Food and Agriculture Organization of the United Nations

International Plant Protection Convention

中国农业大学 China Agricultural University

Prevention and Control of Economically Important Fruit Flies in China

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FAO-IPPC Global Project, Sri Lanka, December 16, 2019.

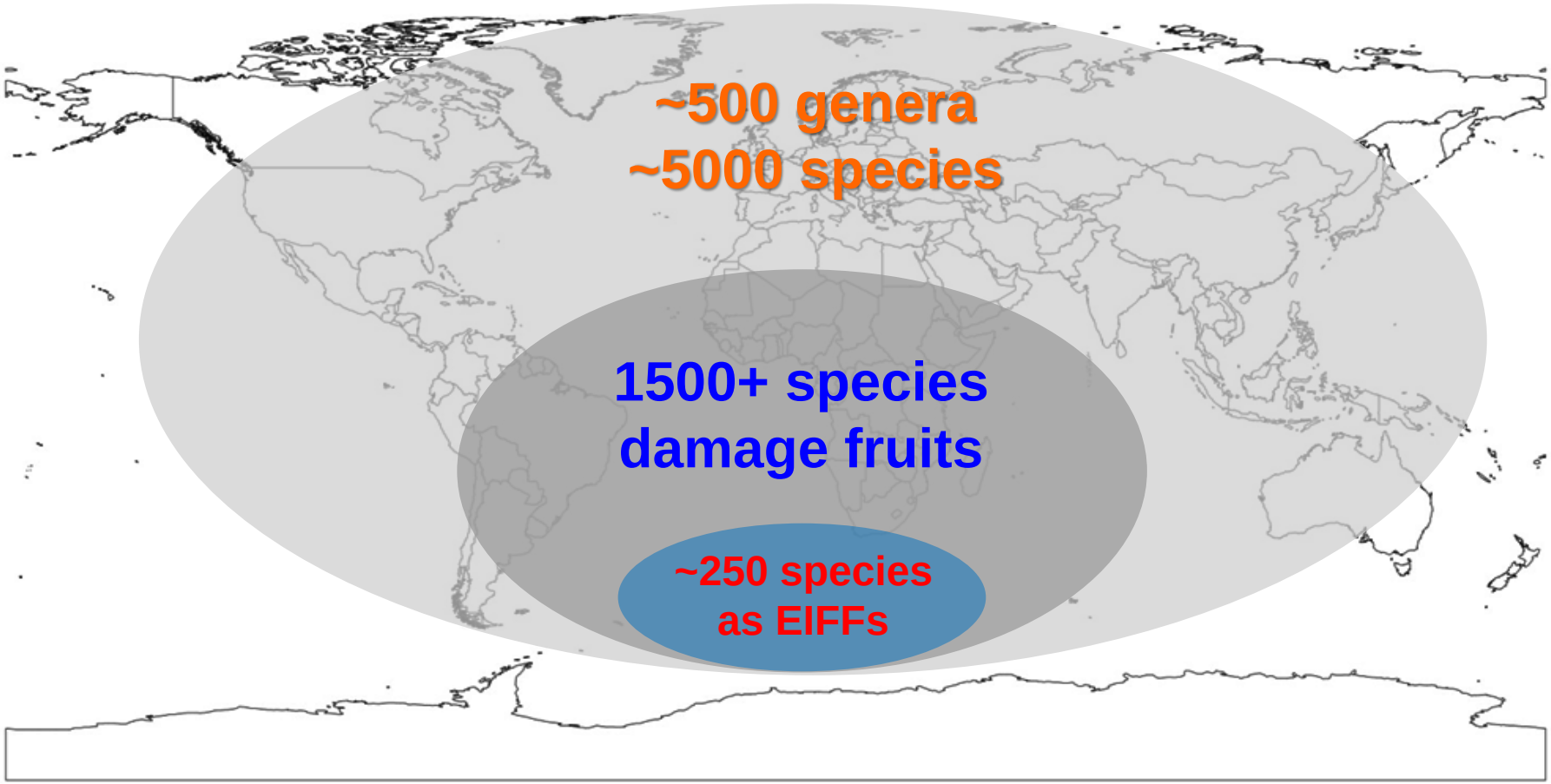
Outline

- The general situation of prevention and control of EIFFs
- The education, research and services on EIFFs in China: CAU as an example
- The challenges, opportunities and prospects of prevention and control of EIFFs

Ⅰ. The general situation of prevention and control of EIFFs

1.1 The basic information of EIFFS in the world

- In the trends of economic globalization and integration, **EIFFs are spread more quickly and widely in the world**, which are causing significant economic and biological losing of fruits.
- **China pays more attention on the prevention and control of EIFFs.**



The revision of taxonomic status of *Zeugodacus:*

from subgenus of Bactrocera to genus Zeugodacus, e.g., Z. cucurbitae，Z. tau，Z. scutellatus, Z. depressus etc..

Molecular Phylogenetics and Evolution 64 (2012) 513–523

Contents lists available at SciVerse ScienceDirect

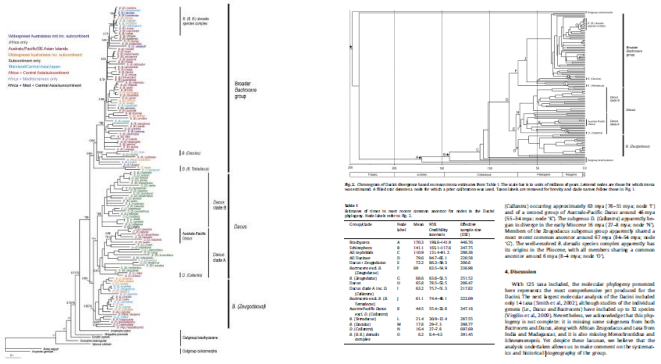
Molecular Phylogenetics and Evolution

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

A molecular phylogeny for the Tribe Dacini (Diptera: Tephritidae): Systematic and biogeographic implications

Matthew N. Krosch [a,*], Mark K. Schutze [a,b], Karen F. Armstrong [c], Glenn C. Graham [d], David K. Yeates [e], Anthony R. Clarke [a,b]

[a] School of Earth, Environment and Biological Sciences, Science and Engineering Faculty, Queensland University of Technology, GPO Box 2434, Brisbane 4000, Queensland, Australia
[b] CRC for National Plant Biosecurity, LPO Box 5012, Bruce 2617, ACT, Australia
[c] Bio-Protection Research Centre, PO Box 84, Lincoln University, Canterbury, New Zealand
[d] Centre for Identification and Diagnostics, School of Life Sciences, The University of Queensland, Brisbane 4072, Queensland, Australia
[e] CSIRO Ecosystem Sciences, PO Box 1700, Canberra 2601, ACT, Australia



(Krosch *et al*., 2012)

ZooKeys 730: 19–56 (2018)
doi: 10.3897/zookeys.730.21786
http://zookeys.pensoft.net

CHECKLIST

A peer-reviewed open-access journal
ZooKeys
Launched to accelerate biodiversity research

A global checklist of the 932 fruit fly species in the tribe Dacini (Diptera, Tephritidae)

Camiel Doorenweerd[1], Luc Leblanc[2], Allen L. Norrbom[3], Michael San Jose[1], Daniel Rubinoff[1]

1 *University of Hawaii, Department of Plant and Environmental Protection Services, 3050 Maile Way, Honolulu, Hawaii, 96822-2231, USA* 2 *University of Idaho, Department of Entomology, Plant Pathology and Nematology, 875 Perimeter Drive, MS2329, Moscow, Idaho, 83844-2329, USA* 3 *Systematic Entomology Laboratory, ARS, USDA, c/o Smithsonian Institution, P.O. Box 37012, MRC 168, Washington, DC 20013-7012, USA*

Corresponding author: *Camiel Doorenweerd* (camiel.doorenweerd@hawaii.edu)

Academic editor: *M. De Meyer* | Received 20 October 2017 | Accepted 14 December 2017 | Published 17 January 2018

http://zoobank.org/F1BF770B-254D-4F8F-976B-A2F53A7E4A60

Citation: Doorenweerd C, Leblanc L, Norrbom AL, Jose MS, Rubinoff D (2018) A global checklist of the 932 fruit fly species in the tribe Dacini (Diptera, Tephritidae). ZooKeys 730: 19–56. https://doi.org/10.3897/zookeys.730.21786

(Doorenweerd *et al*., 2018)

The academic controversy about species:

Are *Bactrocera papayae*, *B. invadens* and *B. philippinensis* the synonym of *B. dorsalis*?

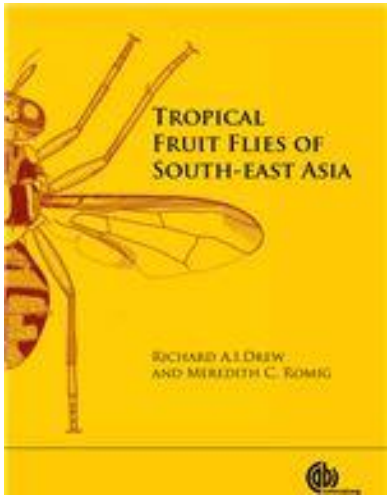
Systematic Entomology

Systematic Entomology (2015), **40**, 456–471 DOI: 10.1111/syen.12113

Synonymization of key pest species within the *Bactrocera dorsalis* species complex (Diptera: Tephritidae): taxonomic changes based on a review of 20 years of integrative morphological, molecular, cytogenetic, behavioural and chemoecological data

MARK K. SCHUTZE[1,2], NIDCHAYA AKETARAWONG[3], WEERAWAN AMORNSAK[4], KAREN F. ARMSTRONG[5], ANTONIS A. AUGUSTINOS[6,7,8], NORMAN BARR[9], WANG BO[6,7,10], KOSTAS BOURTZIS[6,7], LAURA M. BOYKIN[11], CARLOS CÁCERES[6,7], STEPHEN L. CAMERON[1], TONI A. CHAPMAN[2,12], SUKSOM CHINVINIJKUL[13], ANASTASIJA CHOMIČ[5], MARC DE MEYER[14], ELLENA DROSOPOULOU[15], ANNA ENGLEZOU[2,12], SUNDAY

(Schutze *et al*., 2015)



(Drew *et al*., 2016)

Systematic Entomology

Systematic Entomology (2017), **42**, 609–620 DOI: 10.1111/syen.12250

OPINION

Integrative taxonomy versus taxonomic authority without peer review: the case of the Oriental fruit fly, *Bactrocera dorsalis* (Tephritidae)

MARK K. SCHUTZE[1,2], KOSTAS BOURTZIS[3,4], STEPHEN L. CAMERON[5], ANTHONY R. CLARKE[1,2], MARC DE MEYER[6], ALVIN K. W. HEE[7], JORGE HENDRICHS[3,4], MATTHEW N. KROSCH[1,2] and MAULID MWATAWALA[8]

[1]School of Earth, Environmental and Biological Sciences, Queensland University of Technology, Brisbane, Australia, [2]Plant Biosecurity Cooperative Research Centre, Canberra, Australia, [3]FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Vienna, Austria, [4]FAO/IAEA Division of Nuclear Techniques in Food and Agriculture, Seibersdorf, Austria, [5]Department of Entomology, Purdue University, West Lafayette, IN, U.S.A., [6]Invertebrates Section, Royal Museum for Central Africa, Tervuren, Belgium, [7]Faculty of Science, Department of Biology, Universiti Putra Malaysia, Serdang, Malaysia and [8]Department of Crop Science and Production, Sokoine University of Agriculture, Morogoro, Tanzania

(Schutze *et al*., 2017)

The global spread of EIFFs:

Among countries and regions, e.g., B. dorsalis, spreaded from Asia to other continents, from tropical area to subtropical area and temperate area.

