, the use of synthetic chemicals is not likely an effective long-term control strategy, as evidenced by the high levels of FAW resistance to them in the Americas. Further, the use of chemical pesticides is associated with serious adverse impacts on both human and environmental health, including damaging the biodiversity that is needed to control the pests, such as the presence of natural FAW predators. Further problems may arise if GM crops are widely adopted as a solution. The practice of industrialised GM farming systems promotes monocropping and reduces biodiversity, soil health and climate resilience, all factors that can negatively affect the impact of pest attacks. With FAW resistance to both synthetic pesticides and Bt toxins likely to occur in the near future, if not already present on the continent, the evidence to date strongly suggests that neither Bt crops nor chemical pesticides are effective long-term solutions for controlling FAW across Africa. Indeed, Brazilian researchers appear to be increasingly turning to indigenous plant knowledge systems as a result of such problems.

As an alternative to the industrial model, agro-ecological methods that provide a holistic, non-toxic and cost-effective approach are being researched and practised. The push-pull system for example, which is a type of intercropping, has been shown to produce very effective results in a new large-scale study (Midega *et al*. 2018), and is a method that can be immediately deployed. It was also developed for dry/hot conditions, suitable for addressing recent droughts in various regions. The push-pull system involves the use of companion plants to emit volatiles that 'push' the pest away from the crop, and also the use of trap plants that are cultivated on the perimeter of the field to 'pull' the pest towards them, resulting in pest mortality or acting as a haven for them, thus keeping the pests away from the crop. The recent, peer-reviewed publication worked with 250 farms to test the method across dry areas of Uganda, Kenya and Tanzania in 2017. Maize was planted with both the legume plant Greenleaf *desmodium* (*Desmodium intortum*), and *Brachiaria* cv Mulato II. The study documented an 87% reduction in crop damage, an 83% reduction in average number of larvae per plant and yield increases of 2.7 times on average (2.5, 2.1 and 3.5 times higher in Kenya, Tanzania and Uganda, respectively), compared to maize monocrops that were planted adjacently. Proportions of the maize plants damaged by the larvae in Kenya ranged from 3.2 to 18.6% with the climate-adapted push-pull, and from 80.0 to 95.4% in the maize monocrop. In Uganda, the damage ranged from 22.0 to 27.3% in the climate-adapted push-pull, and from 80.0 to 94% in the maize monocrop. In Tanzania, the damaged averaged 5.4% in the climate-adapted push-pull, and 67.1% in the maize monocrop. Furthermore, the farmers interviewed observed first-hand the differences between the two planting systems and overwhelmingly supported the push-pull technology. In terms of actual damage to maize by the larvae, 92.9% of the respondents in the three countries reported no damage, to low (<25%) levels of damage in climate-adapted push-pull plots. Conversely, 96.7% of the respondents reported high (50–75%) and severe (> 75%) damage levels caused by the larvae in the maize monocrop plots.

The recent FAO guide on FAW management (FAO 2018d) recommends integrated pest management strategies that can be immediately implemented, rather than GM crops as it is "too early to draw conclusions", due to the issue of resistance seen in the Americas. Recommended methods instead include preventative measures such as monitoring, avoiding both late and staggered planting to reduce the food available to the FAW; maintaining good soil health

and moisture in order to promote plant health and thus its ability to withstand pest attacks, and increasing plant diversity via intercropping or other practices to reduce egg laying, increase natural predators and increase soil organic matter. Recommended control strategies include push-pull technologies described above; mechanical removal and pheromone traps; biological control via the encouragement of natural predators and enemies such as ants, birds, bats, earwigs and parasitoid wasps and flies, pathogens such as viruses and fungi (some of which have already been spotted in Africa), and botanical pesticides.

Some of the above strategies recommended by the FAO are already practiced by farmers and various reports of their efficacy have been published. For example, botanical pesticides deriving from the neem tree (*Azadirachta indica*) have been employed in Malawi (AllAfrica 2017). Neem is considered to have low toxicity for mammals, and it is efficient even in low concentrations. Like other active plant molecules, there is a lower probability of resistance development due to the complexity of its active components. Many experiments on neem derivatives have shown its insecticidal potential on the fall armyworm to be similar to those obtained with synthetic products (Maredia *et al*. 1992; Prates *et al*. 2003; Viana & Prates 2003).

