IWGO

International Working Group on Ostrinia and other maize pests

28th IWGO Conference

2nd to 4th of May 2023

KEPHIS Conference Centre

Nairobi, Kenya

The International Working Group on *Ostrinia* and other Maize Pests (IWGO)
is a Working Group of the International Organization of Biological Control – Global (IOBC - Global)

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SCIENTIFIC PROGRAMME*

28th IWGO Conference

*Please note that only the name of the presenting author is provided in the IOBC Global IWGO scientific programme

SCIENTIFIC PROGRAMME

Monday, 1 May 2023

17:00 ***Registration, Lobby, Hotel Tamarind***

- *Provision of PowerPoint Oral Presentations on USB stick*

19:00 ***Welcome Reception, Hotel Tamarind***

- *Welcome Remarks, Ulli Kuhlmann, IWGO-IOBC-Global Convenor*

Tuesday, 2 May 2023

07:45 ***Registration & Drop-off Point Posters, KEPHIS Conference Centre***

09:00 ***Welcome Addresses – KEPHIS Conference Centre***

- *Welcome Address, KEPHIS*
- *Welcome Address, Vice-President IOBC Afrotropical Regional Section*

09:20 ***Scientific Session 1***

Scientific Session 1: Maize lepidopteran pests and mycotoxins

Session Organizers: Art Schaafsma, University of Guelph, Ridgetown, Ontario, Canada & Gary Munkvold, Iowa State University, Ames, Iowa, USA

09:20	Art Schaafsma	Introduction – Mycotoxins and human health
09:30	Jocelyn Smith	Ear feeding maize pests and mycotoxins in the Great Lakes region of North America
09:50	Gary Munkvold	Contributions of transgenic insect protection to managing mycotoxins in maize
10:10	Nancy Njero	Impact of push–pull cropping system on pest management and occurrence of ear rots and mycotoxin contamination of maize in western Kenya
10:30	Yasmine Farhan	The influence of *Striacosta albicosta* (Smith) management on mycotoxin accumulation in grain corn, *Zea mays* L.

10:50 ***Coffee/Tea Break & Posters***

11:20 ***Scientific Session 2***

Scientific Session 2: New developments in the biological control of fall armyworm

Session Organizers: Marc Kenis, CABI, Delémont, Switzerland & Samira Mohamed, International Centre of Insect Physiology and Ecology – icipe, Nairoibi, Kenya

11:20	Marc Kenis & Samira Mohamed	Introduction
11:30	Michael Hilary Otim	Effect of biopesticides on the abundance and diversity of *Spodoptera frugiperda* (J.E. Smith) natural enemies
11:50	Lakpo Koku Agboyi	Assessment of the effectiveness of some commercial biopesticides against fall armyworm in northern Ghana and their effects on larval parasitism rates
12:10	Diana Kemunto	Potential of rabbit urine in managing fall armyworm (*Spodoptera frugiperda* J.E. Smith)
12:30	Patrick Fallet	A gel formulation of entomopathogenic nematodes to control caterpillars of the fall armyworm, *Spodoptera frugiperda*: an effective, safe and sustainable alternative to chemical insecticides
12:50	Bancy Waithira Waweru	Field efficacy of entomopathogenic nematodes in controlling fall armyworm in comparison to local pest management practices

13:10 ***Lunch Break***

14:10 ***Scientific Session 2 (continued)***

Scientific Session 2: New developments in the biological control of fall armyworm (continued)

Session Organizers: Marc Kenis, CABI, Delémont, Switzerland & Samira Mohamed, International Centre of Insect Physiology and Ecology – icipe, Nairoibi, Kenya

14:10	Samira Mohamed	No enemy free space: The case of alien invasive *Spodoptera frugiperda* in African ecologies
14:30	Marc Kenis	High parasitism on fall armyworm in Africa and Asia. Where do all these parasitoids come from?
14:50	Francis Obala	Effectiveness of generalist native parasitoid, *Cotesia icipe* against *Spodoptera frugiperda* and other key pests in maize agroecosystem
15:10	Patrick Beseh	Biology and host age preference of *Coccygidium luteum* (Hymenoptera: Braconidae): a larval parasitoid of the fall armyworm (*Spodoptera frugiperda*)
15:30	Dirk Babendreier	Augmentative biological control of fall armyworm: how can we make it work?

15:50 ***Coffee/Tea Break***

16:20 ***Scientific Session 3***

Scientific Session 3: Free themes

Session Organizers: Tom Sappington, USDA-ARS, Ames, Iowa, USA & Ulli Kuhlmann, CABI, Delémont, Switzerland

16:20	Tom Sappington & Ulli Kuhlmann	Introduction
16.30	Helena Viric Gasparic	Pesticide residues and ground beetle communities in intensive maize production
16:50	Ricardo Ramirez & Mercy Odemba	Using host plant resistance and drought-tolerance in maize to respond to a dual threat of water-stress and spider mite herbivory
17:10	Mercy Odemba	Weed host interactions with spider mites in Intermountain West corn production
17.30	Sri Ita Tarigan	Microbial biostimulants registered for maize with potential side-effects on its insect pests: A review
17:50	Dominic Reisig	An overview of stink bugs (*Euschistus servus* and *Nezara viridula*) as pests of southern US corn

18:10 ***End of Day 1***

19:00 ***Individual Dinner Arrangements***

Wednesday, 3 May 2023

09:00 ***Scientific Session 4***

Scientific Session 4: Challenges and opportunities for IPM/IRM in a scenario of biological invasions of polyphagous lepidopteran pests

Session Organizers: Silvana Vieira de Paula Moraes, University of Florida, Milton, Florida, USA & Johnnie van den Berg, North-West University, Potchefstroom, South Africa

09:00	Silvana Vieira de Paula Moraes & Johnnie van den Berg	Introduction
09:10	Casper Nyamukondiwa	Geographic dispersion of invasive crop pests: the role of basal, plastic climate stress tolerance and other complimentary traits in the tropics
09:30	Subba Reddy Palli	Development of functional genomics tools to study mechanisms of insecticide resistance in the fall armyworm
09:50	Francis Reay-Jones	Managing fall armyworm with transgenic *Bt* maize in the southeastern United States
10:10	Eliseu Pereira	Managing *Bt* resistance in the fall armyworm: can we better exploit the evolutionary trade-offs of multi-toxin adaptation in IPM programs?
10:30	Emily Bick	Listening to insects: using microphones and deep learning algorithms to monitor corn pests

10:50 ***Coffee/Tea Break***

11:20 ***Scientific Session 4 (continued)***

Scientific Session 4: Challenges and opportunities for IPM/IRM in a scenario of biological invasions of polyphagous lepidopteran pests (continued)

Session Organizers: Silvana Vieira de Paula Moraes, University of Florida, Milton, Florida, USA & Johnnie van den Berg, North-West University, Potchefstroom, South Africa

11:20	Katelyn Kesheimer	Extension as an IPM tool: The Land Grant University program and its role in pest management
11:40	Amanda Hodges	Preparing the new generation of the workforce for the challenges of invasion biology in plant protection

12:00 ***Scientific Session 5***

Scientific Session 5: Host plant resistance to achieve more effective and sustainable control of fall armyworm

Session Organizers: Craig A. Abel, USDA-ARS, Ames, Iowa, USA & Prasanna Boddupalli, International Maize and Wheat Improvement Center, Nairobi, Kenya

12:00	Prasanna Boddupalli & Craig A. Abel	Introduction
12:10	Prasanna Boddupalli	Host plant resistance to fall armyworm in the Tropics: status and prospects
12:30	Craig Abel	Native resistance to leaf feeding fall armyworm discovered in maize population BS39 and partial inbred GEMN-0095

12:50 ***Lunch Break***

14:00 Scientific Session 5 (continued)

Scientific Session 5: Host plant resistance to achieve more effective and sustainable control of fall armyworm (continued)

Session Organizer: Craig A. Abel, USDA-ARS, Ames, Iowa, USA & Prasanna Boddupalli, International Maize and Wheat Improvement Center, Nairobi, Kenya

14:00	Yoseph Beyene	Breeding for native genetic resistance to fall armyworm in Africa-adapted early- and intermediate-maturing tropical maize germplasm
14:20	Bruce Tabashnik	Managing fall armyworm in Africa: Can *Bt* maize sustainably improve control?

14:40 Scientific Session 6

Scientific Session 6: Genomics in current and future maize pest research

Session Organizer: Brad Coate, USDA-ARS, Ames, Iowa, USA & Marce Lorenzen, North Carolina State University, Raleigh, North Carolina, USA

14:40	Brad Coates & Marce Lorenzen	Introduction
14:50	Marce Lorenzen	Development of genomic resources and tools for a hemipteran pest of maize
15:10	Tiantao Zhang	Genomics comparision of sibling species of *Conogethes punctiferalis* and *C. pinicolalis*

15:30 ***Coffee/Tea Break***

16:00 ***Scientific Session 6 (continued)***

Scientific Session 6: Genomics in current and future maize pest research (continued)

Session Organizers: Brad Coates, USDA-ARS, Ames, Iowa, USA & Marce Lorenzen, North Carolina State University, Raleigh, North Carolina, USA

16:00	Emmanuelle Jacquin-Joly	Chemosensory receptors as targets for the identification and design of new behavioural disruptors for maize Lepidoptera pests
16:20	Kiwoong Nam	Evolutionary history of the fall armyworm invasion inferred by population genomics approach
16:40	Ahmed G. Hussain	Viruses of the fall armyworm *Spodoptera frugiperda*; hidden gems for biological control
17:00	Brad Coates	Genomic responses of western corn rootworm to *Bacillus thuringiensis* pesticidal proteins
17:20	Juan Luis Jurat-Fuentes	Monitoring for resistance to *Bt* corn using targeted sequencing

17:40 ***End of Day 2***

19:00 ***Individual Dinner Arrangements***

Thursday, 4 May 2023

09:00 *Scientific Session 7*

Scientific Session 7: Integrated pest management approaches and solutions for fall armyworm

Session Organizers: Zhenying Wang, IPP-CAAS, Beijing, China; Amanuel Tamiru, International Centre of Insect Physiology and Ecology – icipe, Nairoibi, Kenya & Feng Zhang, CABI, Beijing, China

09:00	Zhenying Wang, Amanuel Tamiru & Feng Zhang	Introduction
09:10	Emmanuel Peter	Crop diversification for fall armyworm management: elucidating pest-plant-natural enemy interactions
09:30	Léna Durocher-Granger	Effect of planting dates on fall armyworm infestation and its parasitoids
09:50	Daniel Mutyambai	Alteration of maize phytochemistry and fall armyworm (*Spodoptera frugiperda*) resistance by push-pull cropping soil legacies
10:10	Abdul A. Jalloh	Maize-legume intercropping soil legacies alter maize growth and fall armyworm (*Spodoptera frugiperda*) larval feeding

10:30 *Coffee/Tea Break*

11:00 *Scientific Session 7 (continued)*

Scientific Session 7: Integrated pest management approaches and solutions for fall armyworm (continued)

Session Organizers: Wang Zhenying, IPP-CAAS, Beijing, *China; Amanuel Tamiru, International Centre of Insect Physiology and Ecology – icipe, Nairoibi, Kenya & Feng Zhang, CABI, Beijing, China*

11:00	Rhian Whelan	Preliminary studies on the use of *Metarhizium rileyi* for control of fall armyworm in Zambia.
11:20	Ivan Rwomushana	A novel approach to management of *Spodoptera frugiperda* J.E. Smith for small-holder farmers using virus extract from larvae treated with baculovirus under field conditions
11:40	Robert Meagher	Trapping fall armyworm: the use of pheromones, trap design and lures for fall armyworm control
12:00	Benjamin Mbatha	Fish soup attracts biodiversity of natural enemies of fall armyworm (*Spodoptera frugiperda* J.E. Smith)
12:20	Qiulin Wu & Zhenying Wang	Migration patterns of the invasive fall armyworm *Spodoptera frugiperda* (J.E. Smith) in China

12:40 *Lunch Break*

13:40 ***Scientific Session 7 (continued)***

Scientific Session 7: Integrated pest management approaches and solutions for fall armyworm (continued)

Session Organizers: Wang Zhenying, IPP-CAAS, Beijing, China; Amanuel Tamiru, International Centre of Insect Physiology and Ecology – icipe, Nairoibi, Kenya & Feng Zhang, CABI, Beijing, China

13:40	Amanuel Tamiru	Exploiting agroecological approach for sustainable fall armyworm management in smallholder farming systems
14:00	Daibin Yang	Broadcasting of tiny granules by drone for the control of fall armyworm (*Spodoptera frugiperda*)
14:20	Jerry Asalma Nboyine & Lakpo Koku Agboyi	Assessment of the optimal frequency of insecticide sprays required to manage fall armyworm (*Spodoptera frugiperda* J.E. Smith) in maize (*Zea mays* L.) in northern Ghana
14:40	John E. Kang'ati	Indigenous agroecological strategies for controlling fall armyworm (*Spodoptera frugiperda* J.E. Smith) in Africa

15:00 ***Coffee/Tea Break***

15:30	Zhenying Wang	Integrated management for the invasive fall armyworm in China
15:50	Feng Zhang	Attraction of *Spodoptera frugiperda* to a host plant volatile compound
16:10	Johnstone Mutua	Competitive plant-mediated and intraguild predation interactions of the invasive *Spodoptera frugiperda* and resident stemborers *Busseola fusca* and *Chilo partellus* in maize cropping systems in Kenya

16:30 IWGO Business Meeting

16:45 Poster Presentations & Refreshments

17:15 Visit to KEPHIS

17:45 ***End of Day 3***

18:30 ***Farewell Dinner Restaurant (optional booking required)***

Friday, 5 May 2023

06:00 ***Excursion (optional booking required; description of excursion please refer to www.iwgo.org)***

