New Technology for Ecological Control of Asian Longhorn Beetle Disasters

Dead-end trap tree of *Anoplophora glabripennis* and its application in Northeast China

Youqing Luo[1], Lili Ren[1], Lixiang Wang[2], Chengcheng Li[1], Jiahe Pei[1]

1. Beijing Forestry University
2. Gansu Agricultural University

Sino-France Joint Laboratory for Invasive Forest Pests in Eurasia

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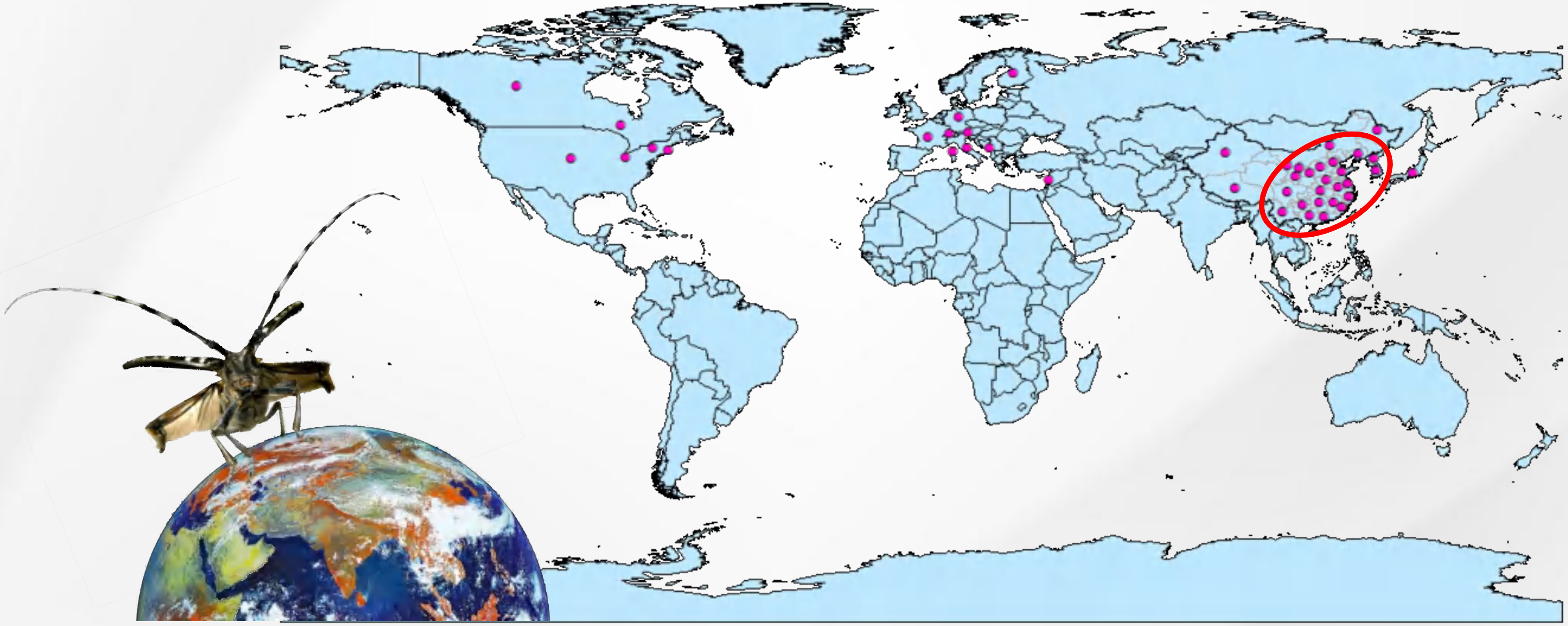
1. INTRODUCTION

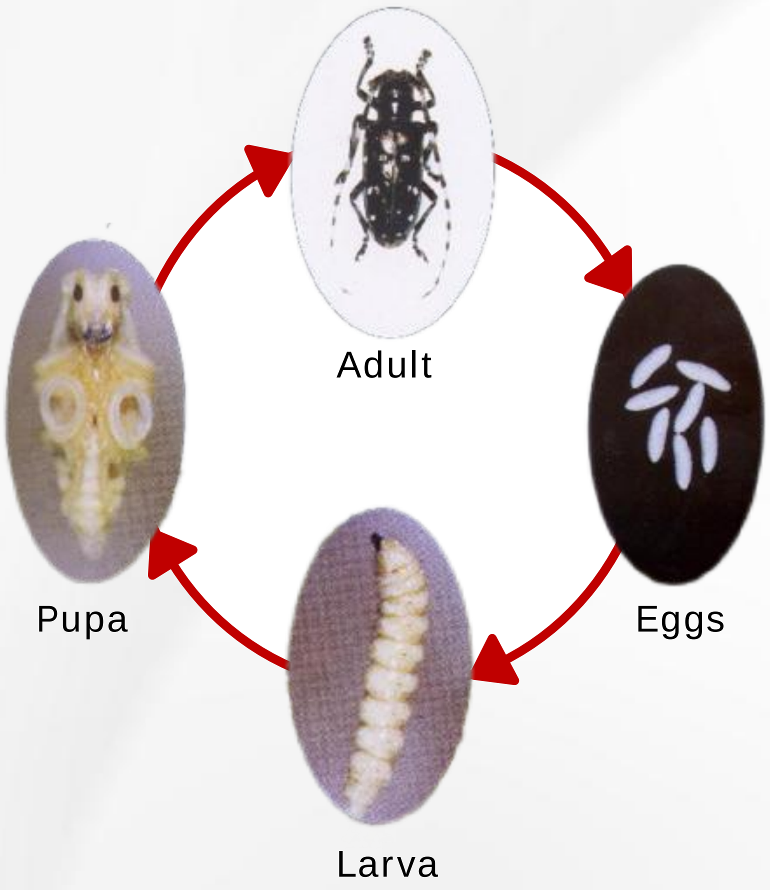
1.1 INTRODUCTION OF ALB

- Asian longhorn beetle (ALB), *Anoplophora glabripennis* (Motschulsky, 1854) , (Coleoptera: Cerambycidae).
- ALB originally native to eastern Asian, that became a serious pest of hardwood trees in North America and Europe.

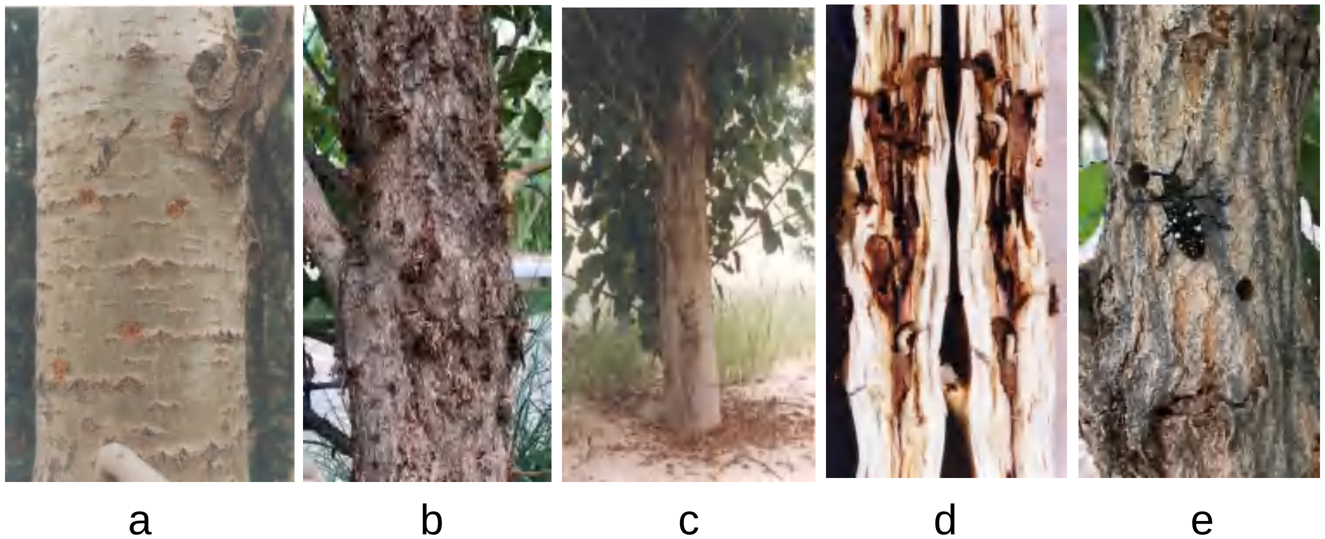


Global distribution of *Anoplophora glabripennis*.

