

Project No. and Title: NC246: Ecology and Management of Arthropods in Corn
Period covered: 1/01/2023-12/31/2023
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Annual Meeting Dates: 01/23/2024-1/25/2024

Officers for 2024-25

Chair: Nick Seiter (Univ. of Illinois)
Vice Chair: Silvana Paula-Moraes (Univ. of Florida)
Secretary: Adrian Pekarcik (USDA-ARS, Brookings SD)

Contents

Participants	1
Brief summary of minutes of annual meeting	1
Accomplishments	5
Impacts	7
Publications	8

Participants

Bryant, Tim - Clemson University, Dayton, Jacob - Tufts University, Deeb, Susanne - University of Georgia, Buntin, G. David - University of Georgia, Calixto Soares, Eduardo – University of Florida, Caprio, Michael A. - Mississippi State University, Coates, Brad - USDA-ARS, DiFonzo, Chris - Michigan State University, Fisher, Kelsey - Connecticut Experiment Station, Gassmann, Aaron - Iowa State University, Guedes Pereira, Eliseu J. - University of Florida, Hamby, Kelly - University of Maryland, Huang, Fangneng - Louisiana State University, Hutchison, Bill - University of Minnesota, Jurat-Fuentes, Juan Luis - University of Tennessee, Krupke, Christian - Purdue University, Ludwick, Dalton - USDA-ARS, McManus, Bradley - South Dakota State University, Owens, Avalon - Harvard University, Paula-Moraes, Silvana - University of Florida, Pekarcik, Adrian - USDA-ARS, Porter, Pat - Texas A&M AgriLife Extension Service, Reay-Jones, Francis - Clemson University, Reisig, Dominic - North Carolina State University, Ruberson, John - University of Nebraska, Santiago Gonzalez, Jose - Texas A&M AgriLife Extension Service, Sappington, Tom - USDA-ARS, Seiter, Nicholas - University of Illinois, Smith, Jocelyn - University of Guelph - Ontario, Canada, Spencer, Joseph - Illinois Natural History Survey, Sword, Gregory - Texas A&M University, Yang, Fei - University of Minnesota

Brief Summary of Minutes of Annual Meeting

Tuesday, January 23, 2024 (restricted to NC246 members)

8:00 am - Administrative update by John Ruberson (University of Nebraska-Lincoln)
This year is a renewal year for our project. The project needs to be submitted to Dr. Ruberson by September 1 and completed by December 2024.

8:15 am - NC246 Group Discussion
Representatives of each state briefly reported updates about their work:

Florida: the year-round trapping of *Helicoverpa armigera* in collaboration with USDA/APHIS has not detected the target species. Collaborative work with representatives of the group from NCSU, Clemson, UMN, and Canada, led by UF has documented the long and short-distance capacity of CEW and the reproductive traits associated with flight capacity.

Tennessee: There is collaborative work in place *Ostrinia nubilalis* (ECB) for monitoring resistance. The work with CEW resistance to VIP and mechanism is in progress and it looks to be related to the binding mechanism of resistance. The laboratory of Fuentes has been producing toxins and providing to laboratories in other states to screen resistance.

Louisiana: The collaborative work with FAW has provided populations from several locations from the Gulf Coast and a reversion of susceptibility of FAW has been detected when contrasting previous data. This is especially true for populations from Florida.

Minnesota: Currently, there is collaborative work with ECB, including work with a population from a field close to Canada that was highly infested.

Maryland: The collaborative work of sentinel plots of sweet corn last year, led by UMD, had 62 planting plots. The results indicate variability in the performance of Bt traits throughout the areas. Sentinel plots will incorporate ECB damage ratings in 2024.

Connecticut: Corn is a small commodity in the state. Sampling detected *O. nubilalis* infestation on Cry 1 AB and Vip had an infestation in the ear and stalk. The larvae were collected but did not survive.

