

East meets West or Out of Africa? Genomic evidence and trade data to understand pest risks and globalization of *Spodoptera frugiperda*

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Spodoptera frugiperda: Africa & beyond

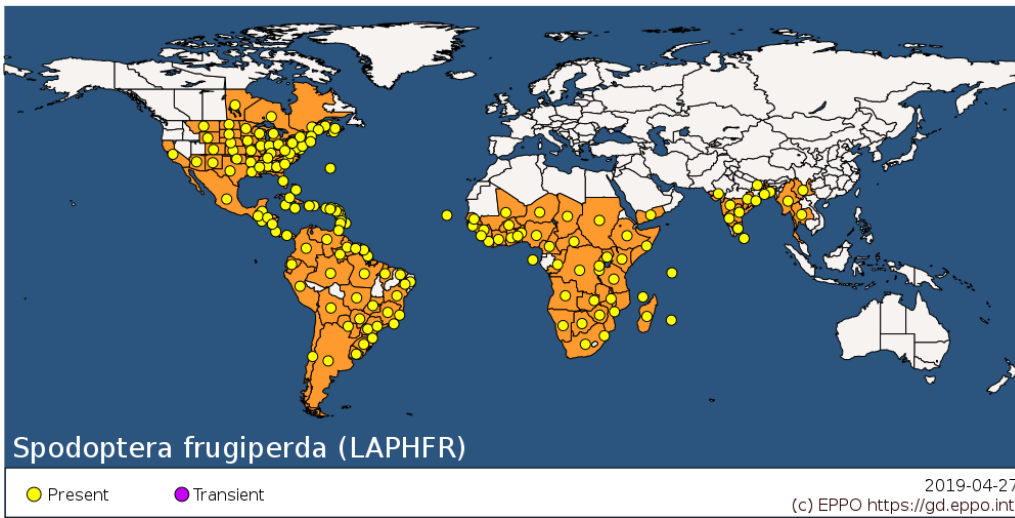
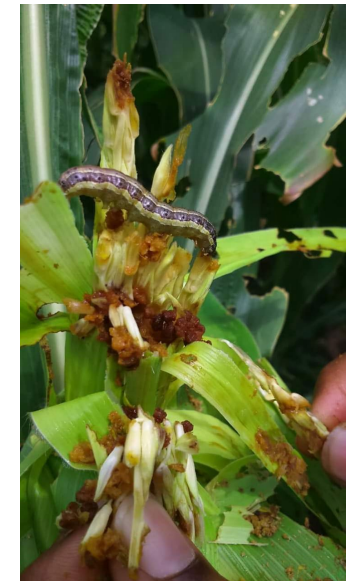


Figure 1 Distribution map of *Spodoptera frugiperda* from the EPPO Global Database accessed 27/04/2019.

TABLE 1: TOP 20 PESTS BY RECENT PUBLICATION NUMBERS

Ranking is based on abstract searches on all 1,187 arthropod pests with full datasheets in the CABI Compendia on crop protection, forestry and invasive species. Also included are the number of pesticide active ingredients to which they are reported to be resistant, and summaries of their reported distribution and reported hosts.

	SCIENTIFIC NAME	COMMON NAME	NUMBER OF PUBLICATIONS (2012–16)	NUMBER OF PESTICIDES RESISTANT TO	CONTINENTS PRESENT ^A	NUMBER OF HOST GENERA ^B	TOP HOSTS (BY PUBLICATION NUMBER) ^{C+}
5	<i>Spodoptera litura</i>	taro caterpillar	853	39	Asia, Africa, N America, Europe, Oceania*	66	<i>Glycine max</i> (soybean), <i>Arachis hypogaea</i> (peanut)
8	<i>Spodoptera frugiperda</i>	fall armyworm	668	24	Africa, N/S America, Europe (few occurrences)	72	<i>Zea mays</i> (maize), <i>Gossypium</i> (cotton)
11	<i>Spodoptera exigua</i>	beet armyworm	506	39	Asia, Africa, N America, Europe, Oceania	50	<i>Gossypium</i> (cotton), <i>Zea mays</i> (maize)
16	<i>Spodoptera littoralis</i>	cotton leafworm	401	30	Asia, Africa, Europe	96	<i>Gossypium</i> (cotton), <i>Zea mays</i> (maize)



Spodoptera frugiperda

(Fall Armyworm)

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Fall Armyworm Status

Impacts and control options in Africa:
Preliminary Evidence Note (April 2017)