06:00 Meeting in the lobby of the Hotel Tamarind

14:00 Arrival Hotel Tamarind

14:00 End Excursion

POSTER PRESENTATIONS

Poster 01	Brad Coates	The USDA-ARS Ag100Pest Initiative: Developing chromosome-level genome assemblies for corn pest insects
Poster 02	Emmanuelle Jacquin-Joly	Reverse chemical ecology leads to the identification of new agonists of insect odorant receptors
Poster 03	Andrea Rilakovic	Western bean cutworm (*Striacosta albicosta* Smith) chemical management in intensive corn production in North America
Poster 04	Kajuga Nsamira Joelle & Bancy Waithira Waweru	Minimum effective dosage of entomopathogenic nematodes at controlling fall armyworm and preventing damage under field conditions
Poster 05	Anani Bruce	Response of selected tropical maize genotypes under natural infestation by fall armyworm, *Spodoptera frugiperda* (J.E. Smith)
Poster 06	Dan Makumbi	Breeding for native genetic resistance to fall armyworm in late-maturing tropical maize germplasm
Poster 07	Zhenying Wang	Oviposition behavior and interspecific-competition between *Telenomus remus* (Hymentoptera: Platygastridae) and *Trichogramma* spp. (Hymenoptera: Trichogrammatidae) on *Spodoptera frugiperda* (Lepidoptera: Noctuidae)
Poster 08	Hannalene du Plessis	Susceptibility of fall armyworm to insecticides in South Africa
Poster 09	Thomas W. Sappington	Western corn rootworm: a partial migratory species consisting of 'resident' and 'migrant' behavioral phenotypes
Poster 10	Stefan Toepfer	Engineering bacterial symbionts of entomopathogenic nematodes to enhance their biological potential against the western corn rootworm
Poster 11	Stefan Toepfer	Application techniques for entomopathogenic nematodes against below- and above-ground maize pests
Poster 12	Sri Ita Tarigan	Evaluating dose-responses of commercial insecticides against *Diabrotica v. virgifera* (Coleoptera: Chrysomelidae) for selecting proper positive controls in laboratory bioassays
Poster 13	Frank Chidawanyika	Biogeography of cereal stemborers and their natural enemies: forecasting pest management efficacy

Ear feeding maize pests and mycotoxins in the Great Lakes region of North America

Jocelyn Smith[1], Yasmine Farhan[1], Victor Limay-Rios[1] & Art Schaafsma[1]

[1]*University of Guelph Ridgetown Campus, Ridgetown, Ontario, Canada*

Mycotoxin contamination of grain due to fungal infections can have serious implications for human and animal health, grain marketing, and trade. In the Great Lakes region of North America, climatic conditions are often favourable to support the development of mycotoxigenic fungi in maize, *Zea mays* (L.) and wheat, *Triticum aestivum* (L.). In maize, feeding by a number of lepidopteran insect pests increases the incidence and severity of infection and mycotoxin development. A review of the relevant pest complex from the Great Lakes region will be presented. In particular, the results of research on the interaction of a relatively new pest in this region, western bean cutworm, *Striacosta albicosta* (Lepidoptera: Noctuidae), will be discussed. Current management strategies comprising insecticides, fungicides, and transgenic corn will be summarized.

Contributions of transgenic insect protection to managing mycotoxins in maize

Gary Munkvold[1], Julie A Mandap[1] & Derrick Mayfield[1]

[1]*Iowa State University, Ames, Iowa, USA*

Insect-damaged maize is highly vulnerable to colonization by mycotoxin-producing fungi and is more likely to contain unsafe levels of mycotoxins. The relationship between insect damage and mycotoxin contamination is affected by insect species, maize genetics, fungal populations, and environmental conditions. Meta-analysis of published data indicates that mycotoxin risk is reduced in transgenic, insect-protected hybrids. The benefits of transgenic insect protection are most evident in relation to reduced fumonisin risk associated with European corn borer (*Ostrinia nubilalis*) feeding, while protection against other insects and mycotoxins requires a combination of transgenes. *Bt* maize can contain reduced levels of a wide range of fungal secondary metabolites under some conditions. In field trials in Iowa, *Bt* maize was consistently lower in fumonisins, but beauvericin, moniliformin, fusaproliferin, and fusaric acid were not affected by insect infestations or maize hybrid in plots inoculated with *F. subglutinans* or *F. temperatum*. However, inoculated treatments were significantly lower in fumonisins, suggesting that *F. subglutinans* and *F. temperatum* effectively competed against endemic fumonisin-producing *Fusarium* spp. In stored grain trials with *Aspergillus flavus* and infestation with either Indianmeal moth or maize weevil, conventional and insect-protected maize hybrids were incubated under simulated storage conditions typical of tropical and sub-tropical climates. Mortality of IMM was 100% in hybrids with resistance to lepidopteran pests, and MW suffered 100% mortality in hybrids with resistance to coleopteran pests. Aflatoxin levels in the conventional hybrid were elevated by the insect pests, whereas insect infestations had no effect on aflatoxins in insect-resistant hybrids. Taken together, these results indicate that transgenes targeting a broad range of field pests can reduce mycotoxin risk under diverse conditions, including risks occurring in stored grain.

Impact of push–pull cropping system on pest management and occurrence of ear rots and mycotoxin contamination of maize in western Kenya

Nancy Njeru[1,2,3], Charles Midega[2,4], James Muthomi[3], Maina Wagacha[3] & Zeyaur Khan[2]

[1]Kenya Agricultural and Livestock Research Organization, Nairobi, Kenya
[2]International Centre for Insect Physiology and Ecology, Nairobi, Kenya
[3]University of Nairobi, Nairobi, Kenya
[4]Environmental Sciences and Management Research Unit, North-West University, Potchefstroom, South Africa

Background: Majority (over 70%) of agricultural households in Kenya grow maize. Maize is mainly used as food, feed and raw material for industrial manufacture of maize-based products such as corn flakes and corn flour. Insect pests and fungal diseases have been associated with significant losses in maize. Push–pull, a technology that involves intercropping of cereals with *Desmodium* as a "push" crop and planting Napier grass/*Brachiaria* as the "pull" crop at the border, has been reported to effectively control stemborers, striga weed, and fall armyworm (FAW), and to improve soil nutrition, resulting in increased grain yield. This study evaluated the impact of stemborer and FAW management using this technology on incidence of maize ear rots and preharvest contamination of grains with aflatoxin and fumonisin in western Kenya.

Materials and methods: The study was conducted during three cropping seasons on maize grown under the push–pull system and as a monocrop. Incidence of stemborer and FAW damage was determined as percentage of damaged plants, while incidence of ear rots was determined as percentage of ears with symptoms. At harvest, fungi were isolated from kernels and aflatoxin and fumonisin were quantified using enzyme-linked immunosorbent assay.

Results: Stemborer and FAW damage was significantly (p = 0.001) reduced by over 50% under the push–pull system. There was also a significant (p < 0.001) reduction in the incidence of *Fusarium verticillioides* (60%) and *Aspergillus flavus* (86%), which was reflected in a reduced incidence of ear rots (50%) with the push–pull system (p = 0.001). Fumonisin in maize from push-pull farms was significantly (p = 0.048) reduced (39%) but the technology had no significant (p > .05) effect on aflatoxin.

Conclusions: The study showed that push–pull is an effective strategy for managing maize ear rots and fumonisins, and therefore could play a role in improving food safety among smallholder maize farmers in the region and accross the country.

The influence of *Striacosta albicosta* (Smith) management on mycotoxin accumulation in grain corn, *Zea mays* L.

Yasmine Farhan[1], Jocelyn L. Smith[1], Victor Limay-Rios[1] & Art Schaafsma[1]

[1]*University of Guelph, Ridgetown, Ontario, Canada*

Striacosta albicosta (Smith) (Lepidoptera: Noctuidae) is a major pest of corn [*Zea mays* (L.)] in the Great Lakes region. Larvae of *S. albicosta* feed on corn causing economic damage and the potential for mycotoxin contamination. Transgenic corn expressing the *Bacillus thuringiensis* (*Bt*) insecticidal protein Vip3Aa and foliar insecticides are recommended for the management of *S. albicosta*; however, the effectiveness of these products in reducing mycotoxin contamination is unknown. Field trials were conducted over two years to compare the effectiveness of Vip3Aa and the foliar insecticides chlorantraniliprole, lambda-cyhalothrin, spinetoram, and methoxyfenozide in reducing mycotoxin contamination. Incidence of *S. albicosta* feeding was >5 and >15 times lower on Vip3Aa relative to the foliar insecticides and nontreated control (NTC), respectively. Foliar insecticides did not differ from one another but had >2 times lower incidence of *S. albicosta* feeding than the NTC. Accumulation of the mycotoxin deoxynivalenol (DON) was >3 and >47 times lower in Vip3Aa kernels relative to the foliar insecticides and NTC kernels, respectively. Foliar insecticides had >4 times lower DON concentration than the NTC; except for methoxyfenozide, which did not differ from the NTC in its DON concentration. Accumulation of the fumonisin (FBs) mycotoxins were >3 times lower for Vip3Aa, spinetoram, and the premix of chlorantraniliprole and lambda-cyhalothrin than the NTC. The remaining foliar insecticides did not differ from the NTC in their concentrations of FBs. This study shows that the risk of mycotoxin accumulation posed by *S. albicosta* in the Great Lakes region may be mitigated using either transgenic or foliar insecticides. Additionally, these results highlight the importance and challenges of insect control in corn in the Great Lakes region where mycotoxin infection is common and the need for more tolerant corn hybrids.

Session 2-T 1 - Biocontrol of FAW

Effect of biopesticides on the abundance and diversity of *Spodoptera frugiperda* (J.E. Smith) natural enemies

Michael Hilary Otim[1], Angella Lowra Ajam[1], Geofrey Ogwal[1], Stella Aropet Adumo[1] & Dalton Kanyesige[1]

[1]National Crops Resources Research Institute, Kampala, Uganda

Spodoptera frugiperda is an invasive pest in Uganda and it has spread to all maize-growing regions in the country causing significant yield loss. There is almost no adoption of biological control using predators and parasitoids for the management of *S. frugiperda* by smallholder farmers; however, there has also been a drastic increase in insecticide use. This study aimed to determine *S. frugiperda* damage and abundance, species composition and abundance of *S. frugiperda*'s natural enemies under different insecticide treatments. The experiments were laid out in an RCBD with nine treatments with four replicates at National Crops Resources Research Institute and Ngetta Zonal Agricultural Research and Development Institute for four growing seasons. Damage severity and the number of *S. frugiperda larvae* were significant between treatments in all seasons and locations. Plots treated with synthetic pesticides had less damage than those treated with biopesticides. However, Nimbecidine, *Metarhizium anisopliae* ICIPE 7 and *Metarhizium anisopliae* ICIPE 78 were the best biopesticides in controlling *S. frugiperda.* Larval parasitoids recovered included *Coccygidium luteum, Cotesia icipe, Chelonus insularis,* an unidentified tachinid, and *Charops* cf. *diversipes.* Predators recovered were mostly earwigs in plots treated with bio-pesticides *Metarhizium anisopliae*, *Beauveria bassiana,* and botanical Nimbecidine. The untreated control had the highest overall mean diversity index than all other treatments in all seasons and locations. Plots treated with *Metarhizium anisopliae* and control had the highest mean species richness. In Lira control plots had the highest mean overall parasitism while in Wakiso, it was Nimbecidine. Therefore, biopesticides should be registered and their use encouraged.

Assessment of the effectiveness of some commercial biopesticides against fall armyworm in northern Ghana and their effects on larval parasitism rates

Lakpo Koku Agboyi[1], Jerry Asalma Nboyine[2], Ebenezer Asamani[3], Patrick Beseh[4], Benjamin K. Badii[3], Marc Kenis[5] & Dirk Babendreier[5]

[1]CABI, Accra, Ghana
[2]Council for Scientific and Industrial Research, Savanna Agricultural Research Institute, Tamale, Ghana
[3]Department of Crop Science, University for Development Studies, Tamale, Ghana
[4]Plant Protection and Regulatory Services Directorate, Accra, Ghana
[5]CABI, Delémont, Switzerland

The outbreak of the fall armyworm, *Spodoptera frugiperda,* in Africa has led to several recommendations of insecticides, including biopesticides. However, the effects of these products on the environment, especially on parasitoids have not been assessed under field conditions. Here, we investigated the effect of commonly used biopesticides on *S. frugiperda* management and larval parasitoids of *S. frugiperda* in northern Ghana. The experiments were conducted both on-station in Wa and Nyankpala and on-farm in Wa during the 2020 rainy season. Active ingredients tested included neem oil (3% Azadirachtin), maltodextrin (282 g/l), 55% *Bacillus thuringiensis* (*Bt*) combined with 45% Monosultap, and a *Pieris rapae* granulosis virus combined with 5% *Bt*. A chemical insecticide based on emamectin benzoate and acetamiprid was used as positive control while non-treated maize plots were considered as untreated control. The two most abundant parasitoids in Wa were *Coccygidium luteum* and *Chelonus bifoveolatus*, while in Nyankpala they were *C. luteum* and *Meteorus* sp. Total larval parasitism rates on-station were 18.7% and 17.6% in Wa and Nyankpala, respectively, and 8.8% in Wa on-farm. Parasitoid species diversity and evenness indexes did not vary among treatments, but parasitism rates were significantly lower with the chemical on-station in Wa and with the virus and *Bt* product in Nyanpala. Untreated maize plots showed the highest larval density and plant damage, the highest cob damage, and generated the lowest yields. The other treatments showed hardly any difference in cob damage and yields, suggesting that biopesticides should be preferred over chemical pesticides for *S. frugiperda* control.

Keywords *Spodoptera frugiperda*, parasitoid species, maize, side-effects of pesticides, environment

Potential of rabbit urine in managing fall armyworm (*Spodoptera frugiperda* J.E. Smith)

Diana Kemunto[1]

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The fall armyworm (FAW) (*Spodoptera frugiperda* J.E. Smith) is a major pest of cereals. The pest has negatively impacted cereal productivity and, consequently, threatening livelihood and escalating food insecurity in Africa. Many farmers apply chemical insecticides as major control measure, and this has become unreliable due to health and environmental risks. Some African smallholder farmers apply various cost-effective, indigenous pest management practices, including rabbit urine; however, there is no scientific evidence for its efficacy. The FAW eggs, first, second and third instar larvae and moths were exposed to rabbit urine-treated maize leaves alongside untreated maize leaves (control). More FAW larvae preferred the untreated leaves (46.0–70.0%) to the rabbit urine-treated leaves (27.0–43.0%). Rabbit urine caused 6.4 and 12.8% damage reduction of the second and third instars, respectively, 24 h post-exposure. Rabbit urine significantly reduced the survival of FAW, with lethal time (LT50) of 5.0, 7.3 and 8.7 days and a lethal dose (LD50) of 48, 94, and 55% for the first, second and third instars, respectively. Rabbit urine reduced egg hatchability and adult emergence by 55.0 and 13.3%, respectively. The FAW female moths laid more eggs on the rabbit urine-treated plants (647 ± 153 eggs) than they did on the untreated plants (72 ± 64 eggs). This study shows that rabbit urine is effective in repelling and reducing the damage of FAW larvae, attract FAW moths but limit the egg hatchability and emergence of adult from pupae. This confirms farmers' assertions of using rabbit urine to manage FAW. For successful integration into the FAW IPM package, additional studies on the chemistry of rabbit urine, the behavioral response and the field might be required.

