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Biological control of insect pests in litchi orchards in China

Dun-Song Li [a,c,*], Chunyan Liao [b], Bao-Xin Zhang [a,c], Zi-Wei Song [a,c]

[a] Plant Protection Research Institute, Guangdong Academy of Agricultural Sciences, Guangzhou, China
[b] Entomology and Sustainable Ecosystems (formerly), CSIRO, Black Mountain, Canberra, 2601, Australia
[c] Guangdong Provincial Key Laboratory of High Technology for Plant Protection, Guangzhou, China

HIGHLIGHTS

- Litchi stink bug is the most significant pest in litchi and longan orchards.
- *Anastatus japonicas* is an efficient enemy of *Tessaratoma papillosa*.
- *A. japonicus* has been mass reared and successful used as a biocontrol agent.
- Many factors constraint the utilization of *A. japonicas*.

GRAPHICAL ABSTRACT

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ABSTRACT

This paper describes the current state of the biological control of insect pests in litchi orchards in China. Litchi is growing in importance as a fruit in China and the control of litchi stink bug, *Tessaratoma papillosa* (Drury) (Hemiptera: Pentatomidae) by the solitary egg endoparasitoid *Anastatus japonicus* (Ashmead) (Hymenoptera: Eulophidae) is an example of successful classical biological control. This review will cover the current economic status of litchi production in China, the challenges faced in litchi pest management, and possible solutions. The review will also focus on research activities and experiences drawn from many years of experimentation and field work by researchers in an attempt to promote biological control and reduce insecticide use to produce healthier food and a safer environment. Studies on the biology and ecology of *T. papillosa* and its egg parasitoid *A. japonicas* will be summarized. The adult longevity and long oviposition period, in combination with the short life cycle, high fecundity, and resistance to harsh environmental conditions make this parasitoid ideal for biological control. The straightforwardness of mass-rearing and easy access to high quality factitious host eggs have made it possible to control *T. papillosa* with this parasitoid in litchi orchards over large areas in China. Both pest and parasitoid have been thoroughly studied, and *A. japonicus* has been used in the field for control since late 1960s. The introduction of techniques for mass-rearing of *A. japonicus* and the parasitoid's efficacy in controlling *T. papillosa* once released will be discussed. Finally, we will address the problems currently facing litchi pest management and the importance of conservation biological control in the development and implementation of integrated pest management (IPM).

1. Introduction

Litchi (*Litchi chinensis* Sonn.) originated in southern China and possibly northern Vietnam, and has for centuries been one of the most highly-prized fruits in south-east Asia because of its excellent flavor and rarity. It is an extremely environmentally sensitive tree that requires specific climate conditions, growing best in regions with short, dry, and cool but frost-free winters (daily maximums below 20–22 °C), and summers that are long and hot (daily maximums above 25 °C) with high rainfall (1200 mm) and high humidity (Singh, 2002). The areas in China where litchi can be grown

* Corresponding author. Address: Guangdong Provincial Key Laboratory of High Technology for Plant Protection, Guangzhou, China. Fax: +86 20 87597447.
E-mail address: dsligz@139.com (D.-S. Li).

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successfully are situated between 19°N and 24°N, covering Guangdong, Guangxi, Fujian, Hainan, and Yunnan provinces (Chen and Huang, 2004). Today, litchi cultivation is widely dispersed in the tropics and warm subtropics, in such countries as Thailand, India, South Africa, Madagascar, Mauritius, and Australia where production is steadily growing (Mitra, 2002).

Litchi cultivation in China goes back over 2000 years (Mitra, 2002), however, until the early 1980s it was grown on a relatively small scale either by individual farmers or by agricultural communes for the local market in the south of the country, and the fruit rarely reached the markets of the northern provinces. In Guangdong, the largest litchi producing province, the area under litchi cultivation was about 26,933 hectares in the early 1980s and the average annual output was about 40,000 tons between 1949 and 1982 (Huang, 2002). From the early 1980s onwards, a rapid expansion of the area under litchi cultivation occurred as a result of rural reforms and the introduction of a market economy. These policy changes enabled farmers themselves to decide what crops they would plant on the basis of economic return. Meanwhile, strong market demand stimulated a vigorous expansion of the litchi industry and this continued until the end of the 1990s (Huang, 2002; Ye et al., 2011). During the 1990s, corporations began investing in litchi plantations and some of these now cover hundreds of hectares (Huang, 2002).

China accounts for 50% of world litchi production. In 2005, Chinese output was 1.4 million tons from 580,700 hectares, with Guangdong alone producing 862,000 tons (Huang, 2007). In 2008, Chinese production increased to 1.5 million tones, of which Guangdong contributed 913,000 tons (Ye et al., 2011). The industry is very important in terms of employment, involving about 500,000 people in China (Mitra and Pathak, 2010). In Guangdong, litchi is now the biggest fruit industry in terms of area in the province, accounting for 32% of the total area under fruit cultivation (946,527 hectares) (Huang, 2002).