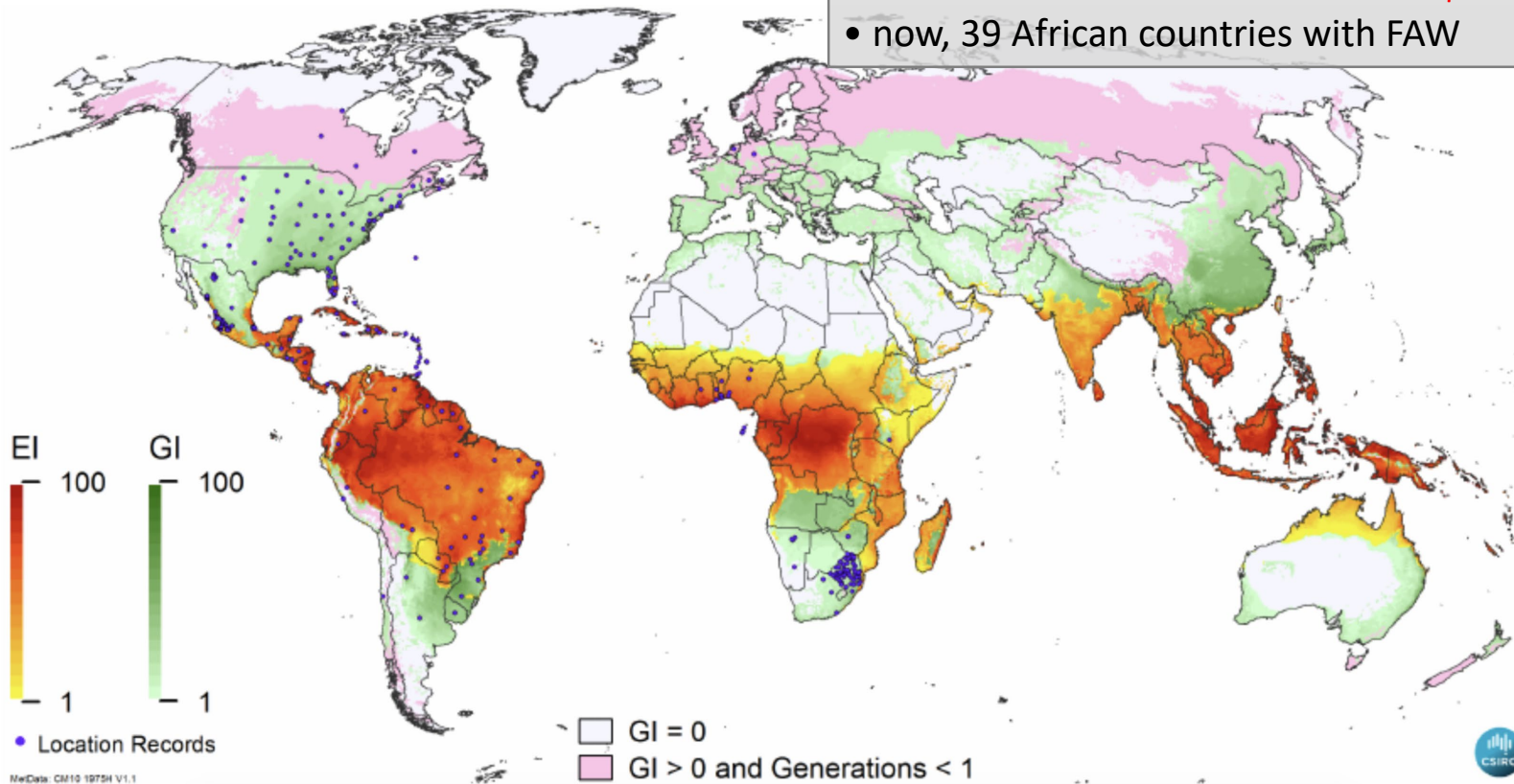
P. Abrahams, T. Beale, M. Cock, N. Corniani, R. Day*, J. Godwin,

S. Murphy, G. Richards & J. Vos



FAW affected crops in all countries	Total production (tonnes, m) assuming no FAW	Yield loss (tonnes, m)	Estimated/predicted loss (US\$, m)
Maize	67.0	13.5	3,058
Sorghum	25.5	1.90	827
			Area of crop at economic risk (US\$, m)
Rice, paddy	17.1	9.6	6,699
Sugarcane	90.1	46.0	2,798
		Total	13,383

- From 11 countries... **Estimated US \$13.3 billion**
- now, 39 African countries with FAW



The Very Hungry Caterpillar ...

ANTARANEWS

Ministry takes precautionary measures against armyworm pest attacks

© 31st May 2019



KHMER TIMES

National June 15, 2019

Worm epidemic destroys 10, 000 hectares of corn

Mom Kunthea / Khmer Times

Share: f t G+ @



The Fall Armyworm which ravaged corn crops in South

nature
International journal of science

NEWS • 17 JUNE 2019



Caterpillar's devastating march across China spurs hunt for native predator

Scientists hope that insects such as stink bugs could keep the fall armyworm in check.

ox f t v

Fall armyworms have come to Nepal from America, and they can trouble maize farmers here

Bhutan

Adults reared from larvae
(T. Zangpo, Dept. Ag.)

XINHUANET

Crop-eating fall armyworm spread across Taiwan

Source: Xinhua | 2019-06-18 16:56:45 |

f t in v

TAIPEI, June 18 (Xinhua) -- The fall armyworm, a crop-eating pest, has been detected in 18 counties and cities across Taiwan as of Monday, the island's agricultural authorities said.

malaysiakini

Home News Parliament Editor's Pick Sp



Fall armyworm invades crops across Asia

Patpicha Tanakasempipat and Naveen Thukral, Reuters
Jun 20th, 2019 (Updated Jun 20th, 2019)

- Confusing species status: corn- or rice-preferred ...
- Highly invasive: detected in **> 60** countries since 2016
- African + SE Asia: corn yield loss: 50%
- China: 2nd world corn producer
- **How did it spread across the world?**
 - **Origins** of invasive Sfc & Sfr populations?
 - Corn / Rice; **hybrids?**

