Workshop: Regional Resistance Management Plan for Southeast Asia

ASEAN FAW ACTION PLAN
Supporting IPM Across Southeast Asia

Time	Topic	Speaker
14.50	Welcome to the Zoom platform	Dr Alison Watson (Grow Asia)
15:01	Introduction	**Dr. Andi Trisyono, University of Gadjah Mada (UGM)**
15:05	**The Role of Host Plant Resistance in Managing Resistance and Enhancing Resilience of ASEAN Maize Crops**	**Dr. Prasanna Boddupalli (CIMMYT)**
15:25		Q & A Session
15:35	**Resistant Management Strategies: Good practice and current management strategies**	**Dr. Srinivas Parimi (IRAC ASIA)**
15:50		Q & A Session
16:00	**Resistance research in Southeast Asia and Australia.**	**Dr. Tek Tay (CSIRO)**
16:10		Q & A Session
16:18	**Experience in the US in managing FAW resistance - tactics, challenges, and opportunities.**	**Dr. Silvana Paula-Moraes (University of Florida)**
16:28		Q & A Session
16:35	**Resistance research in China, the importance of work on resistance management in China.**	**Dr. Kongming Wu (CAAS)**
16:45		Q & A session
16:55	**Summary**	**Dr Andi Trisyono (UGM)**
17:00	Close	

A recording of the webinar will be made and be distributed 1 week after this session – please go to www.aseanfawaction.org and to the regional resistance project page.

Housekeeping

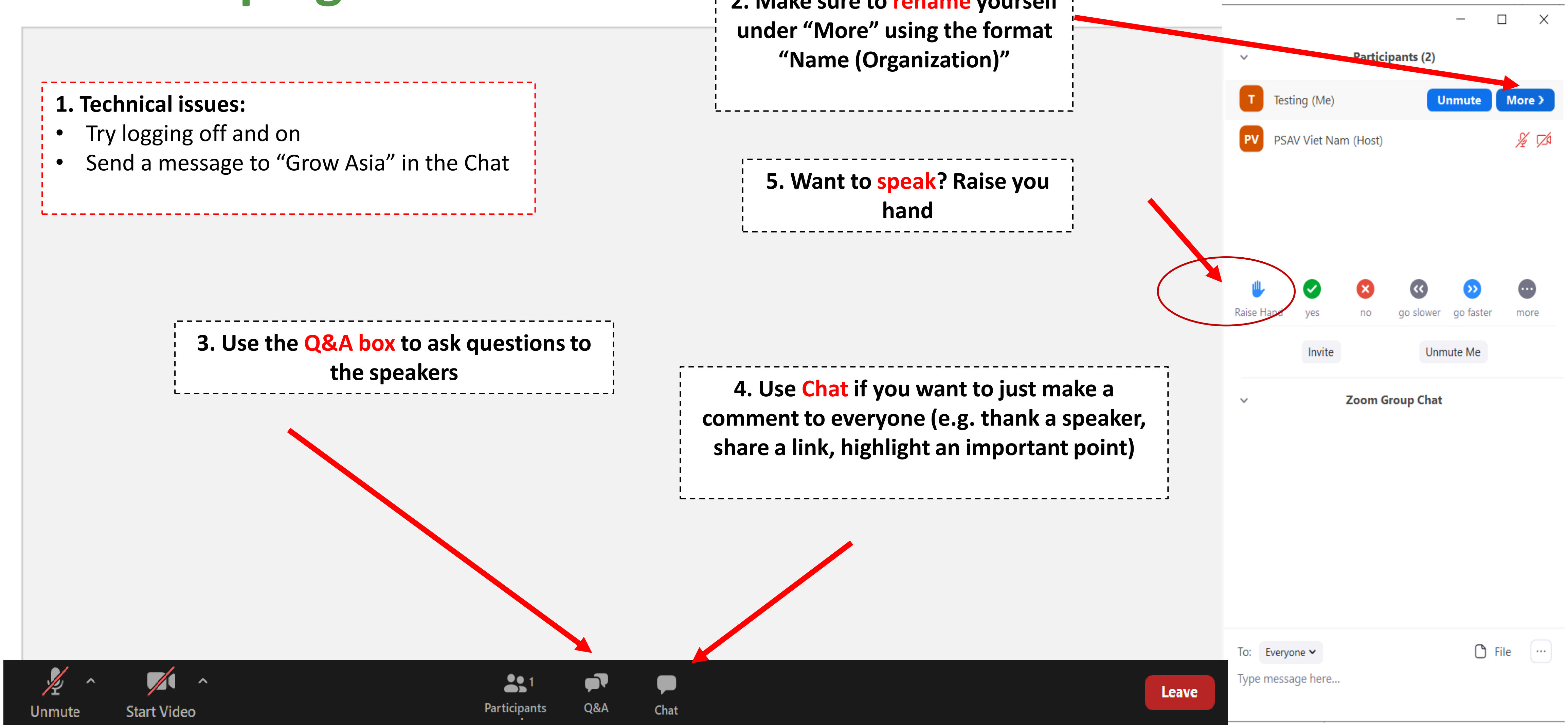
1. Technical issues:
- Try logging off and on
- Send a message to "Grow Asia" in the Chat

2. Make sure to rename yourself under "More" using the format "Name (Organization)"

3. Use the Q&A box to ask questions to the speakers

4. Use Chat if you want to just make a comment to everyone (e.g. thank a speaker, share a link, highlight an important point)

5. Want to speak? Raise you hand



Introduction

Dr. Y Andi Trisyono

Professor at Gadjah Mada University, Indonesia

Why?

- Farmers need a range of effective, economic and safe approaches and technologies to control FAW
- A regional resistance plan is important because we need to ensure that FAW populations don't become resistant to the different tactics and measures we have in our IPM toolbox.
- A coordinated regional approach is important because FAW is a fast-moving transboundary pest. We are only as strong as our weakest link in managing FAW resistance.

What is proposed?

The proposed regional approach to resistance management focuses on 3 specific areas:

1. Integrating host plant resistance with other compatible IPM tactics for sustainable FAW control in the ASEAN
2. Country-specific and regional FAW resistance management guidelines inclusive of all possible IPM practices
3. Regional FAW surveillance and resistance monitoring

You will hear about these components today!

How to get involved?

- We want your feedback today and your questions.

- You can download the concept paper at http://bit.ly/ASEANFAWresistance and provide written feedback on the concept paper to faw@growasia.org **by 1 May 2021.** (An email will also be sent tomorrow to participants)

- The concept paper has been sent to the ASEAN Expert Working Group on Phytosanitary Measures and ASEAN Working Group on Crops - for feedback.

ASEAN Webinar; April 27, 2021

Fall Armyworm Resistance Management in the ASEAN: What needs to be done on the Host Plant Resistance front in Maize

B.M. Prasanna

Director, Global Maize Program, CIMMYT
& CGIAR Research Program MAIZE
Email: b.m.prasanna@cgiar.org

CIMMYT

Insecticide Resistance in FAW Populations

Molecular Ecology Resources (2020)

Genetic structure and insecticide resistance characteristics of fall armyworm populations invading China

Lei Zhang[1] | Bo Liu[1] | Weigang Zheng[1] | Conghui Liu[1] | Dandan Zhang[2] | Shengyuan Zhao[2] | Zaiyuan Li[1] | Pengjun Xu[3,4] | Kenneth Wilson[4,1] | Amy Withers[4] | Christopher M. Jones[5] | Judith A. Smith[6] | Gilson Chipabika[7] | Donald L. Kachigamba[8] | Kiwoong Nam[9] | Emmanuelle d'Alençon[9] | Bei Liu[1] | Xinyue Liang[1] | Minghui Jin[1] | Chao Wu[1] | Swapan Chakrabarty[1] | Xianming Yang[2] | Yuying Jiang[10] | Jie Liu[10] | Xiaolin Liu[11] | Weipeng Quan[12] | Guirong Wang[1] | Wei Fan[1] | Wanqiang Qian[1] | Kongming Wu[2] | Yutao Xiao[1]

Protein & Cell (2020)

Genomic and transcriptomic analysis unveils population evolution and development of pesticide resistance in fall armyworm *Spodoptera frugiperda*

Furong Gui[1,12], Tianming Lan[2,9], Yue Zhao[1], Wei Guo[3,15], Yang Dong[1,12], Dongming Fang[2], Huan Liu[2,9], Haimeng Li[2], Hongli Wang[2], Ruoshi Hao[12], Xiaofang Cheng[5], Yahong Li[16], Pengcheng Yang[4], Sunil Kumar Sahu[2], Yaping Chen[1], Le Cheng[7], Shuqi He[1], Ping Liu[5], Guangyi Fan[6], Haorong Lu[8,10], Guohai Hu[8,10], Wei Dong[2], Bin Chen[1], Yuan Jiang[18], Yongwei Zhang[18], Hanhong Xu[17], Fei Lin[17], Bernard Slipper[19], Alisa Postma[19], Matthew Jackson[19], Birhan Addisie Abate[20], Kassahun Tesfaye[20,21], Aschalew Lemma Demie[20], Meseret Destaw Bayeleygne[20], Dawit Tesfaye Degefu[22], Feng Chen[5], Paul K. Kuria[23], Zachary M. Kinyua[23], Tong-Xian Liu[13], Huanming Yang[10,11], Fangneng Huang[14]✉, Xin Liu[2,10]✉, Jun Sheng[1,12]✉, Le Kang[3,4,15]✉

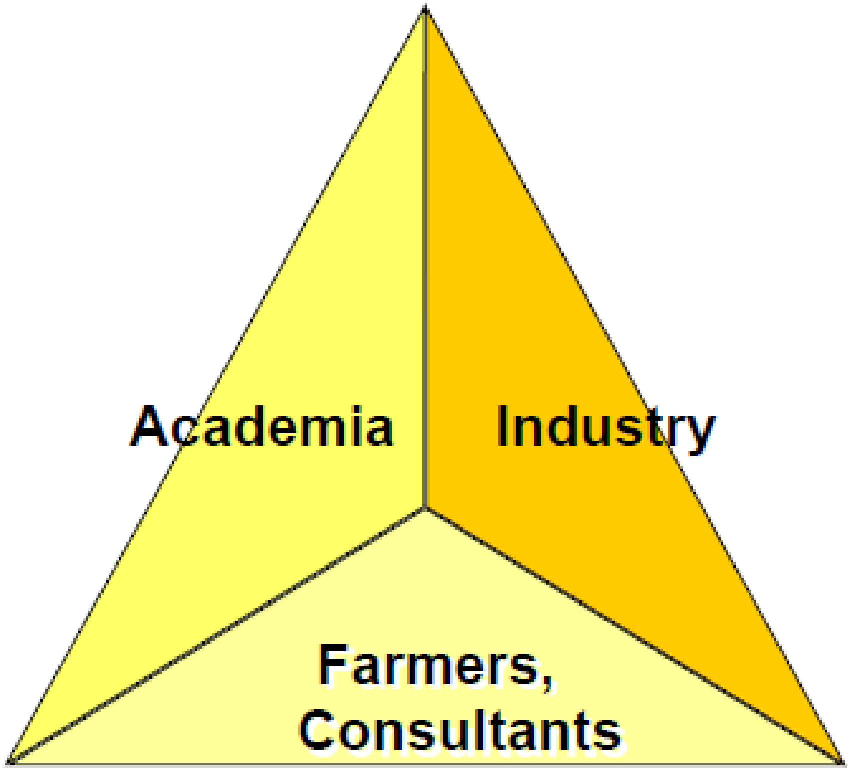
Globally FAW is resistant to at least 41 active ingredients of insecticides, across the various mode of action groups:

- Carbamates (Group 1A)
- Organophosphates (Group 1B)
- Pyrethroids (Group 3)
- Bacillus thuringiensis protein (Group 11A)

CIMMYT

Insect Resistance Management (IRM)

- Robust IRM and product stewardship → preventing or mitigating the onset of resistance in FAW populations to insecticides (synthetic and *Bt*)
- Better understanding of FAW population dynamics and resistance profiles across the region → will help guide present and future FAW response strategies.

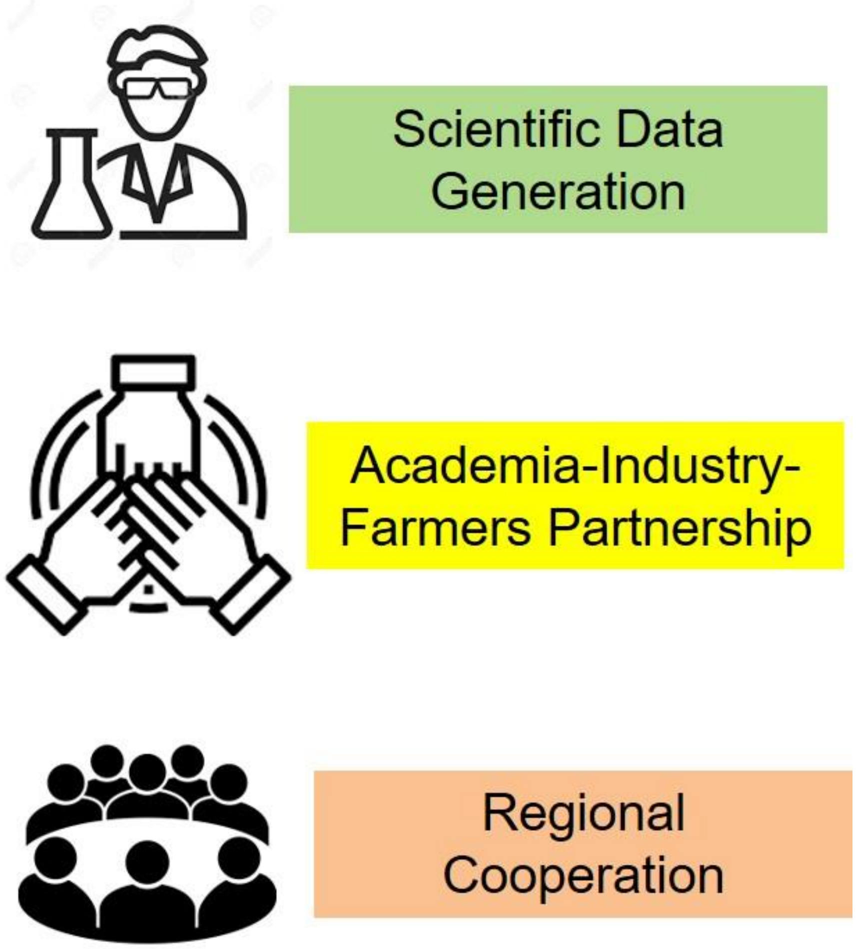


Needs a holistic approach and well-coordinated, joint actions by the Industry, Academia, Farmers and Government Agencies in the ASEAN

FAW Resistance Management in the ASEAN

Three specific and complementary actions are critical:

1. Regional FAW surveillance and resistance monitoring
2. Country-specific and regional FAW resistance management
3. Integrating host plant resistance with other compatible IPM tactics



Host Plant Resistance

"The collective heritable characteristics by which a plant species may reduce the probability of successful utilization of that plant as a host by an insect species"

(Beck, 1965)

Transgenic Resistance

- High levels of resistance
- Monogenic/Oligogenic
- High selection pressure on the insect → needs IRM

Native Genetic Resistance

- Moderate resistance
- Polygenic
- Low selection pressure on the insect → more durable

Efficacy and Benefits of *Bt* Maize in FAW Control

GM CROPS & FOOD
2020, VOL. 12, NO. 1, 71–83
https://doi.org/10.1080/21645698.2020.1816800

Taylor & Francis
Taylor & Francis Group

RESEARCH PAPER

OPEN ACCESS Check for updates

The impact of using genetically modified (GM) corn/maize in Vietnam: Results of the first farm-level survey

Graham Brookes[a] and Tran Xuan Dinh[b]

[a]Agricultural Economist with PG Economics Ltd, Dorchester, UK; [b]Former Deputy Director General Crop Production Department, Ministry of Agriculture and Rural Development (CPD MARD), Vietnam

Philippines

- MON810 (*Cry1Ab*) in 2002
- Bt11 (*Cry1Ab*) in 2005
- MON89034 (*Cry1A.105 + Cry2Ab2*) in 2010
- TC1507 (*Cry1F*) in 2013
- MIR162 (*Vip3Aa20*) in 2018
- TC1507 x MON810