Keywords: agroecological farming systems; biopesticides; indigenous knowledge; maize; IPM package; oviposition

Session 2-T 4 - Biocontrol of FAW

A gel formulation of entomopathogenic nematodes to control caterpillars of the fall armyworm, *Spodoptera frugiperda*: an effective, safe and sustainable alternative to chemical insecticides

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To fight the fall armyworm, farmers in Africa and Asia mostly rely on chemical insecticides. In collaboration CABI, Rwanda Agriculture and Animal Resources Development Board (RAB) and the University of Neuchâtel of Switzerland developed a biocontrol formulation of entomopathogenic nematodes (EPN) as an alternative to pesticides.
In a first step, we tested the efficacy of differently formulated EPN in laboratory trials. Applied in a gel into the whorl of FAW-infested maize seedlings, a low dose of EPN (3000 EPN/plant) caused up to 100% mortality of FAW caterpillars. In a second step, we evaluated the efficacy of the formulation under realistic farming conditions in Rwanda, a hotspot of the FAW invasion with FAW populations overlapping nearly year-round. One-time treatment of naturally infested young maize plants with EPN formulated in the gel appeared as effective in reducing FAW infestation and plant damage as applying the locally registered contact insecticide cypermethrin. We then tested the repeated applications of EPN over a full growing season of maize. With just four applications of EPN, yields significantly increased as compared to untreated control plots. These results demonstrate that formulated EPN hold great promise as an effective, safe and sustainable alternative to conventional chemical insecticides.
We intend to further improve the EPN-formulation to meet the specific needs of both small- and large-scale maize cropping systems.

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Session 2-T 5 - Biocontrol of FAW

Field efficacy of entomopathogenic nematodes in controlling fall armyworm in comparison to local pest management practices

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The invasion of the fall armyworm, *Spodoptera frugiperda* (FAW), into Africa and Asia has dramatically increased the use of insecticides in maize. Less disruptive pest management approaches are urgently needed. In collaboration, the University of Neuchâtel in Switzerland, CABI and Rwanda Agriculture and Animal Resources Development Board (RAB) have developed a novel gel-based formulation of entomopathogenic nematodes (EPN) for their above-ground use against FAW caterpillars. Repeated treatments of those formulated EPN have shown to reduce pest levels, to prevent leaf damage and to positively affect yield. Subsequently, we wanted to know whether such an approach could be successful under the light of local pest management practices. We therefore implemented two field experiments to compare the newly developed gel formulation of EPN to a formulation using local gels, as well as to a locally available pyrethrum botanical and to the practice of adding soil into the whorls of maize. Treatments were applied twice in two-week intervals. The experiments were being implemented in Rwanda following a systematic block design with four plots per treatment per field, including an untreated negative control and a locally registered profenophos + cypermethrin insecticide as positive control.
Preliminary results revealed that treatments regardless of type are in many cases able to reduce FAW levels and to prevent some damage, but may occasionally fail. Further experimental repetitions are currently running, as natural infestation and re-infestation as well as local conditions can largely differ between fields. Nevertheless, we can already conclude that there are several effective options to manage FAW, and their choice may be based on safety, practicability and local availability aspects.

Session 2-T 6 - Biocontrol of FAW

No enemy free space: The case of alien invasive *Spodoptera frugiperda* in African ecologies

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The invasion by and establishment of fall armyworm (FAW), *Spodoptera frugiperda,* across Africa wreaked havoc through its devastating impact on maize production coupled with its rapid spread. Fortunately, the continent is bestowed with high diversity of native and introduced parasitoids, which could be tapped into for biocontrol of the alien invasive pests such as. Therefore, this study, explored the potential of seven of these parasitoid species for suppression of FAW. The effectiveness of the egg parasitoids, *Telenomus remus* and *Trichogramma chilonis;* the egg-larval parasitoid, *Chelonus bifoveolatus*; and the larval parasitoids, *Cotesia icipe*, *Charops ater*, *Coccygidium luteum* and a tachinid fly against FAW were assessed under laboratory condition. We further assessed the effectiveness of *T. remus, T. chilonis* and *C. icipe* against FAW under field conditions, using augmentative releases. We also estimated the dispersal range of *T. remus* and *T. chilonis.* The laboratory results showed that *T. remus*, *T. chilonis* and *C. bifoveolatus* achieved up to 76, 75 and 80% parasitism, respectively. Larval parasitoids, *C*. *icipe*, *C*. *ater*, *C*. *luteum* and tachinid fly had 78, 60, 78, and 62% parasitism, respectively. In the field, we registered a steady increase of parasitism by three parasitoids over the years, between 2020 and 2022: with parasitism being 55, 50, and 38% in 2020/2021, and ~90%, 65%, and 45% in 2022, for *T. remus*, *T. chilonis* and *C. icipe*, respectively. The dispersal range of *T. remus* and *T. chilonis* was recorded to be ~1.3 km in a single maize-growing season in western Kenya. The steady increase in the effectiveness of the parasitoids in the field is indeed a proof that biocontrol of *S. frugiperda* population to below economic threshold could be achieved, signifying that FAW did not land in an enemy free space. However, more effort is required in terms of consistent and careful augmentative releases of the parasitoids in the fields.

Key words: Biological control, parasitism, dispersal augmentative releases

Session 2-T 7 - Biocontrol of FAW

High parasitism on fall armyworm in Africa and Asia. Where do all these parasitoids come from?

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Since its recent arrival in Africa and Asia, the fall armyworm, *Spodoptera frugiperda*, has been adopted by more than 50 parasitoid species, which often reach high parasitism rates. Most are larval, or egg-larval parasitoids, killing larvae before they reach maturity and cause damage on crops. Egg parasitism by *Telenomus remus* and *Trichogramma* spp. is also surprisingly high, given that the same species or genera rarely attack fall armyworm naturally in the native range of the pest. Parasitism rates of invasive insects in their area of introduction are highly variable. Some are not attacked by any parasitoid species whereas others are quickly adopted by a whole cohort of parasitoids causing substantial mortality to their new host. Several factors may explain these differences, but the main one is the presence, or not, of congeneric hosts in the area of introduction. In the case of fall armyworm, all main parasitoids come from other *Spodoptera* spp. The implications of such large parasitoid complex and high rates of parasitism in Africa on biological control strategies will be discussed.

Session 2-T 8 - Biocontrol of FAW

Effectiveness of generalist native parasitoid, *Cotesia icipe* against *Spodoptera frugiperda* and other key pests in maize agroecosystem

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Following the invasion of fall armyworm (FAW), *Spodoptera frugiperda,* into Africa, the use of parasitoids for its biological control has been explored. One of the native parasitoids, *Cotesia icipe*, which is associated with other indigenous *Spodoptera* species in Africa, has been found to be very promising against FAW. However, parasitoids with broader host range can be less ideal candidates for biocontrol of invasive pests as their affinity to invasive pest compared to their coevolved hosts is unknown. This necessitates a more detailed examination of the performance of this parasitoid against FAW and other lepidopteran pests in maize agroecosystem. In this regard, we assessed the preference for, acceptability by *C*. *icipe* to key lepidopteran maize herbivores in Africa (*Busseola fusca*, *Sesamia calamistis*, *Chilo partellus*) in the presence/absence of *S. frugiperda* and *S. littoralis*. We further evaluated the suitability of these hosts for *C*. *icipe* development and their effect on the fitness of the parasitoid progenies. Furthermore, we investigated the behavioural (In a Y-tube olfactometer) and electrophysiological responses of the parasitoid to the host larvae and herbivore-induced maize plant volatiles, respectively. We found that, besides *S. littoralis* and *S. frugiperda*, *C*. *icipe* parasitized the stemborers, although they had highest performance on *Spodoptera* species in terms of preference, acceptability, suitability, and fitness of their offspring. In the Y-tube olfactometer, the parasitoid preferred *S. frugiperda* to stemborers. Despite this, the GC-EAD recordings revealed that there are no qualitative differences in the volatile organic compounds (emitted by herbivore-damaged maize plant) that elicited antennal responses of *C*. *icipe*. Our findings confirms that *C*. *icipe* highly prefers and performs on *S. frugiperda* in maize agroecosystem. Hence, it could be a potent augmentative biocontrol agent for FAW management in Africa.

Keywords: *C*. *icipe*, parasitoid performance, new association, invasive pests

Biology and host age preference of *Coccygidium luteum* (Hymenoptera: Braconidae): a larval parasitoid of the fall armyworm (*Spodoptera frugiperda*)

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Coccygidium luteum is a solitary larval parasitoid which is newly-associated with the fall armyworm (FAW), a widely distributed invasive pest across Africa. However, there is a lack of information on its reproductive biology, host age preference and other factors influencing its life strategies. We conducted a laboratory experiment to gain new insight into the biology of *C. luteum* reared on FAW as the host. Host age preference, reproductive biology, lifetime fecundity, life cycle and adult longevity were studied at 28 ± 1 °C and relative humidity of 70%. This study showed that *C. luteum* prefer early (1st–3rd) instars of FAW for oviposition. An average pre-oviposition period of 123.12 ± 15.36 hours and oviposition period of 120 hours (5 days) were observed. There was no post-oviposition period. A female *C*. *luteum* was able to parasitize an average of 49 ± 24 FAW larvae in a lifetime. Longevity was 346.56 ± 34.32 hours (14.44 days) for males and 307.92 ± 26.88 hours (12.83 days) for females. Progeny per adult female was 28.11 female and 39.89 male, with an overall sex ratio of approximately 1:1. Total life cycle from oviposition to adult emergence was 23 ± 1 days. Our study provides the basic information for further studies and evaluation of *C. luteum* as possible agent for augmentative biological control of FAW.

Augmentative biological control of fall armyworm: how can we make it work?

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The fall armyworm (FAW), *Spodoptera frugiperda* (Smith), has become one of the major threats to maize production in Africa and Asia. The use of pesticides has increased substantially to control this key pest, but is not sustainable. We here provide recent data on the use of egg parasitoids for augmentative biological control of FAW, focusing on *Telenomus remus* and several species from the genus *Trichogramma*. For *Trichogramma* species it is known that the small wasps have difficulties to reach all eggs in an egg mass, however, we have shown that *Trichogramma* egg parasitoids can parasitize at maximum between 57.0% (*Trichogramma brassicae*) and 76.3% (*Trichogramma dendrolimi*), when offered a range of egg masses with or without hairs and with one, two or three layers of eggs. *Telenomus remus* is highly efficient when parasitizing egg masses, i.e. can reach all eggs within a given egg mass, but is not easy to mass produce and field efficacy still is not consistent.

Session 3-T 1 - Free themes

Pesticide residues and ground beetle communities in intensive maize production

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Maize cultivation requires the use of intensive agrotechnical measures, especially tillage and crop protection. Carabids are predators that feed on insects, small invertebrates, and weed seeds while serving as a food source for animals at a higher trophic level. Intensive production and pest control lead to a decline in biodiversity. The greatest negative impacts of pesticides are on survival and reproduction. The most harmful groups include neonicotinoids, carbamates, organophosphates, strobilurins, triazoles, and sulfonylureas. The study was conducted in Lukac, where conservation tillage is common, and in Tovarnik with conventional tillage. The aim was to study the composition of carabid species present in maize fields and the pesticide residues in their body tissues. Samples were collected during vegetation using pitfall traps. Pesticide residue analysis was performed using the QuEChERS method based on LC-MS / MS. A total of 5,656 carabids were collected in Lukač and 342 in Tovarnik. According to the Bray-Curtis dissimilarity index, a large difference in species populations was found between the sites, with only slightly more than one-third of the same species found at both sites. Lukac has greater overall diversity, while a single species is abundant at both sites. Of the pesticides detected in carabid samples, the insecticide fipronil had the highest concentration in Tovarnik at 0.040 mg/kg, while imidacloprid was detected in Lukač at 0.027 mg/kg. The fungicide epoxiconazole was detected at both sites at concentrations ranging from 0.016 mg/kg in Tovarnik to 0.052 mg/kg in Lukač. The herbicide ethofumesate was also present at both sites, with a much higher concentration of 0.281 mg/kg in Tovarnik. It should be considered that some pesticides can bind to the fatty tissues of the body. Various indices of dominance, persistence and ecological importance show that the conditions at Lukac are more favorable for the composition of carabid species.

Session 3-T 2 - Free themes

Using host plant resistance and drought-tolerance in maize to respond to a dual threat of water-stress and spider mite herbivory

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Water stress is a condition that frequently occurs in the western part of the United States and other parts of the world and is predicted to become more severe, due to increases in temperature and reduced frequency of precipitation events in the region. The ability for crop producers to manage crops in a water-challenged environment has become difficult not only because crops must thrive in the face of extreme abiotic stresses but also because as a consequence, growers may predict more serious pest infestations from once innocuous plant pests that thrive under these conditions. The two-spotted spider mite and Banks grass mite are not historically recognized as major pests of maize in wetter areas but thrive on heat and drought-stressed plants resulting in yield loss. Here, an investigation on the response of maize to a combination of water-stress and spider mite herbivory are discussed. More specifically, an evaluation of maize lines shows high levels of host plant resistance even in the face of water-stress for the generalist two-spotted spider mite, but not a specialist Banks grass mite. Despite a lack of resistance for Banks grass mite, results suggest that the use of drought-tolerant corn hybrids may provide an ability to alleviate both water-stress and spider mite herbivory. Considering the interactions between biotic and abiotic factors on maize, the discussion further highlights water-efficient technologies in the management of spider mites and improvement of crop health.

