Biocontrol Technical Workshop Series 2022

Session 7: Semiochemicals

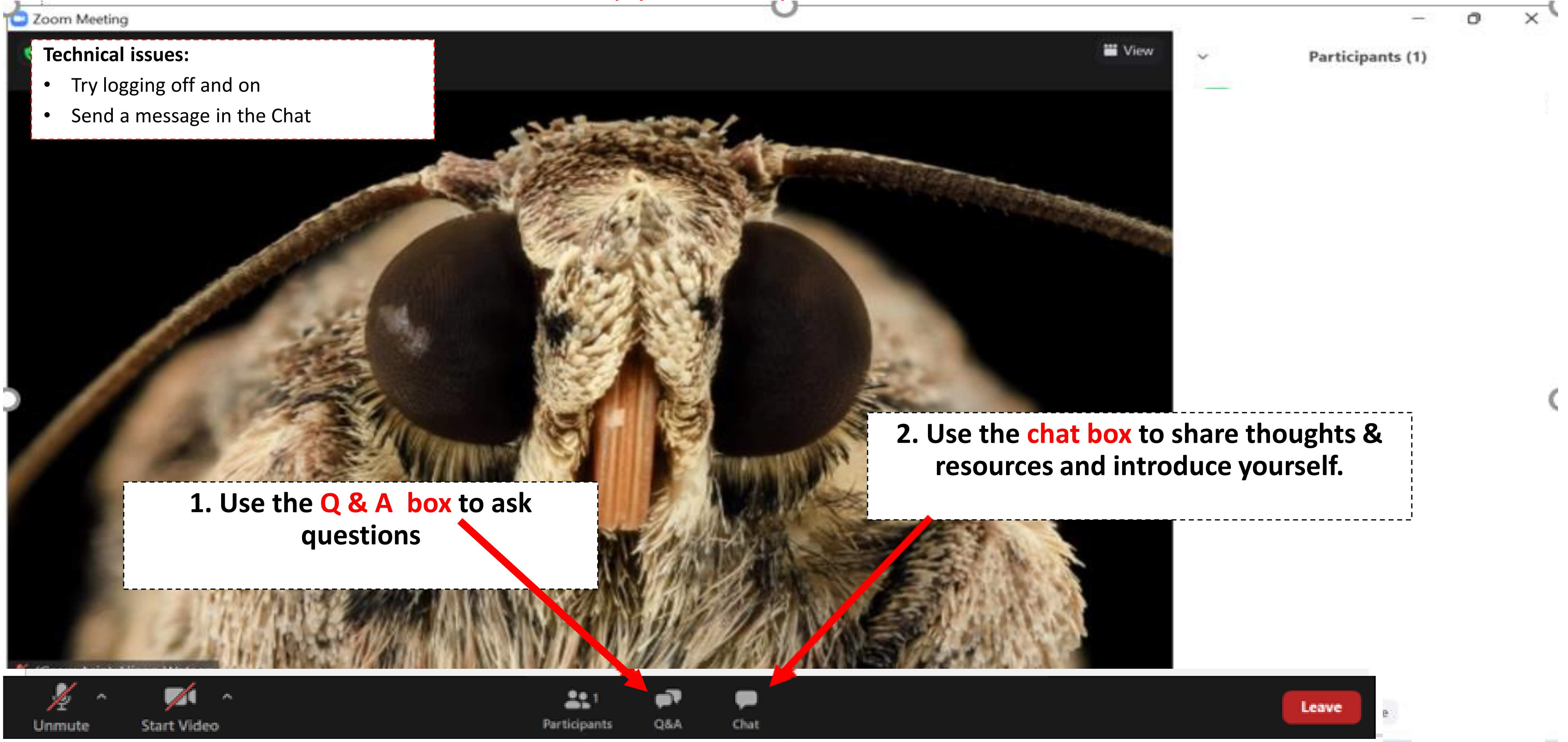



13 December 2022

CABI

ASEAN FAW ACTION PLAN
Supporting IPM Across Southeast Asia

The session will be recorded. A copy will be posted 1 week after this session.



Biocontrol Workshop Schedule

1: Bt Biopesticides Part A — 5 May 2022

2: Bt Biopesticides Part B — 30 June 2022

3. New Frontiers — 11 Aug. 2022

4. Baculoviruses — 25 Aug. 2022

5. Nematodes and Fungi — 29 Sep. 2022

6. Botanicals — 23 Nov. 2022

7. Semiochemicals — 13 Dec. 2022

REGISTER for all sessions: https://www.aseanfawaction.org/events

WATCH the sessions: **https://www.aseanfawaction.org/videos**

Speakers

Research And Applied Pheromone Trap in IPM For Fall Armyworm In Vietnam, Dr Tran Thi Thu Phuong, Vietnam National University of Agriculture

Trapping FAW: the use of pheromones, trap design and lures for FAW control. Dr Rob Meagher, Research Entomologist, Agricultural Research Service, USDA

POLL (anonymous)

1. Have you worked with or researched semiochemicals for FAW Control?

- Yes
- No
- No, but I will be in the next 6 months

2. An important tool for monitoring *S. frugiperda* is pheromone trapping. Does the design of the trap or lure make a difference to how many FAW caught?

- Yes
- No
- Maybe
- I don’t really know

HỌC VIỆN NÔNG NGHIỆP VIỆT NAM
VIETNAM NATIONAL UNIVERSITY OF AGRICULTURE

RESEARCH AND APPLIED PHEROMONE TRAP IN IPM FOR FALL ARMYWORM IN VIETNAM

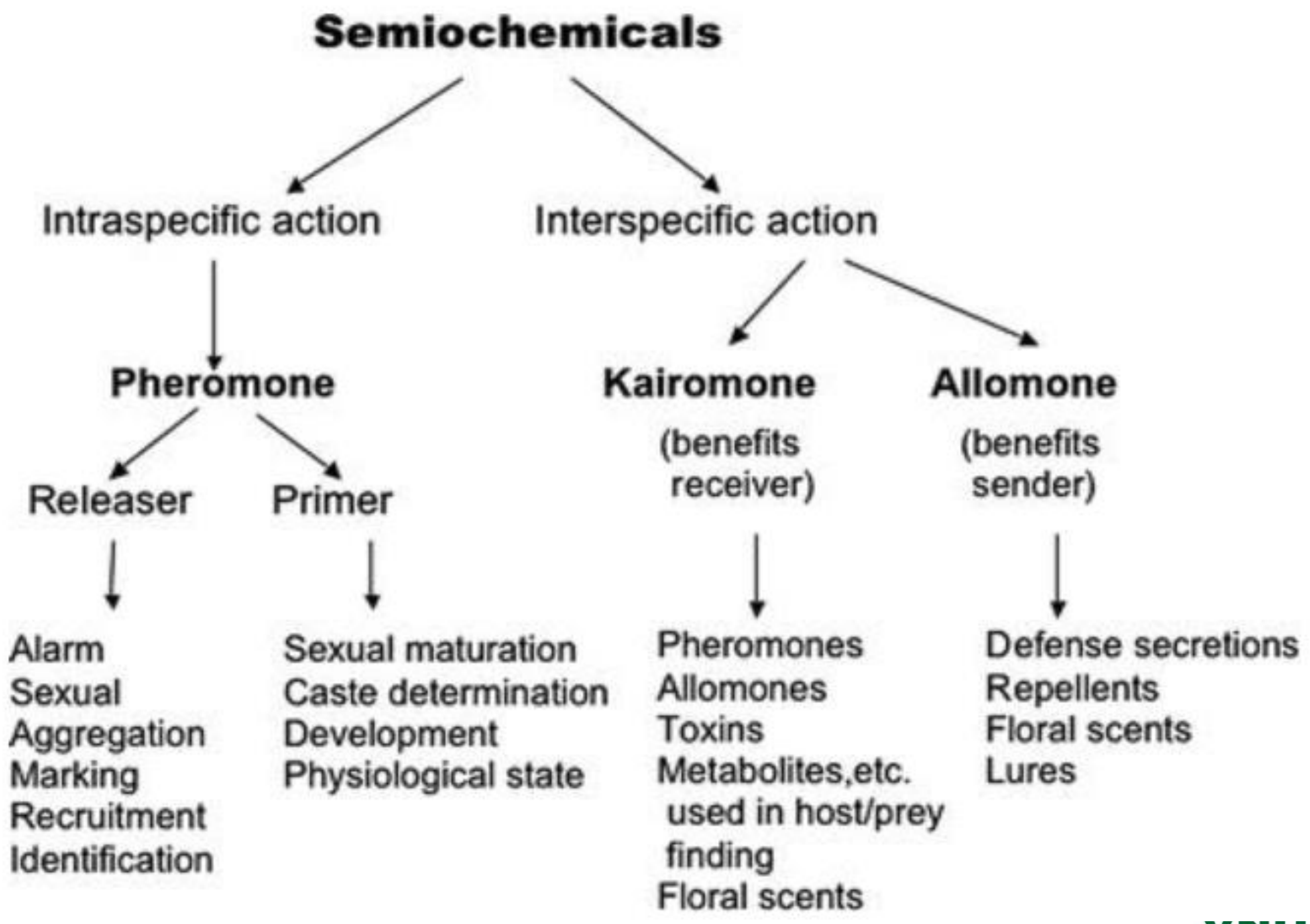
1. Dr. Tran Thi Thu Phuong

Department of Entomology, Faculty of Agronomy

Vietnam National University of Agriculture

December 13, 2022

ROLE OF SEMIOCHEMICALS IN PEST MANAGEMENT



LEPIDOPTERAN SEX PHEROMONES

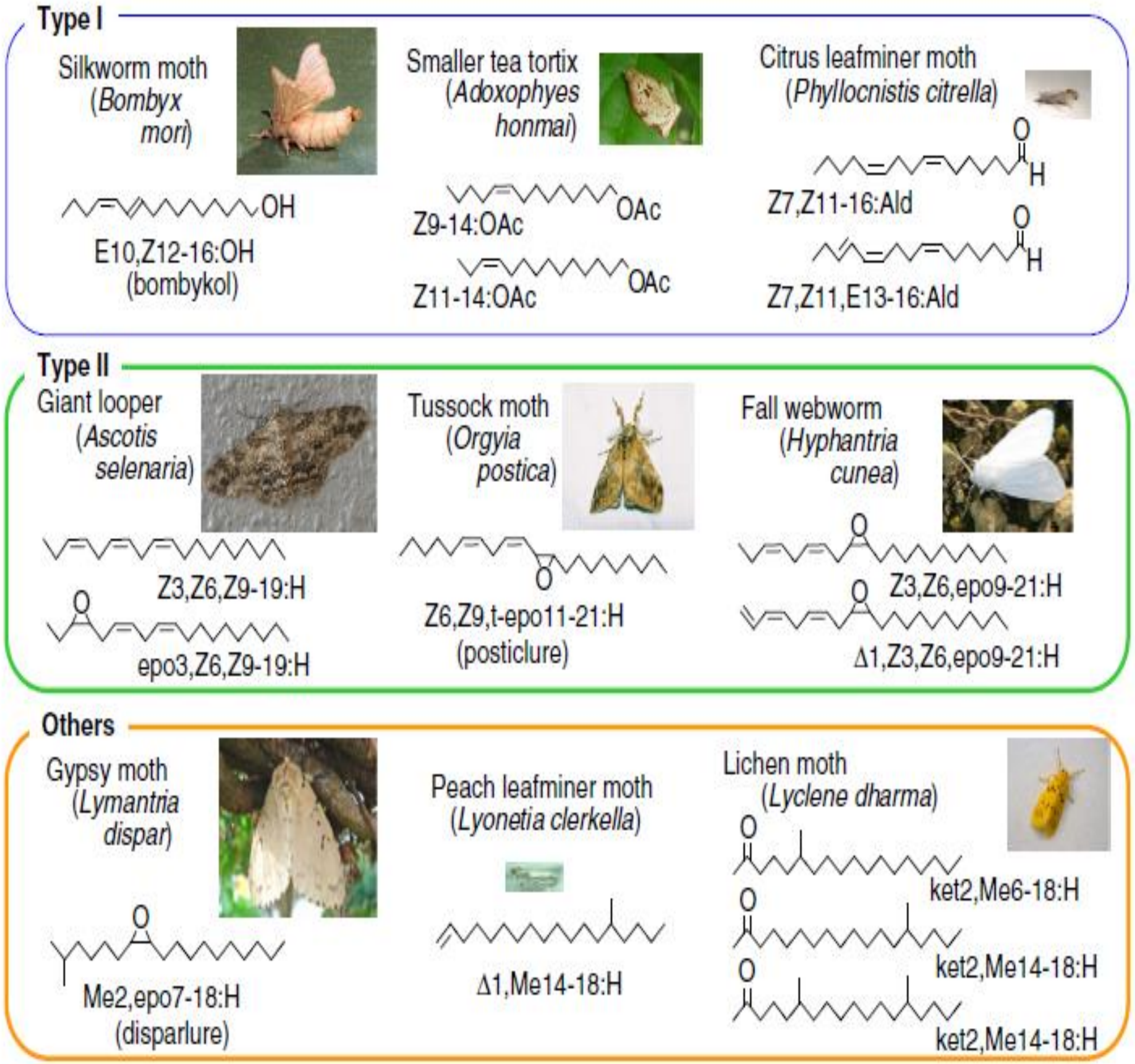


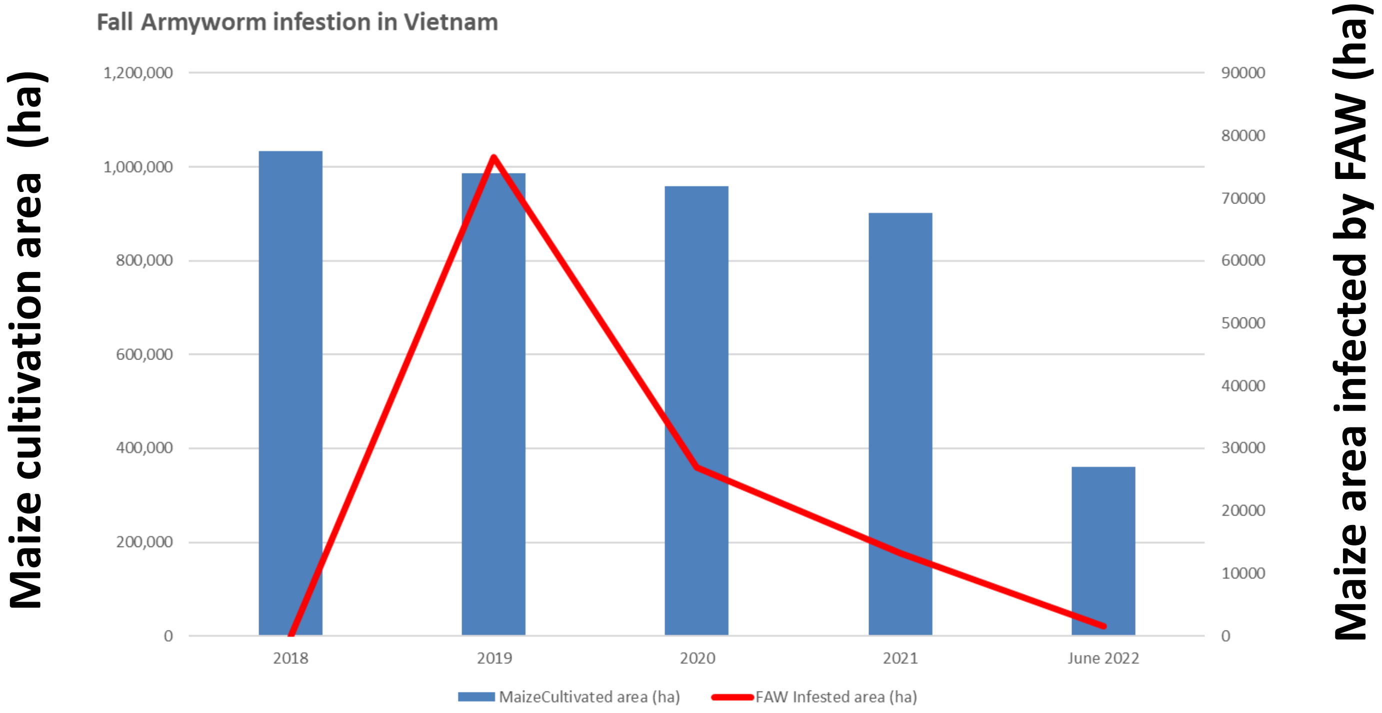
Figure 1. Representative lepidopteran sex pheromones. Compounds are abbreviated as follows: Z = (Z)-double bond; E = (E)-double bond; =terminal double bond; the number before the hyphen=position of the double bond, epoxy ring, or methyl branch; number after the hyphen=the carbon number of the straight chain; OAc=acetate; OH=alcohol; Ald=aldehyde; H=absence of a terminal functional group; epo=cis-epoxy ring; t-epo=trans-epoxy ring; Me=methyl branch; and, ket=keto group.

