The spread of the Fall Army Worm *Spodoptera frugiperda* in Africa – what has to be done next?

Report on the Section Plant Protection in the Tropics and Subtropics, 61. German Congress of Plant Protection

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Abstract

The following text summarizes the different perspectives of participants of *the Section Plant Protection in the Tropics and Subtropics, 61. German Congress of Plant Protection, held on* 11th September 2018, University of Hohenheim, Germany

The aims of the symposium were to develop a critical perspective on the status fighting against the spreading Fall Army Worm (FAW) *Spodoptera frugiperda* in Africa. The results of the presentations and discussions are reported here.

The symposium topic

In total, more than 120 scientists from 14 countries participated in the symposium, representing regulatory bodies, universities, federal research institutions, advisors for plant protection, and enterprises.

Results

Spread of *Spodoptera frugiperda*

Georg Görgen (IITA) reported on the rapid spread of the Fall Army Worm (FAW) in Africa. Discovered first in Nigeria in January 2016 (Görgen et al. (2016) it is found already in 44 African countries on more than 25 million km^2. Currently, it prepares for spreading around the Sahara desert to the North, reached Jemen and even India in the East. The high spreading speed is caused by the ability of the insect to fly 100km per night. Originating from the two Americas, FAW is known to carry out migrations from Central America to the North reaching Canada and to the South reaching Argentina. The area of permanent reproduction ends in the North of Mexico and the South of Brasil and merges to a certain area with temporary reproduction.

Görgen pointed out that the genus *Spodoptera* includes 31 species which are distributed on 6 continents, 8 of which occurring in Africa. Here, populations of the FAW performs two strains which are morphologically not distinguishable but by their behavior (reproduction in compatibility, resistance formation, pheromone affinity). Invading Africa from America, in West Africa a new haplotype can be found, which seems to be Africa specific (Nagoshi et al., 2018).
The FAW meets in Africa a completely different situation as in the Americas. Very small and small fields are threatened and not medium to large-scale fields like e.g. in Brasil (Fritz et al., 2015).

The approach to control the FAW in Africa, Görgen said, should base on an integrated pest management system with all components like regulatory framework, capacity building and education, monitoring and warning systems, pesticide options, bio-control, cultivation aspects and mechanical control, and resistance breeding.

Bio-pesticides and farmer scouting for FAW management

Manuele Tamò (IITA-Benin) reported about a real case scenario in Benin, West Africa. Here, most of the farmers are planting their crops on small-scale fields of less than 0.5 ha to 3ha or larger than 3ha. Following to their experience, the pesticides can control the FAW but their use creates challenges on several levels: pesticide legislation does exist, but its performance is difficult. Markets for pesticides are unregulated, imports cheap and often of doubtful quality. The farmer can hardly protect himself when spraying because protective equipment is normally not available or affordable and a lack of technical knowledge exists. Pesticide residues due to missing testing infrastructure and use of post-harvest pesticides intoxicate consumers. Undesired environmental side like groundwater contamination effects are common and negative impact to pollinators and natural enemies of pests currently inevitable.

On this background the FAW management approaches in Africa base on the use of bio-pesticides. There are commercial products on the market like *Spodoptera frugiperda multiple nucleopoly-hedrovirus* (SfMNPV) and *Beauveria bassiana*. Locally–made bio-pesticides like Neem oil and insect-specific baculoviruses can be produced on farm and provide additional income to disadvantaged groups such as women and youth.

In order to take action at best time, low-literacy farmers are introduced to a new FAW monitoring and early warning system (FAMEWS), Tamò said. The link between bio-pesticides and farmer scouting is currently planned through a Farmer Interface Application (FIA). FIA ntegrates a scouting algorithm guiding the farmer with voice commands in local language how to move randomly in the field and to check a number of crop plants, inspect them for pests (or damage symptoms), and press the right symbol to record presence/absence of the pest. This will allow the FIA, independently from being connected to the internet, to calculate an intervention threshold and allow the farmer to make an informed decision about protective measures. The current prototype FIA is currently being upgraded to allow for collecting real-time and geo-referenced field data(e.g., plant phenology and incidence of pests) and transmitting them to the VIPS platform developed by Norwegian Institute of Bioeconomy NIBIO (https://www.vips-landbruk.no/information/1/) to make use of the VIPS ‘expert system’ for implementing IPM with support of real-time weather data and pest models.

Overall, early warning & rapid response, citizen science & ICT tools, safe crop protection products including cost-effective biopesticides, together with host plant tolerance and genetic studies of FAW populations are the IITA long-term strategy to manage FAW in Africa.