It is well known that litchi can be difficult to grow, and that consistent yields are hard to obtain. Climate, irrigation, tree nutrition, unnecessary flushing and flowering, and poor fruit retention constitute the major issues for litchi production, while fruit bearing in alternate years only, and small fruit size, also reduce the return to growers (Singh, 2002). Pests, diseases, and physiological disorders are also major obstacles to achieving consistently high-quality fruit and high yields (Poo et al., 1965; Chiu and Chen, 1987; Gu et al., 2000; Singh, 2002; Huang, 2002; Hu et al., 2010; Ye et al., 2011). The damage caused by insect pests and diseases involves multiple species acting at the same time, and high pest populations prolong the period that litchi orchards are under threat (Chiu and Chen, 1987; Liu and Zhang, 1998; Ye et al., 2011). The loss caused by insect pests and diseases is compounded by poor horticultural practices such as the over-use of nitrogenous fertilizer (leading to excessive vegetation growth in winter), delayed pruning and garden cleaning after harvesting, and excessive use of insecticides (Hu et al., 2010; Ye et al., 2011).

According to Huang et al. (2005a,b), in China there are 193 species of litchi pests in two classes, 11 orders, and 57 families. The majority belong to the Lepidoptera and Coleoptera, followed by the Homoptera and Hemiptera. However, only about a dozen species are major pests which require regular control, and the species involved vary between orchards. They include fruit- and flower-borers, stem-borers, fruit-piercing moths, defoliators, sucking bugs, and erinose mites.

The litchi fruit-borers (or litchi stem-end borers) *Conopomorha sinensis* Bradley and *Conopomorha litchiella* Bradley (Lepidoptera: Gracillariidae) bore into developing fruit through the stem and then feed on the seed inside the fruit (Yu et al., 1995; Chen and Yao, 2001). Litchi longhorn beetles (also known as litchi bark-miners) *Aristobia testudo* (Voct), *Arbela dea* (Swinhoe), and *Arbela baibarana* (Mats) (Coleoptera: Longicornidae) burrow beneath the tree's bark (Tan et al., 1999; Huang et al., 2005a,b). Leaf-eating chafer beetles (Coleoptera: Scarabeidae) and chrysomelid beetles (Coleoptera: Chrysomelidae) are the primary defoliators of litchi (Pu, 1992; Huang et al., 2005a,b). Geometrid moths *Thalassodes immissaria* (Walker) and *Buzura suppressaria* (Guenée) (Lepidoptera: Geometridae), etc, cause damage when the larvae eat fresh shoots, leaves, flowers, and young fruits (Zhou and Deng, 2006; Chen et al., 2010). Litchi leaf gall midges, *Mayetiola* spp. (Diptera: Cecidomyiidae), and the eriophyid mite *Aceria litchii* (Kiefer) (Acari: Eriophyidae) cause leaf galls (known as 'erinose' galls) and leaf loss (Yu et al., 1995; Shen, 2006; Su et al., 2006). However, the commonest and most significant pest in terms of pesticide usage is the litchi stink bug, *Tessaratoma papillosa* Drury (Hemiptera: Pentatomidae). It is highly mobile, and occurs in all litchi orchards in southern China and must be closely monitored and controlled during almost the entire year (Poo, 1965, 1992; Chiu and Chen, 1987; Chen, 2009). *T. papillosa* attacks litchi during the whole year, either as over-wintering adults (January to August), as nymphs (March to June), or as newly-emerged adults (June to December). *T. papillosa* is also the most serious pest of longan, *Dimocarpus longan* (Sapindaceae), a close relative of litchi and also an important fruit crop in China (Deng et al., 1999).

It has been estimated that *T. papillosa* may account for between 20% and 30% of litchi losses in normal years, and 70–90% of losses in the worst years (Gu et al., 2000; He et al., 2001). Every year, the pest affects about 330,000 hectares litchi plantations in China, severely affecting 200,000 hectares. The total annual loss of litchi and longan to *T. papillosa* is 30,000–60,000 tons, equivalent to ¥0.2–0.4 billion (He et al., 2001).

Successful and reliable methods for controlling *T. papillosa* biologically have been available in China since the late 1960s, however, in most situations the current control strategy simply involves spraying according to a pre-determined calendar, with little monitoring. Most farmers prefer chemical spraying because it is quick and easy, and its impact is immediately visible. They believe the high price litchi fetches in the market justifies the cost of treatment. Insecticides are sprayed 13–18 times a year in some orchards, whenever insects are seen in the trees (Chiu and Chen, 1987; Huang, 2002). Such heavy insecticide use results in pollution of the surrounding environment and leaves orchards in poor condition, with degraded biodiversity and fewer natural enemies, and makes them more susceptible to outbreaks of minor pests which may reduce or completely destroy the crop in some years (Chiu and Chen, 1987; Chen et al., 2010).

In this report, we focus on the biological control of*T. papillosa*. We will summarize the research experience of the last 40 years, the development of the use of *Anastatus japonicus* (Hymenoptera: Eulophidae) as a biological agent, and the current state of biological control using this parasitoid against *T. papillosa* in southern China. Mass-rearing of *A. japonicus*, its field release, and the evaluation of its efficacy as a control agent will be discussed. We will also describe the current pest management challenges facing the litchi industry today, and we recommend the application of integrated pest management (IPM) to litchi pest management.

2. Biology and natural enemies of litchi stink bug *T. papillosa* in southern China

2.1. Distribution of T. papillosa

In southern China, *T. papillosa* occurs in Guangdong, Guangxi, Fujian, Yunnan, Geizhou, and southern Jiangxi; it also occurs in Taiwan, Vietnam, Thailand, India, Malaysia, the Philippines, Nepal,