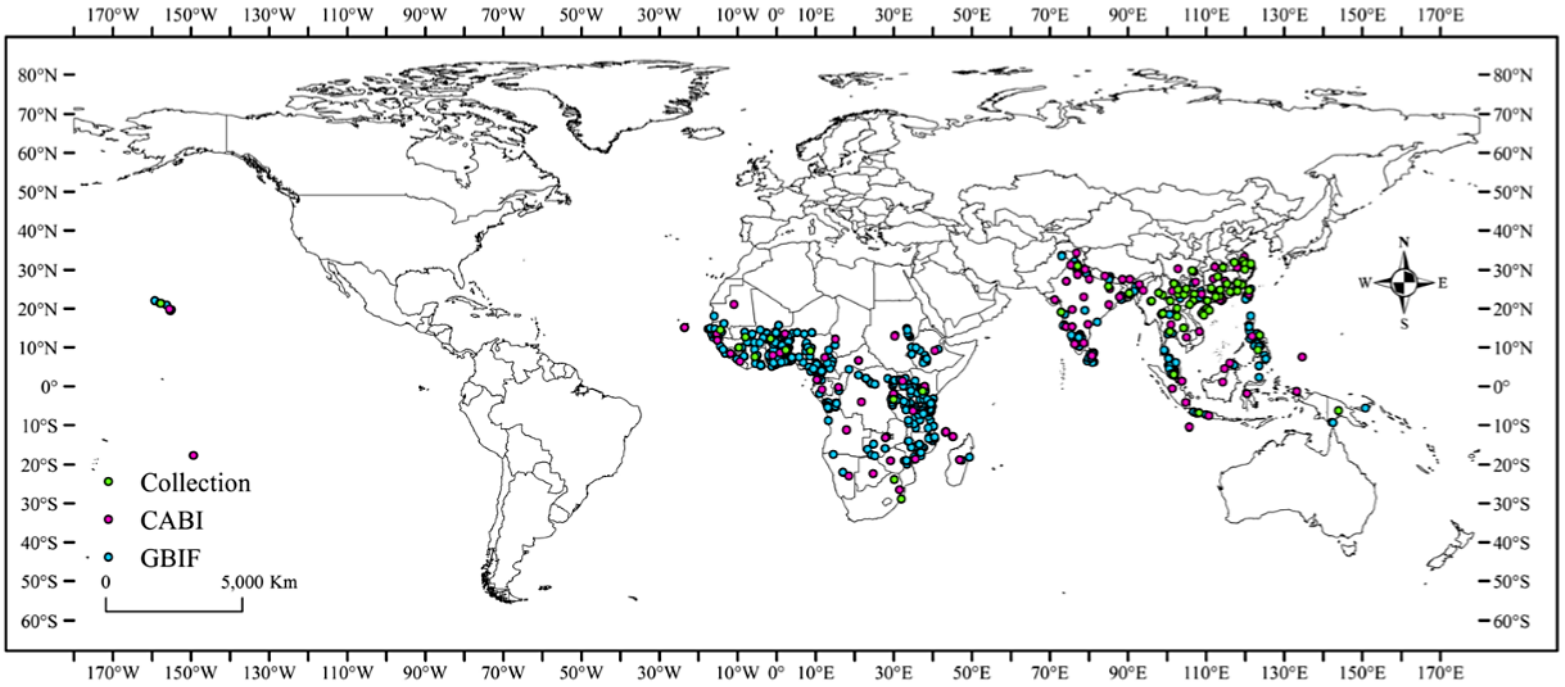


Fig. 1 Global distribution data from collection efforts (Qin et al. 2018) (*green* points), CABI (*pink* points), and GBIF (*blue* points) used to build and evaluate the MaxEnt models of *B. dorsalis*

(Qin *et al*., 2019)

Prevention and control of pests invasion:

as early as we could

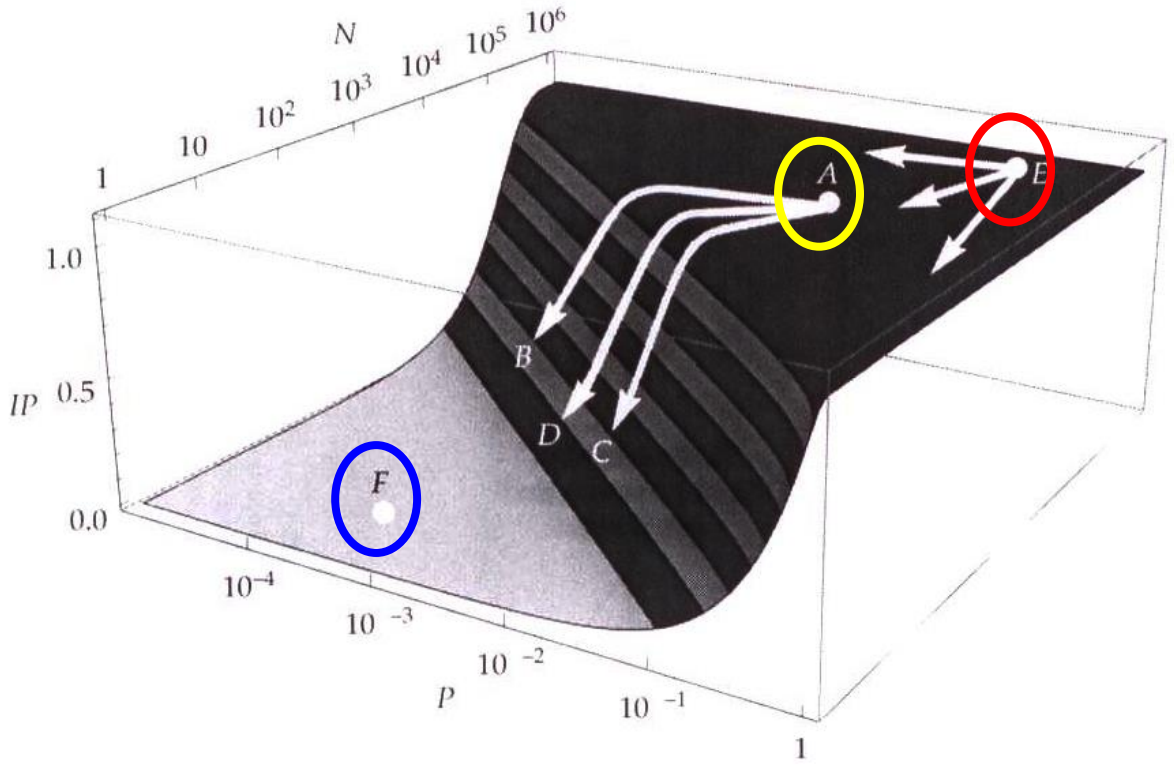


Fig. 8.1 Illustrated substantial declines in invasion pressure (*IP*) when management efforts reduce invasibility ($A \rightarrow B$), propagule pressure ($A \rightarrow C$), or both ($A \rightarrow D$). If the system begins in position *E*, comparable reductions in either or both variables will not visibly reduce invasion pressure, suggesting that the management efforts have failed. However, as shown, the efforts have moved the system much closer to the invasion cliff, making it more likely that additional management efforts may successfully push the system over the edge. If the system begins in position *F*, the purpose of any management efforts would be to prevent increases in either or both invasibility and the number of arriving propagules in order to keep the invasion pressure from increasing from the current negligible levels.

(Davis, Invasion Biology, 2009)

Prevention and control of EIFFs:

IPPC + ISPMs (especially for the surveillance, diagnosis and treatment of EIFFs)

English French Spanish Russian Arabic Chinese

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22-07-2019
Call for Abstracts: IPPC International Symposium for Pest Free Areas and Surveillance - DEADLINE EXTENDED

Resources & Tools
Phyto Resources website
Phytosanitary Capacity Evaluation (PCE)
Online Comment System (OCS)

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Phytosanitary treatment options for plant health: the IPPC Technical Pane on Phytosanitary Treatments meeting

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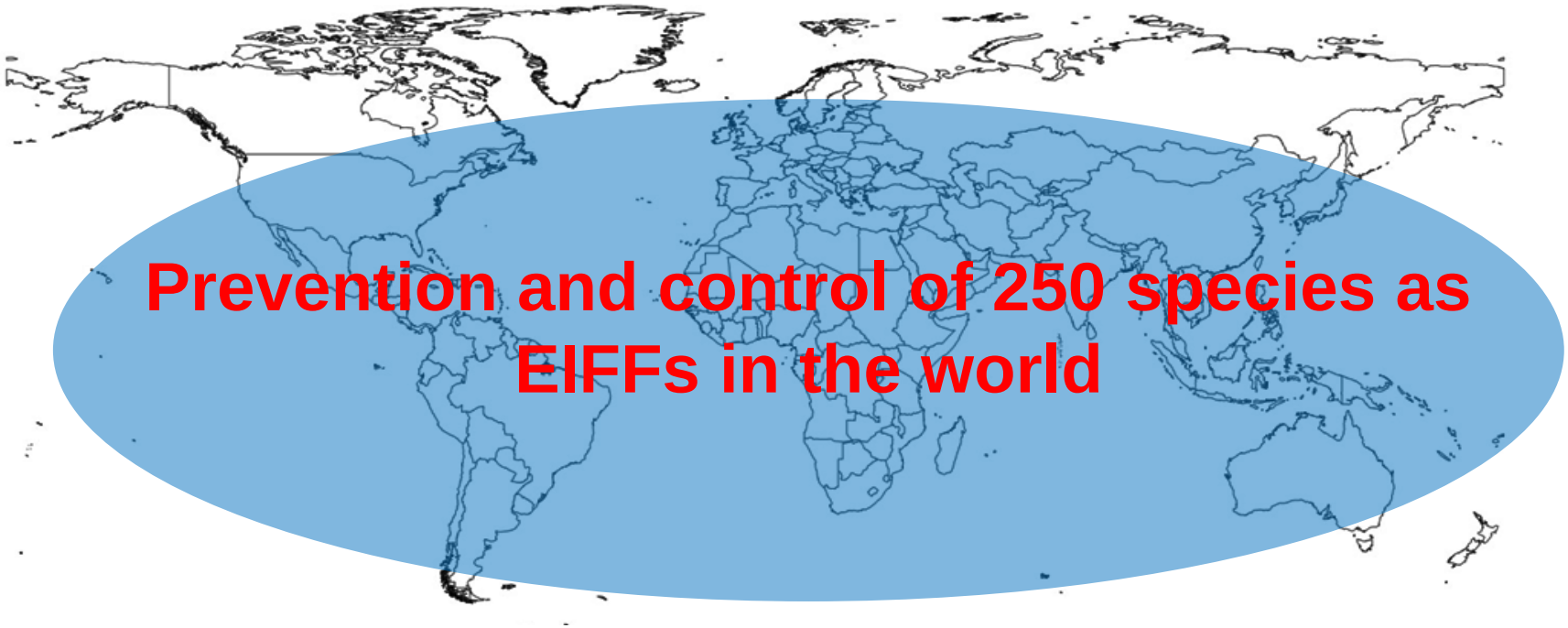
17-07-2019 New publication: IYPH get started
09-07-2019 The presentations for the 2019 IPPC Regional Workshops are now posted!
03-07-2019 Draft Ministerial declaration for CPM-15 open for comments
01-07-2019 The first consultation period on the CPM Recommendation for Safe provision of food and other aid is now open!
01-07-2019 The 2019 consultation period on draft ISPMs has opened today, 01 July 2019!
28-06-2019 The report of the 2019 meeting of the Standards Committee Working group (SC-7) is now posted!
24-06-2019 The report of the IC May 2019 meeting is posted
21-06-2019 The Report of the first meeting of the IYPH ISC is now online
18-06-2019 VACANCY ANNOUNCEMENT(Job Description – Public Information Specialist)
14-06-2019 Workbook developed by NAPPO and partners estimates sample sizes based on Risk-Based Sampling

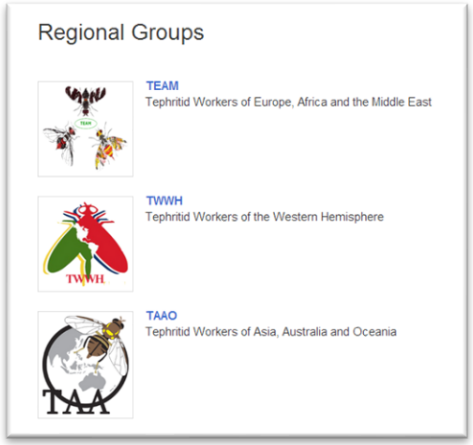
(https://www.ippc.int/, 2019)



- ***Bactrocera***：Asia, Oceania and Africa
- ***Zeugodacus***：Asia and Oceania
- ***Ceratitis***：Africa and Europe
- ***Dacus***：Africa
- ***Anastrepha***：America
- ***Rhagoletis***：Europe and America

Prevention and control of EIFFs:

IAEA + Regional group of EIFFs (especially TAAO etc.)



https://www.iaea.org/

IAEA | NAIPC Nuclear Applications for Insect Pest Control

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TAAO

TAAO

Tephritid workers of Asia, Australia and Oceania

TAA

About Us

Welcome to the TAAO!

Tephritid fruit flies are among the world's most destructive horticultural pests, infesting a wide range of fruit and impacting on regional quarantine, trade, and food security. They are also an incredibly diverse group of insects and the subject of fundamental research into biodiversity, evolution, and general biology.

The Asian, Australian, and Oceanic region is a centre of tephritid diversity, particularly of genus *Bactrocera* which contains over 500 species; and regional horticulture is seriously affected by pests such as the Oriental Fruit Fly *(B. dorsalis)*, the Melon Fly (*B. cucurbitae*), and the Guava Fruit Fly (*B. correcta*) to name just a few.