(Ando T. & R. Yamakawa, 2011)

FEMALE SEX PHEROMONES OF SOME INSECT PESTS ON MAIZE

Name of species	Sex pheromones	Ratio	References
Asian corn borer *Ostrinia furnacalis*	(*Z*)-12-tetradecenyl acetates (*E*)-12-tetradecenyl acetates	62 38	(Ishikawa et al. 1999).
Tobacco cutworm *Spodoptera litura*	(Z,E)-9,11-Tetradecadienyl acetate (Z,E)-9,12-Tetradecadienyl acetate (Z)-9-Tetradecenyl acetate (E)-11-Tetradecenyl acetate	100 27 20 27	(Sun et al. 2002)
Ear-cutting *Mythimna separata*	(Z)-11-Hexadecenal (Z)-11-Hexadecenyl acetate (Z)-11-Hexadecen-1-ol	5 5 1	(Lin et al., 1982)
Black cutworm *Agrotis ipsilon*	(Z)-9-Tetradecenyl acetate (Z)-11-Hexadecenyl acetate (Z)-7-Dodecenyl acetate	6.12 3.66 1.79	(Gemeno et al., 2000)
Fall armyworm *Spodoptera frugiperda*	(Z)-9-Tetradecenyl acetate (Z)-7-Dodecenyl acetate (Z)-11-Hexadecenyl acetate (Z)-11-Tetradecenyl acetate (E)-9-Dodecenyl acetate (Z)-9-Tetradecen-1-ol	100 0.9 10 1.3 0.13 1.8	(Wakamura et al., 2021)

FALL ARMYWORM IN VIETNAM



- The maize cultivation area lightly decreased from 1,032,900ha in 2018 to 901,456ha in 2021.
- The infected maize area by FAW was 76,000ha in 2019, decreased to 29,000ha (2020) and 15,000ha (2021).
- The yield loss by FAW was estimated about 50% if without applying prevention methods

HOST PLANTS FALL ARMYWORM IN VIETNAM

- 353 host plant species in Brazil, from 76 plant families, principally Poaceae (106), Asteraceae (31) and Fabaceae (31) (Montezano et al., 2018)
- The most commonly recorded from wild and cultivated grasses; from maize, rice, sorghum and sugarcane
- In Vietnam, fall armyworm has been reported on maize, paddy rice, onion, elephant grass.

Fall armyworm on maize

Fall armyworm on paddy rice

NATURAL ENEMIES OF FALL ARMYWORM IN VIETNAM

Taxon/Species	Family	Stages Attacked	Degree of Occurrence
I. Parasitoid wasps			
Hymenoptera			
Telenomus remus Nixon	Scelionidae	Egg	+++
Trichogramma sp.	Trichogrammatidae	Egg	++
Microplitis manilae Ashmead	Braconidae	Larvae	+
Chelonus sp.	Braconidae	Egg-Larvae	++
II. Insect predators			
Dermaptera			
Euborellia annulata (Fabricius)	Anisolabiidae	Egg and Larvae	+++
Chelisoches variegatus (Burr)	Chelisochidae	Egg and Larvae	+
Chelisoches sp.	Chelisochidae	Egg and Larvae	++
Coleoptera			
Chlaenius bioculatus Chaudoir	Carabidae	Larvae	++
III. Entomopathogenic fungi			
Hypocreales			
Metarhizium anisopliae	Clavicipitaceae	Larvae	+++

Parasitoid wasps of fall armyworm in Vietnam

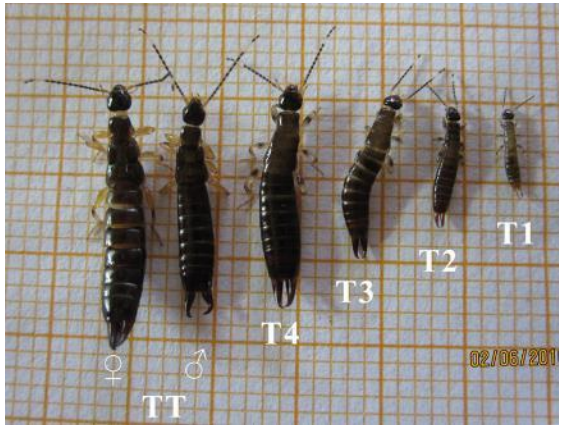
Telenomus remus Nixon

Chelonus sp.

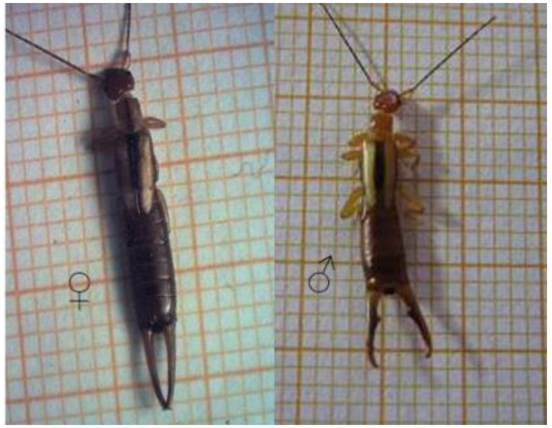
Trichogramma sp.

Microplitis manilae Ashmead

Predators and insect pathogens of FAW



Euborellia annulata (Fabricius)



Chelisoches variegatus (Burr)

Chelisoches sp.

Chlaenius bioculatus Chaudoir

Metarhizium anisopliae

MORPHOLOGICAL CHARACTERISTIC OF FALL ARMYWORM IN VIETNAM

Egg mass

Larvae

Pupae

Male moth

Female moth

DAMAGE SYMPTOMS OF FALL ARMYWORM IN VIETNAM


Early leaves


Whorl leaves


Young flower


Ear corn


Damage of fall armyworm on maize field


Control and None control FAW on maize field

HOSTRAINS OF FALL ARMYWORM IN VIETNAM

Fall armyworm
Spodoptera frugiperda

- Corn Strain
- ≠
- Rice Strain

Locus sites

TTAGGAGCTCCTGATAT
TTAGGAGCTCCTGATAT
TTAGGAGCCCCTGATAT
TTAGGAGCCCCTGATAT

Restriction enzymes

Corn Strain:
- MspI: CCGG
- BsmI: GAATGC
- HinfI: GANTC

Rice Strain:
- SacI: GAGCTC
- AciI: CCGC

Female sex pheromones

Ratio of pheromone components:
(Z9-14:OAc)
(Z7-12:OAc)
(Z9-12:OAc)
(Z11-16:OAc)

DEVELOPMENT TIME OF FALL ARMYWORM IN VIETNAM

Table 1. The mean development time (days ± S.E.) of different life stages of *Spodoptera frugiperda* at constant temperatures.

Development Stage	Temperature (±1◦C)				
	20	25	27.5	30	33
Egg	$4.63^{a} \pm 0.045$	$3.28^{b} \pm 0.028$	$2.63^{c} \pm 0.040$	$2.14^{d} \pm 0.025$	$2.00^{e} \pm 0.000$
Larvae	$25.24^{a} \pm 0.206$	$19.43^{b} \pm 0.143$	$17.59^{c} \pm 0.108$	$13.03^{d} \pm 0.131$	$10.44^{e} \pm 0.137$
Pupae	$15.75^{a} \pm 0.121$	$11.76^{b} \pm 0.133$	$9.66^{c} \pm 0.134$	$6.42^{d} \pm 0.116$	$6.14^{d} \pm 0.056$
Egg to adult	$45.39^{a} \pm 0.258$	$34.43^{b} \pm 0.218$	$29.31^{c} \pm 0.256$	**$21.47^{d} \pm 0.170$**	**$18.58^{e} \pm 0.157$**
Life cycle	$50.56^{a} \pm 0.334$	$36.93^{b} \pm 0.289$	$31.91^{c} \pm 0.290$	**$24.28^{d} \pm 0.219$**	**$22.28^{e} \pm 0.543$**

MANAGEMENT OF FALL ARMYWORM IN VIETNAM

- Plant Protection Department organized training courses on FAW and control measures for technical staff of the Regional Plant Protection Centers and Sub-Departments of Crop Production and Plant Protection in 63 provinces/cities

- Training of trainers on integrated pest management (IPM) on maize, including FAW, for technicians in maize growing provinces in the Vietnam.

- Training on integrated pest management, including the fall armyworm on maize by the field-based learning approach (FFS- FarmerField School) for farmers and extension workers

MANAGEMENT OF FALL ARMYWORM IN VIETNAM

Intergrated Pest Management for Fall Armyworm:

1. Cultural control
2. Host-Plant Resistance
3. **Pheromone Control**
4. **Biological Control**
5. Chemical Control

INTERGRATED PEST MANAGEMENT FOR FALL ARMYWORM

Sowing maize seeds

Preparing pheromone traps

Place pheromone traps

Survey male moths in traps

Pheromone traps on maize fields at V3 stage of maize plant

Survey FAW larvae and natural enemies of FAW in maize field

Training of IPM on FAW in maize field

1. Cultural control

- Intercropping beans and maize
- Intercropping peanuts and maize
- Crop rotation of paddy rice and maize

Soybean and maize

Green bean and maize

Peanut and maize

Peanut and maize

2. Host-Plant Resistance

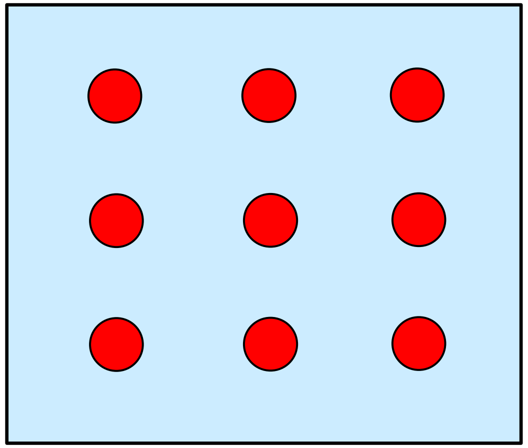
Maize varities resistance to fall armyworm:

- **NK66Bt/GT, NK4300Bt/GT; NK67Bt/GT; NK7328Bt/GT.**
- **DK6919S; DK9955S; CP501S; DK8868S.**

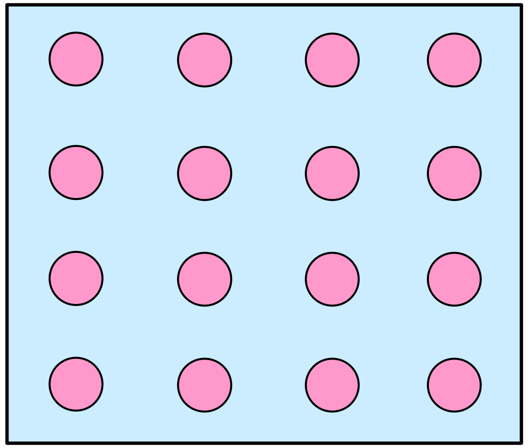
3. Pheromone Control

- Monitoring fall armyworm on the fields
- Mass trapping male moths of fall armyworm
- Mating interruption adult moths of fall armyworm on the fields

Mating disruption



Mating confusion



Identify female sex pheromone of Fall armyworm in Vietnam

Female sex pheromone components of fall armyworm in Vietnam:

1) (Z)-9-tetradecenyl acetate (Z9-14:OAc) - ($C_{18}H_{34}O_2$) :

Main component

2) (Z)-7-dodecenyl acetate (Z7-12:OAc) - ($C_{14}H_{26}O_2$):

Strong bioactive

3) (Z)-9-dodecenyl acetate (Z9-12:OAc) - ($C_{14}H_{26}O_2$):

Week bioactive

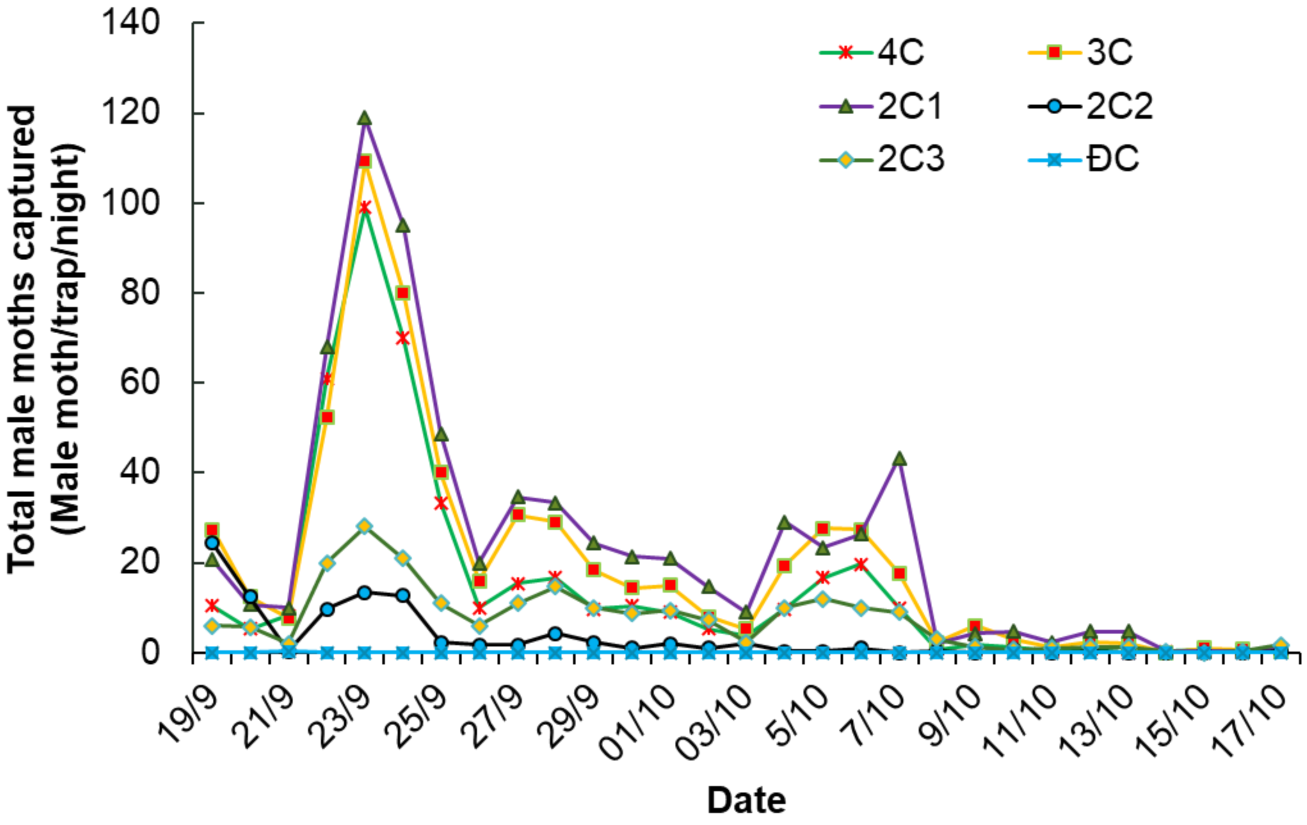
4) (Z)-11-hexadecenyl acetate (Z11-16:OAc) - ($C_{18}H_{34}O_2$):

Medium bioactive

Identify pheromone lures for Fall armyworm in Vietnam

Pheromone lures:

1) **Lure 2C1: Z9-14:OAc; Z7-12:OAc**
2) **Lure 2C2: Z9-14:OAc; Z11-16:OAc**
3) **Lure 2C3: Z9-14:OAc; Z9-12:OAc**
4) **Lure 3C: Z9-14:OAc; Z7-12:OAc; Z11-16:OAc**
5) **Lure 4C: Z9-14:OAc; Z7-12:OAc; Z9-12:OAc; Z11-16:OAc**