1.2 THE LIFE HISTORY OF ALB



The life history of ALB



Main damage characteristics

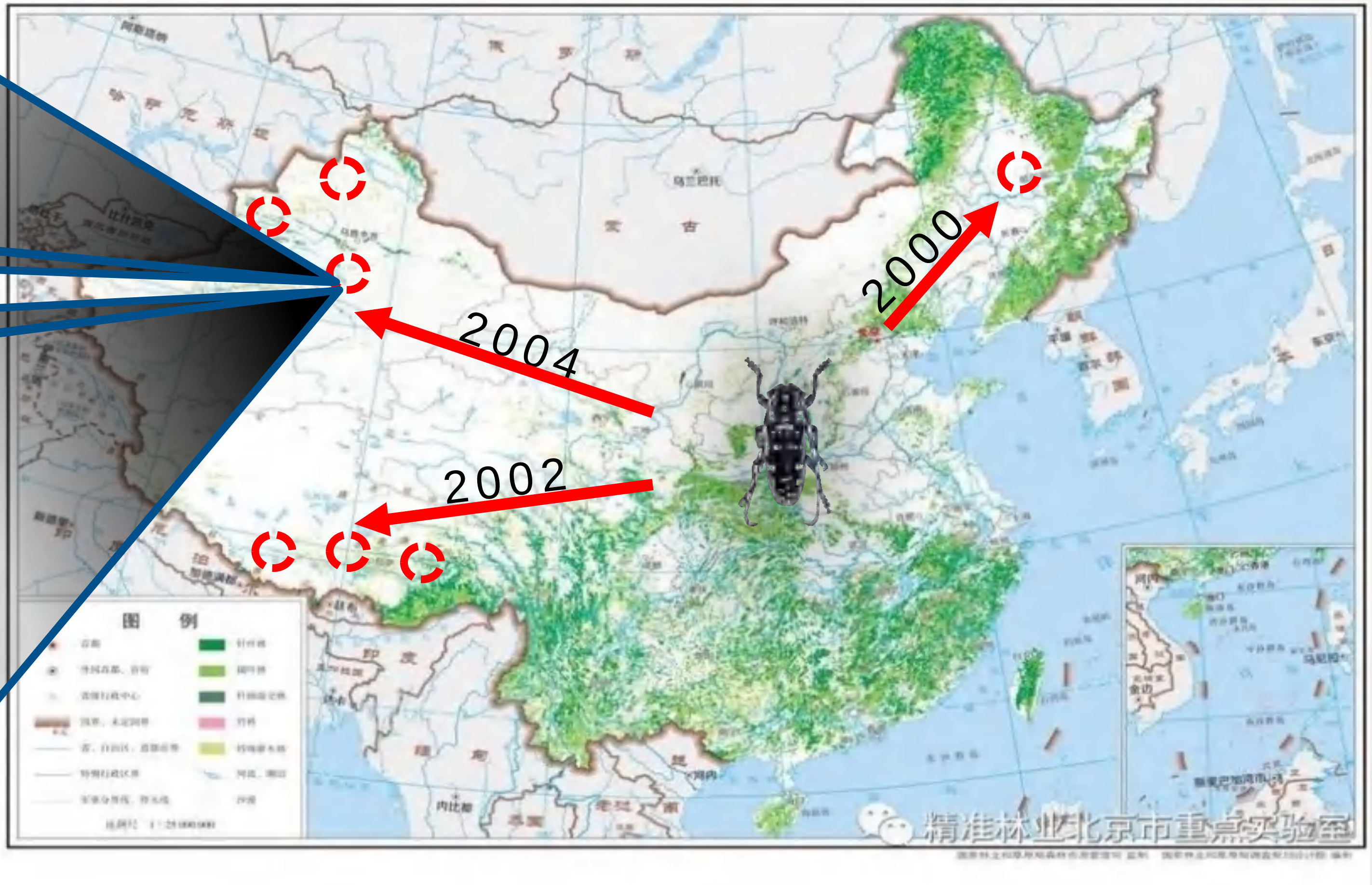
a. Oviposition Scar
b. Excretion hole
c. Above ground frass pile
d. Larval tunnel
e. emerging hole (popular)

Photo by Luo Youqing

1.3 WIDESPREAD AND SERIOUS DAMAGE IN CHINA

Larvae burrow
and feed destroying poplar

ALB disaster in Jiuquan City,
Gansu Province, 2019



The spread of ALB in China in the past 20 years

2. PREVIOUS PREVENTION AND CONTROL TECHNIQUES FOR ALB

- In the 1990s, ALB caused the complete destruction to the poplar plantation of the three-north shelterbelt project.
- Our team developed a sustainable control technology for longhorned beetle disaster based on rational allocation of multiple tree species (including trap trees).

National Prize for Progress in Science and Technology

The trap tree, *Populus × xiaozhuanica*, mixed with the resistant species, *P. alba* var. *pyramidalis*

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3.PHENOMENON DISCOVERY

3.1 RUSSIAN OLIVE ATTRACTS ALB, BUT *WITHOUT EMERGING(EXIT) HOLE*

Russian Olive
Elaeagnus angustifolia
Linn. var. *angustifolia*

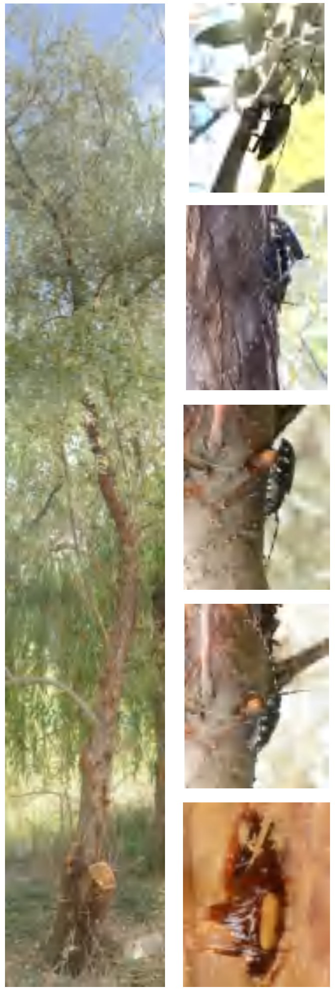
ALB feeds and oviposits in Russian olive

Many gum lumps are on a Russian olive branch

Gum cover oviposition scars, and kill ALB eggs.

Photo by Luo Youqing, 2021.7

3.2 THE INTERACTION BETWEEN ALB AND RUSSIAN OLIVE



ALB take in nutrients on russian olive twigs.

↓

ALB climbs down to the branch to mate.

↓

ALB bite oviposition scars on russian olive branches.

↓

ALB lays eggs in the oviposition scar.

↓

Russian olive secretes gum in the scar, killing the eggs.

×

The eggs hatch into larvae, caries into the xylem, then pupate and emerge from the trunk.

Photo by Pei Jiahe, 2021.7

Important discovery

Russian olive is a unity of lure and kill for ALB.

LURE

RO is a powerful attractor of ALB, and its attractant ability is comparable to that of willow, which was used as a trap tree.

KILL

RO can kill ALB eggs, some of them hatch into larvae, but also die of tree gum or stunted growth.

3.2.1 RUSSIAN OLIVE STRONGLY LURE ALB STEP-1 NUTRITION

- Adults of ALB feed on the leaves, petioles and 1-2 years twigs of Russian olive to take in nutrition.

ALB supplement nutrition on Russian olive

Photo by Luo Youqing, 2021.7

3.2.1 RUSSIAN OLIVE STRONGLY LURE ALB STEP-2 OVIPOSITION

Photo and edit by Pei Jiahe, 2021

- ALB is transferred from nutrient-supplemented twigs to big branches, mating, biting incisions and laying eggs.

3.2.2 RUSSIAN OLIVE KILL ALB

- Russian olive secretes gum to cover and kill ALB eggs (or larvae).