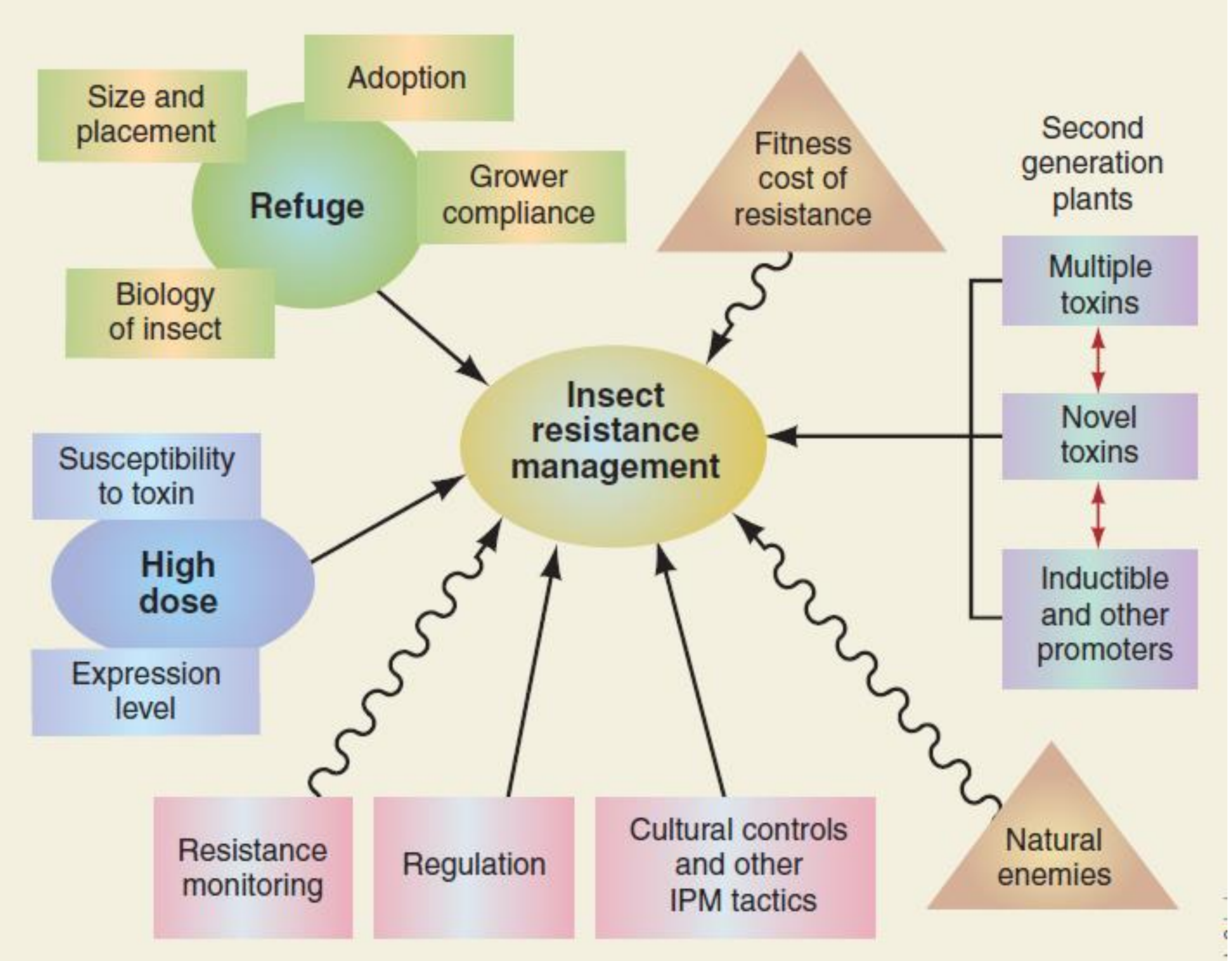
Vietnam

- MON89034 (*Cry1A.105 + Cry2Ab2*)
- Bt11 (*Cry1Ab*)

Risk of Rapid Evolution of Insect Resistance to *Bt* Crops

- High risk of rapid evolution of resistance to single-toxin *Bt* maize by FAW.

- FAW evolved resistance to Cry1Ab maize in Brazil and Cry1Fa maize in Argentina, Brazil, Puerto Rico, and the southeastern USA (Tabashnik and Carrière 2017, 2019; Huang 2020).



Source: Bates et al. (2005)

Elements of an Effective IRM Plan

- Learning from the experiences in other countries
- Product deployment strategies to reduce selection pressure on the insect.
- Monitoring changes in insect susceptibility to the expressed protein.
- Monitoring fields for signs of unexpected levels of damage due to a key target pest.
- Broader stakeholder participation in IRM plan development and dissemination, with an understanding of local cropping systems.
- Communication/education at various levels.

Frontiers in Bioengineering and Biotechnology (2020)

A Framework for Effective Bt Maize IRM Programs: Incorporation of Lessons Learned From *Busseola fusca* Resistance Development

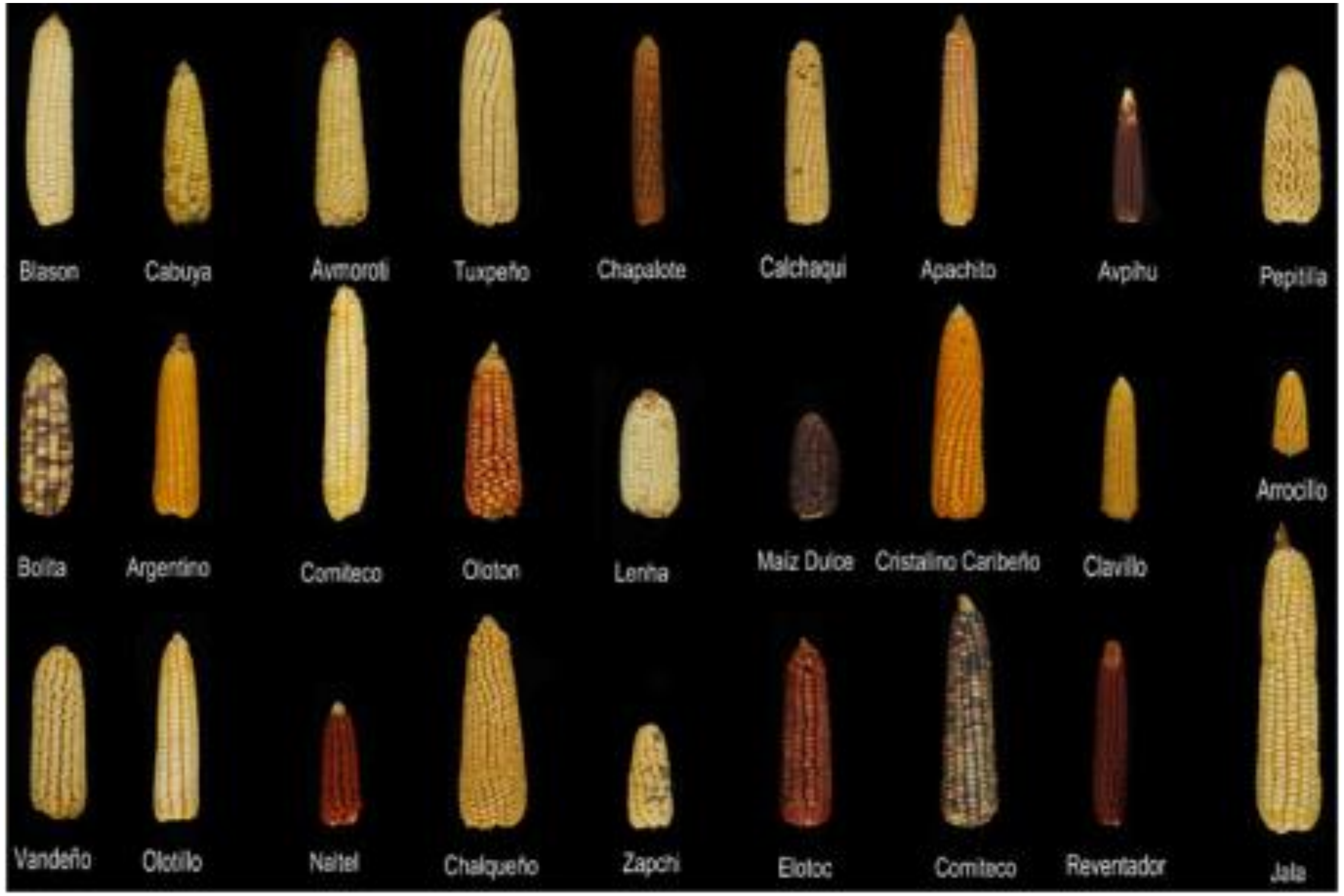
Gustav Bouwer*

Invertebrate Pathology and Biocontrol Laboratory, School of Molecular and Cell Biology, University of the Witwatersrand, Johannesburg, South Africa

CIMMYT

Source: Bates et al. (2005)

Native Genetic Resistance to FAW



Source: Prasanna (2012) *Journal of Bioscience*

Incredible genetic diversity in maize landraces → CIMMYT maize team in Mexico unraveled native genetic resistance in some of the landraces (especially Cuban flints and Mexican Tuxpeños) to several insect-pests, including FAW.

CGIAR CIMMYT

Intensive Breeding Efforts

CIMMYT's FAW Screening Facility at KALRO-Kiboko, Kenya

Similar facilities being established at Hyderabad, India

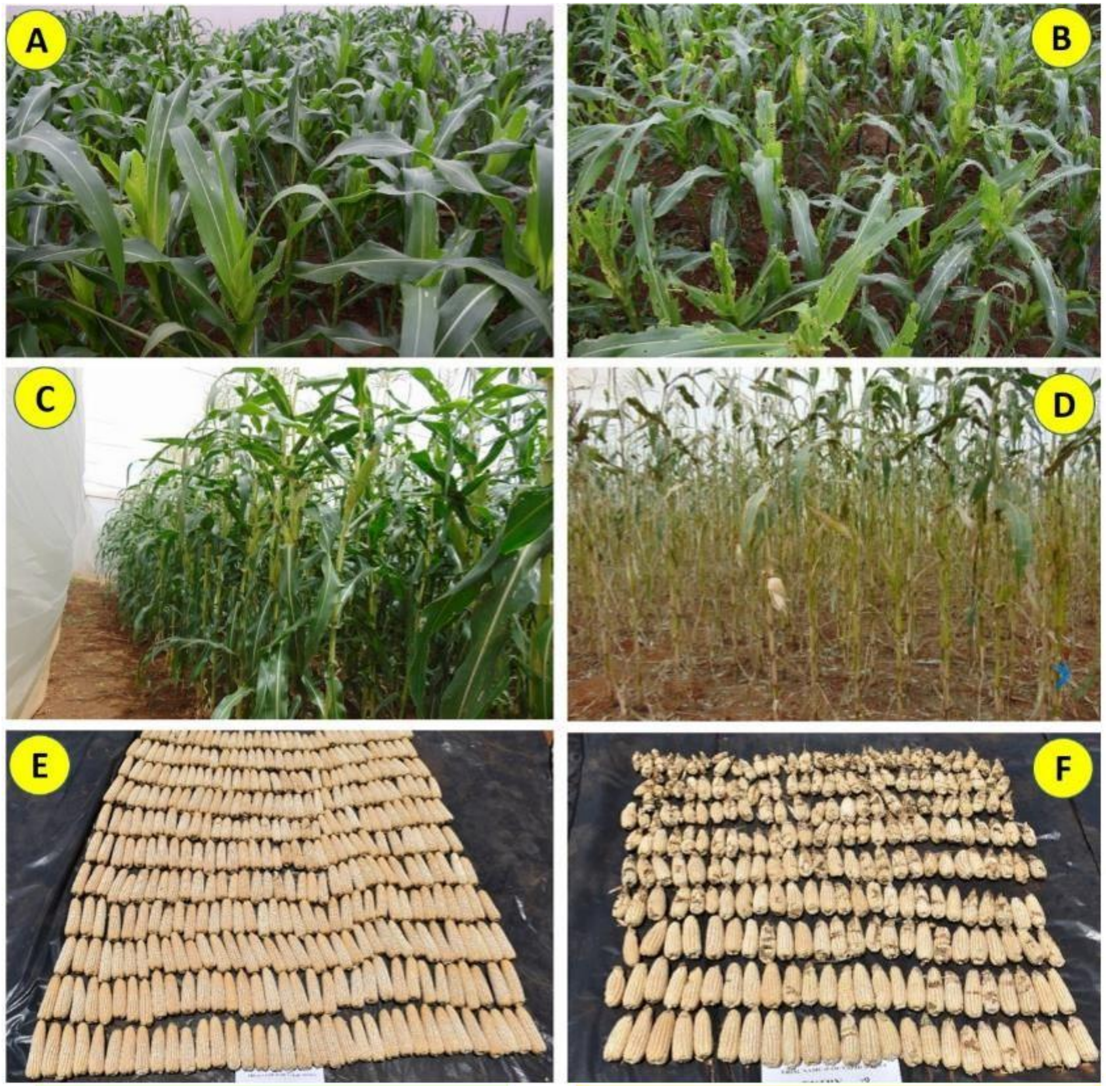
- More than **6000** CIMMYT maize germplasm entries screened so far against FAW under artificial infestation at Kiboko, Kenya, during 2017-2020
- Need to intensify work on native genetic resistance to FAW in the ASEAN

FAW-tolerant CIMMYT Inbred Lines shared globally…

CIMMYT Maize Lines (CMLs) with native genetic resistance to FAW (e.g., CML71, CML125, CML330, CML338, CML370, CML574) disseminated to partners across Africa and Asia.

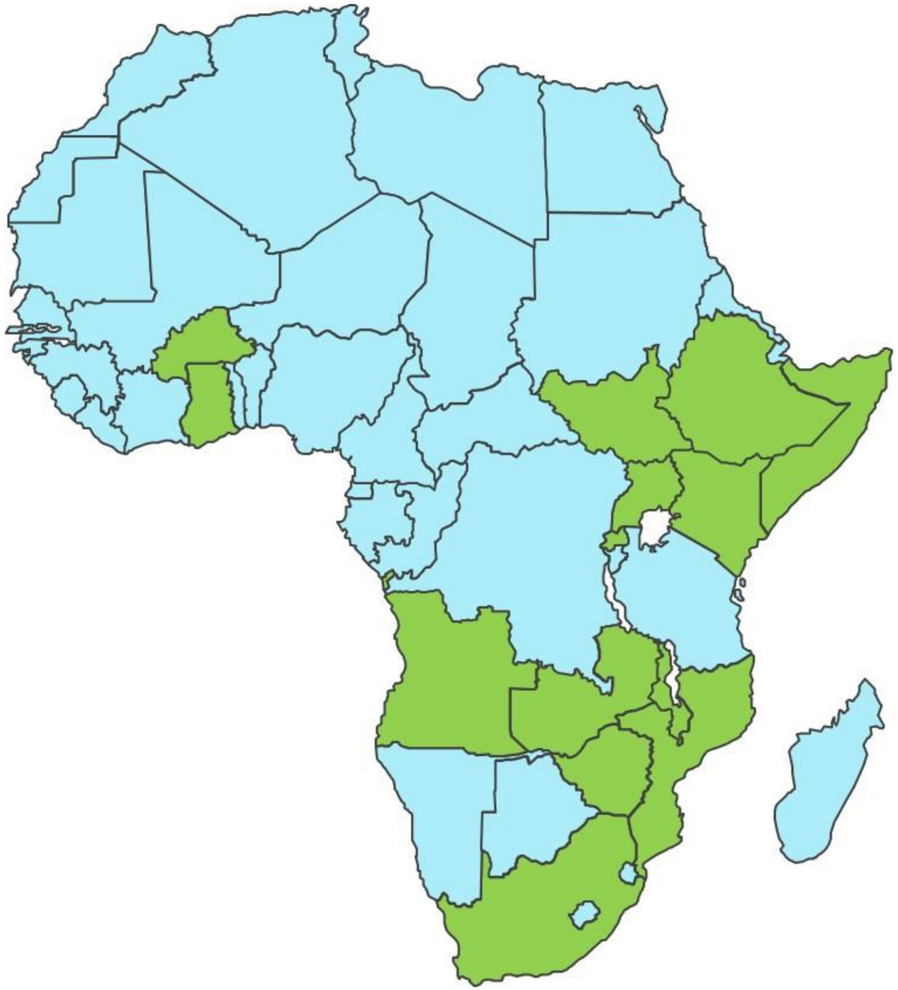
Native Genetic Resistance to FAW

FAW-tolerant Maize Hybrids from CIMMYT



FAW-tolerant Hybrids

FAW-susceptible Checks



National Performance Trials (NPTs) in 2021 across Africa, including **Ethiopia, Kenya, Rwanda, Uganda, South Sudan, Somalia, Angola, Malawi, Mozambique, South Africa, Zambia, Zimbabwe, Ghana and Burkina Faso**.

Integrating HPR with other compatible IPM tactics in the ASEAN

1. Use HPR in concert with other tactics (e.g., good agronomic practices, biological control, biopesticides etc.) as part of an IPM/IRM strategy.
2. Avoid or reduce as much as possible exposure to single-toxin *Bt* crops that can diminish the durability of *Bt* pyramids.
3. Introduce *Bt* maize pyramids producing two or more toxins that are each highly effective against FAW and are encoded by linked genes.
4. Transfer *Bt*-based resistance into appropriate Asia-adapted genetic backgrounds, with native genetic resistance to FAW and other climate-resilient traits.

Farmers need improved crop varieties with higher yield and multiple stress tolerance (yield stability), not just a solution to one specific problem!!

Thanks!