3. Pheromone Control

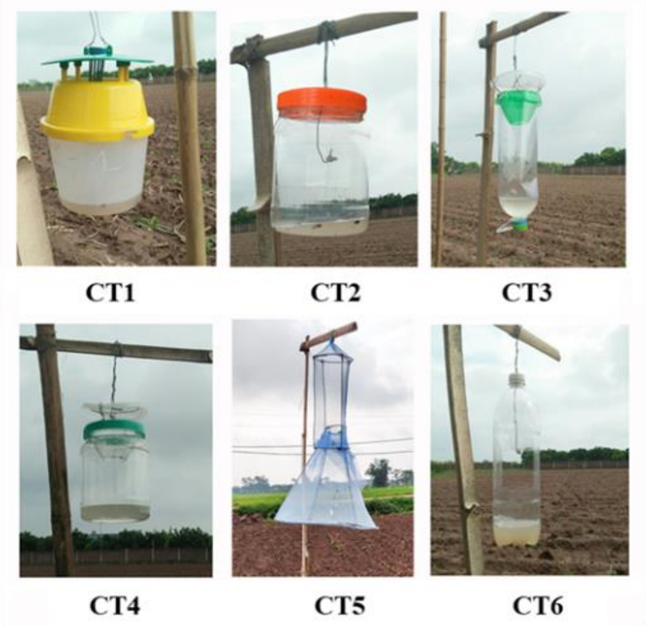
PHEROMONE LURES:

1) Lure 2C-1: Z9-14:OAc; Z7-12:OAc

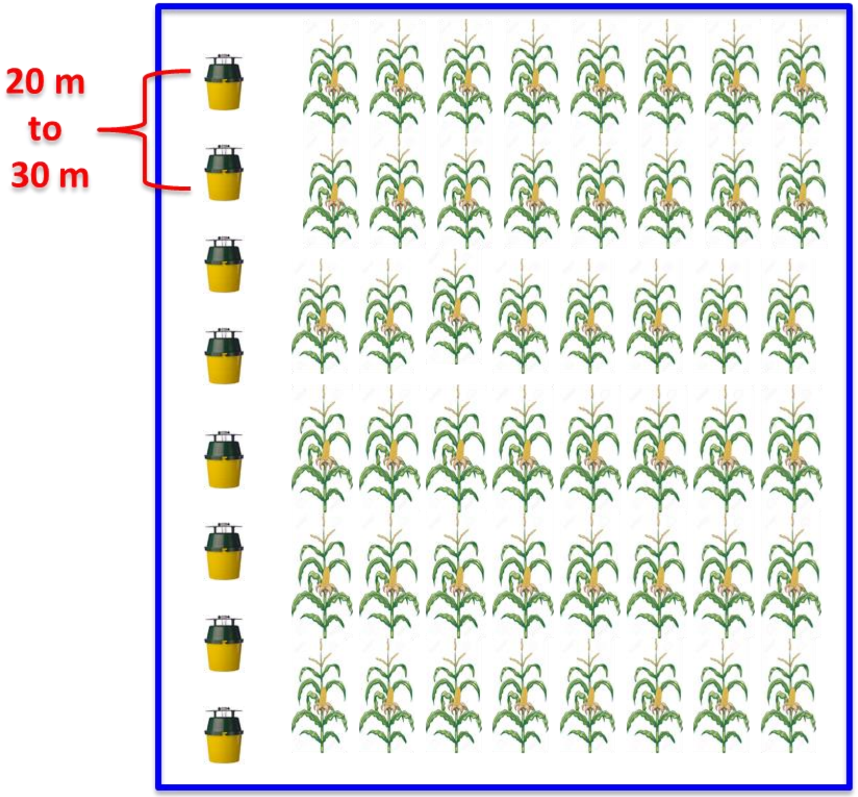
2) Lure 2C-2: Z9-14:OAc; Z11-16:Oac

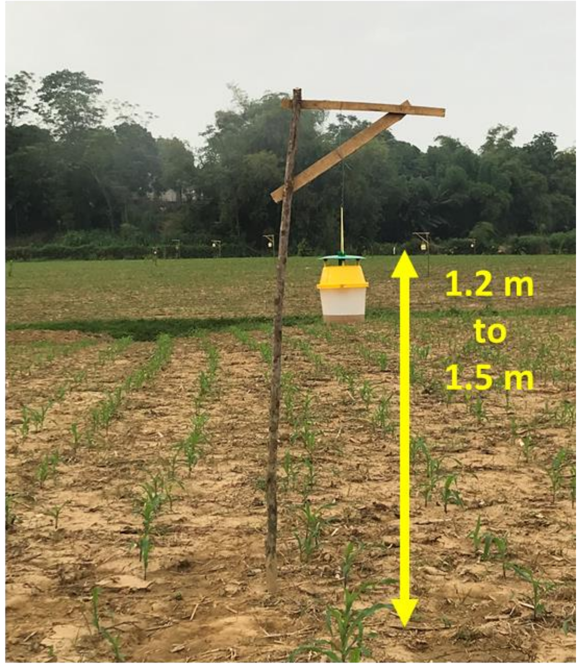
3) Lure 3C: Z9-14:OAc; Z7-12:Oac; Z11-16:OAc

PHEROMONE TRAPS:



3. Pheromone Control

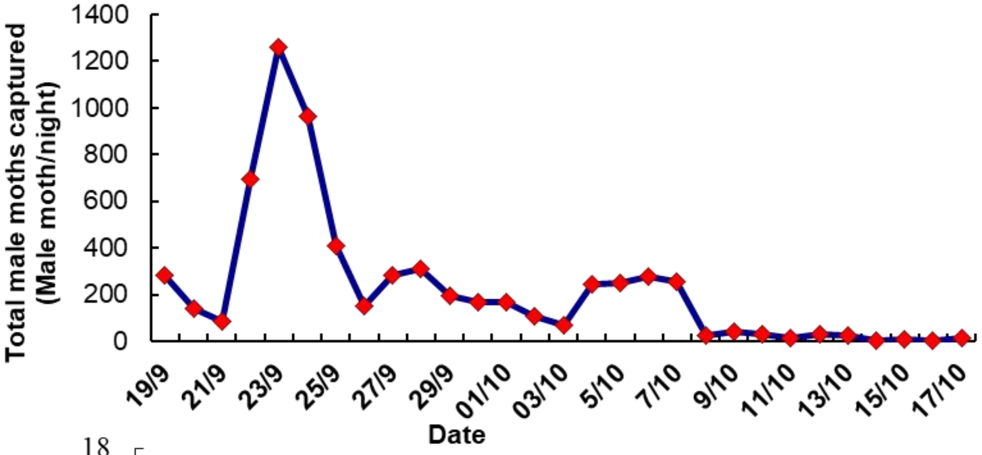




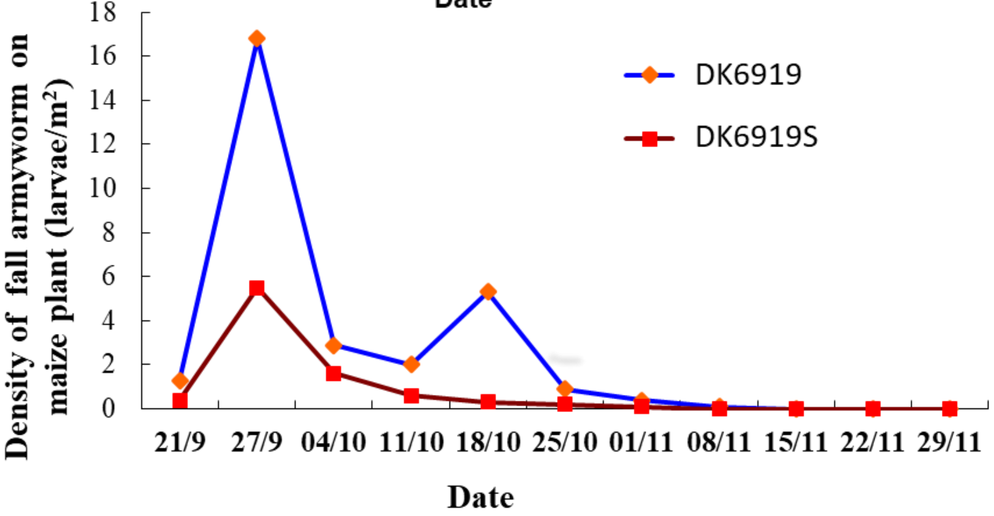
Time applied pheromone traps

3. Pheromone Control

A



B



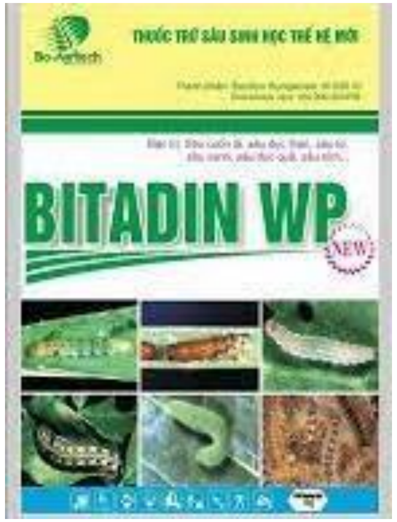
A) Total male moths captured by pheromone traps per night on maize field from September 19 to October 17, 2019.

B) Density of fall armyworm on maize plant (DK6919 and DK6919S-insect resistant and herbicide tolerant) from September 21 to Novemver 29, 2019.

4. Biological Control

<u>1. Insect pathogenic fungus, bacteria and virus</u>

- *Metarhizium anisopliae*
- *Bacillus thuringiensis*
- *Bacillus thuringiensis* and *Granulosis virus*



4. Biological Control

- Ginger, garlic, and chili
- Ginger and garlic
- Ginger, garlic, chili, lemongrass
- Neem oil, ginger, garlic, and chili

5. Chemical Control

- **Emamectine benzoate**
- **Spinetoram**
- **Indoxacarb**
- **Lufenuron**

Provinces applies IPM for fall armyworm in Vietnam

Dien Bien

Tuyen Quang

Ha Nam

Gia Lai

Dak Lak

- Reduce insecticide applied on the field from 4-5 time to 1-2 times per maize season.

- Economic efficiency in the IPM model has increased from 17 to 25% compared to outside the model.

Hoa Binh

Phu Tho

Thank you very much for your attention!

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Trapping FAW: The Use of Pheromones, Trap Design and Lures for FAW Control

Robert L. Meagher, Jr.

USDA-ARS

Gainesville, Florida

Objectives

- Trap designs
- Pheromone composition
- Commercial pheromone lures
- Habitat influence w/ host strains
- Management using pheromones
- “Extreme” monitoring / migration

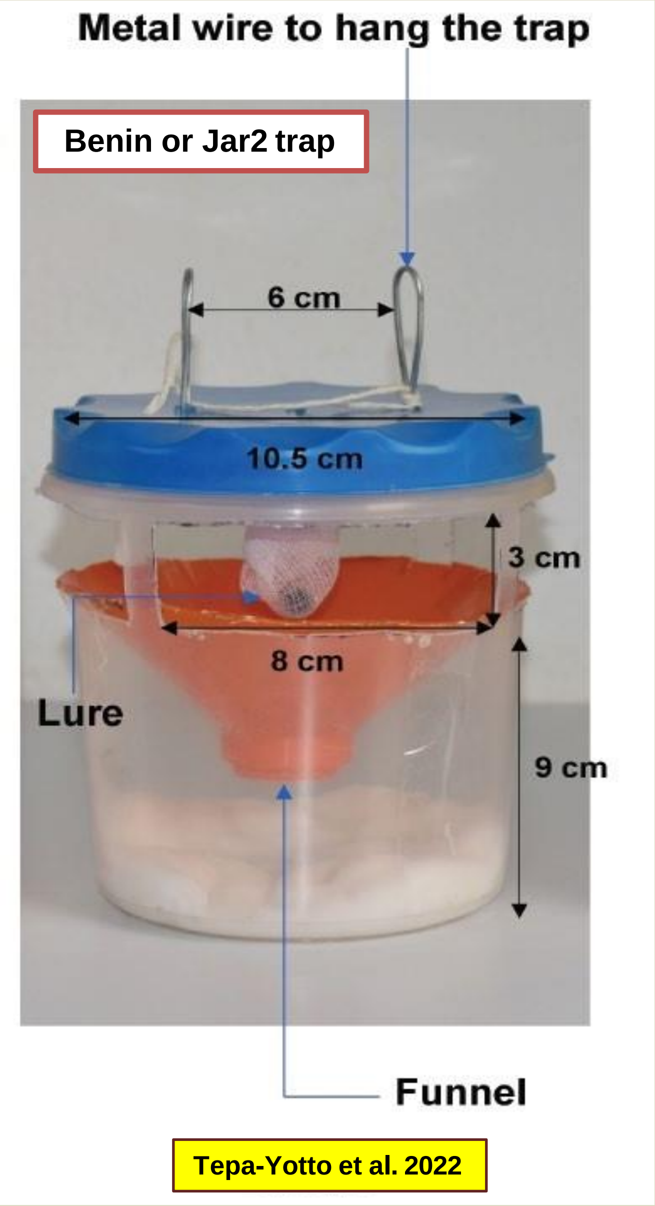
Traps


Unitrap, standard
R. Meagher - USDA

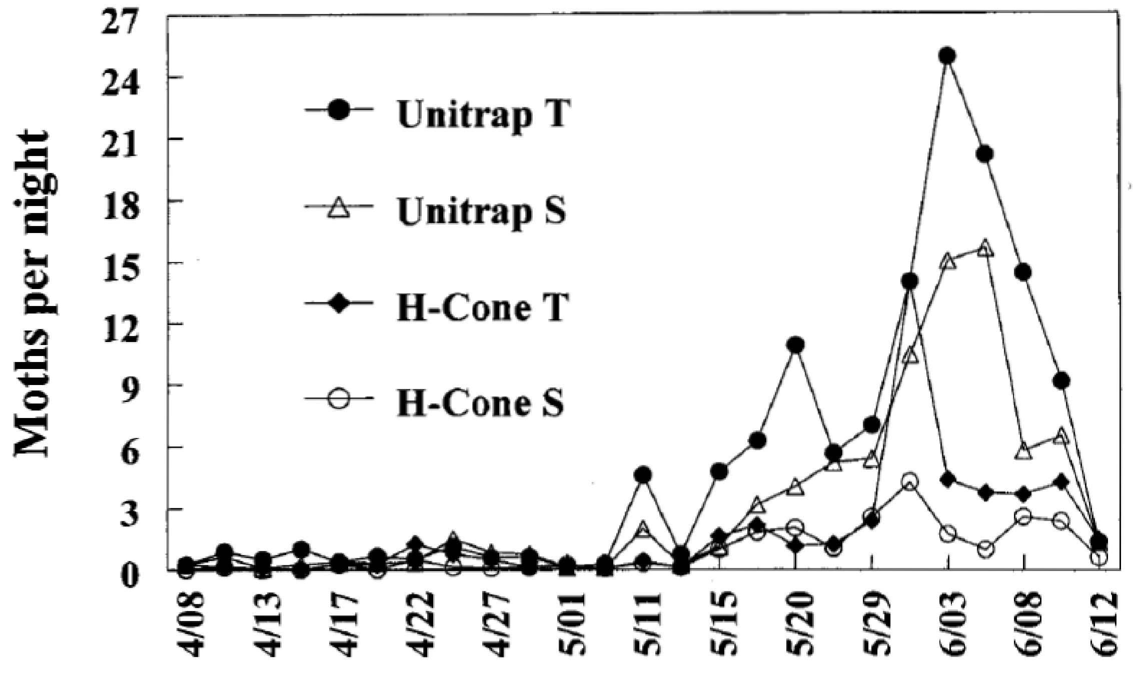

Delta trap
R. Meagher - USDA


Heliothis / wire cone
R. Meagher - USDA


Togo trap
Meagher et al. 2019
K. Agboka – Université of Lomé


Metal wire to hang the trap
Benin or Jar2 trap
6 cm
10.5 cm
3 cm
8 cm
Lure
9 cm
Funnel
Tepa-Yotto et al. 2022

Trap Comparison



Meagher & Mitchell 2001

Fig. 1. Capture of male fall armyworm in Unitraps or *Heliothis* cone traps (H-Cone) baited with either Trécé (T) or Scentry (S) pheromone lures, Alachua, FL, 1998.