Session 3-T 3 - Free themes

Weed host interactions with spider mites in Intermountain West corn production

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With climate change, it is predicted that more frequent high temperatures and drought severity will lead to an increase in damage caused by pests that thrive under these conditions. Spider mite outbreaks, for example, are associated with plant water-stress and there is evidence that some weeds are more resilient and adapted to drought than crops, leading to major concerns for the management of these two pest types. Weeds directly compete with crops for limited resources, but what is unclear is which weeds harbor spider mites and whether they exacerbate the impact of spider mites on corn. A survey was conducted to identify weed species at the edges of corn fields and their host association with spider mites. Fifteen corn fields were surveyed from northern Utah. We also conducted a parallel field study to investigate how varied irrigation levels impact spider mite infestations from weeds and whether the selection of drought-tolerant corn hybrids alters interactions. We paired either redroot pigweed and two-spotted spider mite or green foxtail and Banks grass mite, and then randomly assigned these pairs to field cages receiving optimal or suboptimal irrigation. Results showed that field bindweed and bitter nightshade were the most common weeds hosting two-spotted spider mites and banks grass mites, respectively. Further results showed that mite populations were higher under reduced irrigation than under optimal irrigation, while mite populations were increased on drought susceptible corn. This information may assist in developing strategies for managing these two pests and contribute to the development of integrated pest management for corn production systems in water-stressed environments.

Session 3-T 4 - Free themes

Microbial biostimulants registered for maize with potential side-effects on its insect pests: A review

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Plant biostimulants are ingredients with the sole aim to improve the agronomic performance of a plant. However, they often have a multitude of effects, some of them being little understood. We tried to review microbial plant biostimulants for their potential side effects on insects pests in maize. First, we reviewed commercial products from countries that have a detailed registration process and/or an accessible and searchable database for plant biostimulants (e.g. Hungary, Switzerland, Spain, France, Indonesia, Canada). We found that about 18 ± 25 microbial plant biostimulants are registered for maize per country. Those contain 16 ± 34 different micro-organisms. Subsequently, we reviewed those products with regard to their potential effects on maize pests such as on the soil pests *Diabrotica virgifera virgifera* (Coleoptera: Chrysomelidae) using databases of the scientific literature. About 23% of products (3 ± 7) contained microorganisms reported to affect insect pests, which is 41% of all used microorganims species (3 ± 2). Among them, about 20% of products (41 ± 46) contained 10% microorganism species (7 ± 2) reported to affect *Diabrotica spp.* It needs to be noted that the diverse effects of microorganims in biostimulants may depend on the considered strain of a microorganism, which is often neither stated on the product label nor in the registration lists or in the reviewed scientific studies in the literature. Nevertheless, it became clear that a number of microbial stimulants also have plant protection properties for maize. In conclusion, growers may profit from, but should be made aware of the multiple effects of microbial plant biostimulants.

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Session 3-T 5 - Free themes

An overview of stink bugs (*Euschistus servus* and *Nezara viridula*) as pests of southern US corn

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Previously the stink bug *Euschistus servus* was a major problem in corn, but primarily isolated to corn fields bordering wheat. After wheat was harvested, *E. servus* would disperse into and damage neighboring corn fields. During the past ten years, the stink bugs *E. servus* and *Nezara viridula* have become the most problematic insect pest of corn, and continue to be major pests of soybean and cotton across the southern US. Also during the past ten years, these stink bugs have been problematic in corn fields that are not associated with wheat. This presentation details past, recent, and future studies describing the ecology and management of stink bugs in southern US corn.

Geographic dispersion of invasive crop pests: the role of basal, plastic climate stress tolerance and other complimentary traits in the tropics

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Global pest invasions have significantly increased in recent years. These invasions together with climate warming can directly impact agriculture. Tropical climates feature with extreme weather events, including high temperatures and seasonal droughts. Thus, successful invasive pests in tropics have to adapt to these climate features. The intrinsic factors relevant to tropical invasion of insects have been explored in many studies, but the knowledge is rather dispersed in contemporary literature. Here, we reviewed the potential biophysical characters of successful invasive pests' adaption to tropical environments including (1) inherent high basal stress tolerance and advanced life-history performances, (2) phenotypic plasticity, (3) rapid evolution to environmental stress, polyphagy, diverse reproductive strategies and high fecundity. We summarised how these traits and their interactive effects enhance pest invasions in the tropics. Understanding these characters facilitating invasion helps develop/improve models for predicting the ecological consequences of climate change on invasive pest species and improve pest management.

Development of functional genomics tools to study mechanisms of insecticide resistance in the fall armyworm

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The fall armyworm (FAW), *Spodoptera frugiperda*, is a polyphagous insect pest feeding on many host plants, including some major crops such as corn and rice. This pest has also developed resistance to many insecticides. The lack of methods for transgenesis, as well as knockdown and knockout of the gene, is hindering our understanding of molecular mechanisms of insecticide resistance and physiological processes responsible for the invasion capacity of this insect. Recent genome and transcriptome sequencing efforts identified many P450 genes in the FAW, but their function in detoxifying plant toxins and insecticides is largely unknown. A P450 gene, SfCYP321A8, is upregulated in the first instar FAW larvae fed on deltamethrin. We established a piggyBac-based germline transformation system for the fall armyworm. A transgenic FAW overexpressing SfCYP321A8 was produced to investigate its function in deltamethrin resistance. Transgenic FAW expressing the gene coding for a P450, TcCYP6BQ9, known to metabolize deltamethrin in *Tribolium castaneum*, was also produced. P450 genes are highly expressed in different tissues of transgenic larvae. The P450 activity in both transgenic FAW lines' midgut and fat body is significantly higher than in wild-type larvae. Deltamethrin bioassays showed that the transgenic larvae expressing SfCYP321A8 or TcCYP6BQ9 are 10.3- or 15.3-fold more tolerant, respectively, than the wild-type larvae. SfCPH38/P2000 promoter with the highest activity and midgut-specificity was used to drive the expression of a P450, SfCYP321A8 in transgenic FAW. Higher mRNA levels of SfCYP321A8 and P450 activity were detected in the midgut of transgenic larvae than in wild-type larvae. Bioassays showed that the transgenic larvae expressing SfCYP321A8 in the midgut are tolerant to deltamethrin. The use of CRISPR/Cas9 system in model insects has facilitated functional genomics studies. However, this system has not been applied to many pest insects. Multiple transgenic CRISPR/Cas9-based genome editing methods were developed for FAW. The multiple transgenic CRISPR/Cas9-based genome editing methods developed provide invaluable tools for gene editing and functional genomics studies in this global pest and other lepidopteran pests.

Managing fall armyworm with transgenic *Bt* maize in the southeastern United States

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The fall armyworm, *Spodoptera frugiperda* (J.E. Smith), is a major pest of maize that is managed in the Americas primarily with transgenic hybrids-producing *Bacillus thuringiensis* (*Bt*) insecticidal proteins. This presentation will provide an overview of trials in the southeastern United States showing the variability in efficacy among *Bt* maize traits. While single-toxin *Bt* traits can be only moderately effective, most two- or three-toxin *Bt* maize traits provide very good to excellent levels of control. Insecticide applications are generally less effective in reducing infestations and injury than *Bt* maize. The value of using *Bt* maize to manage *S. frugiperda* will be discussed.

Managing *Bt* resistance in the fall armyworm: can we better exploit the evolutionary trade-offs of multi-toxin adaptation in IPM programs?

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Alleles conferring resistance to xenobiotics or pathogens can lead to pleiotropic effects that reduce individual fitness in environments without the selective agent (e.g., refuge areas deployed along with *Bacillus thuringiensis* (*Bt*) transgenic crops). Pleiotropic effects of resistance alleles may depend on genetic background and ecological factors, among which host-plant suitability is central for herbivorous insects. Here we examined fitness costs of resistance to pyramided *Bt* corn in the invasive fall armyworm, *Spodoptera frugiperda*, a model species notorious for holding four cases of field-relevant resistance to *Bt* crops. Using *Bt*-resistant and -susceptible strains of similar genetic background, we compared insect life-history traits and population growth rates on the foliage of *Bt* or non-*Bt* cultivars of corn, soybean, and cotton. We found that (i) the resistance alleles led to a large reduction in insect fitness on seven of the eight host crops studied; (ii) developmental time was the life-history trait that accounted for most of the fitness variation of the armyworm, and (iii) the magnitude of fitness reduction of the resistant individuals was stronger on cotton foliage. These results show that the fitness costs of resistance to multi-toxin *Bt* crops can be strong, and some host-plant cultivars that magnify the fitness differential of susceptible insects could be specifically deployed as a refuge to improve resistance management to *Bt* crops.

Listening to insects: using microphones and deep learning algorithms to monitor corn pests

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Insect pest data is critical for agricultural decision-making. Acquiring accurate information on an insect pest's presence, identification, and location is labor-intensive and costly, resulting in increased inequity. Larval boring insects are especially difficult to detect without destroying a crop, as they are located within the plant. Yet, larvae are often the primary economically damaging life stage. To address this discrepancy, we developed and tested a novel cost-effective method to determine 1) the presence of boring larval insects and 2) identify the species of boring larvae. Specifically, we hypothesized that microphones paired with bespoke deep-learning algorithms could be interpreted as insect presence and species identification data. We tested the hypothesis in a laboratory and controlled environment setting across several insect pests and crop species, including European corn borer in corn. Early results are highly promising. The next research stage is to field test the method in corn fields under both observational and experimental conditions. Knowing the species and density of boring larval pests increases the capability to precisely time and space agricultural interventions, such as pesticides and beneficial insects. Specifically, this data has the potential to dial in the timing of insecticide interventions, increasing the efficacy of our tools. Future work might will explore the detection of parasitoids within boring pests of corn. Overall, an accessible digital tool should decrease the economic cost of managing insect pests in corn systems.

Extension as an IPM tool: The Land Grant University program and its role in pest management

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Land Grant Universities in the United States are public universities with special funding to carry out a particular three-part mission. Teaching, Research, and Extension are all components of the 100+ universities with Land Grant designations. The role of Extension within this system is to provide non-formal education and learning activities to thousands of people throughout the country, including farmers and other residents of rural and urban communities. It does this through practical, research-based knowledge from the universities delivered to the public to create positive change. Extension entomology programs in the U.S. have taken this same approach to provide integrated pest management resources to growers based on local, unbiased data. This talk will explore the role of entomology in Extension, and discuss future prospects for Extension education.

Preparing the new generation of the workforce for the challenges of invasion biology in plant protection

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The University of Florida, Institute of Food and Agricultural Sciences (IFAS) launched a novel, interdisciplinary Doctor of Plant Medicine (DPM) program in 1999. DPM students are intensively trained within the educational disciplines of entomology, nematology, plant pathology, agronomy, horticulture, and soil science. With this interdisciplinary training, DPM students often also complete training or internships in plant protection with the coordination of the Certificate of Plant Pest Risk Assessment and Management through the DPM program.
As Florida has a temperate to tropical climate, numerous ports of entry, and approximately two to three new arthropods establish in Florida every month, student learners at the University of Florida are uniquely prepared to address large-scale agriculture questions and develop an understanding of plant protection issues from a local and global scale. Information related course and internship training opportunities as well as graduate success stories will be presented.

Session 5-T 1 - Host plant resistance to FAW

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

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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 strategies, in which host plant resistance is one of the key components. 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 CIMMYT, 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 agro-ecologies in Africa and Asia. During 2022–2023, CIMMYT-derived FAW-tolerant maize hybrids have been released in four countries in Africa (South Sudan, Zambia, Malawi, and Kenya) while national performance trials are ongoing in eight other countries in sub-Saharan Africa. Moreover, under the 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, biopesticides, push-pull, etc.) integrating innovations from different partner institutions, are being evaluated in participatory engagement with farmers and extension personnel. Independently, genetically modified *Bt* maize with resistance to FAW is already commercialized in South Africa, and in a few countries in Asia (Philippines and Vietnam), 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 briefly 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.

Session 5-T 2 - Host plant resistance to FAW

Native resistance to leaf feeding fall armyworm discovered in maize population BS39 and partial inbred GEMN-0095

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Native to the Americas, the fall armyworm was accidentally introduced into Africa in 2016. The pest quickly expanded its geographic range and is a threat to global food security. Feeding in protected areas of the maize plant, the pest is resistant to several insecticide classes and toxins of *Bt*-maize. Using native resistance in maize along with existing tactics could improve control outcomes. The United State Department of Agriculture – Agricultural Research Service has made research on this insect a priority issue. Since 2018, many maize genotypes have been screened for resistance to leaf feeding fall armyworm in Ames, Iowa, USA. Several maize genotypes were identified with moderate levels of resistance and two maize lines have been derived from these sources that have high levels of resistance to fall armyworm leaf feeding, comparable to the resistant check Mp708. Current and planned research will be discussed. Research goals include acquiring genetic control and mechanisms of resistance information needed to develop and apply these resistant resources in a way that meets producer needs.

Session 5-T 3 - Host plant resistance to FAW

Breeding for native genetic resistance to fall armyworm in Africa-adapted early- and intermediate-maturing tropical maize germplasm

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Fall armyworm (FAW) (*Spodoptera frugiperda* (J.E. Smith)) first reported in Africa in 2016 is a serious threat to maize production in Africa. One of the key approaches to manage this pest is to develop and deploy maize lines and hybrids with resistance/tolerance to FAW and utilize host plant resistance in integrated pest management (IPM). Incorporating native genetic resistance to FAW into CIMMYT's Eastern Africa Product Profile 1 (EA-PP1) with early- to intermediate maturity is ongoing since 2018. EA-PP1 focuses on eastern Africa (Ethiopia, Kenya, Tanzania, and Uganda) with tropical mid-altitude agroecology, serving a total of 3.17 million hectares. We have initially screened maize lines from CIMMYT-Mexico and CIMMYT-Kenya that were previously found to have some level of resistance to insect-pests, especially FAW (in Latin America), and stalk borers (e.g., Antigua, multiple bore resistant germplasm, MBR, and multiple insect-resistant tropical, MIRT) under FAW artificial infestation in net houses at Kiboko, Kenya, to identify donors and to make new F_1s for doubled haploid (DH) line development. Since 2018, a total of 3590 inbred lines, 611 single-cross hybrids, and 1589 three-ways hybrids were evaluated under FAW artificial infestation. The results showed that 386 inbred lines, 140 single-crosses, and 186 three-way hybrids had foliar damage scores of ≤ 4.0 (on a 1–9 scale; 1 = no damage, and 9 = highest damage). In addition, several experiments (NCII, L x T, and diallel) were undertaken to determine the inheritance of resistance for FAW. The results revealed that both additive and nonadditive gene action were important in the inheritance of FAW resistance. A total of 25 inbred lines with very good general combing ability (grain yield more than 1 t/ha) were identified as new donors and were used for developing new breeding populations against FAW. These lines were shared with several public and private partners. In this presentation, we will discuss the breeding strategy for native genetic resistance to FAW, identification of donor lines resistant to FAW, and the performance of new FAW-resistant and high-yielding maize hybrids released in eastern and southern African countries.