Biological control such as ants are also being deployed, as well as additional practices used to encourage the ants, such as the addition of fish broth known as *bonya* to the crops in Malawi (VOAnews 2018). In South Sudan, reports of recipes used by previous generations such as mixtures of ash, powdered soap, tree leaves or neem and red pepper, are also being employed. Substances such as ash, sawdust and sand have also been used in Central America according to the FAO, which acts by desiccating the larvae. Ash and soap is also very alkaline for FAW. Kenya's Agricultural and Livestock Research Organization has announced that it is researching the use of natural enemies including the egg parasitoid *Telenomus remus*, a tiny wasp that lays its eggs on FAW eggs, which the wasp larvae then consume. The FAO guide states that South American countries have seen rates of 80% parasitism (African Harvesters 2018). Pheromone traps have also been widely deployed for monitoring. The Tanzanian Ministry of Agriculture, for example, has distributed traps in Dar es Salaam, Songwe, Mbeya, Shinyanga, Arusha, Mwanza and Tabora, with more to be distributed. The FAO donated 500 to Kenya's government last year, and to other nations, including Rwanda, in joint strategies with the government (AllAfrica 2018b).

Some maize varieties also show partial natural resistance to the FAW. The latest unpublished information from PELUM Uganda is that several farmers have reported that local varieties are withstanding FAW attacks better than commercial hybrid varieties that are planted side by side. Research by PELUM Uganda is being planned to document and further follow up on these observations. Naturally occurring resistance is also raised in the Feed the Future guide, with reference to projects by CIMMYT to screen for resistance and, along with the IITA, to use conventional breeding to develop 'elite products' with public- and private-sector partners. The guide states that:

> *Germplasm with native resistance to FAW…together with Africa-adapted maize inbred lines, pre-commercial and commercial hybrids, and OPVs, are currently being evaluated by CIMMYT against FAW populations in Africa, to validate and/or identify new sources of resistance in the African context. (Feed the Future 2018, p.47)*

However, CIMMYT employs a private sector approach for future commercialisation and profit, off the back of Africa's diverse maize germplasm. Nonetheless, it is testament to the potentially valuable traits that offer a more sustainable alternative to the transgenic introduction of resistance genes, with CIMMYT stating:

> *[N]ative resistance is generally more durable, both because it is usually quantitative in nature (with several genes underlying the expression of resistance, making it harder for the pest to 'escape' control) and because it is typically less effective at controlling the pest (and therefore exerts less pressure on the pest to overcome HPR). In contrast, the possibility that an insect pest will evolve*

resistance to the highly efficacious transgenes used in GM crops is a major concern – particularly for early transgenic varieties that rely on expression of a single, highly effective dominant gene (such as cry1Ab in MON810 and Bt11). (Feed the Future 2018, p.50)

Conclusions

The FAW is a real and present threat to crop production and farmer livelihoods both in the Americas and now in Africa. The experiences in the Americas serve as a warning that industrialised farming systems using chemical pesticides and GM crop practices are not effective in the long term. These experiences expose the push for the commercialisation of GMOs as a solution to the FAW as yet another Trojan horse being used to open up African countries to GM crops. This strategy is merely a continuation of that being employed for the WEMA project, where so-called GM drought-tolerant crops 'generously donated' by multinational corporations and philanthropists, are needed to stave off climate-change-induced food shortages. A solution that claims to be on the side of modern science, however, is yet to be backed up by rigorous scientific results and analysis, available for public and independent scientific scrutiny. GM insects are also on the horizon, developed by Oxitec, as a method to control FAW numbers (Genetic Literacy Project 2018). Again, experiences to date with Oxitec's GM mosquitoes suggest that this strategy is also ineffective and very costly.

We urge our governments not to bow to external pressure to serve multinational corporate interests by weakening biosafety laws and allowing GMO commercialisation. Instead, we urge them to take note of the evidence on GM crop failures to deal with the FAW, and to implement holistic strategies, which are already showing efficacy in the field, to support small-holder farmers. Various agro-ecological strategies being implemented in both the Americas and Africa provide sustainable solutions to the FAW and will not further indebt farmers, compromise on their health or that of their surrounding environment.

