# Corn-Cotton-Soybean
# Pests & Resistance Situation

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COMITÊ BRASILEIRO DE AÇÃO A RESISTÊNCIA A INSETICIDAS

# OUTLINE

- **Brazilian agriculture: implications for IPM**

- **Cross-crop pests**

- **Research Projects -- IRAC-BR**

  **ESALQ/USP – Prof. Celso Omoto**

  **- *Helicoverpa armigera***

  **- *Spodoptera frugiperda***

  **PROMIP – Dr. Marcelo Poletti**

  **- *Euschistus heros***

  **- *Bemisia tabaci***

  **Instituto Biológico – Dr. Mário E. Sato**

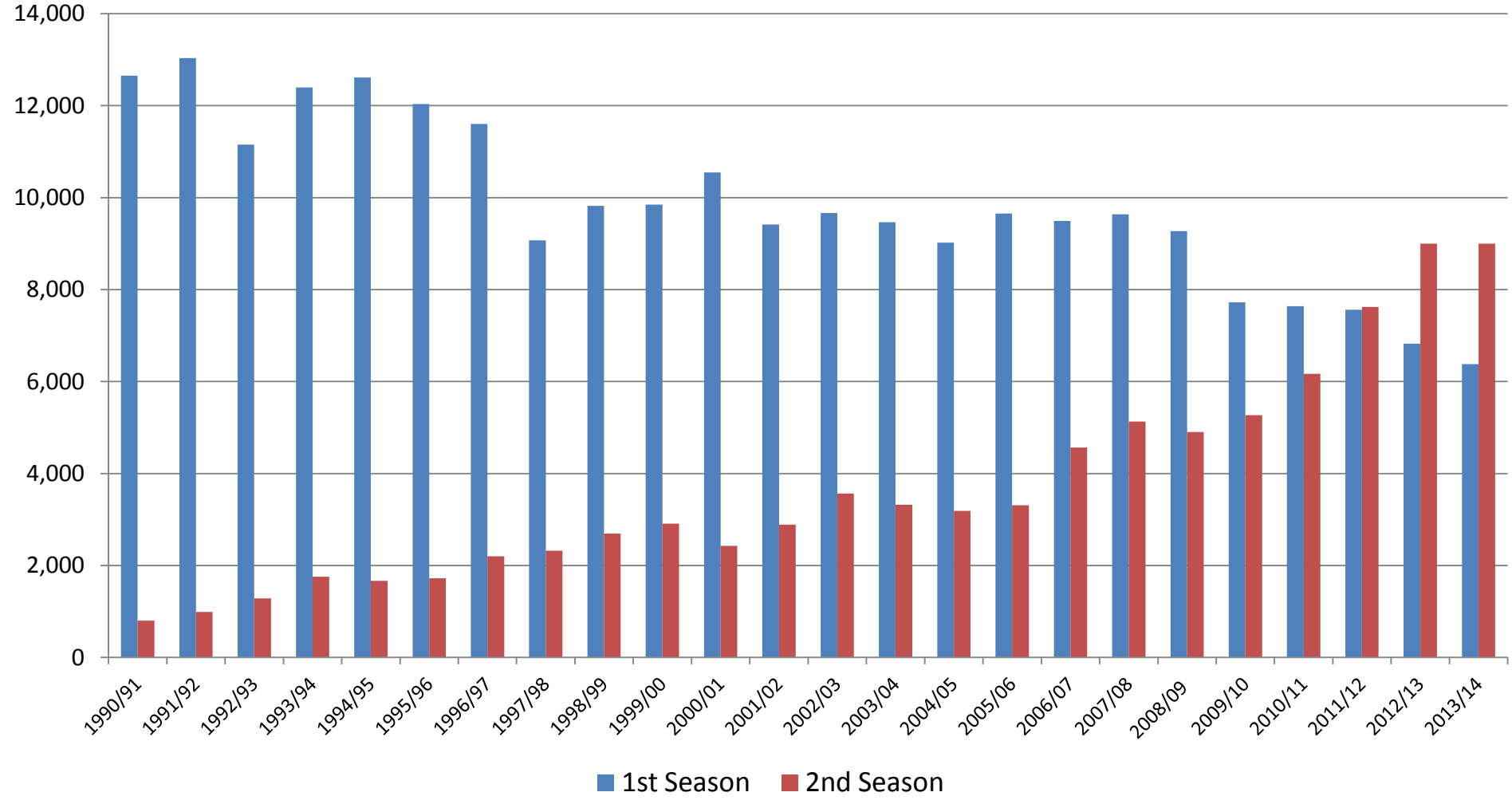
  **- *Tetranychus urticae***


# The miracle of Cerrado

The Economist

Available at: http://www.economist.com/node/16886442

# Corn Production Area in Brazil (1990-2013)
# (million of hectares)




Source: CONAB

# Corn-Growing Seasons in Brazil


OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP

**Cotton**

≈ 0.893 million ha

**Soybean**

≈ 27.7 million ha

Source: Conab / IBGE (2013)

# Soybean in Western Bahia

- 1980´s ➔2 to 4 insecticide sprays

  Production cost: US$ 300-400/ha
- 1990´s ➔ 5 to 7 insecticide sprays

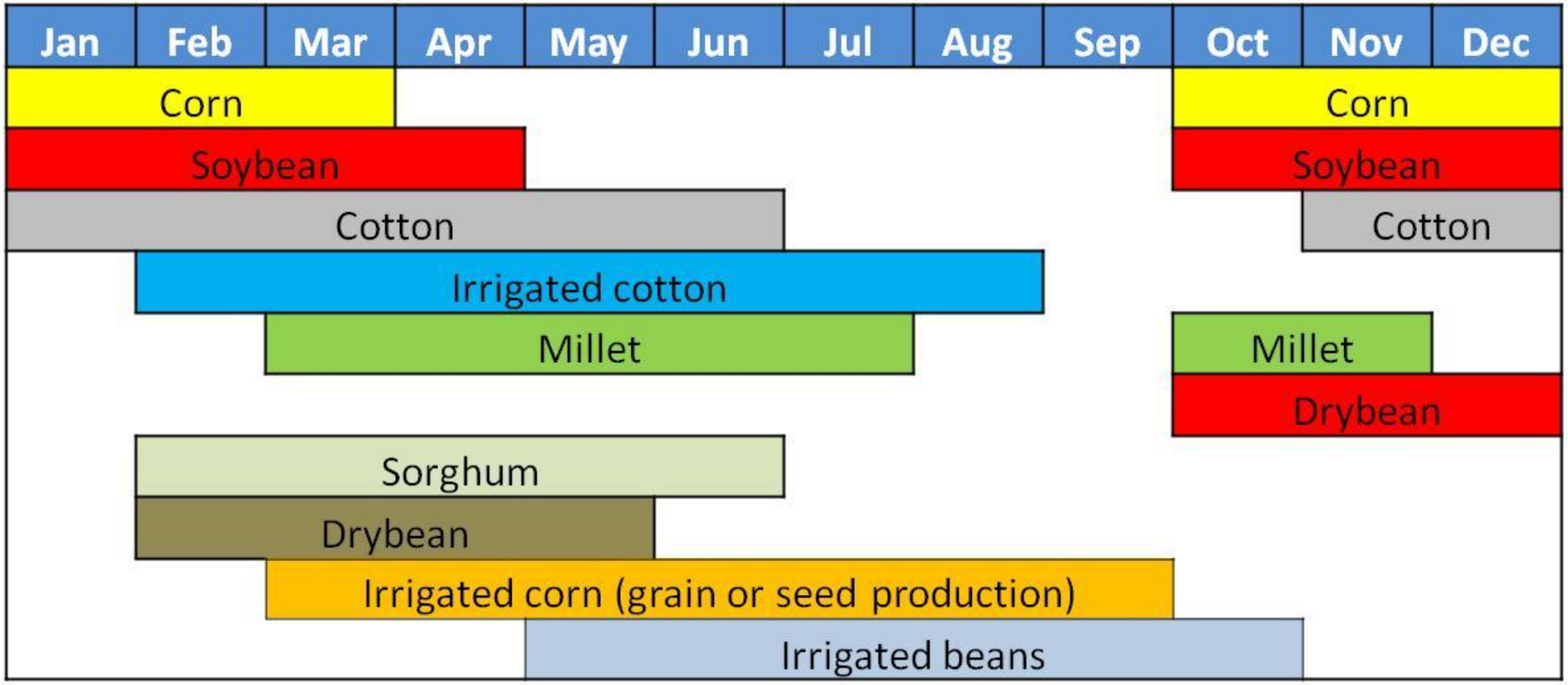
  Production cost: US$ 500-600/ha
- 2000´s ➔ 6 a 8 insecticide sprays