Fall Armyworm management and Resistance Management Guidelines

Srinivas Parimi
Chair, IRAC Asia,
Bayer Crop Science

////////////

April 27, 2021

ASEAN Regional Resistance Management Workshop

Bt technologies and Insecticide Modes of action (MoA) approved for control of Fall armyworm

Insecticide MoAs

MoA	Primary Target Site	Chemical Class	Performance rating
1A	Acetylcholinesterase inhibitors	**Carbamates**	++
1B	Acetylcholinesterase inhibitors	**Organophosphates**	++
3A	Sodium channel modulators	**Pyrethroids, Pyrethrins**	+
5	Nicotinic acetylcholine receptor allosteric activators	**Spinosyns**	++++
6	Chloride channel activators	**Avermectins, Milbemycins**	++++
15	Inhibitors of chitin biosynthesis	**Benzoylureas**	++
28	Ryanodine receptor modulators	**Diamides**	++++

Source: Nigel Godley, IRAC International

Bt technologies

- ✓ *Cultivated – since 2003-04 in Philippines and 2015 in Vietnam*
- ✓ *Cry1Ab based technologies*
- ✓ *Stacked products viz., Cry1A.105 + Cry2Ab2 Cry1Ab + Cry1F*

CropLife

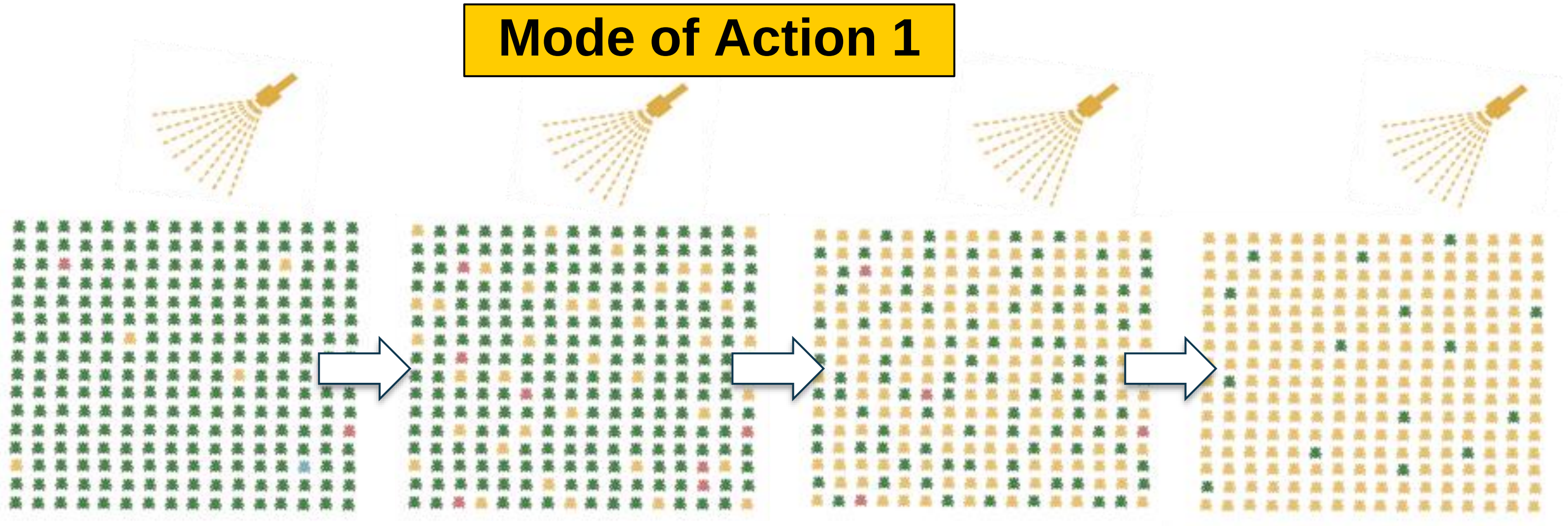
IRAC

Insecticide Resistance Management Principles

Rotate Modes of action to delay resistance

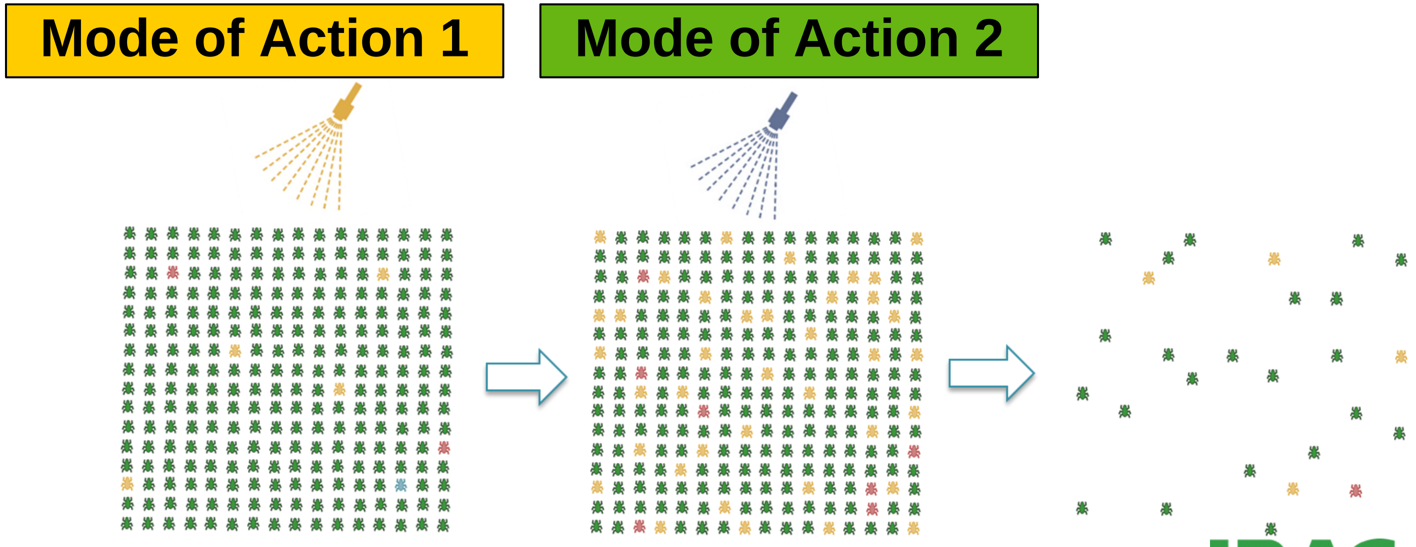
After repeat applications of the same Mode of Action 1

- **Insects less sensitive are likely to survive**
- **Over time pests become more difficult to control**



After alternate applications of Modes of Action 1 + 2

- **Insects less sensitive to one MoA are likely to be sensitive to the other**
- **Pest control is more sustainable**



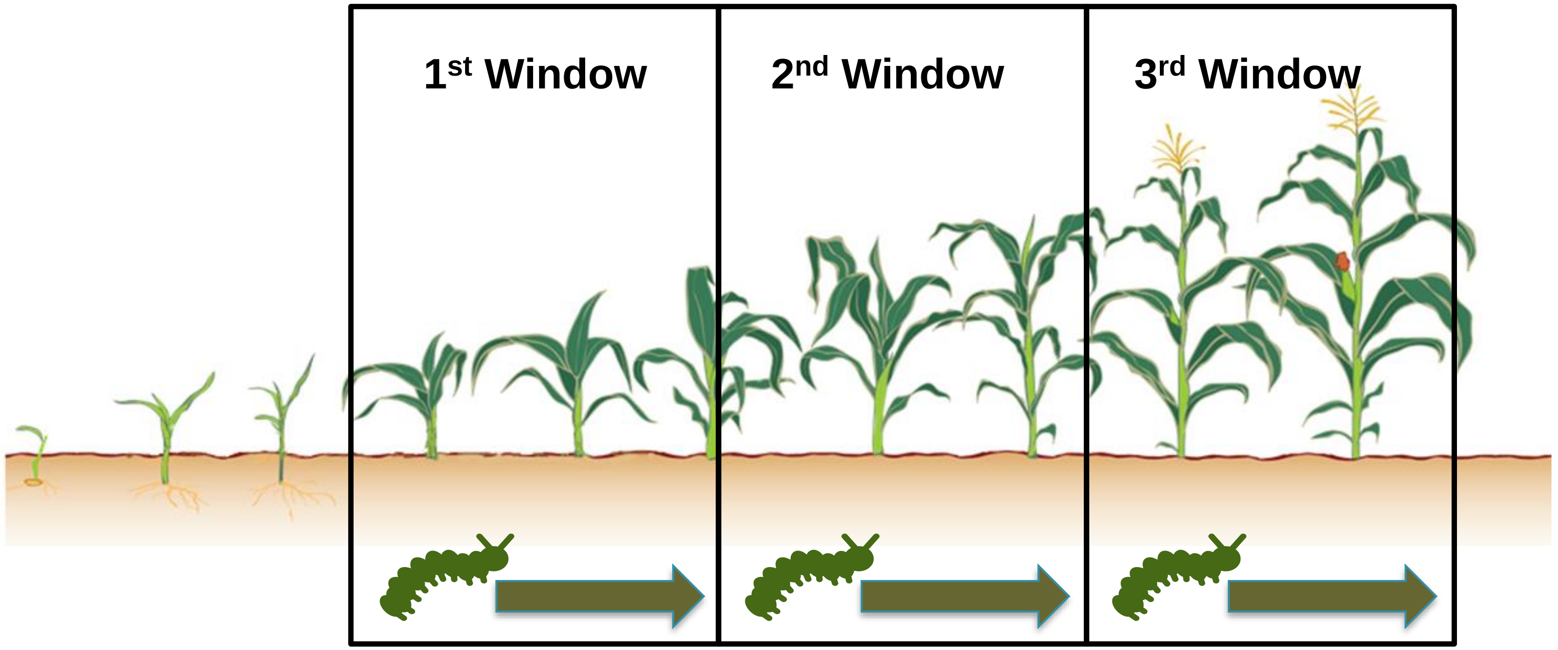
Source: Nigel Godley, IRAC International

Insecticide Resistance Management Principles

IRAC recommends rotation of Modes of action in Spray Windows

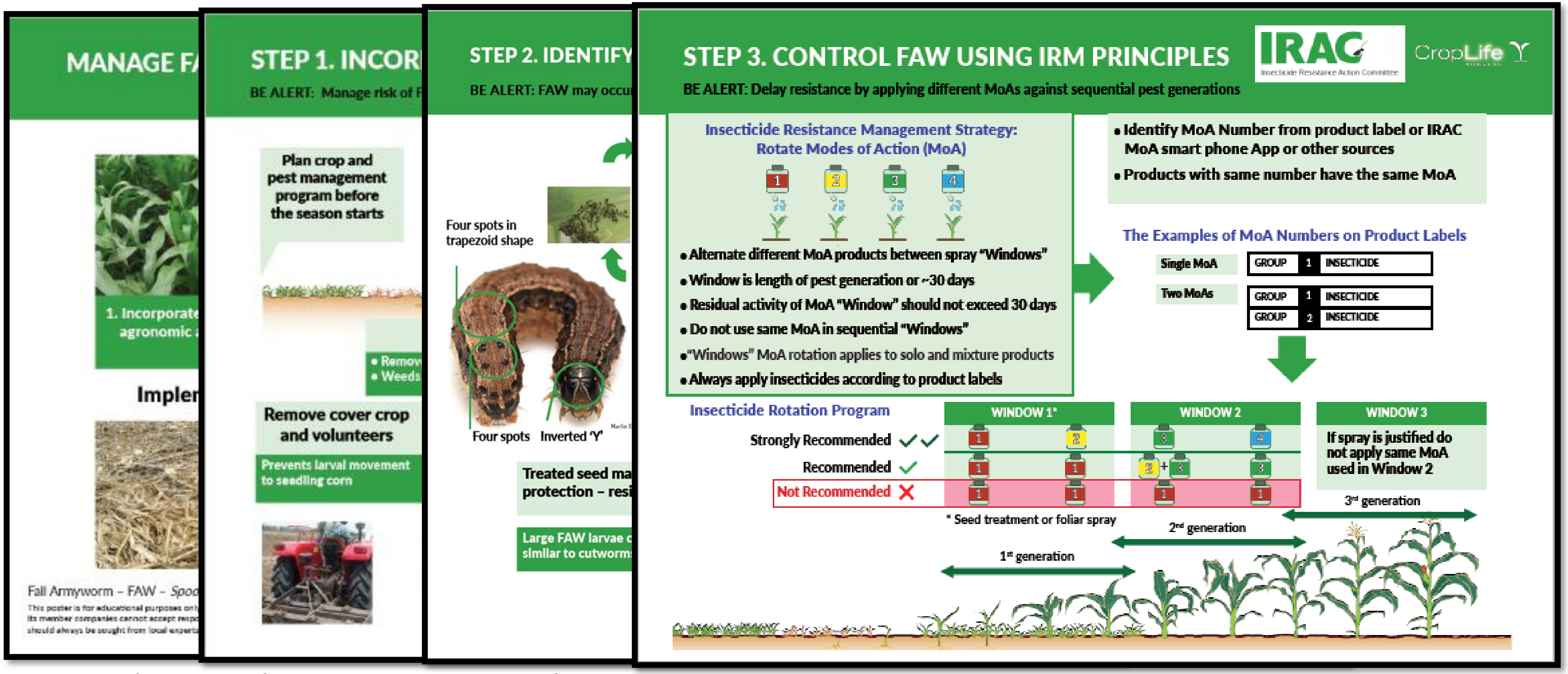
- Divide the crop growth period into sequential Spray Windows Defined as, '*the time period for an insect pest to go through 1 generation'*, which for FAW is around 30 days

- Apply insecticides with different MoA in sequential Windows
- Best practice - use multiple effective MoA in a program



	1st Window	2nd Window	3rd Window
Strongly Recommended ✓	1	2	3
Not recommended ✗	1	1	1

New IRAC guidelines - Fall Armyworm Africa / Asia

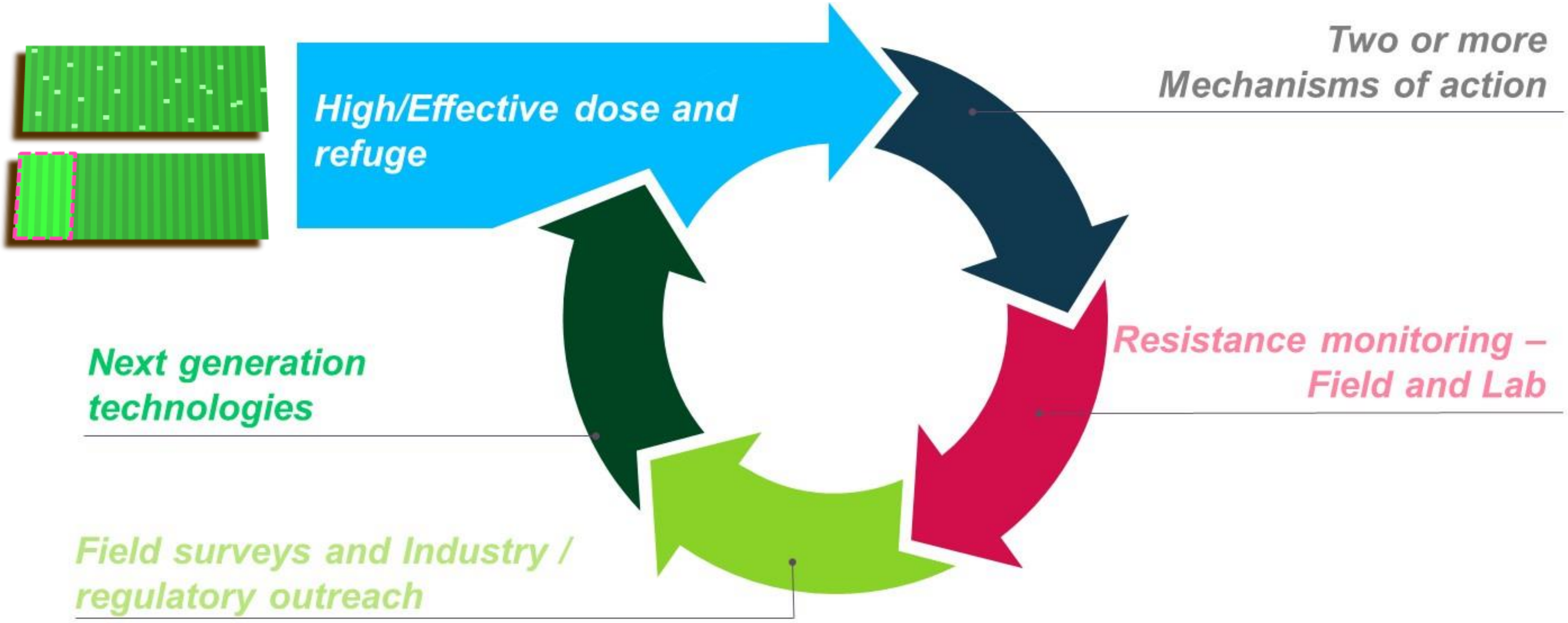


Source: Lepidopteran working group, IRAC International, 2021

Resistance management programs provide opportunity to monitor resistance development in the pest while using all available tools of an IPM program.