Annex I

Response to Africa Centre of Biodiversity (ACB)

(Dr Eva Sirinathsinghji, ACB's Independent Researcher) Response from WEMA Project Manager, Dr Sylvester Oikeh, African Agricultural Technology Foundation

1. Scientific evidence on the use of Bt traits in controlling the pest

Response: The Water Efficient Maize for Africa (WEMA) project conducted efficacy trials for insect protected *Bt* single gene and stacked drought-tolerant (DT) and insect-protected (*Bt*) events at six confined field trials sites in Kenya (Kitale and Kiboko), Uganda (Namulonge and Kasese), Tanzania – Makutupora, and Chokwe in Mozambique.

In 2017, artificial infestation was used for the respective stemborer species (*Chilo partellus* or *Busseola fusca*) at the respective sites. In addition, the trials received heavy natural infestation of fall armyworm. The same trials were replicated in 2018 though some are yet to be harvested.

Preliminary CFT results from data for 2017 plantings showed that under artificial infestation in Kenya and Uganda for stacked DT + *Bt* (TELA®) hybrids yielded more than the same non-GM (isogenic) hybrids.

Under natural infestation of both stem borer and FAW in Mozambique, stacked DT + *Bt* (TELA®) hybrids yielded more than the same non-GM (isogenic) hybrids, with some showing yield advantage of 9–98% better than isogenic hybrids depending on the level of infestation.

Similarly, under natural infestation of FAW and artificial infestation of stem borer larvae in Kenya, some stacked TELA® hybrids yielded 15–27% higher than non-GM, isogenic hybrids. *Bt* gene thus, conferred complete control of stem borers, and partial but significant protection against the FAW (see attached photos from Uganda [Figure 2]. Similar observations were made in all CFTS).

Figure 2: Photo provided by WEMA of non-GM maize (left) and Bt maize (right) in Uganda trials

Bt Maize with Potential to Control Fall Army Worm (Confined Field Trials of stacked DT + *Bt* traited hybrids, Uganda, January 2017).

2. With resistance to Bt traits common in South America, it is critical to know whether resistance already exists in the African populations prior to commercialisation of Bt GM crops.

Response: Fall Armyworm is a new pest to Africa. It is rather too early to speculate about FAW developing resistance on *Bt* crops, or even on *Bt* sprays commonly used by organic farmers in Africa. At this stage, we should advocate for the immediate use of all available technologies in an integrated pest management approach to protect farmers' crops from huge losses caused by the pest.

References

AATF (2017a). *Biotechnology, panacea to army worm maize infestation*. Available at: https://aatf-africa.org/node/862. [Accessed 15 June 2018].

AATF (2017b). African states urged to adopt Bt maize to control armyworm. *AATF Partnerships*. Issue 19, January–June 2017. Available at: https://www.aatf-africa.org/files/Partnerships-Issue-19-Jan-Jun-2017.pdf. [Accessed 15 June 2018].

ACB (2017). *WEMA project shrouded in secrecy: open letter to African governments to be accountable to farmers, civil society*. The African Centre for Biodiversity, South Africa. Available at: http://www.acbio.org.za/en/wema-project-shrouded-secrecy-open-letter-african-governments-be-accountable-farmers-civil-society. [Accessed 15 June 2018].

African Harvesters (2018). *Kenya plans to use biological pest to fight armyworm*. Available at: https://africanharvesters.com/2018/04/24/kenya-plans-use-biological-pest-fight-armyworm/. [Accessed 15 June 2018].

AllAfrica (2017). *Malawi: fall armyworm, farmer's worst nightmare*. Available at: http://allafrica.com/stories/201708070641.html. [Accessed 15 June 2018].

AllAfrica (2018a). *Fall armyworm causing losses of over 50 per cent*. Available at: http://allafrica.com/stories/201804120858.html. [Accessed 15 June 2018].

AllAfrica (2018b). *Rwanda: new strategy to avert armyworm invasion*. Available at: http://allafrica.com/stories/201803050748.html. [Accessed 15 June 2018].

Alvi AH, Sayyed AH, Naeem M and Ali M. (2012). Field evolved resistance in *Helicoverpa armigera* (Lepidoptera: Noctuidae) to *Bacillus thuringiensis* toxin Cry1Ac in Pakistan. *PLoS One* [Online] 7(10): e47309. doi: 10.1371/journal.pone.0047309.