  Production cost: US$ 800/ha
- 2012/13 ➔ > 10 insecticide sprays

  Production cost: ≈ US$ 950/ha

Source: ADAB, ABAPA, AIBA, Fundação BA

# Major Cropping Systems in Western Bahia, Brazil




Source: Círculo Verde

# Cross-Crop Pests

## Soybean

*Spodoptera frugiperda*
*S. eridania*
*S. cosmioides*
*Helicoverpa* spp.
*Heliothis virescens*
*Chrysodeixis includens*
Stink bugs and other bugs
Whiteflies
Spider mites

## Corn

*Spodoptera frugiperda*
*Helicoverpa* spp.
Stink bugs and other bugs
Aphids
Whiteflies

## Cotton

*Spodoptera frugiperda*
*S. eridania*
*S. cosmioides*
*Helicoverpa* spp.
*Heliothis virescens*
*Chrysodeixis includens*
Stink bugs and other bugs
Whiteflies
Spider mites

# *Chrysodeixis includens* in soybean and cotton

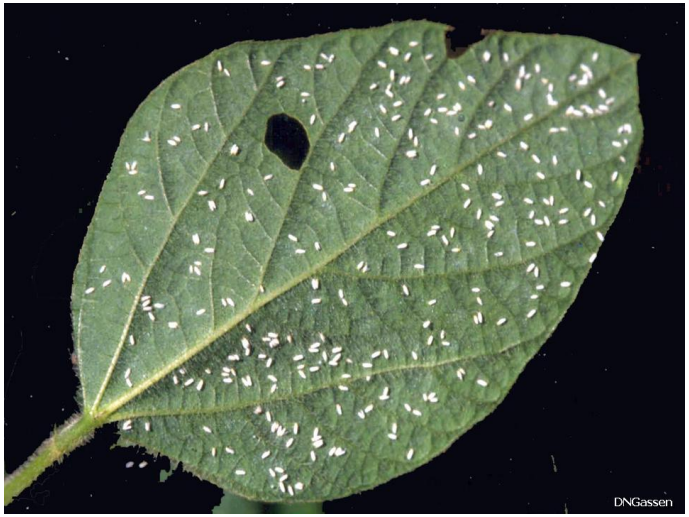
Credit: Paulo E. Saran

# Tetranychid mites in soybean and cotton

Credit: Flávio Moscardi

Credit: Paulo E. Saran

# *Bemisia tabaci* Biotype B



# Stink bugs in cotton

Credit: Paulo E. Saran

# *Dysdercus* spp.

**Soybean**

**Maize**

**Millet**

Credit: Paulo E. Saran

# *S. frugiperda*
# in cotton and soybean crops

Credit: Paulo E. Saran

# Increase problem of *Spodoptera* spp. in cotton and soybean crops

# Increase problem of *Heliothis virescens* in soybean

Credit: Paulo E. Saran

# Detection of *Helicoverpa armigera* in Brazil in 2013



**Source: Czepak et al. (2013); Spetch et al. (2013)**

Credit: Barbosa

# Insecticides for Emergency Use Permit

- Flubendiamide
- Chlorantraniliprole
- Spinosad
- Spinetoram
- Lufenuron
- Novaluron
- Chlorfluazuron
- Methoxifenozide
- Chlorfenapyr
- Indoxacarb
- Metaflumizone
- Thiodicarb
- Methomyl
- Chlorpyrifos

- *Bacillus thuringiensis*
- NPV

- Bifenthrin
- Zeta cypermethrin

- Chlorantraniliprole + Lambda-cyhalothrin
- Bifenthrin + Zeta cypermethrin
- Bifenthrin + Carbosulfan

- Novaluron + Methomyl
- Lufenuron + Profenofos

Source: Embrapa (2013)

Arthropod Pesticide Resistance Database

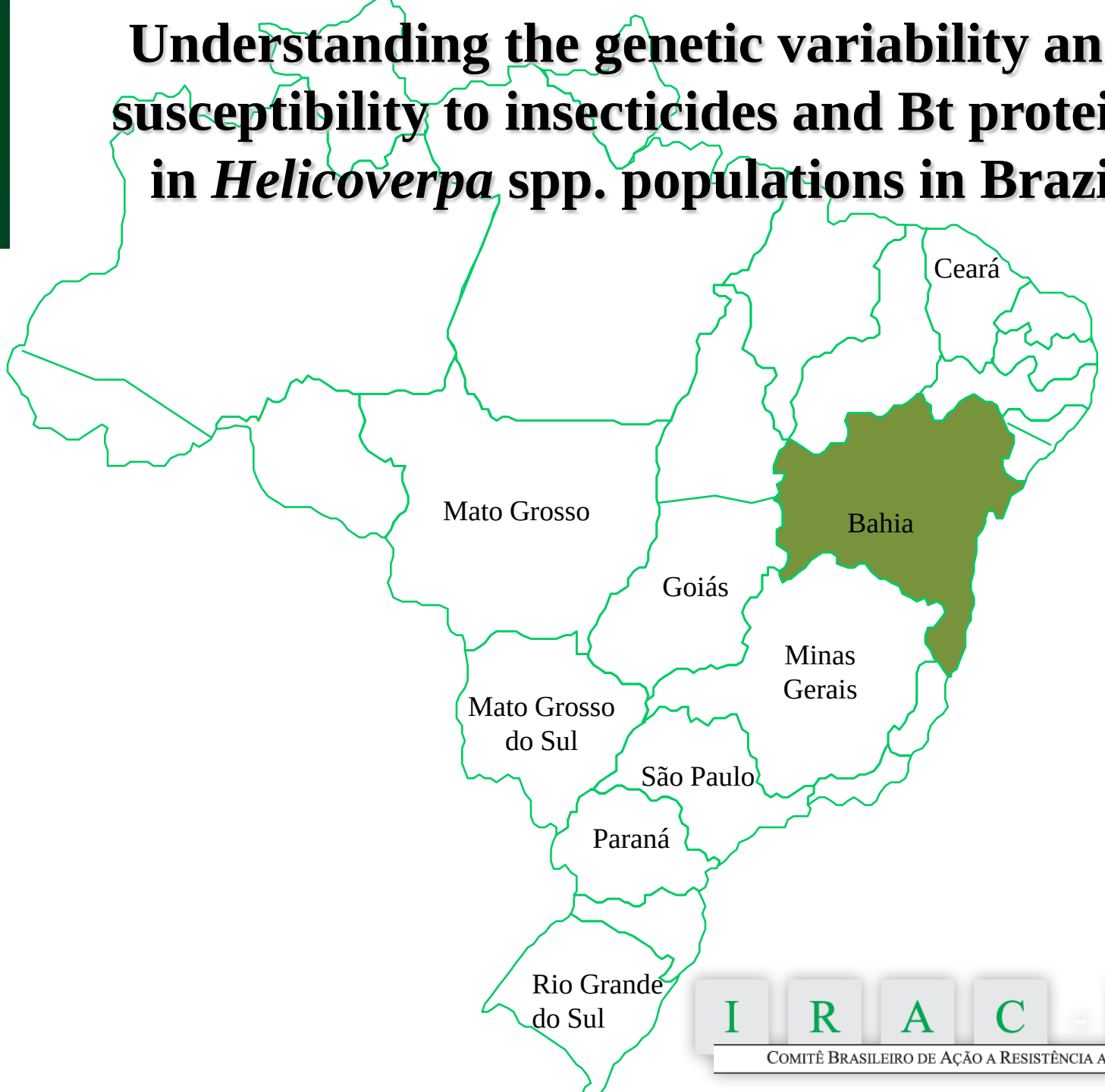
# Resistance cases in the world - *H. armigera*

- ✓ 686 cases
- ✓ 246 locations
- ✓48 active ingredients
  - Spinosad
  - Bifenthrin
  - Zeta cypermethrin
  - Lambda-cyhalothrin
  - Fenvarelate
  - Thiodicarb
  - Chlorpyrifos

IRAC MICHIGAN STATE UNIVERSITY

http://www.pesticideresistance.com

# Understanding the genetic variability and susceptibility to insecticides and Bt proteins in *Helicoverpa* spp. populations in Brazil

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# Samples of *Helicoverpa* spp.