1:15 pm - Kemper Sutton (University of Georgia)

Results of a study of the impact of irrigation and crop (peanut and corn) in the rootworm *Diabrotica balteata* abundance was performed.

1:30 pm - David Buntin (University of Georgia)

Nurizma, a novel in-furrow liquid insecticide, demonstrated efficacy of control against rootworms.

1:45 pm - Avalon Owens (Rowland Institute of Harvard University)

A collaborative work in several states has been performed to document the impact of light pollution on responses of CEW across the U.S. The research is using CEW as a template organism since is a species that has been trapped for several decades. The decline in light traps may be due to competition with other sources of light or because of the decline. The data suggest that looking at light trap data alone should be done with caution when inferring a decrease in native species targeted by conservation. Several other factors may be related to the flight of CEW, considering flight behavior and even adaptive evolution to light population.

2:15 pm - Greg Sword (Texas A&M University)

Genomic surveillance and timely tales: introgression and evolution of pesticide via adaptation. The first evidence of OWB gene flow in the U.S. using insects across the south. At the whole

genome level, no evidence of introgression. Looking across the genome there is evidence of introgression at individual at the individual chromosome level. There are two individuals showing introgressions. CYp337B3 gene – chromosome 13– cytochrome P450: resistance to pyrethroids, novel to OWB, 1st found in Brazilian hybrids. In addition, based on the integrative approach to FAW population genomics, the whole genome analysis and strain composition differ across regions. The results indicated a selection of strains by geographics. Based on selective sweeps looked to Cytochrome P450, GST, and Ryanodine receptor. R and C strains are incipient species undergoing allochronic divergence.

3:00 pm – Short discussion to organize the NC246 project for industry discussions on January 24.

3:45 pm - Group discussion followed by decision to have the 2025 meeting location in Pensacola, FL.

4:30 pm - Silvana Paula-Moraes recognized Bill Hutchison and contribution to the group and Pat Porter recognized the work of Tom Sappington

5:00 pm – Adjourn

Wednesday, January 24, 2024 (open to industry)

8:00 am - Eduardo Calixto (University of Florida) – A collaborative work between Florida, North and South Carolinas, Minnesota, and Canada has estimated the continental movement of CEW based on isoscapes built considering Deuterium (^2H) latitude gradients. The results indicated a prevalence of migratory moths in northern locations and a mix of origins in FL, SC, and NC. The samples of moths from Puerto Rico indicated 15% being migratory populations.

8:15 am - Dominic Reisig (North Carolina State University)

The idea is to promote the refuge plantings. Several aspects influence farmers not to adopt refuge. Local marketing for non-Bt hybrids was not good. The “emotional appeal” has been used and the idea is to measure conditional cooperation using the example of the drainage problem in North Carolina. Farmers already involved in the drainage effort are more willing to adopt refuge. Cooperative growers are more receptive to refuge. Other cooperation in other areas/systems can contribute to the adoption of refuge, such as water conservation, etc.

8:30 am - Tom Sappington (USDA-ARS)

The presentation focuses on moths of ECB movement ecology. There are different types of flight behavior in this species, and important points should be considered when modeling. This species is a partially migratory species, with a dispersal capacity of 12 km, leaving the field on the night of the emergence, most of the moths mating in the nearby grass, and oviposition in a field that did not emerge. ECB movement can occur to at least 600-720km in regions of abundant host plants and few topographic barriers to movement like corn fields.

9:00 am - Jocelyn Smith (University of Guelph)

The presentation gave an overview of the ECB resistance to Bt corn Cry 1F in Canada. In the region that detected the resistance, there were still single toxin hybrids. The monitoring effort

increased and currently, a whole range in Canada is in place, including sentinel plots, pheromone traps, and talking with growers. The Resistance Ratio indicates an increase (>35) based on the criterion of $RR \geq 10$. In 2022, field sampling detected 10-15 % of plants with ECB injury, and bioassays indicated resistance to Cry1Ab and Cry1A.105. Resistance was also detected in Connecticut, which is approximately 800 km from the affected region in Canada. A fitness cost study was conducted, and the fecundity increased in the resistant population. Inheritance study of Cry 1F resistance indicated a single gene, autosomal, and recessive.