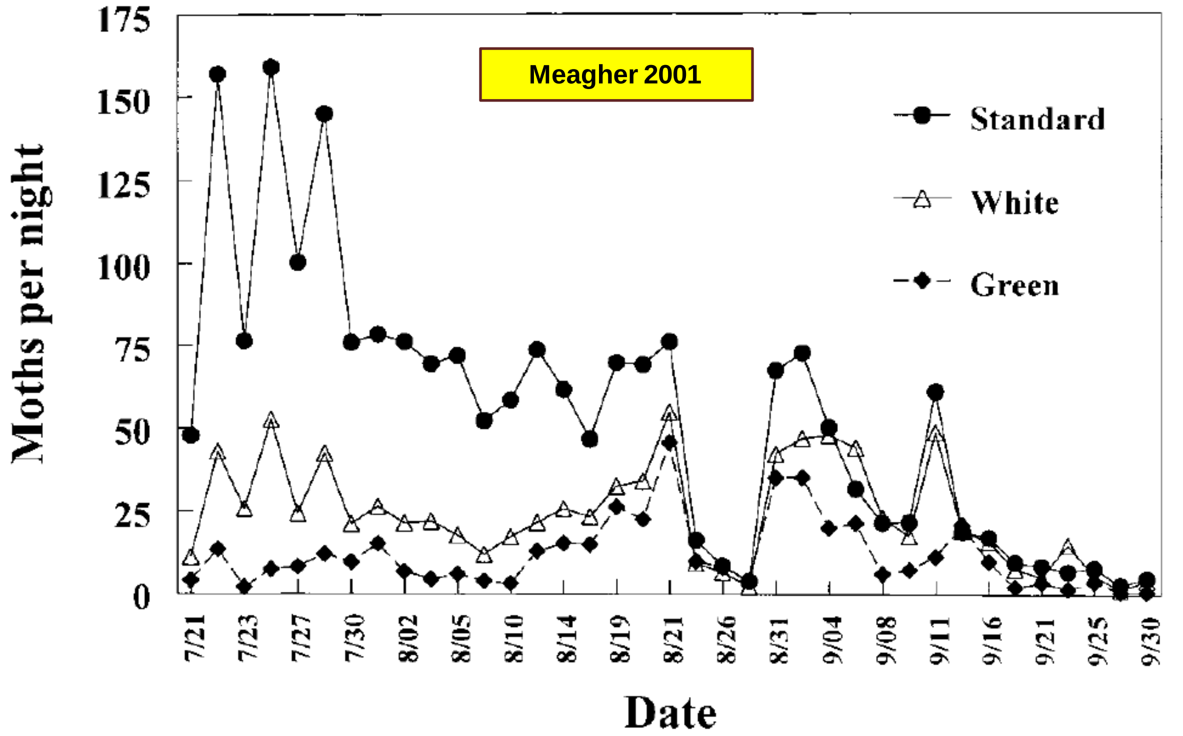
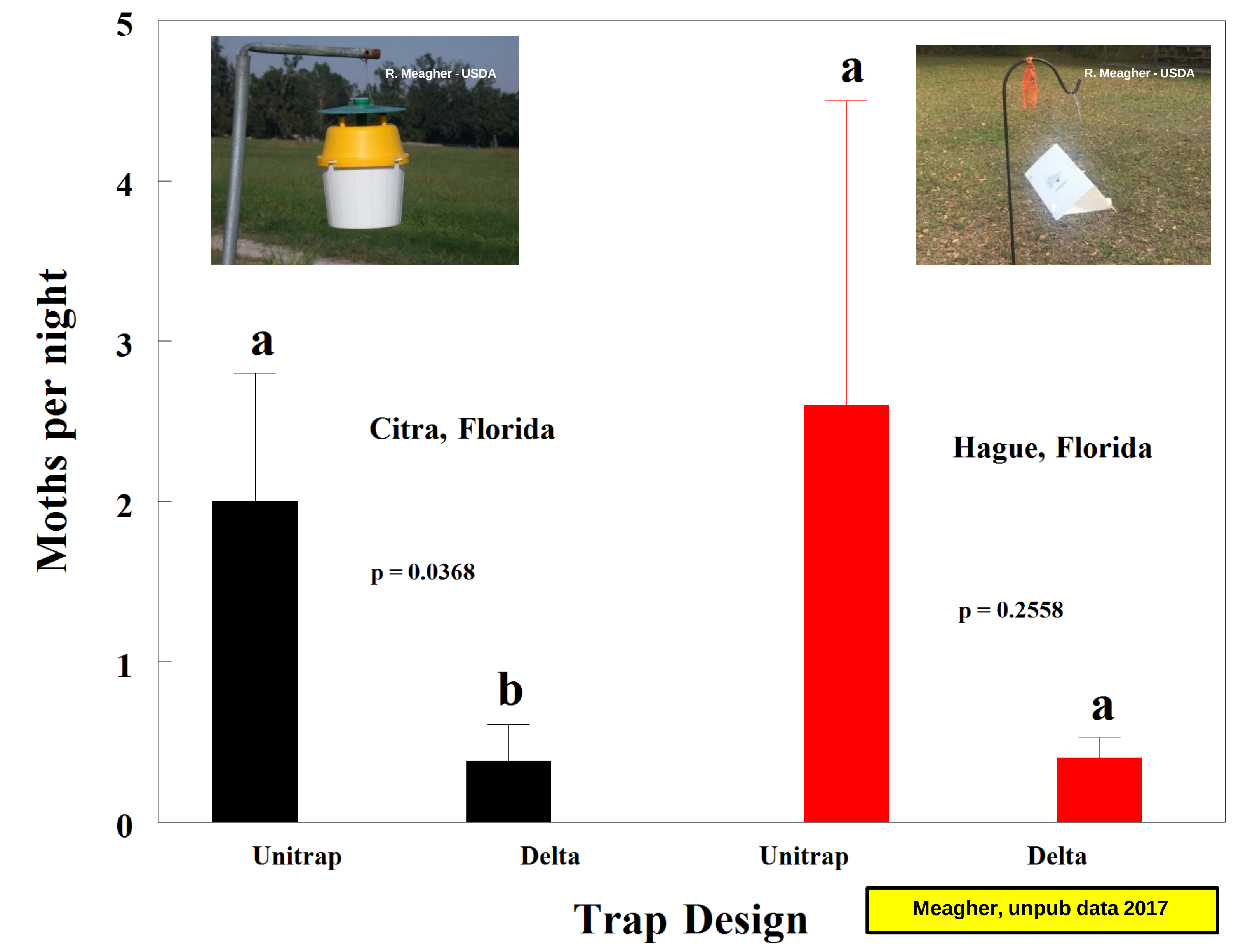


Fig. 1. Capture of male Fall Armyworm in standard (green canopy, yellow funnel, white bucket), all-white, or all-green Unitraps baited with sex pheromone lures, Alachua, FL, 1998.

Trap Comparison

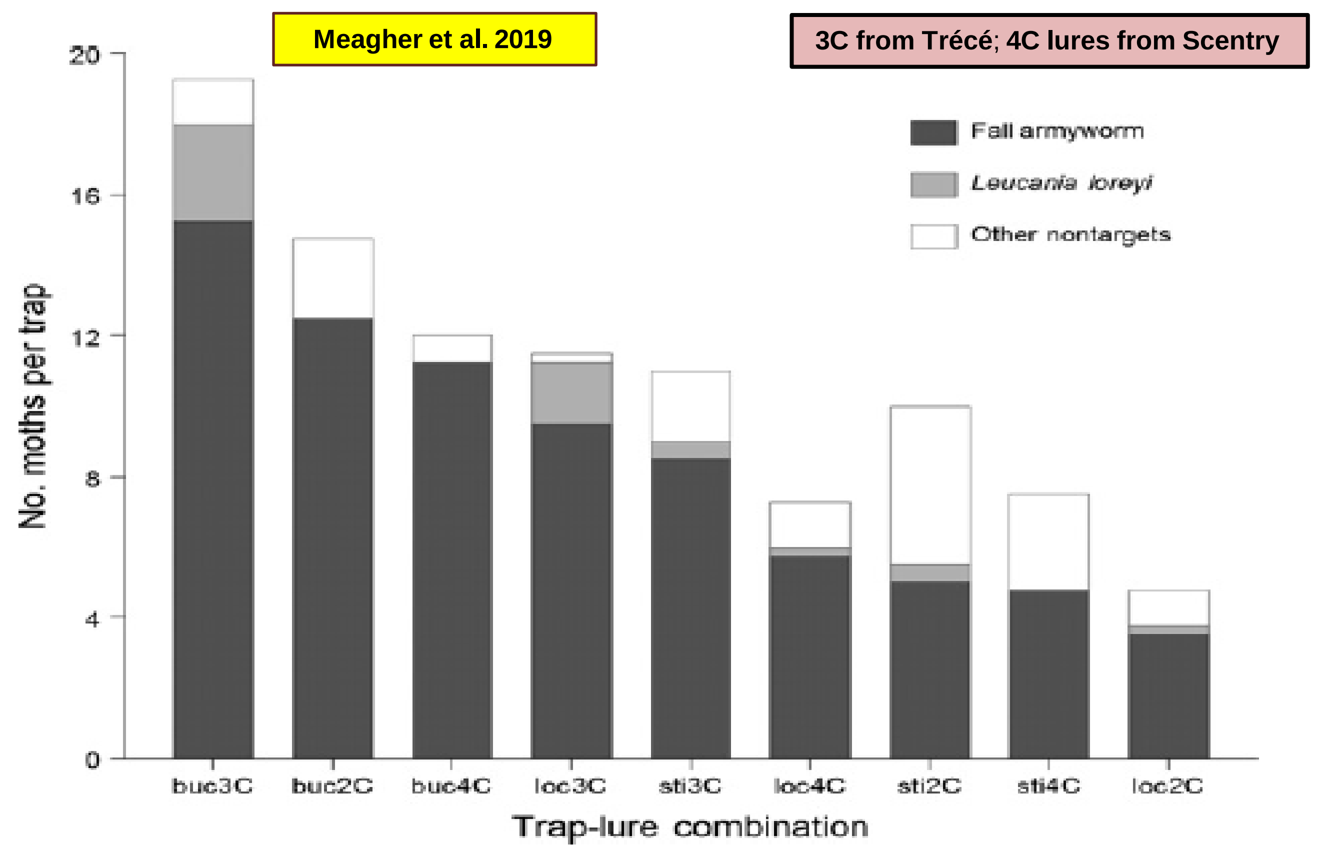


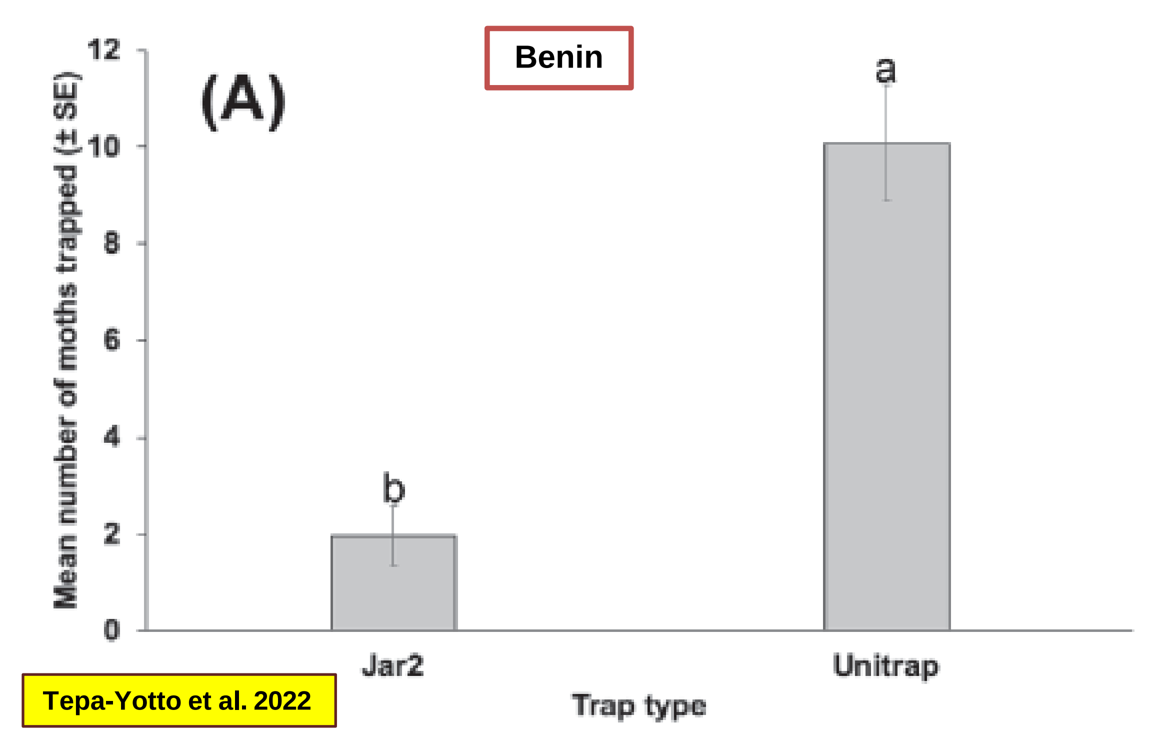
Meagher, unpub data 2017

Traps in Togo & Benin

Togo

Trap	*Spodoptera frugiperda*
Bucket	13.0 ± 1.5a
Local	6.25 ± 1.3b
Sticky	6.08 ± 0.9b
	$F_{2,24}$ = 19.0, P<0.0001





Pheromone Components

Z9-14:Ac

(Z)-9-tetradecenyl acetate

Z7-12:Ac

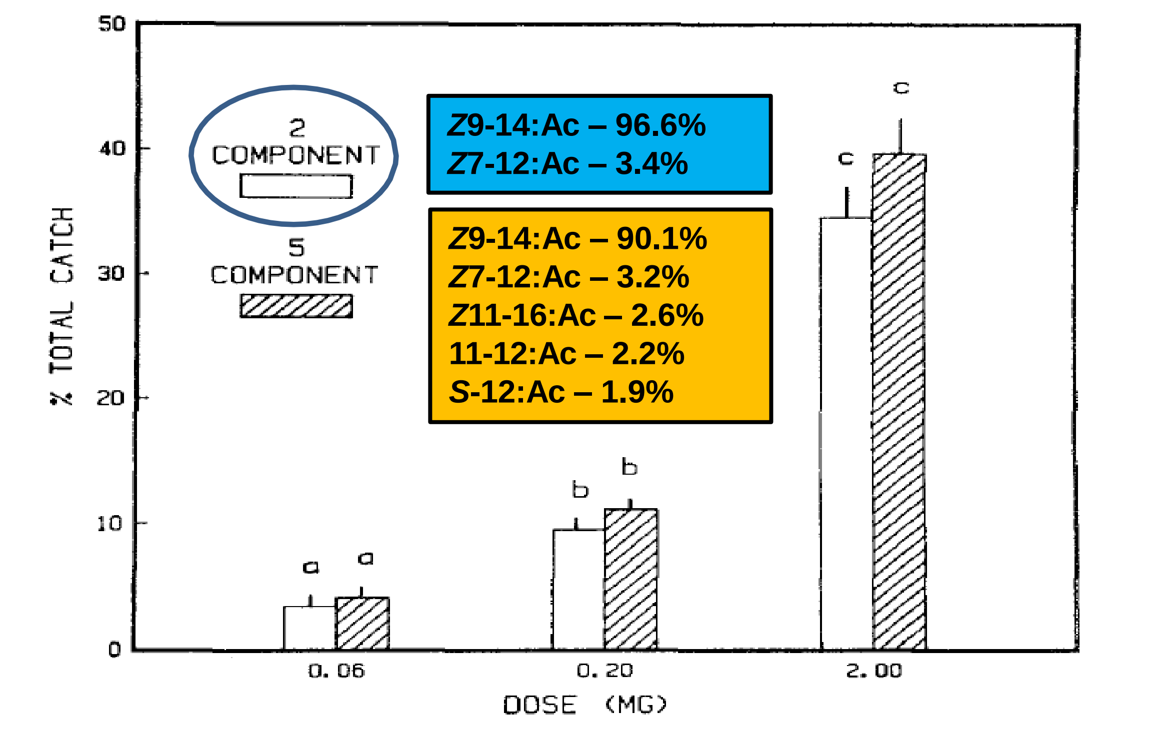
(Z)-7-dodecenyl acetate

Z11-16:Ac

(Z)-11-hexadecenyl acetate

Z9-12:Ac

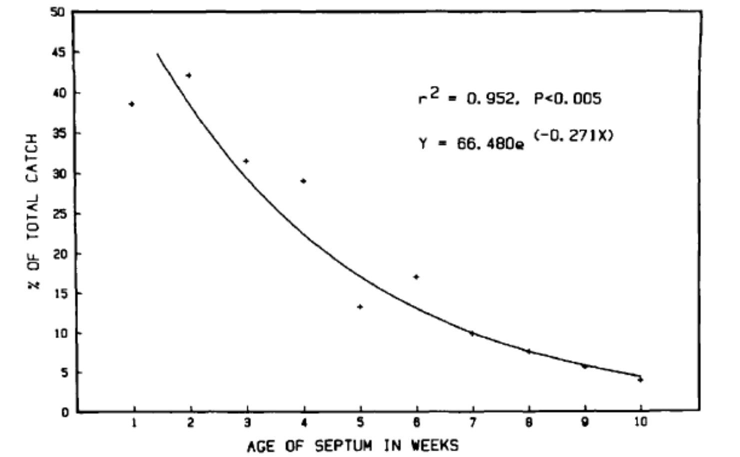
(Z)-9-dodecenyl acetate



Z9-14:Ac – 96.6%
Z7-12:Ac – 3.4%

Z9-14:Ac – 90.1%
Z7-12:Ac – 3.2%
Z11-16:Ac – 2.6%
11-12:Ac – 2.2%
S-12:Ac – 1.9%

Mitchell et al. 1985
Tumlinson et al. 1986



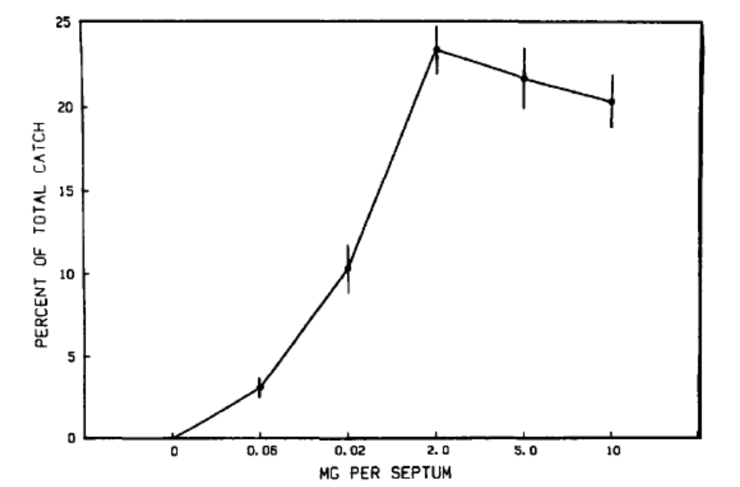


Fig. 1. Hartstack 75-25 cm screenwire cone trap (left) and IP moth trap (right). The IP trap is equipped with a Vapona insecticide strip as a killing agent.