TheFir 'Tephritid workers of Asia, Australia, and Oceania' (TAAO) was

https://nucleus.iaea.org/sites/naipc/twd/Pages/default.aspx

The composition of the **TAAO Steering Committee (February 2016)**:

Members of the TAAO SC. Top row L-R: **Mark Schutze**, TAAO chair (australia), **Alvin Hee** as Organizing Committee Chair for the First TAAO Symposium (Malaysia 2016) (Malaysia), **Zhihong Li** (China), **Tati Suryati Syamsudin** (Indonesia), **Sujinda Thanaphum** (Thailand), **Suksom Chinvinijkul** (Thailand). Bottom row L-R: **Suk Ling Wee** (Malaysia), **Kenji Tsuruta** (Japan), **Bonifacio Cayabyab** (Philippines), **Sandeep Singh** (India), **Phil Taylor** (Australia), **Annastasia Priscilla Kawi** (Papua New Guinea).

https://nucleus.iaea.org/sites/naipc/twd/Pages/default.aspx

1.2 The plant quarantine and field control of EIFFS in China

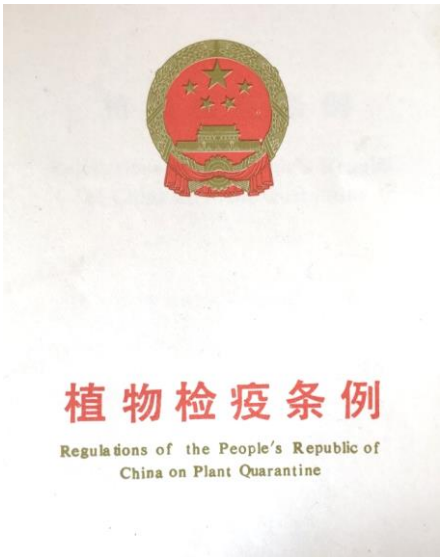
Main regulations:

- Law of the People's Republic of China on the Entry and Exit Animal and Plant Quarantine: 1991.
- Regulations of the People‘s Republic of China on Plant Quarantine: 1983.
- Lists of quarantine pests:

✓ For entry, 2007.

✓ For domestic agriculture, 2009.

✓ For domestic forestry, 2013.

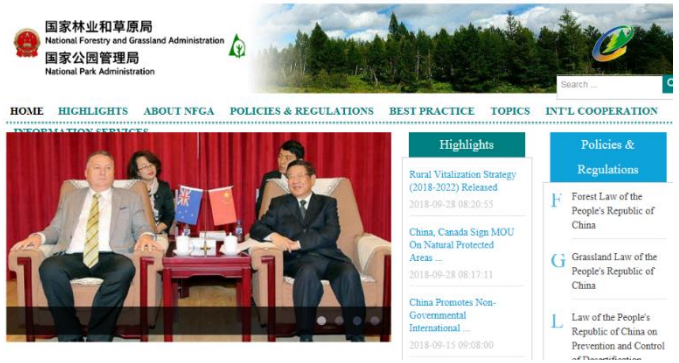


Main Organizations of Management:

- **GACC:** General Administration of Customs, P. R. China. For entry and exit quarantine.
- **MARA:** Ministry of Agriculture and Rural Affairs, P. R. China. For domestic agricultural quarantine.
- **MEE-NFGA:** National Forestry and Grassland Administration, Ministry of Ecology and Environment, P. R. China. For domestic forestry quarantine.

(http://english.customs.gov.cn/)

(http://english.agri.gov.cn/)



(http://english.forestry.gov.cn/)

Main Organizations of E/R/S:

- **Technical Centers of Customs CAIQ** (Chinese Academy of Inspection and Quarantine)
- **NATESC** (National Agro-technical Extension and Service Center) and branches in provinces
- **CAAS** (Chinese Academy of Agricultural Sciences) and the academies of agricultural sciences in provinces
- **CAF** (Chinese Academy of Forestry Science) and the academies of forestry sciences in provinces
- **CAU** (China Agricultural University) **and other Universities**

The quarantine EIFFs in China:

Import quarantine FFs: 6 genera + 5 species, 2007

- *Anastrepha*
- *Bactrocera*
- *Zeugodacus*
- *Ceratitis*
- *Dacus* spp. (non-Chinese)
- *Rhagoletis* spp. (non-Chinese)
- *Carpomya incompleta*
- *Carpomya vesuviana*
- *Monacrostichus citricola*
- *Myiopardalis pardalina*
- *Toxotrypana curvicauda*

Export regulated FFs: 2 genera

- *Bactrocera*
- *Zeugodacus*

Domestic quarantine FF of agriculture: 1 species, 2009

- *Bactrocera tsuneonis*

Domestic quarantine FF of forestry: 1 species, 2013

- *Carpomya vesuviana*

The main EIFFs of field control in China:

Main EIFFs in field: 4 species

- *Bactrocera dorsalis*
- *Bactrocera minax*
- *Zeugodacus cucurbitae*
- *Zeugodacus tau*

- *Bactrocera dorsalis*

- *Bactrocera minax*

Field control strategy of EIFFs in China

(provided by NATESC)

Prevention and Control of EIFFs

- **Official Control**
- **Education, Research and Services**
- **Public Participation**

Governments

Universities & Institutes

Companies etc.

Farmers, citizens etc.

Ⅱ. The education, research and service on EIFFs in China: CAU as an example

2.1 The Four-in-ONE Education System of Plant Quarantine in China

The origin of phytosanitary education system

- **The professional education of plant protection in China:** has a history dated back **1905**, courses of Plant Pathology and Entomology were opened in the College of Agriculture at Imperial University of Peking.

Group photo of teachers and students in the College of Agriculture (**The first graduates in 1913**)

Group photo of the graduates in the College of Agriculture (**1916**)

Establishment of the Department of Pest and Disease(**1923**)

(Photos cited from internet)

Dr. Bingwen ZOU

Dr. Fengmei ZHU

(Photos cited from internet)

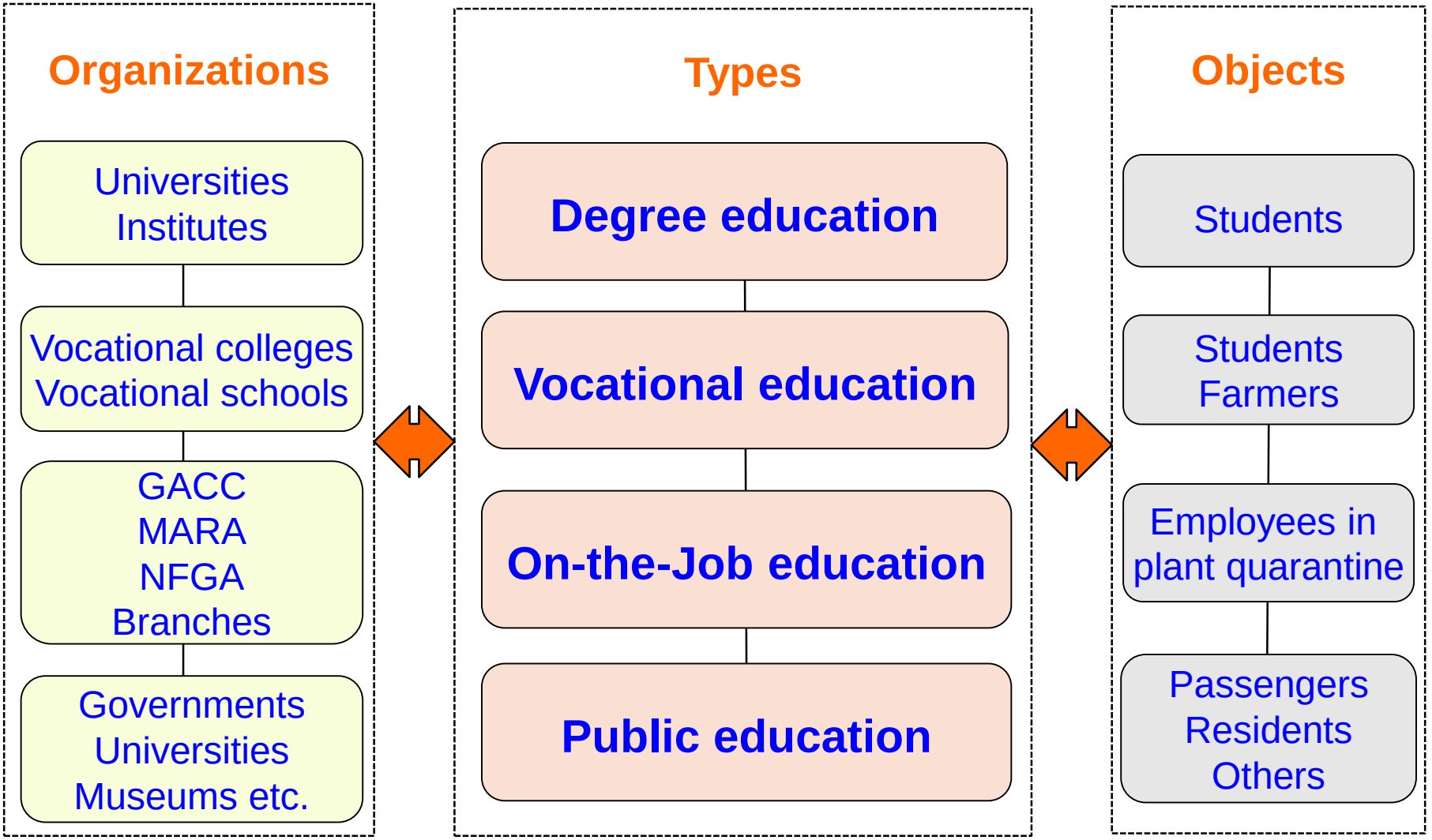
- **The earliest suggestion of plant quarantine in China:** in **1916** by Dr. Bingwen ZOU. He emphasized **the importance of plant quarantine**.

- **The first paper named as plant quarantine in China:** in **1927** by Dr. Fengmei ZHU. These papers emphasized the significance and basic methods of plant quarantine, including **the import quarantine and export quarantine**.

- **From 2001,** as one member of WTO, China has faced more challenges from the **global market** and the international regulations.
- **In the trends of economic globalization and integration, pests are spread more quickly and widely in the world**, which are causing significant economic and biological losing of plants and plant products.
- **China pays high attention to the phytosanitary education** through **Four-in-One system**.


(Photos provided by quarantine officers in China)

The Four-in-One Education System



Public education: governments and universities mainly

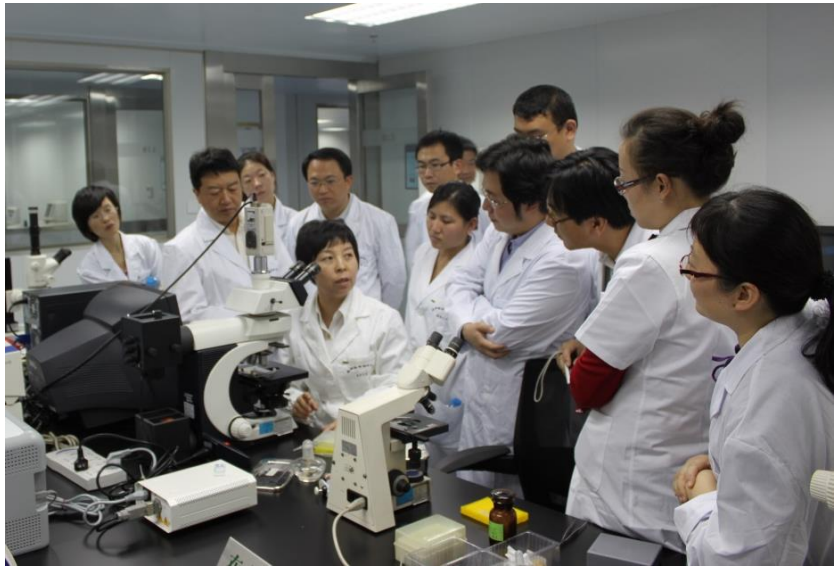
- Passengers, regular program.
- Residents and other publics, periodical program.

The public phytosanitary education in China: phytosanitary regulations, phytosanitary procedures and quarantine pests

(Photos in 2017-2019, provided by plant quarantine workers in China)

On-the-job education: GACC, MARA, NFGA mainly

- Civil servants of plant quarantine, periodical program.
- Technicians of plant quarantine, periodical program.



The on-the-job phytosanitary education in China:
national and regional technical training of plant quarantine

(Photos cited from the related news of plant quarantine on internet)

Vocational education: colleges and schools mainly

- Junior college students, 3-year program.
- Farmers, periodical program.

The farmer education in China: plant quarantine and IPM techniques

http://www.crdenet.net.cn/

Degree education: 50+ universities and institutes

- Undergraduates, 4-year program, Bachelor D.
- Postgraduates, 2-year / 3-year programs, Master D.
- Postgraduates, 3-year / 4-year / 5-year programs, PhD.

The degree education of plant protection in China: script, thesis, and dissertation.