Global effort on forecasting FAW spread

NeoBiota 40: 25–50 (2018)
doi: 10.3897/neobiota.40.28165
<http://neobiota.pensoft.net>

RESEARCH ARTICLE

A peer-reviewed open-access journal
 NeoBiota
Advancing research on alien species and biological invasions

Forecasting the global extent of invasion of the cereal pest *Spodoptera frugiperda*, the fall armyworm

Regan Early¹, Pablo González-Moreno², Sean T. Murphy², Roger Day³

¹ Centre for Ecology and Conservation, Exeter University, Penryn, Cornwall, TR10 9FE, UK ² CABI, Bakeham Lane, Egham TW20 9TY, UK ³ CABI, Canary Bird, 673 Limuru Road, Muthaiga, PO Box 633-00621, Nairobi, Kenya



Food and Agriculture Organization
of the United Nations

Fall Armyworm likely to spread from India to other parts of Asia with South East Asia and South China most at risk

FAO offers its expertise to farmers and governments in Asia on best ways to manage the invasive pest

© FAO, 2019

- trade & transport routes from Africa are important factors

- high threat of FAW originating from Africa to:

China, Thailand, Australia, Indonesia, Malaysia, Philippines

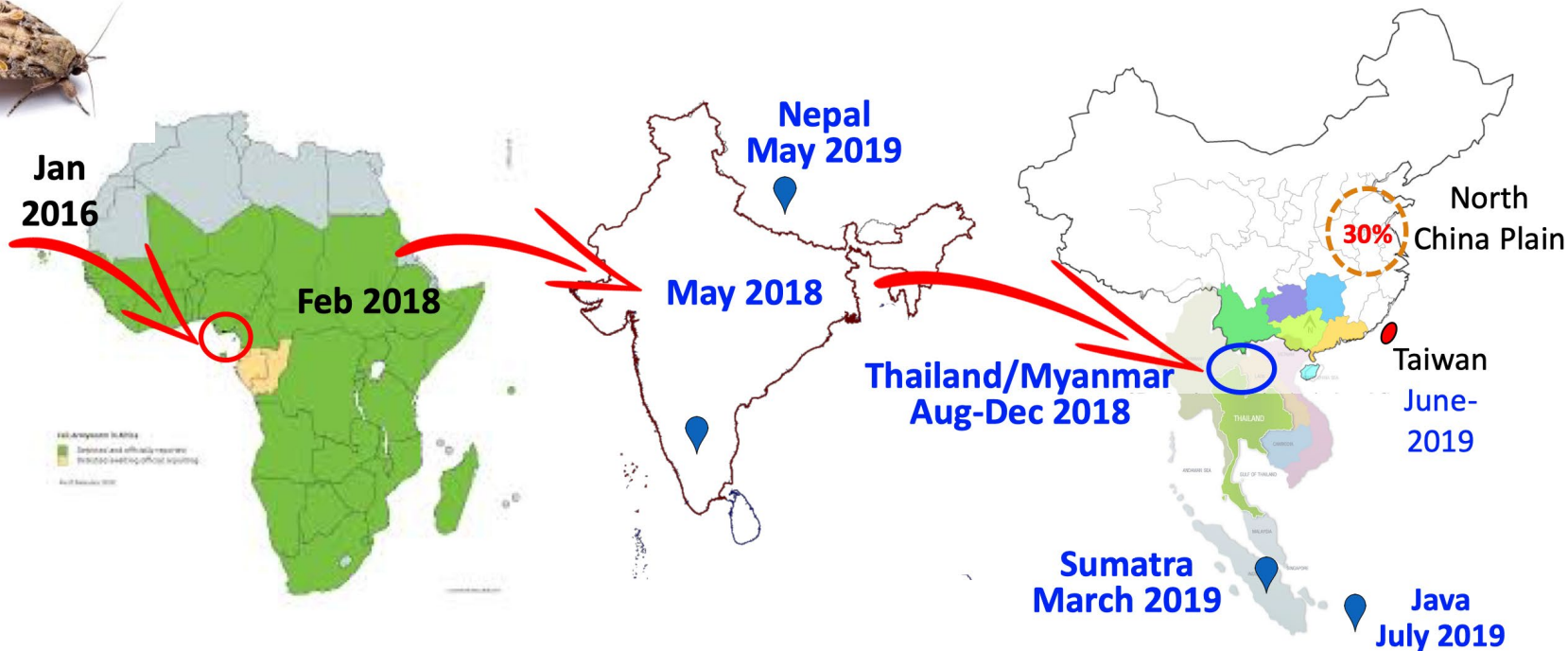
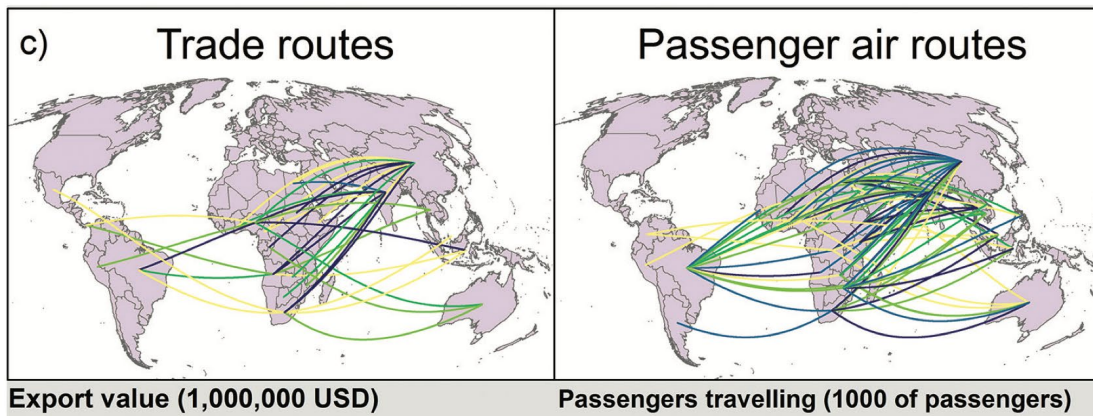
- Genomic evidence?