Pheromone Components (Brazil)

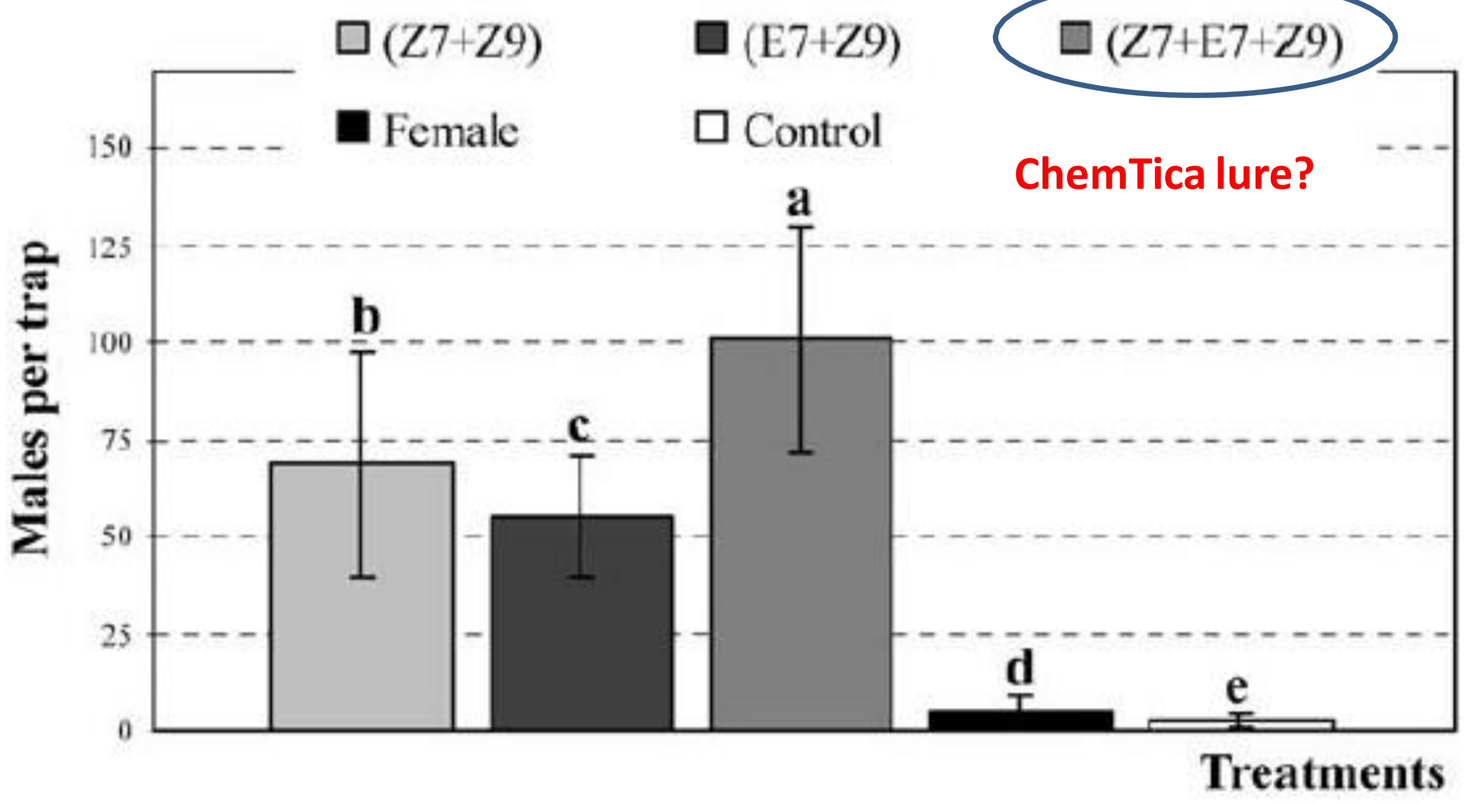
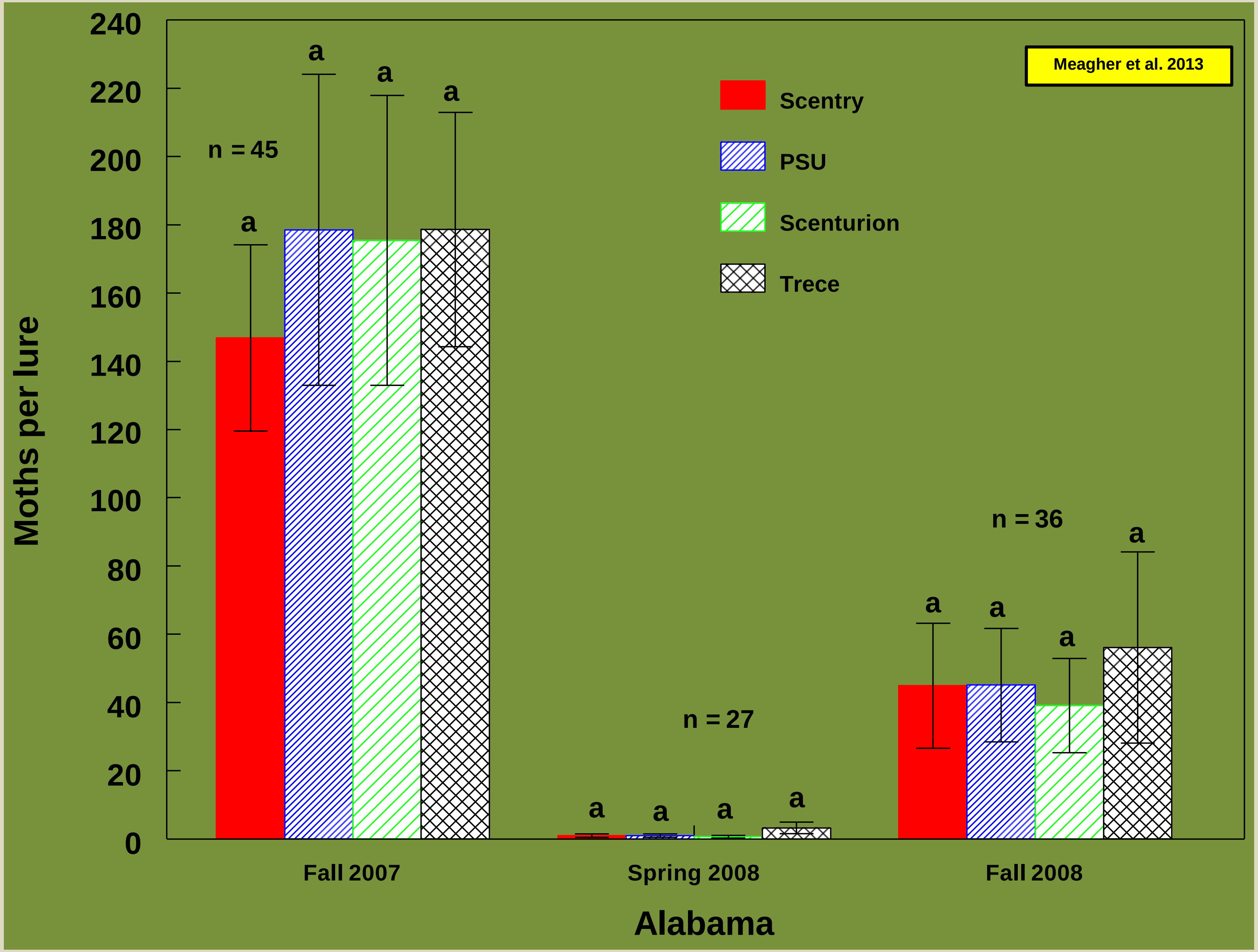


Fig. 9 Number ($X \pm$ SD) of *S. frugiperda* males captured in Pherocon 1C traps baited with *Z*7-12:Ac + *Z*9-14:Ac at ratios of 0.01:1.00 mg, *E*7-12:Ac + *Z*9-14:Ac at ratios of 0.01:1.00 mg, *Z*7-12:Ac + *E*7-12:Ac + *Z*9-14:Ac at ratios of 0.01:0.01:1.00 mg, hexane solvent, and two virgin females (five replicates and 14 collections). Mean values with the same letter are not significantly different (two-way ANOVA followed by Tukey's test; $P < 0.05$)

E7-12:Ac
(E)-7-Dodecenyl acetate

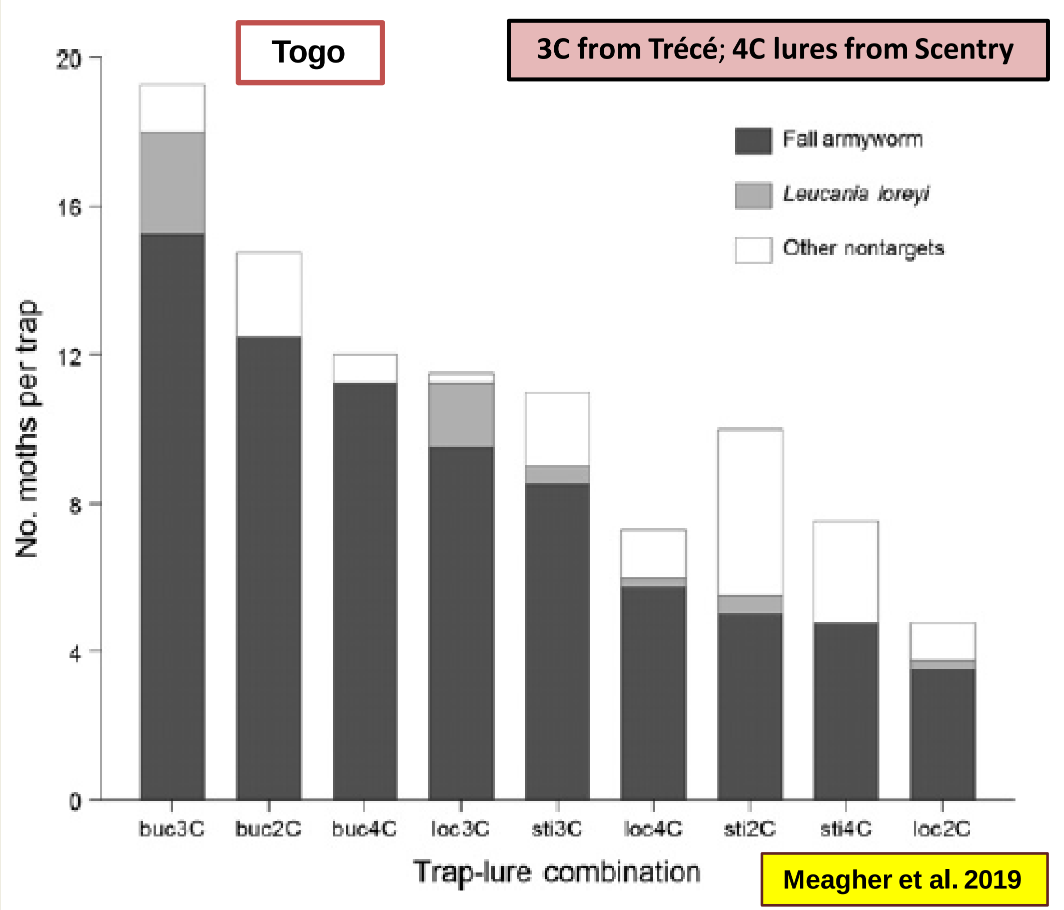
Batista-Pereira et al. 2006

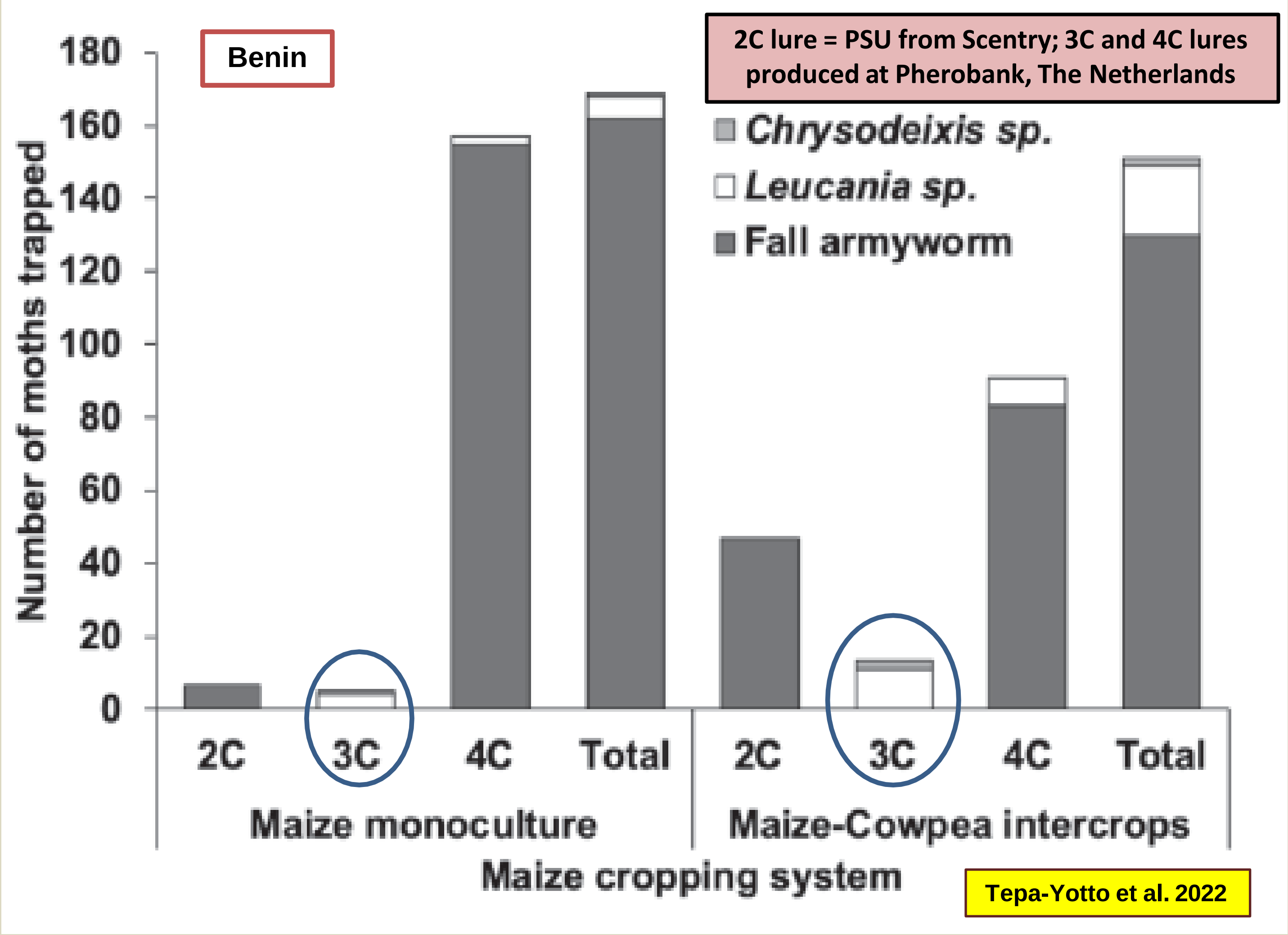
Lure Comparison



Lures in Togo & Benin

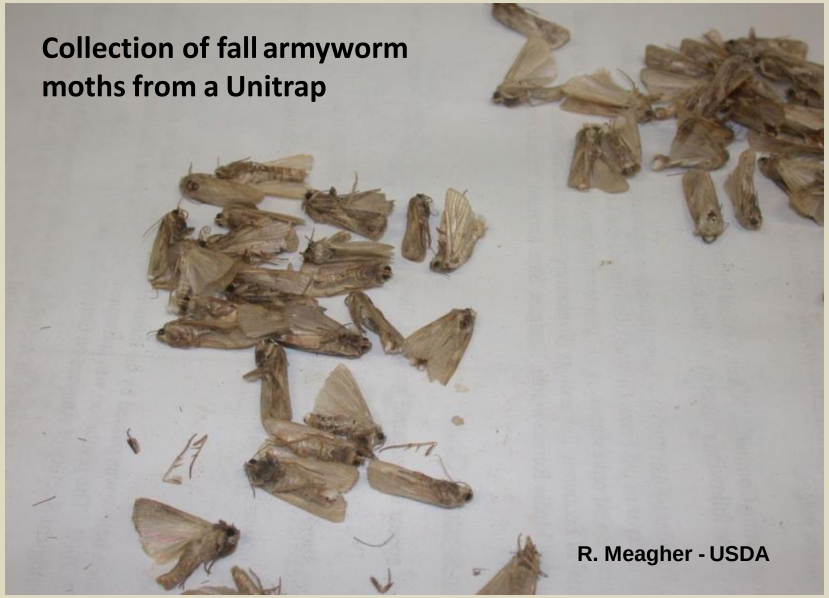
Lure	2C	7.0 ± 1.5b
	3C	11.1 ± 1.7a
	4C	7.25 ± 1.2b
		$F_{2,24} = 6.7, P = 0.0048$