9:45 am - Tracey Baute (Ontario Ministry of Agriculture, Food, and Rural Affairs)

The discussion focused on ECB Bt resistance and possible resistance mitigation approaches to be adopted to monitor resistance and establish recommendations for resistance management.

2:00 pm - Kara Welch (Environmental Protection Agency)

In the last 6-7 years there was an expectation of a new IRM framework, which may be coming soon. There are some traits in the process of analysis.

2:30 pm - Matthew Carroll (on behalf of ABSTC)

An update on the IRM framework and PIPs was provided. Based on the EPA's proposal to review the IRM framework for lepidopteran pests, the following activities were performed: general alignment between industry and EPA; current focus on negotiation ongoing "co-packing" Bt and refuge seed; proof of refuge purchase; future topics for discussion regarding nationwide increase in refuge for all seed blend products from 5% to 10%. The 2023 sentinel plot results indicated that no site met or exceeded the phenotypic ratio of resistance (PRR). In 2024, the suggestion is to include injury to cover the larval hole. The focus of the investigation of unexpected injury (UXI) is focused on VIP for CEW. The monitoring of ECB resistance monitoring is primarily from Iowa, Minnesota, Nebraska, and South Dakota. More geographic locations need to be included and this is an ongoing discussion.

3:30-5:15 pm - Restricted presentations by Bayer and Corteva AgriScience

5:15 pm - Adjourn

Thursday, January 25, 2024 (restricted to NC246 members)

8:00 am – Dominic Reisig (North Carolina State University)

Southern corn billbug is an increasing pest in NC, especially in poor drainage areas. Adults feed on the corn plant and cause an injury that looks like FAW feeding. The primary way to control is using neonicotinoids (Poncho 1250) and it seems that the population is becoming resistant to chemical control. It seems there are several species, but the billbug is the main species causing damage in the region.

8:15 am - NC246 Group Discussion

The experience with entomopathogenic nematodes for pest control was discussed. In Texas, the nematodes were used in 2016 and the grower liked and asked to increase the application area by irrigation. In Iowa, Nebraska, and Illinois, there is ongoing research to assess the impact of agronomic practices and the impact on root health when EPNs are applied. With "Persistent Biocontrol", the nematode was applied via irrigation over fields with and without cover crops in

Nebraska, Iowa, and Illinois. No significant differences were found for adult abundance with sticky cards or emergence cages. Overall, the establishment may take time, and problems with equipment or environmental conditions. The future effort will be looking at the genetic analysis of recovered nematodes to determine if they are the species applied. In Canada, studies with the nematode have been also conducted with farmer interest concerning silage quality.

9:15 am - Silvana Paula-Moraes (University of Florida)

A short update was provided regarding the Endangered Species Act and the new EPA registration and re-registration of pesticides approach. Information about the new regulations for pesticides has been updated in the Entomological Society of America homepage and is available to be used for the effort to educate farmers and stakeholders in Extension.

9:30 am - Eliseu Pereira (University of Florida)

Results of the ecology of FAW resistance and associated fitness costs were presented and the work with populations of FAW in Brazil, documented a strong fitness component in corn, in cotton (with a magnification of feeding on cotton leaves). In addition, an incomplete resistance was detected.

9:45 am - Tim Bryant (Clemson University)

Several species of stink bugs are associated with crops and this complex represents the most important pests for corn in South Carolina. The ET has been established. Spatial patterns of stink bugs in field corn indicated that the late vegetative stage is the most critical moment for sampling them. Stink bug feeding/injury was negatively related to CEW larval injury.