Keywords: FAW, native genetic resistance, inbred lines, hybrids

Session 5-T 4 - Host plant resistance to FAW

Managing fall armyworm in Africa: Can *Bt* maize sustainably improve control?

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The recent invasion of Africa by fall armyworm (FAW), *Spodoptera frugiperda*, a lepidopteran pest of maize and other crops, has heightened concerns about food security for millions of smallholder farmers. Maize genetically engineered to produce insecticidal proteins from the bacterium *Bacillus thuringiensis* (*Bt*) is a potentially useful tool for controlling FAW and other lepidopteran pests of maize in Africa. In the Americas, however, FAW rapidly evolved practical resistance to maize producing one *Bt* toxin (Cry1Ab or Cry1Fa). Also, aside from South Africa, *Bt* maize has not been approved for cultivation in Africa, where stakeholders in each nation will make decisions about its deployment. Here we address strategies to make *Bt* maize more sustainable and accessible to smallholders in Africa. We recommend mandated refuges of non-*Bt* maize or other non-*Bt* host plants of at least 50% of total maize hectares for single-toxin *Bt* maize and 20% for *Bt* maize producing two or more distinct toxins that are each highly effective against FAW. The smallholder practices of planting more than one maize cultivar and intercropping maize with other FAW host plants could facilitate compliance. We also propose creating and providing smallholder farmers access to *Bt* maize that produces four distinct *Bt* toxins encoded by linked genes in a single transgene cassette. Using this novel *Bt* maize as one component of integrated pest management could sustainably improve control of lepidopteran pests including FAW.

Development of genomic resources and tools for a hemipteran pest of maize

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The ability to utilize state-of-the-art genomic tools can open the door to a wide range of new pest control solutions, including the use of gene drive-based technologies. However, there may be considerable barriers to deploying these tools in a new species. For example, despite the power of CRISPR/Cas9-based genome editing, published reports of confirmed genome editing in hemipteran species are rare. Here we will describe the addition of a new hemipteran species to the list, the corn planthopper, *Peregrinus maidis*, and offer tips and tricks we wish we had known at the outset of the project. Like many agricultural pests, *P. maidis* lacked a sequenced genome, and therefore generating this genomic resource was a necessary first step. Assembly of the estimated 750-Mb genome was not a straightforward task, due to challenges posed by co-isolation of DNA from endosymbionts. We will describe the steps that ultimately enabled the production of a reference-quality chromosome-level genome assembly for this species, as well as how we are using these genomic and transcriptomic resources to bring game-changing genomic resources to enable the control of this pest of maize.

Genomics comparision of sibling species of *Conogethes punctiferalis* and *C. pinicolalis*

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Conogethes punctiferalis and *C. pinicolalis* are sibling species and similar in morphologic observation, but their feeding types are tremendously different. In the early stages, *C. punctiferalis* was classified to Pinacear-feeding type, but *C. punctiferalis* was a famous pest on fruit and maize. For further analysis and reveal the feeding difference in these two species, genomics of both species was sequenced and compared. We successfully assembled two high-quality genomes of *C. pinicolalis* of 595.29 Mb and *C. punctiferalis* of 521.87 Mb, with Contig N50 of 4.2 Mb and 11.56 Mb. Totally 17,774 and 16,989 genes were annotated in C. pinicolalis and *C. punctiferalis* genomes separately. For phylogenetic analysis, *C. pinicolalis* and *C. punctiferalis* were close to *Ostrinia furnacalis* and *Chilo suppressalis* and diverged from *O. furnacalis* about 46–93 million years ago. *Conogethes pinicolalis* and *C. punctiferalis* are diverged about 5–29 million years ago in Neoproterozoic. To explore the potential mechanism of oligophagy and polyophagy in *C. pinicolalis* and *C. punctiferalis*, we manually annotated all the chemoreception related genes in *C. pinicolalis* and *C. punctiferalis* genomes. We found more genes were expanded in detoxification related genes in *C. punctiferalis*, that probably caused the feeding differences in these two species.

Chemosensory receptors as targets for the identification and design of new behavioural disruptors for maize Lepidoptera pests

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Chemosensory perception (olfaction and taste) in insects is vital for many behaviors, such as finding a mate or adequate host plants. Disturbing this chemical communication is thus an environmental-friendly solution to fight against pests.
Today, the development of sequencing technologies has open up the possibility to identify the chemosensory receptor repertoires of crucial species. In insects, these receptors include three main families, the odorant receptors (ORs) involved in volatile detection at a distance, the gustatory receptors (GRs) involved in detection at contact, and the ionotropic receptors (IRs) involved in olfaction and taste.
Using transcriptomics and genomics, we have identified the whole set of chemosensory receptors in one the most harmful pests worldwide, the fall armyworm *Spodoptera frugiperda*. Manual curation allowed us to annotate 69 ORs, 43 IRs, and an impressive number of 278 GRs arranged in large tandems in the genome. This number of GRs is three times more than what has been described in mono/olygophagous Lepidoptera, suggesting that the number of GRs has greatly increased during evolution in polyphagous species via gene duplication.
Our collection of curated genes constitutes a valuable resource for functional characterization. Indeed, chemosensory receptors appear as key targets to identify new behaviorally active semiochemicals to be used in pest control. They offer the possibility of large *in vivo* and *in silico* screens, as we demonstrated for ORs in the sister species *S. littoralis*. Their 3D structure can be modelled and used for molecular docking, allowing the design of agonists, antagonists/receptor blockers. For instance, we have recently characterized the receptors to the main sex pheromone component in the two *S. frugiperda* strains (maize and corn) as promising targets for mating disruption.
Our work highlights how chemosensory genomics can help finding new solutions for the control of *Spodoptera* but also any other maize Lepidoptera pests.

Evolutionary history of the fall armyworm invasion inferred by population genomics approach

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The fall armyworm (*Spodoptera frugiperda*) is one of the most damaging pest insects, especially against corn. The fall armyworm is native to North and South America. After the invasion was first reported from West Africa in 2016, fall armyworms were detected from almost whole Sub-Sahara Africa, Middle East Asia, South Asia, South East Asian East Asia, Oceania, and Egypt. The invasive fall armyworm populations cause serious losses in corn production, around 40% on average in Sub-Saharan Africa. We performed population genomics analysis from globally sampled 177 individuals to infer invasive history and to identify evolutionary factors under the invasive success. We observed that invasive populations were originated from hybrids between two host-plant strains. Population genetics statistics support the hypothesis that fall armyworms were first introduced to the Old World a long time before 2016 and that a population of the introduced insect experienced explosive population expansion later. The composite likelihood approach shows that the invasive success was accompanied by host-plant adaptation/insecticide resistance. We also observed that the invasive populations have higher copy numbers of P450 genes and higher allele frequency of insecticide resistance mutations, supporting the role of insecticide resistance in invasive success. Notably, population genomics statistics and diffusion approximation show that the introduction of the fall armyworms into the Old World occurred a long time before 2016, suggesting the presence of a lag phase before being invasive. This information could be useful to make a plan to control invasive fall armyworm populations.

Viruses of the fall armyworm *Spodoptera frugiperda*; hidden gems for biological control

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The fall armyworm (FAW), *Spodoptera frugiperda*, originally from the Americas, has spread to Africa, Asia, and the Australian continents in recent years, threatening the production of staple crops. Since pest control with pesticides involves the risk of pesticide resistance development, there is a need for developing more sustainable, safe, and environmentally friendly pest control alternatives. Naturally occurring insect viruses could proffer alternative solutions to control FAW. Among insect viruses, baculoviruses are one of the most promising viral candidates. However, their usage in biological control is limited by several factors, including low efficacy compared to chemical pesticides, efficacy only against the early larval stage and lack of indigenous isolates of *Spodoptera frugiperda* multiple nucleopolyhedrovirus (SfMNPV). Hence, there is a need to explore other viral candidates. In this study, we genetically describe the virome of FAW from two African populations of FAW (Benin and Kenya), highlighting the different viruses present and the possible implication for biological control. In addition, we performed genetic and biological characterization of the first SfMNPV isolated from FAW in Africa in the laboratory and defined the specificity by comparing the virulence in Benin and Kenya FAW populations. Furthermore, we conducted a semi-field trial with the most promising isolate to test the efficacy under field conditions. The results of findings from this study show the promising prospect of using viruses to control local FAW populations.

Genomic responses of western corn rootworm to *Bacillus thuringiensis* pesticidal proteins

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Arthropod pests can cause significant damage to agricultural crops, and are managed by use of insecticidal agents, including *Bacillus thuringiensis* (*Bt*) pesticidal proteins expressed by genetically modified (GM) crops. *Diabrotica virgifera virgifera*, the western corn rootworm, is a major pest in the United States and Europe, which feed on roots of cultivated maize during larval growth stages. *Bt*-expressing GM crops are widely used by growers in many countries including the United States. Resistance to *Bt* proteins expressed by GM maize among *D. v. virgifera* field populations threaten the sustainability of current crop protection practices in the United States. Analysis of F_2 pedigrees defined a single major QTL on chromosome 8 (chr8) contributing to *Bt* Cry3Bb1 resistance. Genome-wide estimates of differentiation (F_{ST}) between pools of individuals from resistant and susceptible populations were generated based on alignment of short read sequence data to a draft genome assembly. A narrow genome interval with most significant level of divergence was located between protein coding genes. Although located in intergenic space, this region impacts the expression of nearby genes. This information demonstrates that variants within intergenic regions contribute to *Bt* Cry3Bb1 resistant phenotypes in *D. v. virgifera*. The role of this nucleotide variation in causing differences in *Bt* resistance remains unknown, and remains the focus of continued research.

Session 6-T 7 - Genomics in current and future maize pest research

Monitoring for resistance to *Bt* corn using targeted sequencing

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The evolution of resistance is the biggest threat to the sustainable use of insecticidal proteins used as plant incorporated protectants (PIPs) in transgenic maize. Monitoring of resistance alleles is critical to implement effective resistance management programs in preserving economic and environmental benefits of PIPs. Hi-plex targeted sequencing represents a DNA-based approach to detect candidate resistance alleles and predict resistant phenotypes in field-collected insects. In this presentation, we will share our work on validating targeted sequencing to monitor for resistance to PIPs from the bacterium *Bacillus thuringiensis* (*Bt*) in populations of the fall armyworm (*Spodoptera frugiperda*), a superpest threatening global food and fiber production. Current challenges and limitations of this technology will also be discussed.

Crop diversification for fall armyworm management: elucidating pest-plant-natural enemy interactions

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The fall armyworm (FAW), *Spodoptera frugiperda*, is a devastating invasive crop pest and a threat to food security in Africa, with yield losses of 20–50%. Previous work from our laboratory highlighted the importance of cereals such as maize and sorghum as the most preferred host plants for oviposition by the FAW. In this study, we hypothesized that odours released by companion crops in a maize-based intercropping system would reduce oviposition responses of the FAW. In dual choice oviposition assays, we found that the FAW laid significantly more eggs on maize than on beans, groundnut, sweet potato, cassava, greenleaf and silverleaf desmodium. However, significantly fewer eggs were laid on maize when companion plants volatiles were present. Markedly, the presence of cassava did not affect the oviposition responses of the FAW. Wind tunnel bioassays confirmed decreased maize attractiveness to FAW moths in the presence of companion plant volatiles. Interestingly, FAW larval endo parasitoid *Cotesia icipe* was attracted to volatiles from the individual companion plants and when they were combined with maize. Coupled gas chromatography-mass spectrometric (GC-MS) analysis detected major volatile organic compounds such as (*E*)-β-ocimene, (*E*)-4,8-dimethyl-1,3,7-nonatriene, camphor, and (*E, E*)-4,8,12-trimethyl-1,3,7,11-tridecatetraene in the headspace collection of companion plant volatiles influencing FAW and *C. icipe* behaviour. Our finding provided evidence supporting that maize diversification could reduce FAW damage by repelling the pest while recruiting its natural enemies and could serve as an ecologically sustainable FAW management strategy.

Key: crop diversification, fall armyworm, plant volatiles, companion plants, bioassay, pest management

Effect of planting dates on fall armyworm infestation and its parasitoids

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Since its invasion in Africa, fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith), has been studied considerably. However, much research still remains to be done in order to fully understand its biology and ecology in its new environment. Agronomic advice recommends farmers to plant early to avoid peak infestation later in the rain season. As this advice wasn't supported with empirical evidence, we assessed the effect of planting dates on FAW infestation and parasitoid occurrence. We planted maize plots at three different dates; at the onset of the rain (early), at three weeks (medium) and six weeks (late) after the onset of the rain. From maize emergence, FAW larvae and eggs were collected randomly every week on 100 plants for each plot. Larval stage was recorded in the laboratory, and larvae were fed until moth or parasitoid emergence. Our results indicate a significant effect of planting dates treatment on FAW density where late planting has 3.17 times higher FAW density than the early planting. Planting date treatment and FAW stage had a significant effect on parasitism rate of FAW. The early planting date treatment had lower parasitism rate than the late planting date treatment. Results on parasitoids occurrence showed a significant effect of maize stage and FAW density on parasitoid abundance and diversity. In conclusion, our study supports the general recommendation that planting early is advantageous to avoid the build-up of FAW population and provide new insights into local parasitoids' ecology.