China Agricultural University

- **US News & World Report (2018):** Agricultural Sciences, the 4th university
- **MOE China (2017):** First-class university and 9 Top disciplines (including Plant Protection)

College of Agriculture at Imperial University of Peking

(predecessor of Peking University)

1905

Beijing Agricultural University

Merged by

- College of Agriculture of Peking University
- College of Agriculture of Tsinghua University
- College of Agriculture of North China University

1949

China Agricultural University

Merged by

- Beijing Agricultural University
- Beijing Agricultural Engineering University

1995

中國農業大學

The main organizations on EIFFs in China

Main Universities: 7 universities

- ✓ China Agricultural University (CAU), Prof. Zhihong Li etc.
- ✓ Fujian Agriculture and Forestry University (FAFU), Prof.Qinge Ji etc.
- ✓ Huazhong Agricultural University (HZAU), Prof. Changying Niu and Prof. Hongyu Zhang etc.
- ✓ South China Agricultural University (SCAU), Prof. Yongyue Lu etc.
- ✓ Southwest University (SWU), Prof. Jinjun Wang etc.
- ✓ Xinjiang Agricultural University (XJAU), Prof. Adili Shataer etc.
- ✓ Yunnan Agricultural University (YNAU), Prof. Chun Xiao etc.

Main Institutes: 5 institutes

- ✓ Technology Center of Guangzhou Customs, Dr. Jiajiao Wu etc.
- ✓ Technology Center of Shenzhen Customs, Dr. Daojian Yu etc.
- ✓ China Academy of Inspection and Quarantine (CAIQ), Mr. Yuejin Wang and Mr. Guoping Zhan etc.
- ✓ China Academy of Science (CAS), Dr. Xiaolin Chen etc.
- ✓ China Academy of Agricultural Science (CAAS), Prof. Guifen Zhang etc.

2.2 The Practices of Education, Research and Services on EIFFs in CAU

The Development of CAUPQL

- **From 2001 to now:** Laboratory of plant quarantine and invasion biology (CAUPQL), leading by Dr. Zhihong Li.
- **From 2004 to now:** Direction of plant quarantine and invasion biology leading by Dr. Zhihong Li, especially the education of postgraduates.

The Missions of CAUPQL

- **Education:** training the undergraduates and postgraduates with advanced theory, method and technology of plant quarantine and invasion biology.
- **Research:** studying the techniques, measures and mechanism of prevention and control of quarantine pests and invasive alien species.
- **Service:** providing the technical guidance, decision supports and outstanding professionals of plant quarantine and invasive alien species management to government and other organizations.

The Team of CAUPQL

Prof.: Dr. Zhihong Li

Associate Prof.: Dr. Zhihua Zhao, Dr. Lijun Liu, Dr. Yujia Qin

Visiting Prof.: Prof. Shuifang Zhu, Prof. Guoping Zhan, Prof. Yucheng Sun, Dr. Xubin Pan, Dr. Fenfen Kang and Dr. Wei Fu

PhD Students

- Shuhua Wei
- Shiqian Feng
- Shibly Noman
- Wenjie Xu
- Yan Fang
- Yue Zhang
- Xiaoliang Wang
- Chaonan Wang
- Chunmeng Huang
- Xiaoxue Wang
- Hao Li
- Yan Zhao
- Farman Ullah
- Junxia Shi

Direction: Plant Quarantine & Invasion Biology

- *Regulated Pests*
- *Potential Regulated Pests*
- *Invasive Alien Species*

Invasion Tracing & Mechanism

Phytosanitary Identification & Treatment

Invasion Model & Pest Risk Analysis

Master Degree Students

- Delin Kang, Yun Su, Sultana Afroz, Yannan Wang, Yu Zhang, Shuai Lan, Zijiao Song, Yuguang Li, Xiao Liu
- Qingyiing Zhao, Jiahui Tong, Lin Wang, Xiaotian Zhang
- Lingyu Zeng, Wenzhao Yang, Linyu Zheng, Yidan Wang, Tao Sun, Yuzhou Xie, Mingdi Liu, Yijun Zhao, Danyang Li, Chang Hao

Biological Technology **Information Technology**

Sample collecting and rearing tech., Basic biological tech., Molecular tech., Bioinformatic tech., Big Data tech. etc.

The Education and Research of CAUPQL

The phytosanitary education and research in CAU:

more practices on course, thesis/dissertation, and research program.

The Courses of CAUPQL

- Plant Quarantine: 32 hours, required course for undergraduates
- Outline of Animal and Plant Quarantine: 32 hours, elective course for undergraduates
- Invasion Biology: 32 hours, elective course for undergraduates
- Principles and Techniques of Plant Quarantine: 32 hours, elective course for postgraduates
- Invasion Biology: 32 hours, in English, elective course for postgraduates
- Professional English and Scientific Writing : 16 hours, required course for postgraduates

The Graduates of CAUPQL

- from 2001-2019, 85 Bachelors
- from 2005-2019, 73 Masters
- from 2007-2019, 25 PhDs

Most of **183 graduates** are working in the fields of plant protection, including the plant quarantine.

The main researches of EIFFs in CAU

- Invasion model and Pest Risk Analysis: quantitative assessment, e.g., R language, SOM+MatLab, CLIMEX/MaxEnt/Biomodel+ArcGIS, and @Risk etc.
- Species diagnosis: phylogenetic relationship and molecular identification, e.g. mitochondrial genome analysis, DNA barcoding, PCR, Real-time PCR, chip and etc.
- Phytosanitary treatment: methyl bromide alternative, e.g., cold treatment and irradiation treatment etc.
- Invasion tracing: population genetic structure and stable isotope analysis, e.g., sequence analysis, SSR, and hydrogen stable isotope.
- Invasion mechanism: molecular mechanism, e.g., transcriptome sequencing, real-time PCR, RNAi etc.

Invasion model and PRA: integrated technical system

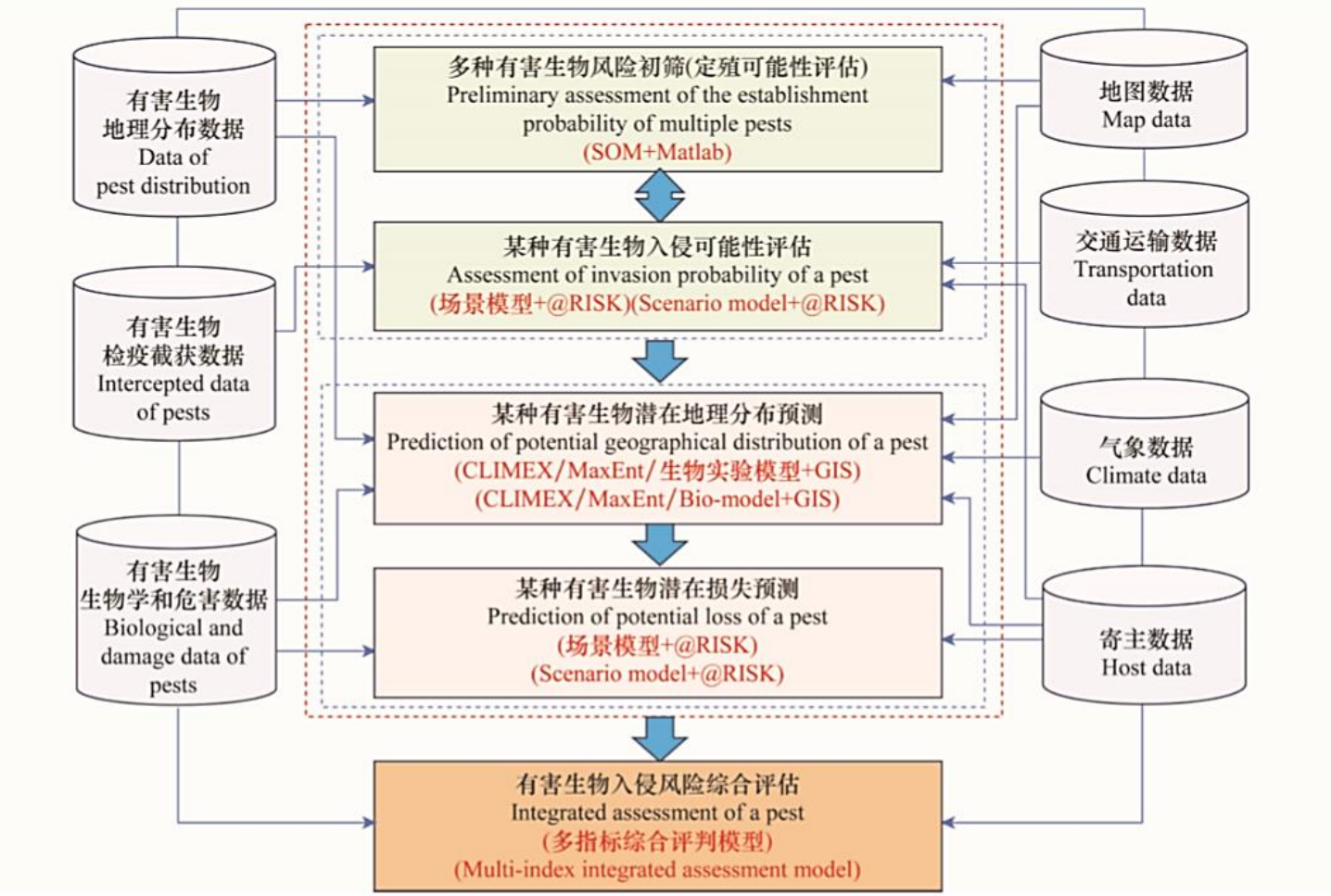


图 1　有害生物风险分析定量评估集成技术体系

Fig. 1　The integrated technical system of quantitative risk assessment of PRA

(Li et al. Plant Protection (in Chinese), 2018)

- **Invasion model and PRA:** SOM+MatLab, establishment risk of 180 species of EIFFs for 118 countries/regions.

Global Establishment Risk of Economically Important Fruit Fly Species (Tephritidae)

Yujia Qin[1], Dean R. Paini[2]*, Cong Wang[1], Yan Fang[1], Zhihong Li[1]*

1 Department of Entomology, College of Agronomy and Biotechnology, China Agricultural University, B
P. R. China, 2 CSIRO Biosecurity Flagship, Canberra, Australia

Table 1. Numbers of fruit fly species in each continent (except for the Antarctic).

	Anastrepha	*Bactrocera*	*Ceratitis*	*Dacus*	*Rhagoletis*	others	Total
Asia	0	33	2	8	2	15	60
Africa	0	5	12	14	0	13	44
North America[a]	26	5	1	0	15	7	55
South America	36	0	1	0	6	1	44
Europe	0	1	1	0	4	5	11
Oceania	0	25	1	3	0	3	32
world	44	51	12	19	22	32	180

Table 2. Top ten ranked fruit fly species by establishment index for six countries. Only those species currently absent from a country and a known pest of a host commercially grown in that country were included (for full list see S1 Table).

China	SOM Index	South Africa	SOM Index	The United States	SOM Index
Bactrocera albistrigata	0.58	*Bactrocera cucurbitae*	0.55	*Anastrepha obliqua*	0.83
Bactrocera carambolae	0.48	*Dacus momordicae*	0.41	*Anastrepha striata*	0.79
Bactrocera umbrosa	0.48	*Ceratitis anonae*	0.39	*Anastrepha bezzii*	0.60
Bactrocera zonata	0.40	*Acanthiophilus helianthi*	0.21	*Anastrepha pickeli*	0.58
Bactrocera papayae	0.37	*Dacus telfaireae*	0.20	*Anastrepha antunesi*	0.52
Adrama determinata	0.37	*Dacus humeralis*	0.20	*Anastrepha grandis*	0.51
Bactrocera arecae	0.29	*Bactrocera latifrons*	0.11	*Anastrepha leptozona*	0.50
Monacrostichus citricola	0.29	*Dacus vansomereni*	0.10	*Anastrepha macrura*	0.45
Ceratitis capitata	0.20	*Bactrocera zonata*	0.09	*Anastrepha sororcula*	0.45
Bactrocera musae	0.19	*Ceratitis malgassa*	0.08	*Anastrepha rheediae*	0.38
Argentina	**SOM Index**	**Italy**	**SOM Index**	**Australia**	**SOM Index**
Anastrepha obliqua	0.74	*Rhagoletis cingulata*	0.30	*Bactrocera latifrons*	0.75
Anastrepha serpentina	0.69	*Carpomya pardalina*	0.21	*Bactrocera tau*	0.72
Anastrepha striata	0.65	*Rhagoletis indifferens*	0.08	*Bactrocera dorsalis*	0.58
Anastrepha distincta	0.62	*Dacus ciliatus*	0.06	*Bactrocera caudata*	0.56
Anastrepha manihoti	0.47	*Bactrocera invadens*	0.03	*Dacus longicornis*	0.54
Toxotrypana curvicauda	0.43	*Dacus frontalis*	0.02	*Bactrocera carambolae*	0.48
Anastrepha sororcula	0.41	*Ceratitis cosyra*	0.02	*Bactrocera umbrosa*	0.48
Anastrepha bezzii	0.37	*Ceratitis quinaria*	0.02	*Bactrocera zonata*	0.40
Anastrepha antunesi	0.33	*Ceratitis rosa*	0.02	*Bactrocera pedestris*	0.39
Anastrepha leptozona	0.31	*Bactrocera zonata*	0.01	*Bactrocera papayae*	0.39

doi:10.1371/journal.pone.0116424.t002

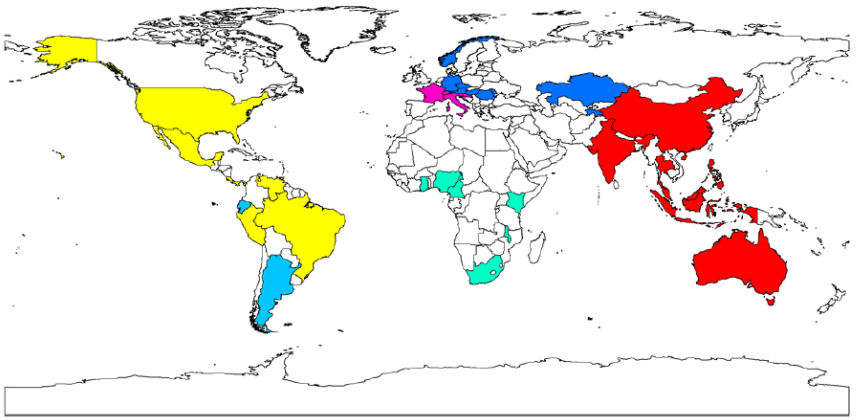


Figure 1. Countries clustering based on fruit fly species assemblages. Map of world showing those countries that were allocated to the same neuron in a SOM analysis (same colour) and hence those countries that have the most similar fruit fly species assemblages.