✓ A total of 274 *Helicoverpa* caterpillars were collected at 19 sampling sites from six different crops

✓ Species identification was carried out using the sequence fragment of COI mitochondrial gene by comparing with *H. zea* and *H. armigera* species barcodes and determining homology with BlastN tool.

## Apr - Jun/2012

**Maize**

***H. zea***

- BA
- SP
- MG
- MS
- MT

**Millet**

***H. zea***

***H. armigera***

- BA

**Cotton**

***H. zea***

- BA

***H. armigera***

- BA
- MA

**Bean**

***H. armigera***

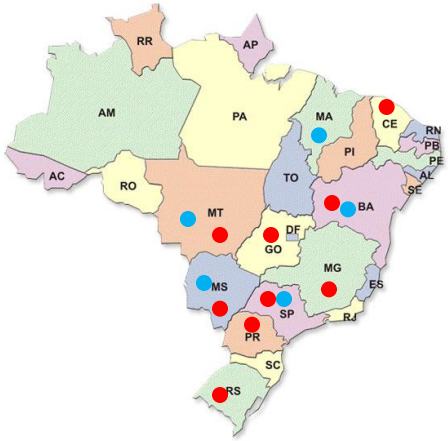
- BA

**Sorghum**

***H. armigera***

- BA

## Sep-Nov/2012




**Cotton**

***H. zea***

- CE

**Bean**

***H. armigera***

- BA

**Soybean**

***H. armigera***

- BA
- MT
- MS

## Dec-Mar/2013

**Maize**

***H. zea***

- BA
- SP
- MG
- PR
- RS
- GO

***H. armigera***

- BA

**Cotton**

***H. armigera***

- BA

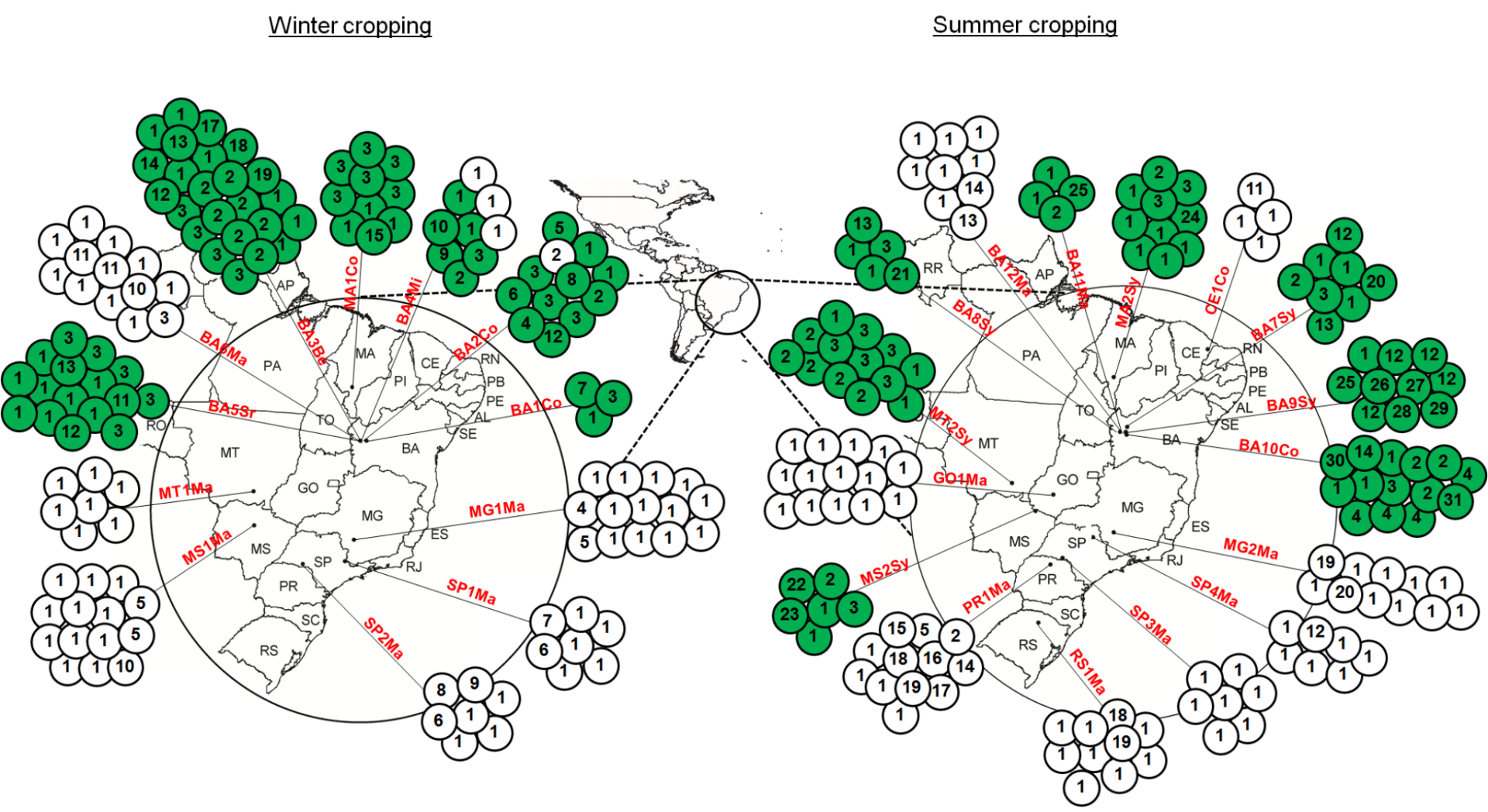
**Soybean**

***H. armigera***

- BA
- MT
- MA

Leite et al.(2014) – Plos One

# Geographic distributions of COI haplotypes of *H. armigera* and *H. zea*




*H. armigera* *H. zea*

Leite et al.(2014) – Plos One

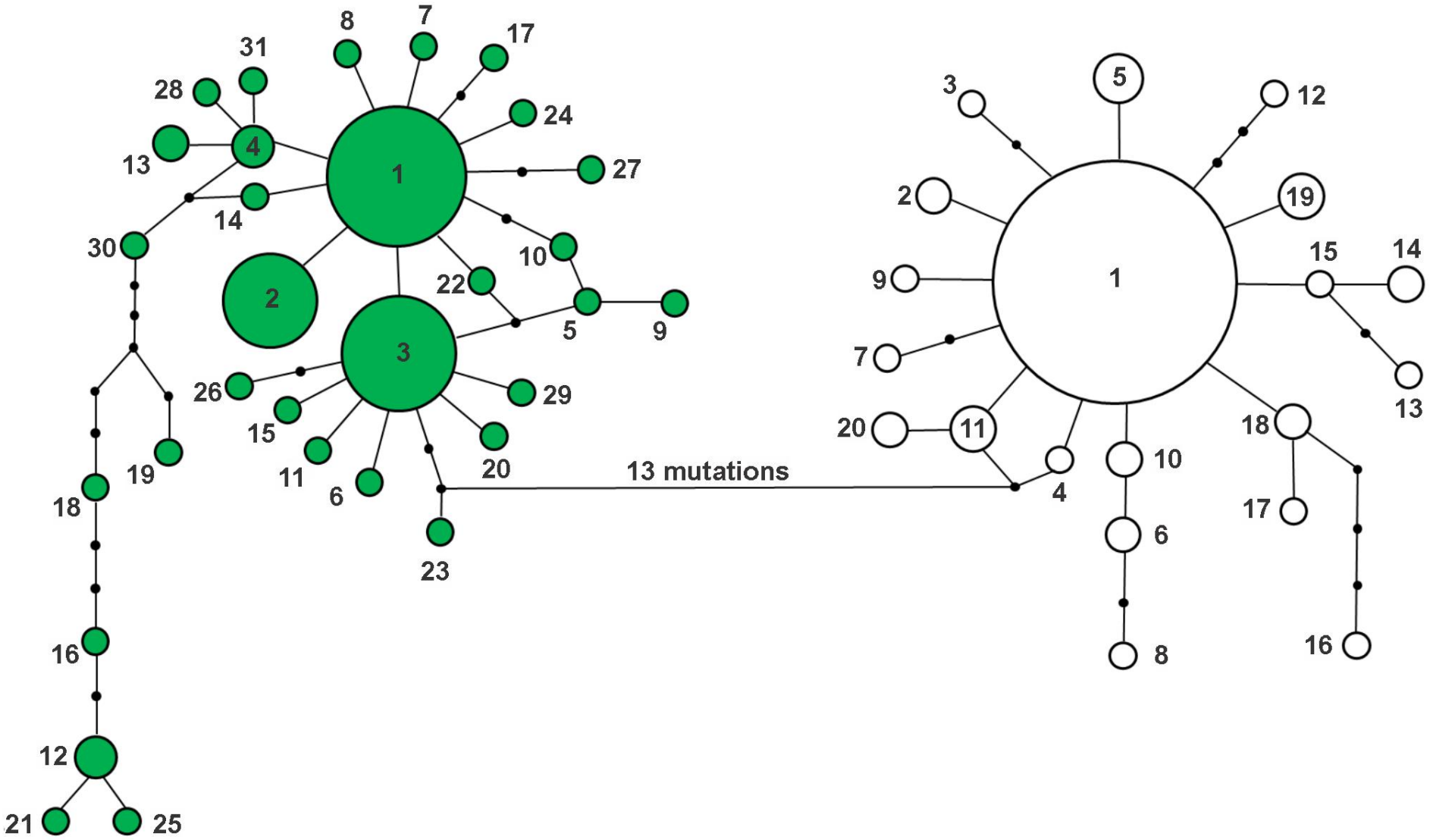
## No genetic structure in *H. armigera* and *H. zea* populations