Biocontrol of *Spodoptera frugiperda*

Jörg Wennmann (Julius Kühn-Institut, Germany) illustrated that a number of natural antagonists of FAW are available in the natural area of propagation in North and South America, which could be used for biocontrol of FAW in Africa and Europe. Resistance of FAW populations demand all elements of integrated plant protection including innovative and sustainable methods. In contrast to chemical insecticides. biocontrol products have the advantage of a narrow host spectrum which does not cover non-target organisms like pollinators and natural enemies, Wennmann explained. This is true for some highly effective, non toxic bioproducts as well.

As an example, the ubiquitious entomopathogenic bacterium *Bacillus thuringiensis* is used in form of transgenic Bt-maize in North- und South America. However, resistances against the insecticidal protein Cry1Fa occurred already. This has to be kept in mind when thinking about the use of transgenic plants in Africa.

Besides cultivation of Bt-maize, the application of products containing *B. thuringiensis*, entomopathogenic fungi and Baculoviruses are most promising. In several countries of Africa such products have already been developed and have been tested. It is not yet sure in how far the microorganisms are ubiquitious in Africa, too, or have to be treated as non-indigenous alien organisms.

Currently, Baculoviruses of the family Baculoviridae play an important role in organic and integrierted plant protection. They are used worldwide in plant protection in biocontrol products to control different Lepidotera caterpillars in agriculture. Own studies demonstrated that Baculoviruses could be isolated from caterpillars of *S. frugiperda* and *S. littoralis*, which have a high effectiveness against FAW and should be used preferentially as biocontrol agents in Africa.

Chemical control of Spodoptera frugiperda

Hartwig Dauck (Bayer) described the current chemical control option of FAW in Africa. Chemical products to control *Spodoptera frugiperda* in maize are essential tools to safeguard the agricultural yield, he said. Until recently, the relevant distribution of *Spodoptera frugiperda* was limited to the warmer zones of the American continents. In the USA and in South America, maize is largely cultivated for animal feed or for energy generation. Here a number of chemical crop protection products for *Spodoptera frugiperda* control are available since many years. However, after invasion of the African continent *Spodoptera frugiperda* pose a new challenge for the chemical crop protection, especially because here maize is mostly used and essential for human nutrition. Furthermore, availability of registered suitable chemical products is scarce, and knowledge of many farmers on correct use of such crop protection products is limited.

The range of potentially suitable chemical crop protection compounds reaches from Carbamate (e.g. Methomyl), Benzoylurea (e.g. Lufenuron), Benzoylhydrazine (e.g. Methoxyfenozide), Bt leaves (e.g. foliar *B.thuringiensis*), Carboxylate (e.g. Indoxacarb), Diamide (e.g. Chlorantraniliprole), Macrolide (e.g. Emamectin-B), Organophosphate (e.g. Chlorpyrifos), Phenylpyrazole (e.g. Fipronil), Plant extracts (e.g. Azadirachtin), Pyrethroide (e.g. Cypermethrin), Pyrrole (e.g. Chlorfenapyr) and Spinosyne (e.g. Spinetoram).

Unfortunately, the efficacy spectrum of most chemical classes is broad, i.e. several non-target organisms can be influenced as well. The mode of action covers oral uptake or contact and larvae and adults can be hit. The velocity of activity may be slow to rapid and the duration small to moderate. That means that the subsequent requirements for appropriate use from technical and stewardship point of view have to be integrated in a local management action plan.

In Africa, Bayer is in the act to extend the labels of our available and suitable chemical crop protection products to include control of *Spodoptera frugiperda*, and to prepare according training for the farmers. Furthermore, we work on development of biological control measures as well, to be able to offer sustainable, integrated concepts

Breeding against the Fall Army Worm

Boddopally M. Prasanna (CIMMYT) referred about current actions in Africa to breed against FAW. Developing and deploying effective host plant resistance is one of the pillars of an Integrated Pest Management (IPM) strategy against Fall Armyworm (FAW; Spodoptera frugiperda). Naturally occurring, or “native,” resistance has been identified in several maize inbred lines/populations/hybrids, especially in the Americas, where the trait has long been incorporated into conventional breeding programs. Most native resistance in maize is polygenic and quantitative in nature, conferring tolerance or “partial resistance”. Throughout the 1970s to 1990s, research conducted at CIMMYT in Mexico, EMBRAPA in Brazil, USDA-ARS (Mississippi), and some universities in the USA, led to the identification and development of a number of improved tropical/sub-tropical/temperate maize inbred lines with at least partial resistance to FAW. Some of these sources of insect resistance were specifically tested for FAW resistance, while others were tested for resistance to other insect pests but have potential to confer resistance to FAW. While identifying materials with native resistance to FAW, it is important to consider not only foliar rating but also ear/kernel ratings, as FAW can also cause significant ear/kernel damage, especially when the larvae gain entry into the developing ears.