Bernardi D, Salmeron E, Horikoshi RJ, Bernardi O, Dourado PM, Carvalho RA, Martinelli S, Head GP and Omoto C (2015). Cross-resistance between Cry1 Proteins in fall armyworm (*Spodoptera frugiperda*) may affect the durability of current pyramided Bt maize hybrids in Brazil. *PLoS One* [Online] 10(10): e0140130. doi.org/10.1371/journal.pone.0140130.

Bird LJ and Downes SJ (2014). Toxicity and cross-resistance of insecticides to Cry2Ab-resistant and Cry2Absusceptible *Helicoverpa armigera* and *Helicoverpa punctigera* (Lepidoptera: Noctuidae). *Journal of Economic Entomology* 107: 1923–1930. doi: 10.1603/EC14230.

Bloomberg (2018). *Kenya armyworm corn-area infestation to worsen, Ministry says*. Available at: https://www.bloomberg.com/news/articles/2018-05-24/kenya-armyworm-corn-area-infestation-to-worsen-ministry-says. [Accessed 15 June 2018].

Business Daily (2018). Editorial: Ward off worm attack. Available at: https://www.businessdailyafrica.com/analysis/editorials/-Ward-off-worm-attack/4259378-4578430-15mvexjz/index.html. [Accessed 14 June 2018].

Cock MJW, Beseh PK, Buddie AG, Cafá G and Crozier J (2017). Molecular methods to detect *Spodoptera frugiperda* in Ghana, and implications for monitoring the spread of invasive species in developing countries. *Scientific Reports* 7(1): 4103. doi: 10.1038/s41598-017-04238-y.

Cornell Alliance for Science (2017). *African stakeholders push for innovations to combat the fall armyworm*. Available at: https://allianceforscience.cornell.edu/blog/2017/09/african-stakeholders-push-for-innovations-to-combat-fall-armyworm/. [Accessed 15 June 2018].

Cornell Alliance for Science (2018a). *As armyworm invasion devastates crops, Ugandan scientists bemoan GMO political stalemate*. Available at: https://allianceforscience.cornell.edu/blog/2018/03/armyworm-invasion-devastates-crops-ugandan-scientists-bemoan-gmo-political-stalemate/. [Accessed 15 June 2018].

Cornell Alliance for Science (2018b). *WEMA maize shows resistance to destructive fall armyworm pest*. Available at: https://allianceforscience.cornell.edu/blog/2018/04/wema-maize-shows-resistance-destructive-fall-armyworm-pest/. [Accessed 15 June 2018].

Dhahabu Kenya (2018). *Kenya seeks reinforcement from Brazil to help in fighting the armyworm menace*. Available at: http://www.dhahabu.co.ke/2018/04/03/kenyan-experts-brazil-armyworm-agribusiness/. [Accessed 15 June 2018].

FAO (2018a). Map of areas affected by fall armyworms. Available at: http://www.fao.org/resilience/multimedia/maps/detail/pt/c/902959/. [Accessed 15 June 2018].

FAO (2018b). *GIEWS - Global Information and Early Warning System. Country briefs. Kenya*. Available at: http://www.fao.org/giews/countrybrief/country.jsp?code=KEN. [Accessed 15 June 2018].

FAO (2018c). *GIEWS - Global Information and Early Warning System. Country briefs. Uganda*. Available at: http://www.fao.org/giews/countrybrief/country.jsp?code=UGA. [Accessed 15 June 2018].

FAO (2018d). *Integrated management of the fall armyworm on maize. A guide for farmer field schools in Africa*. Rome: Food and Agriculture Organization of the United Nations.

Fatoretto J, Michel AP, Silva Filho MC and Silva N (2017). Adaptive potential of fall armyworm (Lepidoptera: Noctuidae) limits Bt trait durability in Brazil. *Journal of Integrated Pest Management* 8 (1): 17. doi.org/10.1093/jipm/pmx011.

Feed The Future (2018). *Fall armyworm in Africa: A guide for integrated pest management*. First Edition. Available at: https://reliefweb.int/sites/reliefweb.int/files/resources/FallArmyworm_IPM_Guide_forAfrica.pdf. [Accessed 14 June 2015].

Financial Times (2017). Invasion of fall armyworms ravages crops in 20 African countries. Available at: https://www.ft.com/content/93222f52-2b46-11e7-9ec8-168383da43b7. [Accessed 15 June 2018].