Alteration of maize phytochemistry and fall armyworm (*Spodoptera frugiperda*) resistance by push-pull cropping soil legacies

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Plants can alter nutritional availability, structure and chemistry of the soil they grow in. These soil changes can positively or negatively influence growth and metabolism of other plants that co-occur or grow later in the conditioned soil. Plant-soil feedbacks could affect community interactions and dynamics but also be applied in sustainable agriculture to promote plant growth and resistance to pests. In this study we used a maize-*Desmodium*-*Brachiaria* grass companion cropping system, commonly known as “push-pull”, as a model to investigate soil-mediated effects of functional biodiversity, on maize plant growth and resistance against the newly invasive herbivore, *Spodoptera frugiperda*. We grew maize in soils collected from push-pull (polyculture) and non-push-pull (monoculture) smallholder farms. We evaluated maize performance by measuring plant growth, as well as resistance traits (larval feeding, production of defense-related volatile and non-volatile secondary defense metabolites). Maize plants grown in soil conditioned by push-pull had a higher growth rate compared to those grown in soil from non-push-pull fields. In addition, soil from push-pull fields induced a constitutively higher and qualitatively different emission of volatile organic compounds than soil from non-push-pull fields. Moreover, secondary defense metabolites including 2,4-dihydroxy-7-methoxy-2H-1,4-benzoxazin-3(4H)-one, were produced in larger quantities in plants grown in soil from push-pull fields compared to those from monoculture fields. These soil-mediated alterations in plant secondary metabolism were associated with reduced herbivory by larvae of *S. frugiperda*. This study provides novel evidence that plant-soil feedback can affect plant metabolism, growth and resistance to a new invasive pest as well as additional mechanism of pest control in push-pull cropping systems.

Maize-legume intercropping soil legacies alter maize growth and fall armyworm (*Spodoptera frugiperda*) larval feeding

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Plant-soil feedback can influence aboveground interactions between plants and herbivores by affecting plant chemistry. Such interactions can be utilized in pest management in agroecosystems. However, how different maize-legume intercropping (MLI) systems affect these interactions is not well understood. In this study, we used soil conditioned by different MLI and maize-monoculture (MMC) cropping systems to explore the effects of cropping system soil legacies maize plant growth and invasive *Spodoptera frugiperda* (Lepidoptera: Noctuidae) larval feeding. Soil samples were collected from smallholder farms in eastern Kenya, where different MLI and MMC cropping systems were being practiced and analyzed for physico-chemical properties using black oxidation and Walkley methods. Maize plants were grown in the collected soil in greenhouse and maize used for larval feeding when it was three weeks old by cutting leaf discs and carrying out disc feeding. Unfed *S. frugiperda* neonate larvae were also inoculated in another set of plants for 15 days and the larval survival and development monitored. Results indicated significant differences in growth parameters when maize plants were grown in MLI soil compared to those in MMC and sterilized soils. A high correlation was found between pH and plant biomass and a negligible correlation between some plants' biomass and N, Fe, OC, and K, while no significant correlation was noted for other physico-chemical properties. There were significant differences in larval feeding when unfed *S. frugiperda* neonates were exposed to constitutive and induced maize leaf discs. When allowed to feed for 15 days, *S. frugiperda* larval weights and lengths were significantly lower on maize plants grown in soils conditioned by MLIs than those grown in soil conditioned by MMC and sterilized soil. These findings show that MLI cropping system soil legacies improve soil nutrients, maize growth and reduces *S. frugiperda* larval feeding.

Preliminary studies on the use of *Metarhizium rileyi* for control of fall armyworm in Zambia

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As in most of sub-saharan Africa, fall armyworm (FAW) (*Spodoptera frugiperda* J.E. Smith) is a major pest of maize and other cereal crops. Currently, most of the control of FAW is carried out by applying chemical pesticides. However, natural alternatives are available. *Metarhizium (Nomuraea) rileyi* (Farlow) Kepler S.A. Rehner & Humber (Ascomycetes: Hypocreales), has been identified as a potential biocontrol agent. Initially, the fungus was isolated from infected FAW larvae and molecularly identifed prior to testing the isolates for their mass production capabilities. The *M. rileyi* was mass produced using a two-phase system resulting in commercial grade quality pure conidia. The conidia were intially tested with no formulating agent on FAW larvae, at extremely high doses, which resulted in 100% larval mortality. Further laboratory bioassays used sunfoil as the formulation agent. The sunfoil was toxic to the young larvae and not suitable as a formulating agent. Furthermore, field collected FAW were not ideal for carrying out bioassays as a large number of them were infected with parasitoids. At the end of January, a very early preliminary field trial will be carried out in Siavonga, Zambia. The results will be presented at the meeting.

A novel approach to management of *Spodoptera frugiperda* J.E. Smith for small-holder farmers using virus extract from larvae treated with baculovirus under field conditions

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Fall armyworm (FAW) is a major pest of maize and causes huge losses especially when control measures are delayed. Chemical control is the commonly used strategy against FAW since its arrival in Kenya in 2016. However, this strategy fraught with many challenges including cost, human and environmental safety and undesirable impact on beneficial organisms. Use of more sustainable and environment friendly options is more desirable. Efficacy of baculovirus against FAW has been proven and some commercial products are available but there is none in Kenya. This study evaluated potential of virus extracted for FAW larvae treated with baculovirus (Littovir, commercial baculovirus) for management of FAW under laboratory and field experiments. From the laboratory experiments, the virus extract from 25, 50, 75 and 100 FAW larvae caused varied mortality on FAW at different developmental stages. The highest mortality (45%) on 1st–3rd instars was caused by Littovir followed by virus extract for 100 FAW larvae (36%). Under field conditions damage and yield assessment showed that even though the virus extracts from FAW larvae did not offer adequate protection against the FAW, the yield in plots treated with the virus extract was comparable to those treated with commercial insecticides since there was no significant difference between the yields. This study has shown the potential of the use of virus extracts for management of FAW. This would offer the farmers a sustainable and affordable option for management of FAW as it would require the farmers to purchase the baculovirus once and collect larvae from treated plots for repeat application.

Trapping fall armyworm: the use of pheromones, trap design and lures for fall armyworm control

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Fall armyworm, *Spodoptera frugiperda*, is now a world-wide pest of maize and other agricultural crops. Pheromone traps and lures have been used in the U.S. since the 1970s and the pheromone blend, trap design, and trapping methodology has been improved over the years. Trapping can be used for monitoring migrating populations, determination of host strain status of populations, and in some instances, used as a threshold for management tactics. Trapping studies in the U.S. and in West Africa will be reviewed.

Fish soup attracts biodiversity of natural enemies of fall armyworm (*Spodoptera frugiperda* J.E. Smith)

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The fall armyworm (FAW), *Spodoptera frugiperda,* is an invasive pest that has wreaked havoc throughout Africa and beyond. It has caused crop losses across Africa which are estimated at $16 billion annually. The pest has rapidly spread and can develop resistance to chemical pesticides. Smallholder farmers have been applying various indigenous methods including the use of fish soup to control various lepidopteran pests of cereals. However, the abundance and diversity of insects attracted to cereal plants treated with fish soup are yet to be documented. This study assessed the impact of various concentrations of fish soup (100%, 50% and 10%) alongside control (water only) on the biodiversity of visiting insects and the damage caused by FAW under semi-field conditions. Pitfall traps and sticky yellow traps were used to catch visiting insects, their abundance and diversity were calculated using the Shannon-Weiner diversity index. Compared to the control, the plant sprayed with fish soup had the least foliar damage. Evidently, plants sprayed with fish soup attracted a rich diversity of visiting insects which are potential natural enemies of fall armyworms. The biodiversity of attracted insects in different orders varied across fish soup concentrations. Coleoptera, Diptera, Hemiptera, and Hymenoptera were the main four taxonomic orders of insects observed with the following abundance: - 426, 475, 253, and 1,096, and diversity: - 4.0, 5.3, 5.5, and 4.8, respectively. Unlike the dipterans, the biodiversity of coleopterans and hemipterans increased with an increase in the fish soup concentration. The biodiversity of hymenopterans was least affected by fish soup concentration. Identified natural enemies of FAW in different fish soup concentrations were from the following families: Ichneumonidae, Braconidae, Formicidae, Chalcididae, Eurytomidae, Diapriidae, Bethylidae, Agaonidae, Figitidae, Scelionidae, Platygastridae, Eulophidae, Chloropidae, Tachinidae, Sarcophagidae, Calliphollidae, Reduviidae, Nabidae, Pentatomidae, Miridae, Chrysomellidae, Carabidae, Coccinelidae, Staphynillidae, and Forficullidae. This study confirms that the fish soup has attractive effects on natural enemies that could be used to suppress the population of FAW. Further research is needed under field conditions to affirm these findings and for wider adoption of this low-cost agroecological practice.

Migration patterns of the invasive fall armyworm *Spodoptera frugiperda* (J. E. Smith) in China

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The fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith), is a crop pest native to the Americas and with long-distance migration capacity, omnivorous, high fecundity, and resistance to pesticides. It has spread since 2016 across the whole sub-Saharan Africa and rapidly invaded Asia and the Pacific, which have caused huge losses to global food security. In mid-December 2018, the invasion of FAW was detected in Yunnan Province of China. Maize is the most suitable host plant for the colonization of the invasive FAW in China, and it is also the most important crop with widest area in China. In this study, the atmosphere-related migration patterns from meso-scale to large scale of the windborne FAW in cropping regions of China will be revealed using data from field surveys, searchlight traps, meso-scale numerical simulations of atmospheric circulations, atmospheric trajectory analysis, Geographic Information System (GIS), and synoptic analysis. Two migration pathways of FAW were performed in China. The western pathway initiated from Myanmar and Yunnan Province of China, and FAW can simultaneously migrate along the eastern pathway from Indo-China and its year-round breeding regions in southern China. Moreover, the migration taking place over eastern China develops faster, which is strongly associated with the typhoon events that frequently occur in China. These results will provide key evidence to the early warning, green prevention, and ecological control for this invasive pest.

Exploiting agroecological approach for sustainable fall armyworm management in smallholder farming systems

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Smallholder farmers in Africa are vulnerable to crop losses to pests as they depend directly on the crops for their food security. The fall armyworm, *Spodoptera frugiperda,* is a new invasive pest that has rapidly spread across Africa since its arrival in early 2016, causing extensive damage to the staple food and cash crops like maize. As the result, the pest has become a serious and growing threat to food security and livelihoods for millions of resource poor smallholder African farmers. For example, *S. frugiperda* causes yield losses of about a third of the annual maize production in Kenya alone, estimated at about 1 million tons. Unlike large-scale farmers affected by FAW in America, use of insecticides and transgenic crops is problematic due to cost and availability of the technologies to smallholder farmers in Africa. Furthermore, the technologies may have undesirable consequences such as resistance development, environmental pollution, and risk to spray operators. To cope with these challenges, there is an urgent need to develop effective, affordable, and ecologically sustainable pest control strategies compatible with the local agroecosystems. In this talk, the prospect of agroecological approach for sustainable *S. frugiperda* management will be discussed using push-pull cropping system as an example.

Keywords: agroecology, push-pull, fall armyworm, food security, smallholder farming

Broadcasting of tiny granules by drone for the control of fall armyworm (*Spodoptera frugiperda*)

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The fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith), is an invasive pest. Corn is one of its preferred host plants. Traditional insecticide spraying provides poor control of FAW as FAW caterpillars live in the whorl of corn plants and a small amount of spraying droplets can be deposited in the plant whorl. This study innovates a method to replace liquid spraying by broadcasting tiny granules through drones for FAW control. For this method, the size of tiny granules was 40–60 mesh (0.25–0.43 mm), which was similar to the size range of spraying droplets. When tiny granules were broadcasted by a drone, the architecture of corn plant and the downward airstream of the drone impart favorable conditions for granule deposition in whorls. In our study, a drone equipped with a centrifugal granule sprayer was used to broadcast the tiny granules. Tiny granules gathered in the whorl accounted for 50.8–58.7% of the total tiny granules deposited in the corn canopy. The flight height of the aircraft was 1.5–4.0 m above the corn canopy, and the flight speed was 4–6 m s^{-1}. The field experiments demonstrated that the efficacies of tiny granules containing chlorantraniliprole + emamectin benzoate, chlorantraniliprole + lufenuron, or chlorantraniliprole + chlorfenapyr were > 90%. Besides, the *Bt* insecticide can also be formulated into tiny granules and broadcasted by a drone for the control of FAW.

Assessment of the optimal frequency of insecticide sprays required to manage fall armyworm (*Spodoptera frugiperda* J.E. Smith) in maize (*Zea mays* L.) in northern Ghana

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Insecticide use is an important component of integrated pest management strategies developed for fall armyworm (FAW), *Spodoptera frugiperda* J.E. Smith, control in maize in many African countries. In this study, the optimum number of synthetic insecticide and biopesticide applications needed to effectively manage FAW at a minimal cost in maize was studied. A 3 × 4 factorial experiment arranged in a split plot design was used. Insecticides [Neem seed oil (NSO), 3% Azadirachtin); Emastar 112 EC (emamectin benzoate 48 g/l + acetamiprid 64 g/l); Eradicoat (282 g/l Maltodextrin)] were on the main plots, while spraying regimes [untreated control, spraying once (at VE-V5 stage), twice (at VE-V5 and V6-V12 stages), thrice (at VE-V5, V6-V12 and V12-VT stages), four times (at VE-V5, V6-V12, V12-VT and R1-R3 stages)] were on the sub-plots. The results showed that larval infestations were generally lower in Emastar 112 EC treated maize than in those sprayed with Eradicoat or NSO. Infestations were higher in the untreated control (no spray) but decreased with increases in number of spray applications in insecticide-treated plots. Again, crop damage was low in Emastar 112 EC treated maize. This variable also decreased with an increase in the number of spray applications. Grain yield was significantly affected by the spraying regime only, with this variable being lowest in the untreated control. In both years, yields were at least 1.5-fold higher in maize sprayed twice, thrice or four times compared to the untreated control. Emastar 112 EC had the highest net economic benefits. A single spray of Emastar 112 EC at the VE-V5 stage resulted in maximum profits, while two sprays (i.e., at VE-V5 and V6-V12) were needed for Eradicoat and NSO. Hence, synthetic insecticides and biopesticides require different frequency of spray applications for cost effective management of FAW in northern Ghana. These findings are potentially applicable in other sub-Saharan African countries where this pest is present.