An ALB egg
covered by gum

Photo by Luo Youqing, 2021.7

Inside and outside a new ALB oviposition scar on Russian olive.

3.2.2 RUSSIAN OLIVE KILL ALB

Bark outside Xylem side Phloem side

Photo by Luo Youqing, 2021.7

Inside and outside the oviposition scar of ALB on different host species

3.3 THE SUSTAINED KILLING ABILITY

■ ALB lays eggs on branches with a certain range of years and thickness, thus, Russian olive can continuously provide suitable niche and sustainly luring and killing.

1-2 years 3 years 4 years 5 years 6 years 7 years 8-9 years

Photo by Luo Youqing, 2021.7

Different parts of Russian olive were affected by ALB

3.3 THE SUSTAINED KILLING ABILITY

■ Moreover, the oviposition scars on Russian olive can recover after 1-2 years.

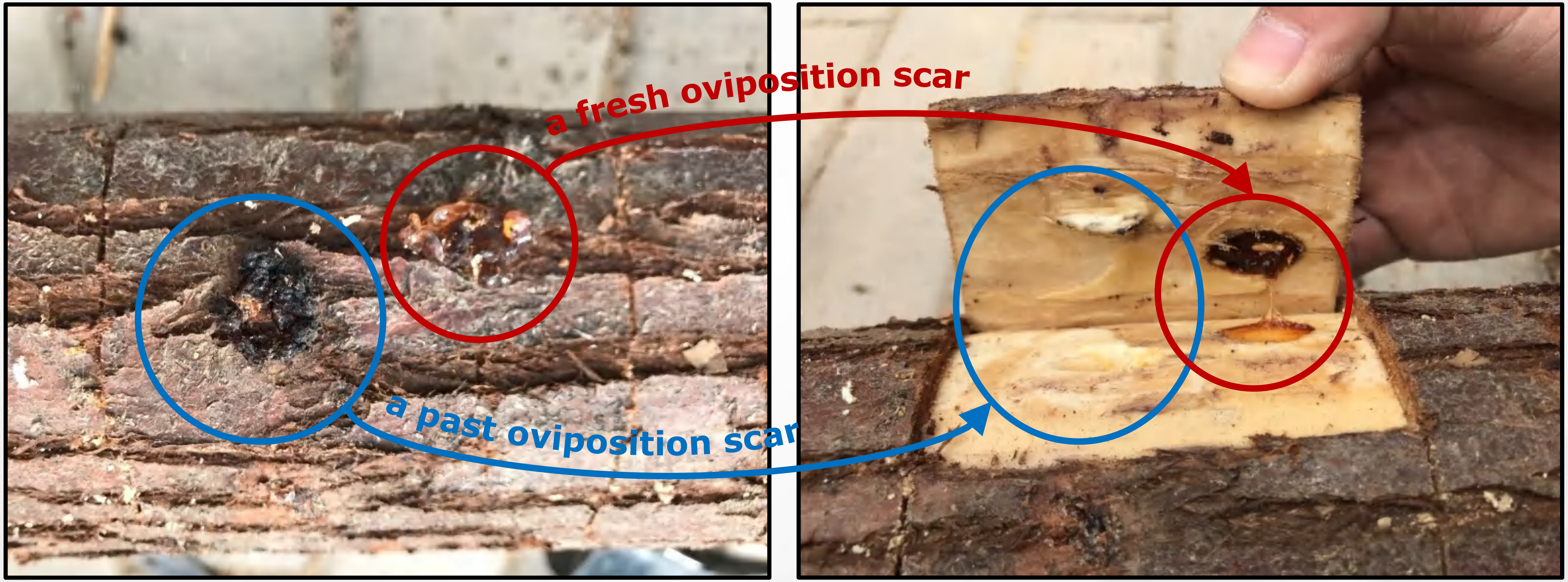


Photo by Luo Youqing, 2021.7

Inside and outside the oviposition scar of ALB in Russian olive.

3.4 HIGH-EFFICIENCY KILLING ABILITY

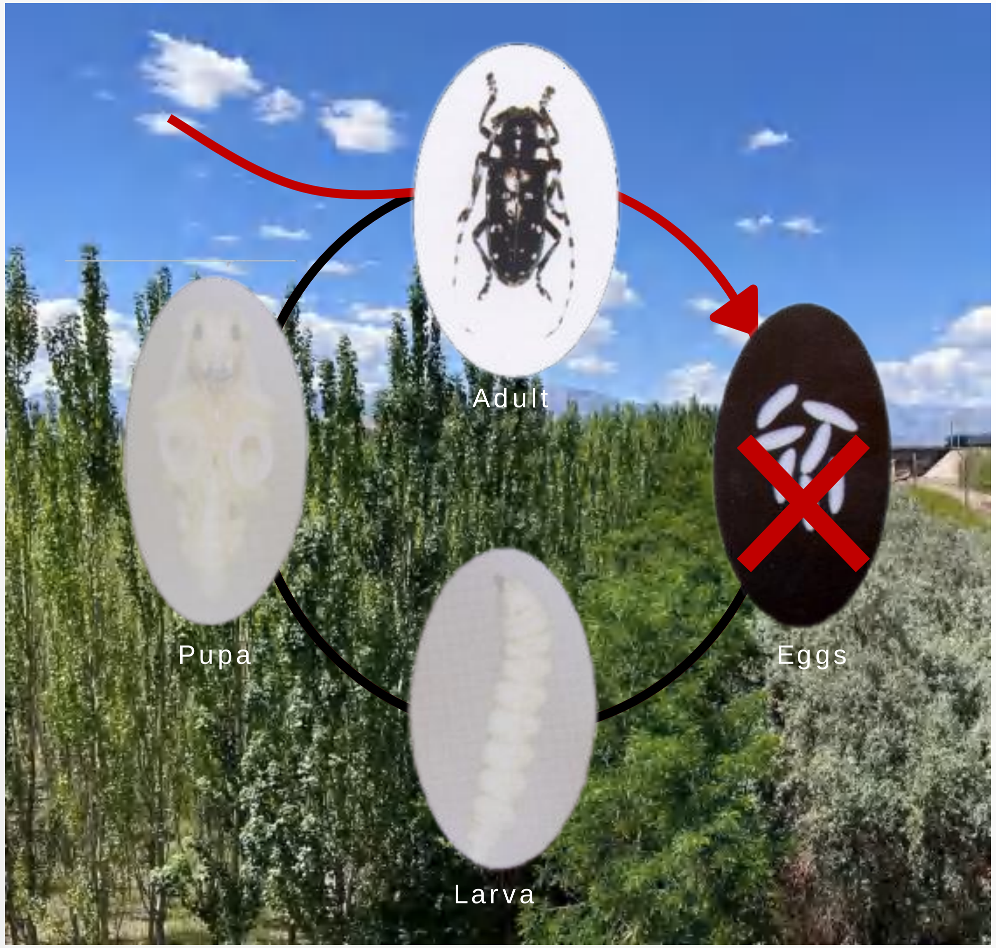
- The niche utilization rate of oviposition is high.
- Oviposition scar can heal themselves later on.



Photo by Luo Youqing, 2021.7

Russian olive branches with multiple oviposition scars covered by gum slumpies

3.5 BREAKING-OFF-POSTERITY PARASITISM



The life history of ALB on Russian olive.

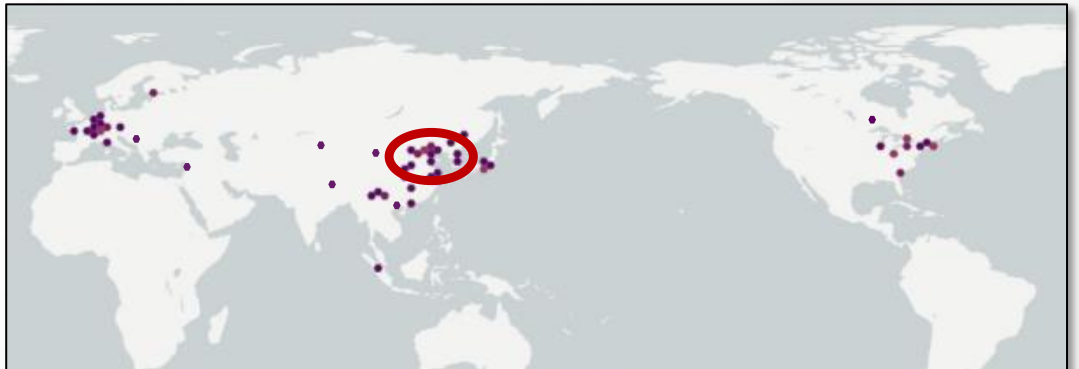
■ "Life history" of ALB on russian olive
Russian olive only provides the favorable conditions for ALB adults to take in nutrition and oviposition, but does not allow their eggs hatching.