- Spread of FAW **likely** from India to South China and South East Asia

- Genomic evidence?

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



Molecular identification of invasive fall armyworm *Spodoptera frugiperda* in Yunnan Province

ZHANG Lei¹, JIN Minghui¹, ZHANG Dandan², JIANG Yuying², LIU Jie², WU Kongming², XIAO Yutao²

¹. Agricultural Genomics Institute at Shenzhen, Chinese Academy of Agricultural Sciences, Shenzhen 518120, China;

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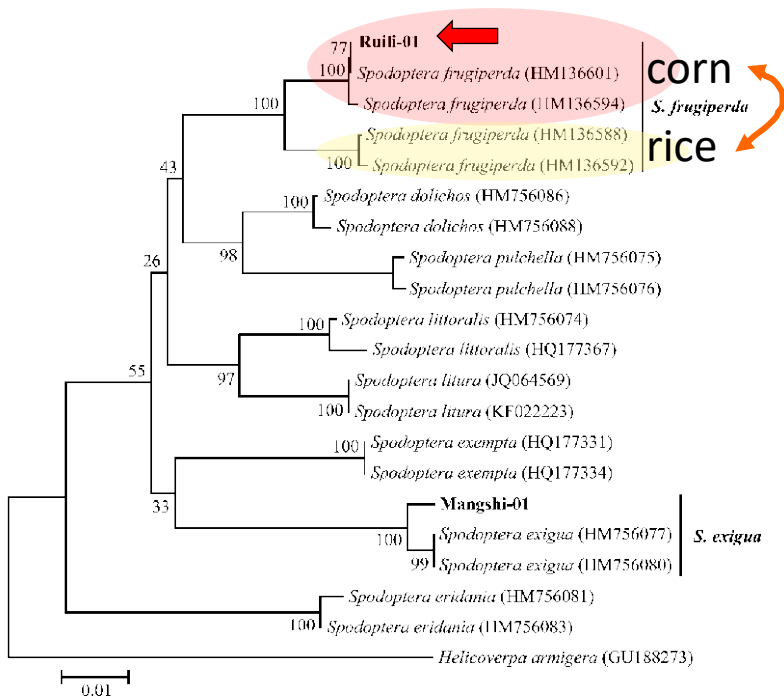


图 2 基于 CO I 序列构建的 NJ 系统树

Fig. 2 Phylogenetic tree constructed by NJ analysis based on CO I gene fragments

K2P, NJ, 1,000 bootstrap replications

Genetic identity of Myanmar populations?

Analysis of migration routes of the fall armyworm *Spodoptera frugiperda* (J. E. Smith) from Myanmar to China

WU QiuLin¹, JIANG Yuying², WU Kongming

(1. State Key Laboratory for Biology of Plant Diseases and Insect Pests, Institute of Plant Protection,

Chinese Academy of Agricultural Sciences, Beijing 100193, China; 2. National Agro-Tech

Extension and Service Center, Beijing 100125, China)

By end of 2018, Myanmar FAW “sporadically entered southwestern Yunnan”

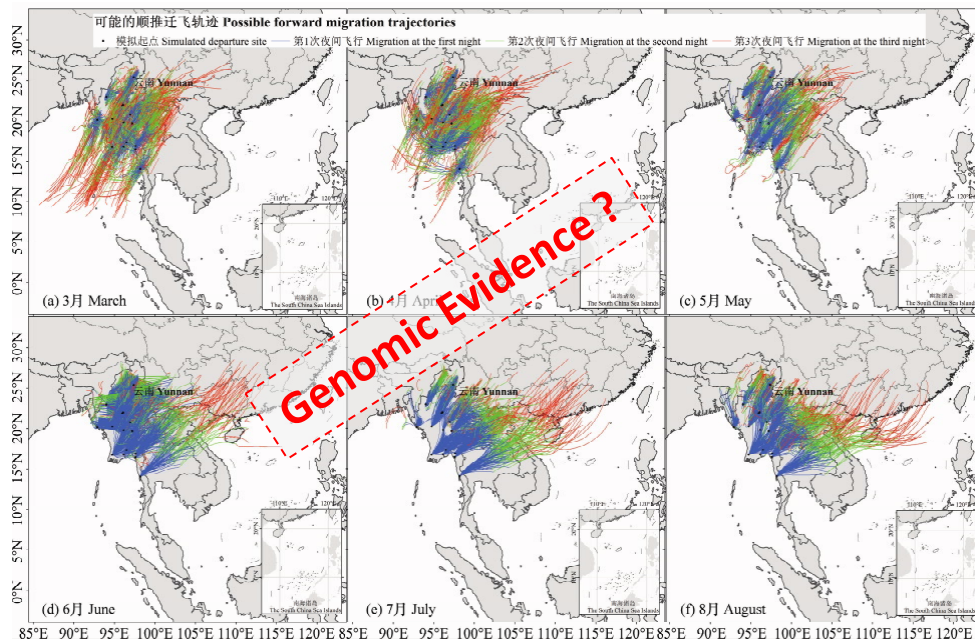


图 2 春季(a~c)与夏季(d~f)缅甸草地夜蛾随东亚季风可能的迁飞路径

Fig. 2 Possible migration trajectories of the fall armyworm in Myanmar with East Asian monsoon in spring (a~c) and summer (d~f)

