Food and Agriculture Organization of the United Nations

FAO Global Symposium on Sustainable Fall Armyworm Management

CHARTING A GLOBAL RESPONSE TO FUTURE INVASIVE PESTS

Beijing, 31 October — 2 November 2023

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Foreword

The fall armyworm (FAW), which originated in the Americas, is aptly named *Spodoptera frugiperda* (lost fruit) due to the species' destructive impact on crops, particularly maize and other cereals. It is a transboundary pest with a high potential for mobility owing to its natural spread capacity and opportunities created by international trade, ultimately presenting a threat to global food security.

Since it was first reported in Africa in 2016, this pest has invaded more than 80 countries in Africa, the Near East, Asia and the Pacific, and Europe. It reduces maize yields by up to 73 percent and inflicts economic losses worth USD 9.4 billion in Africa alone. But its impacts extend further: FAW jeopardizes sustainable agricultural production, food security and nutrition, the environment and rural livelihoods. This highlights the interconnectedness of human, animal and environmental health, or what we refer to as One Health.

To address these challenges, Director-General Qu Dongyu of the Food and Agriculture Organization of the United Nations (FAO) launched the Global Action on Fall Armyworm Control in 2019 to coordinate efforts while adopting an integrated pest management (IPM) approach. Since then, FAO has been working with stakeholders and partners through this programme to reach impact on a scale – at global, regional and national levels.

With on-the-ground work spanning Africa, the Near East, and Asia and the Pacific, this programme has provided a strong, coordinated mitigation response. We have established partnerships with national governments and international collaborators to offer prevention, preparedness and sustainable pest control options for farmers and crop protection professionals. We have built a global platform to coordinate plant health research, extension, and policy support across disciplines and at different scales.

Over the past four years, we have developed and validated sustainable management solutions and upscaled them through Farmer Field Schools (FFS) and public-private partnerships. We have trained over 300 000 farmers, extension workers and researchers on pest monitoring, early warning, and IPM. By prioritizing non-chemical methods such as microbial biopesticides and emphasizing the role of preventative measures, we have reduced the use of chemical pesticides. We have also seen that FAW-related losses are down to 3 to 5 percent.

These achievements and outcomes were showcased at the FAO Global Symposium on Sustainable Fall Armyworm Management held in Beijing, China, from 31 October to 2 November 2023. The symposium focused on "Charting a global response to future invasive pests" and brought together more than 40 speakers and 200 worldwide participants. They shared their best practices and exchanged valuable knowledge, drawing lessons from the past and laying a robust foundation for the active prevention and sustainable response to future biological invasions. Given the central contribution of plant health to the Sustainable Development Goals (SDGs) and to achieving FAO's core

mandate, the symposium provided an opportunity to chart the way forward. And now, we need to transition from an emergency response to a single pest, such as FAW, towards the sustainable management of a broader suite of pests.

Through the symposium, 16 actionable recommendations were identified to support future plant pest management activities and resource mobilization efforts. I urge each of you to continue these important discussions, continue building on the symposium's recommendations and work together to truly make an impact in our work in plant pest management.

These symposium proceedings capture the legacy of FAO's Global Action on FAW Control (GA), which has served as the basis for coordinated interventions to protect plant health around the world. I encourage all stakeholders, especially governments, researchers, extension agents and the private sector, to use these proceedings as a reference and to build on the momentum of the symposium.

Beth Bechdol
Deputy Director-General, FAO

Preface

The Food and Agriculture Organization of the United Nations (FAO) organized the first-ever Global Symposium on Sustainable Fall Armyworm (FAW) Management in Beijing, China from October 31 to November 2, 2023, with the theme of "Charting a global response to future invasive pests". The symposium was supported by the Chinese Academy of Agricultural Sciences (CAAS), and the National Agro-tech Extension and Service Center (NATESC), Ministry of Agriculture and Rural Affairs (MARA) in China. The objective of the symposium was to facilitate a worldwide dissemination of results and lessons learned from the successful implementation of FAO Global Action on FAW Control (GA) over the course of four years (2019-2023) to improve the global response to FAW and other invasive plant pests and diseases in future.

Organization of the symposium was facilitated through three governance bodies: the global organizing committee (GOC) and the local organizing committee (LOC) of the global symposium, and the FAW Secretariat of FAO. The GOC was chaired by Mr Robert Bertram, Chief Scientist of the United States Agency for International Development (USAID), and co-chaired by Mr Kongming Wu, President of CAAS, who was instrumental in providing advice on all technical aspects of the symposium. The LOC was chaired by Mr Kongming Wu and co-chaired by Mr Qiwen Wei, Director-General of NATESC, who was responsible for local arrangements and onsite logistics of the event in Beijing, China. The FAW Secretariat of FAO was presided over by Mr Jingyuan Xia, Executive Secretary of FAW Global Action, and assisted by Mr Buyung Hadi, Global Coordinator of the FAW Secretariat, in providing daily support to both GOC and LOC.

The symposium convened over 200 participants in person, including more than 60 international participants and over 30 observers from an International Plant Protection Convention (IPPC) high-level training course, and more than 100 local participants from China. The three-day event consisted of an opening and keynote address plenary session, followed by six scientific sessions, each of which was geared towards a specific thematic area. A total of 40 keynote remarks and scientific presentations were given, touching upon a wide array of disciplines, and covering both field- and laboratory-derived findings. Dialogue was further fostered by alternating presentations and open discussion, during which inputs and feedback were actively sought from all participants.

Scientists and government officials mingled with molecular biologists, pest risk analysts, migration modelers and plant protection professionals. As such, the symposium provided an unprecedented opportunity for government-level decision-makers, researchers, extension agents and other key stakeholders to interact, debate and consider practicable, cost-effective, and environmentally-sound solutions for the invasive FAW. Participants also had a chance to reflect and to plan.

These proceedings are an important legacy for the symposium, and composed of the following ten chapters:

- Chapter one contains welcome, opening and introductory remarks from the senior representatives of CAAS, the technical committee of the GA, and FAO.
- Chapter two covers the five keynote addresses on achievements and impacts of the GA, host plant resistance to FAW in the tropics, nature-based solutions for FAW management in Africa, FAW monitoring and management in China, and impact assessment of the GA.
- Chapters three to eight include six thematic sessions on prevention and preparedness, monitoring and early warning, FAW ecology, FAW integrated pest management (IPM) in its native and invasive range, farmers and extension, and enabling environments.
- Chapter nine consists of the closing statements from regional and global perspectives.
- Chapter ten provides 16 calls to action, as forged by members of the GOC, and further enriched by contributions from all participants.

The 16 items in this call to action could serve as a unique compass for further coordinated action, provide guidance for future investment, and build critical momentum towards integrated plant health management globally. This call to action could also be translated into concrete deeds under the contexts and scope of different actors, such as governments, development partners and other relevant stakeholders. To collectively move forward in the right direction, I encourage all to widely publish these calls to action and incorporate these into advocacy materials.

I hope you will enjoy reading these proceedings. Moreover, I urge you to integrate these global learnings into action within your own country and/or your own institution. Only by doing so can we tackle new and emerging pest and disease threats in a proactive, effective, and environmentally responsible manner.

Jingyuan Xia
Executive Secretary of FAW Secretariat, FAO
Special Advisor to FAO Director-General

Acknowledgements

The organization and implementation of the Global Symposium Sustainable Fall Armyworm Management was possible due to the invaluable support and commitment of many people.

Special thanks go to the global organizing committee (GOC) for overall advice on technical aspects of the symposium, chaired by Mr Robert Bertram from United States Agency for International Development (USAID), and co-chaired by Mr Kongming Wu from the Chinese Academy of Agricultural Sciences (CAAS), with Mr Jingyuan Xia from the Food and Agriculture Organization of the United Nations (FAO), Mr Prasanna Boddupalli from the International Maize and Wheat Improvement Center (CIMMYT), Mr Sevgan Subramanian from the International Centre of Insect Physiology and Ecology (*icipe*), and Ms Frances Williams from CAB International acting as vice-chairs.

Much appreciation goes to the local organizing committee (LOC) for local arrangements for the symposium. The LOC was chaired by Mr Kongming Wu, President of the Chinese Academy of Agricultural Sciences (CAAS), and co-chaired by Mr Qiwen Wei, Director-General of China's National Agro-tech Extension and Service Center (NATESC), with Mr Ke Jin from the Department of International Cooperation, Chinese Academy of Agricultural Sciences (DIC-CAAS), Mr Yanhui Lu, Director-General of the Institute of Plant Protection (IPP-CAAS) and Mr Fuxiang Wang from NATESC serving as vice-chairs.

The GOC deployed its expertise and technical networks to develop the programme for the global symposium, with active support from the group chairs of the technical committee of Global Action for Fall Armyworm Control (GA), including Mr Chris Dale from the Department of Foreign Affairs and Trade, Government of Australia (DFAT), Mr Henri Tonnang from *icipe*, Mr Rhett Harrison from Center for International Forestry Research-World Agroforestry (CIFOR-ICRAF), Mr Carlos Blanco from United States Department of Agriculture (USDA), Ms Alia Diyana from Pesticide Action Network Asia Pacific (PANAP), and Mr Prasanna Bodduppali from CIMMYT.

The FAW Secretariat, anchored in FAO's Plant Production and Protection Division (NSP), was responsible for core technical and organizational activities for the symposium. The Secretariat was led by Mr Jingyuan Xia, NSP Director (2020-23) and coordinated by Mr Buyung Hadi, Global Coordinator (2020-23), with technical and administrative support from Mr Maged ElKahky, Ms Anne-Sophie Poisot, Ms Sarah Brunel, Ms Verena Wilke, Mr Jean Claude Rwaburindi, Mr Kris Wyckhuys and Ms Jianqi Ding, as well as Mr Paolo Amici, Ms Sandra Cordon and Ms Valeria Awad.

Mr Paul Howard and Mr Francisco Martinez from NSP are especially recognized for their kind contributions to supporting the successful organization of the symposium.

Deserving of special commendation are the colleagues from IPP-CAAS and student volunteers who did an extraordinary job in making all technical and logistical arrangements in Beijing, including onsite registration, guidance, airport pick-up and visa assistance.

Particular thanks go to Mr Yanhui Lu, of IPP-CAAS, for his strong leadership and support, Ms Tian Fang, Deputy Division Director of IPP-CAAS for her effective and efficient coordination among GOC, LOC and FAW Secretariat of FAO, and to Mr Zhang Tiantao for his excellent coordination of all activities during the three-day event.

Sincere recognition is owed to all international participants who served as chairs, panelists, presenters, moderators, and rapporteurs of the different thematic sessions, and ensured a wide diversity of global technical views and opinions on sustainable FAW management. The work of all these behind-the-scenes professionals is gratefully acknowledged.

All international participants to the symposium from the developing countries and the publication of this proceedings have been fully financed by the project on supporting the implementation of FAO Global Action for Fall Armyworm Control under the framework of FAO-China South South Cooperation (SSC) Programme (2022-25).

Finally, sincere gratitude is extended to Mr Ibrahim Al-Jboory, President and Professor of Arab Society for Plant Protection (ASPP), Mr Buyung Hadi, currently serving as Senior Regional Technical Specialist of International Fund for Agricultural Development (IFAD), and Ms Mia Rowan, NSP Communication Specialist, for their intensive review of the draft proceedings and valuable inputs; and to the editor, Ms Sandra Cordon, and the graphic designer, Ms Ginevra Virgili, for their sophisticated professional work.

Abbreviations

ASEAN	Association of Southeast Asian Nations
AU-IAPSC	African Union Inter-African Phytosanitary Council
BARCIK	Bangladesh Resource Center for Indigenous Knowledge
BARI	Bangladesh Agricultural Research Institute
BWMRI	Bangladesh Wheat and Maize Research Institute
CAAS	Chinese Academy of Agricultural Sciences
CABI	CAB International
CAS	Chinese Academy of Sciences
CGIAR	Consultative Group on International Agricultural Research
CIFOR-ICRAF	Center for International Forestry Research-World Agroforestry
CIMMYT	International Maize and Wheat Improvement Center
CSIRO	Commonwealth Scientific and Industrial Research Organization, Australia
DAFF	Department of Agriculture, Fisheries and Forestry, Government of Australia
DFAT	Department of Foreign Affairs and Trade, Government of Australia
FAMEWS	Fall Armyworm Monitoring and Early Warning System
FAO	Food and Agriculture Organization of the United Nations
FAW	fall armyworm
FLS	field learning site
GA	Global Action for Fall Armyworm Control
GE	genetically engineered
icipe	International Centre of Insect Physiology and Ecology
IPPC	International Plant Protection Convention
IPP-CAAS	Institute of Plant Protection, Chinese Academy of Agricultural Sciences
IPM	integrated pest management
KALRO	Kenya Agricultural and Livestock Research Organization
KEPHIS	Kenya Plant Health Inspectorate Service
MARA	Ministry of Agriculture and Rural Affairs, China
NARO	National Agriculture and Food Research Organization, Japan

NATESC	National Agro-tech Extension and Service Center
NENA	Near East and North Africa region
NGO	Non-governmental organization
NIBIO	Norwegian Institute of Bioeconomy Research
NPPO	National Plant Protection Organization
NTF	National task force
OAU	Organization of African Unity
PAN	Pesticide Action Network
PANAP	Pesticide Action Network Asia Pacific
PCE	Phytosanitary capacity evaluation
POARS	Pest Outbreak Alert and Response System
PPD MARD	Plant Protection Department Ministry of Agriculture and Rural Development, Viet Nam
PPRI	Plant Protection Research Institute
PRA	Pest risk assessment
RAP	Regional Office for Asia and the Pacific
SDM	Spatial distribution model
ToT	Training of trainers
TR4	Fusarium Tropical race 4
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
VNUA	Viet Nam National University of Agriculture
WHO	World Health Organization


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1. WELCOME, OPENING AND INTRODUCTORY REMARKS

Mr Kongming Wu
President, Chinese Academy of Agricultural Sciences (CAAS), China

In the golden autumn of Beijing, today, under the initiative of the Food and Agriculture Organization of the United Nations (FAO), experts and scholars on fall armyworm (FAW) prevention and control from around the world gathered here to review and share experience in monitoring and control of FAW, further explore strategies for continued control of FAW, and discuss international cooperation in this area. This symposium is significantly meaningful and will definitely promote international cooperation and improve the level of prevention and control of plant pests and diseases.

On behalf of the Ministry of Agriculture and Rural Affairs of China (MARA) and the Chinese Academy of Agricultural Sciences (CAAS), I would like to extend a warm welcome to all the guests and express my heartfelt thanks to FAO and all parties for their long-term commitment and support for China's agriculture development and plant disease and pest control.

China is a major agricultural and grain production country. Since ancient times, it has been said that "Food security is the fundamental guarantee for world peace." The Chinese government has always attached great importance to the issue of food security. One of China's main experiences in securing food production is to adhere to disaster prevention and reduction. After FAW invaded China in 2019, the Chinese Government attached great importance to the prevention and control of FAW as a major issue in order to secure a bumper grain harvest. The Chinese Government scientifically studied and evaluated the situation, fully mobilized and deployed resources, and refined practical plans. By clearly defining local responsibilities and implementing key measures, after more than four years of continuous efforts, China has achieved a milestone victory in the prevention and control of FAW. Not only has China reversed its recurrence and achieved the goal of ensuring a bumper harvest, but China has also innovated prevention and control mechanisms and built a comprehensive prevention and control technology system to effectively curb the damage caused by large-scale outbreaks of FAW and effectively guarantee a stable and bumper harvest of grain, while reducing the source of insects migrating back to Southeast Asian countries.

This year marks the 40th anniversary of FAO in China. Over the past four decades, FAO has been steadfast in providing support for agricultural development in China. Through project collaborations, FAO has brought about positive impacts in various areas, including agricultural policies and strategies, food security and nutrition, crop intensification, fisheries, forestry, livestock development, environment, climate change, and sustainable natural resource management.

China has become the most crucial strategic partner of FAO in promoting South-South and Triangular Cooperation in the agricultural sector, making a significant contribution to enhancing agricultural production capacity and technological innovation in developing countries.

Since FAO initiated the Global Action for Fall Armyworm Control (GA) in 2019, experts and research teams from CAAS have actively participated in this action plan. We have collaborated with FAO to design and implement the project "Strengthening inter-regional cooperation for sustainable management of FAW through South-South Cooperation". In 2022, CAAS and FAO jointly established the FAO-CAAS Innovation Platform. This platform leverages the technical expertise and talent advantages of CAAS and explores FAO's extensive international network to serve the transformation of global agriculture and food systems. Within the framework of China-FAO South-South Cooperation, it offers effective solutions for developing countries' agricultural science and technology system development.

FAW is a common issue and challenge facing the world. Based on the past cooperation, China is willing to work with other countries to consolidate the existing cooperation platform, continuously innovate cooperation mechanisms, and work with the international community to prevent and control FAW with a more open attitude and play a positive role in global plant protection. Here I would like to make three suggestions:

First, establish and improve a cooperation mechanism. Take this symposium as an opportunity to extensively carry out and deepen international cooperation on major invasive pests such as FAW and promote the exchange of information on the occurrence and harm of pests and diseases, advanced prevention and control technologies, and prevention and control experience.

Second, strengthen capacity development in monitoring, prevention, and control. Strengthen the development of global monitoring and early warning mechanisms for major invasive pests such as FAW, analyse the prevalence patterns of cross-border migration and disaster mechanisms of pests and diseases, build a technological system for monitoring and prevention of cross-border pests and diseases, promote information sharing, strengthen collaboration and exchanges, and improve the scientific prevention and control level.

Third, support international organizations to play a better role. FAO plays a vital role in FAW prevention and control cooperation. The Chinese Government actively supports FAO in playing a greater role in preventing and controlling the spread of diseases and pests and strengthening international cooperation and exchanges.