## High genetic diversity in *H. armigera* and *H. zea* populations

| Species | # individuals (samples) | # Haplotypes | Haplotype Diversity (Hd) | Nucleotide Diversity (Pi) | Tajima's D test (p value) | Fu's Fs test (p value) |
|---|---|---|---|---|---|---|
| *H. armigera* | 139 (14) | 31 | 0.821 | 0.0028 | -1.729 (<0.01) | -26.361 (<0.01) |
| *H. zea* | 135 (16) | 20 | 0.42 | 0.0011 | -2.190 (<0.01) | -22.912 (<0.01) |

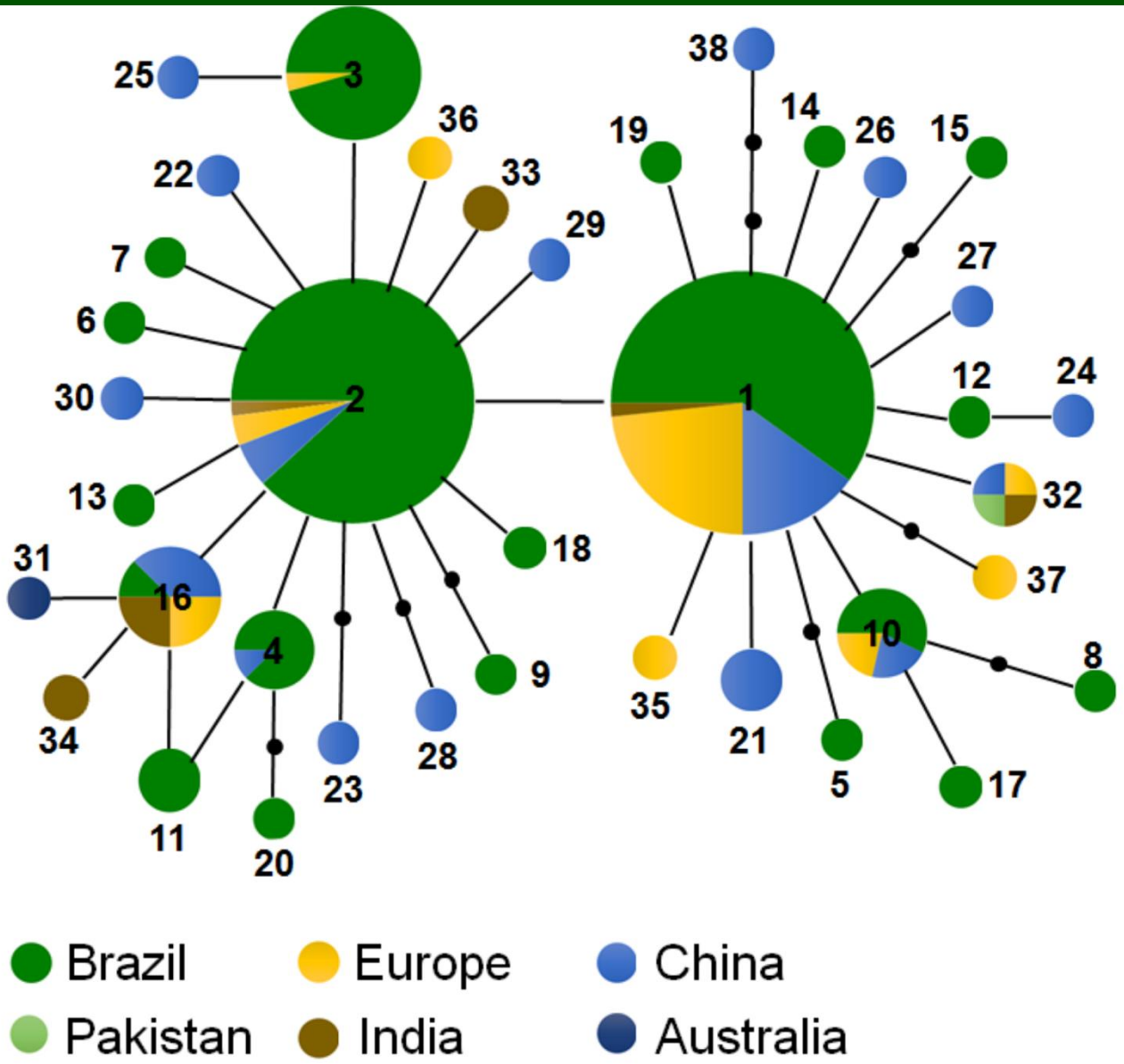
Leite et al.(2014) – Plos One

# Haplotype network based COI sequences from *H. armigera* and *H. zea* samples collected in Brazil



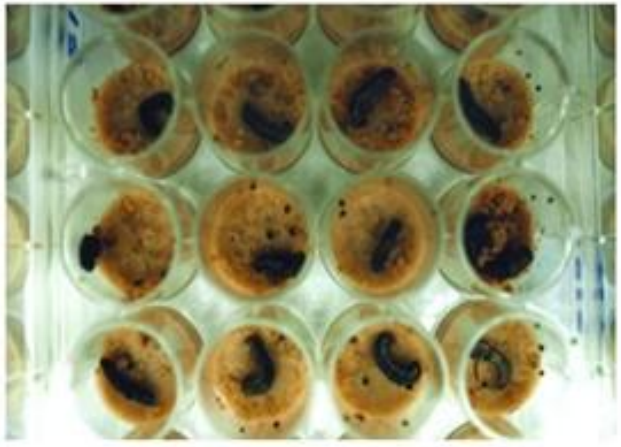

Leite et al.(2014) – Plos One

# Haplotype network based COI sequences from *H. armigera* samples from Brazil and Old World specimens



# Diet Overlay Bioassay





✓3rd instar larvae;

✓30 µL cell;

✓6-8 concentrations;

✓ After 2 and 4 days;

✓ Probit Analysis.

- Spinosyns
- Diamides
- Benzoylurea
- Diacylhydrazin
- Pyrazole
- Oxydiazine

# Topical Bioassay

- Deltamethrin
- Fenvarelate
- Thiodicarb
- Chlorpyrifos

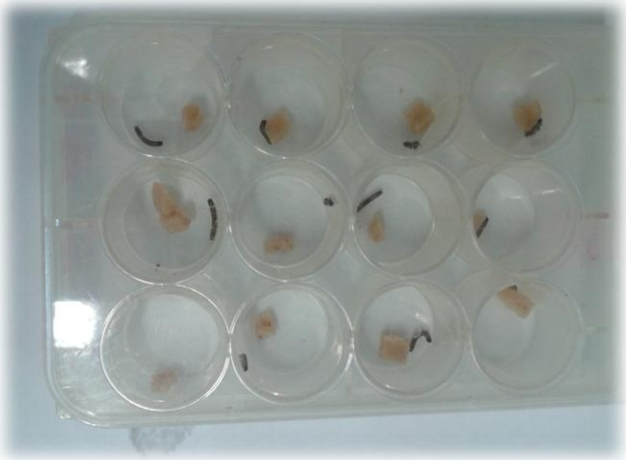
✓3rd instar larvae;

✓1 µL larvae;