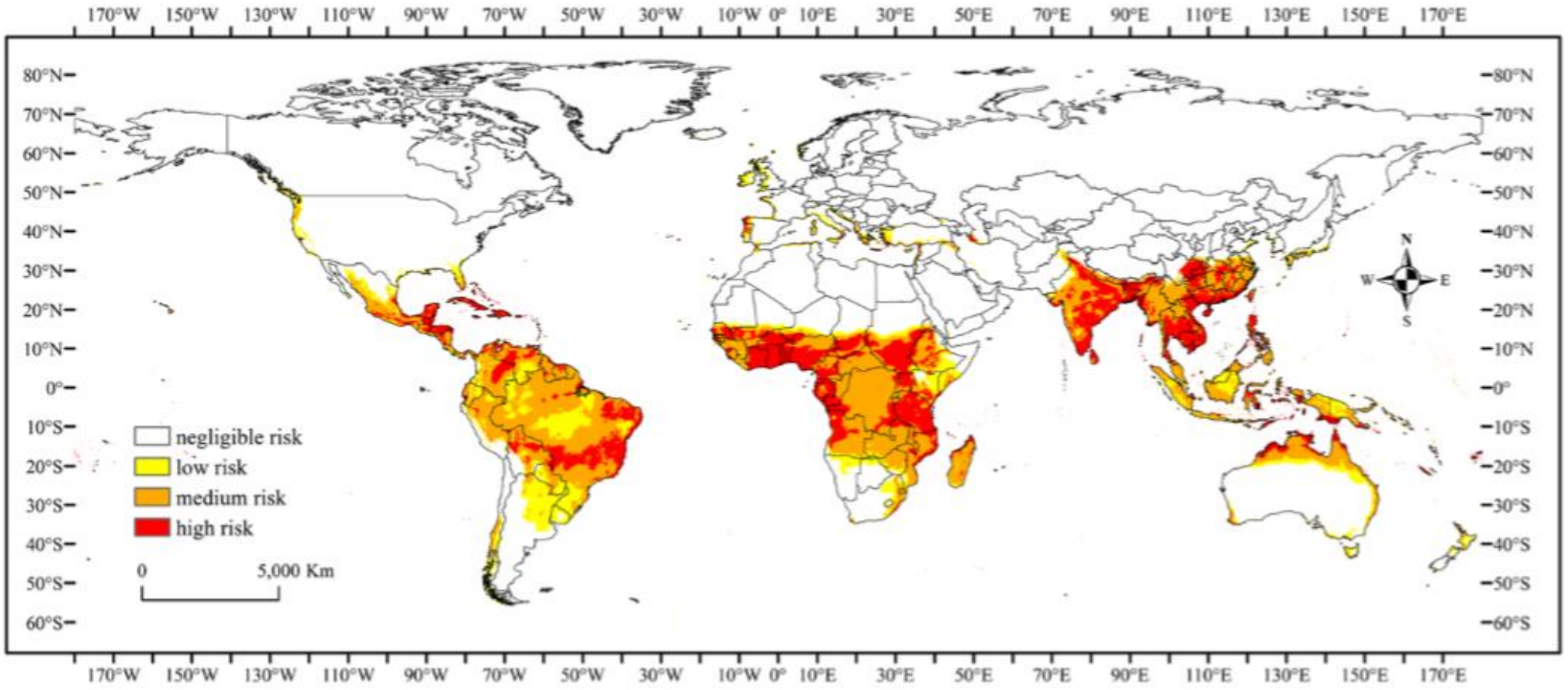
doi:10.1371/journal.pone.0116424.g001

(Qin et al. PLoS ONE, 2015)

- **Invasion model and PRA:** MaxEnt+ArcGIS, potential geographical distribution of *Bactrocera dorsalis.*

Climate change impacts on the global potential geographical distribution of the agricultural invasive pest, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae)

Yujia Qin [1,2] · Cong Wang [3] · Zihua Zhao [1] · Xubin Pan [3] · Zhihong Li [1]



(Qin et al, Climatic Change, 2019)

Invasion model and PRA: bio-model+ArcGIS, potential geographical distribution of main species of *Bactrocera and Zeugodacus.*

Appl Entomol Zool (2015) 50:371–381
DOI 10.1007/s13355-015-0344-9

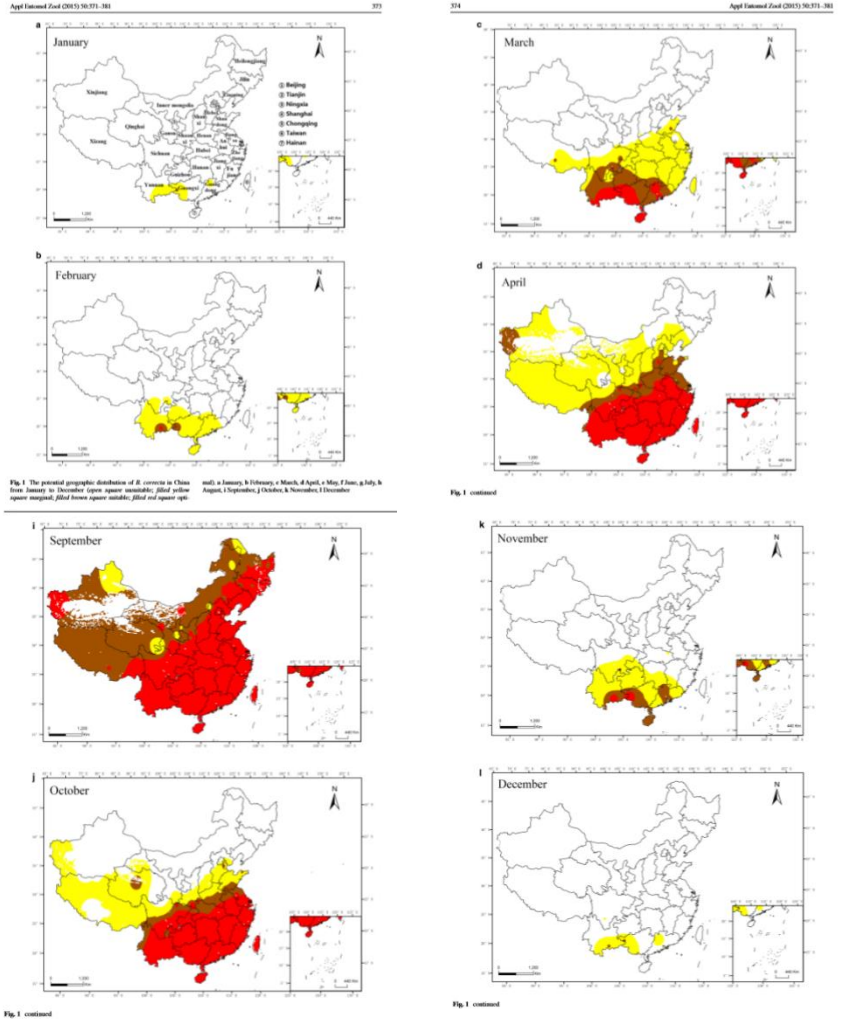
ORIGINAL RESEARCH PAPER

The potential geographic distribution of *Bactrocera correcta* (Diptera: Tephrididae) in China based on eclosion rate model

Yujia Qin[1] · Wenlong Ni[2] · Jiajiao Wu[3] · Zihua Zhao[1] · Hongjun Chen[4] · Zhihong Li[1]

$$Z = -0.00346313X^2 - 0.0000811Y^2 + 0.16755X + 0.00939Y - 1.448,$$

where: Z is the ER (eclosion rate) of *B. correcta*, X is the soil temperature, and Y is the soil moisture.

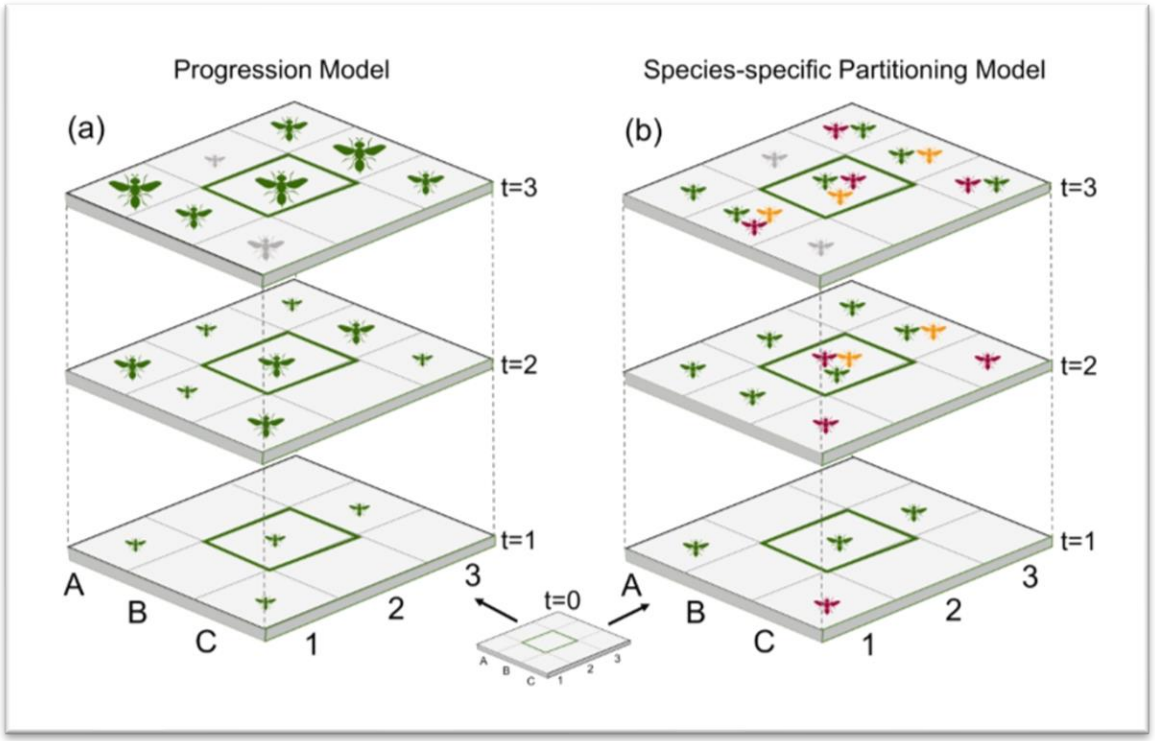


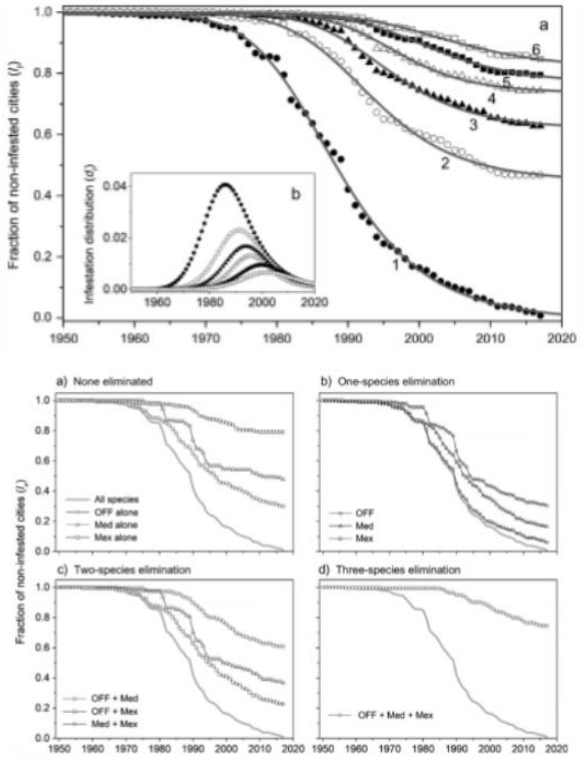
(Wang et al, 2009; Li et al, 2013; Qin et al, 2015)

- **Invasion model and PRA:** monitoring data in California USA (17 species and 366 regions) + R, invasion model for invasion rate etc.