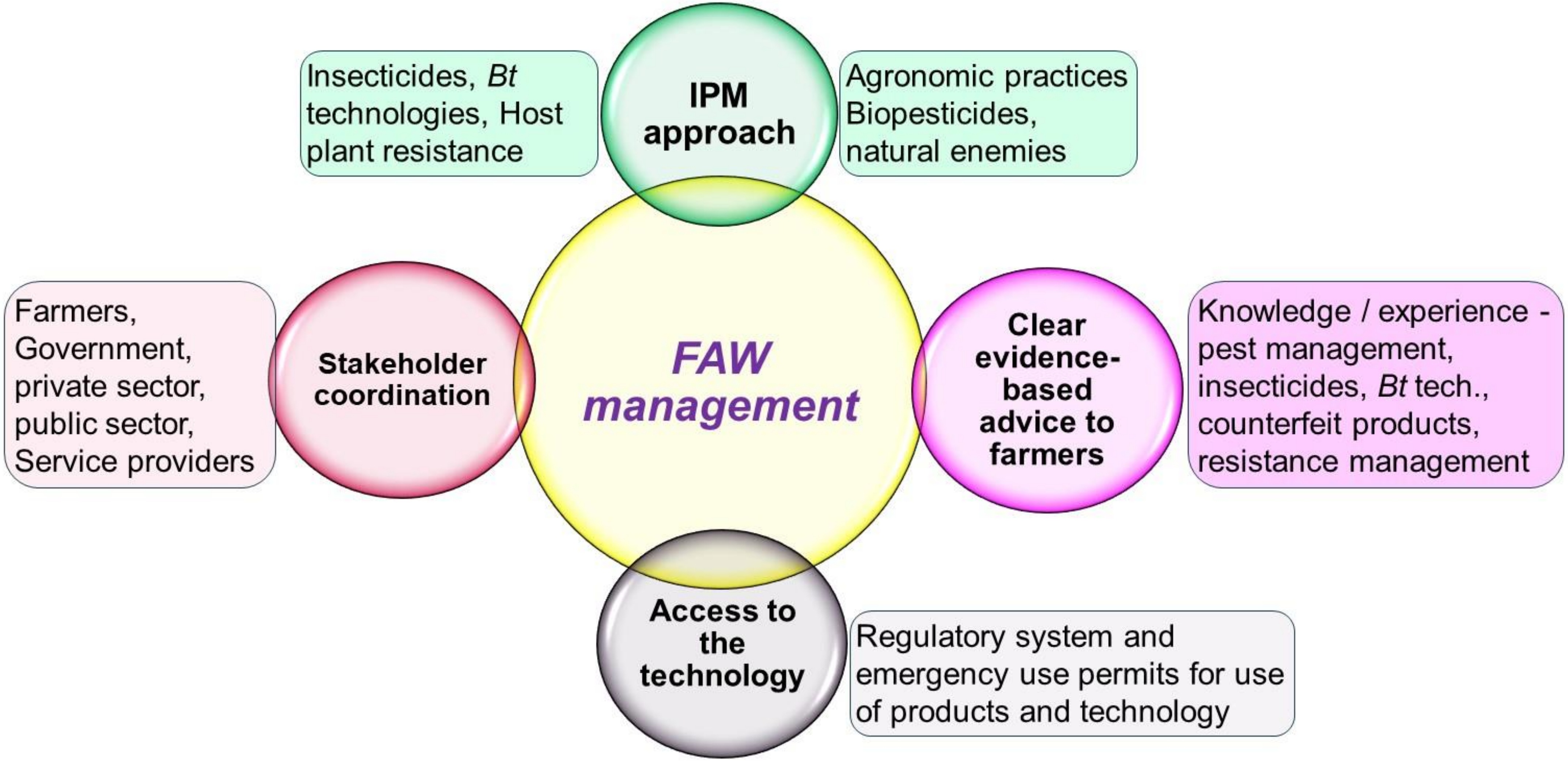
Bt technologies - Insect Resistance Management

Currently followed in cultivated / approved countries



Appropriate hybrids, Right size of refuge, awareness on management

Multi-stakeholder holistic approach



Source: Crop Life International/Crop Life Asia 2019

Key takeaways

Follow resistance management guidelines of the product

Multi-stakeholder approach and evidence-based advice to the farmers

Scouting/monitoring and Resistance monitoring

IPM and agronomic practices reduce the risk of pest damage

Thank You!!

Workshop on the Regional Resistance Management Plan: Australian Research

WT Tay | 27 April 2021

Australian Government
Australian Centre for International Agricultural Research

Australian Government
Grains Research and Development Corporation

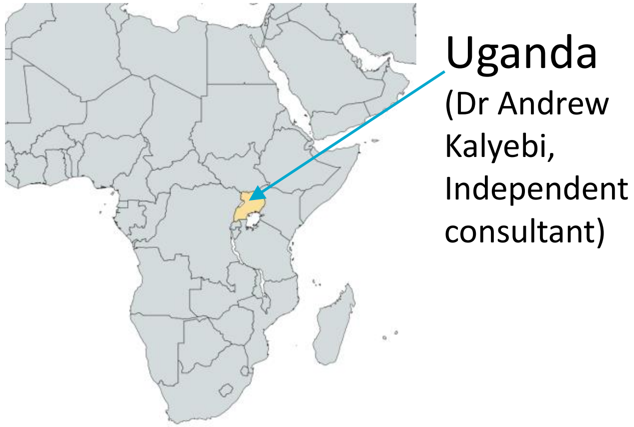
GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

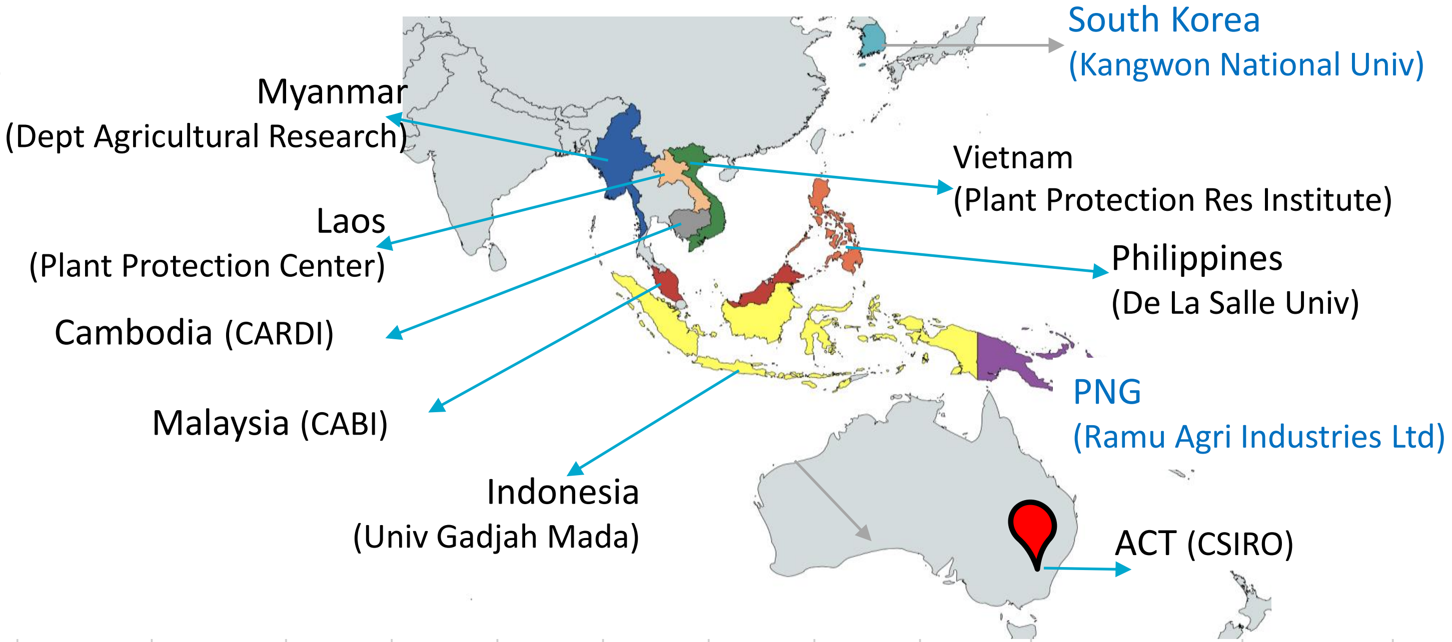
CSIRO

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Prevention and preparedness for fall armyworm (*Spodoptera frugiperda*) – Output 2 (REFERENCE: CSP2003-008RTX**)**

Research Teams





	Alpha-Cypermethrin *	Chlorantraniliprole	indoxacarb	emamectin benzoate	methomyl *	spinetoram	Dipel	Xentari	Cry1F	Cry1Ac	Cry2Ab	VIP3A	Bacillus subtilis	Bacillus amyloliquefaciens	Metarhizium
Australia															
Indonesia															
Malaysia															
Myanmar															
Cambodia															
Lao PDR															
Vietnam															
Philippines															

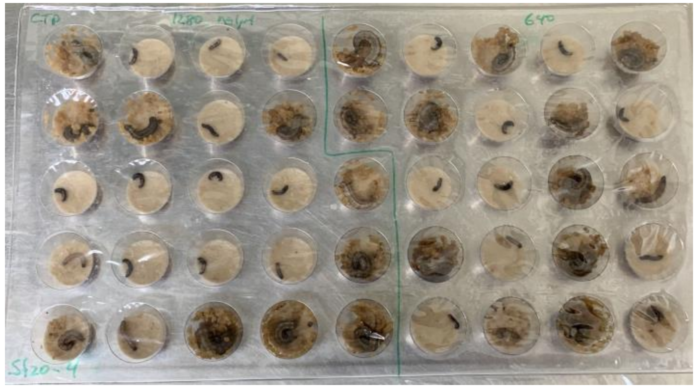
indicated

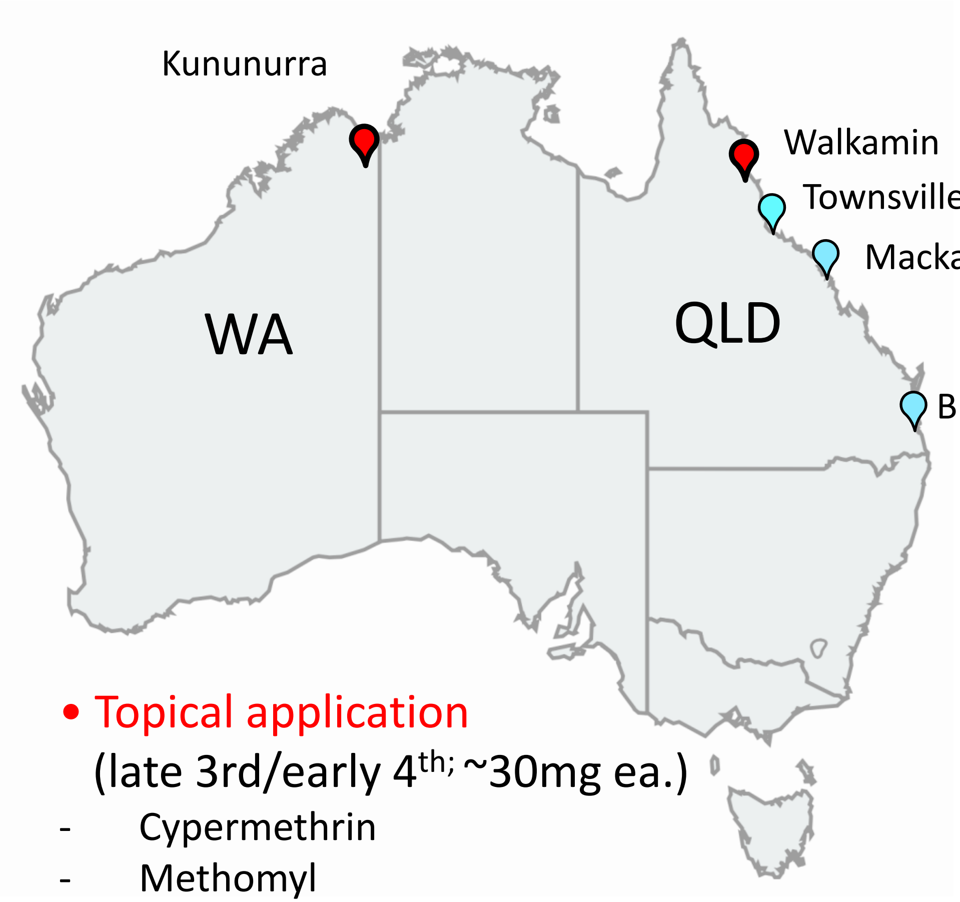
possible

* topical

CSIRO Bioassay results

- Two Aust populations: Kununurra, Walkamin





- Diet incorporation (2nd/early 3rd)

- Chlorantraniliprole
- Indoxacarb
- Emamectin
- Spinetoram

- Surface treatment (Bt/VIP toxins; neonates)

- Cry1Ac
- Cry2Ab
- XenTari (Cry1D, Cry1C, Cry1Ab, Cry1Aa)
- Dipel (Cry2A, Cry2B, Cry1Ab, Cry1Aa, Cry1Ac)
- Vip3A
- Cry1F

- Topical application (late 3rd/early 4th; ~30mg ea.)

- Cypermethrin
- Methomyl

Visit GRDC Fall armyworm portal

https://grdc.com.au/resources-and-publications/resources/fall-armyworm

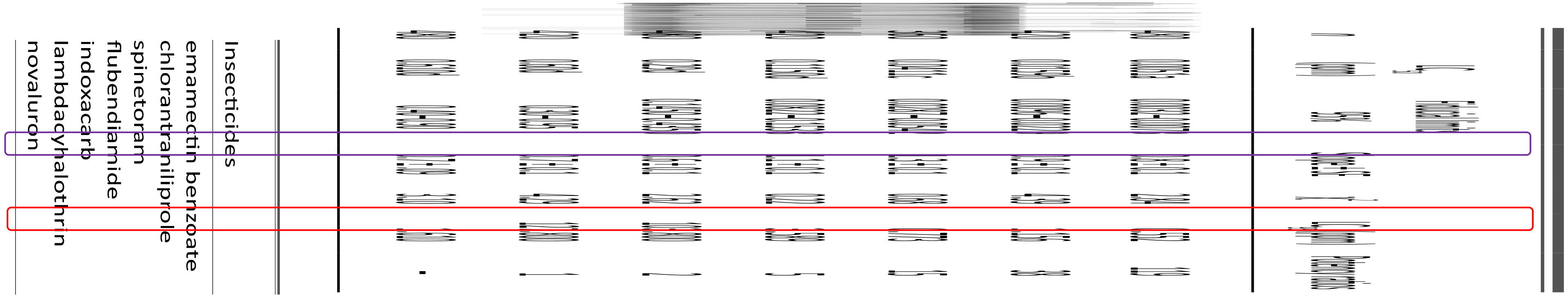
CSIRO

2020 — Florida Entomologist — Volume 103, No. 2

Field efficacy of insecticides for management of invasive fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) on maize in India

Sharanabasappa Deshmukh[1,], H. B. Pavithra[1], C. M. Kalleshwaraswamy[1], B. K. Shivanna[1], M. S. Maruthi[1], and David Mota-Sanchez[2]*

campo y sorgo de grano. El objectivo de estos estudios fue para generar una linea basal de respuestas a las dosis mortales para el gusano cogollero en bioensayos del laboratorio, para confirmar la eficacia en el campo contra infestaciones naturales, y para determinar la eficacia de residuos de insecticidas seleccionados. Estos estudios evaluaron 4 de los insecticidas recién desarrollados (chlorantraniliprole, cyantraniliprole, flubendiamide y spinetoram) y 5 productos comerciales estandares (indoxacarb, lambda-cyhalothrin, methoxyfenozide, novaluron, y spinosad). En ensayos de dietas incorporadas, los valores de CL_{50} de chlorantranilprole y spinetoram fueron significativamente más bajos que los CL_{50} de los otros insecticidas. Los resultados de las pruebas de campo contra una infestación nativa del gusano cogollero en sorgo de grano indicaron que chlorantraniliprole redujó el número de los cogollos infestados y fue mas bajo que en las parcelas de control no-tratadas y tratadas con lambda-cyhalothrin- y methoxyfenozide a los 3 dias despues del tratamiento (con sus siglas en inglés - DAT). A los 7 DAT, ninguno de los insecticidas redujeron significativamente el número de cogollos infestados más bajo que en las parcelas no-tratadas. En estudios de la eficacia de residuo, larvas de gusano cogollero expuestas al



Spinetoram	USA(LSU)	0.066	0.053 – 0.081	-
	India	0.0411	0.0287 – 0.0542	0.6
	Qld	0.118	0.101 – 0.137	1.8 - 2.9
	WA	0.102	0.092 – 0.112	1.5 - 2.5
Chlorantraniliprole	USA(LSU)	0.068	0.317 – 0.481	-
	India	0.0159	0.0096 – 0.0229	0.2
	Qld	0.032	0.024 – 0.043	0.5 - 2
	WA	0.163	0.132 – 0.201	2.4 - 10
indoxacarb	USA(LSU)	0.392	0.317 – 0.481	-
	India	0.29	0.145 – 0.435	0.7
	Qld	1.203	1.031 – 1.398	3 - 4
	WA	11.206	9.254 – 13.654	29 - 39

Not yet scrutinized.
Results indicate gap in our knowledge

CSIRO

Detection of resistance alleles

insects

MDPI

Article

Monitoring of Target-Site Mutations Conferring Insecticide Resistance in *Spodoptera frugiperda*

Debora Boaventura [1,2], Macarena Martin [3], Alberto Pozzebon [3], David Mota-Sanchez [4] and Ralf Nauen [2,*]

Table 1. Genotyping by pyrosequencing for different target-site mutations in major insecticide targets. In total, larvae of 34 populations from Brazil, Puerto Rico, Kenya and Indonesia were analyzed. Homozygous susceptible (SS), heterozygotes (RS) and homozygous resistant (RR).