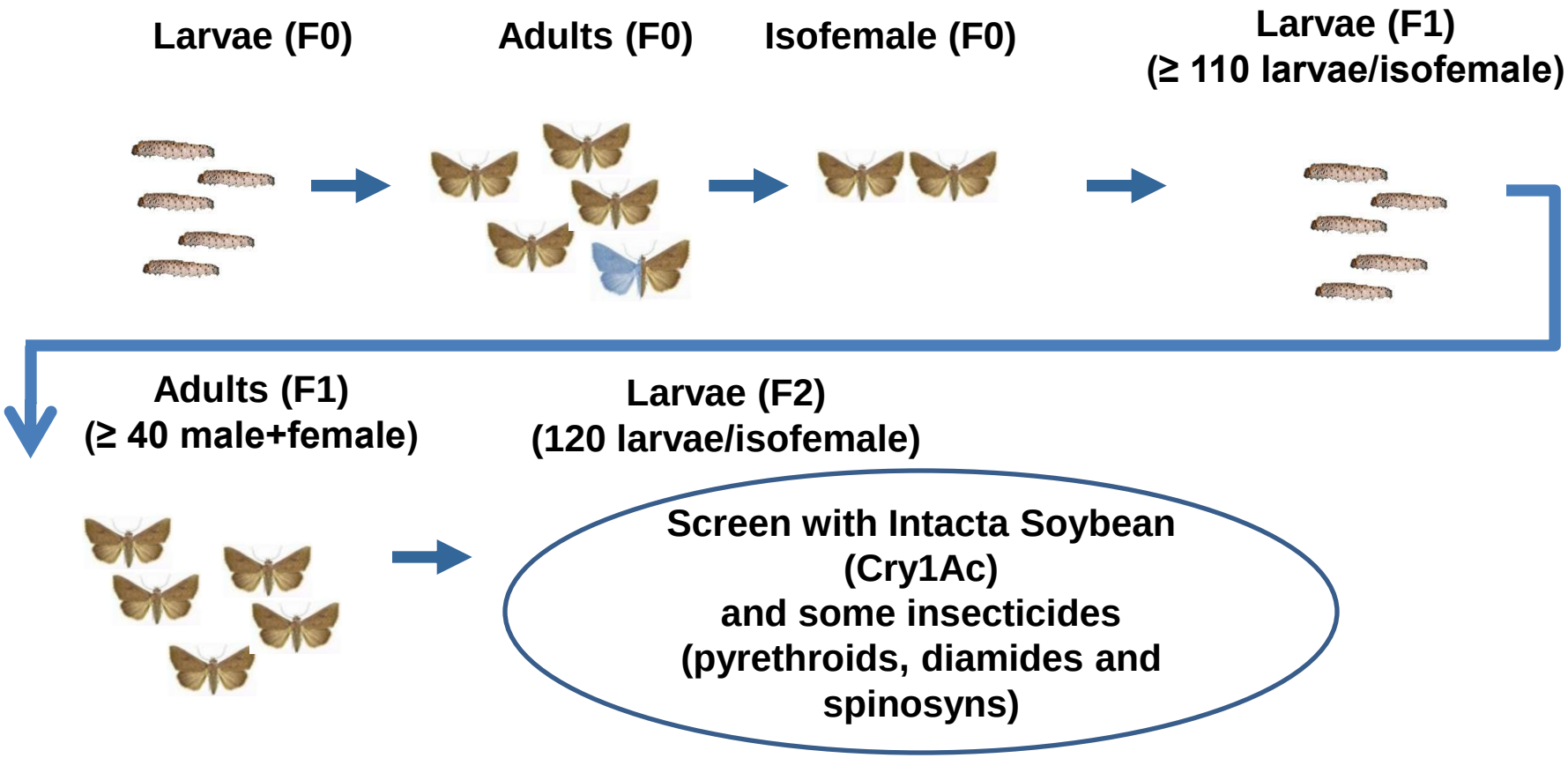
✓6-8 concentrations;

✓ After 24 and 48 h

✓ Probit Analysis.



# F2 screen




Andow & Alstad (1998)