Life table invasion models: spatial progression and species-specific partitioning

Zihua Zhao,[1,10] Cang Hui,[2,3] Richard E. Plant,[4] Min Su,[5] Tim Carpenter,[6] Nikos Papadopoulos,[7] Zhihong Li,[1] and James R. Carey[8,9]





(Zhao et al, Ecology, 2019)

- **Species diagnosis:** DNA barcodes database and identification system, ~190 species of EIFFs.

TBIS: A Web-Based Expert System for Identification of Tephritid Fruit Flies in China Based on DNA Barcode

Zhimei Li[1], Zhihong Li[1,*], Fuxiang Wang[2], Wei Lin[3], and Jiajiao Wu[4]

D. Li, Y. Liu, and Y. Chen (Eds.): CCTA 2010, Part III, IFIP AICT 346, pp. 563–571, 2011.

Species diagnosis: mtDNA COI, 1426 sequencesof 73 species of *Bactrocera*, species complex.

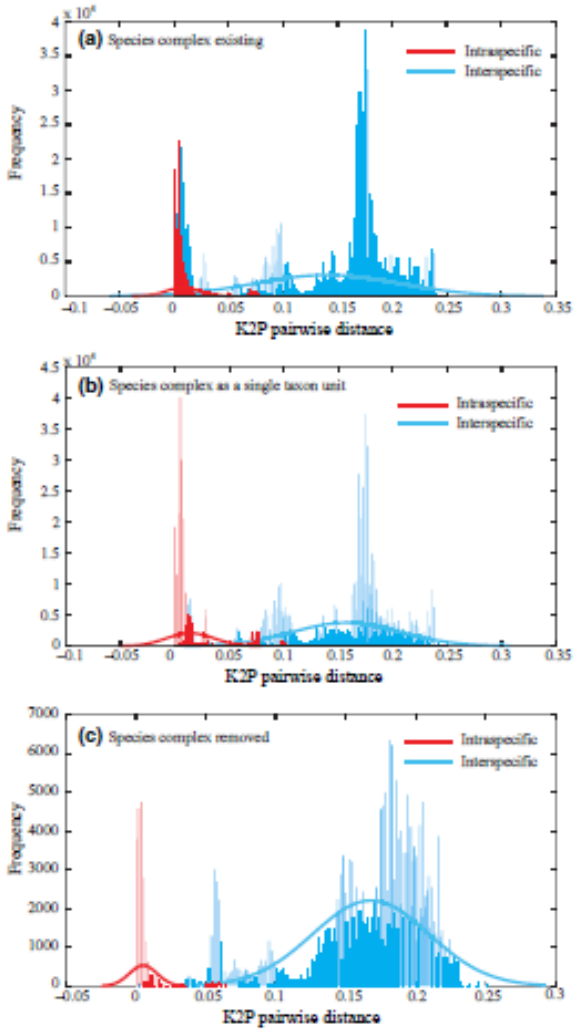
MOLECULAR ECOLOGY RESOURCES
Molecular Ecology Resources (2014) doi: 10.1111/1755-0998.12259

Existence of species complex largely reduced barcoding success for invasive species of Tephritidae: a case study in *Bactrocera* spp.

F. JIANG,*[1] Q. JIN,†[1] L. LIANG,‡ A. B. ZHANG† and Z. H. LI*
*Department of Entomology, College of Agronomy and Biotechnology, China Agricultural University, Beijing 100193, China, †College of Life Sciences, Capital Normal University, Beijing 100048, China, ‡Institute of Agro-Products Processing Engineering, Chinese Academy of Agricultural Engineering, Beijing 100125, China

Abstract

Fruit flies in the family Tephritidae are the economically important pests that have many species complexes. DNA barcoding has gradually been verified as an effective tool for identifying species in a wide range of taxonomic groups, and there are several publications on rapid and accurate identification of fruit flies based on this technique; however, comprehensive analyses of large and new taxa for the effectiveness of DNA barcoding for fruit flies identification have been rare. In this study, we evaluated the COI barcode sequences for the diagnosis of fruit flies using 1426 sequences for 73 species of *Bactrocera* distributed worldwide. Tree-based [neighbour-joining (NJ)]; distance-based, such as Best Match (BM), Best Close Match (BCM) and Minimum Distance (MD); and character-based methods were used to evaluate the barcoding success rates obtained with maintaining the species complex in the data set, treating a species complex as a single taxon unit, and removing the species complex. Our results indicate that the average divergence between species was 14.04% (0.00–25.16%), whereas within a species this was 0.81% (0.00–9.71%); the existence of species complexes largely reduced the barcoding success for Tephritidae, for example relatively low success rates (74.4% based on BM and BCM and 84.8% based on MD) were obtained when the sequences from species complexes were included in the analysis, whereas significantly higher success rates were achieved if the species complexes were treated as a single taxon or removed from the data set – BM (98.9%), BCM (98.5%) and MD (97.5%), or BM (98.1%), BCM (97.4%) and MD (98.2%).



(Jiang et al, Molecular Ecology Resource, 2014)

- **Species diagnosis:** mtDNA COI, PCR of *Bactroceraminax and Bactrocera tsuneonis*.

Article

New Species-Specific Primers for Molecular Diagnosis of *Bactrocera minax* and *Bactrocera tsuneonis* (Diptera: Tephritidae) in China Based on DNA Barcodes

Linyu Zheng [1,†], Yue Zhang [1,†], Wenzhao Yang [1], Yiying Zeng [1], Fan Jiang [2], Yujia Qin [2], Jiafeng Zhang [3], Zhaochun Jiang [4], Wenzhao Hu [5], Dijin Guo [6], Jia Wan [6], Zihua Zhao [1], Lijun Liu [1] and Zhihong Li [1,*]

Table 2. List of specific primer sequences for *B. minax* and *B. tsuneonis*.

Species	Primer	Primers Sequence (5′-3′)	Size (bp)	Tm (°C)
B. minax	Bm-F	AATTTATAACGTAATCGTTACAGCC	422	53.9
	Bm-R	AAGTATTGTGATAGCTCCGGCTAGG		60.2
B. tsuneonis	Bt-F	TAATGTAATCGTTACTGCTCACGCC	456	59.9
	Bt-R	CTGGGTCAAAGAAGGATGTATTTAG		56.1

(Zheng&Zhang et al, Insect, 2019)

- **Species diagnosis:** DNA barcodes, microfluidic dynamic array as new method for 27 species of EIFFs.

MOLECULAR ECOLOGY RESOURCES
Molecular Ecology Resources (2016) doi: 10.1111/1755-0998.12542

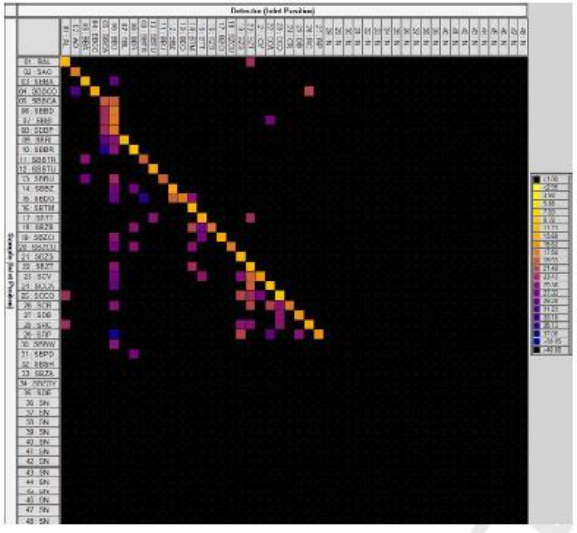
A high-throughput detection method for invasive fruit fly (Diptera: Tephritidae) species based on microfluidic dynamic array

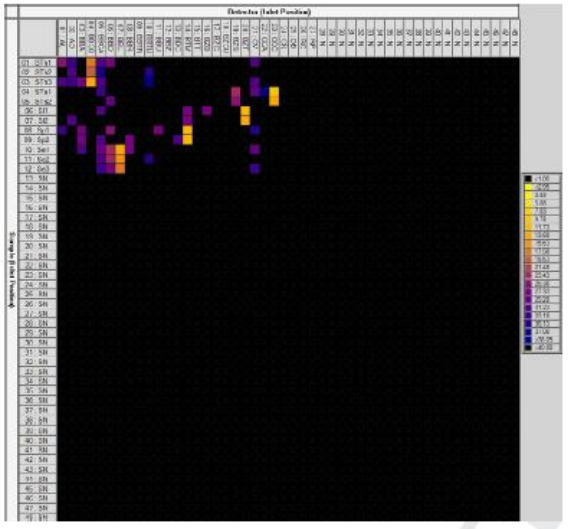
FAN JIANG,*† WEI FU,† ANTHONY R. CLARKE,‡ MARK KURT SCHUTZE,‡ AGUS SUSANTO,§ SHUIFANG ZHU† and ZHIHONG LI*

*College of Plant Protection, China Agricultural University, Beijing 100193, China, †Institute of Plant Quarantine, Chinese Academy of Inspection and Quarantine, Beijing 100176, China, ‡School of Earth, Environmental and Biological Sciences, Queensland University of Technology (QUT), G.P.O. Box 2434, Brisbane 4000, Qld, Australia, §Faculty of Agriculture, Padjadjaran University, Jatinangor, 40600 West Java, Indonesia

Abstract

Invasive species can be detrimental to a nation's ecology, economy and human health. Rapid and accurate diagnostics are critical to limit the establishment and spread of exotic organisms. The increasing rate of biological invasions relative to the taxonomic expertise available generates a demand for high-throughput, DNA-based diagnostics methods for identification. We designed species-specific qPCR primer and probe combinations for 27 economically important tephritidae species in six genera (*Anastrepha*, *Bactrocera*, *Carpomya*, *Ceratitis*, *Dacus* and *Rhagoletis*) based on 935 COI DNA barcode haplotypes from 181 fruit fly species publically available in BOLD, and then tested the specificity for each primer pair and probe through qPCR of 35 of those species. We then developed a standardization reaction system for detecting the 27 target species based on a microfluidic dynamic array and also applied the method to identify unknown immature samples from port interceptions and field monitoring. This method led to a specific and simultaneous detection for all 27 species in 7.5 h, using only 0.2 μL of reaction system in each reaction chamber. The approach successfully discriminated among species within complexes that had genetic similarities of up to 98.48%, while it also identified all immature samples consistent with the subsequent results of morphological examination of adults which were reared from larvae of cohorts from the same samples. We present an accurate, rapid and high-throughput innovative approach for detecting fruit flies of quarantine concern. This is a new method which has broad potential to be one of international standards for plant quarantine and invasive species detection.



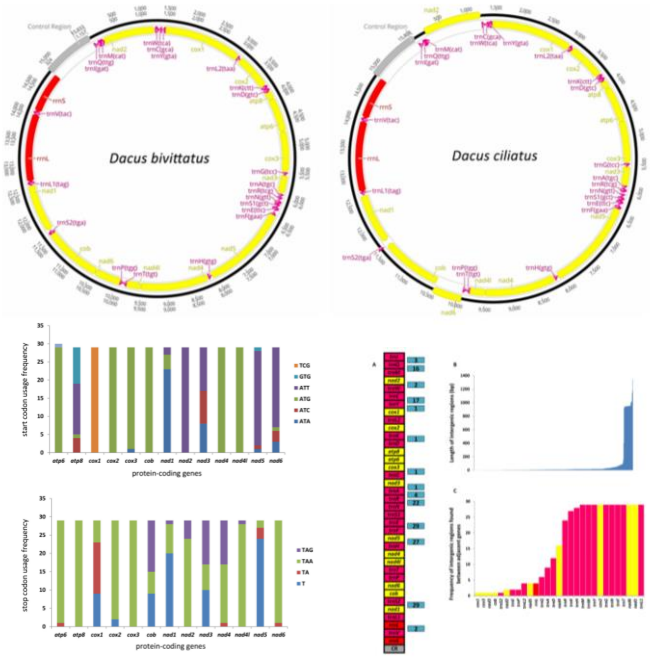


(Jiang et al, Molecular Ecology Resource, 2016)

- **Species diagnosis:** whole mitochondrial genome, 2 species of EIFFs, further support of genus *Zeugodacus* and species identification.