Target	Country	Mutation	N	SS (%)	RS (%)	RR
Voltage-gated sodium channel (VGSC)	Brazil	L1014F	140	100.0	0.0	0
	Puerto Rico		70	100.0	0.0	0
	Kenya		76	100.0	0.0	0
	Indonesia		110	98.2	1.8 *	0..
Acetylcholinesterase (AChE)	Brazil	G227A	161	55.3	32.3	12.4
	Puerto Rico		29	100.0	0.0	0.0
	Kenya		76	100.0	0.0	0.0
	Indonesia		86	83.7	16.3 *	0.0

Pesticide Biochemistry and Physiology 168 (2020) 104623

Contents lists available at ScienceDirect

Pesticide Biochemistry and Physiology

journal homepage: www.elsevier.com/locate/pest

ELSEVIER

PBP

Susceptibility of fall armyworm, *Spodoptera frugiperda* (J.E. Smith), to eight insecticides in China, with special reference to lambda-cyhalothrin

Yun-Xia Zhao, Jing-Mei Huang, Huan Ni, Di Guo, Feng-Xia Yang, Xin Wang, Shun-Fan Wu*, Cong-Fen Gao*

College of Plant Protection, Nanjing Agricultural University, State & Local Joint Engineering Research Center of Green Pesticide Invention and Application, Weigang Road 1, Nanjing 210095, Jiangsu, China

Mutation	Population (N[a])	Codons[b] (Frequency [%])
		Homozygous wild
L1014F	Dongtai (19)	CTT (100)
	Jingxian (17)	CTT (100)
G227A	Dehong (12)	GGA (100)
	Dongtai (25)	GGA (100)
	Jingxian (15)	GGA (100)

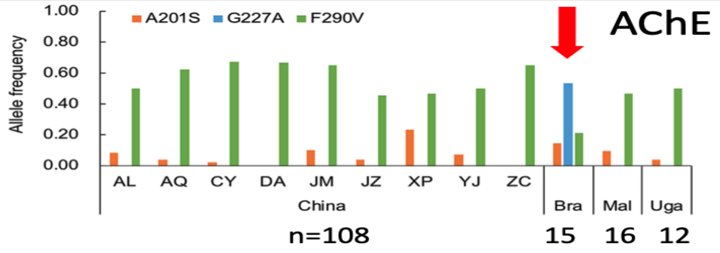
Insect Science

Insect Science (2020) 00, 1–12, DOI 10.1111/1744-7917.12838

ORIGINAL ARTICLE

Whole-genome sequencing to detect mutations associated with resistance to insecticides and Bt proteins in *Spodoptera frugiperda*

Fang Guan[1], Jianpeng Zhang[1], Huiwen Shen[1], Xingliang Wang[1], Amanda Padovan[2], Tom K. Walsh[2], Wee Tek Tay[2], Karl H. J. Gordon[2], William James[2], Cecilia Czepak[3], Michael Hilary Otim[4], Donald Kachigamba[5] and Yidong Wu[1]



VGSC: 100% SS

VGSC	China: > 251 Africa: 104 Indonesia: 110*	AChE	China: > 267 Africa: 104 Indonesia: 86*

CSIRO

Introduction Pathways

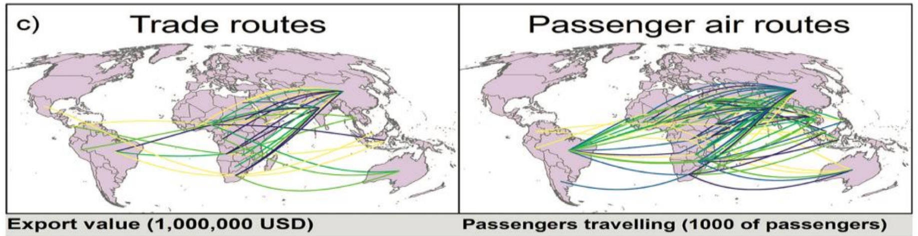
- Agricultural commodities export/tourists: US (FL) to West Africa
- Once in Africa, natural spread/commodity movements/human-assisted

Africa to Middle East; India; SEA (Myanmar); China; Taiwan, South Korea; Japan (Far East)
Thailand/Cambodia/Laos, Vietnam, Philippines

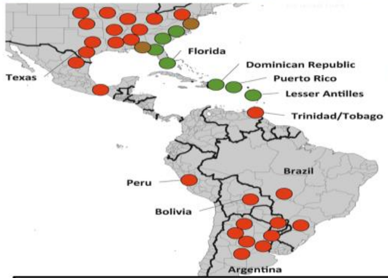
F
A
W

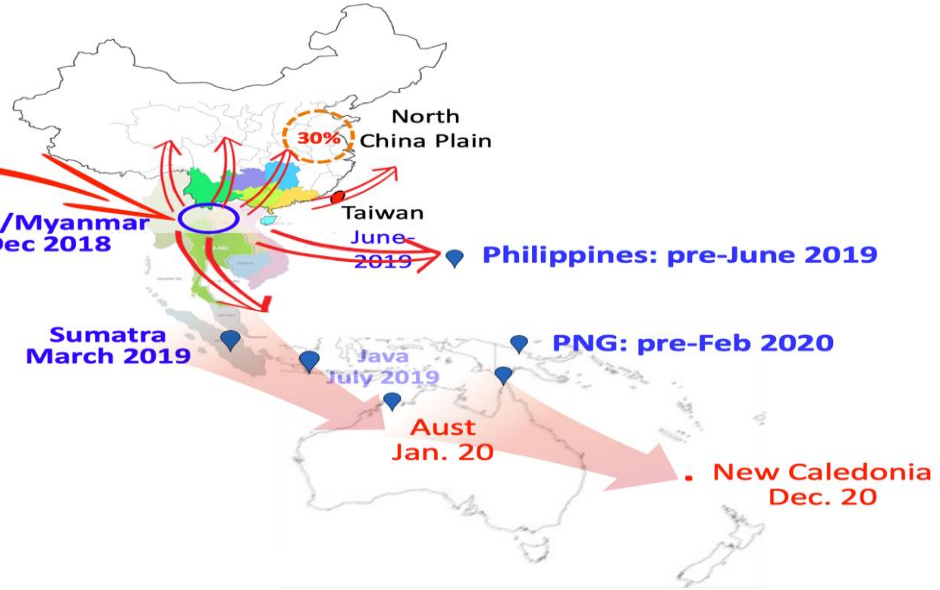
Early et al. (2018)

- UN data (total exports) from sub-Saharan African countries to all countries between 2012-2016.
- total trade volume >USD$ 500 M as most likely to introduce FAW
- Passenger (air) also considered



2 SNPs on COI
1 SNP on Tpi





Origin of Togo FAW: Eastern USA & the Greater Antilles

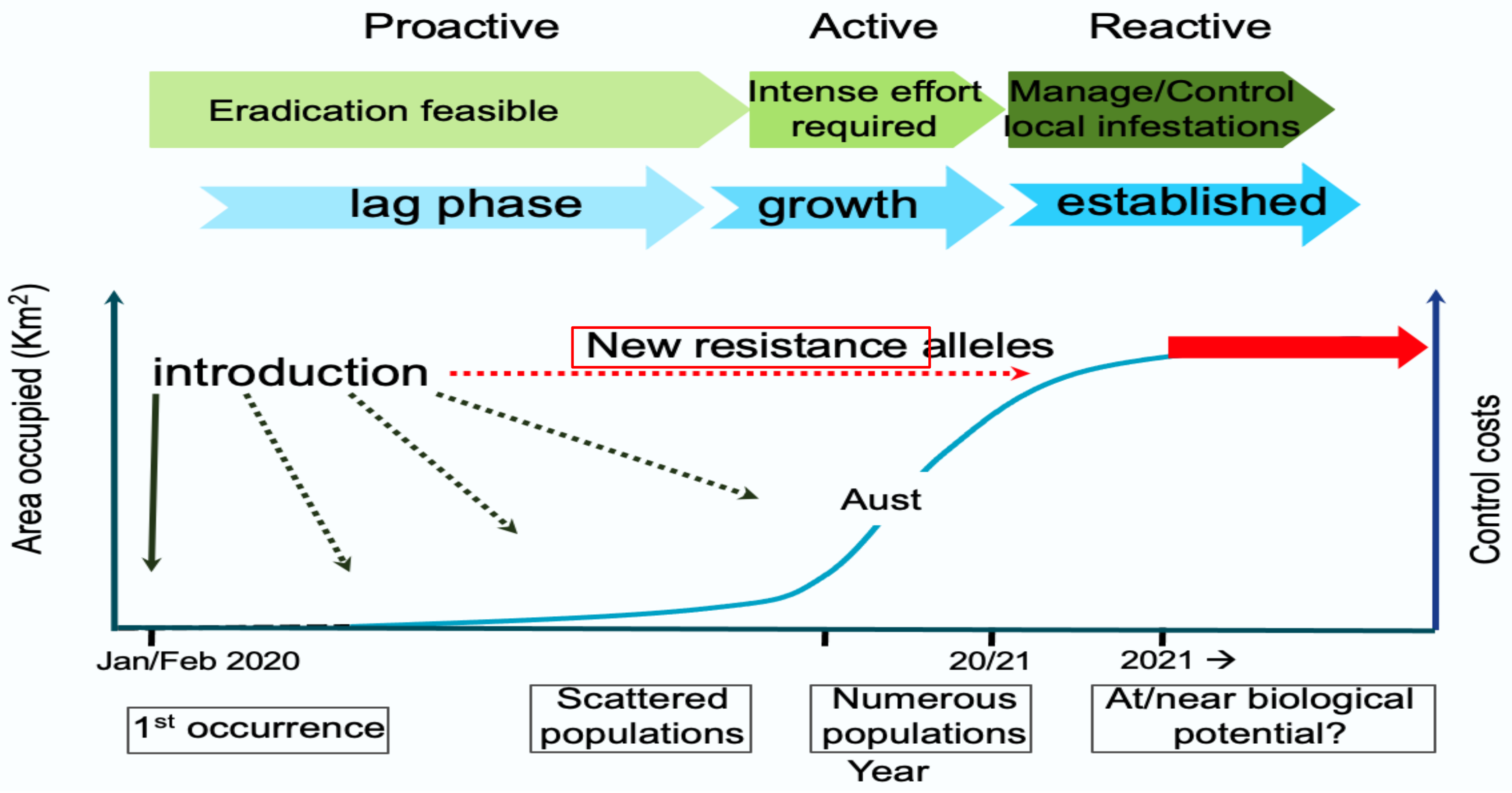
Nagoshi et al. 2017
(PLoS ONE 12, e0181982)

Current hypothesis
West to East spread of FAW
based on reported detection

Invasion Processes & Reintroduction

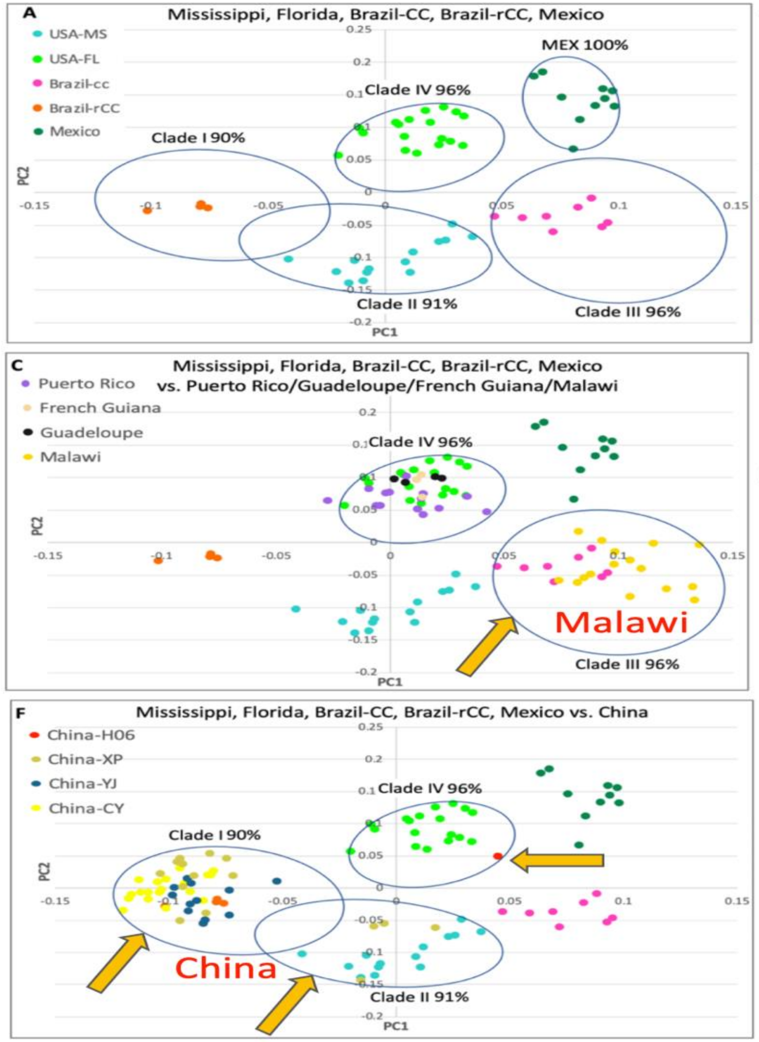
Australia: Established FAW populations from Jan/Feb-2020

New genotypes introduced will bypass the lag & growth phases



* New resistance alleles from natural migration and/or accidental introduction (e.g., via international trade)

Genomic evidence



Global FAW population genomic signature supports complex introduction events across the Old World

WT Tay, R Rane, A Padovan, T Walsh, S Elfekih, S Downes, K Nam, E d'Alençon, J Zhang, Y Wu, N Nègre, D Kunz, DJ Kriticos, C Czepak, M Otim, KHJ Gordon

doi: https://doi.org/10.1101/2020.06.12.147660

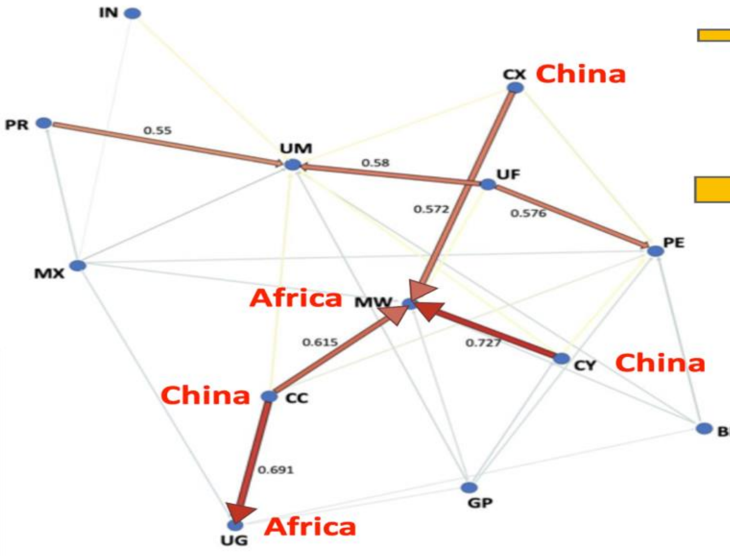
Protein Cell
https://doi.org/10.1007/s13238-020-00795-7
Protein & Cell

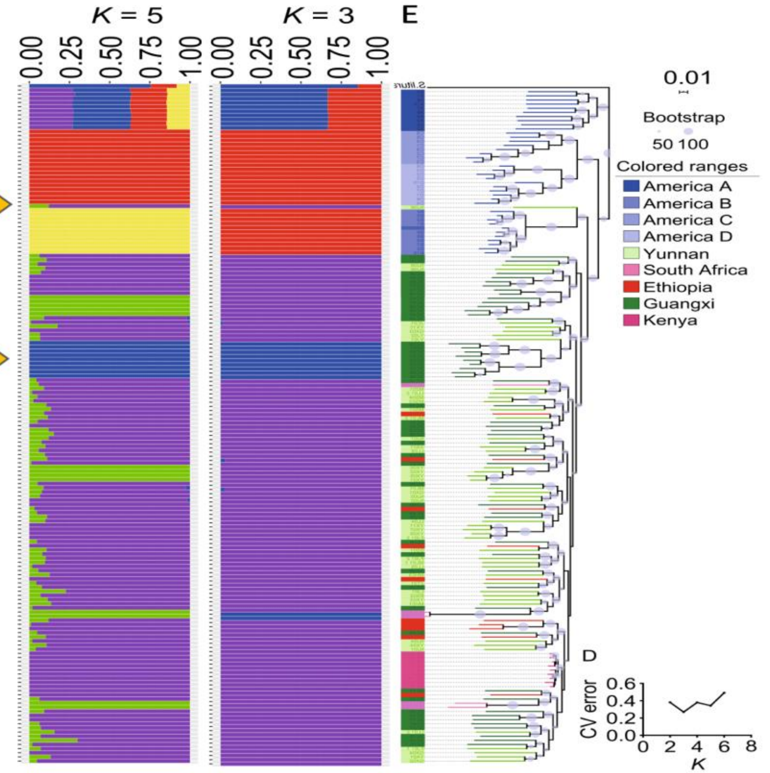
RESEARCH ARTICLE

Genomic and transcriptomic analysis unveils population evolution and development of pesticide resistance in fall armyworm *Spodoptera frugiperda*

Furong Gui[1,12], Tianming Lan[2,9], Yue Zhao[1], Wei Guo[3,15], Yang Dong[1,12], Dongming Fang[2], et al.