Breaking-off-posterity parasitism:
refers to the phenomenon that the "host" can provide some favorable living conditions for parasites, such as nourishment and habitat, but it hinders the parasites from completing their life history (or generation development).

3.5 BREAKING-OFF-POSTERITY PARASITISM

- In Northwest China, they are Exotie Pest versus local Tree, and they have different origins without co-evolution.
- Russian olive and ALB are both invasive species in some regions, such as North America, and both of them have strong adaptability at the introduced areas.

Elaeagnus angustifolia
Native to the northwest of China, it is distributed in the Soviet Union, the Middle East, as far east as Europe, and is classified as an invasive species in North America and other places.



Anoplophora glabripennis
Originated in Northeast Asia, it has spread to many countries in Europe and America and caused serious harm. It was introduced into Gansu and Xinjiang at the end of last century.

Distribution data from EPPO and Xu Xinwang et al., 2020

Breaking-off-posterity parasitism is a kind of special parasitic relationship that occurs between exotic organisms and native organisms and is formed without co-evolution.

3.6 DEAD-END TRAP TREE

- Dead-end trap tree: the tree that can Strong attract adult insect infestation and high-efficiency kill their offspring so that insect cannot continue their population.
- Dead-end trapping technology: an ecological control technology that uses the dead-end trap tree to strongly attract pests and high-efficiency kill their offspring.

Strong Attractant

Luring adults

It can be used as a trap tree if there is only high efficiency of induction without natural killing ability.

High-efficiency Killing

Killing the next generation

If there is no attracting ability or low attracting ability, it can be regarded as a highly resistant tree.

Other properties:

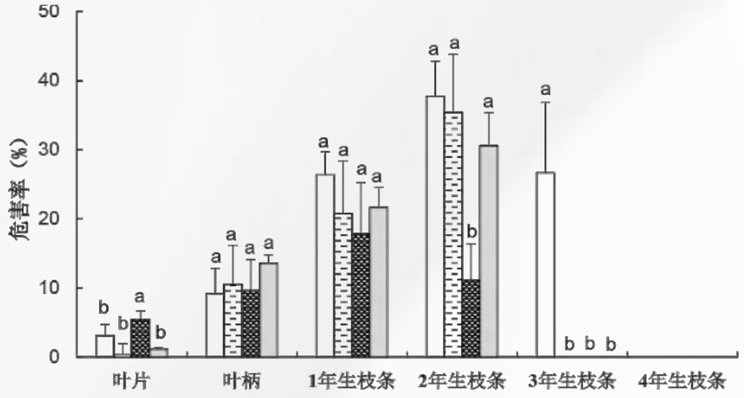
strong adaptability, easy cultivation, low cost, sustained effects

4. RESEARCH PROGRESS

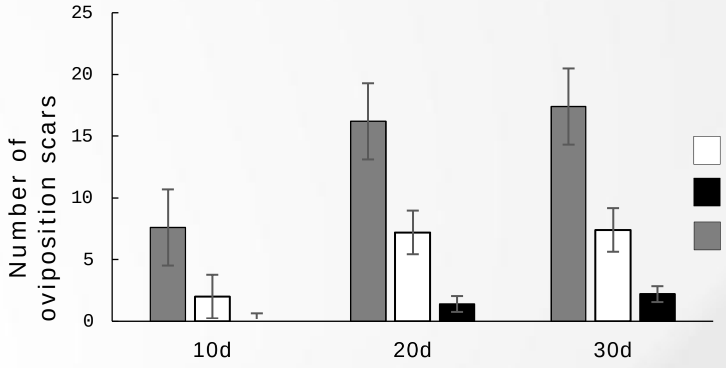
Photo by Luo Youqing, 2022.7

4.1 THE ATTRACTION RATE AND MORTALITY

■ ALB prefers to feed on Russian olive, and its oviposition rate is equivalent to that of common favorite hosts (willows, etc.), and four times that of Xinjiang poplar.



Field investigation on the damage rate (%) of ALB of different hosts' leaves, petioles and branches (1-4 years).



Oviposition behavior assay results of ALB to different hosts for 10, 20 and 30 days.

Take the statistics of two adjacent *S. matsudana* and *E. angustifolia* as an example.

	Number of oviposition scars	Number of excretion holes	Number of emerging holes	Diameter at breast height (cm)	Tree height (m)
S. matsudana	51	13	23	70.6%	20
E. angustifolia	50	0	0	0	26

Unpublished data.

4.1 THE ATTRACTION RATE AND MORTALITY

- Through investigation of more than 1,000 oviposition scars (from 549 trees), we calculated that Russian olive killed 99.93% of ALB egg, and only 1.4% can hatch into larvae.

a b c d

A few excretion holes and emerging holes, and they are on some weak trees or dead trees.

Note:

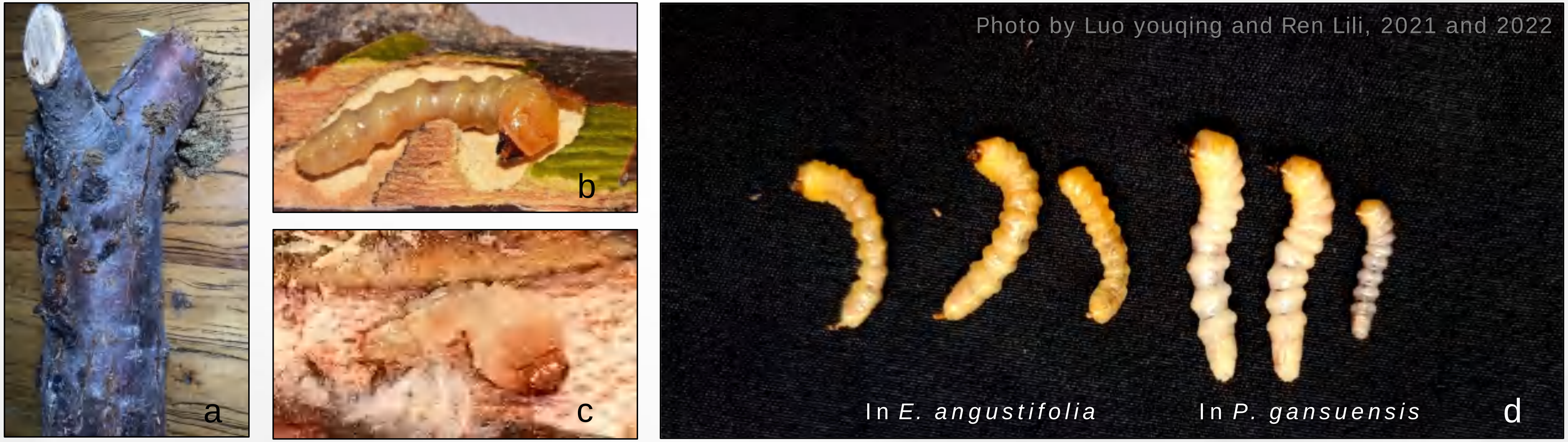
a. Excretion holes in a dead Russian olive.
b. Excretion holes in a week Russian olive.
c. Three emerging holes in a dead Russian olive.
d. A withered larvae in xylem tunnels of a dead Russian olive.

Photo by Luo Youqing , Jiayuguan, July-1-2002.

Unpublished data.