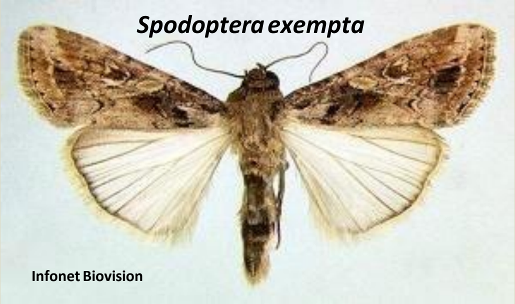


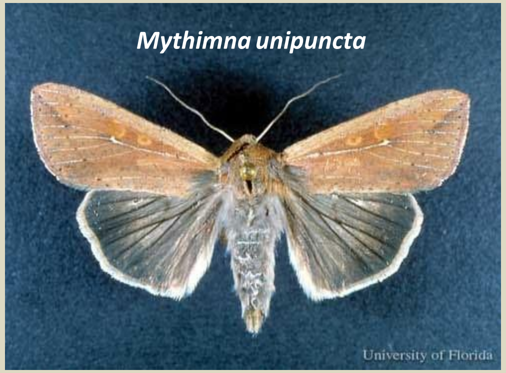


Non-target Moths

- **ChemTica, Trécé, or PSU lures will attract about the same number of moths**
  - **however, something that I haven't mentioned is the number of nontarget moths attracted to the traps**







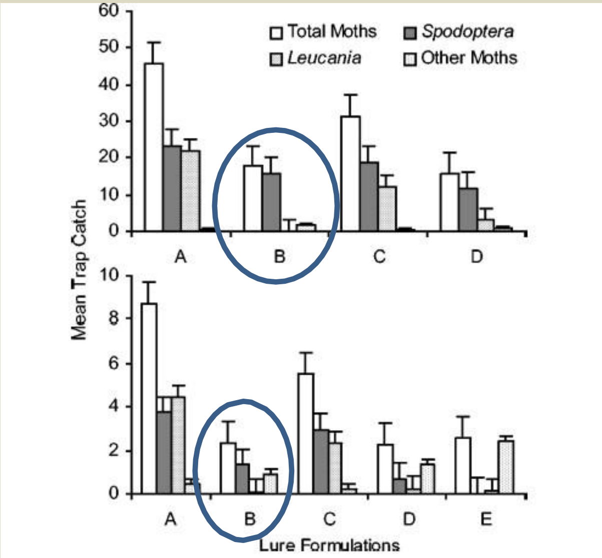


Fig. 2. Seasonal mean weekly trap catch of *S. frugiperda*, *L. phragmatidicola*, and other species from four lures (described in Table 1) in 2000 (top) and 2001 (bottom).

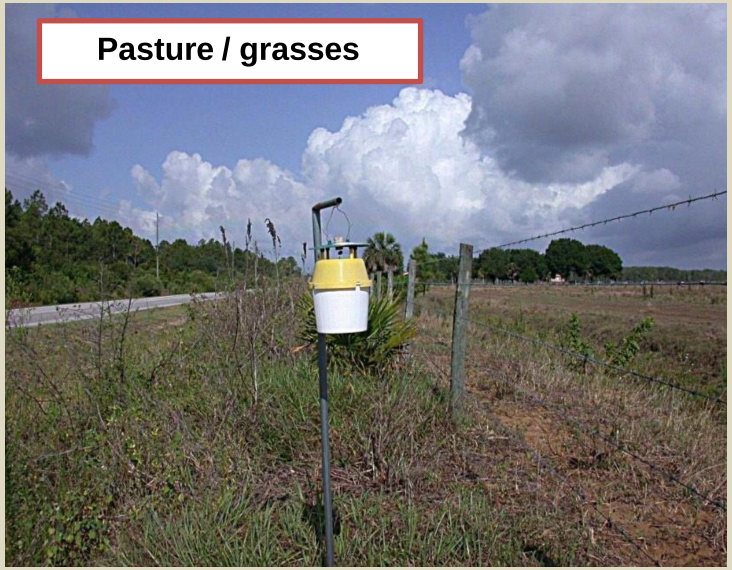
Fleischer et al. 2005

Togo

2C	0.25 ± 0.13b
3C	1.67 ± 0.48a
4C	0.08 ± 0.08b
	$F_{2,24} = 11.4, P = 0.0003$

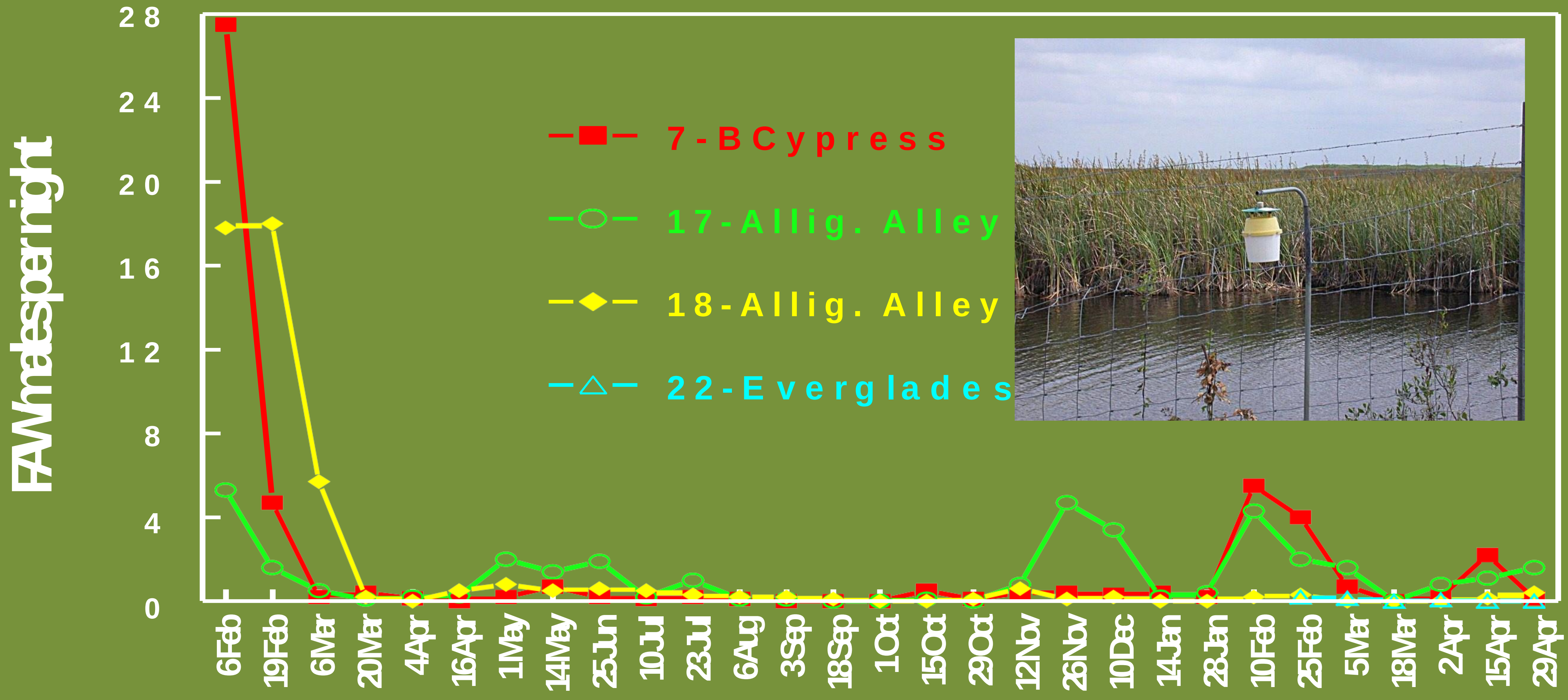
Meagher et al. 2019

South Florida Habitats



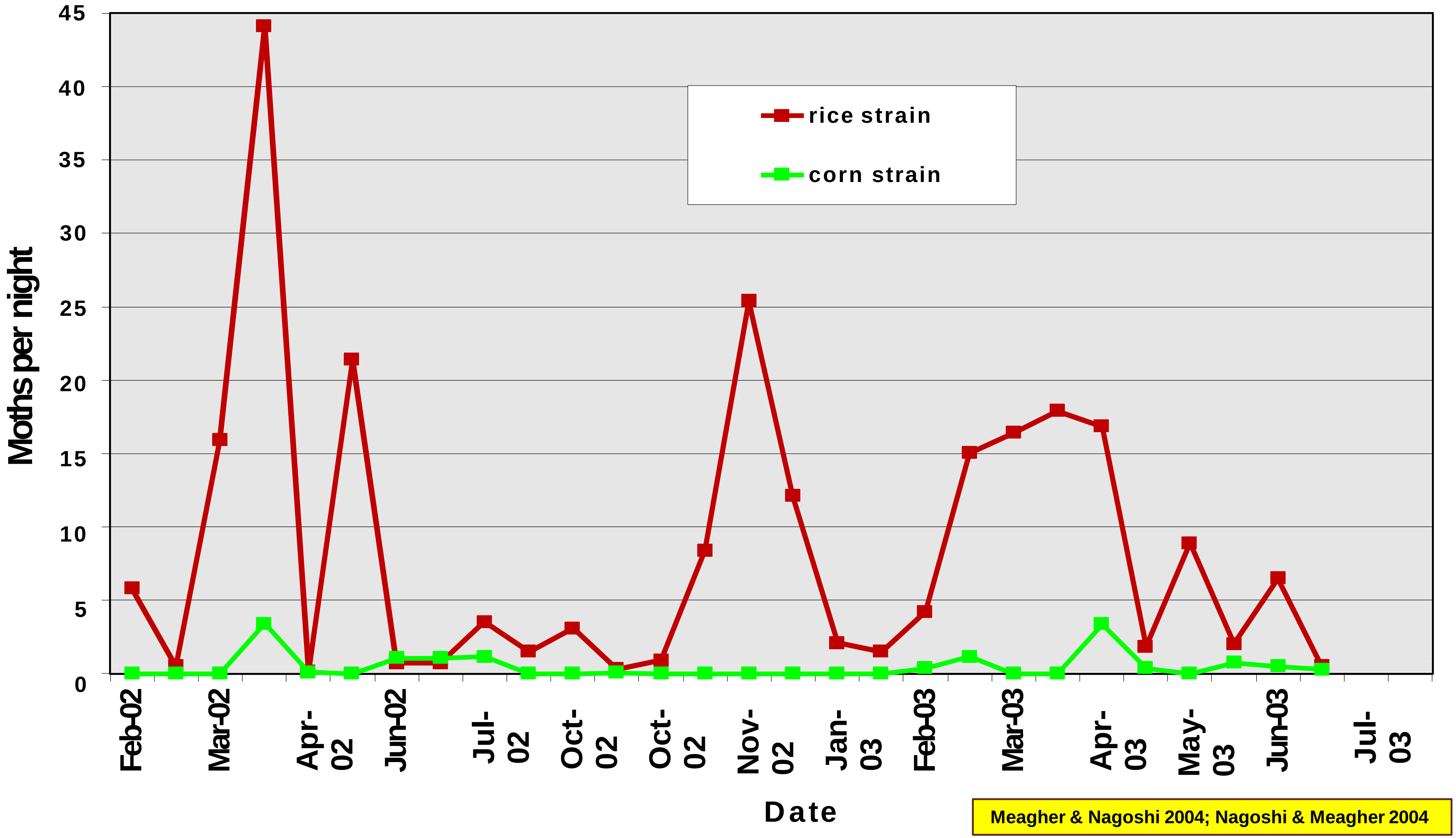
All photos R. Meagher - USDA

Natural



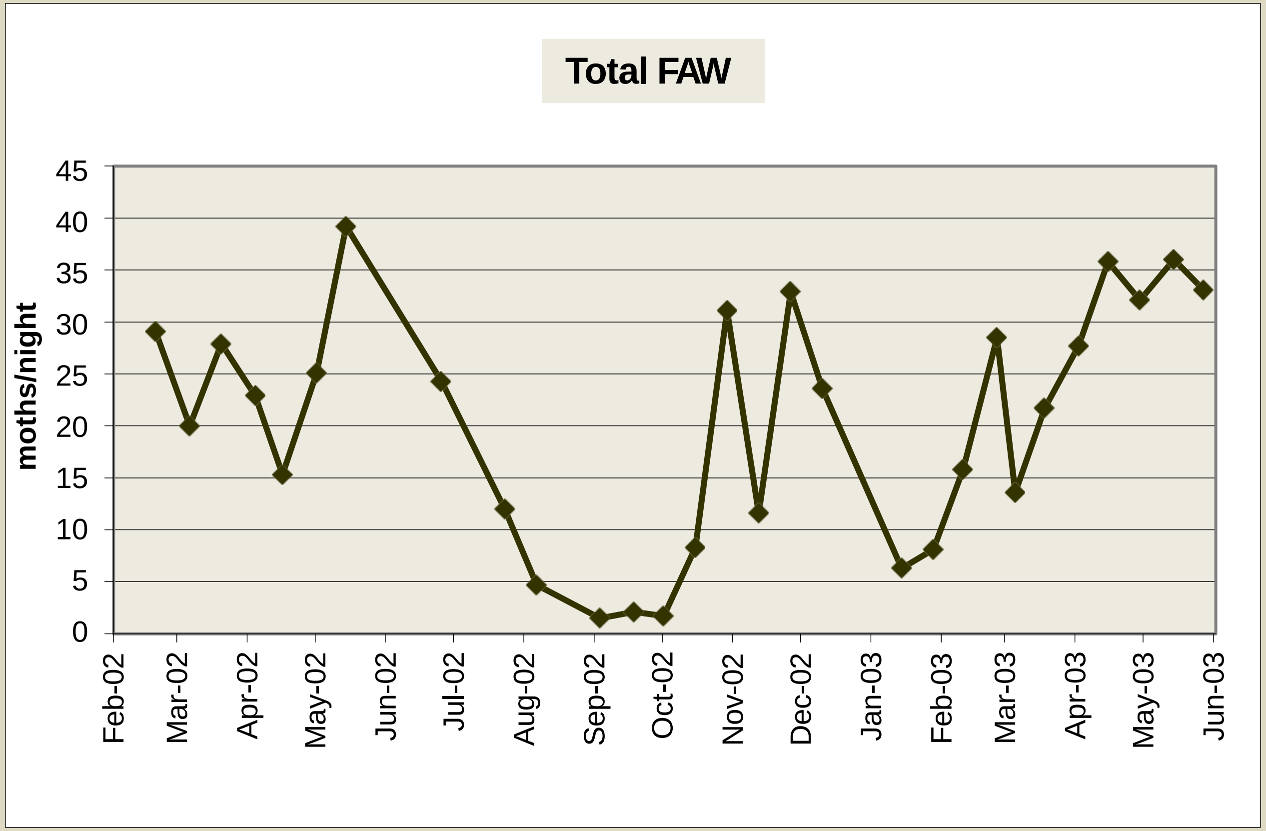
Meagher & Nagoshi 2004; Nagoshi & Meagher 2004