At the recent Third Belt and Road (BRI) Forum for International Cooperation, President Xi Jinping of China announced support for the high-quality construction of the BRI action plan, emphasizing the promotion of green development, driving technology innovation, and conducting practical cooperation. Today's symposium is graced by the presence of experts and scholars from all around the world. It is our joint effort that this Global Symposium on Sustainable Fall Armyworm Management serves as an opportunity for strengthening exchanges, sharing scientific knowledge and experiences on FAW prevention and control, addressing cross-border pest issues, and collectively advancing the sustainable control of global FAW, thereby safeguarding global food

security, and making new and greater contributions towards the realization of the United Nations 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs).

I wish this symposium a great success and wish you all a pleasant stay in Beijing!

Mr Robert Bertram

Chair, technical committee of FAO Global Action on Fall Armyworm Control

As chair for the technical committee of Food and Agriculture Organization of the United Nations (FAO) Global Action on Fall Armyworm Control (GA) and chair of the organizing committee for this event, I welcome you to the Global Symposium on Sustainable FAW Management. The symposium aims to facilitate dissemination of results and lessons learned from the GA to improve the global response against fall armyworm (FAW) and other invasive plant pests and diseases. I thank the Chinese Academy of Agricultural Sciences (CAAS) and National Agro-tech Extension and Service Center (NATESC) for hosting this gathering, and FAO for its overall organization.

FAW was first detected beyond its native range in 2016 in West Africa. By March 2023, FAW had been reported in over 80 countries in Africa, the Near East, Asia and the Pacific, and Europe.

FAW primarily attacks maize, a critically important food crop, with an enormous impact on nutritional security and livelihoods of smallholder farmers. The negative impact of FAW on maize yield is immense, with an average yield loss of about 18 percent in its first years of invasion.

FAW-induced yield losses have, in many cases, increased pesticide use and expenditure among smallholder farmers. This intensification of chemical pesticide use puts the health of humans and the environment at risk.

In response to the FAW crisis, in 2019 FAO's Director-General launched the GA to provide a coordinative platform for multiple partners to mitigate the impact of FAW. The GA mobilized technical and financial resources to support government responses to FAW and activate capacity enhancement programmes.

The FAO-led GA has worked through a functional and effective coordination network across eight geozones, each with a demonstration country that is, in turn, linked with 54 pilot or scale-up countries. Work to manage the insect pest is being coordinated across Africa, the Near East, Asia and the Pacific.

The GA is inclusive in its approach, encompassing techniques and technologies in phytosanitary measures, monitoring and early warning, as well as integrated pest management (IPM).

The technical committee for the GA comprises representatives from global and regional research centers in FAW native and newly invaded ranges. The committee was able to quickly collect and review evidence for various IPM tactics, evaluating them for their efficacy, costs, availability, and affordability for farmers as well as potential human and environmental risks. In the early years, much of the evidence came from the Americas as

FAW's native range. This review was quickly translated into a global guideline, a menu of potential solutions that national governments can further validate and scale up on their own.

Since then, the GA has worked with government partners in eight demonstration countries and a number of pilot or scale-up countries to do just that: evaluate and scale up the solutions through field research, training and other actions.

The member organizations of the technical committee continue to push the boundaries for new IPM tactics:

The International Maize and Wheat Improvement Center (CIMMYT), for example, produced tolerant maize lines that countries can register and release.

The International Centre of Insect Physiology and Ecology (*icipe*) screened its entomopathogenic fungal collections to identify strains with good efficacy and make them available in the market through a collaboration with the private sector.

The Center for International Forestry Research-World Agroforestry (CIFOR-ICRAF), in collaboration with FAO, developed a protocol for IPM tactics evaluation and worked with countries to collect and analyse data.

CAB International (CABI) catalogues available biopesticides for FAW in their BioProtection Portal and collaborated with FAO in piloting impact assessment exercises in Kenya and India. They also supported the national institution in Ghana to mass produce and release arthropod natural enemies.

We also put national research institutions in the driver's seat for work in countries and regions:

- In the Philippines, the National Crop Protection Center has led the work in scaling-up various interventions such as biological control and developing a regional IPM strategy.
- In Kenya, the field evaluation of various IPM tactics is being conducted by Kenya Agricultural and Livestock Research Organization (KALRO) in its research stations.
- In Egypt, national laboratories have conducted successful surveys of ambient natural enemies, followed by mass production of the identified parasitoid wasps for release in farmers' fields.
- In Burkina Faso and Cameroon, national universities are leading the evaluation and adaptation of techniques such as push-pull, microbial and botanical pesticides to the national contexts.

Finally, here in China, CAAS provides the technical leadership in monitoring FAW populations and migrations, formulating recommendations and developing new management technologies.

In the next three days, we will hear from all these partners about the results of their work. Indeed, after four years of implementation, I'm sure there are multiple lessons that we can extract. This includes insights on strategic and policy responses to invasive pests, technologies validated and adapted to manage an emerging invasive pest, and training techniques and other interventions needed to boost adoption of sustainable management practices.

These lessons learned from the GA and best practices must be shared to prepare a foundation for responding to future, costly, biological invasions. Damage caused

by invasive species is extremely expensive, costing the global economy more than USD 423 billion annually – and these costs have quadrupled every decade since 1970.

From my vantage point, a few key lessons to tackle future invasives may include the following:

- It is important to start with an inclusive approach and build collaborations across institutions, both in public and private sectors, that are working on various fronts, including: preparedness, prevention, monitoring and early warning, IPM, extension, and capacity building as well as policy and regulatory aspects.
- Science-based recommendations are essential and need to be summarized and channeled quickly from experts in different parts of the world to the countries in the invaded range.
- To validate and scale-up the adoption of these recommendations requires a highly collaborative approach, involving farmers, farmer groups, Farmer Field Schools (FFS), NGOs, national and international research institutes and universities, extension services and the private sector. Levers such as traditional outreach, field demonstrations, mass and social media, market solutions as well as policy and regulatory action need to be engaged.
- Government buy-in and leadership are essential for the success of invasive pest response. Countries with active national task forces can make quick gains in the fight against invasive pests.
- Finally, global and regional coordination is a key factor that ensures exchange of information and effective recommendations.

I'm sure there is more that we will learn in the next few days. I do look forward to hearing more from all of you and to reflecting together on what we can do together to face the next invasive pests.

Ms Beth Bechdol
Deputy Director-General, FAO

On behalf of the Food and Agriculture Organization of the United Nations (FAO) and the Director-General Mr Qu Dongyu, I warmly welcome all of you to the FAO Global Symposium on Sustainable Fall Armyworm Management.

The fall armyworm (FAW) was first reported outside its native range of the Americas in 2016, when just six African countries reported the pest. Since then, this pest has spread so rapidly that it is now reported in over 80 countries in Africa, the Near East, Asia and the Pacific, and Europe.

FAW has had a profound impact on livelihoods and food security for millions of people. In Africa alone, FAW inflicts yield losses worth USD 9.4 billion per year.

In response to this pest crisis, the Director-General of FAO launched the Global Action on Fall Armyworm Control (GA) in December 2019.

This GA is working in the three regions and eight geographical zones around the world, providing a global platform to co-ordinate research, extension, and policy support

across disciplines and scales. The GA links activities in all these sectors directly with the farmers' fields, to ensure that solutions are delivered where they are needed most.

A great deal of progress has been made under this GA, with extensive impact at global, regional, national, and farmer-field levels. Here, I would like to highlight some important work that has been done in strengthening national and farmers' capacities:

First, the microbial and botanical biopesticides are being validated and scaled out through public and private sectors in China, India, and Kenya, where multiple microbial biopesticides are shown to have 80 to 100 percent efficacy and exhibit high speed of kill.

Second, the surveys for natural enemies of FAW in Africa, Asia, and the Near East have shown that, while it highly depends on ambient contexts, locally occurring parasitic wasps inflict mortality levels up to 90 to 100 percent and omnivorous predators such as ground-foraging ants kill nearly 100 percent of FAW larvae or pupae.

Third, more than 70 000 reports from scouting surveys and traps in 63 countries in both Africa and Asia have been recorded in the FAW Monitoring and Early Warning System (FAMEWS) global platform.

Fourth, over 300 000 farmers, extension workers and researchers have been trained in applying tools and techniques including monitoring, early warning, prevention and preparedness, as well as integrated pest management (IPM) approaches.

Now, we must transition from an emergency response to FAW towards a sustainable management of the pest.

Moreover, we need to extract the lessons learned from the GA and share best practices to prepare a foundation for actively preventing and responding to future biological invasions.

Damage caused by invasive species in agriculture is extremely expensive, costing the global economy more than USD 423 billion annually – and these costs have quadrupled every decade since 1970.

Consistently, agriculture is the sector most impacted: invasive species in the United States have cost agriculture there an average of USD 9.5 billion per year over the past 60 years.

In Africa, invasive species currently cost the local agriculture sector USD 65.5 billion.

To help us to prepare for future biological invasions, this global symposium provides a platform for stakeholders to come together, learn from each other, and set up a roadmap for a global response to the future invasive pests.

Ultimately, this symposium must formulate clear calls to action for a global response to future invasive pests or pathogens.

We know the challenges are great, but through the mechanism created by the GA, and our pooled knowledge and experience, I am confident that we will find sustainable solutions.

Before closing, please allow me to express my sincere gratitude to Mr Robert Bertram, the Chief Scientist of the United States Agency for International Development (USAID), and the chair of the technical committee of the GA; to Mr Jingyuan Xia, the Executive Secretary of the FAW Secretariat; and to many other colleagues in the technical committee and the FAW Secretariat for their strong support and excellent work towards the implementation of the GA.

I wish you all a very productive and fruitful symposium.

Mr Jingyuan Xia
Executive Secretary of FAW Secretariat, FAO; Special Advisor to FAO Director-General

I am honoured to welcome you all to this extremely important event. This Global Symposium on Sustainable Fall Armyworm Management has more than 200 participants, including over 60 international participants, 30 observers from an International Plant Protection Convention (IPPC) high-level training course, special guests and over 100 local participants from across China.

Fall armyworm (FAW) originated in the Americas. Most probably, this pest moved to West Africa by international trade some time ago and was first reported by Nigeria in 2016. Since then, over the past seven years, FAW has aggressively spread across the globe. It has traveled from West to East Africa in a very short time span, and subsequently invaded the Near East, India, China, Southeast Asia and the Pacific. It then made its unwelcome arrival into Australia and was only recently reported in New Zealand. FAW currently affects 80 countries and poses an immediate risk for southern Europe.

The rapid pest spread, and proliferation is reminiscent of that of COVID-19. Figuratively, FAW represents a sort of COVID-19 disease for plants or for plant health globally. It is ranked as one of the top-ten plant pests threatening food and agriculture worldwide, and it is, notoriously, the top-single damaging crop pest in China. This was rapidly recognized by Director-General Mr Qu Dongyu of the Food and Agriculture Organization of the United Nations (FAO). Soon after his appointment as FAO DG in September 2019, the DG met with me in October 2019, and we resolved to provide a solution for the global FAW crisis. This resulted in the formal launch of the FAO Global Action on Fall Armyworm Control (GA) during FAO's Governing Council in December 2019.

The GA was characterized by the following three key elements. First, a very large coverage area, including the entire African continent, the Near East, and Asia for FAW management, as well as southern Europe and the Pacific for prevention. Second, a large coverage of disciplines, ranging from prevention, monitoring and early warning, and key management tactics such as host plant resistance, cultural control, biological control, and trapping control. Third, it included a large range of stakeholders, including governments, academia and research, education and extension, NGOs, private sector, and resource partners.

Through collective efforts by all engaged stakeholders and partners over the past four years (2019-2023), three key achievements have been made. First, FAW-related yield losses have been reduced markedly, from 50 percent to 20 percent, and even below 3 to 5 percent, which is exactly what the GA aimed for. Second, the GA has brought about substantial environmental benefits, where pesticide usage was drastically reduced, thereby promoting natural regulation, and protecting farm environments. Third, sustainable societal benefits have been gained, as a wide range of stakeholders, including farmers and extension agents, now know the way forward in dealing with this devastating pest.

The objective of this global symposium is to facilitate a worldwide dissemination of results and lessons learned from the successful implementation of FAO GA over the past four years to improve the global response against FAW and other invasive plant pests

and diseases in future. The onset of this global symposium would be undoubtedly the largest legacy of the GA that allows us to recall its history and achievements to better plan for future. In this context, we should learn from China, one of eight demonstration countries for the GA, how to successfully manage FAW by effective national coordination, and efficient collaboration among agricultural research and extension. The Chinese experience has also shown effective innovation, integration, demonstration, and extension of advanced and practical technologies, covering all elements of sustainable pest management – from country-wide monitoring to all aspects of integrated pest management (IPM) to farmer extension.

This global symposium has been carefully designed: it starts off with an opening ceremony and ends with a closing ceremony, and in between several blocks covering different thematic areas. After this opening session, we will have five keynote lectures, and then move into six successive thematic sessions – each of which covers a specific thematic area, ranging from prevention and preparedness, monitoring and early warning, ecology, IPM, farmers and extension, to enabling environments. In between these scientific sessions, we will have a field visit to the Chinese Academy of Agricultural Sciences (CAAS) gene bank – which is truly amazing, very large, modern, and effective – and the Institute for Plant Protection (IPP), which is China's centre for plant protection research. The global symposium will culminate in the joint formulation of 16 calls to action, which are recommendations that are directly drawn from the three-day event and will serve as guidelines for future invasive plant pest mitigation or, more broadly, plant health management.

We have worked very hard for the past four years, with most of our work done online, and this is really the first time for us to meet in person. This global symposium indeed can become a major success if we devote ourselves to active engagement in discussions, sharing comments and providing inputs as well as active friendship-building, especially with the local participants.

Before closing, I wish to convey a big thanks to all the people who made the GA successful and this symposium possible. First, allow me to convey a special word of thanks to the donors, including the European Union (EU), the Norwegian Agency for Development Cooperation (NORAD), and FAO-China South-South Cooperation Programme. Second, we are very grateful to the FAO GA steering committee, which was chaired by FAO Director-General Qu Dongyu and co-chaired by Deputy Director-General (DDG) Beth Bechdol, and its technical committee, which was chaired by the United States Agency for International Development (USAID) Chief Scientist Robert Bertram and consisted of seven technical working groups. Third, we are extremely grateful to the local organizing committee, which was composed of staff of IPP-CAAS and National Agro-tech Extension and Service Center (NATESC), all under the leadership of CAAS President Kongming Wu. Lastly, we wish to convey sincere thanks to Mr Buyung Hadi and all colleagues of the FAW Secretariat for all their hard work, excellent performance, and outstanding contributions to the effective implementation of the GA and organization of this global symposium.

Let's all work together to make this global symposium a global success.

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2. KEYNOTE ADDRESSES

2.1 Achievements and impacts of FAO Global Action on Fall Armyworm Control

Mr Jingyuan Xia
Executive Secretary of FAW Secretariat, FAO; Special Advisor to FAO Director General

Launched in December 2019, the Food and Agriculture Organization of the United Nations (FAO) Global Action on Fall Armyworm Control (GA) has now completed four years. Offering a globally coordinated approach to tackle the most rapidly spreading migratory crop pest in history, this GA has made exceptional progress. Critical awareness has been raised on the issue: global guidelines and webinars on key topics such as prevention and preparedness or integrated pest management (IPM) have reached decision-makers in more than 70 countries. By gathering more than 70 000 pest sightings, FAO's Fall Armyworm Monitoring and Early Warning System (FAMEWS) crowdsourcing tool has permitted the development of near real-time spread maps, climate-based forecasting, and early-warning systems. In close collaboration with national governments, more than 200 000 people were trained on core IPM technologies, including host plant resistance, natural enemy conservation, augmentative use of biological control agents (or biopesticides) and cultural control. Together with national governments and international cooperators, FAO has effectively put FAW front-and-centre.

The GA has generated decisive impacts. First and foremost, the area affected by FAW is steadily decreasing and its yield losses have been brought down to no more than 3 to 5 percent in multiple countries such as China, Burkina Faso, India, and Indonesia. In Kenya and the Philippines, critical momentum has been built for invertebrate or microbial FAW biological control, with increasing numbers of farmers embracing this approach. Aside from being an effective and practicable measure for FAW management, biological control has generated resounding win-win benefits for farmers and nature: in South Sudan, spray applications of biopesticides such as NPV lift crop yields, raise farmer profits, and shield biodiversity on- and off-farm.

Valuable lessons can be drawn from this four-year concerted effort. First, a change of mindset is needed, in which non-chemical, preventative measures warrant substantially more attention than curative solutions. Second, a strong coordination across spatial scales, i.e. from global to local is the *sine qua non*. Third, inclusiveness of stakeholders, technical disciplines and individual nations is key to fostering success. Fourth, plant health solutions

need to be globally relevant and locally appropriate, tailored to the contexts of a given geozone and molded to the unique agroecological conditions of individual farms. Lastly, Farmer Field Schools (FFS) – tactically coupled with new digital technologies such as social media – play a pivotal role in taking proven technologies to scale.

Now that FAW is widely established in Africa, Near East and Asia-Pacific, FAO and its partners need to shift gears. Indeed, we need to progressively transition from the emergent control to a sustainable management of FAW and myriad other biotic constraints. This entails an increased investment in the development, field-level validation, and up-scaling of agroecological or biodiversity-driven solutions such as varietal resistance, biological control or biopesticides. As per the global IPM definition, these measures truly constitute the 'first line of defense' for any new, emergent, or long-standing plant pest threat.