4.2 WOOD SECTION WITHOUT GUM, CANNOT KILL EGGS BUT STILL STRESS LARVAE.

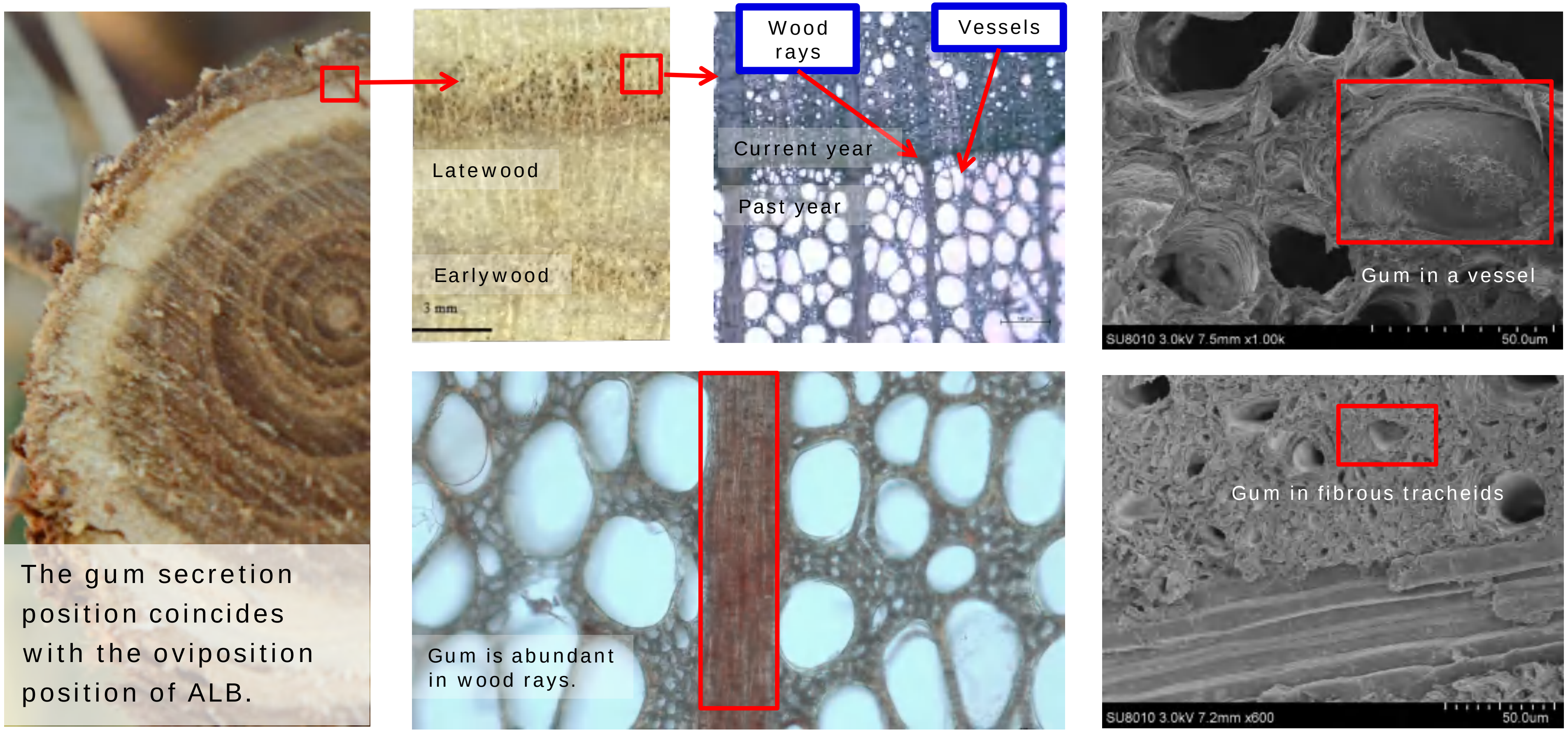
- Eggs can hatch and develop for a period of time in Russian olive wood logs that was cut down just after ALB lying eggs.
- Hypothesis: the wood logs can not secrete gum.



larvae in Russian olive segment. a. On the healthy Elaeagnus angustifolia wood segment that was cut down (2021-08-02) just after the longicorn laid eggs, the eggs could hatch into larvae and defecate. b and c. Most of larvae withered and died in the young larval stage, and a few of them could develop into middle-aged larvae (autopsy on December 14th, 2021), but all of them failed to complete the generation development. d. Comparison between Larvae in *E. angustifolia* and *P. gansuensis.*

4.3 THE REGULARITY OF GUM SECRETION

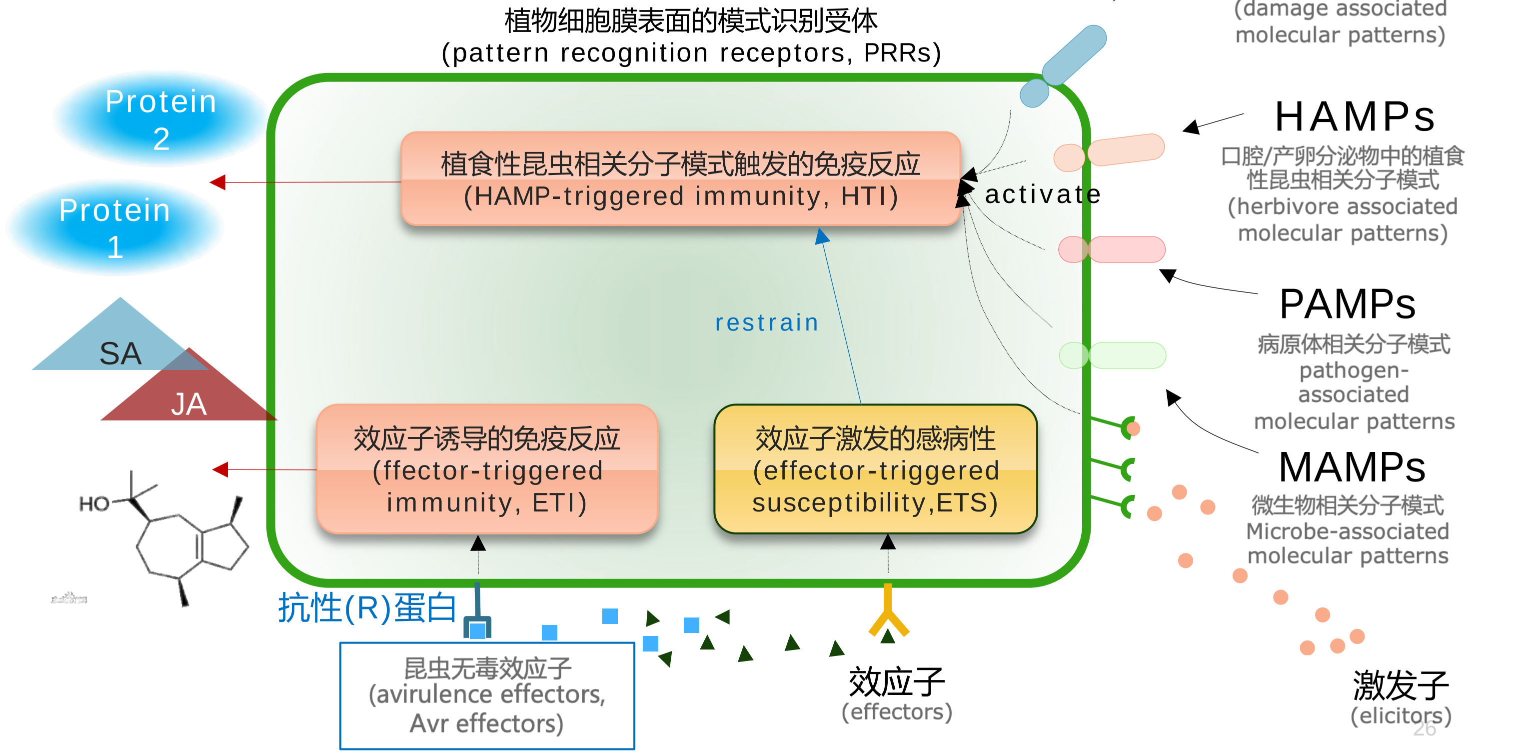
■ Gum is stored in vessels, fibrous tracheids and wood rays (secreted after mechanical trauma).



4.4 KEY FACTORS AND MODES IN MOLECULAR

■ Hypothesis: the key link of Russian olive luring and killing ALB-Russian olive immune response (gum secretion) mode.

Imaginary diagram of trigger mode of *Elaeagnus angustifolia* immune response (gum secretion)



4.4 KEY FACTORS AND MODES IN MOLECULAR

- ✓ We have reached cooperation with *Professor Shen Xiang of Shandong Agricultural University* and obtained the genome and annotation of *Elaeagnus angustifolia* and *Anoplophora glabripennis*.
- ■ It can support the analysis of molecular regulation mechanism of *E. angustifolia* luring and killing *A. glabripennis*.