Flagel L, Lee YW, Wanjugi H, Swarup S, Brown A *et al*. (2018). Mutational disruption of the ABCC2 gene in fall armyworm, *Spodoptera frugiperda*, confers resistance to the Cry1Fa and Cry1A.105 insecticidal proteins. *Scientific Reports* 8(1): 7255. doi: 10.1038/s41598-018-25491-9.
Filho JBS, Alves L, Gottardo L and Georgino M (2010). Dimensionamento do custo econômico representado por *Spodoptera frugiperda* na cultura do milho no Brasil. 48 *Congresso Sociedade Brasileira de Economia, Administração e Sociologia Rural*, p.21.
Genetic Literacy Project (2018). *Talking biotech: can Oxitec's genetically engineered insects combat fall armyworm crop damage and famine in Africa?* Available at: https://geneticliteracyproject.org/2018/02/12/talking-biotech-can-oxitecs-genetically-engineered-insects-combat-fall-armyworm-crop-damage-famine-africa/. [Accessed 15 June 2018].
GhanaWeb (2018). *Ghana to focus on bio-rational products for the management of fall armyworm infestation*. Available at: https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Ghana-to-focus-on-bio-rational-products-for-the-management-of-Fall-Armyworm-infestation-643009. [Accessed 15 June 2018].
Goergen G, Kumar PL, Sankung SB, Togola A and Tamò M (2016). First report of outbreaks of the fall armyworm *Spodoptera frugiperda* (J E Smith) (Lepidoptera, Noctuidae), a new alien invasive pest in West and Central Africa. *PLoS One* 1(10): e0165632. doi: 10.1371/journal.pone.0165632.
Horikoshi RJ, Bernardi D, Bernardi O, Malaquias JB, Okuma DM *et al*. (2016). Effective dominance of resistance of *Spodoptera frugiperda* to Bt maize and cotton varieties: implications for resistance management. *Scientific Reports* 10(6): 34864. doi: 10.1038/srep34864.
Huang F, Qureshi JA, Meagher RL Jr, Reisig DD, Head GP *et al*. (2014). Cry1F resistance in fall armyworm *Spodoptera frugiperda*: single gene versus pyramided Bt maize. *PLoS One* 9(11): e112958. doi: 10.1371/journal.pone.0112958.
ISAAA (2018). *Scientists recommend Bt maize as solution to fall armyworm infestation in Kenya*. Available at: http://www.isaaa.org/kc/cropbiotechupdate/article/default.asp?ID=16136. [Accessed 15 June 2018].
Maredia, KM, Segura OL and Mihm JA (1992). Effects of neem, *Azadirachta indica*, on six species of maize insect pests. *Tropical Pest Management* 38: 190–195.
MASA (Mozambique Ministry of Agriculture and Food Security) (2018). Letter No. 128 MASA/IIAM-DG/113.1/2018.
Midega CAO, Pittchar JO, Picket JA, Hailiu GW and Khan ZR (2018). A climate-adapted push-pull system effectively controls fall armyworm, *Spodoptera frugiperda* (J E Smith), in maize in East Africa. *Crop Protection* 105: 10–15.
Miranda R, Zamudio FZ and Bravo A (2001). Processing of Cry1Ab delta-endotoxin from Bacillus thuringiensis by Manduca sexta and Spodoptera frugiperda midgut proteases: role in protoxin activation and toxin inactivation. *Insect Biochemistry and Molecular Biology* 31(12): 1155–63.
Monsanto (2018). *Bt technology helps protect crops from fall armyworm*. Available at: https://monsanto.com/innovations/crop-protection/articles/bt-technology-fall-armyworm/. [Accessed 15 June 2018].
Nagoshi RN, Koffi D, Agboka K, Tounou KA, Banerjee R *et al*. (2017). Comparative molecular analyses of invasive fall armyworm in Togo reveal strong similarities to populations from the eastern United States and the Greater Antilles. *PLoS One* 12(7): e0181982. doi.org/10.1371/journal.pone.0181982.
Nagoshi RN, Goergen G, Tounou KA, Agboka K, Koffi D and Meagher RL (2018). Analysis of strain distribution, migratory potential, and invasion history of fall armyworm populations in northern sub-Saharan Africa. *Scientific Reports* 8(1): 3710. doi: 10.1038/s41598-018-21954-1.
Niu Y, Qureshi JA, Ni X, Head GP, Price PA *et al*. (2016). F2 screen for resistance to *Bacillus thuringiensis* Cry2Ab2-maize in field populations of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) from the southern United States. *Journal of Invertebrate Pathology*, 138: 66–72. doi: 10.1016/j.jip.2016.06.005.
Otim MH, Tay WT, Walsh TK, Kanyesigye D, Adumo S *et al.* (2018). Detection of sister-species in invasive populations of the fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae) from Uganda. *PLoS One* 13(4): e0194571. doi: 10.1371/journal.pone.0194571.
Prates HT, Viana PA and Waquil JM (2003). Activity of neem tree (*Azadirachta indica*) leaves aqueous extract on *Spodoptera frugiperda*. *Pesquisa Agropecuária Brasileira* 38: 437–439.
Purdue Extension Entomology (2016). *Vegetable insects. Available at: Managing Insects in Commercially Grown Sweet Corn*. https://extension.entm.purdue.edu/publications/E-98/E-98.html. [Accessed 15 June 2018].
Premium Times (2017). Nigeria projects N2.98 billion to check Armyworm invasion. Available at: https://www.premiumtimesng.com/news/more-news/234594-nigeria-projects-n2-98-billion-check-armyworm-invasion.html. [Accessed 13 June 2018].
ReliefWeb (2017). *West Africa: armyworm infestation – Mar 2017*. Available at: https://reliefweb.int/disaster/2017-000055-gha. [Accessed 15 June 2018].
Sayyed AH, Moores G, Crickmore N and Wright DJ. (2008) Cross-resistance between a *Bacillus thuringiensis* Cry toxin and non-Bt insecticides in the diamondback moth. *Pest Management Science* 64: 813–819. doi: 10.1002/ps.1570.
Standard Media (2017). *New maize variety gives farmers hope against deadly armyworm*. Available at: https://www.standardmedia.co.ke/article/2001232639/new-maize-variety-gives-farmers-hope-against-deadly-armyworm. [Accessed 14 June 2018].
The Economist (2018). An army of worms is invading Africa. Available at: https://www.economist.com/middle-east-and-africa/2018/01/18/an-army-of-worms-is-invading-africa. [Accessed15 June 2018].
The Herald (2017). Biotech part of solution to Africa's food insecurity. Available at: https://www.herald.co.zw/biotech-part-of-solution-to-africas-food-insecurity/. [Accessed 13 June 2018].
The Herald (2018). Combined effort sees army worm attacks decline. Available at: https://www.herald.co.zw/combined-effort-sees-army-worm-attacks-decline/. [Accessed 15 June 2018].
USDA (2018a). *Kenya grain and feed annual*. Global Agricultural Information Network. Available at: https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Grain%20and%20Feed%20Annual_Nairobi_Kenya_3-28-2018.