Aside from fortifying the techno-scientific underpinnings of these nature-based solutions, parallel advances are required in awareness-raising, capacity-building, and policy advocacy. When aiming to take integrated plant health management to scale, a holistic approach is imperative. Only by consciously reaching out across geographic, disciplinary, and ideological boundaries can we ensure that plant health delivers upon its promise and becomes a core One Health pillar.

2.2 Host plant resistance to fall armyworm in the tropics: status and prospects

Mr Prasanna Boddupalli
International Maize and Wheat Improvement Center (CIMMYT) & Consultative Group of International Agricultural Research (CGIAR) Plant Health Initiative

The fall armyworm (*Spodoptera frugiperda* [J.E. Smith]) (FAW) has emerged as a serious pest since 2016 in Africa, and since 2018 in Asia, affecting the food security and livelihoods of millions of smallholder farmers, especially those growing maize.

Sustainable control of FAW requires implementation of integrated pest management (IPM) strategies, in which host plant resistance is a key component. Significant strides have been made in breeding elite maize lines and hybrids with native genetic resistance to FAW in Africa, based on the strong foundation of insect-resistant tropical germplasm developed at International Maize and Wheat Improvement Center (CIMMYT) in Mexico. These efforts are being further intensified to develop and deploy elite maize cultivars with native FAW tolerance/resistance and farmer-preferred traits suitable for diverse agroecologies in Africa and Asia.

CIMMYT-derived FAW-tolerant maize hybrids have been already released in five countries in Africa (Ghana, Kenya, Malawi, South Sudan, and Zambia) while national performance trials are ongoing in a few other countries in sub-Saharan Africa. Under

the Consultative Group of International Agricultural Research (CGIAR) Plant Health Initiative, a FAW Innovation Platform has also been established at Kiboko, Kenya, where different IPM combinations (including host plant resistance, biological control, and biopesticides) integrating innovations from different partner institutions, have been evaluated in participatory engagement with farmers and extension personnel. Independently, genetically modified *Bacillus thuringiensis* (Bt) maize with resistance to FAW is already commercialized in South Africa, and in a few countries in Asia (the Philippines and Viet Nam), while efforts are being made to commercialize Bt maize events in additional countries in both Africa and Asia. In countries where Bt maize is commercialized, it is important to implement a robust insect resistance management strategy. Combinations of native genetic resistance and Bt maize also need to be explored as a path to more effective and sustainable host plant resistance options.

In this presentation, I will highlight the status, critical gaps, and priorities for host plant resistance research and development in maize, particularly in the context of sustainable FAW management in Africa and Asia.

2.3 Nature-based solutions for fall armyworm management in Africa

Mr. Sevgan Subramanian
International Centre of Insect Physiology and Ecology (icipe)

Cereals such as maize, sorghum, millets, wheat and rice contribute to the food security of over 962 million people in Africa. They are cultivated in over 98 m ha (40 percent of African arable land). However cereal productivity in Africa is only 40 percent of the global average. A combination of insect pests, diseases and weeds are among the major production constraints for cereals in Africa. Research efforts have focused on the development and implementation of sustainable and integrated pest management (IPM) strategies for tackling these constraints with significant economic benefits. However, invasion, extensive damage and the alarming spread of fall armyworm (*Spodoptera frugiperda*) (FAW) across Africa since 2016 has emerged as a major threat to food security and livelihoods in Africa.

Currently, FAW management strategies in the western hemisphere are largely based on the use of transgenic maize, augmentative release of parasitoids and pheromone-based monitoring and application of synthetic pesticides/biopesticides. However, such an intensive management strategy is less likely to be economically viable for smallholders in Africa, where maize productivity is significantly lower compared to North and South America. This necessitates the development of an IPM strategy that suits the smallholder production systems in these regions.

Recent research outcomes from Africa have highlighted the potential to develop a sustainable and nature-based IPM strategy, including a diversified maize cropping

system (push-pull/maize-legume intercropping), resistant maize hybrids, promotion of alternatives to pesticides such as biopesticides and botanical pesticides, and conservation of native natural enemies that are already associated with FAW (such as *Telenomus remus, Trichogramma chilonis, Cotesia icipe*).

Further, farmers in Africa have also been innovating with their indigenous knowledge and practices (for example, sprays of fish soups and application of botanical concoctions) to counter FAW with locally available resources. Such practices need to be scientifically validated, optimized, and scaled to other fellow farmers in Africa. One of the critical constraints to scaling these nature-based solutions lies in the mass production of IPM tools associated with such nature-based solutions (e.g. seeds of companion crops/intercrops, resistant and improved maize seeds, biopesticides and biological control agents).

On one end, supplies of FAW IPM tools are a constraint, while on the other end, unemployment, especially among youths, is a major challenge Africa is facing. Building entrepreneurial skills among youths to establish businesses and scale sustainable and nature-based FAW IPM tools to farmers and national governments at affordable prices could be a great strategy. Further applications of the nature-based solutions can be effectively complemented with the establishment of area-wide FAW monitoring networks to guide timely and effective management interventions:

1. Nature-based solutions that are effective, sustainable, and affordable are well suited to manage FAW in the smallholder maize production systems of Africa.
2. There is an immediate need to create wider awareness of the nature-based solutions among smallholder farmers and promote their adoption.
3. Building entrepreneurship among youths in Africa to produce, supply and scale nature-based solutions is critical and needs to be supported by national governments.

2.4 Fall armyworm monitoring and management in China

Mr Kongming Wu
Chinese Academy of Agricultural Sciences (CAAS), China

The fall armyworm (*Spodoptera frugiperda* [J. E. Smith]) (FAW), a notorious migratory pest native to tropical and subtropical America, invaded China in 2019.

Maize was the most severely affected crop, although wheat and other plants were also ruined. Population monitoring and early-warning programmes form the foundation for prevention and control of FAW. The Ministry of Agriculture and Rural Affairs of China (MARA) required plant protection institutions in all provinces to carry out regional joint monitoring using a unified method. The National Agro-tech Extension and Service Center constructed the National Information Platform for the Prevention and Control of the fall armyworm at the county level, and the Chinese Government could fully grasp the dynamics of the FAW and realize real-time dissemination of information.

Considering the biological characteristics, incidence regularity and migration patterns of the FAW populations, the national government implemented a regional control strategy and divided the areas infested with FAW into the annual breeding grounds in Southwest and South China, the transitional migratory area in Jiangnan-Jianghuai region, and the key preventive area in the Huang-Huai-Hai region and North China. According to forecasting information, millions of extension workers and small-scale growers in the entire country were rallied by local governments to fight the pest through integrated pest management (IPM) tactics including chemical, physical, biological, and ecological measures.

By relying on coordinated monitoring and a regional management strategy, maize yield loss was limited to 5 percent of the total during 2019-2022.

2.5 Impact assessment of FAO Global Action on Fall Armyworm Control: Key findings and recommendations

Ms Frances Williams
CAB International

The Food and Agriculture Organization of the United Nations (FAO) launched the Global Action for Fall Armyworm Control (GA) in December 2019 to strengthen preventative and sustainable pest control measures across countries affected by FAW. The GA established a global coordination mechanism delivered through national task forces (NTFs), the FAO GA technical committee and the GA FAW Secretariat, regional steering committees and seven technical working groups. This study examines whether the GA has fulfilled its aims. Research questions include whether losses due to FAW have changed between 2018 and 2022, the impacts of these changes, and whether the GA contributed to the changes.

Bungoma and Embu counties in Kenya, and Karnataka state in India were selected as the study areas. Maize was selected as the study crop. The study comprised: a literature and desk review, a quantitative farmer household survey and a qualitative survey. The qualitative data was used to triangulate the quantitative data, as well as to understand the contributions of the GA and NTF partners to changes at farmer level.

The study found the FAW response, with its associated works and interventions, was effective as it was inclusive, empowering, built knowledge and embedded pest management skills for extension staff. There was a highly collaborative approach involving many actors including farmers, farmer groups, Farmer Field Schools (FFS), NGOs, national and international research institutes, extension services, and government officials. Government buy-in and leadership were essential in the FAW response, and coordination was the key factor that ensured an effective response.

FAW remains a challenge to maize production for smallholder households. However, infestation and damage levels are decreasing. Yield loss estimates associated with FAW

presence were 5.5 percent in Kenya and 5 percent in India, demonstrating a reduction in maize production losses associated with FAW when compared with previous farmer estimates. Farmers use cultural, mechanical, biological methods for FAW management, rather than relying solely on synthetic pesticides. The choice of management practices was influenced by exposure to information channels, with FFS and village awareness meetings driving adoption of integrated pest management practices in Kenya and India, respectively. Participation in FFS, demonstrations, plant clinics and village awareness meetings stimulated the adoption of biological control practices. Access to free or subsidized inputs enhanced the adoption of biological control in India and chemical control in Kenya. Subsidizing biological controls products could provide farmers with the incentives they need to adopt these products and practices.

Key lessons include the need for deliberate efforts to create and sustain collaboration between government and the private sector, especially in relation to supplies of pest control products. GA activities should be scaled-up to build the capacity of a wide range of farmers. Other extension approaches, including traditional and social media, plant clinics, village awareness meetings and private input suppliers, should be used to complement FFS.

It is worth noting that during the 2022 cropping season, maize productivity was more affected by drought and other pests than by FAW. Therefore, policy actions aimed at fighting FAW should also address recurrent challenges faced by smallholder farmers, such as rainfall shocks and other crop pests.

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3. PREVENTION AND PREPAREDNESS

3.1 A global effort in the prevention and preparedness of fall armyworm

Mr Chris Dale
Department of Foreign Affairs and Trade (DFAT), Australia

Biosecurity and plant protection are shared responsibilities. The coordination of biosecurity and plant protection efforts at a national level has its challenges. The coordination of biosecurity efforts at global and regional levels across geographical, political, and institutional boundaries presents an even greater challenge. This presentation provides an overview of collaborative efforts of international organizations, regional plant protection bodies, and technical specialists over the past three years to coordinate biosecurity and phytosanitary initiatives to help countries prevent, prepare, and respond to biosecurity threats at the global, regional, and national level.

Biosecurity and transboundary pest threats such as the fall armyworm (*Spodoptera frugiperda*) (FAW) have caused devastating impacts upon agricultural sectors at a global level in recent years and are threatening the biosecurity and pest status of FAW-free countries as the pest moves via natural and trade pathways through the Pacific, Near East, African and European regions. Agricultural production and food trade needs to continue for economic and food security reasons but requires coordination and collaboration at a global, regional, and national level to support local biosecurity and phytosanitary systems.

Global, regional, and national level biosecurity programmes such as the FAO Global Action for Fall Armyworm Control (GA), the ASEAN Fall Armyworm Action Plan, and the Department of Agriculture, Fisheries and Forestry (DAFF) Pacific Biosecurity Partnership Program are coordinating the mobilization of technical, operational, academic, research and communication expertise in a collaborative effort to manage the global spread and impact of FAW. These initiatives are not only providing technical and operational support to biosecurity and plant protection agencies through the development of regionally and globally consistent FAW phytosanitary resources, but they are also supporting livelihoods at the village, grower, and commercial level through the implementation of globally harmonized preparedness, response, and management initiatives.

3.2 FAW prevention and preparedness in the Near East and North Africa

Ms Sameh Benammar
Ministry of Agriculture, Water Resources and Maritime Fisheries of Tunisia, Tunisia

The Near East and North Africa (NENA) region is facing a significant threat from the fall armyworm (*Spodoptera frugiperda*) (FAW), a highly destructive pest that poses a serious risk to food security and agricultural production. To effectively address this threat, the Global Action for Fall Armyworm Control (GA) was implemented, focusing on preparedness, prevention, and control measures.

Preparedness is crucial to minimize the impact of FAW on the NENA region. This involves developing strategies and plans to prevent the introduction and spread of the pest. Through cooperation programmes, countries in the region benefited from the tools necessary for early warning and monitoring systems to detect the presence of FAW and provide timely information to farmers and authorities. Surveillance efforts have been strengthened to ensure that outbreaks are identified early and appropriate control measures can be implemented.

Prevention is another key aspect of the GA. Efforts were made to reduce the risk of further spreading of FAW to new areas within the NENA region. This was achieved through the implementation of strict phytosanitary measures, such as inspections of agricultural imports and exports and quarantine measures. International cooperation is essential in sharing best practices and scientific knowledge to prevent the introduction and spread of FAW.

Improving management practices is also crucial in controlling the spread of FAW. Six technical cooperation programmes were established to provide countries in the NENA region with the necessary technical support and expertise. This included training programmes for farmers (about 2 000 persons) on integrated pest management (IPM) techniques, as well as the establishment of more than 52 Field Farmer Schools (FFS), where farmers learned about effective control methods. Strengthening national capacity-building on survey and massive production of natural enemies of FAW was also an important area of work. Many centres in the region were provided with effective technical and logistics support.

Raising awareness among stakeholders is vital in mobilizing support for FAW control efforts. This was done through the production of videos, social media campaigns and the publication of guidance materials. Coordination and communication among different stakeholders – including governments, farmers associations, private sector, research institutions and regional organizations – were promoted to ensure a comprehensive approach to control the spread of FAW.

Partnerships among different actors are essential for effective FAW control. A prevention and control network were established between National Plant Protection Organizations (NPPOs), governments and stakeholders to develop and implement strategies for pest management. More than 3 500 training programmes were successfully established to reach specific goals.

In conclusion, the GA in the NENA region requires a comprehensive approach that focuses on preparedness, prevention, and control measures. This includes strengthening early warning and monitoring systems, implementing phytosanitary measures, providing technical support, and training programmes, raising awareness among stakeholders, promoting coordination and communication, and establishing partnerships. By working together, countries in the NENA region can effectively mitigate the impact of FAW on agricultural production and food security.

3.3 FAW prevention and preparedness in the Pacific

Mr Hemant Nitturkar
FAO Subregional Office for the Pacific Islands

Prevention is better, and cheaper, than a cure. This saying resonates very well for any emerging transboundary pests, equally so for the fall armyworm (*Spodoptera frugiperda*) (FAW) that has been relentlessly spreading and rampantly impacting food security and livelihoods in many countries throughout the world today. The number of countries that FAW has invaded since it first escaped from its native Americas and landed into regions of African, Asia and the Pacific within a span of seven years is not only unprecedented but alarming and mind-boggling. The first record of FAW in the Pacific Islands was in 2020 when it invaded Timor-Leste, Australia, and Papua New Guinea. The pest has continued to expand its territory in the Pacific Islands by invading Solomon Islands in 2021, New Zealand and New Caledonia in 2022, and Vanuatu in 2023. Other Pacific Island countries are on alert and in preventative and preparedness mode for FAW.

Obviously, Pacific Islands countries and territories are up against surmountable challenges when it comes to prevention, preparedness, and response for transboundary pests like FAW. As nations of many islands in the vast ocean space, they must contend with vast distances, accessibility issues, higher vulnerability to natural disasters and climate change impacts – in addition to issues like the resource crunch, capacity constraints and lack of awareness. There have been lessons learned from the impacts of emerging pests that had inadvertently made their way into the Blue Pacific Island nations in recent years that have reminded the countries of their vulnerability and lack of preparedness to respond effectively and efficiently to prevent, contain and manage pests with robust and functioning biosecurity systems. The only silver lining is that the Pacific region can learn from other countries in FAW management.

Essentially, two systematic approaches are usually deployed when dealing with emerging pests. The first approach applies to countries that have not yet reported FAW incursions. Here, National Plant Protection Organizations (NPPOs) recognize the threat of emerging pests, and as much as possible prepare themselves to avoid the pest's entry. The Food and Agriculture Organization of the United Nations (FAO) is helping the Pacific Island countries in putting together a six-pronged guideline for countries

where FAW is still absent. This includes: FAW pest risk analysis, FAW phytosanitary regulations, inspection and diagnostics, surveillance, communication and awareness building, and preparation of a response plan.

The second approach applies to Pacific Island countries that have already been invaded by FAW. They are adopting a four-pronged guideline that includes: FAW delimiting surveys, application of FAW phytosanitary measures, suppression of FAW populations, and communications and information sharing with stakeholders. Striving to find sustainable management solutions for FAW is perhaps the sensible way forward in dealing with this pest among Pacific Island countries.

3.4 FAW prevention and preparedness in Europe

Ms Mariangela Ciampitti
Regional Phytosanitary Service Lombardy, Italy

The global alert raised on fall armyworm (*Spodoptera frugiperda*) (FAW) within the International Plant Protection Convention (IPPC) community enabled countries of the European regional group to prepare for a possible introduction of the pest and to issue the most appropriate prevention measures.

The first reports of the presence of FAW in the European region date back to 2020 when the pest was found in Israel; the following year, the report came from the Canary Islands and in 2022 from Türkiye. In 2023, unfortunately, the pest was also found in Cyprus, Madeira in Portugal, and very recently, in five locations in Greece.

So far, no significant crop damage has been reported in Europe due to the presence of FAW.

Supported by the Food and Agriculture Organization of the United Nations (FAO)-IPP guidelines and information shared during a series of well-attended webinars, European National Plant Protection Organizations (NPPOs) have been encouraged to promote preparedness and prevention activities and to respond promptly if the pest is found.

Over the last few years, several studies have been conducted to support pest risk analysis, and a tool for the analysis and the management of the risks of FAW was developed by a research group of the University of Brescia in Italy. A physiologically based population dynamics model of FAW has been applied to explore the potential risk posed by FAW to Europe. Results of this study show that the species can establish in Europe with three to four generations per year in the coastal areas of the Mediterranean basin and in some warmer inland areas of southern Europe. The species can generate transient populations in southern and in central Europe that can reach, during the favourable season, population abundance representing a risk to susceptible crops. The model can be used to define strategies for reducing the risks of establishment of the pest at the country level. Predictions on the dynamics and phenology of the pest can also be used to support its management at the local level.