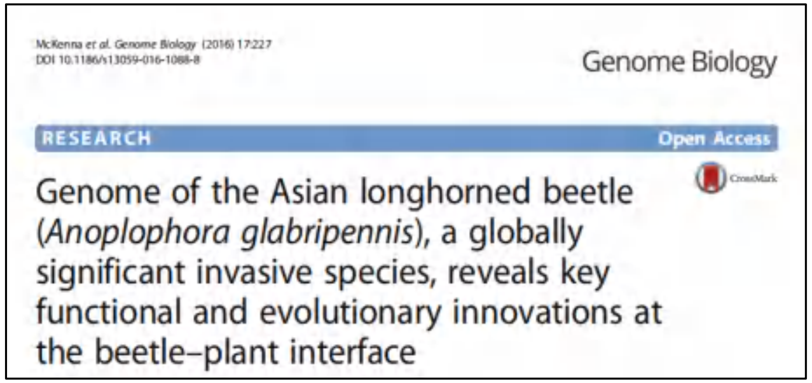
Mao et al. Plant Methods (2022) 18:84
https://doi.org/10.1186/s13007-022-00915-w

Plant Methods

RESEARCH Open Access

De novo assembly provides new insights into the evolution of *Elaeagnus angustifolia* L.

Yunfei Mao[1], Xueli Cui[1], Haiyan Wang[1], Xin Qin[1], Yangbo Liu[1], Yijun Yin[1], Xiafei Su[1], Juan Tang[2], Fengling Wang[2], Fengwang Ma[3], Naibin Duan[4], Donglin Zhang[5], Yanli Hu[1], Wenli Wang[1], Shaochong Wei[1], Xiaoliu Chen[1], Zhiquan Mao[1], Xuesen Chen[1] and Xiang Shen[1*]

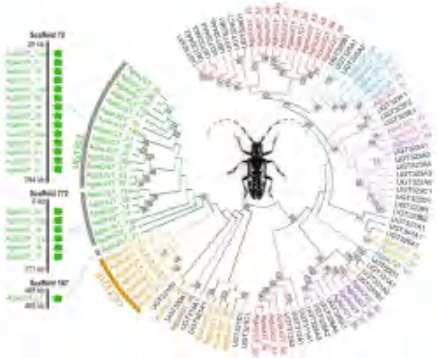


McKenna et al. Genome Biology (2016) 17:227
DOI 10.1186/s13059-016-1088-8

Genome Biology

RESEARCH Open Access

Genome of the Asian longhorned beetle (*Anoplophora glabripennis*), a globally significant invasive species, reveals key functional and evolutionary innovations at the beetle–plant interface

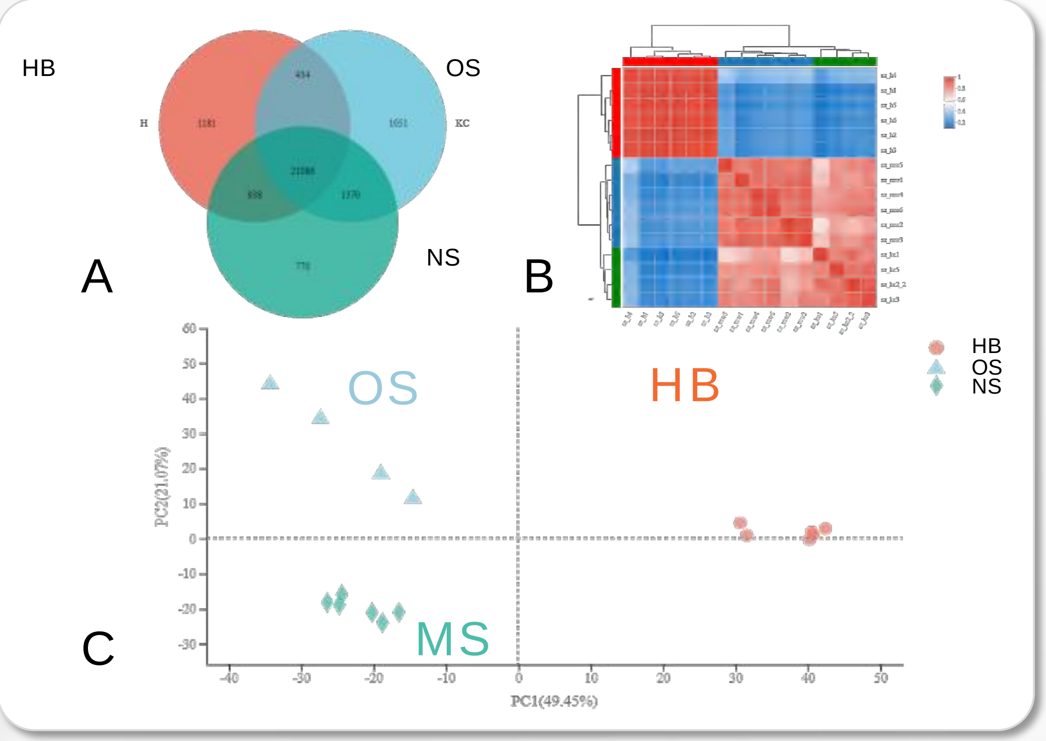


Phylogenetic tree of *Anoplophora glabripennis*

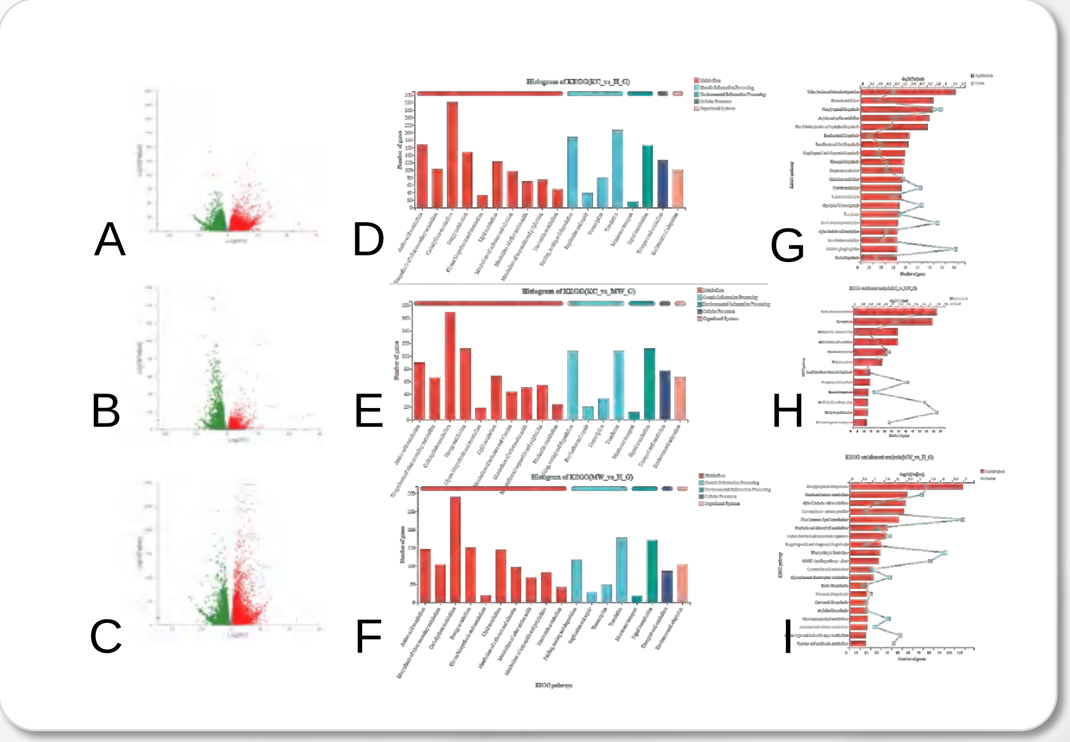
4.4 KEY FACTORS AND MODES IN MOLECULAR

- We measured transcription of three groups (HB, OS and MS) of groups, and found that the differences of gene expression mainly annotated in signal transduction, protein, sugar synthesis and metabolism, and stress resistance.