# Resistance Monitoring 1996-2014

***Spodoptera frugiperda***

Mato Grosso

Bahia

Goiás

Minas Gerais

Mato Grosso do Sul

São Paulo

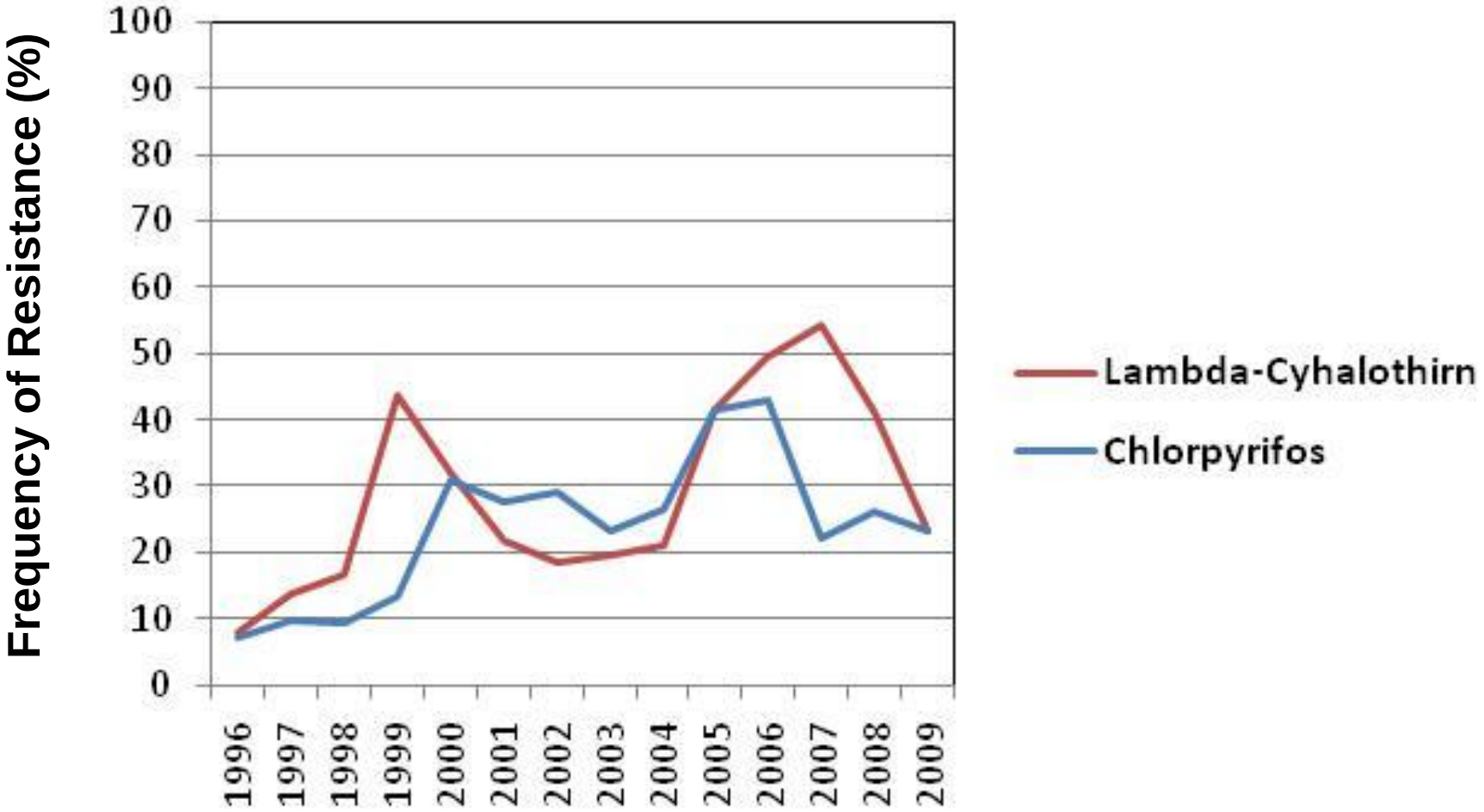
Paraná

Rio Grande do Sul

IRAC-BR

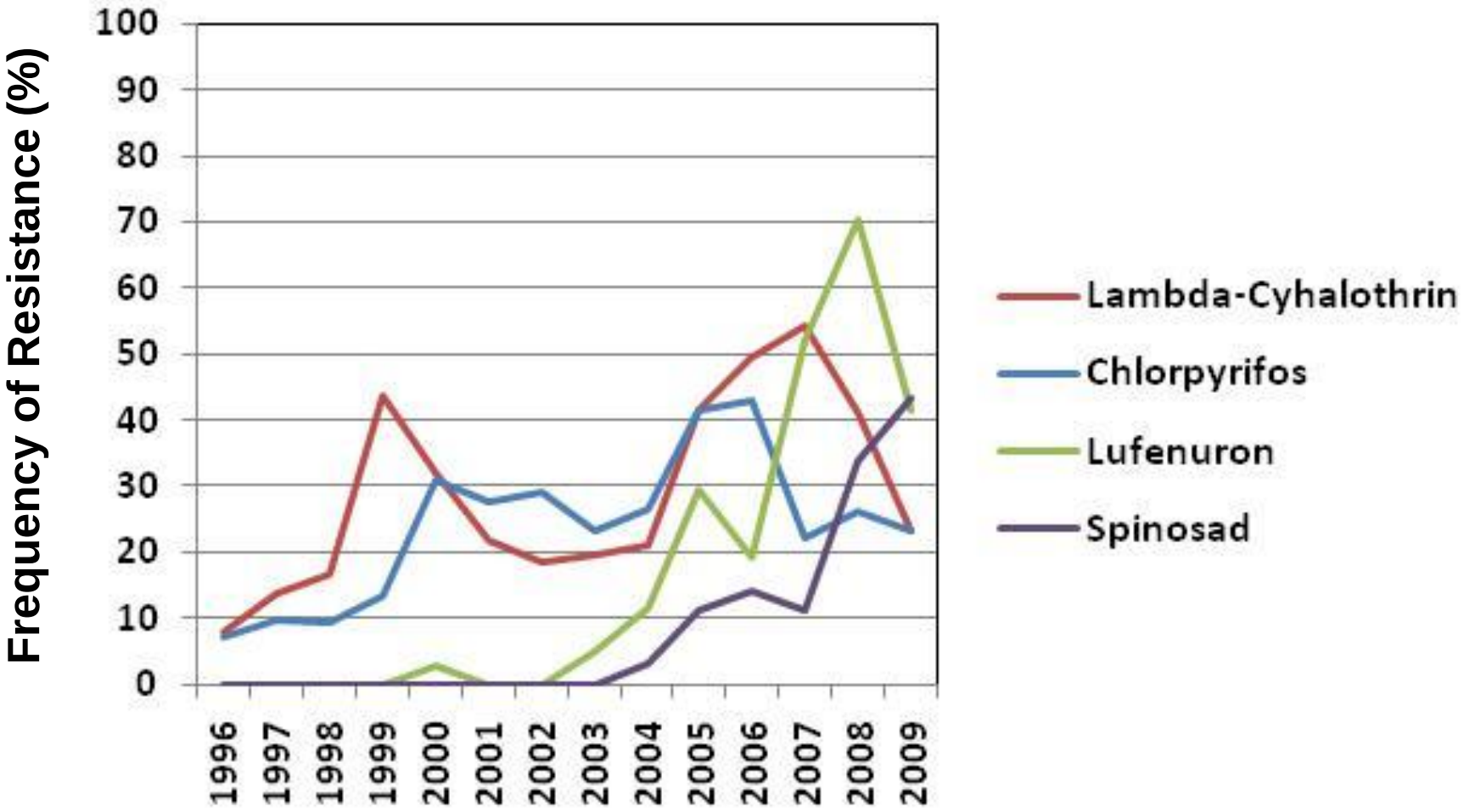
Comitê Brasileiro de Ação a Resistência a Inseticidas

# Insecticide Resistance Monitoring in Rio Verde, Goiás State, Brazil




Omoto et al. (in prep.)

# Insecticide Resistance Monitoring in Rio Verde, Goiás State, Brazil

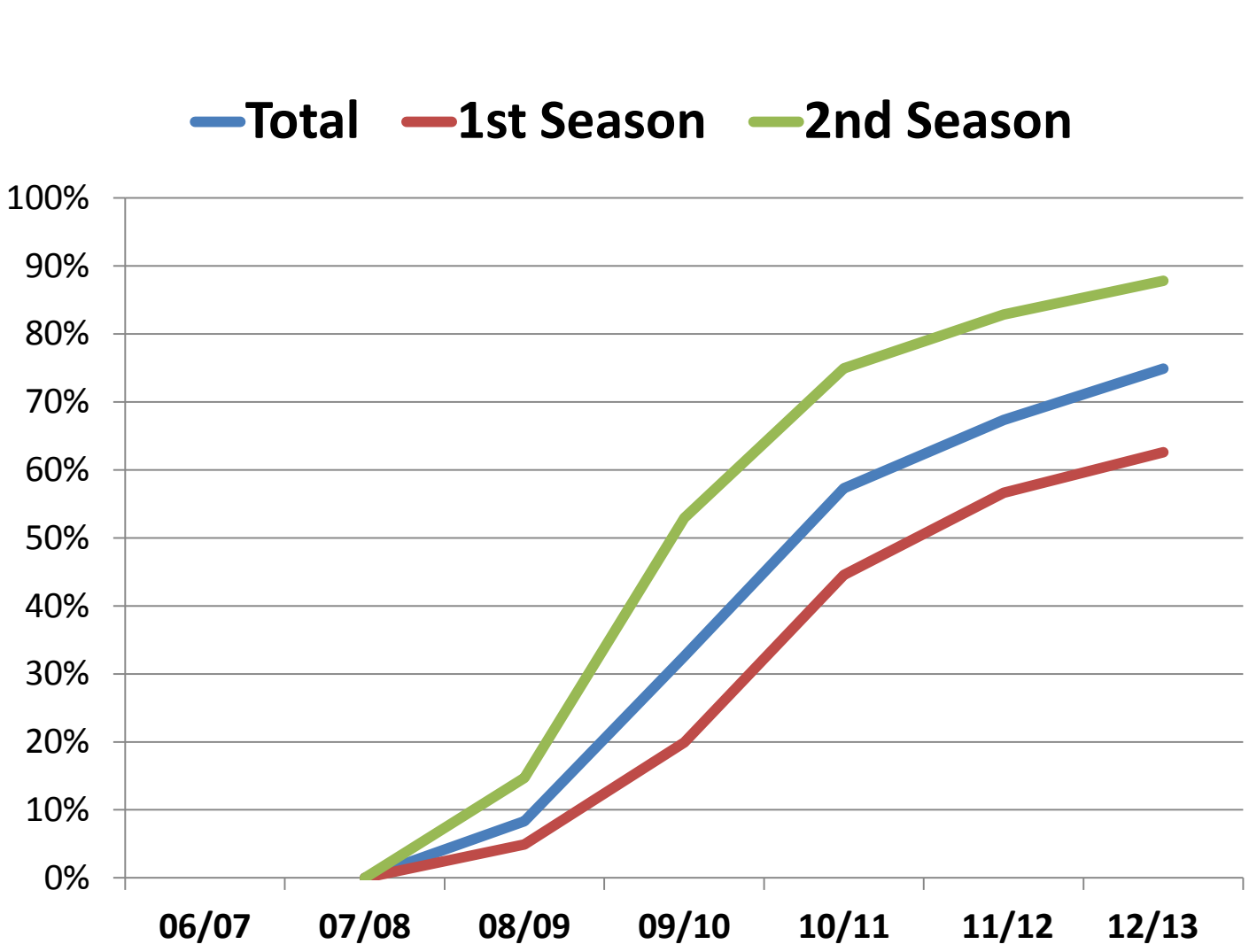


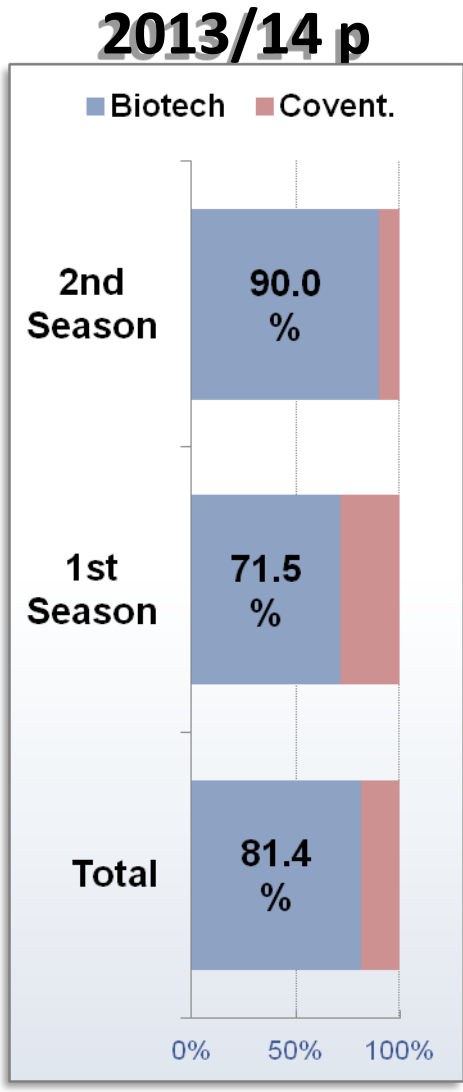

Omoto et al. (in prep.)