FAW is categorized as quarantine pest for most countries in the Europe region and included in the list of 20 priority pests by the European Union (EU) and Central European Free Trade Agreement (CEFTA) countries. Analysis of data relating to FAW interception in the EU from 2018 to 2023 showed that 54 percent involved three commodities imported: Asparagus officinalis, fruits of *Capsicum spp*., and fruits of *Solanum spp*. To prevent the introduction and spread of FAW in the EU, a new temporary implementing regulation (EU) 2023/1134 came into force in July 2023, replacing the previous regulation (EU) 2018/638. New requirements apply to imports of fruits, plants, and parts of host species posing a phytosanitary risk.

Many activities have been implemented by NPPOs for early detection and prompt reaction. Special attention was paid to carrying out surveys using traps and training laboratory technicians for pest identification. Information and communications material, such as dedicated web pages, datasheets, leaflets, social media posts, have been made available by the European Plant Protection Organization (EPPO), European Food Safety Authority (EFSA) and NPPOs.

The Europe region in the Global Action for Fall Armyworm Control (GA) supported the drafting of the contingency plans in Europe, gave direct access to international research results, and set up a valuable network of experts, providing precious support for the effective management of this pest.

3.5 Preparing for the next quarantine plant pest outbreak

Ms Sarah Brunel
International Plant Protection Convention (IPPC) Secretariat, FAO

The International Plant Protection Convention (IPPC) Secretariat, through its Implementation and Facilitation Unit (IFU), has been instrumental in leading the prevention activities in the Food and Agriculture Organization of the United Nations (FAO) Global Action on Fall Armyworm Control (GA) framework. Under the guidance of the FAO/IPPC fall armyworm technical working group (FAO/IPPC FAW TW), all available technical resources on FAW prevention were gathered, assessed and shared with the IPPC community. Also, the "Prevention, preparedness and response guidelines for FAW" were published and the content was shared through global webinars.

This innovative initiative was exemplary and laid the foundation for conducting other global activities aimed at preventing other quarantine plant pest outbreaks, particularly *Fusarium oxysporum f. sp. cubense* Tropical race 4 (TR4). The IPPC community, through the Commission on Phytosanitary Measures (CPM), tasked the IPPC Secretariat to undertake global coordination on TR4. In addition, guidelines for the prevention, preparedness and response to this pest were published and shared through webinars, and a series of training courses and simulation exercises are also being organized.

Activities on such emerging pests are well structured under the IPPC Strategic Framework Development Agenda "Strengthening pest outbreak alert and response systems", for which top experts on the topic provided concrete recommendations. The efficiency of prevention activities strongly depends on the strength of the national phytosanitary systems. Therefore, a comprehensive effort to support these systems is crucial for the prevention success.

The IPPC Secretariat, under the guidance of the implementation and capacity development committee, published over 24 guides and five e-learning courses on diverse phytosanitary aspects to provide all countries with the tools to strengthen their National Plant Protection Organizations (NPPOs). In addition, the IPPC Secretariat manages the phytosanitary capacity evaluation (PCE), a fully comprehensive NPPO-led, facilitator-enabled, IPPC Secretariat-supported process of multiple phases with a wide range of benefits. The PCE helps countries evaluate their phytosanitary capacities, preparing them to be ready for the next quarantine plant pest outbreak.


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Robert Bertram
Chair, Global Organizing Committee of the Symposium
Chief Scientist, USAID
Food and Agriculture Organization of the United Nations

4. MONITORING AND EARLY WARNING

4.1 Efficacy of sex pheromones and trap designs in monitoring fall armyworm on maize

Mr Johnson Nyasani
Kenya Agricultural and Livestock Research Organization (KALRO), Kenya

Fall armyworm (*Spodoptera frugiperda* [J.E. Smith]) (FAW) is a serious pest of maize and a wide variety of crops. Management of FAW is challenging due to the pest's characteristics, such as its high reproductive rate, short lifecycle, ability to disperse rapidly, wide host range, and development of pesticide resistance. Information on the pest's presence, movement, and population buildup is important to initiate timely management options.

The objective of this study was to determine the efficacy of commercially available FAW sex pheromones and trap designs in monitoring male FAW moths on maize. Two trap designs, delta and funnel trap, in combination with four FAW sex pheromones – Falltrack lure, *Spodoptera frugiperda* pheromone lure, PHEROCON FAW pheromone lure, and SpoFru lure – were used as treatments in field experiments.

In the first seven days after trap placement in the field, there were no male FAW moth catches on the delta and funnel traps equipped with Falltrack lure. Conversely, varying numbers of male FAW moths were caught on the two trap designs equipped with *Spodoptera frugiperda* pheromone lure, PHEROCON, and SpoFru. The results indicated that delta traps equipped with FAW sex pheromone lures resulted in lower catches of male FAW moths and attracted many non-target insects. Conversely, funnel traps equipped with FAW sex pheromone lures, especially SpoFru lure, resulted in higher catches of FAW moths and very low numbers of non-target insects.

Results from this study suggest that commercially available FAW sex pheromones differ in efficacy in attracting male FAW moths. The results indicate that a funnel trap equipped with SpoFru lure is ideal for early warning and monitoring of male FAW moths on maize. Farmers should place the funnel trap in the field before planting maize to ensure early detection and timely management of FAW. Periodic emptying of trap catches, and cleaning of pheromone traps is important to enhance trap catches of FAW. Pheromone lures should also be replaced after 21 days for enhanced efficacy in monitoring.

4.2 Modeling and communication of fall armyworm risks based on FAMEWS data

Mr Henri Tonnang
International Centre of Insect Physiology and Ecology (icipe)

Fall armyworm (*Spodoptera frugiperda* [J.E. Smith]) (FAW) has emerged as a significant threat to cereal production in Africa, especially maize. Over the past four years, its rapid invasion has necessitated the development of innovative and sustainable management strategies. Our collaborative efforts in early warning for FAW encompass the conceptualization and development of tools, analytics and algorithms to gain a comprehensive understanding of FAW's dynamics, invasion mechanisms, and interactions with natural enemies across Africa and beyond. Initially, using FAW density data spanning from January 2018 to December 2020, integrated with monthly average climatic and environmental variables, we employed advanced multilevel analytics to identify key factors influencing FAW's spatial and temporal density.

Our results have shown that FAW's monthly density projections are notably influenced by the seasonal variability of host vegetation and climatic factors. The diverse climate patterns and cropping systems in various African sub-regions play a pivotal role in influencing FAW abundance and variation. Simultaneously, we introduced a computational index grounded in fuzzy sets theory to identify potential deployment sites for the push-pull technology, a climate-smart integrated pest management (IPM) strategy against FAW. This index, validated through established push-pull deployments, is based on the presence of companion plants, maize, and livestock. Our findings have revealed that all maize farming areas in Africa are viable for push-pull technology, with the eastern and southern regions deemed highly suitable. The suitability index demonstrates a stronger correlation with rainfall and soil nutrient levels than with temperature, offering valuable guidance for promoting climate-smart intercropping throughout Africa. Moreover, our research underscores the potential of biological control (BC) technologies as sustainable alternatives to chemical control.

We employed a systematic modeling approach to map suitable sites for BC technologies, focusing on the parasitoid *Cotesia icipe*. Our computational results strongly support the effectiveness of *C. icipe* as a biocontrol agent during maize cropping seasons. Artificial intelligence, combined with data science and knowledge representation, serves as an effective advisory tool for guiding the deployment of biological control agents. This approach enhances the efficacy of FAW management strategies by offering valuable insights and recommendations based on data-driven and computer intelligence analyses. Our central focus on the early warning system is paramount in predicting and mitigating FAW infestations. As we move forward, we prioritize the integration of digital twins as an advanced analytical tool. Digital twins create a dynamic, real-time mirror of physical systems, enabling us to refine our early warning systems further. They capture intricate interactions between FAW and its natural enemies, providing real-time insights and predictive analytics. This forward-thinking approach aims to harness the power of

digital twins to design a sophisticated monitoring tool, ensuring effective management and intervention strategies against FAW.

In conclusion, our collaborative efforts offer a multifaceted and forward-thinking approach to FAW management. We emphasize the significance of early warning systems and the potential of digital twins in future research. We hope to combine methods with cutting-edge technology, to safeguard cereal crops, enhance agricultural productivity, and ensure food security throughout Africa and beyond.

4.3 Harnessing data to improve fall armyworm integrated pest management

Mr Ritter Guimappi
Norwegian Institute of Bioeconomy Research (NIBIO), Norway

Five years after its first report on the African continent, fall armyworm (*Spodoptera frugiperda* [J.E. Smith]) (FAW) is considered a major threat to maize, sorghum, and millet production in sub-Saharan Africa. Despite the rigorous work already conducted to reduce FAW prevalence, the dynamics and invasion mechanisms of FAW in Africa are still poorly understood.

This study applied interdisciplinary tools, analytics, and algorithms on a FAW dataset within a spatial lens to provide insights and project the intensity of FAW infestation across Africa. The data collected between January 2018 and December 2020 in selected locations were matched with the monthly average data of the climatic and environmental variables. The multilevel analytics aimed to identify the key factors that influence the dynamics of spatial and temporal pest density and occurrence at a 2 km x 2 km grid resolution. The seasonal variations of the identified factors and dynamics were used to calibrate rule-based analytics employed to simulate the monthly densities and occurrence of the FAW for the years 2018, 2019, and 2020. Three FAW density level classes were inferred, i.e., low (0–10 FAW moth per trap), moderate (11–30 FAW moth per trap), and high (>30 FAW moth per trap).

Results show that monthly density projections were sensitive to the type of FAW host vegetation and the seasonal variability of climatic factors. Moreover, the diversity in the climate patterns and cropping systems across the African sub-regions are considered the main drivers of FAW abundance and variation. An optimum overall accuracy of 53 percent was obtained across the three years and at a continental scale; however, a gradual increase in prediction accuracy was observed among the years, with 2020 predictions providing accuracies greater than 70 percent. Apart from the low amount of data in 2018 and 2019, the average level of accuracy obtained could also be explained by the non-inclusion of data related to certain key factors such as the influence of natural enemies (predators, parasitoids, and pathogens) into the analysis.

Further detailed data on the occurrence and efficiency of FAW natural enemies in the region may help to complete the tri-trophic interactions between the host plants, pests, and beneficial organisms. Nevertheless, the tool developed in this study provides a framework for field monitoring of FAW in Africa that may be a basis for a future decision support system.

4.4 Fall armyworm habitat spatial distribution monitoring and forecasting by remote sensing

Mr Wenjiang Huang
Chinese Academy of Sciences (CAS), China

The fall armyworm (*Spodoptera frugiperda*) (FAW) is a migratory pest that has posed a significant threat to key economic crops worldwide in recent years. In response to this challenge, the Crop Pest and Disease Monitoring and Forecasting System (RSCROP) group has developed a series of correlative spatial distribution models (SDM) and mechanistic SDM models related to FAW monitoring and early warning.

These models are based on remote sensing data and its assimilated data products, combined with ground pest observation data, eco-physiological mechanisms, migration mechanisms, and host plant phenology. The models have initially tracked the spatial distribution and population dynamics of FAW during its overwintering in China and its northward migration, which provided valuable information for pest damage hotspots.

In addition, we are also committed to the construction of FAW monitoring and early warning products and platforms. We hope that this comprehensive research will provide a solid data foundation for the management and decision-making related to FAW, thereby bolstering efforts to safeguard global food security.

4.5 Population genomics of fall armyworm invasion in Asia

Mr Wee Tek Tay
Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia

Invasive species have direct and indirect global ecological and socioeconomic impacts. Understanding factors contributing to pest spread is necessary to protect food security, and to improve biosecurity preparedness in a changing climate scenario. Collaborations between biosecurity agencies and scientists are pivotal to solving invasive species challenges and minimize introductions of: (i) new exotic pest species, (ii) undesirable genetic materials into recently established pest populations, and to disentangle natural

(e.g. migratory ability) versus human-assisted (e.g. via contaminated commodities) spread patterns through analysis of genomic resources.

Misidentification of unrealized independent introduction events from presumed natural spread of pest populations could result in the potential introductions of novel genetic traits (for example, insecticide resistance genes) to complicate management efforts, while failure to address existing but unrecognized biosecurity weaknesses could increase the risk of introduction of new invasive pest species.

This presentation summarized population genomic findings of FAW to disentangle its global spread patterns, multiple independent introduction signatures, and identify Asia and Southeast Asia as biosecurity hotspots that underpin its perceived rapid spread across its invasive ranges. It highlighted population genomic lessons learned to empower biosecurity preparedness of emerging transboundary plant pests within a global context.


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5. FALL ARMYWORM ECOLOGY

5.1 Fall armyworm parasitoid species in Africa

Ms Samira Mohamed Faris
International Centre of Insect Physiology and Ecology (icipe)

The rapid, Africa-wide invasion of the fall armyworm (*Spodoptera frugiperda*) (FAW) has had a devastating impact on local maize production. As an exotic pest, it was assumed that FAW greatly benefits from so-called 'enemy-free' space in its newly invaded range. However, several parasitoid species have formed new associations with the pest.

The presentation highlighted the diversity of native parasitoids recovered from FAW within the continent. Also, the findings on the potential use of seven of these parasitoid species for suppression of FAW are provided. The presentation also details the outcome of the performance of egg parasitoids – *Telenomus remus* and *Trichogramma chilonis*, the egg-larval parasitoid, *Chelonus bifoveolatus*, and the larval parasitoids, *Cotesia icipe*, *Charops sp*., *Coccygidium luteum* and a tachinid fly – against FAW under laboratory conditions. Furthermore, the effectiveness of *T. remus*, *T. chilonis* and *C. icipe* against FAW under field conditions, using augmentative releases, was highlighted. Moreover, our efforts on promotion of augmentation and conservation of egg parasitoids, as well as classical biological control of FAW, are also divulged.

In conclusion, FAW encountered diverse parasitoid species, the experimental augmentation of which has contributed to between 50-98 percent parasitism by *T. remus* and *T. chilonis*, and up to 38 percent parasitism by *C. icipe*.

5.2 Fall armyworm-induced injury and yield loss

Mr Rhett Harrison
Center for International Forestry Research-World Agroforestry (CIFOR-ICRAF)

Fall armyworm (*Spodoptera frugiperda* [J. E. Smith]) (FAW), a serious pest of maize and other cereals, arrived in Africa in 2016. Following its arrival, several publications came out with very high estimates of yield loss and impacts, such as USD 13 billion per annum across sub-Saharan Africa. It is now clear that these were gross overestimates.

However, calculating more accurate figures has proved challenging, but is essential for developing action thresholds under an integrated pest management (IPM) approach.

Overton *et al.* (2021) conducted a review of papers documenting yield loss from FAW in various crops. Three salient results can be drawn from their work: 1) farmers substantially overestimate yield loss, 2) yield loss in studies comparing maize hybrids (without application of pesticides) was estimated at 9.8 percent, and 3) the use of FAW incidence to estimate impact is unreliable with yield losses from 5 percent infestations varying from 0 to 50 percent and from 100 percent infestations varying from 10 percent to 100 percent. Through greenhouse trials we investigated yield loss by inoculating maize plants and examining yield loss at the plant level. Significant yield losses were only detected at one specific stage in the plant development (i.e. early maturing: three weeks, medium maturing: five weeks, late maturing: seven weeks). Yield loss per unit damage score varied from 1.6 percent in the late maturing variety to 6.4 percent in the medium maturing variety, but models based on damage scores only explained up to a maximum of 8 percent of the variance in yields, despite the controlled greenhouse conditions.

Field observational studies on the effect of maize leaf damage on yield found no relationship between damage score and yield. Over three years, we conducted on-farm trials across 144 farms and 12 landscapes in Zambia and Malawi, and we also were unable to detect any significant effect of leaf damage on yield. FAW-induced leaf damage was trivial in most situations. In addition, in all three years, pest infestation and leaf damage levels declined through the growing season, indicating that natural mortality was limiting pest populations.

Several conclusions can be drawn from this body of work: 1) it remains difficult to develop predictive models of yield loss based on FAW induced leaf damage, 2) FAW damage and resulting yield loss have often been grossly overestimated, 3) for smallholder farmers in southern Africa, investment in improved soil management and good agronomic practices such as timely planting, weeding, mulching/composting, and crop rotation will result in far greater yield benefits than a focus on FAW control.

5.3 Fall armyworm natural enemies in Mexico

Mr Urbano Nava-Camberos
Juarez University of the State of Durango, Mexico

Mexico is the fifth largest maize producer and the area of origin and domestication of this crop. Maize is the crop of greatest economic, social, and cultural importance in this country. Mexico's 6.8 million ha annual production of maize represents 30 percent of its total domestic agricultural production. The main insect pest of maize is the fall armyworm, (*Spodoptera frugiperda*) (FAW), followed by the black cutworm, *Agrotis ipsilon* (Hufnagel), and the corn earworm, *Helicoverpa zea* (Boddie). For the control of FAW and other pests, one to three applications of insecticides are made in the different

corn producing regions in Mexico. The natural enemies of FAW are very diverse, including parasitoids, predators and entomopathogens, such as viruses, fungi, bacteria, and nematodes. In Mexico, the greatest interest of researchers has focused on the study of parasitoid insects.

In Mexico, 68 species of FAW parasitoids have been reported, which corresponds to 26 percent of the existing species worldwide (263 species). It is important to indicate that of the total species present in Mexico, 19 are found exclusively here. The most common FAW parasitoid species, in order from highest to lowest distribution in Mexico are: *Chelonus insularis* (Cresson), *Pristomerus spinator* (Fabricius), *Campoletis sonorensis* (Cameron), *Chelonus cautus* (Cresson), *Trichogramma sp*., *Archytas marmoratus* (Townsend), *Cotesia marginiventris* (Cresson), *Meteorus laphygmae* (Viereck), *Ophion flavidus* (Brullé), *Euplectrus plathypenae* (Howard), *Chelonus sonorensi*s (Cameron) and *Eiphosoma laphygmae* (Costa Lima). Parasitoids specialize in attacking a particular developmental stage of FAW.