HB: Health branch. OS: Oviposition scar. MS: Mechanical scar.



Gene expression between samples. A.Venn analysis; B. Correlation analysis; C. PCA analysis.

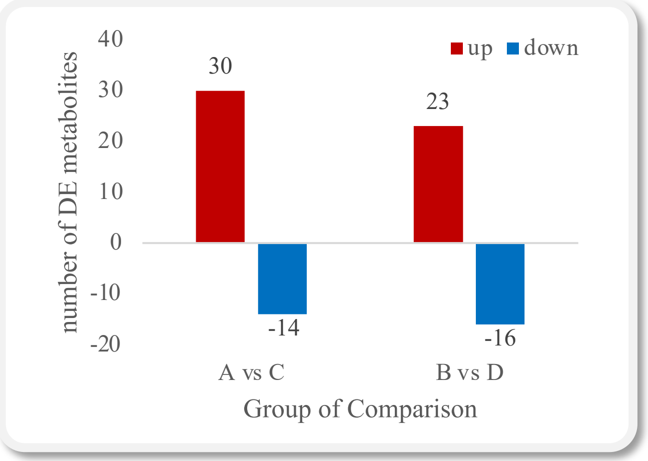


A-C. volcano map of differential gene expression, B-D. KEGG annotation analysis of differential gene function; G-I.KEGG enrichment analysis (A/D/G: OS vs HB, B/E/H: OS vs NS, C/F/I: NS vs HB)

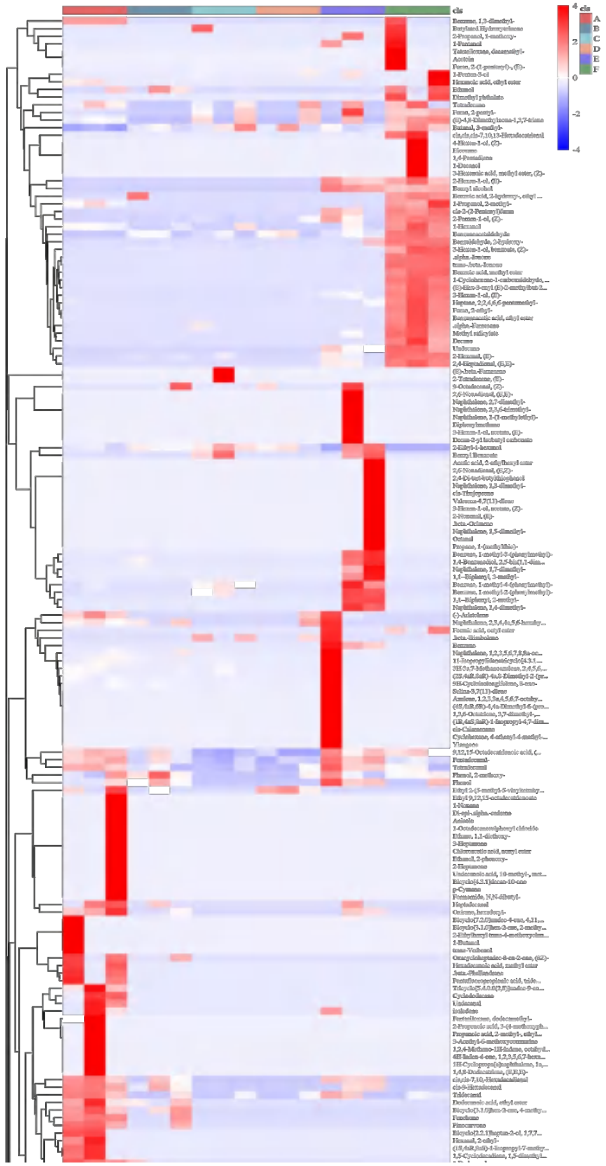
4.5 VARIATION OF METABOLITES IN WOOD TISSUES INFESTED WITH ALB

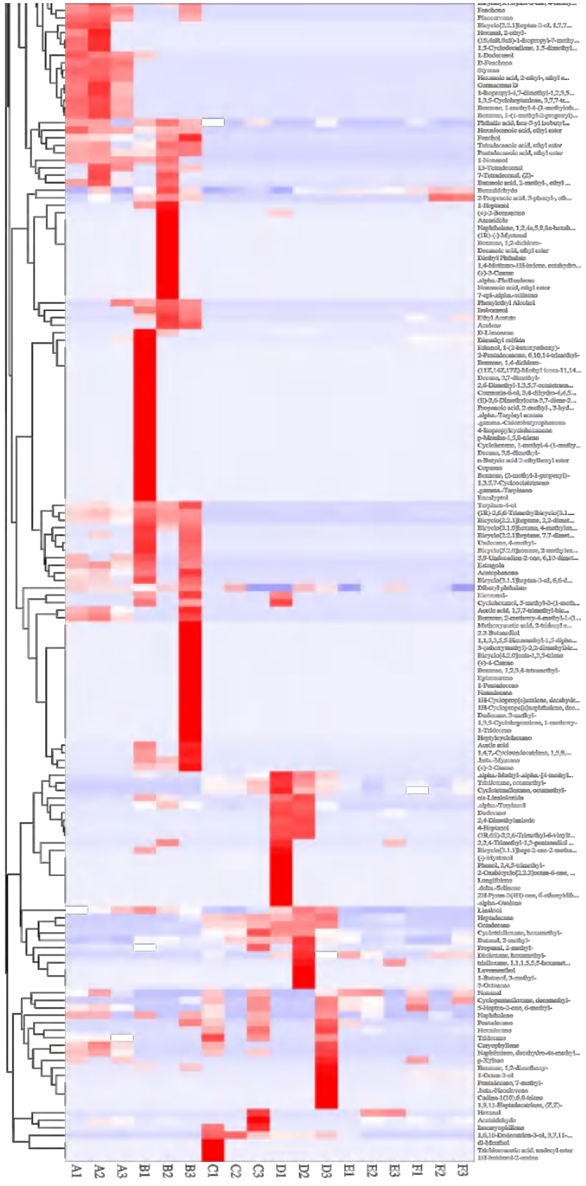
4.5.1 Volatile metabolites between oviposition and healthy tissue

- To understand the accumulation pattern of volatile metabolites in the process of damage, heat map analysis was performed on the volatile metabolites detected in oviposition xylem (A), oviposition phloem (B), healthy xylem (C) and healthy phloem (D).
- 30 and 23 substances with significant differences between A–C and B–D were up–regulated, and 14 and 16 substances were down–regulated. Among them, 11 substances were up–regulated and 9 substances were down–regulated, respectively.
- Among them, (1R)–(+)–α pinene , (–) –camphene , ethyl palmitate (control of pine wood nematode disease) showed significant difference between damaged and healthy tissues.