In view of the nature of the pest and the damage it can cause to maize crops in sub-Saharan Africa, it is imperative that international research centers like CIMMYT and IITA (International Institute of Tropical Agriculture), together with the national and private-sector maize breeding programs, initiate and maintain a strong pipeline of elite products that incorporate native resistance to FAW, along with other important adaptive traits relevant for maize smallholders in sub-Saharan Africa. CIMMYT is presently undertaking intensive screening of tropical/subtropical maize germplasm against FAW under artificial infestation (in screenhouses) in Kenya. The priorities are: a) to Identify potential sources of FAW resistance in CIMMYT’s elite Africa-adapted (sub)tropical maize germplasm (inbreds/DH lines and pre-commercial hybrids) for release and deployment through partners; b) to identify potential first-generation products with FAW resistance among the CIMMYT-derived hybrids/OPVs released under the Insect Resistant Maize for Africa (IRMA) in sub-Saharan Africa; c) to fast-track introgression of native resistance to FAW from exotic sources, including germplasm from USDA-ARS and Brazil, using DH technology and backcrossing; d) to discover/validate genomic regions for FAW resistance using appropriate populations, and explore the possibility of genomic prediction for developing novel Africa-adapted FAW resistant maize varieties.

In his presentation, Prasanna concluded, that CIMMYT currently needs to effectively utilize and quantify the benefits of host plant resistance in the IPM strategies for FAW management in African agro-ecologies and cropping system landscapes. The next steps will be a) Scaling-up and deploying "first-generation FAW-tolerant maize varieties" (those already released in ESA under IRMA) as an immediate relief to the farming communities, b) Accelerated breeding for improved Africa-adapted varieties with FAW resistance and other farmer-preferred traits, c) Varietal release and deployment of "second-generation FAW-tolerant maize hybrids/OPVs in SSA, d) Systematic analysis of compatibility and possible synergies between host plant resistance with other IPM approaches (e.g., biological control) with regard to FAW in Africa.

Communication, information sharing, and advisory services to raise awareness for fall armyworm detection and area-wide management by farmers

Stefan Töpfer (CABI) reported that alien species can cause serious problems to agricultural production as specific and effective natural enemies often lack when they arrive in new ecosystems. Farmers, who are most affected, rarely know about the presence of these newly arrived and spreading species until disastrous damage occurs. This scenario has been also observed for the fall armyworm (FAW), *Spodoptera frugiperda*, invasion across Africa. FAW caterpillars insatiably feed on maize and about 80 other crop species. The value of maize losses associated with FAW attack has been estimated at between US$2 ½ and US$6 million in Africa in 2017.

The FAW is somewhat difficult for farmers to distinguish from other local caterpillar pest species, like the African armyworm (*Spodoptera exempta*) or stalk (stem) borers such as Busseola and Chilo, or *Helicoverpa* species. Therefore, FAW may initially remain unidentified by farmers on their fields aiding the build-up of pest populations To mitigate this, dissemination of information on early warning and management practices to key stakeholders is essential. However, in the absence of effectively functioning extension systems – which is common in a number of countries - this remains a huge challenge.

CABI, working with in-country partners employs mass communication, information-sharing and agricultural extension services to aid early detection and management of FAW at farm level. Unlike face-to-face approaches such as farmer field schools, extension worker visits, or farmer cluster meetings, mass extension achieves wide and fast reach of farmers, often at a lower cost. Various media approaches have been used including farmer television emissions (e.g. Zambia, Kenya), village-based video screening (e.g. Uganda), plant health rallies (e.g. Uganda, Kenya), factsheet and photosheet apps (e.g. Plantwise Factsheet App), or social media chat groups (e.g. Plantwise WhatsApp/Telegram groups - Zambia, Malawi, Uganda). On the medium term, all agricultural extension workers need to be trained by prior trained country trainers. This approach may be effective in countries, where a network of governmental frontline extension workers exists. Besides, CABI has continued to enhance access to extension services through facilitation of plant clinics implemented through the Plantwise program (www.plantwise.org). All above needs to be combined with knowledge sources, and many are available on FAW (see “CABI Invasives Spodoptera frugiperda twitter list”, “PestLens USDA-APHIS”, “IITA News”, “PestNet Listserve”, “EPPO Global Database”, among many others).