pdf. [Accessed 15 June 2018].
USDA (2018b). *Ethiopia grain and feed annual*. Global Agricultural Information Network. Available at: https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Grain%20and%20Feed%20Annual_Addis%20Ababa_Ethiopia_3-16-2018.pdf. [Accessed 15 June 2018].
Vélez AM, Spencer TA, Alves AP, Moellenbeck D, Meagher RL *et al*. (2013) Inheritance of Cry1F resistance, cross-resistance and frequency of resistant alleles in *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Bulletin of Entomological Research* 103(6): 700–13. doi: 10.1017/S0007485313000448.
Viana PA and Prates HT (2003). Larval development and mortality of *Spodoptera frugiperda* fed on corn leaves treated with aqueous extract from *Azadirachta indica* leaves. *Bragantia* 62: 69–74.
VOAnews (2017). *Simple concoction found to halt fall armyworm*. Available at: https://www.voanews.com/a/simple-concoction-found-to-halt-fall-armyworm/3989750.html. [Accessed 15 June 2018].
Xinhuanet (2018). *Fall armyworm invades over 87,000 hectares of maize in Ethiopia: Ministry*. Available at: http://www.xinhuanet.com/english/2018-05/29/c_137215427.htm. [Accessed 15 June 2018].
Zhu YC, Blanco CA, Portilla M, Adamczyk J, Luttrell R and Huang F (2015). Evidence of multiple/cross resistance to Bt and organophosphate insecticides in Puerto Rico population of the fall armyworm, *Spodoptera frugiperda*. *Pesticide Biochemistry and Physiology*, 122: 15–21.

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