Native range
- Five distinct populations
- No 'corn/rice' distinction





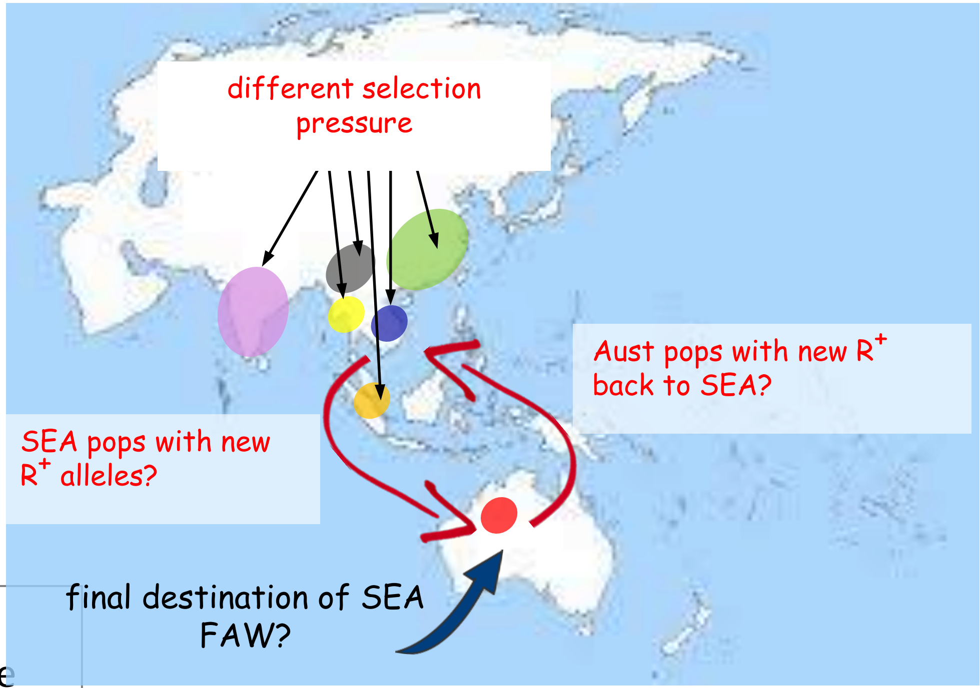
Evidence of multiple introductions & origins
Gene flow direction: Asia → Africa

Are new introduction events from native range still taking place?
Are novel resistance alleles being introduced?

Research Gaps

- How quickly do FAWs adapt to different selection pressure?

Indoxacarb – India (~0) → Aust (~40x)
1.5yrs to Aust, max ~18 generations!
Lab selection experiments: need 12-18 months to confirm – too late?
- need standardise bioassays protocols



- SNP-based management tool to identify populations?

Need insights to gene flow at national & regional levels
- can be useful to growers to understand population characteristics, e.g., resistance
- necessary for identifying new introduction events
- On-going monitoring of populations (regional & national) is needed

- Need a hub (eg, CSIRO's Agripest Challenge) to facilitate national/international approach.

All agricultural/horticultural industries need to get involved!
- A SEA regional hub for all relevant resistance management research
- Strategic approach, including aligned ways of measuring impact
- Measure and understand interactions with other pest species

CSIRO

Acknowledgements

- Grow Asia: A Watson
- GRDC, ACIAR, CRDC, FMC, DOW/Corteva
  SRA, DAWE, PBRI, PHA
- SEA Partners
- CSIRO
  T Walsh, B James, R Rane, S Macfadyen
  K Gordon, S Downes, A Sheppard, D Kriticos, P Hunt
- International Partners
  UFG (Brazil), NaCRRI (Uganda)
  INRAE (France)

Thank you

CSIRO Health & Biosecurity
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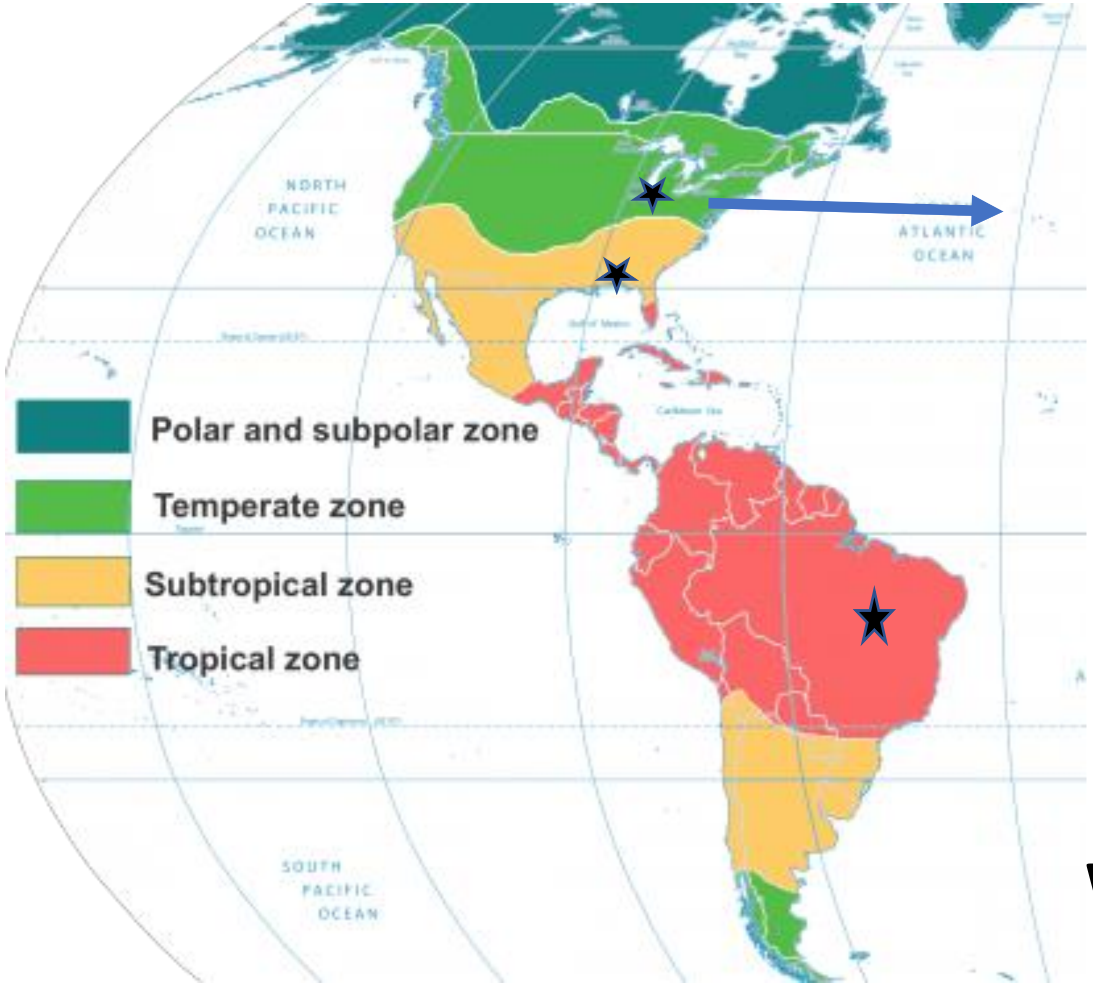
https://www.csiro.au/en/about/people/business-units/health-and-biosecurity

Experience in the US/Brazil in managing FAW resistance tactics, challenges, and opportunities



Meteoblue

FAW
South and North Americas

Florida Panhandle region

Silvana Paula-Moraes
PhD Entomology
West Florida Research and Education Center
UF IFAS
UNIVERSITY of FLORIDA

Experience in the US/Brazil in managing FAW resistance tactics, challenges, and opportunities

Insect resistance to Bt traits in Brazil

- Field-evolved resistance to Cry1F maize in Brazil

Farias et al. 2014

- Cross resistance between Cry1F and some Cry1-based maize hybrids

Bernardi el al. 2015

- Cry1Ac –approx. 100 LC_{50} (µg protein/ml^{-1} diet)

Bernardi et al., 2012

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Experience in the US/Brazil in managing FAW resistance tactics, challenges, and opportunities

Factors that Influence Effective IRM to FAW
Bt traits and insecticides

Genetic

Ecological/behavioral

Operational

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Experience in the US/Brazil in managing FAW resistance tactics, challenges, and opportunities

Factors that Influence Effective IRM to FAW - Bt traits and insecticides

Ecological/behavioral

Operational

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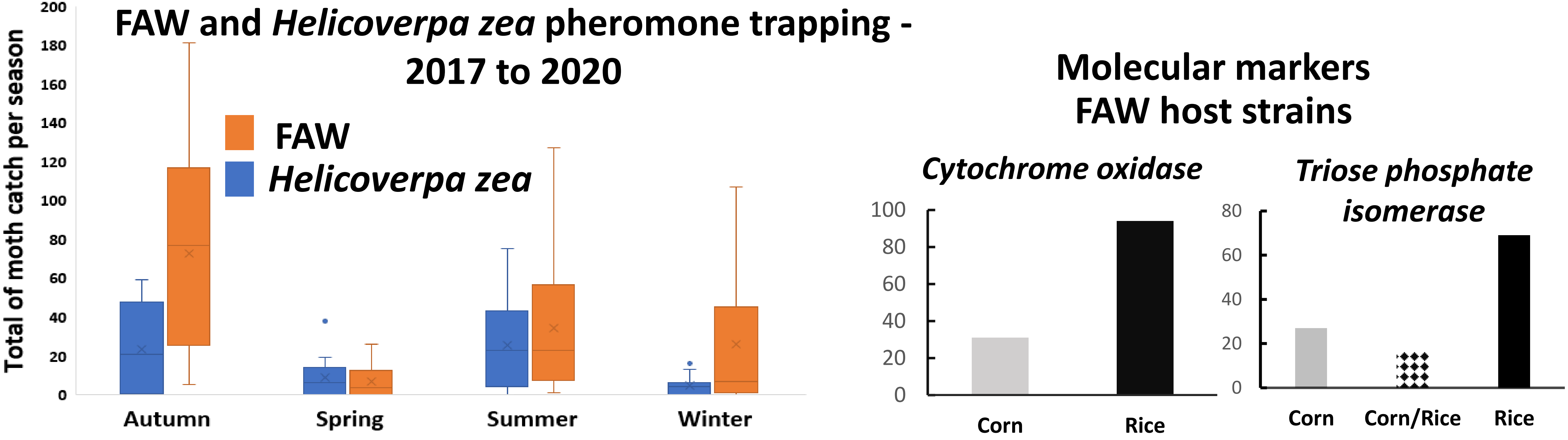
Clear understanding of pest occurrence phenology/ecology/behavior

- **FAW seasonal abundance, strains and origin**

  Phenological occurrence of FAW

  Critical time of pest pressure

  FAW rice and maize strains



Barbosa et al., unpublished data

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Clear understanding of pest occurrence phenology/ecology/behavior

- **FAW oviposition pattern**

  Moths do not distinguish Bt and non-Bt maize plants

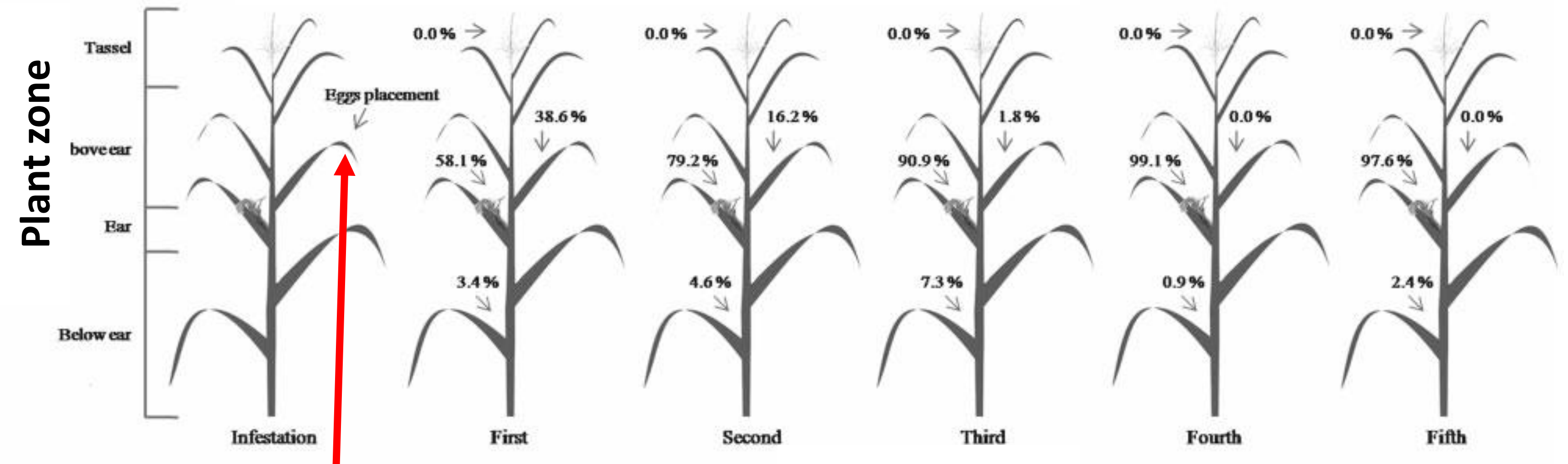
  Larval damage does not interfere in the oviposition choice

Bt non-Bt

Goncalves et al. 2020

- **FAW larval movement – on plant and plant-to-plant**

Larval distribution on maize plant



Sampling date

Egg mass

Larval plant-to-plant movement

0.76 m btw maize rows

0.18 m within maize row

Pannuti et al., 2015

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Clear understanding of pest occurrence phenology/ecology/behavior

- **FAW host plants - polyphagous pest**

  353 larval hosts, 76 plant families — Montezano et al. 2018

- **FAW Life table parameters**

  Larval development time between sexes – diet, temperature and biotype

  Biological plasticity – 5 to 10 instars – survival under adverse conditions

Specht et al. 2016

Feeding site defined by first-instar

Maize in vegetative stage:
Leaf consumer
Seedlings – dead heart

Maize in reproductive stage:

Feeding size - ear zone site
Silk not suitable – growth
Maize kernels diet – faster development

Pannuti et al. 2015

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Clear understanding of pest occurrence phenology/ecology/behavior

- **Intraguild competition**

  FAW vs *H. armigera*

  FAW has competitive advantage over *Helicoverpa* spp.

  Absence of competitor – advantage for FAW larval development

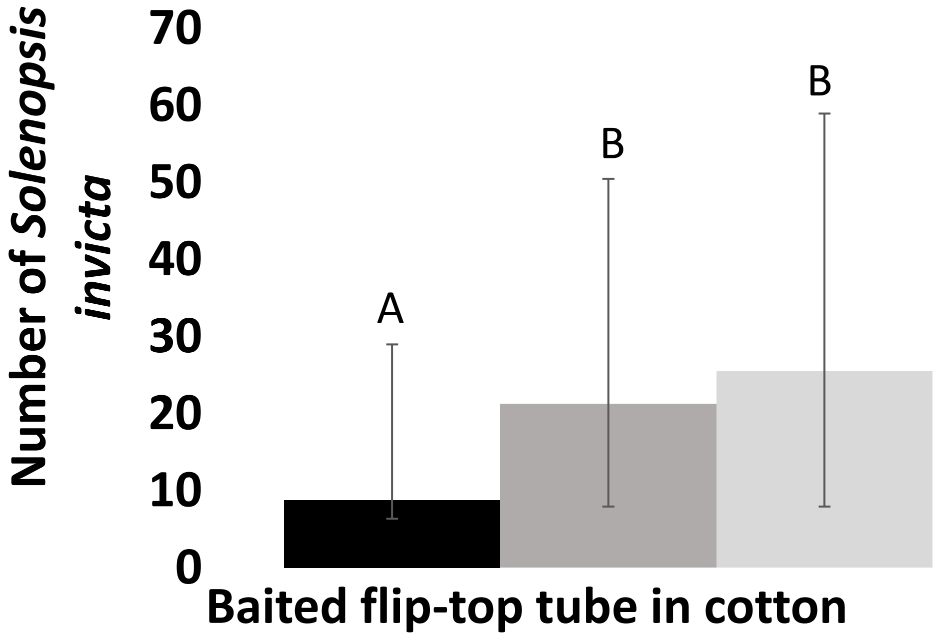
Bentivenha et al., 2016a, 2016b, 2017

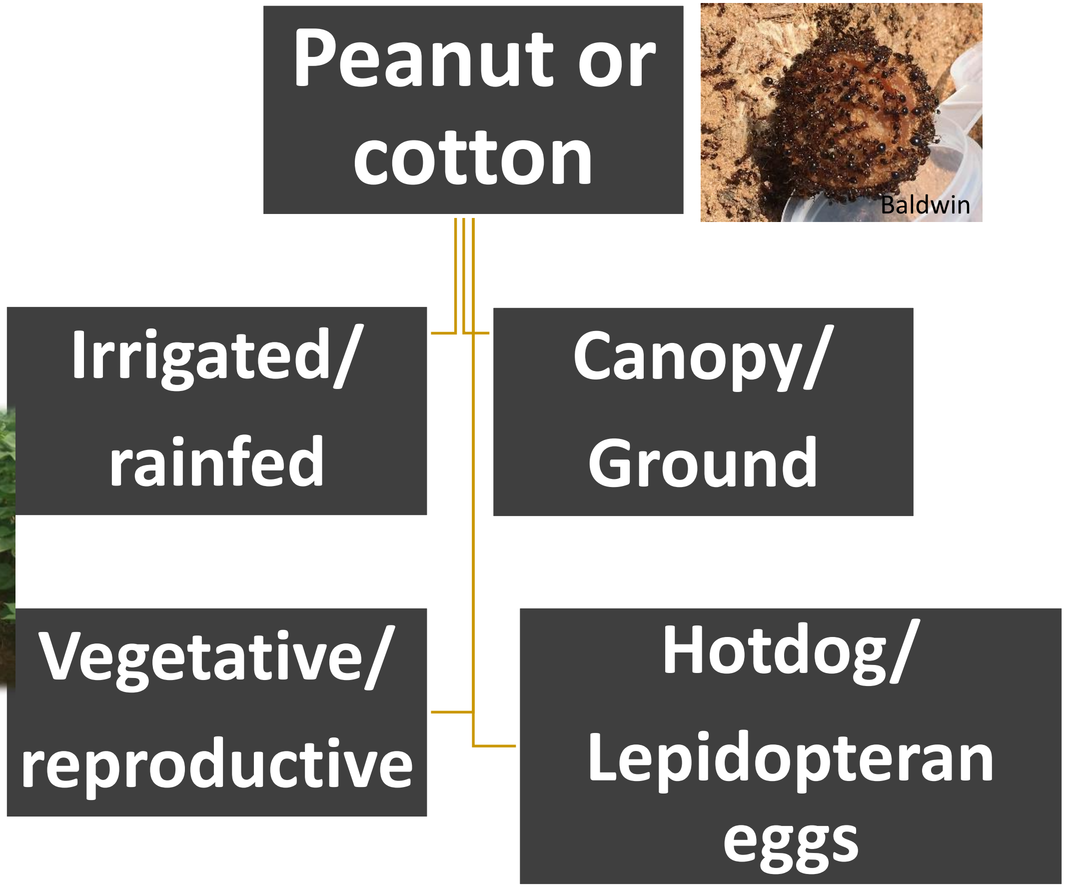
Clear understanding of pest occurrence phenology/ecology/behavior