# Insecticide Resistance Status of *Spodoptera frugiperda* in Brazil

| | Chemical Class | IRAC Classification |
|---|---|---|
| High f(R) | Organophosphates | 1B |
| | Pyrethroids | 3 |
| | Benzoylureas | 11 |
| Low to intermetiate f(R) | Spinosyns | 5 |
| | Carbamates | 1A |
| ? | Indoxacarb | 22A |
| | Diamides | 28 |
| | *Bacillus thuringiensis* | 16 |

# Adoption of transgenic maize technology in Brazil (% cultivated area)




Source: CÉLERES® | % of total maize area | Updated in August 2013


# Field-evolved resistance to Cry1F maize by *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in Brazil

Juliano Ricardo Farias [a, *], David A. Andow [b], Renato Jun Horikoshi [a], Rodrigo José Sorgatto [a], Pablo Fresia [a], Antonio Cesar dos Santos [c], Celso Omoto [a]

[a] *Department of Entomology and Acarology, "Luiz de Queiroz" College of Agriculture (ESALQ), University of São Paulo (USP), Av. Pádua dias 11, Piracicaba, São Paulo 13418-900, Brazil*

[b] *Department of Entomology, University of Minnesota, 219 Hodson Hall, 1980 Folwell Ave., 55108 Saint Paul, MN, USA*

[c] *Dow AgroSciences LLC, 9330 Zionsville Rd, 46268 Indianapolis, IN, USA*

# Bt crops in Brazil

| Crop | Bt protein(s) |
|---|---|
| **Cotton** | Cry1Ac |
| | Cry1Ac/Cry1F |
| | Cry1Ac/Cry2Ab2 |
| | Cry1Ab/Cry2Ae |
| **Corn** | Cry1Ab |
| | Cry1F |
| | Cry1A.105/Cry2Ab2 |
| | VIP3Aa20 |
| | Cry1Ab/VIP3Aa20 |
| | Cry1A.105/Cry2Ab2/Cry1F |
| | Cry1Ab/Cry1F |
| | Cry1A.105/Cry2Ab2/Cry3Bb1 |
| **Soybean** | Cry1Ac |

**Source: CTNBio (2013)**

# High Risk of Resistance Evolution

- Single protein events
- Not a high-dose event to major target pests
- Low refuge compliance
- Intense selection pressure with different Bt crops

# Bt crops in Brazil

| Crop | Technology | Bt Protein | | |
|---|---|---|---|---|
| | | Cry1 | Cry2 | VIP |
| Corn | Yieldgard®; Agrisure TL® | Cry1Ab | | |
| | Herculex®™ | Cry1F | | |
| | Viptera™ | | | Vip3A |
| | Agrisure Viptera™ | Cry1Ab | | Vip3A |
| | Optimum™ Intrasect™ | Cry1Ab + Cry1F | | |
| | Yieldgard VT PRO™ | Cry1A.105 | Cry2Ab | |
| | PowerCore™ | Cry1A.105 + Cry1F | Cry2Ab | |
| Cotton | Bollgard® | Cry1Ac | | |
| | Bollgard II® | Cry1Ac | Cry2Ab | |
| | Widestrike™ | Cry1Ac + Cry1F | | |
| | TwinLink® | Cry1Ab | Cry2Ae | |
| Soybean | Intacta RR2 PRO™ | Cry1Ac | | |

OPEN ACCESS Freely available online

PLOS ONE

# Shared Midgut Binding Sites for Cry1A.105, Cry1Aa, Cry1Ab, Cry1Ac and Cry1Fa Proteins from *Bacillus thuringiensis* in Two Important Corn Pests, *Ostrinia nubilalis* and *Spodoptera frugiperda*

**Carmen Sara Hernández-Rodríguez[1], Patricia Hernández-Martínez[1], Jeroen Van Rie[2], Baltasar Escriche[1], Juan Ferré[1]***

**1** Departamento de Genética, Universitat de València, Burjassot, Spain, **2** Bayer CropScience N.V., Ghent, Belgium

## Bt corn

- Cry1A.105 + Cry2Ab2
- Cry1Ab + VIP3Aa20
- Cry1A.105 + Cry2Ab2 + Cry1F
- Cry1Ab + Cry1F

## Bt cotton

- Cry1Ac + Cry2Ab
- Cry1Ac + Cry1F
- Cry1Ab + Cry1Ae

*Phil. Trans. R. Soc. Lond.* B (1998) **353**, 1777–1786

THE ROYAL SOCIETY

# Two-toxin strategies for management of insecticidal transgenic crops: can pyramiding succeed where pesticide mixtures have not?

**R. T. Roush**

*Department of Crop Protection, University of Adelaide, Waite Campus, PMB1, Glen Osmond, South Australia 5064, Australia (rroush@waite.adelaide.edu.au)*

# Bt maize in Brazil: Key Target Pests at Risk

*Spodoptera frugiperda*
Fall armyworm

*Helicoverpa zea*
Corn earworm

*Diatraea saccharalis*
Sugarcane borer

**Cry1Ab**
**Cry1F**
**Vip3A**
**Cry1Ab + Cry1F**
**Cry1Ab + Vip3A**
**Cry1A.105 + Cry2Ab**
**Cry1A.105 + Cry2Ab + Cry1F**