The first two complete mitochondrial genome of *Dacus bivittatus* and *Dacus ciliatus* (Diptera: Tephritidae) by next-generation sequencing and implications for the higher phylogeny of Tephritidae

Yue Zhang [a], Shiqian Feng [a], Lida Fekrat [b], Fan Jiang [c], Matodzi Khathutshelo [a], Zhihong Li [a,*]



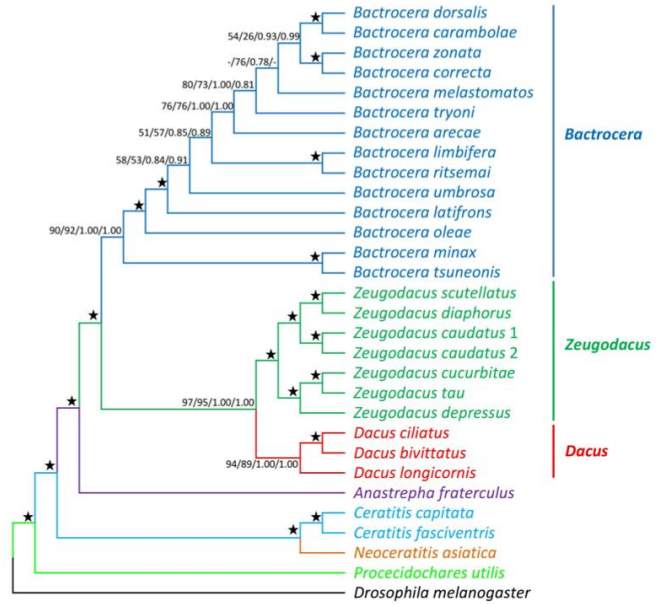


Fig. 4. Maximum Likelihood (ML) and Bayesian inference (BI) phylogenetic trees inferred from mitochondrial genomes of Tephritidae fruit flies based on two datasets a) PCG123; b) PCG123 and 2 rRNAs. *Drosophila melanogaster* was used as outgroup. Values above the nodes represent PCG123 Bayesian posterior probabilities/PCG123 and 2 rRNAs Bayesian posterior probabilities/PCG123 bootstrap values/PCG123 and 2 rRNAs bootstrap values. '-' indicates not support, '★' indicates posterior probabilities = 1.00 or ML bootstrap = 100 in all trees.

(Zhang et al, International Journal of Biological Macromolecules, Aug. 2019)

- **Phytosanitary treatment:** gamma irradiation, *Zeugodacus tau* in pumpkin fruits, 72Gy as dose.

Gamma Irradiation as a Phytosanitary Treatment of *Bactrocera tau* (Diptera: Tephritidae) in Pumpkin Fruits

ZHAN GUOPING,[1] REN LILI,[1] SHAO YING,[2] WANG QIAOLING,[3] YU DAOJIAN,[4] WANG YUEJIN,[1,5] AND LI TIANXIU[1]

Table 3. Estimating the minimum absorbed dose for prevention of adult eclosion from irradiated eggs and larval instars of *B. tau*

Stage	Analyzing model	Slope ± SE[a]	Intercept ± SE[a]	ED_{99} (95% CI)	$ED_{99.9968}$ (95% CI)	Heterogeneity
Egg	Probit	10.06 ± 0.74	−12.52 ± 0.96	29.9 (28.1, 32.5)	43.9 (39.4,50.6)	0.08
	Logit	0.399 ± 0.034	−7.15 ± 0.67	29.4 (27.9, 31.6)	43.9 (40.3, 48.9)	0.13
L_1	Probit	15.20 ± 1.24	−20.76 ± 1.72	33.0 (29.7, 41.9)	42.5 (35.7, 65.1)	3.66
	Logit	0.443 ± 0.039	−10.06 ± 1.00	33.5 (32.0, 35.9)	46.5 (43.2, 51.3)	0.80
L_2	Probit	18.56 ± 1.62	−27.47 ± 2.43	40.8 (38.2, 45.7)	50.8 (45.4, 62.1)	3.35
	Logit	0.421 ± 0.036	−12.71 ± 1.25	41.0 (39.5, 43.2)	54.7 (51.2, 59.6)	0.64
L_3	Probit	13.16 ± 1.00	−19.42 ± 1.52	44.9 (41.1, 52.4)	60.1 (51.7, 79.9)	1.69
	Logit	0.314 ± 0.023	−9.48 ± 0.72	44.8 (41.2, 51.3)	63.1 (55.3, 78.0)	1.94
Late L_3	Probit	10.64 ± 0.61	−15.70 ± 0.93	49.4 (47.2, 52.1)	70.9 (65.6, 78.2)	0.98
	Logit	0.249 ± 0.015	−7.54 ± 0.50	48.8 (44.7, 55.4)	71.8 (63.0, 87.3)	2.72

[a] Mean ± SE; heterogeneity means chi-square divided by degrees of freedom.

(Zhan et al., Journal of Economic Entomology, 2015)

- **Phytosanitary treatment:** cold treatment, *Bactrocera dorsalis* in Navel orange, 1.7℃ and 15 days.

Article

The Effects of a Cold Disinfestation on *Bactrocera dorsalis* Survival and Navel Orange Quality

Yan Fang [1,2], Fenfen Kang [1,2], Guoping Zhan [3], Chen Ma [4], Yuguang Li [1], Lin Wang [1], Yadong Wei [2], Xiwu Gao [1], Zhihong Li [1] and Yuejin Wang [1,3,*]

Table 3. Results of large-scale tests on second instar *Bactrocera dorsalis* larvae in navel oranges for 15 days at 1.7 °C.

Trial No.	Treated		
	No. of Fruit Infested	No. of Insects Treated	No. of Surviving Individuals
Control	18	4724	4445
1	48	13,136	0
2	48	8784	0
3	48	15,872	0
	Total	37,792	0

(Fang et al., Insects, 2019)

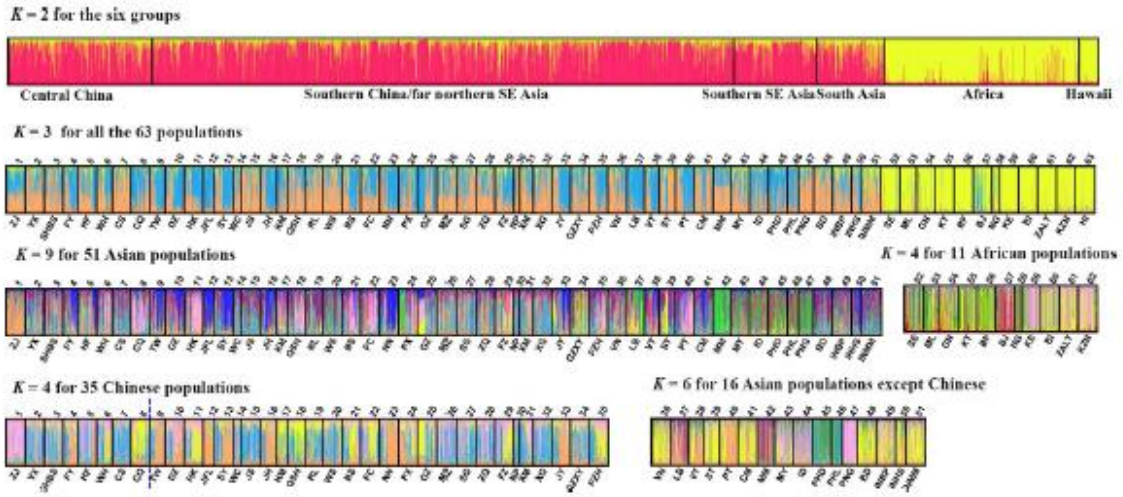
Invasion tracing: population structure based on sequences and microsatellite, 2863 samples of 63 populations of *B. dorsalis*, from India continent to other regions of Asia, Hawaii and Africa.

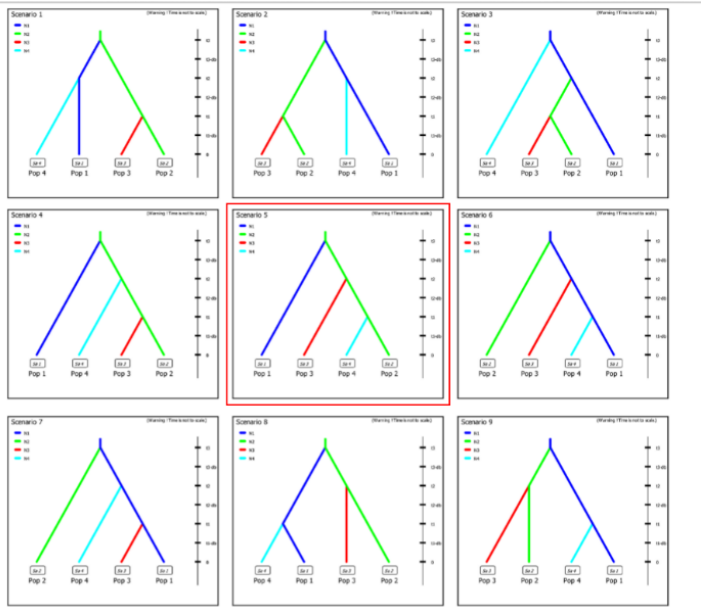
Population structure of a global agricultural invasive pest, *Bactrocera dorsalis* (Diptera: Tephritidae)

Yu-jia Qin[1*] | Matthew N. Krosch[2*] | Mark K. Schutze[2] | Yue Zhang[1] | Xiao-xue Wang[1] | Chandra S. Prabhakar[2,3] | Agus Susanto[4] | Alvin K. W. Hee[5] | Sunday Ekesi[6] | Kemo Badji[7] | Mahfuza Khan[8] | Jia-jiao Wu[9] | Qiao-ling Wang[1] | Ge Yan[1] | Li-huan Zhu[1] | Zi-hua Zhao[1] | Li-jun Liu[1] | Anthony R. Clarke[2] | Zhi-hong Li[1]

	CC	SCNA	SSA	SA	AF	HI
SSR						
SCNA	0.00539	–				
SSA	0.03269	0.02986	–			
SA	0.01698	0.01245	0.02651	–		
AF	0.05488	0.05217	0.0772	0.04672	–	
HI	0.12552	0.12985	0.14766	0.11694	0.13068	–
cox1/nd6						
CC	–	0.00261	0.14469	0.01636	0.16363	0.53646
SCNA	0.00426	–	0.15011	0.01387	0.13823	0.51927
SSA	0.12419	0.10505	–	0.14968	0.32940	0.50660
SA	0.01916	0.00813	0.08465	–	0.13246	0.56882
AF	0.05488	0.21112	0.25283	0.19134	–	0.69480
HI	0.57409	0.50943	0.41203	0.53441	0.69314	

Note. Values in bold are significant at $p < 0.05$.





(Qin et al. Evolutionary Applications, 2018)

- **Invasion tracing:** hydrogen stable isotope, *B. dorsalis* trapped in Beijing was not a resident population and from south China.

Using hydrogen stable isotope ratios to trace the geographic origin of the population of *Bactrocera dorsalis* (Diptera: Tephritidae) trapped in northern China

Zihua Zhao[1], Zhenglong Lu[1], Gadi V.P. Reddy[2], Shuo Zhao[3], Guanghui Lin[4], Jianyun Ding[3], Jiajiao Wu[5], and Zhihong Li[1,]*

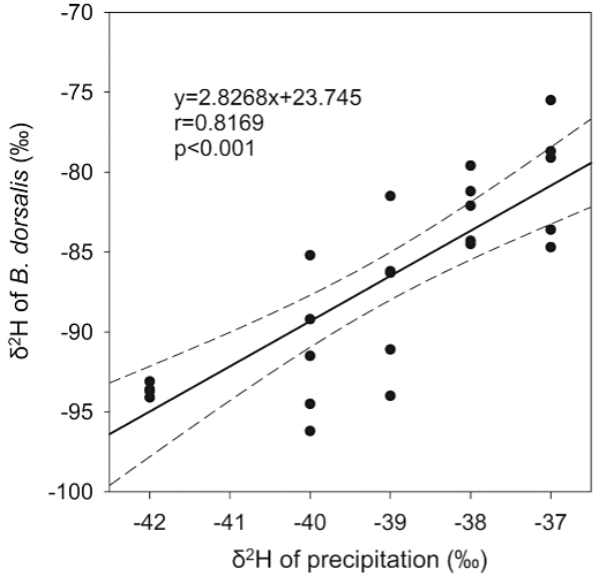


Table 2. The measured values and theoretical values of *Bactrocera dorsalis* δ^2H stable isotope from the Xinfadi market and the Bolongbao grape vineyard (the capital letters indicated the differences of *Bactrocera dorsalis* δ^2H stable isotope between measured values and theoretical values, the lower case letters indicated the differences of *Bactrocera dorsalis* δ^2H stable isotope between Xinfadi market and Bolongbao grape vineyard).