- **Inventory of natural enemies**

Natural biological control of Lepidoptera by red imported fire ants – Florida Panhandle

Field	Number of eggs placed per field	Number of samples with presence of red imported fire ants		% Egg loss
		After 1 hour	After 2 hours	
Cotton	80	15	34	60.0
Peanut	79	34	67	96.2

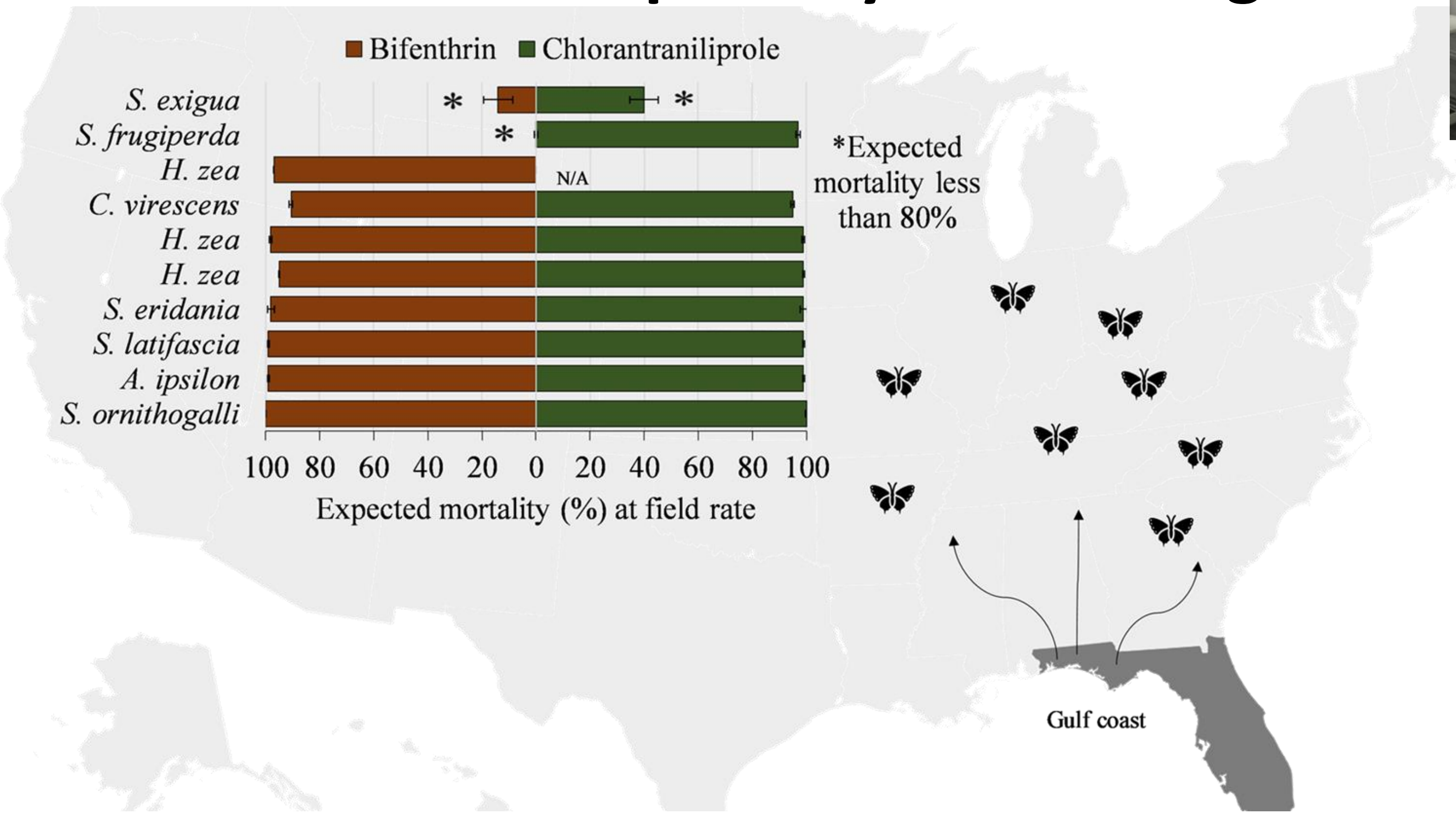




Baldwin et al., 2020

Effective IRM

- **Insecticide susceptibility monitoring**



Expected mortality of pest populations from the Florida Panhandle to insecticides

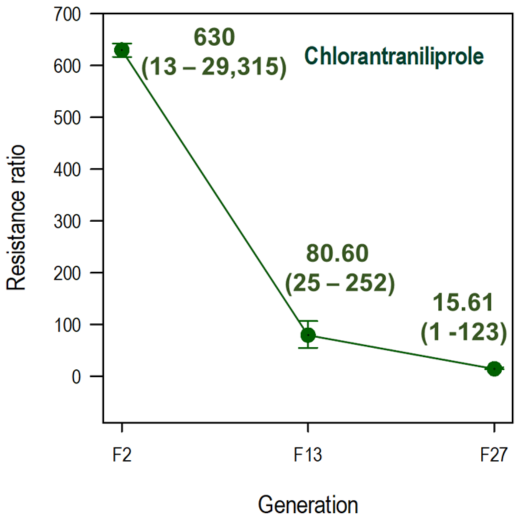
- FAW resistance to pyrethroid
- First resistance report of *Spodoptera exigua* to diamide in the U.S.

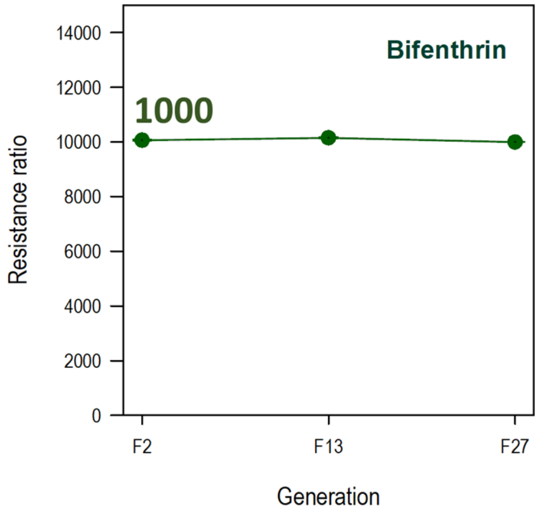
Rabelo et al., 2020

Effective IRM

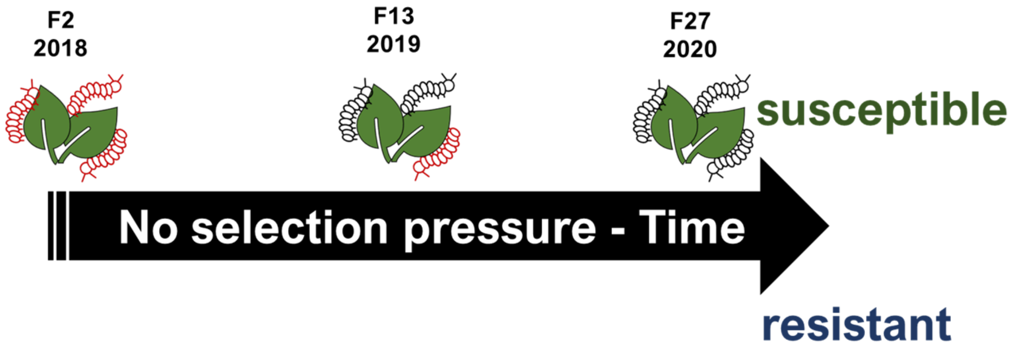
- **Resistance stability and fitness cost in *S. exigua***

Insecticide bioassays at F2, F13, and F27 – Resistance Ratio

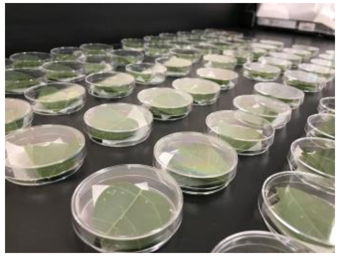




A- Chlorantraniliprole – unstable – fitness cost



B- Bifenthrin – stable – no fitness cost



IRM program:

- Insecticide resistance monitoring
- Rotation of mode of actions – diamide vs pyrethroid

Rabelo et al., unpublished data

Effective IRM

- **Pest behavior vs operational factors**

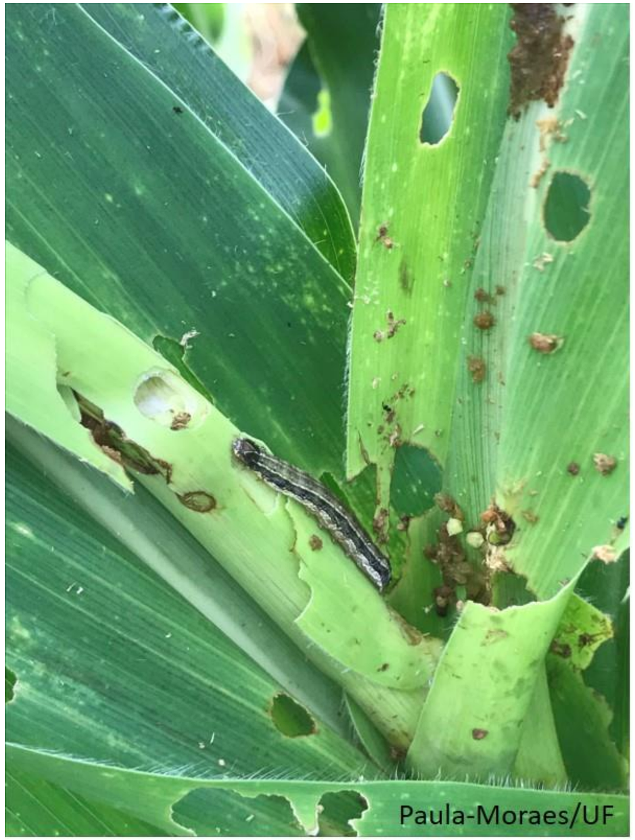
Insecticide efficiency compromised by FAW oviposition and larval behavior

Short interval control window before larval establishment

Paula-Moraes et al. 2017

Key points when spraying - coverage feeding sites, spray volume, flat nozzle

MoA rotation and selective insecticides



Experience in the US/Brazil in managing FAW resistance tactics, challenges, and opportunities

Effective IRM to FAW – Bt traits and insecticides

- IPM Framework – combine management tactics
- Region-specific – one size does not fit all
- Spatial and temporal dynamic of host crops in the agricultural landscape
- Pest genetic, ecology, and behavior
- Monitoring of resistance – coordinate work and collaboration
- Legal framework and some level of regulation
- Coordination of effort among stakeholders
- Farm behavior – social aspects and risk aversion
- Clear recommendations of IRM tactics – e.g. refuge, rotation of mode of action

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Questions?

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UNIVERSITY of FLORIDA

Resistance Monitoring and Manage ment of FAW in China

Kongming Wu
Chinese Academy of Agricultural Sciences

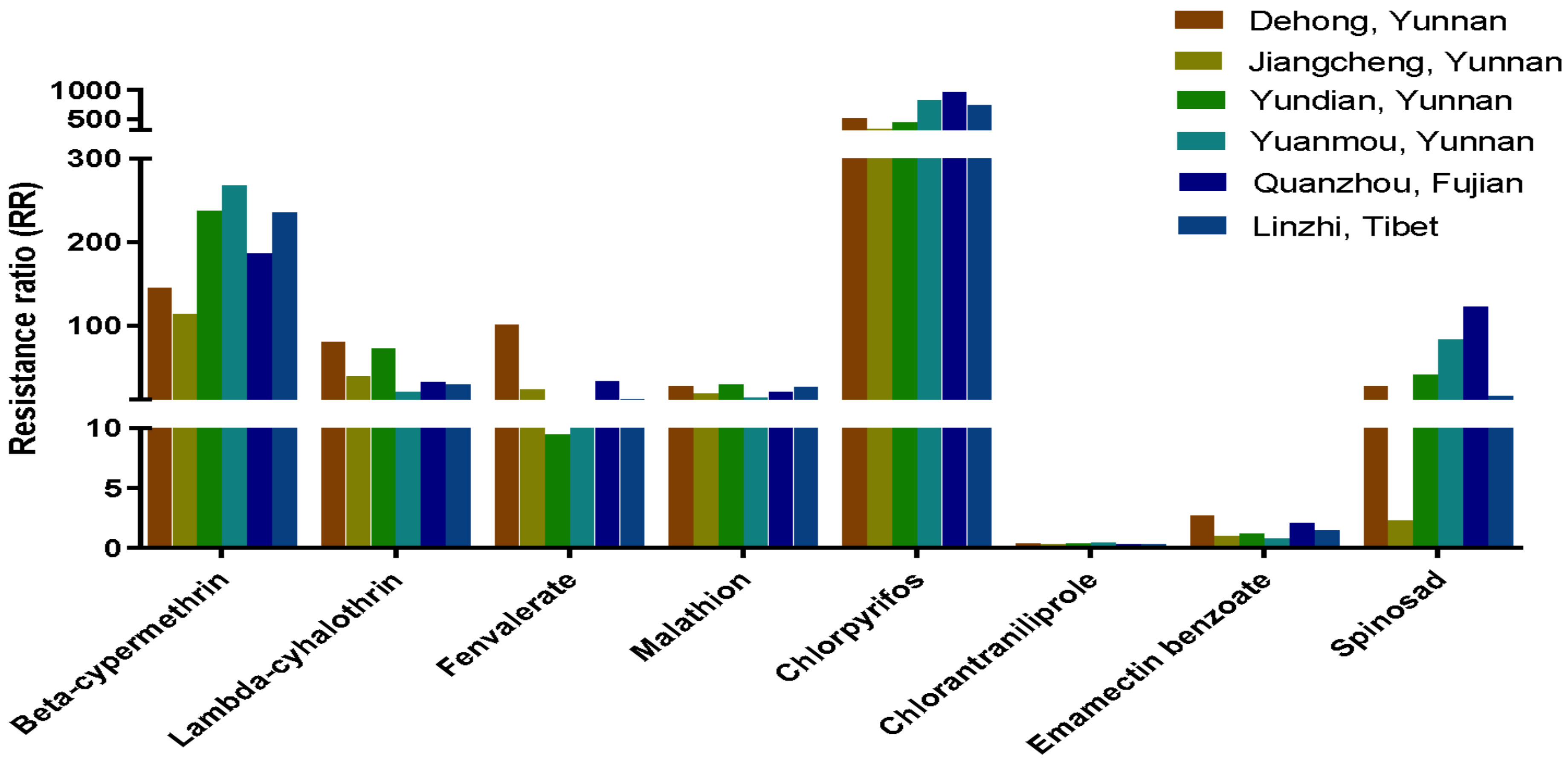
1. Resistance monitoring

Genome scanning of insecticide resistance in FAW field populations

Gene	Acetylcholinesterase (AChE)			Voltagegated sodium channel (VGSC)			Ryanodine receptor (RyR)	
Pesticides type	Organophosphate & carbamate			Pyrethroid			Diamide	
Mutation site	AA201	AA227	AA290	AA929	AA932	AA1014	AA4790	AA4946
Susceptible type	A	G	F	T	L	L	I	G
Resistant type	S	A	V	I	F	F	M	E
Chinese FAW	AA (82.9%) AS (17.1%)	GG (100%)	FF (12.1%) FV (58.2%) VV (29.7%)	TT (100%)	LL (100%)	LL (100%)	II (100%)	GG (100%)