Indigenous agroecological strategies for controlling fall armyworm (*Spodoptera frugiperda* J.E. Smith) in Africa

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Lepidopteran pests are a threat to cereal production in Africa. Therefore, smallholder farmers have over the years used indigenous practices such as fish soup sugar solution, wood ash and diatomaceous earth to manage these pests. With the arrival of fall armyworm (FAW), *Spodoptera frugiperda,* in Africa in 2016, farmers have adopted these existing indigenous methods as part of management options. However, the efficacy and mechanism of actions of these indigenous methods are yet to be explored. Therefore, we assessed their efficacy against FAW in a semi-field experiment and developed a standard operating procedure for scaling. To evaluate their efficiency in FAW suppression, fish soup sugar solution, wood ash, and diatomaceous earth alongside control (water only) were sprayed on potted maize plants (four-week-old) that were artificially infested with FAW eggs. Compared to the control, indigenous practices caused reduction in FAW foliar damage and increased plant recovery rate. The undiluted fish soup (100%) resulted in the least foliar damage (13 ± 3%), followed by 50% fish soup (23 ± 1%), and 10% fish soup (34 ± 3%). When wood ash and diatomaceous earth were applied, foliar damage recorded were 58 ± 9% and 70 ± 9%, respectively. The plant recovery rate inversely correlated with foliar damage. Maize plants treated with water only did not recover from FAW foliar damage. By modelling, we estimated that 25.9% and 21.8% concentrations of fish soup are required to reduce the foliar damage to 17.8% and achieve 73.6% plant recovery, respectively. Maize plants treated with fish soup had least foliar damage, quicker recovery and improved growth (plant height and chlorophyll content) than wood ash and diatomaceous earth. This study confirms the efficacy of the three indigenous management practices and recommends the use of fish soup for effective management of fall armyworm.

Keywords: Fish soup, foliar damage, lepidopteran pests, plant recovery, smallholder farmer.

Integrated management for the invasive fall armyworm in China

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The fall armyworm, *Spodoptera frugiperda* (Smith), is native to the tropical and subtropical regions in the Americas. It has been one of the most important insect pests of corn and another migratory pest that migrate north in spring and back south in autumn and has been observed for infesting corn and other 22 crops in 24 provinces since invaded in China in January of 2019. The annual generations of the fall armyworm were one to seven from north to south of China. In order to manage of the invasive pest, a national monitoring and early warning system based on insect radar combined with searchlight traps and sex pheromone traps was set up to provide the information of population dynamics and the possible landing regions during migrating to the main corn growing regions. Strategies for fall armyworm, including the regionalization management strategy with different control measures, resistant variety screening, biological control with biopesticides and natural enemies, physical control, seed coating, resistance to insecticides monitoring, new application technique for insecticide of broadcasting tiny granules by drone. Several integration and demonstration models for fall armyworm management have been put into use in different corn growing regions. Technical specifications for forecast and control of fall armyworm issued by Ministry of Agriculture and Rural Affairs of China in 2021.

Attraction of *Spodoptera frugiperda* to a host plant volatile compound

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Plant volatiles, released by the majority of vascular plants on a constant basis, play an important role in host location of insects. They could also synergize the effectiveness of sex pheromones of insect pests, and thus contribute to the development of more powerful pheromone lures for insect monitoring and control. In this study, we deployed the electroantennography (EAG), Y-tube and field trials to identify a plant volatile synergist for sex pheromone of the fall armyworm, *Spodoptera frugiperda* (J.E. Smith). The results showed that both male and female moths had an electrophysiological response to linalool oxide. The female moth showed the highest electrophysiology response value (0.40 ± 0.051 Mv) to linalool oxide at lower dose, while significantly repelled by linalool oxide at higher dose. The behavioral bioassays showed the female moths were strongly attracted by linalool oxide at lower dose. Furthermore, field trials showed that the sex pheromone lure with linalool oxide can enhance the trapping efficiency of *S. frugiperda* up to about 50% compared with sex pheromone lure alone on maize plants. The findings of this study showed that there are higher potentials to develop more effective pheromone and pheromone synergist lures for the sustainable management of *S. frugiperda*.

Key words: Fall armyworm; olfactory response; linalool oxide; synergist

Competitive plant-mediated and intraguild predation interactions of the invasive *Spodoptera frugiperda* and resident stemborers *Busseola fusca* and *Chilo partellus* in maize cropping systems in Kenya

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As a result of *Spodoptera frugiperda* invasion in African countries, it now co-exists with resident stemborers such as *Busseola fusca* and *Chilo partellus* causing severe damage to maize crops. Given that these lepidopterans exhibit similar population phenology and feeding preference for several widely distributed cultivated plants including maize, interspecific competitions are likely to occur between both species especially at larval stage. A number of field surveys have reported co-occurrence of *S. frugiperda* and stemborers in maize fields in Africa, but the actual occurrence, magnitude and exact mechanistic basis of interspecific interaction remain unclear. In our study, we assessed plant-mediated interactions and predation in laboratory and semi-field settings, and larval field occurrence of these insect pests. Larval feeding assays to evaluate competitive plant-mediated interactions demonstrated that initial *S. frugiperda* feeding adversely affected subsequent stemborer feeding and survival, suggesting induction of herbivore-induced mechanisms by *S. frugiperda*, to deter colonization and survival of stemborers. Predation assays showed that, at different developmental larval stages, second–sixth instars of *S. frugiperda* preyed on larvae of both *B. fusca* and *C. partellus*. Predation rates of *S. frugiperda* on stemborers was significantly higher than cannibalism of *S. frugiperda* on its conspecifics. Cannibalism of *S. frugiperda* in the presence of stemborers was significantly lower than in the presence of conspecifics. Field surveys showed a significantly higher number of *S. frugiperda* larvae than stemborers across three altitudinally different agroecological zones. The study showed that the invasive *S. frugiperda* has competitive advantages over resident stemborers within maize cropping systems in Kenya. Our findings reveal some of the possible mechanisms employed by *S. frugiperda* to outcompete resident stemborers and provide crucial information for developing pest management strategies for these lepidopteran pests.

Poster 01
Session 6 - Genomics in current and future maize pest research

The USDA-ARS Ag100Pest Initiative: Developing chromosome-level genome assemblies for corn pest insects

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The United States Department of Agriculture Agricultural Research Service (USDA-ARS) Ag100Pest Initiative is generating high-quality reference genome assemblies for the "top 100" arthropod pests of agricultural significance in the United States; https://scinet.usda.gov/working-groups/ag100pest . The maize pest species currently being sequenced include: the corn earworm, *Helicoverpa zea*; western bean cutworm, *Striacosta albicosta*; ecotypes of the European corn borer, *Ostrinia nubilalis*; southwestern corn borer, *Diatraea grandiosella*; corn plant hopper, *Peregrinus maidis*; corn silk flies, *Euxesta* spp.; and the corn rootworms, *Diabrotica barbari*, *D. undecimpunctata, and D. virgifera virgifera*. The project used a strategy to assembly contigs from long circular consensus sequence (CCS) reads followed by high-throughput chromosome conformation capture (Hi-C) scaffolding. Thus far, assemblies for *H. zea* and *P. maidis* are at chromosome-level. The 375.2 Mbp *H. zea* assembly was made from a single male pupa from a *Bacillus thuringiensis* (*Bt*) Cry1AcR resistant strain and comprised of 30 autosomes and the Z sex chromosome that ranged from 7.2 to 18.8 Mb. The 759.6 Mbp *P. maidis* genome is scaffolded onto 15 chromosomes that are 16.6 to 88.9 Mbp. A contig level assembly of the *D. v. virgifera* genome assembly is completed with 2,178 fragments with a median size (N50) of 1.3 Mbp and maximum length of 25.7 Mbp 2,178 fragments, and Hi-C scaffolding is currently underway. These and future genomes will be resources for investigating variation and population dynamics that contribute to the evolution of resistance to control tactics, and may contribute to efforts to develop sustainable insect resistance management practices and improved integrated pest management strategies.

Poster 02
Session 6 - Genomics in current and future maize pest research

Reverse chemical ecology leads to the identification of new agonists of insect odorant receptors

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Odorant receptors (ORs) are transmembrane proteins expressed in animal olfactory sensory neurons. They are at the core of odorant detection since they recognize odorants and trigger a neuronal response that will be transmitted to the central nervous system. However, most of these ORs are still orphans, which means the odorants that activate them are unknown. The so-called "reverse chemical ecology" or "molecular chemical ecology" approaches propose to use OR-ligand and/or OR-sequence characteristics to identify potential new ligands via a combination of modelling and experimentation, which have the potential to accelerate the discovery of new ligands. Using the crop pest moth *Spodoptera littoralis* (Lepidoptera; Noctuidae), we used such approaches for the study of insect ORs. Ligand-based virtual screening coupled to experimental validation led us to extend the range of semiochemicals active at the receptor and the behavioural levels.
Our work opens new routes for i) odorant receptor function analysis, ii) a better understanding of this species odor space, and iii) the development of novel insect pest control strategies targeting chemosensory receptors.

References
-Caballero-Vidal G., Bouysset C., Gévar J., Mbouzid H., Nara C., Delaroche J., Golebiowski J., Montagné N., Fiorucci S., Jacquin-Joly E. (2021). Reverse chemical ecology in a moth: machine learning on odorant receptors identifies new behaviorally active agonists. ***Cellular and Molecular Life Sciences****, 78 (19-20), 6593-6603*
-Caballero-Vidal G., Bouysset C., Grunig H., Fiorucci S., Montagné N., Golebiowski J., Jacquin-Joly E. (2020). Machine learning decodes chemical features to identify novel agonists of a moth odorant receptor. ***Scientific Reports****, 10 (1), 1655*

Poster 03
Session 1 - Maize lepidopteran pests and mycotoxins

Western bean cutworm (*Striacosta albicosta* Smith) chemical management in intensive corn production in North America

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The western bean cutworm (Lepidoptera: Noctuidae) is a native insect owlet moth in North America that is recognized as an economically important pest of corn (*Zea mays* L.) and dry bean (*Phaseolus vulgaris* L.) in the western Great Plains of the United States (US) and the Great Lakes region in the US and Canada. *S. albicosta* is univoltine moth. Direct larval feeding on the kernel can cause severe yield loss in corn. Feeding on ears also provides a suitable environment for secondary fungal infections, which influence the quality of corn grain. The ideal timing for western bean cutworm management with insecticides is once per year when corn is fully grown with 95% of tasseled plants. Therefore, the majority of corn growers apply insecticides by airplane targeting this pest, while some of them apply insecticides by central pivot irrigation which is known as chemigation. Information about efficacy of chemigation for control of *S. albicosta* is limited. For that reason, two years of field studies were conducted to determine the efficacy of chemigation using different insecticides on the control of western bean cutworm. Bifenthrin and chlorantraniliprole were used at their highest (6.4 and 20 fl oz/ac) and lowest label rates (2.1 and 14 fl oz/ac) and applied through central pivot irrigation at two carrier volumes of water (0.25 and 0.75 acre-inches). Plastic jars positioned within each plot were used to collect chemigation samples. Plots were scouted for the presence of live or dead *S. albicosta* adults, eggs, and larvae by destructive sampling of 10 plants per plot at 7, 14, and 21 days after treatment (DAT). At 28 DAT, 10 ears per plot were collected and assessed for the presence and size of larvae and the amount of feeding damage (cm^2) was measured. The percent of infested ears, amount of feeding, and potential yield loss was compared between all treatments.

Poster 04
Session 2 - Biocontrol of FAW

Minimum effective dosage of entomopathogenic nematodes at controlling fall armyworm and preventing damage under field conditions

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Novel formulations of entomopathogenic nematodes (EPN) have been developed as biological control solutions against the caterpillars of the fall armyworm, *Spodoptera frugiperda* (FAW) on maize. This was through a collaboration between the University of Neuchâtel in Switzerland, CABI, and Rwanda Agriculture and Animal Resources Development Board (RAB). We showed in laboratory experiments, that among 40 strains of EPN representing twelve species, most could effectively control FAW caterpillars, while inoculated with just ten EPN. Under field conditions, usually 3000 EPN are advised to be used per maize plant to effectively reduce FAW populations and to prevent damage. In order to potentially reduce costs, we tried to further reduce EPN dosages and to assess the minimum effective dose of those formulated EPN under real-time farming conditions. We implemented dose-response trials in two maize fields in Rwanda, assessing 375, 750, 1500, 3000 and 6000 EPN applied as a gel into the leaf whorl of a maize plant. Preliminary results revealed that the number of recommended EPN can likely not be further reduced under the here-considered farming conditions of Rwanda. Treatments of 3000 or 6000 EPN clearly reduced pest numbers and prevented some damage. However, re-infestation by FAW quickly happened within two weeks after treatment, as common for the region, requiring multiple treatments. In summary, application techniques of EPN against FAW have now been largely resolved, emphasizing the potential for the development of a commercial EPN product against FAW in maize

Poster 05
Session 5 - Host plant resistance to FAW

Response of selected tropical maize genotypes under natural infestation by fall armyworm, *Spodoptera frugiperda* (J.E. Smith)

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Fall armyworm (FAW) (*Spodoptera frugiperda* (J.E. Smith)) is a polyphagous pest causing significant losses to maize crop in sub-Saharan Africa. We undertook a study to evaluate the extent of FAW damage on six selected tropical maize hybrids and OPVs under natural infestation at five locations in Kenya, namely Mtwapa, Kiboko, Embu, Kakamega and Kitale. The selected genotypes included two commercial hybrids (WE2115 and CKH10717), two OPVs (ZM523 and KDV4), and two FAW-tolerant hybrids (CKHFAW180294 and CKH191221). Foliar and ear damage scores were recorded on a 1–9 scale (1 = no damage, and 9 = highest damage) and grain yield was recorded. Highly significant differences ($p \leq 0.001$) were recorded among the tested genotypes for both foliar and ear damage. The lowest average foliar damage scores recorded were 3.2 and 3.6 on CKH191221 and CKHFAW180294, respectively, while the lowest ear damage score (1.8) was recorded on CKH191221. Yield loss was estimated to be 8–10% on the FAW tolerant genotypes, while the losses ranged from 38% to 41% on the two commercials hybrids, and 45% for the two OPVs. Cost analysis showed that adoption of CKHFAW180294 and CKH191221 along with the synthetic pesticide treatment could result in 10–11% extra cost to produce an extra ton of grain per hectare (ha). For the commercial hybrid checks and the OPVs, the cost to produce an extra ton of grain with pesticide treatment was 48–66% and 99–121%, respectively. These results showed it may not be profitable for smallholders to treat FAW-tolerant hybrids with synthetic pesticides. However, the FAW-tolerant hybrids CKH191221 and CKHFAW180294 offer promise to be part of an IPM strategy to control FAW. These hybrids should be further tested widely for adaptability to different agro-ecologies in sub-Saharan Africa.