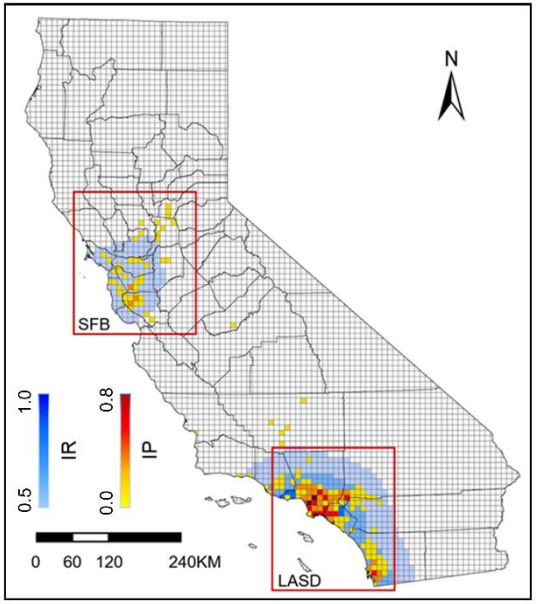
Sampling sites	δ^2H of *B. dorsalis* (Measured value)	δ^2H of *B. dorsalis* (Theoretical value)
Xinfadi market (n = 5)	−88.14 ± 4.71 Ba	−130.85 ± 5.18 Aa
Bolongbao grape vineyard (n = 5)	−87.17 ± 3.66 Ba	−130.85 ± 4.24 Aa

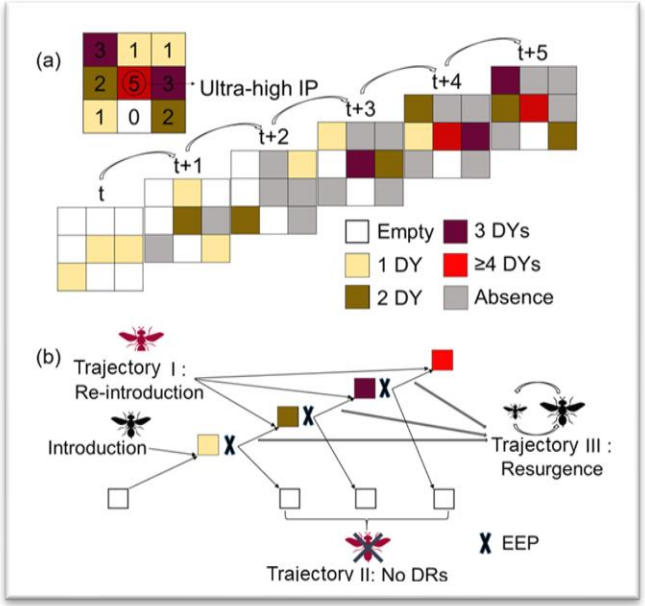
(Zhao et al. Florida Entomologist, 2018)

- **Invasion mechanism:** *B. dorsalis* in California USA, a heterogeneous distributions formed varied invasion dynamics, because of 3 trajectories (reintroduction, partial success of eradication, population resurgence).

The failure of success: Cyclic recurrences of a globally invasive pest

ZIHUA ZHAO[1,9], CANG HUI[2,3], RICHARD E. PLANT[4], MIN SU[5], NIKOS T. PAPADOPOULOS[6], TIM E. CARPENTER[7], ZHIHONG LI[1], JAMES R. CAREY[8]



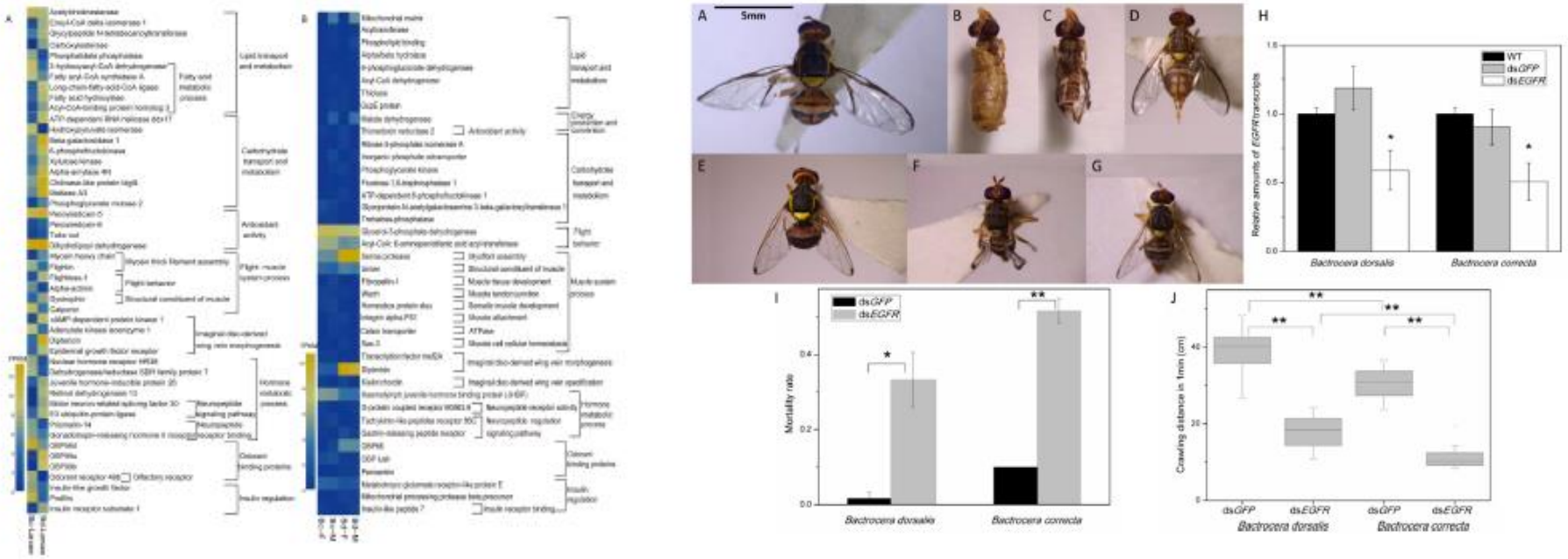


(Zhao et al., accepted for publishing, Ecological Applications, Aug. 2019)

- **Invasion mechanism:** *B. dorsalis* has higher flight capacity than *B. correcta*, EGFR gene as key candidate gene.

Comparative Transcriptome Analyses Uncover Key Candidate Genes Mediating Flight Capacity in *Bactrocera dorsalis* (Hendel) and *Bactrocera correcta* (Bezzi) (Diptera: Tephritidae)

Shaokun Guo, Zihua Zhao, Lijun Liu, Zhihong Li * and Jie Shen *

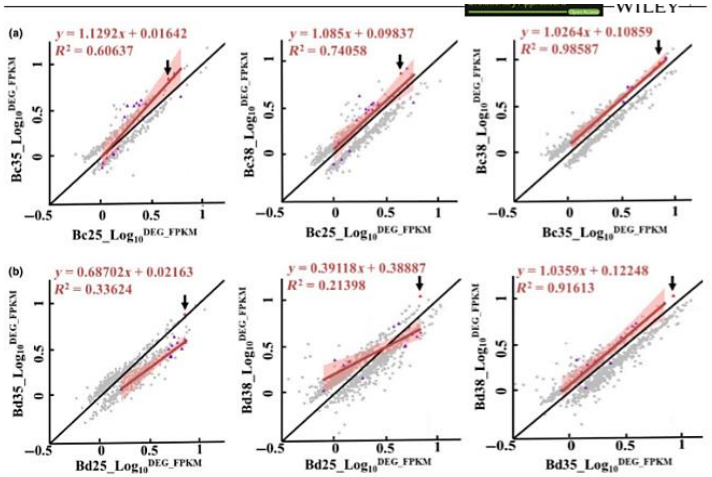


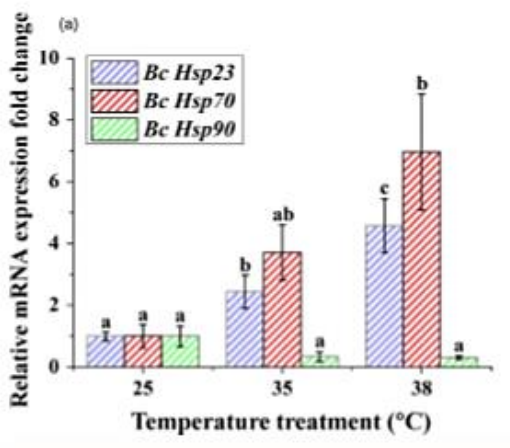
(Guo et al. International Journal of Molecular Sciences, 2018)

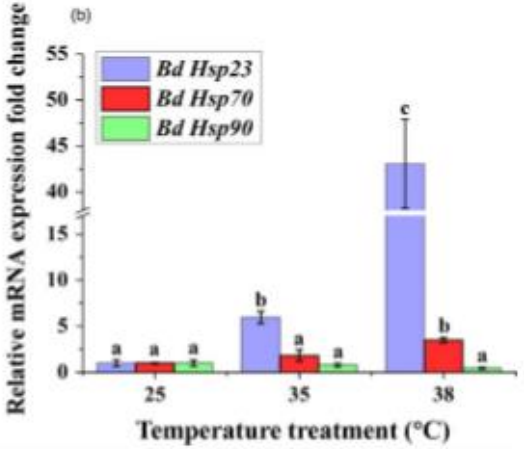
- **Invasion mechanism:** *B. dorsalis* has more adaptation of heat hardening than *B. correcta*, , HSP23 gene as key candidate gene.

A transcriptional and functional analysis of heat hardening in two invasive fruit fly species, *Bactrocera dorsalis* and *Bactrocera correcta*

Xinyue Gu[1] | Yan Zhao[1] | Yun Su[1] | Jiajiao Wu[2] | Ziya Wang[1] | Juntao Hu[3,4] | Lijun Liu[1] | Zihua Zhao[1] | Ary A. Hoffmann[5] | Bing Chen[6] | Zhihong Li[1]







(Gu et al. Evolutionary Applications, 2019)

The New Program: Sino-Czech Program
（No. 2018YFE0108700）

- Title: The invasive mechanisms and key phytosanitary technology on economically important stored insect pests endangering Chinese and European international trades of grain and fruit
- Funds： Chinese side, 1.77 million RMB
- Period: Aug. 2019 to Jul. 2022
- Type: Key program of international S&T innovation and cooperation

Trogoderma granarium

Liposcelis bostrychophila

Bactrocera dorsalis

Drosophila suzuki

The Society Services of CAUPQL

- For GACC and some Customs in China: PRA of import fruits + species diagnosis + monitoring information system of EIFFs.
- For MARA, NATESC and local plant protection stations in China: PRA, species diagnosis, monitoring and invasion tracing of EIFFs.
- For some companies in China: species diagnosis of EIFFs.
- For IPPC, TAAO and some countries: FAO-IPPC Global Project (Sri Lanka), TAAO 2020, Papua New Guinea etc.

TAAO

Tephritid workers of Asia, Australia and Oceania

The Second Symposium of TAAO 2020

2020.8.17–2020.8.21

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Welcome Message

The TAAO was established as an independent professional and scientific organization with the purpose of bringing together tephritid workers from Asia, Australia, and Oceania. The Second Symposium of TAAO will be held from August 17-22 of 2020 in Beijing. The presence of highly invasive tephritid fruit flies continues to threaten the commercial fresh fruit industry arising from higher production costs in controlling those pests and quarantine restrictions. In managing those pests, the threat of multiple species' invasion underpins the need for building an effective collaborative network among agricultural action and research agencies in identifying and halting the spread of those pests.

http://www.aiencode.net

III. The challenges, opportunities and prospects of prevention and control of EIFFs

The Main Challenges:

- **Movement increasing:** especially the development of trade, tour and e-commerce. For EIFFs: So free trip!
- **Global changing:** especially the development of climate change and nitrogen deposition. For EIFFs : So suitable environment!
- **Pests evolving:** especially the development of adaptation of stress. For EIFFs: So happy life!



The main species of EIFFs in the world

The Main Opportunities:

- **More attentions:** Public Education Day of National Security from 2015, including EIFFs.
- **More supports:** CSC program from 2009, National Key R&D Programs from 2016, including EIFFs.
- **More platforms:** TAAO 2020, One Belt and One Road Initiative, and FAO-IPPC Global Project, including EIFFs.

The field investigation of FAO-IPPC Global Project (Feb. 2019)

The kick-off meeting of Sino-Czech Collaboration Program (Nov. 2019)

The Main Prospects:

- **To strengthen the international education system:** especially the public education and the postgraduates education as the basis of prevention and control of EIFFs.
- **To establish the international research platform:** especially the TAAO research center of EIFFs.
- **To share the international service resources:** especially the data, methods and techniques of EIFFs.

The international phytosanitary education on EIFFs: more efforts from the world

Outline

- The general situation of prevention and control of EIFFs
- The education, research and services on EIFFs in China: CAU as an example
- The challenges, opportunities and prospects of prevention and control of EIFFs

Food and Agriculture Organization of the United Nations

International Plant Protection Convention

中國農業大學 China Agricultural University

WELCOME TO CAU!

LOOKING FORWARD TO MORE COLLABORATIONS AND PROGRESS ON EIFFs!