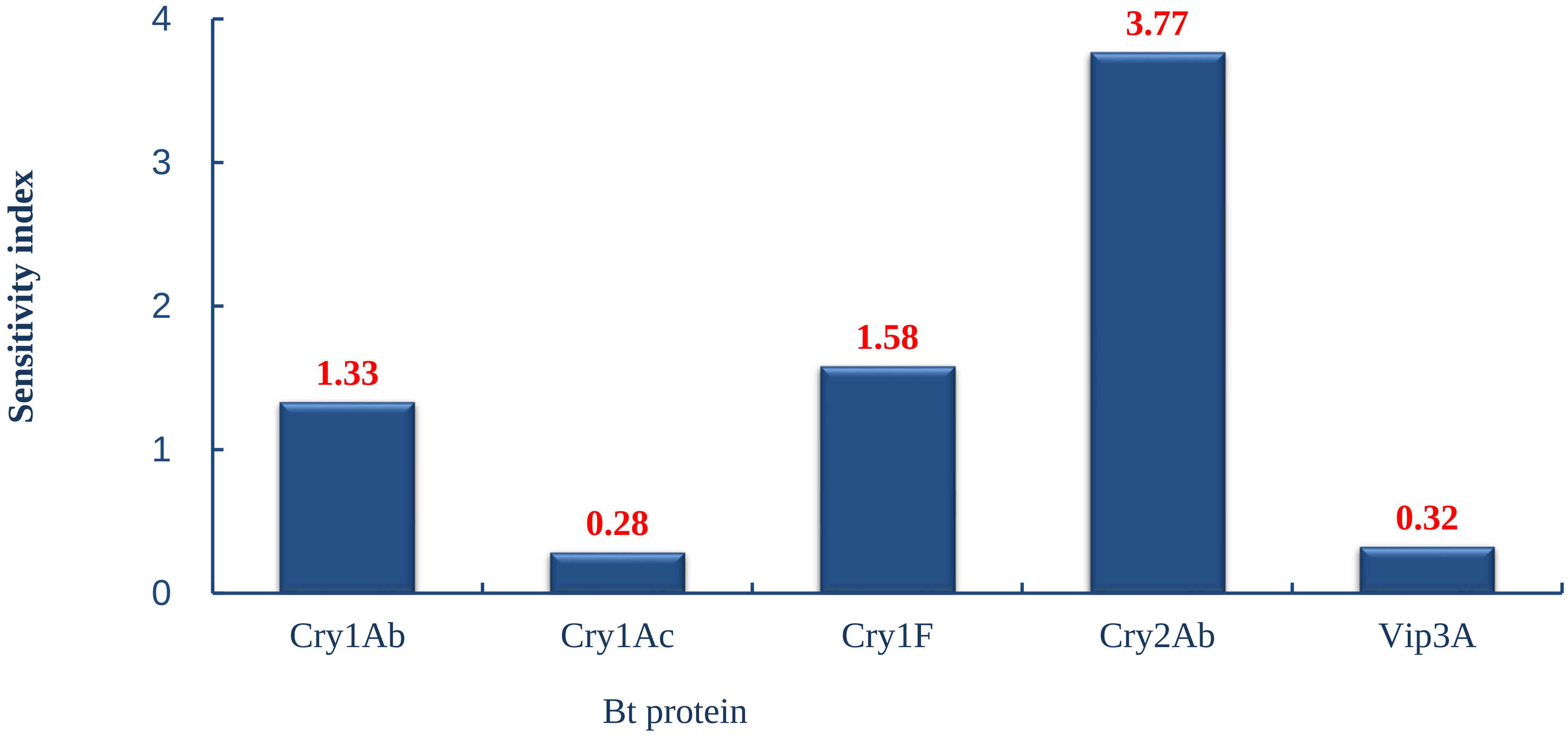
The gene mutation frequencies to organophosphate and carbamate were high, but less to Bt

1. Resistance monitoring



The resistance levels to organophosphates and pyrethroids were relatively high, but chlorantraniliprole and emamectin benzoate kept at low level.

1. Resistance monitoring



Compared to the baselines of SS-population in USA, the sensitivity indexes ranged from 0.28-3.77

2. Resistance Management

Pesticide rotation and mixed application

Insecticide	Type	Target
Emamectin benzoate	Antibiotics	Glutamate-gated chloride channel
Indoxacarb	Oxadiazines	Voltage-dependent sodium channel
Tetraniliprole	Diamides	Ryanodine receptor (RyR)
Chlorantraniliprole	Diamides	Ryanodine receptor (RyR)
Flubendiamide	Diamides	Ryanodine receptor (RyR)
Lufenuron	Benzoylureas	Inhibitors of chitin biosynthesis
Chlorfenapyr	Pyrroles	Uncouplers of Oxidative phosphorylation via disruption of the proton gradient
Spinetoram	Antibiotics	Nicotinic acetylcholine (nAChR)

2. Resistance Management

Bio-pesticide application

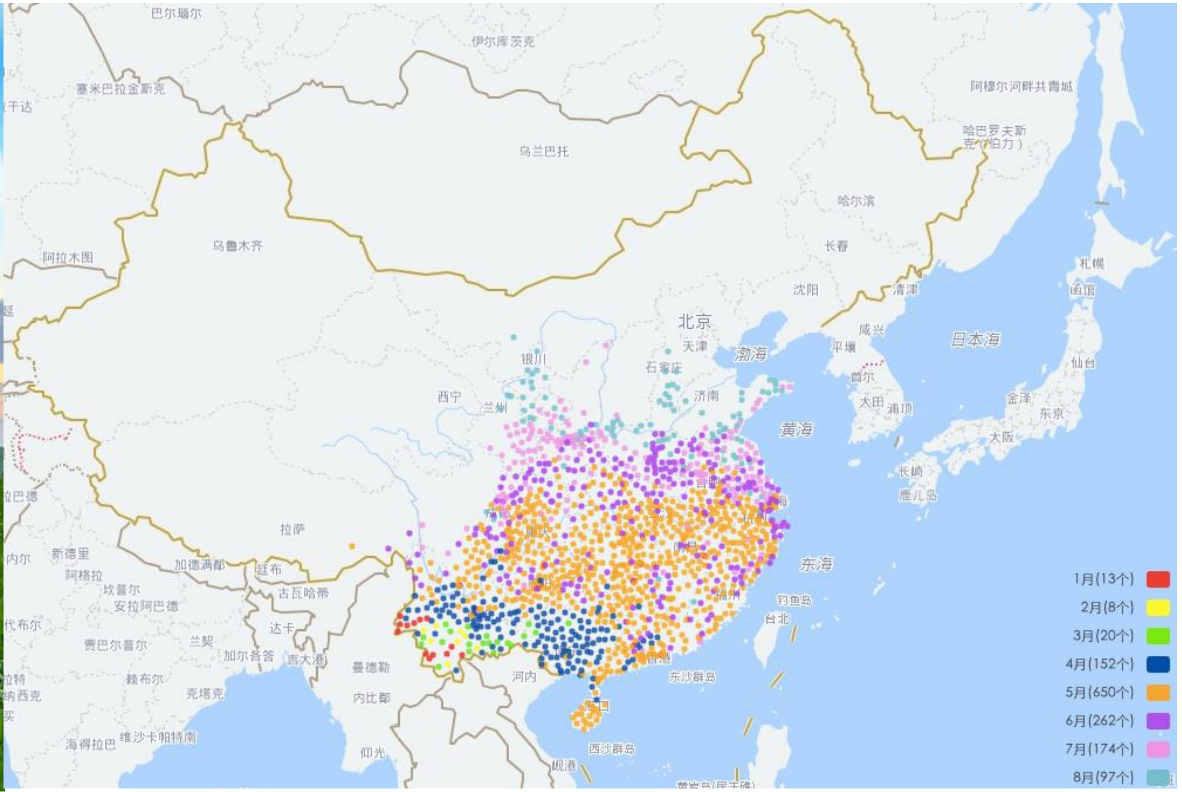
Pesticide	Dosage form	Total content	Spray dosage
Beauveria bassiana	Wettable powder (WP)	30 billion spores/g	45-60 g/acre
Metarhizium anisopliae	Oil Dispersion (OD)	8 billion spores/mL	60-90 mL/acre
Bacillus thuringiensis	WP	32000 IU/mg	150-300 g/acre

2. Resistance Management

China Fall Armyworm Management Information System

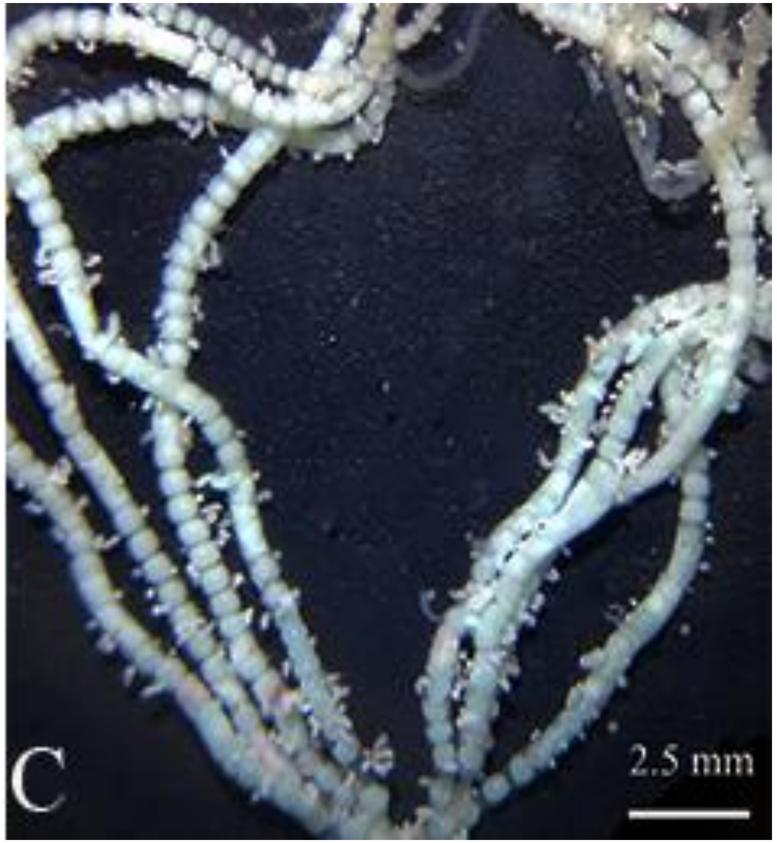
Website : www.ccpmis.org.cn

Releasing 8,000 plus early-warning reports of FAW information annually



2. Resistance Management

Early warning to guide pesticide application in time

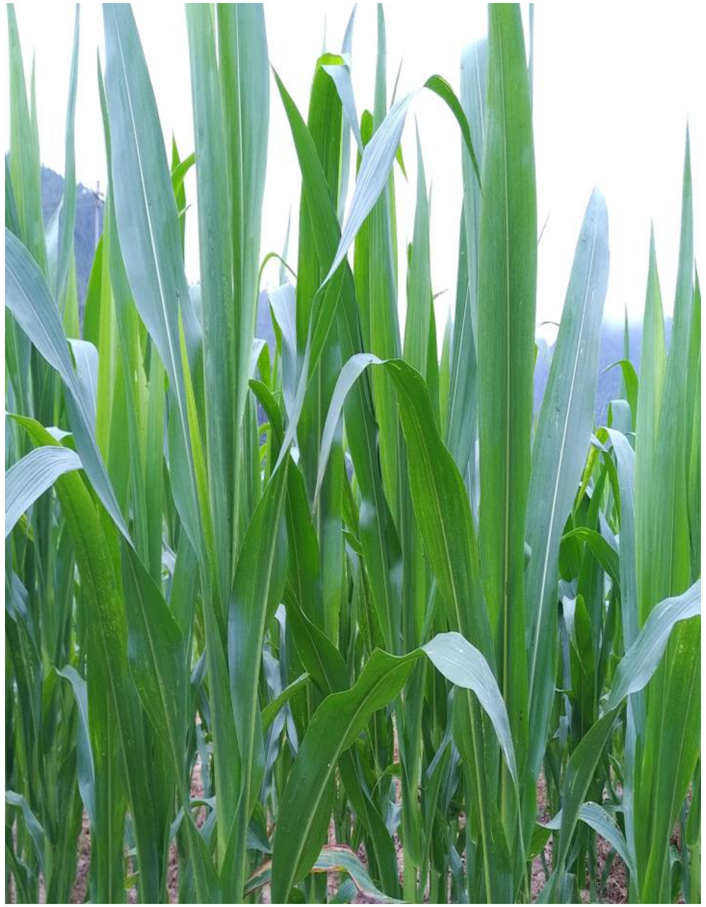


Ovary dissection for prediction

Optimal period for pesticide use

2. Resistance Management

Bt corn

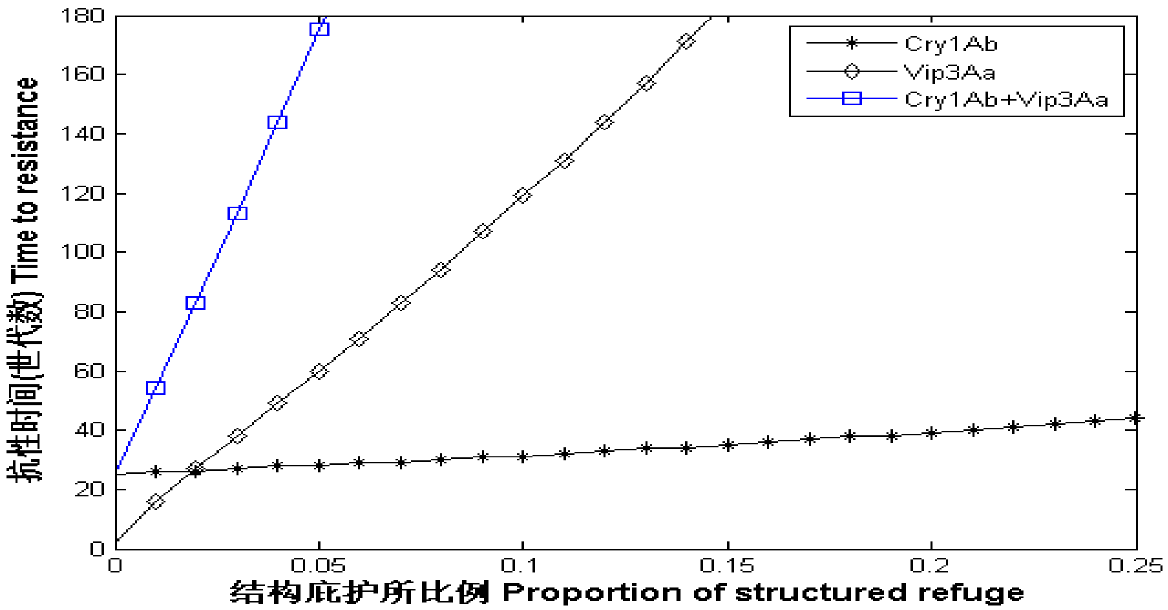


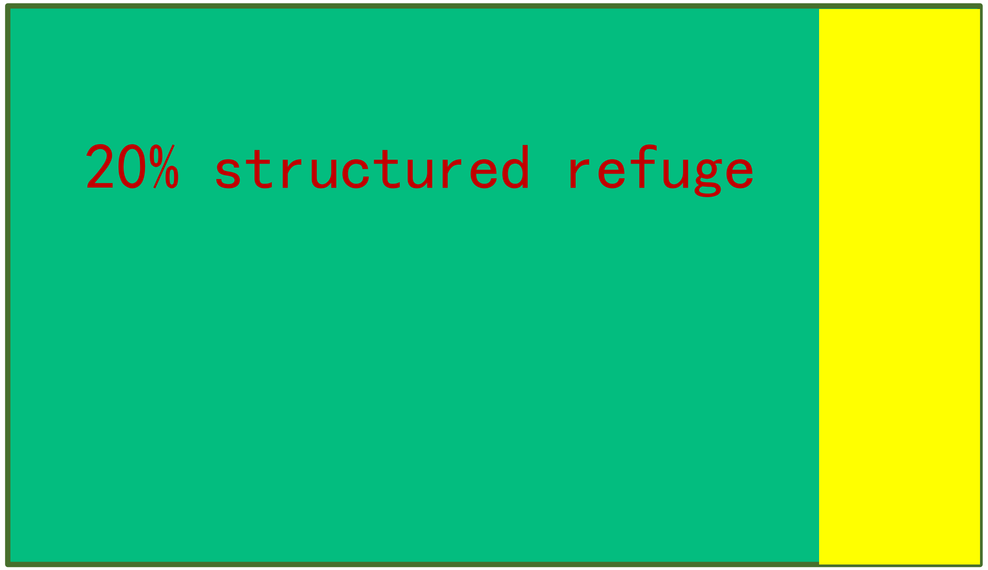
Bt maize

Conventional

2. Resistance Management

Modelling analysis for resistance evolution to Bt corn





Possible strategy : Two Bt genes (Cry1Ab + Vip3A)+ structured refuge

Thanks

Summary

Dr. Y Andi Trisyono

Professor at Gadjah Mada University, Indonesia

Next Steps

1. Revise Concept Paper based on all feedback by
    - You can download the concept paper at http://bit.ly/ASEANFAWresistance and provide written feedback on the concept paper to faw@growasia.org **by 1 May 2021.**

2. Secure funding and develop work-plan

3. Present Final Concept Paper to ASEAN FAW Taskforce on 13 July 2021.


CLOSE
GrowAsia
ASEAN FAW ACTION PLAN
Supporting IPM Across Southeast Asia