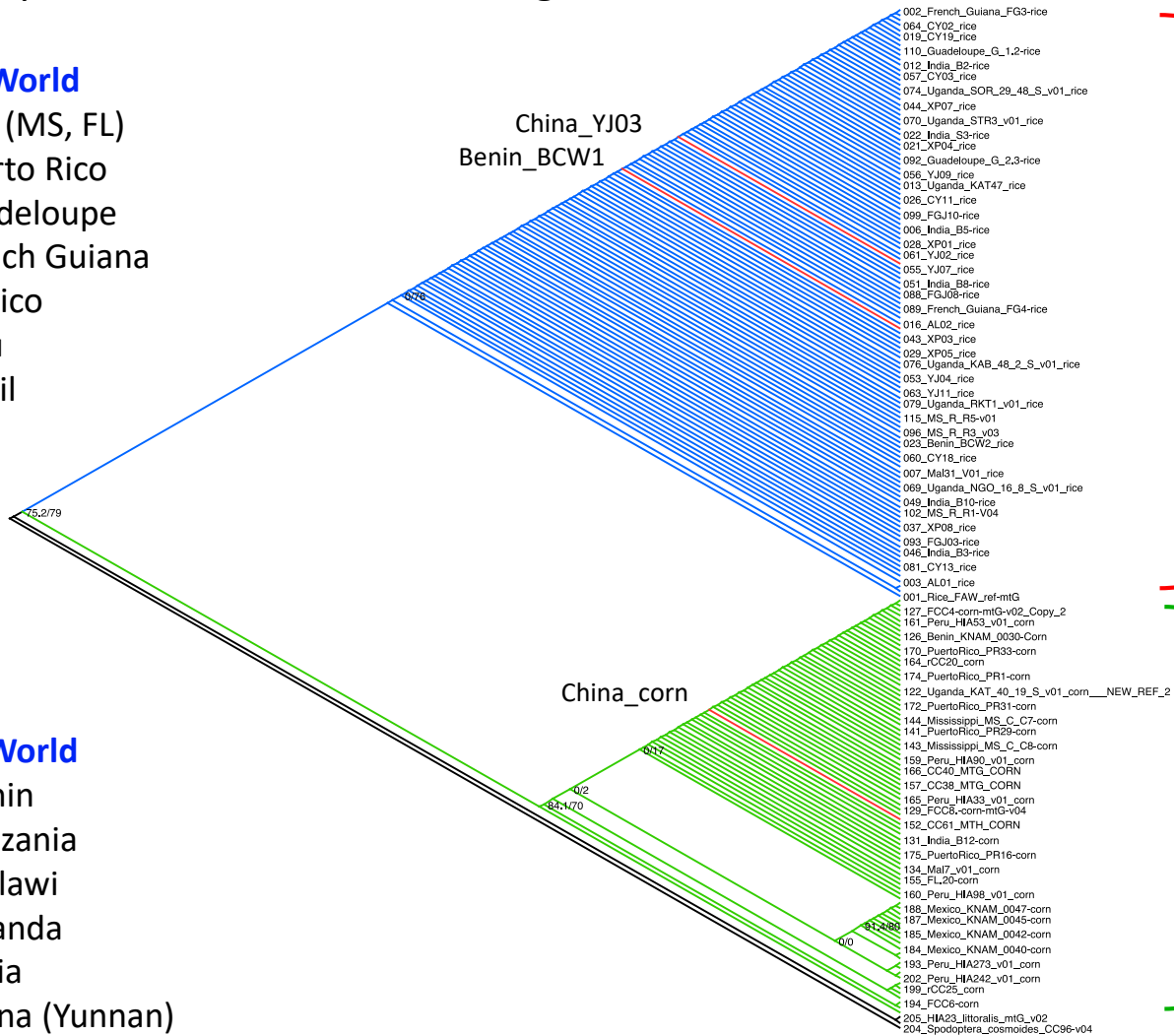
638bp standard mtCOI barcode gene

New World

- USA (MS, FL)
- Puerto Rico
- Guadeloupe
- French Guiana
- Mexico
- Peru
- Brazil

Old World

- Benin
- Tanzania
- Malawi
- Uganda
- India
- China (Yunnan)



• Single origins for Sfc & Sfr...

Sfr

100% nucleotide identity within the major clade

All invasive + New World populations

Sfc

100% nucleotide identity within the major clade

All invasive + New World (excludes MEX) populations

Despite extensive sampling of native populations, failed to ascertain source populations!



Population origins?