The egg parasitoids are *Telenomus remus* (Nixon) (Scelionidae), reported only in the State of Mexico and Nayarit (6 percent), and Trichogramma species (*Trichogrammatidae*) distributed in 11 states (34 percent). The species determined are *Trichogramma pretiosum* (Riley), *T. minutum* (Riley) and *T. atopovirilia* (Oatman & Platner). The degree of parasitism by *Trichogramma spp*. is generally low, in the Comarca Lagunera region touching parts of Coahuila and Durango states, it varied from 0.5 to 6.0 percent. The egg-larval parasitoids are *Chelonus insulari*s (Cresson), *Ch. cautus* (Cresson) and *Ch. sonorensis* (Cameron) present in 27, 12 and 10 states (84, 38 and 31 percent, respectively). The degree of parasitism of *Ch. insularis* is variable, but generally high, in Comarca Lagunera, Coahuila and Durango, ranged from 41.5 to 48.8 percent.

The most common species of flies that parasitize FAW larvae are *Archytas marmoratus* (Townsend) and *Lespesia archippivora* (Riley) (Tachinidae), distributed in 11 and eight states (34 and 25 percent respectively), causing low levels of parasitism (0.02 to 2.5 percent and 0.07 to 6.8 percent, respectively). The most important species of ichneumonid wasps that parasitize FAW larvae are *Pristomerus spinator* (F.), *Campoletis sonorensis* (Cameron), *Ophion flavidus* (Brullé) and *Eiphosoma laphygmae* (Costa Lima) present in 18, 14, 11 and eight states (56, 44, 34 and 25 percent, respectively). *Campoletis sonorensis* causes degrees of parasitism ranging from 0.10 to 23.4 percent. *Eiphosoma laphygmae* is considered a good candidate as a classical biological control agent, mainly due to its high host specificity and importance as a FAW parasitoid.

5.4 Fall armyworm natural enemies in the Philippines

Ms Melissa Montecalvo
University of the Philippines in Los Baños (UPLB), the Philippines

Fall armyworm (FAW) (*Spodoptera frugiperda [J.E. Smith]*) (Lepidoptera: Noctuidae), is an invasive pest species infesting important crops in the Philippines and other Asian countries. With the positive detection of this pest in agricultural fields, various natural enemies were also recorded in different countries. In Asia, effective microbials from various pathogen groups were also documented. Entomopathogenic fungi such as *Metarhizium rileyi*, *M. anisopliae*, and *B. bassiana* caused mycosis to varying biological stages of FAW. Nucleopolyhedrovirus and entomopathogenic nematodes (*Heterorhabditis indica, Steinernema abbasi, and Hexamermis cf. albicans*) also inflicted lethal infection on this invasive pest. In addition, macrobials including parasitoids and predators were identified attacking FAW. Some of the parasitoids include *Chelonus formosanus, Microplitis manilae, Netelia spp., Metopius rufus, Odontepyris sp., Coccygidium melleum*, and *Telenomus remus*. Many predators such as *Euborellia spp., Eocanthecona furcellata, Cosmolestes sp., Oxyopes birmanicus, Rhene flavicomans, Harmonia axyridis, and Orius sauteri* also efficiently kill FAW.

In the Philippines, FAW has been reported infesting corn, rice, and sugarcane. Various research, development, and extension initiatives are being implemented in FAW management. One of the focus areas is the biological control that identified natural enemies native to the Philippines. Parasitoids such as *T. remus* parasitized egg masses collected in the field and progenies. Other parasitoids recorded were *Brachymeria lasus* and *Copidosoma floridanum*. Under laboratory conditions, earwigs, entomopathogenic fungi, and nematodes caused lethal effects on FAW. Earwigs' species including *Euborellia annulata and E. annulipes* were aggressive in attacking FAW. Native entomopathogenic fungus, *M. rileyi*, was also isolated from infected larvae collected in many corn fields in the Philippines. This fungus was infective to resulting neonates from eggs and early larval instars. Cross infection of *M. anisopliae* and *B. bassiana* isolated from other insect pests to reveal the pathogenicity of these two entomopathogenic fungi to FAW. Entomopathogenic nematodes *H. indica* and *S. abbasi* also caused infection to FAW with the associated bacterium *Xenorhabdus sp*. Applying earwigs and entomopathogenic fungi reduced tassel damage and improved the yield of corn. Compatibility of various natural enemies is being evaluated in two cropping seasons of corn. The regional crop protection centres in the Philippines continuously provide free natural enemies for FAW management. To bring FAW's natural enemies to farmers' fields, continuous efforts to develop them – particularly the microbials – should be pursued.

Identification of natural enemies is key in the biological-based management of FAW in the Philippines and other Asian countries. Continuous efforts should be made to improve and promote their utilization. Information dissemination must be done to maintain and enhance the population of these natural enemies in the agroecosystem to prevent economic losses due to FAW. Our farmers will also be enticed to use these natural enemies if they are readily available.

5.5 Occurrence of fall armyworm in Japan and its overseas migration

Mr Akira Otuka
National Agriculture and Food Research Organization (NARO), Japan

The fall armyworm (FAW) arrived in China in 2019, and FAW larvae were found in the southern part of the Republic of Korea in June 2019. Old instar larvae were first confirmed in western Japan in early July. This rapid spatial expansion over East Asia illustrates the insect's strong migratory ability. Migration sources for the first overseas immigrants to the Republic of Korea and Japan were estimated to be in southern or eastern China, which corresponded to the insect's occurrence observed there. The estimated migration duration to Japan ranged from 18 to 35 hours, which is longer than the duration of nocturnal migrations over the continent (about 10 hours). The occurrence of FAW in the first season in Japan was confirmed in 22 prefectures out of 47, mainly in the western region that was the front of the overseas immigration. In the first winter of 2019–2020, the East Asian population of FAW occurred year-round in the tropical and subtropical regions of southern China. Analyses of air temperature and strontium radiogenic isotope ratio of insects trapped in winters also suggested that FAW occurred year-round on small islands of the Japanese Southwestern Islands, indicating the winter occurrence line can be extended from southern China to these islands. As the East Asian summer monsoon began to develop northward in 2020, the population started its migration towards the northern part of the Chinese mainland as well as Japan.

Major immigration to the Japanese mainland started in May 2020 and intermittently continued until the end of the Bai-u rainy season (typically mid-July). Since 2020, this seasonal migration has occurred consistently. Migration analysis showed that among the immigrations, one of the insect's longest overseas migrations occurred from southern China to Tohoku district in northern Japan. Its estimated flight distance and duration were 2 500 km and 31 hours, respectively. This flight path is feasible because most of the route is over the sea where fast winds and less turbulence could carry insects for longer distances.

Based on the migration technique for rice planthoppers and the monitoring data, FAW's migration prediction system for Japan has been developed. Migration characteristics such as take-off area and time, an upward velocity after the take-off, flight speed, etc. were implemented in the migration model. In a prediction evaluation using two-year six-point trapping data, the prediction method achieved an average hitting ratio of 78 percent, indicating sufficient prediction quality for operational use. A prediction system for Japanese plant protection stations is now operated in the JPP-NET, an Internet-based database service by the Japan Plant Protection Association.


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6. INTEGRATED PEST MANAGEMENT FOR FALL ARMYWORM IN ITS NATIVE AND INVASIVE RANGE

6.1 Fall armyworm integrated pest management in East and Southern Africa

Mr Ivan Rwomushana
CAB International

Since its arrival in sub-Saharan Africa, the fall armyworm (*Spodoptera frugiperda*) (FAW) has become a major pest of maize and other cereals, threatening the livelihoods of millions of smallholder farmers. This category of farmers often lacks the knowledge, tools, technologies, management practices, or financial resources to recognize and respond to new pest species such as FAW sustainably. Consequently, emergency responses towards this pest have largely involved the use of highly toxic chemical insecticides, which predisposes farmers to health hazards, poses negative impacts on beneficial insects and could lead to pesticide resistance if used inappropriately. Reliance on pesticides is often associated with the lack of suitable cost-effective alternative pest management options. Besides, smallholders often lack knowledge of pest identification, monitoring, and early detection and therefore resort to harmful pesticides as a curative measure once the pest occurs. Given the variation in rainfall patterns, cropping seasons, and planting dates within and between countries in the East and Southern Africa regions, there is a possibility of year-round breeding and FAW invasion. Therefore, more sustainable management methods are urgently needed if this pest is to be managed in every cropping cycle.

CAB International has been at the forefront of developing and promoting lower-risk integrated pest management (IPM) options for FAW in both these regions. These methods have included exploration for native natural enemies for FAW and their use in augmentative programmes, testing different intercropping systems, manipulating planting dates to avert the impact of peak FAW infestations and maximize the parasitoid efficacy in the maize agroecology, novel biopesticides such as *Metarhizium rileyi*, testing a formulation of native entomopathogenic nematode found to be highly efficient

under natural conditions, and developing a locally produced farmer biopesticide based on *Spodoptera frugiperda* nucleopolyhedro virus (SfNPV).

This presentation will provide an update on CAB International's work on testing the effectiveness and deployment of these FAW IPM tools in East and Southern Africa and propose questions for further research and validation over the wide range of cropping systems and environments where the pest is prevalent. Overall, the cost for nature-based solutions for FAW is still high and research towards reducing costs and increasing availability is critical. The compatibility of the different methods needs to be understood better to design an appropriate IPM strategy for the farmer.

6.2 Fall armyworm integrated pest management in China

Mr Zhenying Wang
Institute of Plant Protection, Chinese Academy of Agricultural Sciences (IPP-CAAS), China

The fall armyworm (*Spodoptera frugiperda [J.E. Smith]*) (FAW) is native to the tropical and subtropical regions in the Americas. It has been one of the most important insect pests of corn and is another migratory pest that migrates north in spring and back south in autumn. It mainly infests corn, as well as another 22 crops as host plants. Infested acreage is well over 1 million ha in 22 provinces since FAW invaded China in January of 2019.

Strategies for FAW management include using different control measures at regional level, including physical control, biological control with biopesticides and natural enemies. Chemical control is also applied when the FAW population is high, or damage is very serious. Several integration and demonstration models for FAW management have been put into use in different corn-growing regions.

FAW occurrence is mainly limited to the southwestern hilly corn region and south hilly corn regions, and annual occurrence includes 0.2 percent occurrence in Huang-Huai-Hai summer corn regions and north spring corn regions, the main corn production regions. FAW is limited by focusing on pest management in its year-round breeding region. It is estimated by field yield measurement that the annual yield loss of corn was reduced by 5 billion kg to 6 billion kg through FAW management. This also significantly alleviated ear and kernel rot and mycotoxin pollution caused by FAW injury, only 4 mg of fumonisin and aflatoxin per kg of corn grain in the FAW control plot, which was 87.9 percent less than 33 mg in an uncontrolled plot in China.

Since 2021, the Ministry of Agriculture and Rural Affairs (MARA) of China has been promoting the pilot work of industrial application of genetically modified corn and soybean. *Bacillus thuringiensis* (Bt) corn will be commercialized in the next several years to manage FAW and other lepidopteran insect pests of corn in China.

6.3 New technologies tested against fall armyworm in the Central Africa geozone

Mr Maurice Tindo
University of Douala, Cameroon

Testing new technologies is one major component of the regional integrated FAW management strategy developed and validated for the Central Africa geozone. Here we summarize some activities conducted and results obtained in Cameroon.

Aqueous extract of fruit or leaves of seven plant species (*Capsicum frutescens, Chromolaena odorata, Hyptis suaveolens, Pteridium aquilinum, Thevetia peruviana, Tithonia diversifolia and Vernonia amigdalina*) were evaluated against FAW starting from the laboratory till the maize field in three agroecologies. Sugar cane juice was also applied on maize plants to attract more natural enemies. Four local plant species, including two poaceae (*Panicum maximum and Penisetum purpureum*) and two abaceae (*Calpogonium sp, Arachis hypogea*), were evaluated for their potential as pull and push respectively. Both in the laboratory and in the field, the randomized complete block design (RCBD) with three or four replicates was used and treatments included plant species, sugar cane juice and two checks (a positive control using a chemical insecticide and a negative control using water). Aqueous extract was obtained by pounding 500 g of fresh leaves or fruit in a mortar. Ten liters of water were added to the resulting paste and left overnight in a container. Then, the content was filtered, and the resulting mixture kept as a stock solution.

FAW collected in the field were reared in the laboratory on ricin leaves until adult emergence. A couple of adults were formed and allowed to lay eggs on folded paper in rearing cages. Caterpillars that emerged from these egg masses were maintained on ricin leaves until adult emergence and the rearing cycle repeated. Third instar larvae from the third generation in the laboratory were used for the experiment. Three concentrations of the extract were prepared from the stock solution and applied directly on larvae, or a portion of ricin leaves were soaked in the solution before feeding this to the larvae placed in petri dish. The mortality was recorded at 24h, 48h and 72h.

Maize fields were established following the cultural calendar of each ecozone. Varieties were selected according to their suitability for agroecology. Organic fertilizer was applied before sowing and mineral fertilizer at three weeks after planting (WAP) and at flowering. Aqueous extract was applied twice: first, when 10 percent of plants showed signs of attack and second, after one week. For the push-pull trial, A. hypogea or *Calpogomium sp*. were planted as a band between maize rows. *Panicum maximum* or *Pennisetum purpureum* were transplanted in two rows at the border of each plot. Starting from the third week after planting, the incidence, the severity of attack, the number of egg masses, the number of larvae per plant were recorded every two weeks.

As results in the laboratory showed, the extraction of all the plant species significantly affects the survival of the FAW and the contact method was more effective than ingestion, depending on the concentration. In the field, their effect on the FAW infestation was not clear since their application did not reduce considerably the incidence of attack, the severity, the number of egg masses and the number of FAW in the fields. The sugar cane

juice attracted more natural enemies on the plant but their effect on the infestation and on the yield was not obvious. The association of a. maximum as pull, and *Calpogonium sp*. as push, significantly reduced the incidence, the severity of attack, the number of egg masses, and the number of larvae per plant even though this was not translated into yield increase.

In conclusion, aqueous extract of the evaluated plant species showed an impact on the mortality of FAW in the laboratory, but a lot of work is still needed to improve the method of their application in the field. *Panicum maximum and Calpogonium sp*. show potential in push-pull technology.

6.4 Fall armyworm situation and management strategies in Viet Nam

Mr Hoang Anh Tuan
Ministry of Agriculture and Rural Development Plant Protection Department (MARD PPD), Viet Nam

Native to the Americas, the fall armyworm (*Spodoptera frugiperda*) (FAW) was first officially detected in Viet Nam in early 2019. By year end, it had spread to 58 of Viet Nam's 63 provinces. In Viet Nam, there are two FAW strains: one primarily feeding on maize and the other on rice. Despite the broad feeding capability of FAW across 80 different plant species, regardless of strain, the biotype introduced into Africa and Asia appears to feed almost exclusively on maize and sorghum and is only found intermittently on other crops, generally during initial outbreaks. Maize is an important crop in Viet Nam, primarily used for animal feed. It is a crucial cash crop for low-resource farmers, and losses due to FAW can have a disproportionate effect on this group of farmers.

In response to the FAW invasion, a collaborative effort was initiated, involving diverse stakeholders. These stakeholders included the Viet Nam Ministry of Agriculture and Rural Development Plant Protection Division (MARD PPD), Viet Nam Plant Protection Research Institute (PPRI), Viet Nam National University of Agriculture (VNUA), Food and Agriculture Organization of the United Nations (FAO), the Association of Southeast Asian Nations (ASEAN), and other institutions. These stakeholders collectively introduced a series of technical guides, regional training meetings, and onsite training seminars. These initiatives were targeted at farmers and agriculture extension officers, aiming to implement integrated pest management (IPM) programmes for effective control of FAW.

This presentation sheds light on the multifaceted strategies employed to manage FAW in Viet Nam, focusing on regionalization management strategies and various control measures. By presenting these strategies and successful implementation models, this conference aims to disseminate valuable insights and best practices in FAW management, emphasizing the importance of collaboration and holistic approaches in mitigating the impact of this invasive pest on crucial agricultural crops in Viet Nam. The goal is to protect the livelihoods of farmers and secure the food supply chain from the destructive influence of FAW.

6.5 Fall armyworm integrated pest management in North America

Mr Carlos Blanco
United States Department of Agriculture (USDA), United States of America

In North America, integrated pest management (IPM) programmes for maize are uncommon. The fall armyworm (FAW) occurs sporadically in Canada and the United States of America, but in Mexico it is the main pest, where growers unnecessarily spray two to three times against it, delivering more than 3 000 tons of insecticide active ingredient into seven million maize hectares each year. In Canada and the United States, corn pests, including FAW, are effectively controlled with genetically engineered (GE) maize that produces several *Bacillus thuringiensis* (Bt) proteins. However, in Mexico, GE maize has not been approved. Over 95 percent of maize in the first two countries is planted with GE cultivars, while in Mexico some of the maize imported from the United States is also planted, becoming a source of transgenes for landraces, but not for hybrids due to their breeding management. Half of the offspring of GE maize express Bt proteins, and currently in Mexico less than 50 percent of the landraces produce them.