10:30 am - Silvana Paula-Moraes (University of Florida) *Helicoverpa armigera*

Currently, the concern is the possible occurrence of genetic introgressions and the risk of impact on the performance of management tools, such as chemical control. The plan was to have Dr. Todd Gilligan, currently the coordinator of the survey program for *Helicoverpa armigera*, but the risk of a shutdown of the federal government resulted in a decision to postpone the invitation to the 2025 meeting.

11:00 am – Adjourn

Accomplishments

Selected outputs:

A draft assemblage of the western corn rootworm genome was published (see Coates et al. 2023 under Research Publications), as well as a genome assembly of a Cry1Ac-resistant strain of corn earworm (Stahlke et al. 2022)

14 peer-reviewed journal articles were published detailing pest susceptibility to Bt toxins in the field, the inheritance of resistance, and/or the identification of resistance mechanisms for western corn rootworm, European corn borer, corn earworm, western bean cutworm, and fall armyworm (see the following under Research Publications: Dively et al. 2023; Huang et al. 2023; Kenedy et al. 2023; Kerns et al. 2023; Lin et al. 2023; Pereira et al. 2023; Reinders et al. 2023; Reisig et al.

2023; Santiago-Gonzalez et al. 2023 (a and b); Silva et al. 2023; Smith et al. 2023; Tandy et al. 2023; Wen et al. 2023).

Peer-reviewed articles were published comparing the movement behavior of western bean cutworm on Bt and non-Bt corn (see Montezano et al. 2023 under Research Publications) and the impacts of seed blend refuges on corn earworm phenological development (Pezzini et al. 2023b).

Management recommendations, actionable information on the components of corn trait packages, and estimates of losses due to invertebrate pests were published in 6 multi-state Extension publications as a result of coordination among members of this multi-state committee.

Multi-state Efforts

- A sentinel plot network coordinated by Galen Dively and Kelly Hamby (University of Maryland) since 2017 now includes sites in 26 U.S. states and 5 Canadian provinces (see publications, Dively et al. 2023). During the 2023 field season, NC246 member Kelsey Fisher observed elevated injury from European corn borer in sweet corn lines expressing several Bt proteins at one of these sentinel plot sites – possibly the first time this has been observed in the U.S.
- Erin Hodgson and Ashley Dean (Iowa State University) and Tracey Baute (Ontario Ministry of Agriculture, Food, and Rural Affairs) coordinated a multi-state corn rootworm monitoring network (see Dean et al. 2023, “Selected Extension Materials”) across 10 U.S. states and 2 Canadian provinces.
- Populations of fall armyworm and corn earworm from 8 states in the southern U.S. (AR, FL, GA, LA, MS, SC, TN, TX) were sent to Fangneng Huang to investigate susceptibility to Bt proteins (FAW) and conventional insecticides (FAW and CEW).
- A USDA-NIFA grant through the Pest and Beneficial Species program area of the AFRI Foundational Program was awarded to Dalton Ludwick with co-PIs from Texas, Nebraska, Illinois, and South Dakota to examine non-target effects EPNs applied for corn rootworm control.
- Julie Peterson (University of Nebraska) obtained funding from the Nebraska Corn board to support a multi-state, on-farm effort funded by Corteva on the application of entomopathogenic nematodes and the adoption of cover crops for rootworm management (other NC246 members involved in this project include Gassmann – IA, Spencer – IL, Seiter – IL)
- Francis Reay-Jones (Clemson), Dominic Reisig (NCSU) and David Buntin (U. Georgia) have combined corn earworm efficacy data for selected Bt products over a 12-year period to examine trends in field efficacy and Bt resistance in corn earworm. Analysis is still on-going but field efficacy of older Cry1 Bt toxins has clearly declined over that time.
- A survey of growers in North and South Carolina highlighted adoption of IPM and IRM practices in field corn (see publications, Bryant et al. 2024).
- NC246 members Aaron Gassman (Iowa State University) and Dominic Reisig (North Carolina State University) reviewed the use of Bt crops in the United States (see publications, Gassmann and Reisig 2023)
- Christian Krupke (Purdue University) completed analysis and manuscript submission summarizing historical trends in Bt-RW corn planting and root damage. Data/contributors