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The FAO´s intervention strategy

Allan Hruska (FAO) explained the FAO´intervention strategy against FAW. The strategy bases on five elements: a) Farmer education & communication, b) Testing and validation of FAW Management Practices, c) Monitoring, Risk Assessment and Early Warning System, d) Policy and regulatory support and e) coordination. Hruska pointed out the following key knowledge and action, which is conveyed: a) Increase plant diversity in plots, b) Scout often and control mechanically, c) Maize plants can compensate for certain levels of foliar damage d) Natural biological control is very important: Farmers’ friends are present and effectiveness can be increased e) Effective control doesn’t have to be fast, f) There are many practices to try, based on local knowledge and materials. If this guideline is combined with modern risk assessment methods (use of FAMEWS) a valid action plan can be built up with four key steps:
1) Prevention: Increase of plant diversity in and around plots. Maize mixed in plots with cassava or yams or other crops may be less attractive to female FAW moths. Some plant species repel female FAW moths. This is the basis of the ‘push-pull’ technology: including a plant species that ‘pushes’ FAW away from maize and to plants that ‘pull’ them (attract them), where they can be easily controlled.
2) Knowlegde to act: a) Do not panic: Maize plants can compensate for certain levels of foliar damage. A low level of FAW infestation may have little yield impact, b) Scout fields often to observe, learn & make decisions, c) Control mechanically: Very effective for smallholders, d) Farmers’ friends (the natural enemies of FAW) are probably present and their effectiveness can be increased.
3) Keep Innovating & Controlling: a) Take action to attract predators & parasitoids. Some farmers have found that they can attract ants to their maize fields by putting cooking grease or fish soup into their maize fields. Some farmers use sugar water to attract and feed the wasps or some ants that can parasitize or eat FAW, b) Recycling” pathogens: Farmers can collect FAW caterpillars killed by pathogens, take them home, grind them, add water, and strain the mixture. The liquid that strains through may be full or fungal spores, bacteria, or virus particles that can be diluted and sprayed back into infested plants. This is a free, effective natural bio-pesticide. Many farmers spray only into the whorls of infested plants, so as not to waste the natural insecticide, c) Local Solutions: Many smallholder farmers around the world try mixtures of local substances applied directly to the whorl of infested plants, and often report satisfaction with their use, d) Local botanicals (neem, Tephrosia, hot peppers, Marigold flowers), e) Other substances often used include soil, ash, sand, lime, salt, soaps, oils. Farmers try these and then compare and share the results, to see which work best under local conditions. Many have been tested and shown to work. Soil often contains pathogens that kill

FAW.
4) Testing & Validation of practices: a) Yield loss due to FAW infestation, b) Role of plant diversity (push-pull), c) Use of biological control, d) Attract predators & parasitoids, e) "Recycling" pathogens, f) Locally-available substances, applied directly to the whorl of infested plants may be effective.

How is Europe prepared for the invasion of the Fall Army Worm?

Peter Baufeld (JKI) highlighted that the EU is already aware of the FAW as a quarantine pest for Europe. He said, Spodoptera frugiperda is listed in Regulation 2000/29/EG (Annex IAI and IVAI). This is the basis for all risk assessments and future action plans to fight FAW. EU is currently developing intervention strategies to defeat FAW if it should be introduced by trade or naturally.

A first assessment revealed the outlook that a colonization and manifestation of FAW is possible and probable only in Southern countries of the EU. Damages have to be expected at different cultivated plant species. Because of the migration potential damages in Northern countries will be possible but temporary and local. The risk of permanent manifestation in Northern countries is not probable in the field, but more probable in protected crops.

Conclusive statement

In the discussion delegates pointed out that the impression that so much action is already on the way is drawing a wrong picture. Clearly spoken, all elements of strategies to defeat the FAW may be available principally but no coordination would currently exist to bring the knowledge effectively and rapidly to the farmers. That means that existing networks have to be used to bring the information top down in every single country of Africa. Exisiting networks should include round tables, scientific networks, extension services, private consultation including training and developmental options offered by industry and trade. Even certification companies like GlobalGAP with their huge network should be included. The FAO could be the organization coordinating the single actions but should work more rapid than the FAW spreads.

Compliance with Ethical Standards

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The authors declare that they have no conflict of interest.

References

Goergen, G., Kumar, P. L., Sankung, S. B., Togola, A. & Tamò M. (2016): First report of outbreaks of the fall army worm Spodoptera frugiperda (J E Smith) (Lepidoptera: Noctuidae), a new alien invasive pest in West and Central Africa. PLoS ONE 11(10): e0165632.

Nagoshi, R. N., Goergen, G., Tounou, K. A., Agboka, K., Koffi, D. and Meagher, R. L. (2018): Analysis of strain distribution, migratory potential, and invasion history of fall army worm populations in northern Sub-Saharan Africa. Scientific reports, 8(1), p.3710.

Fritz, S., See, L., McCallum, I., You, L., Bun, A., Moltchanova, E., Duerauer, M., Albrecht, F., Schill, C., Perger, C. and Havlik, P. (2015): Mapping global crop land and field size. *Global change biology*, *21*(5), pp.1980-1992.