IPM components include antibiosis, which is currently employed in Canada and the United States by planting GE cultivars, and planting dates to reduce the pressure of FAW, or any other maize pest, are uncommon. Growers seed maize following abiotic cues, but in Mexico planting dates also depend on access to irrigation. Young maize plants are rarely affected by FAW in Canada and the United States, where they get protection by the expression of Bt proteins. In Mexico, crop consultants recommend the unfounded 20 percent damaged plants as an action threshold, increasing production costs and pressure on the environment. Pheromones are rarely used in North America as a decision-making tool, and crop consultants determine the appropriate action threshold against FAW, saving the grower about USD 20 per hectare from purchasing FAW lures. Biological control of FAW in North America regularly has an effective range of 0.5-25 percent parasitized larvae, and although in some cases parasitoids may be important, unparasitized larvae often exceed the 20 percent 'weakly supported' threshold in Mexico.

On the promising side, coating maize seeds with fungal, bacterial, or chemical insecticides is an effective and feasible technology to prevent FAW damage in early maize. Coating techniques vary from highly sophisticated to 'do-it-yourself' methods. Minute amounts of fungal, bacterial, or chemical insecticide covering seeds may prevent a FAW attack for the first three weeks, the period when growers routinely spray against FAW in Mexico, and elsewhere. More education is necessary to curtail the unnecessary insecticide sprays against FAW in young maize. That would save growers money, drudgery, and reduce environmental impacts.

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7. FARMERS AND EXTENSION

7.1 Large-scale dissemination of fall armyworm integrated pest management information to farmers and extension officers in China

Mr Jie Liu
National Agro-tech Extension and Service Center (NATESC), China

Since its invasion in 2019, fall armyworm (FAW) has caused serious corn yield loss and mycotoxin pollution in 27 provinces across the country, causing national concern. To minimize the damage of FAW to China's corn industry and ensure China's food safety, we established a monitoring and early warning technology system, which is mainly based on pheromone monitoring and supplemented by high altitude warning lights and insect radar. We also built a comprehensive prevention and control technology model integrating ecological regulation, physical and chemical trapping, biological control and scientific pesticide use. The integrated pest management (IPM) technology extension work has been conducted by uniting the national plant protection and technology extension system with scientific research institutes. Our work has been carried out in accordance with the guiding principles of 'comprehensive monitoring, regional policy, joint prevention and control'. At the same time, monitoring equipment, prevention and control technology and supporting policies are gradually landing, according to the technical extension idea of 'point to surface, step by step expansion'.

Besides applying intelligent devices, big data algorithms and other technologies, intelligent monitoring and migration trajectory tracking has been established in key areas, facilitating inter-regional cooperation on FAW prevention and control. Region-specific technical plans have been distributed to all extension officers as basic guidance every year. With technical equipment all over the country and regional coordinated action plans, China's three-zone, and four-band control pattern of FAW has been formed. IPM strategies and technical plans for FAW prevention and control are propagated through cooperation between agricultural technology extension departments at all levels, new farming entities, specialized service organizations and new media, helping to carry out integrated prevention and control technology promotion work in ecological regions of the country.

In accordance with the integrated FAW prevention and control plan, we have also carried out Farmer Field Schools (FFS) with extensive and practical courses in the southern corn producing areas and the annual breeding area of FAW. So far, the training of trainers (ToT) and FFS have been held in different parts of Yunnan and

Guangxi provinces. Local farmers on the front line have been familiarized with the green prevention and control concepts and comprehensive prevention and control technology, thus building a strong wall of FAW prevention and control. Now, we annually hold IPM technical training courses at the national, provincial, and county levels, comprising five national training courses, 60 provincial training courses and 2 000 county training courses per year, covering more than 10 000 technical officials and more than 200 000 farmers.

Technical guidance and spring, summer, and autumn FAW forecasts have been widely publicized and promoted through WeChat, TV, radio, white papers, video, and other means, reaching more than one million people. Through IPM technical training and promotion on the national scale, farmers' prevention and control methods have changed significantly. We recommend that farmers implement different control measures, according to the occurrence of FAW, giving priority to biological control measures, and solely promoting scientifically underpinned pesticide use under outbreak scenarios while rotating different active ingredients between regions. Through large-scale extension campaigns, farmers reduced chemical pesticide use three- to four-fold, saved about CNY 750 per hectare, increased production by 1 500 kg, and increased benefits by CNY 2 250.

In the future, we hope to tighten research cooperation with neighbouring countries to further explore the FAW migration trajectory, and prevention and control technology research.

7.2 Understanding small-scale farmers' management of fall armyworm

Ms Salma Akter
Sher-e-Bangla Agricultural University, Bangladesh

The fall armyworm (*Spodoptera frugiperda*) (FAW) poses an imminent threat to the cultivation of maize, the second most important cereal crop in Bangladesh. After being identified in late 2018 in two northern districts of Bangladesh, this invasive pest had spread over 35 districts by 2023. In addition, infestation of the pest has been escalating beyond maize, as reported in at least four other crops – cabbage, ginger, tobacco, and tomatoes. This warrants immediate and proper management of the insect at farm level, especially for small farmers who represent lion's share of maize farming in the country.

This study shows that small farmers, having less than 1 ha of land, are largely dependent on about 26 synthetic pesticides to fight FAW – with the most common being nitro 505 EC (a mixture of 50 percent chlorpyrifos and 5 percent cypermethrin) and Tracer 45 EC spinosad). It may be noted that chlorpyrifos is categorized as a Class II pesticide which is moderately hazardous. On the other hand, although the World Health Organization (WHO) classified spinosad as Class III (slightly harmful), it has been shown to reduce the abundance of hymenopteran parasitoids. Pesticide alternatives could include biological control by natural enemies. Research has shown that mass rearing and

inundation of natural enemies are likely to be better options and efficient methods of controlling FAW. However, the high cost of mass rearing is a constraint for small maize producers in Bangladesh.

In this context, the Bangladesh Wheat and Maize Research Institute (BWMRI) and Bangladesh Agricultural Research Institute (BARI) are closely collaborating with biological control approaches, particularly on push-pull and intercropping. It has concluded that steps are to be directed on establishment of suitable habitats in agroecosystems to enhance natural enemies and repel FAW to lessen the usage of harmful pesticides.

7.3 Innovative technologies for farm advisories with some examples in fall armyworm management

Ms Hongmei Li
CAB International

Most of the world's farmers are smallholders, who produce one-third to one-half of the world's food and play an important role in global food security. However, some of them are extremely poor with low levels of literacy. Their incomes and livelihoods greatly rely on the production of staple foods such as maize. Maize is one of the most significant food crops in sub-Saharan Africa, Latin America, and Asia, providing at least 30 percent of the food calories to more than 4.5 billion people in 94 developing countries. Fall armyworm (*Spodoptera frugiperda*) (FAW) is a highly polyphagous migratory lepidopteran pest species of tropical-subtropical origin in the western hemisphere. FAW has invaded several African, Asian, and Oceania countries, and has become a major global threat to maize production since it first invaded Africa in 2016. FAW attacks maize at virtually every developmental stage. A CAB International study showed that in just 12 of Africa's maize-cultivating countries, FAW can cause 8.3 to 20.6 Tg maize yield losses per year (worth USD 2.5 to 6.2 billion) in the absence of any control measures.

Emerging digital technologies present an opportunity to improve access to immediate, accurate and actionable information on how to mitigate, identify and combat FAW under different circumstances for smallholder famers. Digital technologies can be utilized in expanding the frontiers of information access at every level of society. CAB International-led Pest Risk Information Service (PRISE) drew upon data from a variety of sources – satellite observations, weather data, geographic data, and details about the biology of pests – to advise on the best time to act against a pest in any given place. A PlantwisePlus Toolkit has been developed to help identify tried and trusted digital tools that are designed to assist crop production by supporting decision-making. For instance, a crop sprayer app aims to help smallholder farmers calculate how much pesticide to use when treating their crops and protecting them from pests and diseases. The CAB International BioProtection Portal can be used alongside the crop sprayer app

as it provides up-to-date information to identify, source and apply registered microbial biopesticide products in each country, thereby supporting the rational application of these nature-based pest management solutions. This toolkit has been downloaded and used free of charge via Google Play Store.

For the future, successful implementation of the innovation technology against FAW globally relies on the following: increase the adoption of digital tools through implementation of tailor-made training programmes on application of digital tools and adaptation to local conditions, initiate a strategy to enhance communication, coordination and information sharing among all the stakeholders, including smallholder farmers, food suppliers, consumers, policymakers, as well as researchers, fully support the implementation of effective innovative technologies by local government, technology providers and smallholder farmers with sufficient financial support. Finally, public-private partnerships would be a potential funding mechanism to support scale-up and scale-out of the technologies.

7.4 Harnessing youth creativity and energy to scale up sustainable fall armyworm management solutions

Ms Brenda Cheptoo
Dream Team agroconsultancy, Kenya

The fall armyworm (*Spodoptera frugiperda*) (FAW) is now considered the leading insect pest of maize and other crops in Africa and Asia. The pest causes significant yield losses and therefore destabilizes food security. Several management strategies, such as the use of chemicals, have been used to control this pest. However, concerns about health and environment in the use of chemicals have been raised. This necessitated the research on other methods that protect the environment and safeguard human health, such as integrated pest management (IPM). One of the IPM strategies that has been recommended is the use of parasitoids to manage the population of the pest. However, farmers and extension officers have not been able to implement these cost-effective practices due to inadequate knowledge or awareness of available parasitoids.

To help in dissemination of the information, PlantVillage Dream Team came up with an initiative that targets the youths who play a pivotal role in promoting the scaling-up of these sustainable practices. The team has created a chain of different stakeholders that include the research organizations, commercial producers of the parasitoids, extension officers and the youths who spearhead the adoption of these parasitoids in their community. These youths are often creative and innovative, likely to be tech-savvy and able to use social media and other digital tools and therefore, involving them could help in spreading the awareness of FAW control strategies. Through the help of the PlantVillage Dream Team, these youths have successfully participated in farmer training programmes, field releases of parasitoids, and the development of new pest control

technologies that have been of great benefit to the farmers. However, some challenges have been encountered in the process, including limited access to resources, training equipment and facilities used in FAW management, and the negative perceptions about young people as being inexperienced or incapable of contributing to serious issues like FAW management. To address such challenges, raising awareness of FAW among young people, providing them with access to resources and training, and creating opportunities for them to participate in FAW management efforts is appropriate.

The objective of this paper is, therefore, to explore the potential for harnessing youth creativity and energy to scale-up sustainable FAW management. The paper presents several successful youth-led initiatives to address FAW, such as farmer training programmes, field releases of parasitoids, and the development of new pest control technologies. It also highlights the challenges and opportunities associated with harnessing youth creativity and energy to address FAW and provides recommendations on how to support and scale up youth-led initiatives. Different stakeholders such as funding institutions should come in and support in addressing these challenges by developing satellite laboratories that promote training and rearing of the parasitoids, provide training gadgets that can be used in monitoring and scouting of the pests, and strengthen the existing team to promote awareness on the use of parasitoids. This is expected to boost food productivity using safe and cost-effective parasitoids among resource poor farmers.

7.5 Farmer Field Schools as a way to co-create sustainable solutions for fall armyworm management

Mr Touhidul Alam
Bangladesh Resource Centre for Indigenous Knowledge (BARCIK), Bangladesh

The fall armyworm (*Spodoptera frugiperda*) (FAW) was first reported in Bangladesh in November 2018 and, subsequently, it spread to 22 districts by May 2019. Over that period, the FAW attack rapidly spread throughout the country, inflicting severe damage to crops, especially potato, brinjal (eggplant) and other crops in Bangladesh. Effective and sustainable management of FAW requires a multidimensional approach involving farmers as key stakeholders. In Bangladesh, Farmer Field School (FFS) as a participatory and empowering platform could co-create sustainable solutions for FAW management effectively. FFS provides a unique educational space for farmers to gain knowledge, develop skills, and conduct hands-on experiments, leading to the co-creation of contextually relevant and sustainable integrated pest management (IPM) strategies.

The FFS approach utilizes participatory learning methodologies, emphasizing practical training, experimentation, and critical thinking. Active involvement of farmers ensures a comprehensive understanding of FAW biology, behaviour, natural predators, cultural practices, and ecological dynamics. The process facilitates farmer-driven adaptations and the application of strategies based on their local circumstances, cultivating a sense

of ownership and responsibility in pest management. Combining scientific knowledge with new insights from FFS sessions can foster the co-creation of sustainable, context-specific FAW management solutions.

In addition, FFS encourages knowledge sharing among farmers and establishes a robust network for information exchange and mutual learning. By promoting local expertise, the approach encourages collective problem-solving and innovation within the farming community. Farmers can collaboratively identify cost-effective, eco-friendly alternatives to synthetic pesticides, reducing reliance on potentially harmful chemicals while promoting sustainable pest management practices.

As sustainability is a core principle of FFS in FAW management, and by focusing on ecological and economic sustainability, the approach advocates for holistic solutions such as crop diversification, intercropping, and the use of biological control agents, which are important to manage FAW. The knowledge acquired through FFS empowers farmers to make informed decisions aligned with their ecological and economic goals, contributing to not only managing FAW but also the overall sustainability of their farming practices.

The Bangladesh Resource Centre for Indigenous Knowledge – a national non-government development organization – has been facilitating field learning sites (FLS) inspired by FFS in promoting agroecology through hands-on training, participatory and experimental learning, and on-farm action research. FLS typically covers a range of agricultural topics, such as crop management, pest and disease management through indigenous practices, ancestral knowledge, homemade bio-pesticides, soil conservation, and water management by bridging traditional wisdom with modern scientific practices. It has been playing a pivotal role in managing pests, including FAW, through ecological means.

In conclusion, FFS has ample scope and can create a promising avenue for co-creating sustainable solutions for FAW management. By involving farmers as active learners and participants, the approach can promote sustainable agricultural practices, enhance resilience, and effectively manage the challenges posed by FAW. The inclusive and participatory nature of FFS can cultivate innovation, local empowerment, and the sustainable co-creation of solutions for this pervasive pest, that ultimately ensures long-term food security.

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8. ENABLING ENVIRONMENTS

8.1 Leveraging regional networks to manage invasive pests

Mr Saliou Niassy
African Union Inter-African Phytosanitary Council (AU-IAPSC)

The fall armyworm (*Spodoptera frugiperda*) (FAW) was reported in 2016 and caused panic among farmers, policymakers, and development partners. It was unexpected and highly devastating, and because there was no monitoring effort, it was a serious threat to food security. It was nearly a war declaration, and most countries revived their task forces or Multi-Institutional Technical Teams (MITT). Yield loss was worth USD 9.4 billion per year in Africa, the highest among all invasive alien species in the continent.

The African Union Inter-African Phytosanitary Council (AU-IAPSC) was established on the recommendation of the Food and Agriculture Organization of the United Nations (FAO) in 1956 and became part of the Organization of African Unity (OAU) in 1965. Its key role is the harmonization of regulatory and management strategies for emerging plant health and plant pest challenges in the region. In the case of FAW, several technologies were developed with limited uptake across the continent. We therefore suggest a Community of Practice for the establishment and implementation of early warning systems. We propose a mechanism for coordinating pest reporting, sharing information and record keeping among National Plant Protection Organizations (NPPOs). In the context of scarce skills and competence, we propose a mutualization of resources and competencies through meetings and webinars to build the capacity of stakeholders and NPPOs. Africa, in terms of plant health and process, is highly fragmented.

Our strategy should work toward harmonization of policies and protocols for registration and certification of technologies such as biopesticides, introduction and rearing of natural enemies. A regional digital plant health system for awareness creation is crucial for policy engagement and formulation.

8.2 Strengths and gaps in integrated pest management research in the Global South

Mr Kris Wyckhuys
FAW Secretariat, FAO

Pesticide-intensive crop protection gives rise to multiple, pervasive social-environmental externalities. Since the mid-1900s, it has ensured copious supplies of food but also negatively impacted biodiversity, environmental integrity, and human health. Those phenomena are exacerbated in the Global South with low-income countries experiencing a 153 percent increase in pesticide usage intensity over the past decade. To remediate those externalities and advance more sustainable forms of pest management, such as integrated pest management (IPM), science should proceed along proper trajectories within appropriate institutional contexts. Specifically, more holistic, 'systems-centric' pest management has been advocated repeatedly since the 1950s. In this presentation, we present results from a systematic literature review that: 1) assesses to what extent pest management science aligns with the IPM conceptual framework in the newly invaded range of the fall armyworm (FAW), 2) structurally dissects crop protection science in the Global South, as geared towards a broader complement of arthropod pests, and explores opportunities for interdisciplinarity, and 3) examines whether science conducted in those settings is conducted within appropriate institutional contexts.

Following its invasion of Africa and Asia, FAW has received much scientific attention. Yet, until present, FAW pest management science has been inordinately skewed towards pesticide-based approaches, fine-resolution genetics or basic biology and physiology, while agroecological or biodiversity-based preventative measures have received anemic degrees of attention. In biological control science, biodiversity discovery and description have received ample attention, but efforts to harness such biodiversity are lagging. Further, though scientists sporadically seek to replace pesticidal inputs, they rarely pursue opportunities for a 'wholesale' redesign of farming systems to make them more pest resilient.

A systematic analysis of crop protection publications in the Global South further reveals that science is routinely conducted within 'simplified' experimental contexts or so-called microworlds: 48 percent of studies are performed within laboratory confines and 80 percent consider management tactics in an isolated (vs. integrated) fashion. Comparatively few studies investigate trophic interactions across ecosystem compartments, natural biological control, or home into pesticide-intensive crops such as (tropical) fruits and legumes. Scientific inquiry is routinely centred on the pest and the focal plant (or crop) itself, omitting soil, crop management, farm, or landscape layers and (non-pest) companion biota.