Grasses

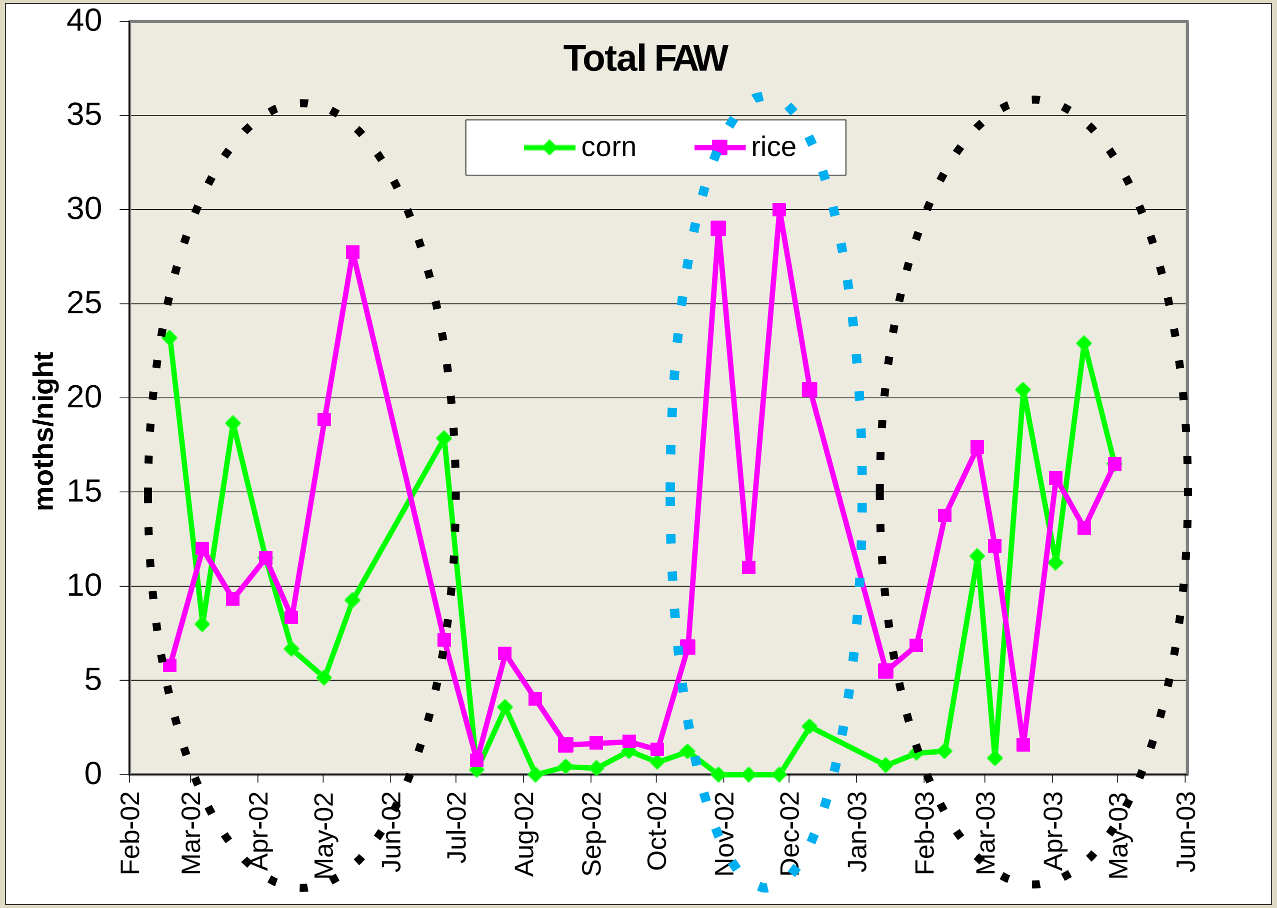


Meagher & Nagoshi 2004; Nagoshi & Meagher 2004

Agricultural



FAW shows a bimodal annual distribution.



The spring peaks are caused by both strains.

The fall peak is caused by the RS. Where is the CS in the fall?

Meagher & Nagoshi 2004; Nagoshi & Meagher 2004

Trapping in Ghana & Togo

3C from Trécé; 4C lures from Scentry

Table 1. *Spodoptera frugiperda* and bycatch moths per trap per date (*n* = 48; 8 dates × 2 lures × 3 blocks) during September 2018 to January 2019 for maize, sorghum, rice, and pasture grass sites in Ghana

Spodoptera frugiperda		Bycatch moths	
Crop	Mean ± SE[a]	Mean ± SE[b]	Percent captured[c]
Maize	7.46 ± 0.94 a	0.17 ± 0.07 a	2.2
Rice	2.42 ± 0.38 b	0.46 ± 0.11 a	15.9
Sorghum	0.77 ± 0.17 c	0.23 ± 0.08 a	22.9
Pasture grass	0.13 ± 0.06 d	0.31 ± 0.09 a	71.4
Lure	Mean ± SE[d]	Mean ± SE[e]	
3C	4.18 ± 0.57 a	0.34 ± 0.07 a	7.6
4C	1.21 ± 0.24 b	0.24 ± 0.06 a	16.5

Table 2. *Spodoptera frugiperda* and bycatch moths per trap per date (*n* = 42; 7 dates × 2 lures × 3 blocks) during September 2018 to January. 2019 for maize, sorghum, rice, and pasture grass sites in Togo

Spodoptera frugiperda		Bycatch moths	
Crop	Mean ± SE[a]	Mean ± SE[b]	Percent captured[c]
Rice	16.8 ± 4.07 a	0.29 ± 0.10 a	1.7
Maize	5.31 ± 1.32 b	0.26 ± 0.10 a	4.7
Pasture grass	0.40 ± 0.17 c	0.12 ± 0.07 a	22.7
Sorghum	0.19 ± 0.07 c	0.19 ± 0.07 a	50.0
Lure	Mean ± SE[d]	Mean ± SE[e]	
3C	9.83 ± 2.22 a	0.25 ± 0.07 a	2.5
4C	1.54 ± 0.53 b	0.18 ± 0.06 a	10.4

Table 3. *Spodoptera frugiperda* and bycatch moths per trap per date (*n* = 60; 10 dates × 3 lures × 3 blocks) during September 2019 to January 2020 for maize and sorghum sites in Ghana

Spodoptera frugiperda		Bycatch moths	
Crop	Mean ± SE[a]	Mean ± SE[b]	Percent captured[c]
Maize	5.25 ± 0.73 a	0.43 ± 0.09 a	7.6
Sorghum	0.80 ± 0.14 b	0.15 ± 0.05 b	15.8
Lure	Mean ± SE[d]	Mean ± SE[e]	
3C	4.78 ± 0.76 a	0.38 ± 0.08 a	7.4
4C	1.27 ± 0.22 b	0.20 ± 0.06 a	13.6

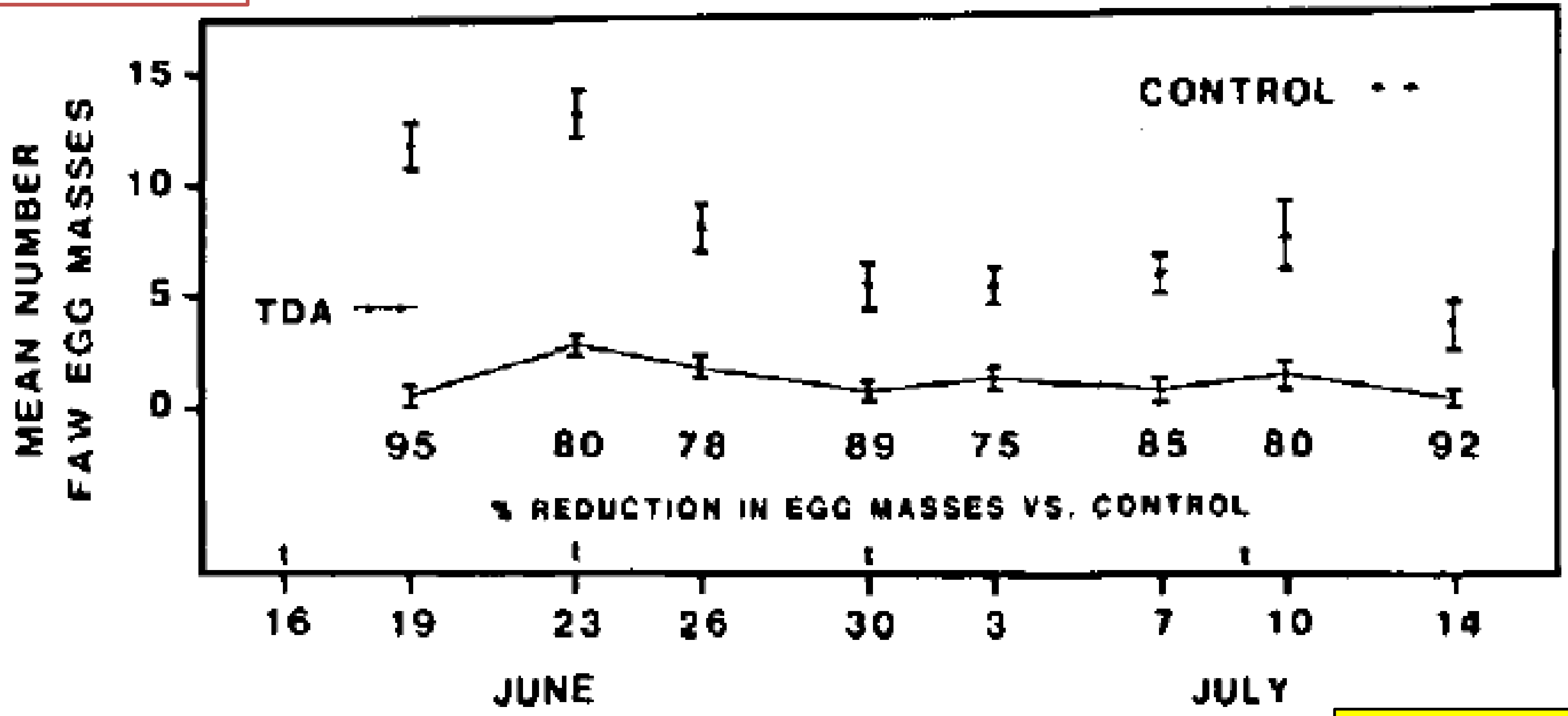
Table 4. *Spodoptera frugiperda* and bycatch moths per trap per date (*n* = 60; 10 dates × 3 lures × 3 blocks) during September 2019 to January 2020 for maize and sorghum sites in Togo

Spodoptera frugiperda		Bycatch moths	
Crop	Mean ± SE[a]	Mean ± SE[b]	Percent captured[c]
Maize	4.28 ± 0.58 a	0.40 ± 0.10 a	8.5
Sorghum	0.53 ± 0.11 b	0.13 ± 0.05 b	20.0
Lure	Mean ± SE[d]	Mean ± SE[e]	
3C	3.33 ± 0.58 a	0.37 ± 0.09 a	9.9
4C	1.48 ± 0.33 b	0.17 ± 0.06 a	10.1

Koffi et al. 2021

Management Using Pheromones

Mating Disruption



Mitchell & McLaughlin 1982

Prediction

Management Using Pheromones

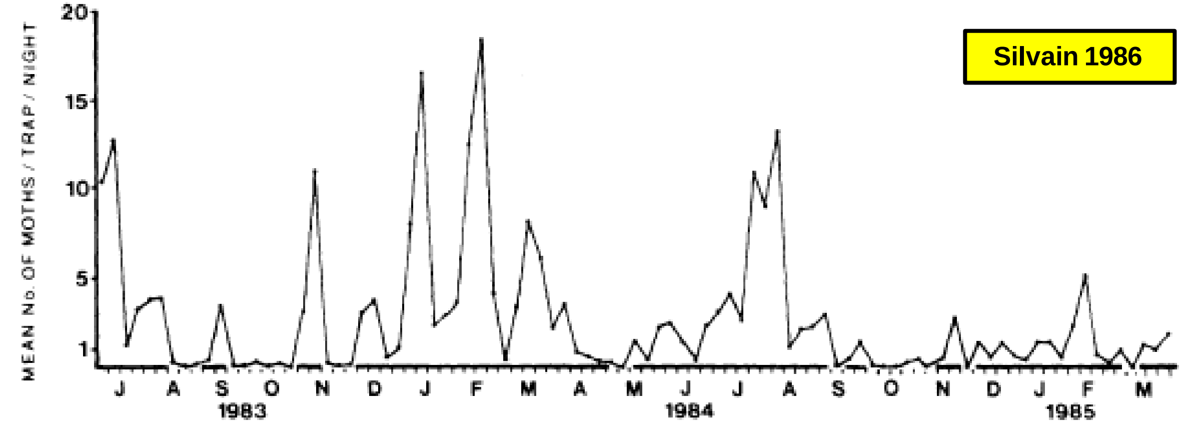


Fig. 1a. *Spodoptera frugiperda* moths captured per night in pheromone traps. Matoury, F. G. 1983-1985.

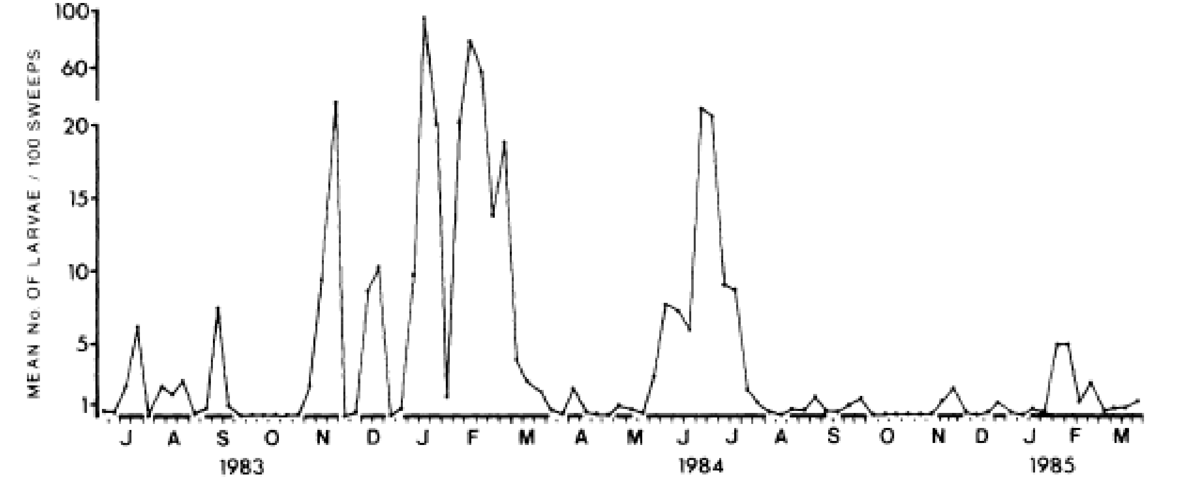


Fig. 1b. *Spodoptera frugiperda* arvae per 100 sweeps on improved pastures.