Substances regulated in healthy and damaged tissue

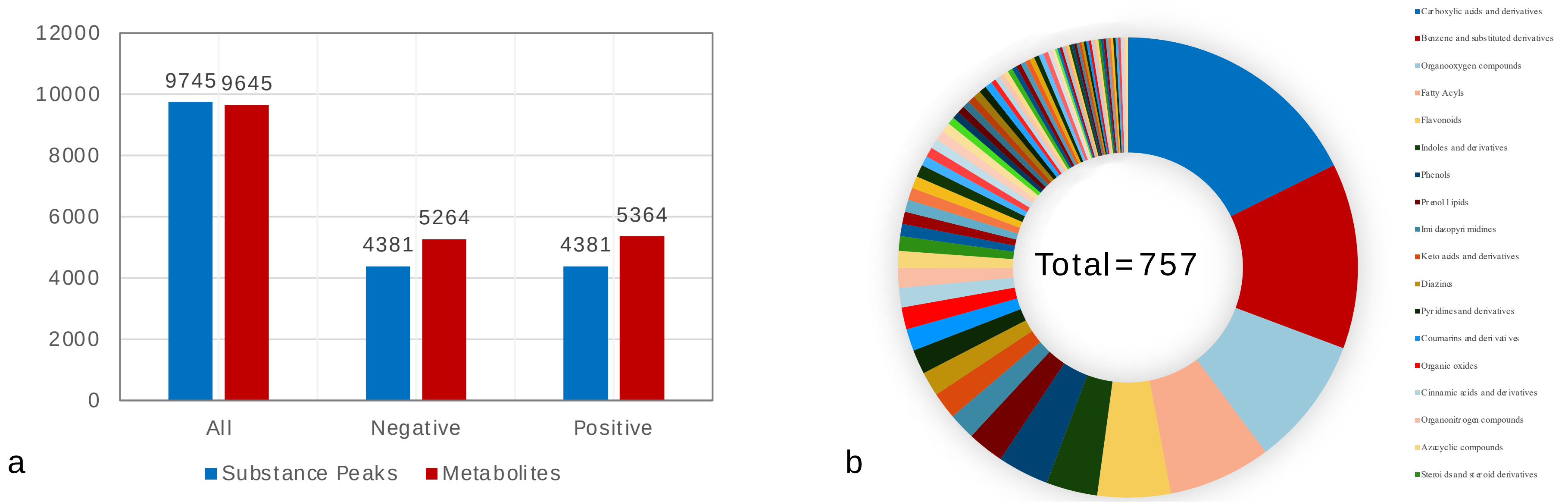




4.5 VARIATION OF METABOLITES IN WOOD TISSUES INFESTED WITH ALB

4.5.2 Metabolite Analysis of ALB scars (OS) and artificial scars (MS)

- These metabolites were grouped into 83 groups, including Carboxylic acids and carboxylic acid derivatives (17.67%), benzene and benzene derivatives (13.04%), organic oxygen compounds (9.09%), fatty acyl groups (7.20%), flavonoids (5.14%)



沙枣受害部木材组织所鉴定的代谢物分类统计。a. 化合物峰值和代谢物的统计图；b. 代谢物分类环形图。

4.5 VARIATION OF METABOLITES IN WOOD TISSUES INFESTED WITH ALB

4.5.3 Phytohormones and derivatives related to insect resistance of OS and MS

- A total of 9 plant hormones and derivatives were screened: Salicylic acid、Salicyl alcohol、Salicin、Methyl jasmonate、Jasmone、Abscisic acid glucose ester、(S)-Abscisic acid、(-)-Jasmonic acid、(+)-7-Isojasmonic acid
- b. Jasmone**茉莉酮**、d. Methyl jasmonate**茉莉酸甲酯**、e. Salicyl alcohol（**水杨醇**）、f. Abscisic acid glucose ester（**脱落酸葡萄糖酯**）、i. (+)-7-Isojasmonic acid（(+)-7-**异黄酮酸**）showed significant differences.
- The relative amounts of significantly different phytohormones and their derivatives in each type of scars were less than in healthy tissue, except for Methyl jasmonate in OS in the fifth day.

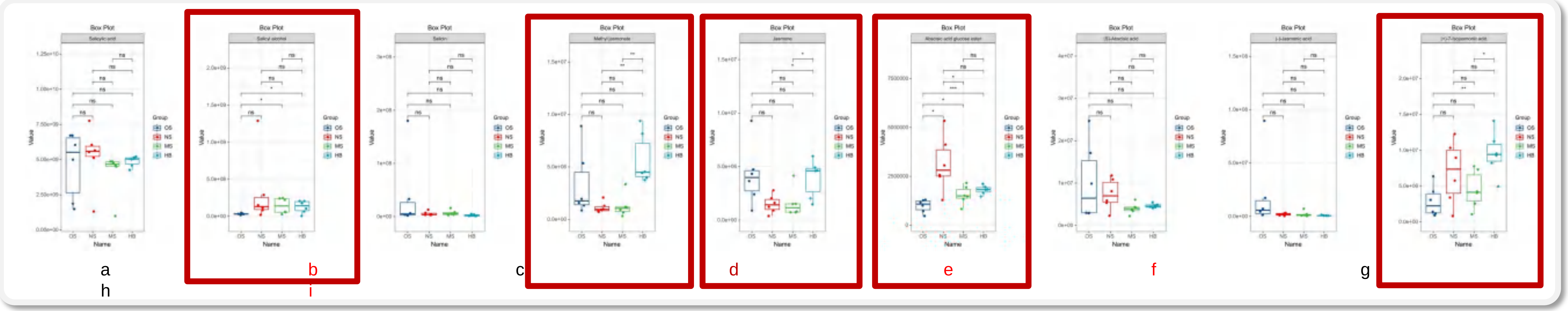


图. OS-MS-NS-HB中Salicylic acid、Salicyl alcohol、Salicin、Methyl jasmonate、Jasmone、Abscisic acid glucose ester、(S)-Abscisic acid、(-)-Jasmonic acid、(+)-7-Isojasmonic acid含量箱线图，*代表p-value (T-test)。

More data is currently under analysis...

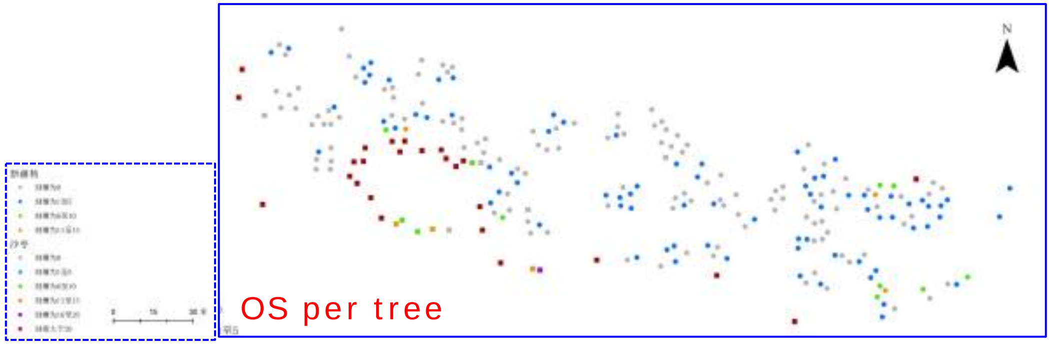
FIELD STUDY SITE

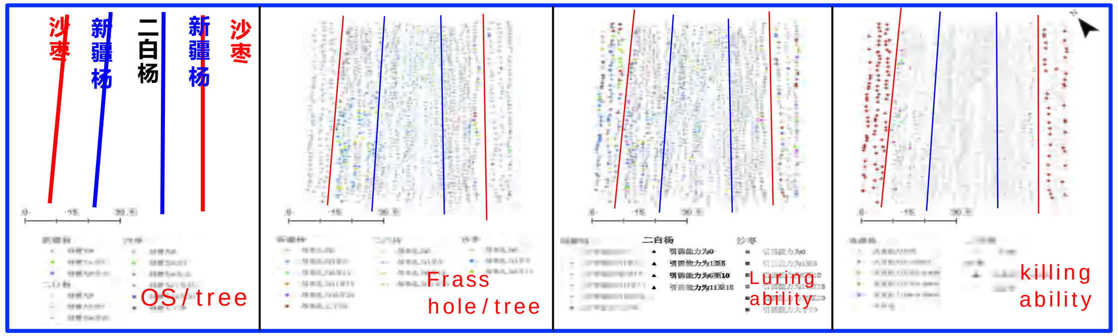
- The sample site is a mixed poplar (*Populus gansuensis*)-Russian Olive (*Elaeagnus angustifolia*) and Tamarix（ *Tamarix ramosissima* ） plantation, all transplanted in 2014.
- Plantations irrigated and infested with ALB.
- The Russian Olive are 12-15 years old, robust, with average trunk diameter of about 10 cm, and partially infested with ALB..

FIELD APPLICAITON

Rational planting strategy and arrangement of Russian Olive to restrain the ALB population under outbreak:

- **Landscaping:**
  - **Planting method: patch planting;** *Populus alba* var. *pyramidalis* ：*Elaeagnus angustifolia* = **7:3**.
- **Shelterbelt :**
  - **Planting method:** The distribution of *Elaeagnus angustifolia* is not less than 20% in the same row.





TO BE DISCUSSED

- Wether *Elaeagnus angustifolia* （Russian Oliva） is distributed in Europe?
  - Described as: is a species of Elaeagnus, native to western and central Asia, Iran, from southern Russia and Kazakhstan to Turkey, parts of Pakistan and parts of India.
  - It is present in central Europe though the exact western limits of its native range are open to speculation. (CABI).
- Possibility of using Russian Oliva as control methods for invasive ALB in Europe.

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THANKS FOR YOUR ATTENTION