Even for mobile, polyphagous herbivores such as FAW, farm- and landscape-strata are only considered in 3 to 8 percent of field studies. The social strata of a farming system are routinely disregarded, which may hamper efforts to capitalize on the sizable research progress in non-chemical preventative management. Thus, as pest- or crop-

centric approaches, curative solutions and reductionism prevail, science is prone to fit-and-conform to the dominant farming model. A scientific overhaul is therefore needed if one aims to achieve transformative change of agrifood production systems.

Institutional context strongly modulates the above nature of inquiry and conceptual basis of pest management science. A wide set of countries and institutions across the Global South engages in scientific knowledge production, with nations such as Benin, Indonesia, Mexico or Türkiye generating vast amounts of knowledge. Conversely, 42 percent of countries generate less than one paper per year. Inter-country cooperation is extensive in Latin America and Africa, where countries such as Brazil or Kenya engage extensively in transnational cooperation.

Besides domestic entities, foreign (western) academia and research centres are prominent contributors to pest management science. Involvement of development partners such as CAB International, International Centre of Insect Physiology and Ecology (*icipe*) or Consultative Group of International Agricultural Research (CGIAR) offers a real yet marginal advantage in terms of holistic system-centric research and does not necessarily alter the pursuit of single-factor solutions or so-called techno-fixes. While transnational institutions such as the CGIAR represent a comparative advantage in host plant resistance, they appear ill-equipped to harness a broader bundle of ecosystem services, e.g., biological pest control for sustainability. This, ideally, is to be remediated through institutional reform.

By integrating system complexity, fortifying the contribution of agroecology or plant, animal biodiversity, and seeking to bolster agroecosystem resilience, more sustainable trajectories can be traced for farming in the Global South. Given the fast-expanding environmental footprint of agrifood production, this is long overdue.

8.3 Public-private partnership for co-development and scaling of microbial biopesticides against fall armyworm in China

Mr Yuxian Xia
Chongqing University, China

Development of microbial biopesticides is regarded as part of a sustainable agriculture strategy. In recent years, the Chinese Government has provided preferential policies to encourage universities, research institutions and enterprises to develop and use biopesticides.

During the very early stage of fall armyworm (*Spodoptera frugiperda*) (FAW) invasion, five microbial biopesticides were recommended for emergency prevention and treatment of FAW by the Ministry of Agriculture and Rural Affairs (MARA) in June 2019, and universities, research institutions and enterprises were organized to co-develop microbial biopesticides for FAW in national key research and development projects.

Four microbial biopesticides for FAW were registered in four enterprises in 2020, and 19 microbial biopesticide products had been registered by 2023.

Mass production systems for viral, bacterial and fungal pesticides have been established, and FAW control technologies have been developed using either microbial biopesticides only or mixing them with a small dose of chemicals. Development involved the joint efforts of national and provincial branches of the National Agro-tech Extension and Service Center (NATESC), universities, research institutions and enterprises. In large-scale applications, the FAW control technologies are as effective as a full dose of chemical pesticides.

As microbial biopesticides, such as fungal biopesticides, can overcome pest resistance and counteract FAW epidemics, their wide application is conducive to reducing the amount, and the market life, of chemical pesticides. Results demonstrate that microbial pesticides are indispensable for green prevention and control of FAW and other insect pests.

8.4 Phytosanitary capacity evaluation and management of emerging pests: A case study from Kenya

Mr Isaac Macharia
Kenya Plant Health Inspectorate Service (KEPHIS), Kenya

Preventing introduction, and management, of regulated pests is an important role of National Plant Protection Organizations (NPPOs). To ensure NPPOs have appropriate capacity, the International Plant Protection Convention (IPPC) Secretariat maintains and manages the Phytosanitary Capacity Evaluation (PCE) tool. This is designed to conduct a situational analysis of the existing phytosanitary system of a country, and to help the NPPO assess implementation of phytosanitary measures and IPPC obligations.

Kenya is a beneficiary of the PCE process. The first PCE was conducted back in 2002 with support from the IPPC Secretariat and led to the identification of key weaknesses in the phytosanitary system, especially in diagnostic capacity, pest risk analysis, surveillance, and import and export controls. Through donor funding, most of the gaps identified were addressed. This included review of regulations, digitalization of import and export systems, and as such Kenya migrated from a manual to an online platform. Additional offices and border points were put in place to enhance import and export certification.

To enhance pest diagnostics, a new plant health laboratory was established and equipped, and new diagnostic approaches were adopted. These include a DNA barcoding technique that was used to identify fall armyworm (*Spodoptera frugiperda*) (FAW) in 2017, when it was first reported. Kenya continued to evaluate its phytosanitary capacity where a PCE was conducted with support from the IPPC Secretariat in 2018. The outcome led to further improvement of the phytosanitary system and in 2018, Kenya

embarked on reviewing its plant health legislation and legal framework. The national phytosanitary policy of 2022 was developed and adopted. The plant protection act (CAP 324) was also reviewed, regulation developed, and a new bill proposed.

Through the implementation of the PCE, KEPHIS identified potential partners and collaborators and over the years, there has been collaborations in various activities such as surveillances, PRA, diagnosis, pest management, and capacity building. These activities directly contribute to the efficient prevention of emerging pests.

8.5 Fall armyworm: Lessons for managing future invasive pests

Mr Roger Day
CAB International

The response of countries, regions, and the global plant health community to the invasion of fall armyworm (FAW) provides many lessons, which can inform future management of invasive pests. Some elements of the response went well; others could have gone better. Five lessons are highlighted, which together contribute to an enabling environment for timely and effective response.

Report new pests promptly. Early field reports of armyworm outbreaks were often not followed up or diagnosed promptly. Once FAW was confirmed, many countries never reported to the International Plant Protection Convention (IPPC). Poor reporting of new pests within a country and internationally hampers response.

Get coordinated (quickly). Effective response to an invasive pest requires good coordination, which, for FAW, was established earlier in some countries than others. For a major invasive such as FAW, international coordination is required, but there is currently no established mechanism for rapidly coordinating a global plant pest emergency response. The IPPC's Pest Outbreak Alert and Response System (POARS) could provide this.

Give farmers appropriate advice. Advice to farmers should consider efficacy, safety, sustainability, practicality, availability, and cost-effectiveness of control methods. In the early stages of the invasion, the need to provide advice quickly resulted in recommendations frequently not meeting these criteria.

Maintain regulatory control of pesticides. FAW exacerbated existing problems with the sale and use of unregistered, adulterated, and counterfeit products. More effective use of existing emergency pesticide authorization procedures could help maintain regulatory control during an invasion, although enforcement capacity is often a constraint.

Be prepared. Preparedness helps address all the other areas. National generic contingency plans helped some countries respond to FAW, but such plans are lacking in many countries. No country in Africa had a FAW-specific contingency plan, though elsewhere some countries were able to prepare, having seen what happened in Africa.

Tools to assist with preparedness include IPPC's guidelines on contingency planning, and an emergency preparedness assessment tool being developed by the Food and Agriculture Organization of the United Nations (FAO). Specific contingency plans can be developed based on risk prioritization, and some countries now use pest risk registers. Horizon scanning and monitoring of emerging or changing risks ensures limited resources are used to manage the highest risks.


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9. CLOSING REMARKS

Mr Thaer Yaseen
FAO Regional Office for the Near East (RNE)

It is evident from this three-day symposium that much knowledge has been accumulated on the non-chemical management of pests. However, translating those scientific findings into real world action continues to pose an important stumbling block. Overall, one needs to actively pursue new modalities for invasive pest mitigation, tap the potential of existing or new natural enemies, and engage more extensively in inter-regional collaboration. Three key recommendations can be made on how to scale up more sustainable forms of endemic, invasive pest management.

First, a close collaboration with the private sector may be vital to advancing biological control. In the Near East region, close engagement with the private sector enabled the production of biopesticides with relatively little investment, such as permitting the establishment of two new laboratories to produce *Bacillus thuringiensis* (Bt). These local enterprises create youth employment, alleviate poverty, and reduce emigration. In these efforts, the availability of microcredit can be a game-changer. Equally, even agrochemical companies can become part of the solution and facilitate transformative change towards plant health.

Second, governments could assume an active role in fomenting the transfer of unbiased knowledge. Oftentimes, farmers, consumers, policymakers, and myriad other stakeholders are ill-informed about the broad societal benefits of biological control, or the food safety risks posed by genetically modified crops. This knowledge can help to alleviate societal concern and build further momentum for sustainable pest management.

Third, the socioeconomic impacts of crop pests and their conventional or alternative management need to be measured more extensively. In those endeavors, one ideally should contrast the impact of pesticide-centred curative control versus that of non-chemical pest prevention. A comprehensive assessment of those impacts, and their ensuing communication to farmers or policymakers, undoubtedly will aid the diffusion of biodiversity-based and agroecological practices such as biological control.

Mr Yubak GC
FAO Regional Office for Asia and the Pacific (RAP)

Three key recommendations can be drawn from this global symposium. First, a closer engagement with policymakers potentially could resolve many bottlenecks for sustainable crop protection or plant health. There is indeed a lot of 'know-how' although insufficient 'do-how' on sustainable crop protection. While scientists have made major strides investigating the biological and ecological aspects of pests and pathogens, they often forget to include policymakers. Yet, government actors and policymakers assume a pivotal role in developing more conducive policies for biological control, in alleviating the (often unsurmountable) registration hurdles of biopesticides, or in effectively harnessing emerging technologies such as drones and digitalization for sustainable purposes. Equally, when equipped with sufficient knowledge, policymakers could more effectively promote plant health as a core component of One Health.

Second, how to scale up successful initiatives requires careful thought and concerted action. Though there is often remarkable, encouraging progress at the local level, such progress is rarely replicated at the national, regional, or even inter-regional levels. When aiming to take sustainable pest management practices to scale, lacking personnel or budgetary support for relevant actors potentially poses a key obstacle.

Third, organismal priorities need to be clearly set to establish broad consortia and attain critical momentum on key food security threats at local, national, and regional levels. In the Asia-Pacific region, urgent attention is needed on new or recurrent threats for several food crops. In addition to fall armyworm (FAW), these include *Fusarium TR4* (banana, multicountry), tomato pinworm (tomato, multicountry), cassava lace bug (cassava, eastern Indonesia), rhinoceros beetle (coconut, Pacific) or polyphagous pests such as desert locust.

Mr Jean-Baptiste Bahama
FAO Regional Office for Africa

Over the course of the three-day symposium, it has been very encouraging to see considerable progress on sustainable fall armyworm (FAW) management throughout Africa. Committed research, often performed on a shoestring budget, has resulted in important advances in, for example, the field of biological control. This contrasts with the millions of dollars that many African governments spent purchasing chemical pesticides at the onset of the FAW crisis. Governments stockpiled vast quantities of toxic chemicals, often including highly hazardous pesticides (HHPs), and now often regret those ill-founded decisions. Given that there are ever more frequent incursions of pests and diseases across the African continent, we clearly need to do better.

Equally, to pinpoint invasion pathways and to effectively prevent incursions of new pests and diseases, pest risk assessment (PRA) and pathway analyses need to be used more extensively. As African governments often do not possess the necessary capabilities to perform these kinds of assessments, the Food and Agriculture Organization of the

United Nations (FAO) can step to the fore and play an active role as a network broker, establishing partnerships and collaborations at the regional or global level. This also applies to other areas of invasive pest mitigation: as the necessary expertise on best practices oftentimes already exists in other parts of the globe, we need to actively learn from others.

Lastly, a strong emphasis on women and youth is especially relevant in Africa. Indeed, in Africa, more than 80 percent of farms are small-scale and are oftentimes managed by women. In the meantime, youth are often not attracted by farming and tend to migrate to urban areas. Clearly, a more extensive use of digital technology can make farming an attractive business or career option for youngsters and thus, help to bring new life into the agrifood sector. This evidently can also benefit sustainable pest management.

Mr Jingyuan Xia

Special Advisor to Director-General, FAO; Executive Secretary of the FAW Secretariat, FAO

Extraordinary success has been achieved with this unprecedented Global Symposium on Sustainable Fall Armyworm Management. This event was truly a historical, remarkable, and memorable moment. Its success can be ascribed to four key aspects. First, the excellent organization where a combined top-down and bottom-up development of the entire programme has been involved, including an inspiring visit to the Chinese Academy of Agricultural Sciences (CAAS) gene bank and to its Institute of Plant Protection (IPP). Second, the outstanding service in which everyone felt at home. Third, active engagement where over 200 participants from more than 50 different countries attended the symposium. Lastly, the tangible results on many fronts: key insights were gained on fall armyworm (FAW), more knowledge was generated, new technologies were devised, for example, on biological control. This was only made possible through strong partnerships between and among national partners and international development cooperators.

Several key lessons can be drawn from the Global Action on Fall Armyworm Control (GA). Firstly, cutting-edge work using advanced modeling or radar monitoring in China or Japan has shown that FAW population dynamics are predictable. Secondly, FAW outbreaks are controllable, and its management can be entirely sustainable. Thirdly, strong coordination through multistakeholder engagement is key for success. Fourthly, the development and implementation of localized control strategies is a critical factor of success. Four key principles for sustainable invasive pest management could be drawn from the effective responses in Malawi: community-based monitoring, threshold-based control, nature-based solutions, and Farmer Field School (FFS)-based technology transfer.

Looking ahead, several key lessons can be drawn from the global symposium. When deploying global mitigation programmes for invasive pest threats, sufficient human and budgetary resources and a sound enabling environment are *condicio sine qua non*. Oftentimes, for new or emerging threats, advanced, feasible and practical management technologies are initially lacking – as a result, governments routinely resort to an extensive use of chemical pesticides. Government-level action is also often

contradictory. While many governments openly call for a broader use of biopesticides, biological control agents or ecologically based integrated pest management (IPM), they gave pesticides away at the onset of the FAW crisis and continue to make biopesticide registration procedures overly cumbersome.

Ideally, when the next invasive species problem presents itself, several sustainable mechanisms could be in place. This entails: 1) a transfer from emergent control to sustainable long-term management, 2) a shift in emphasis from one single pest in a given crop to multiple pests in an entire system, and a resolute transition from plant protection to plant health management. The latter comprises multiple components e.g., seed health, soil health and pollinator health, and calls for a more holistic 'systems approach'. In this regard, the 16 calls to action that were developed over the course of the three-day global symposium should be our guiding compass for the future.

Upon return to their respective home bases, all participants and speakers are encouraged to take follow-up action. Make a report to your colleagues, inform your institute's director, and share your personal impressions or perceptions by email with the FAW Secretariat. Everyone is encouraged to spread the word on FAW biological control and sustainable pest management and become a true plant health champion within your own respective work environments, communities or countries.


FAO Global Symposium on S
Fall Armyworm Managemen
全球草地贪夜蛾可持续防控研讨会
Char global response to future invasive pest
FAO Global Symposium on Sustainable
Fall Armyworm Management
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10. CALL TO ACTION

From 31 October to 2 November 2023, the Food and Agriculture Organization of the United Nations (FAO)'s Plant Production and Protection Division (NSP), the Chinese Academy of Agricultural Sciences (CAAS) and the National Agro-tech Extension and Service Centre (NATESC) of China's Ministry of Agriculture and Rural Affairs (MARA) co-organized the Global Symposium on Sustainable Fall Armyworm Management in Beijing, China. The global symposium attracted strong interest from national and international partners and covered a wide range of inspiring presentations and stimulating discussions on various themes.

To build upon the accomplishments of FAO's Global Action on Fall Armyworm Control (GA) and to gather further global momentum towards effective, sustainable invasive pest management and – more broadly – plant health management, the global organizing committee of this symposium proposed several action-oriented recommendations in the seven core thematic areas for a guideline of invasive plant pest management in future. These recommendations directly sprout from the content of individual presentations and discussions over the course of the three-day symposium and were refined with inputs from all symposium participants. As a result, the following 16 calls to action are put forward:

1. Prepare for emerging and future biological invasions by strengthening national capacities and regional collaboration in performing horizon scanning, conducting pest risk analysis and pathway analysis, and devising generic contingency plans in close collaboration with the International Plant Protection Convention (IPPC).
2. Prevent and/or rapidly respond to new incursions of invasive pests by fortifying existing national or regional task forces, by incentivizing rapid, accurate reporting and by leveraging high-quality support in scientific, technical, managerial and communication aspects of pest detection, containment, and control, including strengthening diagnostics and surveillance capacities at national and regional levels.
3. Facilitate collection of critical data for decision-making in pest management by accelerating the development and roll-out of cost-effective and context-appropriate tools and strategies for monitoring pest populations at field and landscape levels. This includes the use of statistically-sound field scouting tools and mobile apps, 'smart' traps utilizing volatile and other cues, as well as remote sensing technologies.
4. Anticipate near-future fluctuations and movements of pest populations and inform decision-making in pest management by strengthening capacities to conduct national or regional level forecasting by utilizing monitoring data, considering weather and cropping patterns, natural enemy dynamics, seasonal movement, and other outbreak determinants.
5. Support the capacities for innovation, research, and development at the country level by mobilizing resources and incentivizing both laboratory- and field-level research at national research institutions and universities on the biology, ecology, host

plant-pest dynamics, and seasonal movement of endemic and emerging invasive pests with an aim to effectively harness this knowledge for sustainable pest management.

6. Improve the regional and global cross-pollination of ideas by weaving research networks to rigorously assess the host plant-pest relationships, natural enemy communities, and socioeconomic impacts of invasive pests, leveraging regional and global centres of excellence (for example, the Consultative Group of International Agricultural Research [CGIAR], International Centre of Insect Physiology and Ecology [*icipe*], CAB International [CABI], regional universities) as coordination hubs.