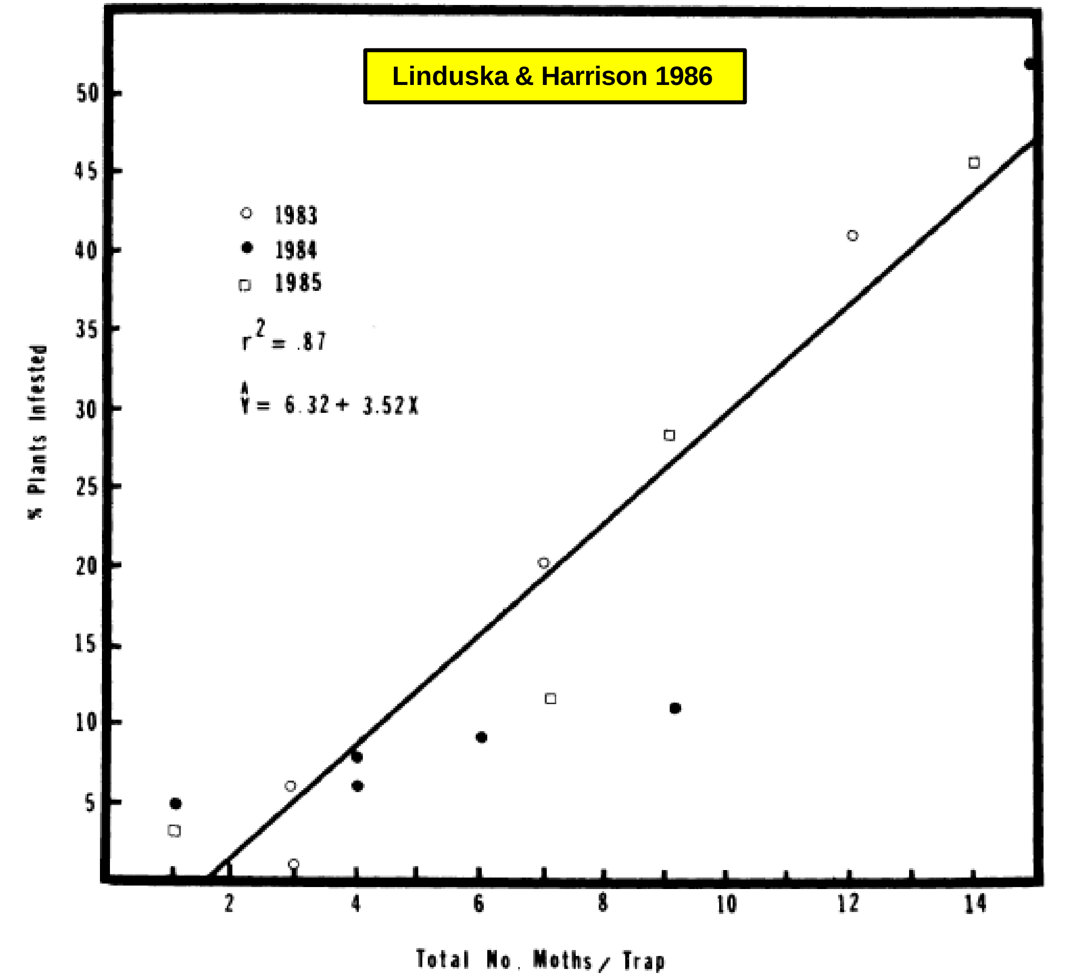
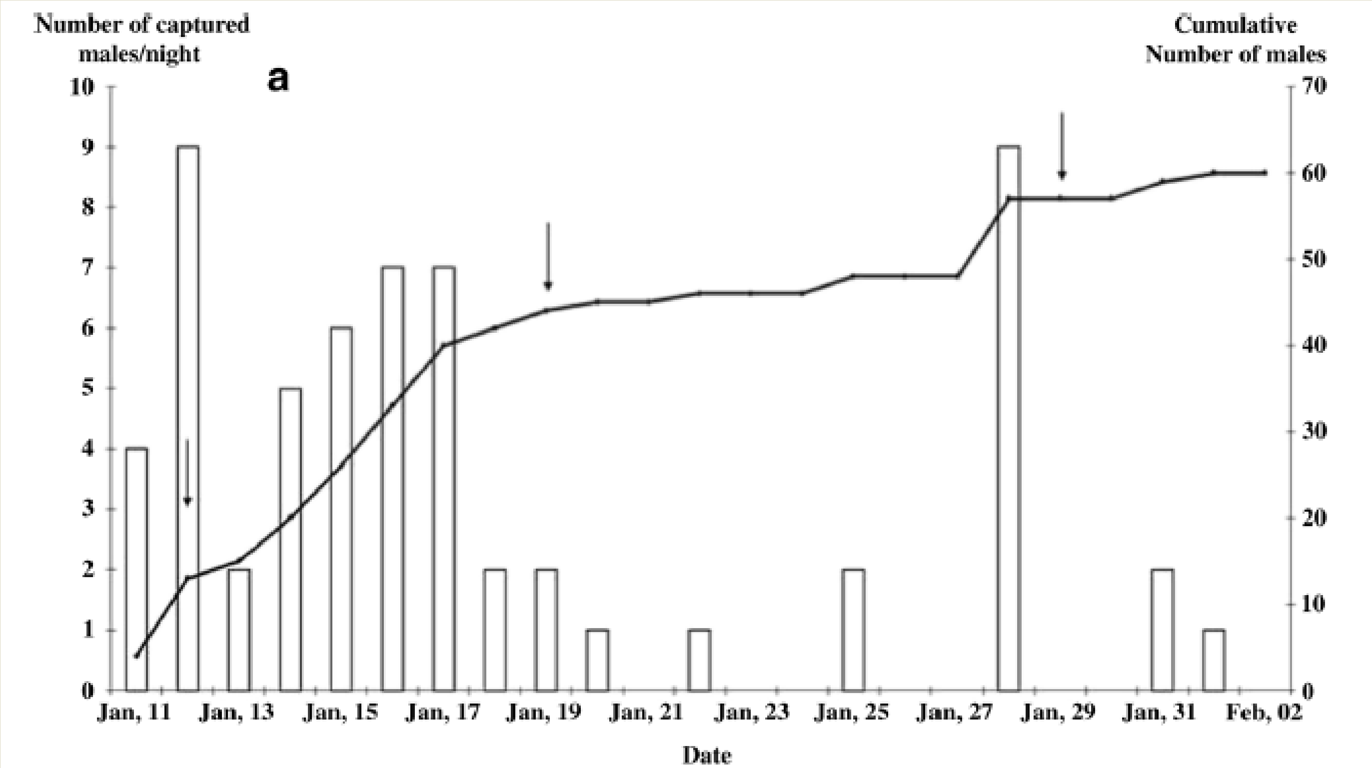


Fig. 1. The relationship between fall armyworms captured from the time of seedling emergence to 40 days post planting and the percent plants infested.

Thresholds

Management Using Pheromones



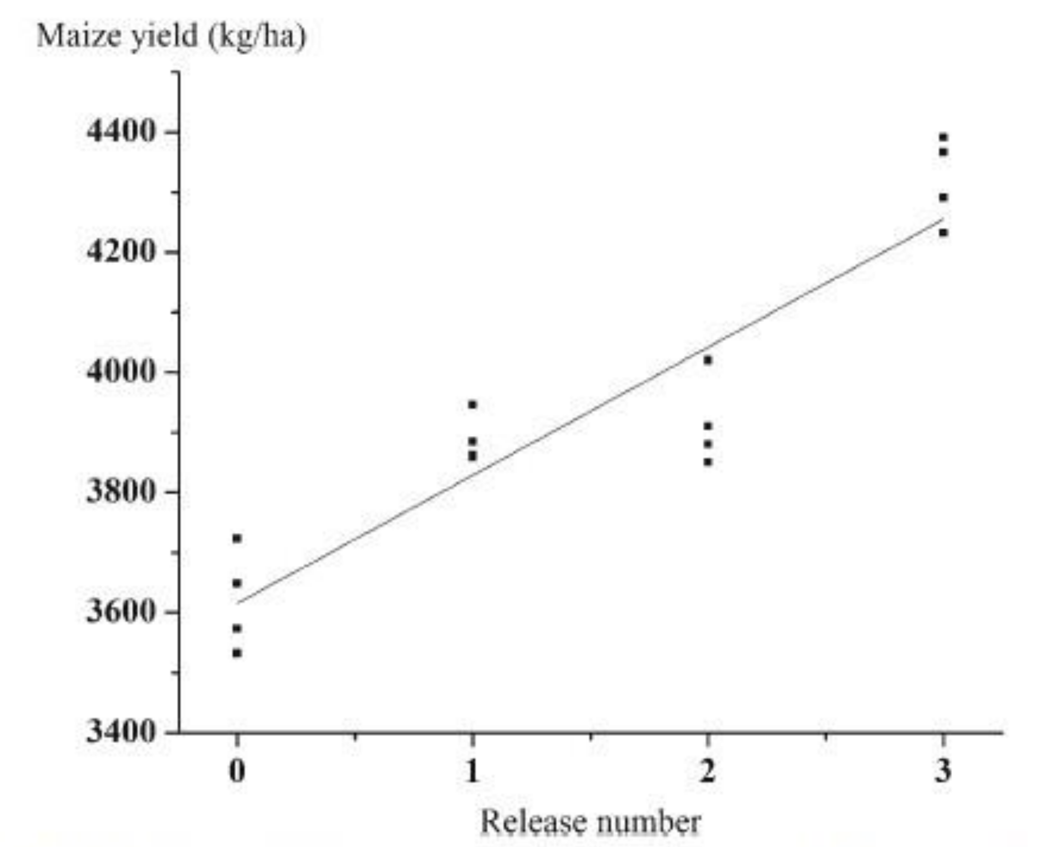


Fig. 3 Maize yield after release of *T. pretiosum* to control *S. frugiperda* (Kg ha^{-1}). Regression equation is y=3615.7+213.0*X*; R^2=0.84; P<0.05

Figueiredo et al. 2015

Seasonal Periodicity

Quebec

Tifton

Gainesville

Homestead

Puerto Rico

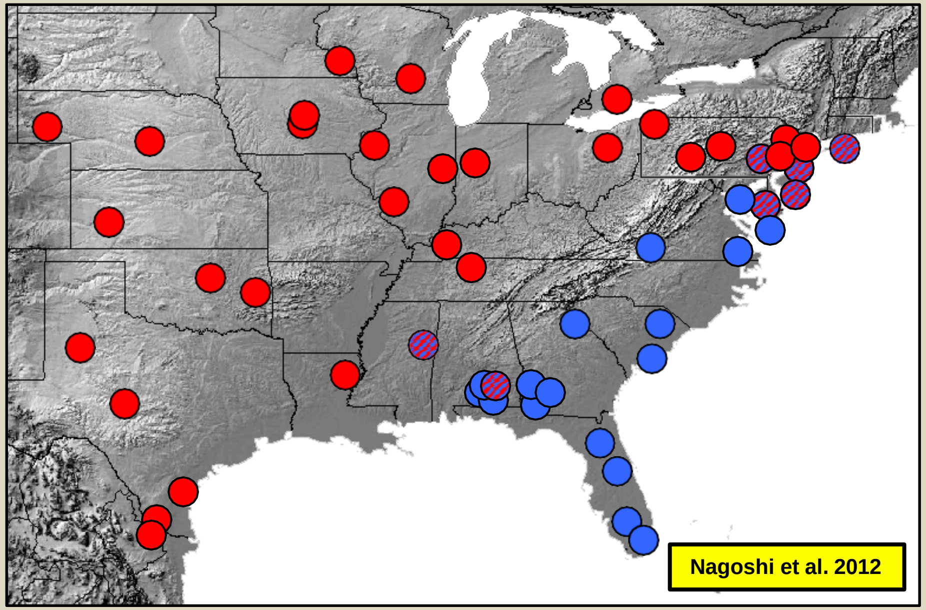
Virgin Is.

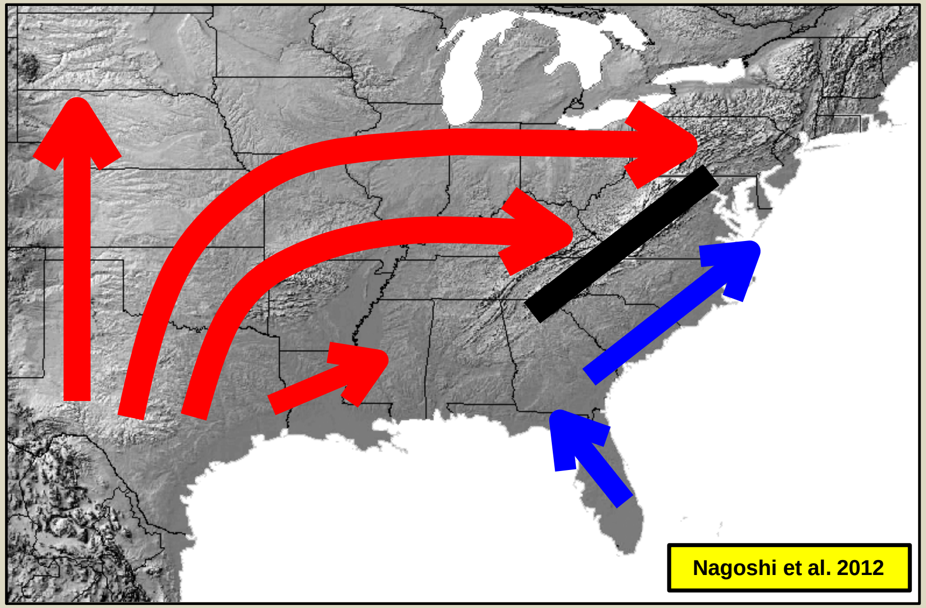
Guadeloupe

French Guiana

Mitchell et al. 1991

Modeling FAW Migratory Flight





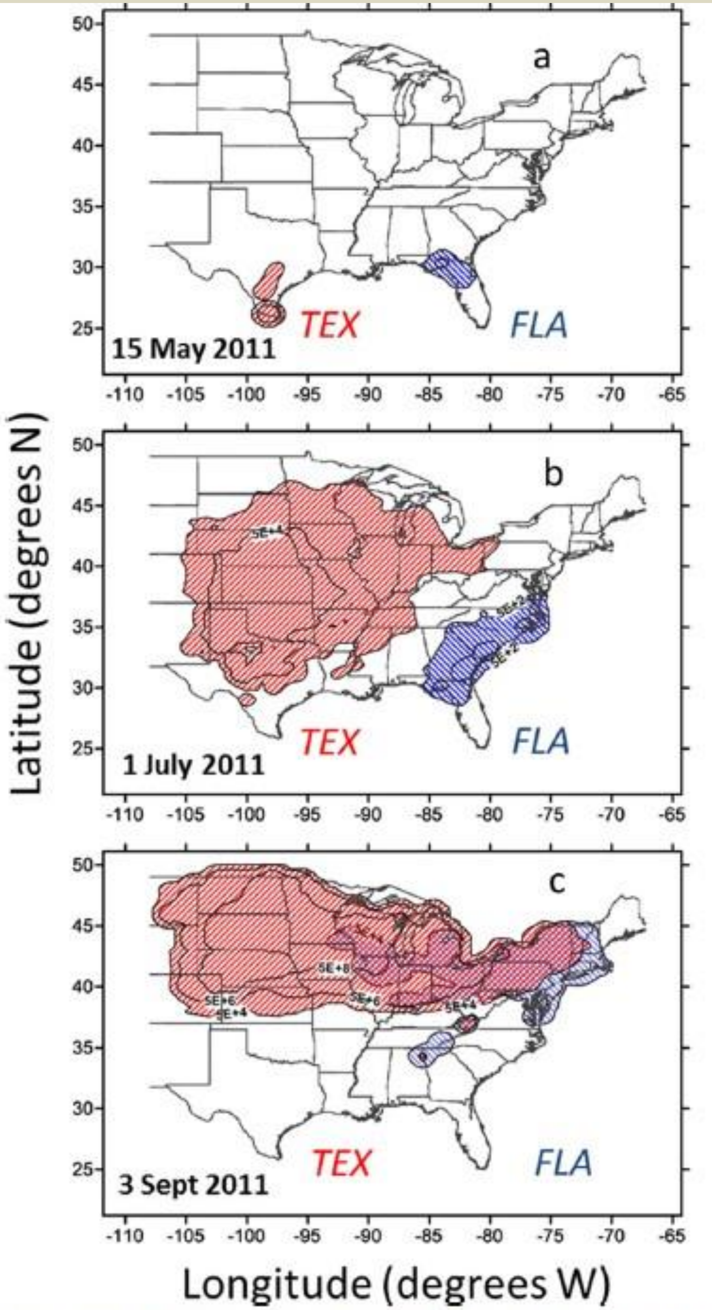


Fig. 3 Simulated weekly concentration of *TEX* (red) and *FLA* (blue) fall armyworm moths, valid on a 15 May, b 1 July, and c 3 September 2011. Values represent the number of moths per 1,600 km^2

Presenter Notes
2022-12-13 01:36:13

With all of this data from the earlier collections, we were now able to model the seasonal migratory patterns. The model results were close what has been found with our haplotype data and is a good starting point.

Westbrook et al. 2016, 2019

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Summary

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13 December 2022

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ASEAN FAW ACTION PLAN
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ASEAN Action Plan on Fall Armyworm

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