**10% Refuge**

*Helicoverpa armigera*

# Bt cotton in Brazil: Key Target Pests at Risk

*Alabama argillacea*
Cotton leafworm

*Pectinophora gossypiella*
Pink bollworm

*Chrysodeixis ncludens*
Soybean looper

*Heliothis virescens*
Tobacco budworm

*Spodoptera frugiperda*
Fall armyworm

*Helicoverpa armigera*

**Cry1Ac**
**Cry1Ac + Cry2Ab**
**Cry1Ac + Cry1F**
**Cry1Ab + Cry2Ae**

**20% Refuge**

# Bt soybean in Brazil: Key Target Pests

*Anticarsia gemmatalis*
Velvetbean caterpillar

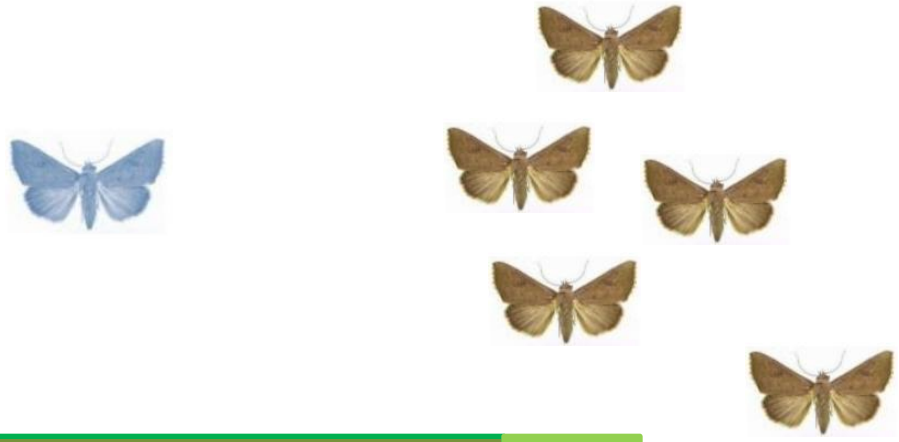
*Chrysodeixis includens*
Soybean looper

*Heliothis virescens*
Tobacco budworm

*Helicoverpa armigera*

- **Cry1Ac (2010) ➔ 20% refuge area**

# Refuge

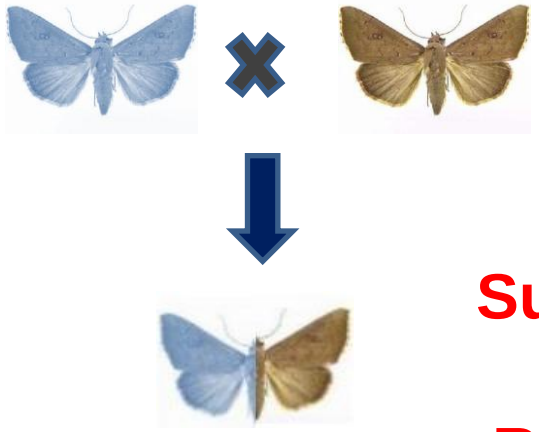


Susceptible

Resistant

**Bt crop** **Refuge**

**Resistant** **Susceptible**



**Susceptible or Resistant?**

➔ **Depend on the Bt protein and concentration expressed in the plant**

# Intense selection pressure with Bt crops

| OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG |
|---|---|---|---|---|---|---|---|---|---|---|
| **MAIZE** | | | | | | | | | | |
| | | | | | **IRRIGATED MAIZE** | | | | | |
| Cry1Ab | | | | | Cry1Ab | | | | | |
| Cry1F | | | | | Cry1F | | | | | |
| Vip3A | | | | | Vip3A | | | | | |
| Cry1Ab + Cry1F | | | | | Cry1Ab + Cry1F | | | | | |
| Cry1Ab + Vip3A | | | | | Cry1Ab + Vip3A | | | | | |
| Cry1A.105 + Cry2Ab2 | | | | | Cry1A.105 + Cry2Ab2 | | | | | |
| Cry1A.105 + Cry2Ab2 + Cry1F | | | | | Cry1A.105 + Cry2Ab2 + Cry1F | | | | | |
| | **COTTON** | | | | | | | | | |
| | | | | **IRRIGATED COTTON** | | | | | | |
| | Cry1Ac | | | Cry1Ac | | | | | | |
| | Cry1Ac + Cry2Ab2 | | | Cry1Ac + Cry2Ab2 | | | | | | |
| | Cry1Ac + Cry1F | | | Cry1Ac + Cry1F | | | | | | |
| | Cry1Ab + Cry2Ae | | | Cry1Ab + Cry2Ae | | | | | | |
| **SOYBEAN** | | | | | | | | | | |
| Cry1Ac | | | | | | | | | | |

# **Bt crops** ➔ Changes in pest population dynamics

## Bt Soybean

~~*Spodoptera frugiperda*~~
*S. eridania*
*S. cosmioides*
~~*Helicoverpa* spp.~~
~~*Heliothis virescens*~~
~~*Chrysodeixis includens*~~
Stink bugs & other bugs
Whiteflies
Spider mites

## Bt Corn

~~*Spodoptera frugiperda*~~
~~*Helicoverpa* spp.~~
Stink bugs & other bugs
Aphids
Whiteflies

## Bt Cotton

~~*Spodoptera frugiperda*~~
*S. eridania*
*S. cosmioides*
~~*Helicoverpa* spp.~~
~~*Heliothis virescens*~~
~~*Chrysodeixis includens*~~
Stink bugs and other bugs
Whiteflies
Spider mites

# PLANT HEALTH PROGRAM IN WESTERN BAHIA REGION


REALIZAÇÃO:

abapa aiba FUNDAÇÃO BA

PARCEIROS:

ADAB AEAB AGROLEM Embrapa

APOIO:

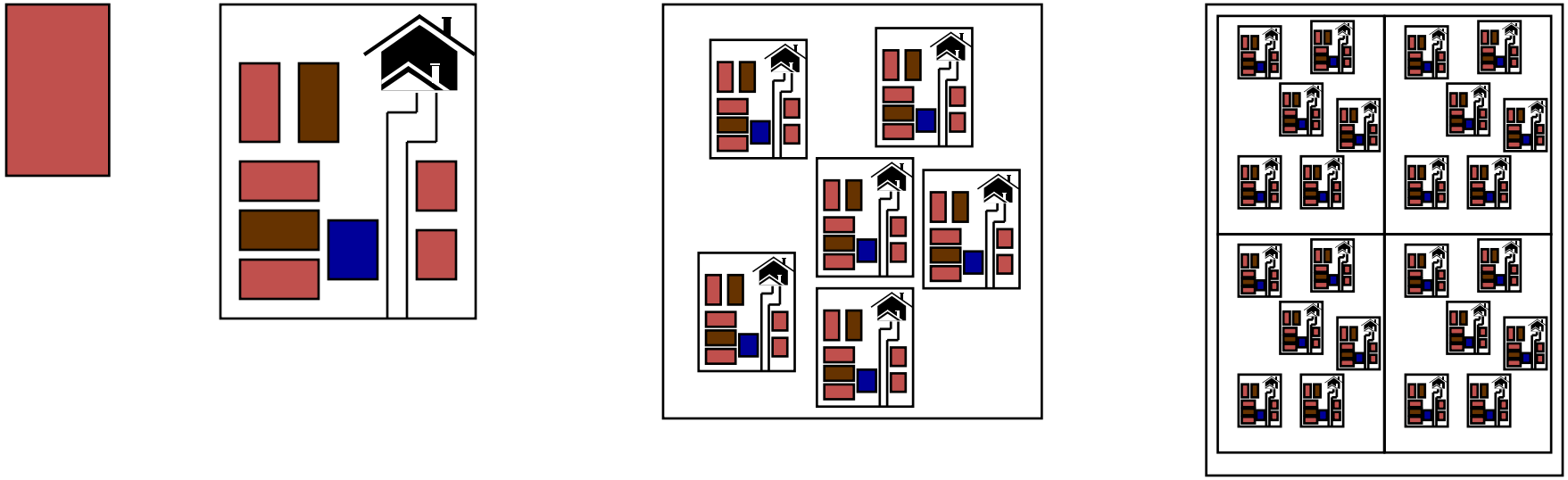
IBA Instituto Brasileiro do Algodão FUNDEAGRO

# Need to integrate Bt crops with other pest control tactics

- Prefer Bt crops expressing at least 2 proteins with different mode of action
- Promote implementation of structured refuges (ideally of 50%) (and alternative hosts)
- Crop calendar (crop-free period)
- Exploit biological control agents
- Chemical control (rotation of MoA and prefer selective insecticides)
- Cultural control

# IPM to Area-Wide Management

Field → Farm → Group of farms → Region

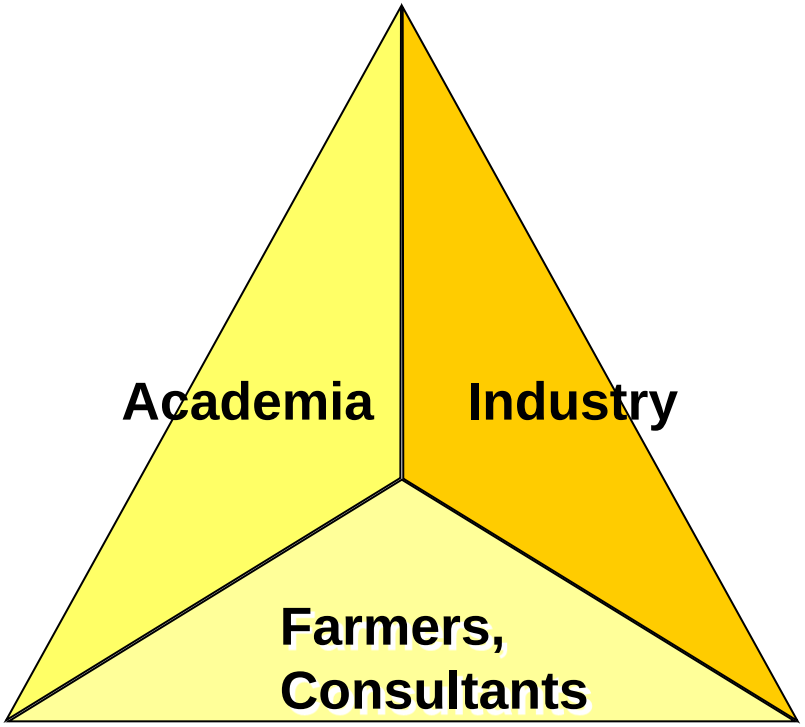


IPM

IPM groups ⇒ Area-wide management

D. Murray

# Major Challenge: Implementation of IRM




➔ **Education, Research and Regulatory Issues**

# Acknowledgments

PG ESALQ 1964 • 2014 anos

CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico

CAPES

IRAC-BR
COMITÊ BRASILEIRO DE AÇÃO A RESISTÊNCIA A INSETICIDAS

**Laboratório de Resistência de Artrópodes a Pesticidas**