7. Harness best expertise worldwide to summarize the global knowledge on integrated pest management (IPM) for emerging invasive pests, including local and indigenous knowledge, to be further validated, refined and deployed at the national and regional level. In this regard, various tactics need to be considered in an integrated and holistic manner as a part of the IPM toolbox, including host plant resistance, cultural practices, intercropping and push-pull, conservation and augmentation biological control. Furthermore, the use of low-risk chemical pesticides must be viewed as a measure of last resort and guided by locally contextualized economic action thresholds.

8. Embed recommendations in rigorously evaluated outcomes of various combinations of eco-friendly IPM tactics along multiple dimensions such as efficacy, productivity, profitability, farmer and consumer safety, sustainability, energy use, environmental footprint, and scalability.

9. Enhance the capacities of smallholder farmers to serve as co-innovators of IPM solutions and early adopters of innovative techniques through participatory approaches such as Farmer Field Schools (FFS) or on-farm research hubs. This should be complemented by continually evolving outreach methods such as the use of social and mass media, plant clinics, village awareness meetings, educational videos, and farmer-to-farmer communication.

10. Scale up adoption of innovative and local farmer-centred techniques of plant health management by exploiting both market and non-market-based strategies, including establishment of public-private partnerships to nurture youth-led entrepreneurs in increasing the availability and affordability of IPM solutions at village level. This should also include improving the effectiveness of national extension systems through critical investment, creating strong linkages between national research and extension systems to facilitate formulation, and delivery of science-based farm advisories.

11. Improve cross-sectoral coordination to sustainably manage emerging or future invasive pests, among other things, between the agriculture and disaster management sectors, by strengthening the representation of relevant stakeholders from research, local and national government, extension, and media in national task forces and empowering them through policy and regulatory action.

12. Adopt policies, strategies and regulatory frameworks that incentivize the development, registration, and wide-scale adoption of eco-friendly IPM interventions

and other practices that build long-term ecological resilience in production context, including resistant varieties, arthropod biological control agents and biopesticides.

13. Strengthen critical capacities to develop and adopt innovation in surveillance, diagnostics, monitoring, early warning, and management of invasive pests, as well as innovation in institutional settings, policy, and regulatory instruments. At the same time smallholder farmers should be kept involved as key partners in the process while consciously drawing upon the comparative advantage of national partners e.g., in taxonomy or molecular diagnostics.

14. Improve the socioecological resilience of agrifood systems against present and future invasive pests by strengthening regional and global collaborations and timely information exchange in prevention and preparedness, research and development as well as policy and regulation, engaging both public and private sector partners.

15. Prioritize the needs and harness the entrepreneurial and innovative potential of youth and women in the overall process of detecting, monitoring, and managing emerging and future invasive pests.

16. Pursue a shift from reductionistic pest or crop foci to a more holistic, system-centric plant health focus, by increasing attention to pesticide-intensive food crops e.g., fruits, and place added emphasis on impact and One Health outcomes in the formulation of policies, programmes and projects.

Governments, development partners and all other relevant stakeholders are encouraged to translate the above calls to action into concrete feats under their contexts and scope. FAO encourages wide publication of these calls to action through appropriate electronic and print media, and their incorporation into advocacy materials. FAO also requests feedback from stakeholders on the successes and failures in the implementation of these strategic actions.

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ANNEX 1.
SYMPOSIUM ORGANIZATIONAL BODIES

A. Global organizing committee

Chairperson

Mr Robert Bertram, Chief Scientist, United States Agency for International Development (USAID)

Co-chairperson

Mr Kongming Wu, President, Chinese Academy of Agricultural Sciences (CAAS)

Vice-chairpersons

Mr Jingyuan Xia, Director, Plant Production and Protection Division of FAO (NSP); Special Advisor to FAO Director- General

Mr Prasanna Boddupalli, Director, Global Maize Program, International Maize and Wheat Improvement Center (CIMMYT)

Mr Sevgan Subramanian, Head, Environmental Health Theme, International Centre of Insect Physiology and Ecology (*icipe*)

Ms Frances Williams, Director of Social Sciences, Centre for Agriculture and Bioscience International (CAB International)

Members

Mr Chris Dale, Biosecurity Specialist, Australian Department of Foreign Affairs and Trade (DFAT)

Ms Sarah Brunel, Implementation and facilitation unit lead, International Plant Protection Convention (IPPC), FAO

Mr Saliou Niassy, Coordinator of the African Union Inter-African Phytosanitary Council (AU-IAPSC)/ Head, Technology Transfer Unit, International Centre of Insect Physiology and Ecology (*icipe*)

Mr Rhett Harrison, Scientist, Center for International Forestry Research World Agroforestry Centre (CIFOR-ICRAF)

Mr Carlos Blanco, Scientist, United States Department of Agriculture (USDA)

Mr Zhenying Wang, Professor, Institute of Plant Protection, Chinese Academy of Agricultural Science (IPP-CAAS)

Ms Sheila Willis, Head of International Programmes, Pesticide Action Network UK (PAN UK)

Mr Fuxiang Wang, Deputy Director-General, National Agricultural Technology Extension and Service Center (NATESC), China
Mr Yubak GC, Plant Production and Protection Officer, FAO Regional Office for Asia and the Pacific
Mr Jean-Baptiste Bahama, Plant Production and Protection Officer, FAO Regional Office for Regional Africa
Mr Thaer Yaseen, Plant Production and Protection Officer, FAO Regional Office for the Near East
Mr Yanhui Lu, Director-General, Institute of Plant Protection, Chinese Academy of Agricultural Sciences (IPP-CAAS)
Mr Buyung Hadi, Coordinator, FAW Secretariat, FAO
Mr Ke Jin, Director-General, Department of International Cooperation, Chinese Academy of Agricultural Sciences (DIC-CAAS)
Ms Verena Wilke, FAW Secretariat
Mr Henri Tonnang, Scientist, International Centre of Insect Physiology and Ecology (*icipe*)
Mr Sheikh Ahaduzzaman, FAO Representative ad interim for China
Ms Alia Diyana, Research Officer, Pesticide Action Network Asia Pacific (PANAP)
Ms Valeria Awad, Administrative Support Officer, FAW Secretariat

B. Local organizing committee

Chairperson

Mr Kongming Wu, President, Chinese Academy of Agricultural Sciences (CAAS)

Co-chairperson

Mr Qiwen Wei, Director-General, National Agro-tech Extension and Service Center (NATESC)

Vice-chairpersons

Mr Ke Jin, Director-General, Department of International Cooperation, Chinese Academy of Agricultural Sciences (DIC-CAAS)
Mr Yanhui Lu, Director-General, Institute of Plant Protection, Chinese Academy of Agricultural Sciences (IPP-CAAS)
Mr Fuxiang Wang, Deputy Director-General, National Agro-tech Extension and Service Center (NATESC)

Members

Ms Lin Zhai, Deputy Director-General, Department of International Cooperation, Chinese Academy of Agricultural Sciences (DIC-CAAS)
Ms Juan Zeng, Division Chief, National Agro-tech Extension and Service Center (NATESC)
Mr Jie Zhang, Deputy Director-General, Institute of Plant Protection, Chinese Academy of Agricultural Sciences (IPP-CAAS)

Mr Wende Liu, Assistant Director-General, Institute of Plant Protection, Chinese Academy of Agricultural Sciences (IPP-CAAS)
Mr Wenbo Liu, Deputy Division Chief, Department of International Cooperation, Chinese Academy of Agricultural Sciences (DIC-CAAS)
Ms Yanzhou Qi, Project Officer, Department of International Cooperation, Chinese Academy of Agricultural Sciences (DIC-CAAS)
Mr Jieyin Chen, Division Chief, Institute of Plant Protection, Chinese Academy of Agricultural Sciences (IPP-CAAS)
Ms Fang Tian, Deputy Division Chief, Institute of Plant Protection, Chinese Academy of Agricultural Sciences (IPP-CAAS)
Mr Zhenying Wang, Professor, Institute of Plant Protection, Chinese Academy of Agricultural Sciences (IPP-CAAS)
Mr Qingpo Yang, Agronomist, National Agro-tech Extension and Service Center (NATESC)

C. Secretariat of FAO Global Action on Fall Armyworm Control

Executive Secretary

Mr Jingyuan Xia, Director of Plant Production and Protection Division (NSP), FAO

Deputy Executive Secretary

Mr Chike Mba, Deputy Director of NSP

Coordinator

Mr Buyung Hadi, Agricultural Officer, NSP

Members

Mr Maged ElKahky, Lead of Monitoring and Forecasting, Agricultural Officer, NSP
Ms Anne-Sophie Poisot, Lead of Technology Transfer, Agricultural Officer, NSP
Ms Sarah Brunel, Lead of Phytosanitary Measures, Agricultural Officer, IPPC
Ms Verena Wilke, Programme Support Specialist, NSP
Mr Jean Claude Rwaburindi, Technical Integration, and Technology Transfer Specialist, NSP
Mr Paolo Amici, Programme Support Specialist, NSP
Ms Sandra Cordon, Information Management Specialist, NSP
Mr Kris Wyckhuys, Plant Protection Specialist, NSP
Ms Jianqi Ding, FAMEWS Global Platform Specialist, NSP
Ms Valeria Awad, Administrative Staff, NSP

ANNEX 2.

PROGRAMME OF FAO GLOBAL SYMPOSIUM ON SUSTAINABLE FALL ARMYWORM MANAGEMENT

Theme: Charting a global response to future invasive pests

Empark Grand Hotel, Beijing, China; 31 October-2 November 2023
Co-organized by Chinese Academy of Agricultural Sciences (CAAS)
and National Agro-tech Extension and Service Centre (NATESC)

Day One

Tuesday, 31 October 2023

09:00-10:00

Session 1
Welcome, Opening and Introductory Remarks

Moderator

Mr. Sheikh Ahaduzzaman,
FAO Representative *ad interim*, China

1. **Mr. Kongming Wu**
   President, CAAS
2. **Mr. Robert Bertram**
   Chair, Global Organizing Committee of the Symposium; Chief Scientist, USAID
3. **Ms. Beth Bechdol**
   Deputy Director-General, FAO (Recorded message)
4. **Mr. Jingyuan Xia**
   Executive Secretary of FAW Secretariat; Special Advisor to the Director-General, FAO
5. **Briefing Video of FAO Global Action on FAW control**

10:00-10:30

Group Photo and Tea Break

10:30-12:30

Session 2
Keynote Addresses

Moderator

Mr. Robert Bertram, Chief Scientist, USAID

Five presentations, 15 minutes each (75 minutes in total)

1. *Achievements and impacts of FAO Global Action on FAW Control*
   Mr. Jingyuan Xia, FAO
2. *Plant genetics for FAW management*
   Mr. Prasanna Boddupalli, CIMMYT
3. *Nature-based solutions for FAW management*
   Mr. Sevgan Subramanian, *icipe*
4. *FAW monitoring and management in China*
   Mr. Kongming Wu, CAAS
5. *Impacts of FAO Global Action on FAW control*
   Ms. Frances Williams, CAB International

Panel discussion (45 minutes)

12:30-14:00

Lunch Break

Tuesday, 31 October 2023

14:00-15:30

Session 3
Technical Presentations on Prevention and Preparedness

Chair
Mr. Chris Dale, Department of Foreign Affairs and Trade (DFAT), Australia
Co-chair
Ms. Sarah Brunel, IPPC, FAO

Five presentations, 12 minutes each (60 minutes in total)

1. *Global activities for FAW prevention and preparedness*
   Mr. Chris Dale, DFAT, Australia
2. *FAW prevention and preparedness in NENA*
   Ms. Sameh Benammar, Ministry of Agriculture, Water Resources and Maritime Fisheries, Tunisia
3. *FAW prevention and preparedness in the Pacific*
   Mr. Hemant Nitturkar, FAO Subregional Office for the Pacific Islands
4. *FAW prevention and preparedness in Europe*
   Ms. Mariangela Ciampitti, Regional Phytosanitary Service, Lombardy, Italy
5. *Preparation for the next plant pest invasion*
   Ms. Sarah Brunel, IPPC, FAO

Panel discussion (30 minutes)

15:30-16:00

Tea Break

16:00-17:30

Session 4
Monitoring and Early Warning

Chair
Mr. Henri Tonnang, *icipe*
Co-chair
Mr. Saliou Niassy, AU-IAPSC

Five presentations, 12 minutes each (60 minutes in total)

1. *Comparison of pheromone lures and traps in monitoring FAW*
   Mr. Johnson Nyasani, KALRO, Kenya
2. *Modeling and communication of FAW risks based on FAMEWS data*
   Mr. Henri Tonnang, *icipe*, Kenya
3. *Harnessing data science to improve FAW IPM*
   Mr. Ritter Guimappi, NIBIO, Norway
4. *FAW prediction by using remote sensing*
   Mr. Wenjiang Huang, CAS, China
5. *Population genetics of FAW invasion in Asia*
   Mr. Wee Tek Tay, CSIRO, Australia

Panel discussion (30 minutes)

18:00 – 20:00

Reception at Empark Grand Hotel, Beijing

Day Two

Wednesday, 1 November 2023

09:00-10:30

Session 5
Fall Armyworm Ecology

Chair
Mr. Rhett Harrison, CIFOR-ICRAF

Co-chair
Mr. Yubak GC, FAO Regional Office for Asia and the Pacific (RAP)

Five presentations, 12 minutes each (60 minutes in total)

1. *FAW natural enemies in Africa*
   Ms. Samira Mohamed Faris, *icipe*, Kenya
2. *Insect-host plant interaction: FAW-induced injury and yield loss*
   Mr. Rhett Harrison, CIFOR-ICRAF, Zambia
3. *FAW natural enemies in Central America*
   Mr. Urbano Nava-Camberos, Juarez University of the State of Durango, Mexico (video message)
4. *FAW natural enemies in Asia*
   Ms. Melissa Montecalvo, UPLB, the Philippines
5. *Seasonal movement patterns of FAW in North Asia*
   Mr. Akira Otuka, NARO, Japan

Panel discussion (30 minutes)

10:30-11:00

Tea Break

11:00-12:30

Session 6
IPM for FAW in its Native and Invasion Range

Chair
Mr. Carlos Blanco, USDA

Co-chair
Mr. Zhenying Wang, IPP-CAAS

Five presentations, 12 minutes each (60 minutes in total)

1. *FAW IPM in Eastern and Southern Africa*
   Mr. Ivan Rwomushana, CABI, Kenya
2. *FAW IPM in China*
   Mr. Zhenying Wang, *IPP-CAAS, China*
3. *FAW IPM strategies for Cameroon*
   Mr. Maurice Tindo, University of Douala, Cameroon
4. *FAW IPM strategies in Viet Nam*
   Mr. Hoang Anh Tuan, PPD MARD, Viet Nam
5. *FAW IPM in North America*
   Mr. Carlos Blanco, USDA, USA

Panel discussion (30 minutes)

12:30-14:00

Lunch Break

Wednesday, 1 November 2023

14:00-18:30

Field Visit

Laboratory and facility at IPP-CAAS and Genebank of CAAS

Transportation to and from the hotel will be available

Coordinator

Local organizer

18:30-20:00

Cocktail at Empark Grand Hotel, Beijing

Day Three

Thursday, 2 November 2023

09:00-10:30

Session 7
Farmers and Extension

Chair

Ms. Alia Diyana, PANAP

Co-chair

Mr. Fuxiang Wang, NATESC

Five presentations, 12 minutes each (60 minutes in total)

1. *Large-scale dissemination of FAW IPM information to farmers and extension officers in China*
   Mr. Jie Liu, NATESC, China
2. *Understanding small-scale farmers' management of FAW*
   Ms. Salma Akter, Sher-e-Bangla Agricultural University, Bangladesh
3. *Innovative technologies for farm advisory in FAW management*
   Hongmei Li, CABI, China
4. *Harnessing youth creativity and energy to scale up sustainable FAW management solutions*
   Ms. Brenda Cheptoo, Dream team agro-consultancy, Kenya
5. *Farmer field schools as a way to co-create sustainable solutions for FAW management*
   Mr. Touhidul Alam, BARCIK, Bangladesh

Panel discussion (30 minutes)

10:30-11:00

Tea Break

11:00-12:30

Session 8
Enabling Environment

Five presentations, 12 minutes each (60 minutes in total)

1. *Leveraging regional networks to manage invasive pests: AU-IAPSC example*
   Mr. Saliou Niassy, AU-IAPSC
2. *Strengths and gaps in IPM research in the Global South*
   Mr. Kris Wyckhuys, FAO

3. *Public-private partnership for co-development and scaling of microbial biopesticides against FAW*
   Mr. Yuxian Xia, Chongqing University, China
4. *Phytosanitary capacities as a key factor in mitigating impact of invasive pests*
   Mr. Isaac Macharia, KEPHIS, Kenya
5. *Lessons from the Global South on FAW management to be applied to management of future invasive pests*
   Mr. Roger Day, CABI, UK

Panel discussion (30 minutes)

Fall armyworm (FAW) is a highly destructive, transboundary pest that reduces maize yields by up to 73 percent and inflicts economic losses worth USD 9.4 billion in Africa alone. Since it was first reported in Africa in 2016, this pest has invaded more than 80 countries in Africa, the Near East, Asia and the Pacific, and Europe. FAW jeopardizes sustainable agricultural production, food security and nutrition, the environment and rural livelihoods.

To address these challenges, Director-General Qu Dongyu of the Food and Agriculture Organization of the United Nations (FAO) launched the Global Action on Fall Armyworm Control in 2019 to coordinate efforts while adopting an integrated pest management (IPM) approach.

Achievements, including 300 000 farmers, extension workers and researchers trained on pest monitoring, early warning, and IPM have reduced FAW-related losses. These success were showcased at the FAO Global Symposium on Sustainable Fall Armyworm Management held in Beijing, China, from 31 October to 2 November 2023 and outlined in this document.

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