from NC246 include: Christina DiFonzo, Aaron J. Gassmann, Erin W. Hodgson, Bryan Jensen, Janet J. Knodel, Bradley McManus, Lance J. Meinke, Andrew Michel, Bruce Potter, Nicholas J. Seiter, Jocelyn L. Smith, Joseph L. Spencer, Kelley J. Tilmon, Robert J. Wright.

- Juan Jurat-Fuentes (University of Tennessee) produced insecticidal proteins to facilitate research on resistance, including monitoring of field-evolved resistance. This material was distributed to NC246 members for use in their research: Dominic Reisig (North Carolina State University), Brad Coates (USDA-ARS Iowa), Julie Peterson (University of Nebraska), Jocelyn Smith (University of Guelph), Fei Yang (University of Minnesota).
- Kelley Tilmon (Ohio State) and Chris DiFonzo (Michigan State) completed a joint multiyear project on Asiatic garden beetle biology and management in Michigan and Ohio
- Dominic Reisig (North Carolina State) compiled data from 27 U.S. states and Ontario, Canada to estimate total invertebrate losses in corn for 2023 (see Reisig et al. 2024 under “Selected Extension Publications”).
- Kelly Hamby and Galen Dively (University of Maryland) are working to coordinate real-time sharing of corn earworm trap captures as well as archive historical data in the Southern IPM Center’s database (EDDMaps/AgPestMonitor).

Impacts

- Multi-state and international cooperation facilitated by this group continues to be instrumental in coordinating efforts to characterize and document resistance to corn hybrids with transgenic insect control traits – perhaps the most important insect control tools used by U.S. corn farmers. Committee members have documented field evolved resistance to Bt traits in western and northern corn rootworm, corn earworm, European corn borer, fall armyworm, and other insect pests. Extension efforts by committee members have translated these findings into practical management recommendations for farmers and other stakeholders.
- Members of this committee have developed regional integrated pest management recommendations for farmers to deal with emergent corn pests such as stink bugs in the southeastern U.S., Asiatic garden beetle in the Great Lakes region of northern Ohio and southern Michigan, and slugs in the Mid-Atlantic U.S.
- Multi-state pest monitoring efforts for corn rootworm and developing efforts for corn earworm moths provide actionable management information to U.S. corn farmers.

Multi-state Extension Publications

- Dean, A., E. Hodgson, and T. Baute. 2023 Regional Corn Rootworm Monitoring Network Summary. <https://cornrootworm.extension.iastate.edu/adult-trapping-network>
- DiFonzo, C., A. Pekarcik, K. Tilmon and A. Raudenbush. 2023. Pocket field guide to Asiatic garden beetle with emphasis on Great Lakes field crops. <https://aginsects.osu.edu/news/new-agb-pocket-field-guide-available>
- DiFonzo and Porter 2023 Handy Bt Trait Table. <https://www.texasinsects.org/bt-corn-trait-table.html>
- Igwe, P.-G., Cramer, M., Owens, D., Dively, G., and Hamby, K. 2023. Managing slugs in field crops using IPM principles, University of Maryland Extension Fact Sheet FS-2022-0629
- Reising, D., S. Graham, N. Bateman, G. Studebaker, R. Meyer, F. Reay-Jones, K. Wise, D. Owens, G. D. Buntin, J. Smith, N. Seiter, A. Sisson, A. Zukoff, R. Villanueva, K. Hamby, M. Cramer, C. DiFonzo, F. Yang, W. Hutchison, W. Crow, T. Towles, C. Floyd, J. Bradshaw, J. Peterson, P. Beauzay, J. Knodel, C. Krupke, K. Tilmon, T. Baute, A. Varenhorst, S. Brown, D. Kerns, P. Porter, S. Malone, E. Bick. 2024. Corn invertebrate loss estimates from the United States and Ontario, Canada – 2023. Crop Protection Network publication CPN-2019-23. <https://doi.org/10.31274/cpn-20240219-1>
- Reising, D. and F.P.F. Reay-Jones. 2023. Stink bug scouting guide for field corn in the southeastern US. <https://corn.ces.ncsu.edu/https-content-ces-ncsu-edu-stink-bug-scouting-guide-for-field-corn-in-the-southeastern-us/>