Global populations whole genome sequenced

- USA (MS, FL)
- Puerto Rico, Guadeloupe
- Brazil, Peru, Mexico, French Guiana
- E. Africa (Tz, Ug, Mw)
- W. Africa (Benin)
- India
- China

Sfr: N = 120

Sfc: N = 84

S. eridania

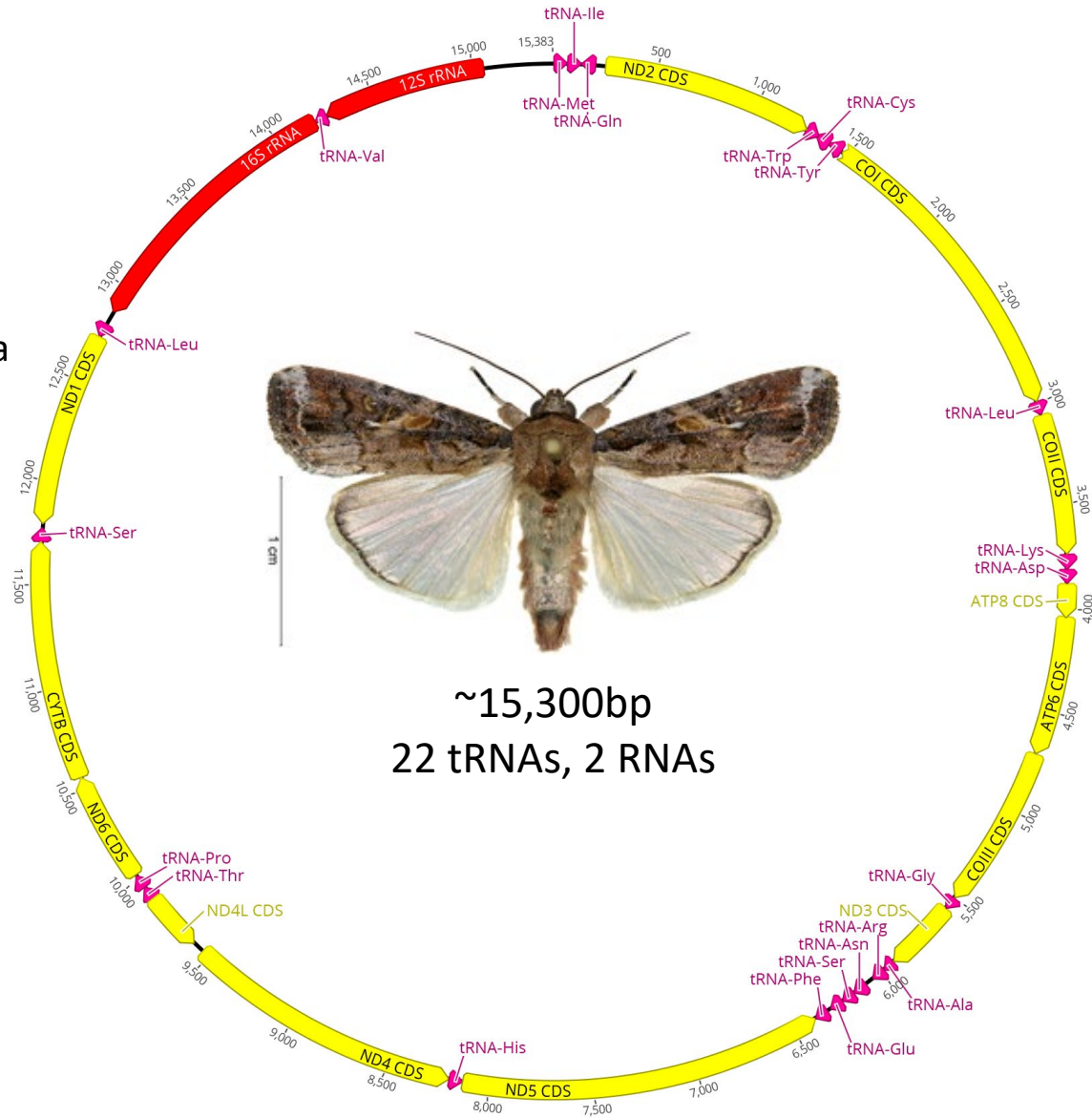
S. litura

S. littoralis

~ 3.16 Mbp

• Missing:

- SE Asia, Japan, South Korea
- West Africa
- South Africa
- Middle East





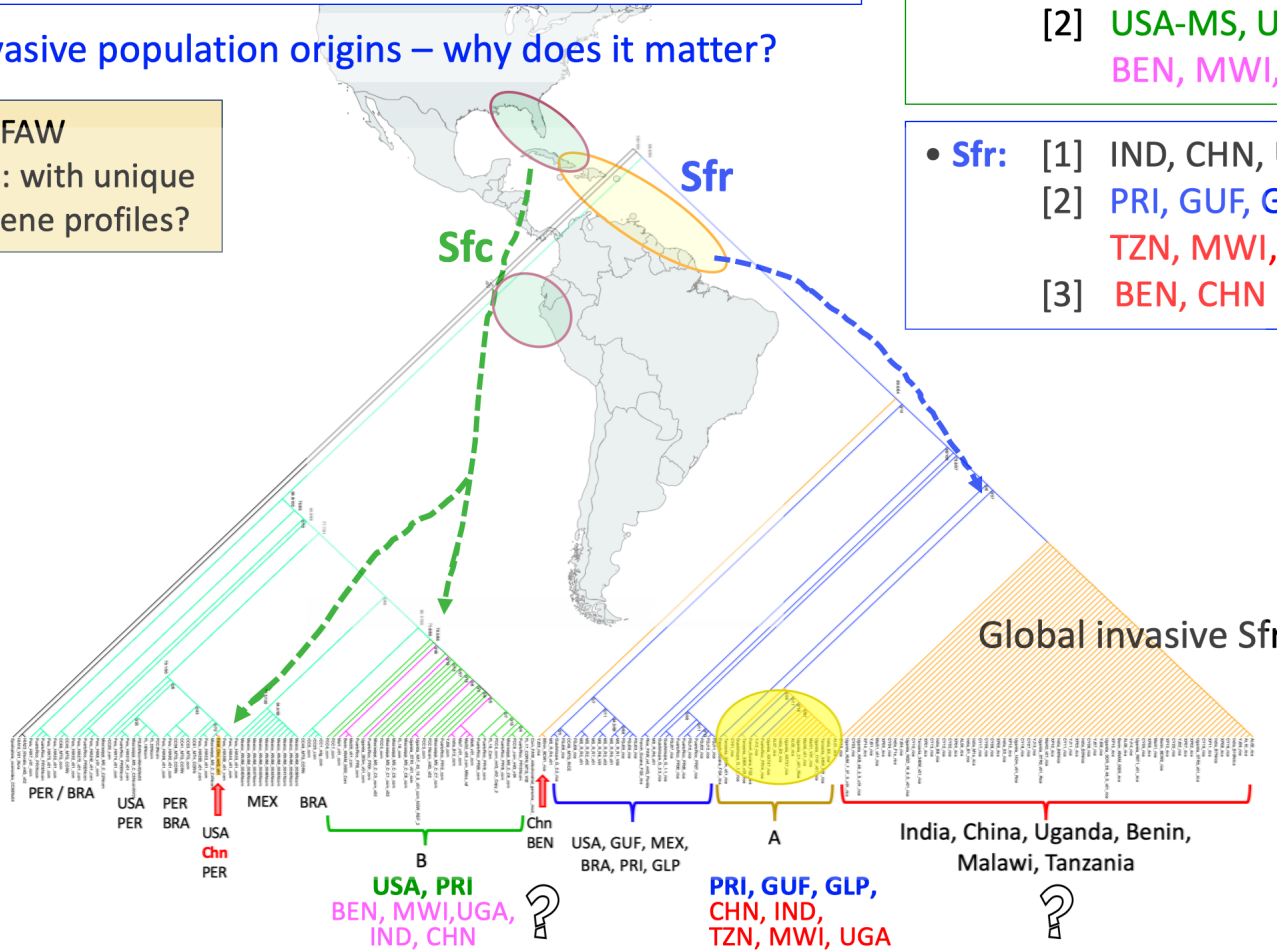
Going global – genomic insights into insect invasions

Wee Tek Tay and Karl Heinrich Julius Gordon



Tracing Invasive population origins – why does it matter?

New World FAW populations: with unique resistance gene profiles?



Evidence of multiple introductions:

- **Sfc:** [1] USA-MS, CHN, PER
[2] USA-MS, USA-FL, PRI, BEN, MWI, UGA, IND, CHN

- **Sfr:** [1] IND, CHN, UGA, BEN, MWI, TNZ
[2] PRI, GUF, GLP, TZN, MWI, UGA, IND, CHN
[3] BEN, CHN

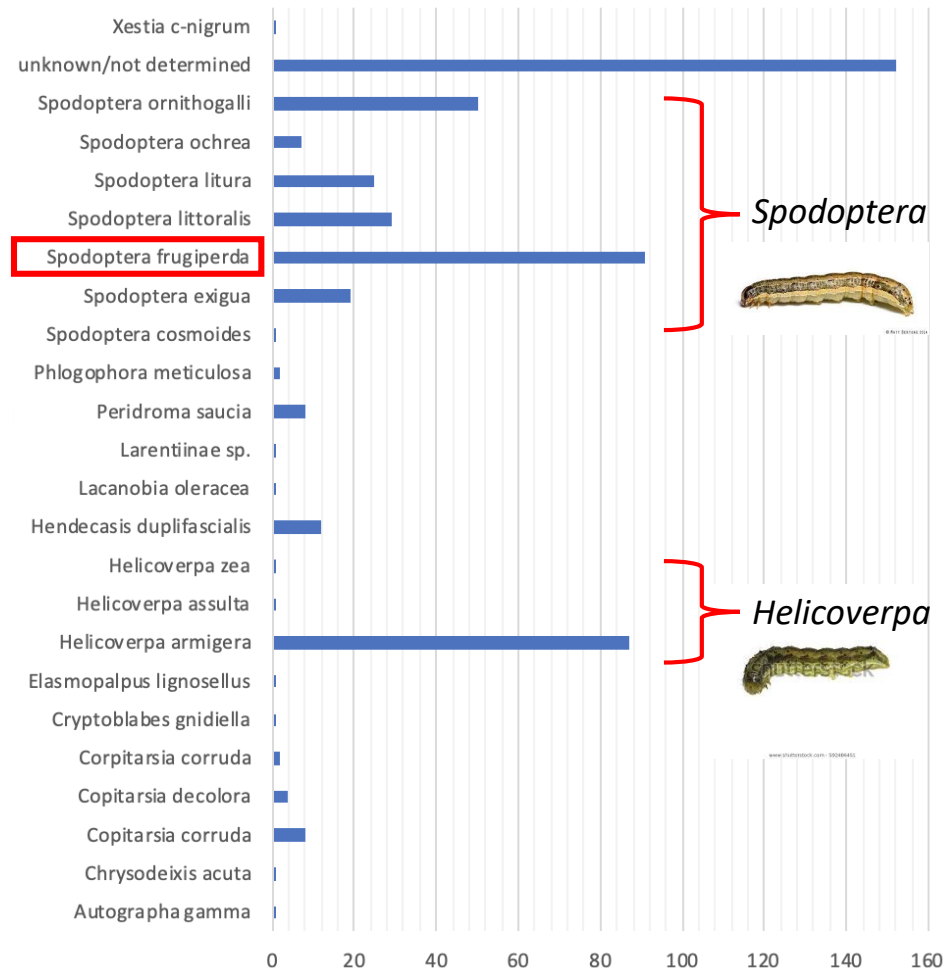


Australia pre-border interceptions (2016 – 2019)

Region	<i>Helicoverpa</i>	<i>Spodoptera</i>	others
Asia	38	46	48
Oceania	0	3	2
Africa	40	16	45
North America	0	1	0
South America	9	155	93
Europe	2	1	7
total	89	222 *	195

- FAW + other *Spodoptera* spp. intercepted
- FAW intercepted (Africa, Asia, Sth America)
- Cut flowers, fresh vegetables

total detection of invasive lepidopteran species





Risks to Australia's agriculture sector?

Where does Australia import Cut Flowers from? (2017)

TOTAL: \$66.1M



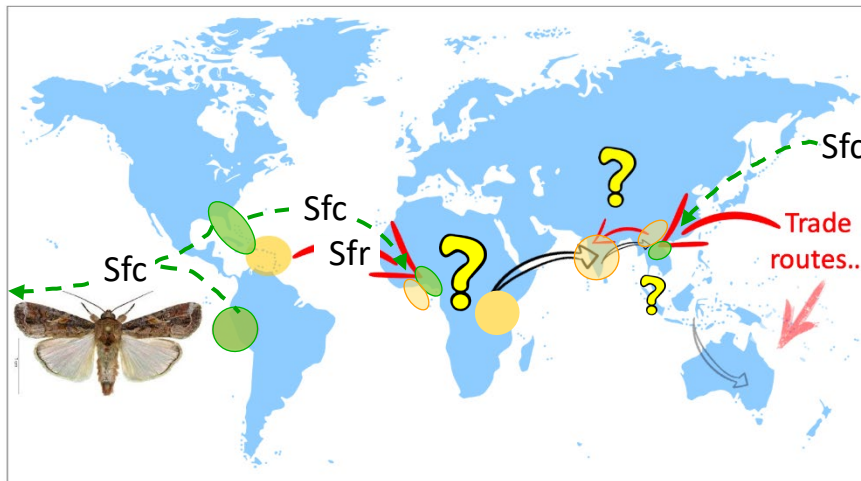
- Singapore
- Israel
- Malaysia
- South Korea
- Japan
- Hong Kong
- Nepal
- India
- Thailand
- Vietnam
- China
- Kenya
- South Africa
- Mauritius
- Ethiopia
- Ecuador
- Colombia

91.85%



May be... Out of Africa & East meets West?

- High genetic diversity in African FAW: ≥ 8 maternal lineages
- Multiple introduction pathways into the Old World: human-assisted / international trade
- Spread across the Old World: Human-assisted / natural migration?



? Implications on pest management strategies, esp. in S.E.A.

- *S. eridania*
- *S. orcha*
- *S. cosmoides*
- *S. ornithogalli*
- *S. marima*
etc!!

- Multiple New World origins for Sfc and Sfr
- 'African origin' theory + 'Myanmar source pop' to China ...
Unresolved by mitogenomes; genome-wide SNPs evidence needed!

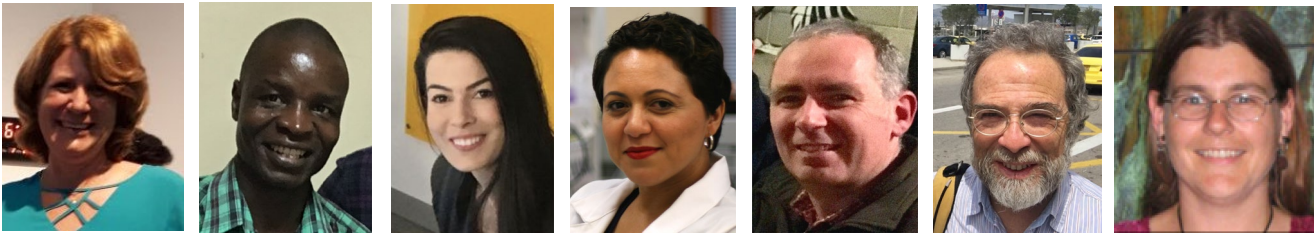
Key Message: Global population genomics and trade pathway analyses needed to understand gene flow patterns and predict future pest spread.

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