Keywords: Fall armyworm, maize, native genetic resistance, yield loss, natural infestation, cost analysis.

Poster 06
Session 5 - Host plant resistance to FAW

Breeding for native genetic resistance to fall armyworm in late-maturing tropical maize germplasm

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Fall armyworm (FAW) [(*Spodoptera frugiperda* (J.E. Smith)] has caused significant losses to maize production in sub-Saharan Africa since it was first identified on the continent in 2016. Maize germplasm resistant to FAW as part of an integrated pest management strategy is needed to reduce the impact of this pest on maize production. The International Maize and Wheat Improvement Center (CIMMYT) screened diverse maize genetic resources since 2018 under FAW artificial infestation at the screening facility in Kiboko, Kenya, and identified FAW-tolerant/resistant lines for introgression into mid-altitude-adapted tropical maize germplasm. Populations were developed between elite late maturity lines and FAW-tolerant lines, and doubled haploid (DH) technology was used to quickly develop new lines. The response of 260 DH lines to FAW artificial infestation was assessed in 2020. Foliar damage (FD) was scored at 7, 14 and 21 days after infestation. Significant differences among the lines were detected for FD and other parameters. FD score ranged from 4.2–7.3, with heritability 0.57. Based on these results, 75 DH lines with FD score similar to that of resistant check CML71 (5.4) were selected for validation under FAW artificial infestation for two subsequent crop seasons. Across seasons, heritability for FD scores at two different vegetative stages (score 2 and 3) was 0.75 and 0.60, respectively, while that for ear damage was 0.59. Four DH lines were identified to have FD score and ear damage comparable to that of the best FAW resistant check, CML71. The four DH lines have been used to develop three-way cross hybrids for testing under FAW infestation and optimal conditions for grain yield potential. The availability of effective screening protocols and use of DH technology to speed up line development are essential for rapid progress in breeding FAW resistant germplasm adapted to the mid-altitudes of sub-Saharan Africa.

Poster 07
Session 7 - Integrated pest management approaches and solutions for fall armyworm

Oviposition behavior and interspecific-competition between *Telenomus remus* (Hymentoptera: Platygastridae) and *Trichogramma* spp. (Hymenoptera: Trichogrammatidae) on *Spodoptera frugiperda* (Lepidoptera: Noctuidae)

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Telenomus remus and *Trichogramma* spp. are the most widely used biocontrol agents in controlling the invasive pest, *Spodoptera frugiperda*. The interspecific competition between *T*. *remus* and *Trichogramma* strains on the same host, egg mass of *S. frugiperda* were investigated for 24 h under laboratory condition at 26 ± 1˚C, 60–70% RH and 16L:8D. *Telenomus remus* collected from China and three *Trichogramma* strains from each of collaborative countries, China and Myanmar, were tested. Significant difference in egg parasitism was recorded when *T*. *remus* and each *Trichogramma* strain were simultaneously released, achieving the higher parasitism by the combined release of *T*. *remus* and *T*. *chilonis* (T. c YS) from Myanmar with 70% (89.8 eggs) than that of *T*. *remus* alone being 51.1 eggs. Overall, the egg parasitism by combined release of *T.* remus and *Trichogramma* strains was significantly higher compared to *T*. *remus* and *Trichogramma* spp. release under laboratory condition, reaching 21.5%–41.4% and 40.7%–65.7%, respectively. The time spent for oviposition process by *T*. *remus* was significantly shorter than that of *Trichogramma* spp. Ovipositional behavior was reflect to the egg parasitism. This study pointed out that combined release of two different egg parasitoids resulted in higher egg parasitism without showing any interfering each other. Further studies on these two parasitoids are still needed to understand in detail their interspecific competition or interaction under field conditions.

Poster 8
Session 7 - Integrated pest management approaches and solutions for fall armyworm

Susceptibility of fall armyworm to insecticides in South Africa

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The fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae), overwinters in tropical and sub-tropical regions only. Most of the South African maize production areas is in a temperate zone, with only a small area in the country suitable for persistence of this pest. Its pest status in the main maize production area is therefore reduced to either an annual or sporadic pest, depending on the production area. Commercial farmers plant mainly genetically modified *Bt* maize, which provide good control of the pest. However, FAW is controlled by means of insecticide applications in maize seed productions and in non-*Bt* crops. One of the challenges posed by chemical control is the potential for resistance evolution. Toxicity bioassays provide base-line data for insecticides and is therefore an important part of an insecticide resistance management program. The aim of this project was to estimate the susceptibility of FAW from its subtropical overwintering area in South Africa to insecticides. Commercial formulations of beta-cypermethrin, chlorantraniliprole, chlorpyrifos, emamectin benzoate, flubendiamide, indoxacarb, lufenuron, methomyl and spinetoram were used in susceptibility testing, which were done according to the protocols of the IRAC susceptibility test methods. The lethal concentration estimated to kill 80% of the FAW population of the respective insecticides, were below the recommended dosage rates, except for beta-cypermethrin. Although control failure is expected with applications of beta-cypermethrin at the recommended rate, control of the pest is expected with chlorantraniliprole, chlorpyrifos, emamectin benzoate, flubendiamide, indoxacarb, lufenuron, methomyl and spinetoram. The rate of resistance evolution to insecticides is influenced by the geographic position of the main maize production area in a temperate climate zone that is not suitable for persistence of FAW and good control of the pest currently provided by *Bt* maize.

Poster 9
Session 3 - Free themes

Western corn rootworm: a partial migratory species consisting of '*resident*' and '*migrant*' behavioral phenotypes

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A coherent understanding of adult western corn rootworm (WCR) (*Diabrotica virgifera virgifera* LeConte) movement ecology has remained elusive, but is critical to developing effective IPM and insect resistance management strategies and tactics. A wide array of data strongly supports both short-distance and long-distance lifetime displacement by WCR adults. The geographic scale of estimated net lifetime displacement of WCR ranges from a few 10s of meters to 100s of kilometers. Based on the evidence accumulated by the research community over many decades, we conclude that field populations of WCR consist of a mixture of two behavioral phenotypes, '*resident*' and '*migrant*'. A case such as this, where some individuals of a population migrate and some do not, is called partial migration, the most common type of migration among animal species. Individuals of both phenotypes engage overwhelmingly in appetitive (non-migratory) flights throughout their life, but only the migrant phenotype also engages in non-appetitive, migratory flight. Migratory flight is not initiated as a direct facultative response to proximate conditions. Instead, migration is innate to the migrant phenotype and is initiated in WCR females during a narrow developmental window after mating but before egg maturation. Migratory flight is straight-line (non-meandering), and in WCR is not directed toward a geographic goal or in a preferred direction. We propose a conceptual model of adult WCR movement ecology under the premise it is a partially migratory species.

Poster 10
Session 3 - Free themes

Engineering bacterial symbionts of entomopathogenic nematodes to enhance their biological potential against the western corn rootworm

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Maize plants synthesize a variety of secondary metabolites which play important roles in the plant's life cycle, including defence and other plant-insect interactions. A particular secondary type of metabolites of maize are benzoxazinoids which act as allelochemicals and natural pesticides. However, the specialist insect *Diabrotica virgifera virgifera* is able to sequester benzoxazinoids and use these plant toxins to defend themselves against entomopathogenic nematodes and their bacterial symbionts, limiting their biocontrol potential. Therefore, we wanted to understand the genetic mechanisms of benzoxazinoid resistance in those symbiotic *Photorhabdus* bacteria. For that reason, we isolated 27 *Photorhabdus* symbionts from different nematodes from all over the world and increased their benzoxazinoid resistance through experimental evolution. Indeed, benzoxazinoid resistance evolved through multiple mechanisms, including a mutation in a multidrug efflux pump. We then reintroduced benzoxazinoid-resistant *Photorhabdus* strains, as well as their non-selected ancestors, into two strains of *H. bacteriophora* nematodes and identified four nematode–symbiont pairs that were able to kill benzoxazinoid-sequestering *D. virgifera virgifera* larvae more efficiently under lab conditions. Tested in the field, the control effects of these nematodes were similar to the effects of commercial nematode strains, suggesting that other pathogenicity factors (rather than benzoxazinoid resistance) are more relevant for biocontrol under field conditions. Nevertheless, our results suggest that modification of bacterial symbionts and targeting candidate genes to engineer better biocontrol agents might provide a successful and time-efficient strategy to improve the pathogenicity of entomopathogenic nematodes against other agricultural pests.

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Poster 11
Session 3- Free themes

Application techniques for entomopathogenic nematodes against below- and above-ground maize pests

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Numerous lepidopteran and coleopteran pests have major impacts on maize production in many regions of the world. On the one hand, there are below-ground pests, such as grubs (Scarabeidae, Melolonthidae), wireworms (Elateridae), corn rootworms (Chrysomelidae), or cutworms (Noctuidae). On the other hand, there are above-ground pests such as armyworms, stem and stalk borers, bud and bollworms (all Noctuidae) or corn borers (Crambidae). Efforts to control these pests have led to an enormous influx of insecticides into the maize agroecosystem. One alternative is the use of entomopathogenic nematodes which can actively search for and kill a target pest, and are safe to humans, livestock, crop, and the environment. So far, their use had been limited to high-value crops. We herewith present recent developments towards more practical and less costly application technologies of nematodes in maize. Soil pests are newly controlled by nematodes through commercial into-soil applicators during sowing of maize, or special into-soil injectors that allow applications after plant emergence. Above-ground maize pests can be controlled by nematodes formulated in gels or other suspensions to protect them from UV light and desiccation and to keep them on the plants. These formulations can be applied as spot applications into leaf whorls. In conclusion, the importance of maize for food security and a decreasing acceptance and availability of insecticides, necessitates novel and more sustainable pest control strategies. Recent improvements of application technologies for the use of entomopathogenic nematodes, as well as an increasing availability of nematode products make them a promising alternative for crop protection.

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Poster 12
Session 3 - Free themes

Evaluating dose-responses of commercial insecticides against *Diabrotica v. virgifera* (Coleoptera: Chrysomelidae) for selecting proper positive controls in laboratory bioassays

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The western corn rootworm, *Diabrotica virgifera virgifera,* is a key insect pest of maize in North America and Europe. Due to recent bans of several insecticides in maize, researchers are in search for novel ingredients. Such assessments often start with standard laboratory bioassays either for the eggs, larvae, or adults of this insect. In order to screen for the effects of novel agents, positive controls are needed for comparisons preferably at a lethal dose of around 70 to 90%. As such information is often not published, and therefore not available for researchers, we investigated the effects of a number of commercial insecticides on the eggs, larvae, and adults of *D. virgifera virgifera*. Those were the neonicotinoids imidacloprid and acetamiprid, the pyrethroid cypermethrin, the organophosphate chlorpyrifos-methyl, the insect growth regulator novaluron, as well as spinosad. We applied dipping assays for eggs, and top-treatment artificial-diet bioassays for the larvae and adults under standardised laboratory conditions. Results revealed that imidacloprid, novaluron, chlorpyrifos methyl, spinosad, cypermethrin, and acetamiprid caused major mortality in the adults. Most insecticides also caused high mortality in larvae, but only few affected the eggs. We provide LD_{50} and LD_{80} values for the tested standard insecticides as positive controls for high-throughput screening assays. In conclusion, we believe that these results can be useful for researchers who want to pursue research on the evaluation new pest control agents.

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Poster 13
Session 3 - Free themes

Biogeography of cereal stemborers and their natural enemies: forecasting pest management efficacy under changing climate

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Climate warming presents physiological challenges to insects, manifesting as loss of key life-history fitness traits and survival. For interacting host–parasitoid species, physiological responses to heat stress may vary, thereby potentially uncoupling trophic ecological relationships. Here, we assessed heat tolerance traits and sensitivity to prevailing and future maximum temperatures for the cereal stemborer pests, *Chilo partellus*, *Busseola fusca* and *Sesamia calamistis* and their endo-parasitoids, *Cotesia sesamiae* and *Cotesia flavipes.* We further used the machine learning algorithm, Maximum Entropy (MaxEnt), to model current and potential distribution of these species. The mean critical thermal maxima (CT_{max}) ranged from 39.5 ± 0.9°C to 44.6 ± 0.6°C and from 46.8 ± 0.7°C to 48.5 ± 0.9°C for parasitoids and stemborers, with *C. sesamiae* and *C. partellus* exhibiting the lowest and highest CT_{max}, respectively. From the current climate to the 2050s scenario, parasitoids recorded a significant reduction in warming tolerance compared with their hosts. Habitat suitability for all stemborer–parasitoid species was spatially heterogeneous under current and future climatic scenarios. *Cotesia sesamiae, C. flavipes* and *B. fusca* exhibited significant habitat loss, whereas *C. partellus* and *S. calamistis* showed a significant habitat gain under future 2050s predictions. Model metrics based on mean area under the curve ranged from 0.72 to 0.84 for all species, indicating a good predictive performance of the models. These results suggest *C. sesamiae* and *C. flavipes* may face survival constraints or extirpation compared with their pest hosts when environmental temperature reaches their upper thermal limits earlier, likely reducing pest regulation through density-mediated effects. The results demonstrate potential destabilization of stemborer–parasitoid trophic systems potentially compromising biocontrol efficacy under climate warming.

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