Other Selected Extension Materials

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- Cramer, M., and Hamby, K. 2023. Wet cool spring may increase slug damage. University of Maryland Agronomy News: May 2023 14(2): 7.
- Gassmann, A. and Brenizer, B. 2023. 2022 Iowa evaluation of insecticides and plant-incorporated protectants. Iowa State University, Department of Plant Pathology, Entomology and Microbiology.
- Gassmann, A. and Brenizer, B. 2023. Evaluation of experimental and registered soil-applied insecticides for management of larval corn rootworm. Central Iowa Research and Demonstration Farm Progress Report, Iowa State University.

- Gassmann, A. and Brenizer, B. 2023. Evaluation of RNA interference (RNAi) and Bt traits for management of larval corn rootworm in northeastern Iowa. Northeast Iowa Research and Demonstration Farm Progress Report, Iowa State University.
- Gerber, C., C. Krupke, et al. 2023. Purdue University Extension. Corn and Soybean field guide, includes pest descriptions, damage, and thresholds. 13,628 copies sold in 2023.
- Hanson, A., Macrae, I., Potter, B., Koch, R., Yang, F., 2023. Updated resource for grasshopper management. MN Crop News, <https://blog-crop-news.extension.umn.edu/2023/08/updated-resource-for-grasshopper.html>
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- Knodel, J.J., P. Beauzay, M.A. Boetel and A. Chirumamilla. 2023. 2024 North Dakota Field Crop Insect Management Guide E1143 (revised). NDSU Ext., Fargo, ND.
- Knodel, J.J., P. Beauzay, A. Friskop and S. Markell. 2023. IPM Basics Integrated Pest Management in North Dakota Agriculture PP863 (revised). NDSU Ext., Fargo, ND. (*Supported by USDA NIFA CCPM EIP)
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- Peterson J & R Wright. July 27, 2023. “Watch for Aphids in Corn.” Nebraska Extension CropWatch: <http://cropwatch.unl.edu>.
- Peterson J, R Wright, J Bradshaw & T Hunt. July 12, 2023. “Scouting and Treatment Recommendations for Western Bean Cutworm.” Nebraska Extension CropWatch: <http://cropwatch.unl.edu>.
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- Reisig, D., and E. Goldsworthy. 2023. Efficacy of selected in-furrow insecticides against southern corn billbug in corn, 2021. *Arthropod Manag. Tests*. Doi: 10.1093/amt/tsad072
- Reisig, D., and E. Goldsworthy. 2023. Efficacy of in-furrow insecticides against insect brown stink bugs in corn, 2020 & 2022. *Arthropod Manag. Tests*. Doi: 10.1093/amt/tsad073
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- Villanueva, R. T. ID-139: A Comprehensive Guide to Corn Management in Kentucky: Insect Pests of Field Corn (pages 74-85). 2023. 107 pp.
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Research Publications

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- Bryant, T., J. K. Greene, D. Reisig, and F.P.F. Reay-Jones. 2023. Within-field spatial patterns of *Helicoverpa zea* (Lepidoptera: Noctuidae) and spatial associations with stink bugs and their injury in field corn. *Journal of Economic Entomology*. 116: 1649-1661.
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