Biological Control 68 (2014) 1–5

Contents lists available at ScienceDirect

Biological Control

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

# Biological Control in China: Past, present and future – An introduction to this special issue

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## HIGHLIGHTS

- Farmers in China started to use natural enemies in pest control before 304 AD.
- Recent progress of biocontrol in 10 major commodities in China is synthesized.
- In addition, future prospects of biological control in China are discussed.

## ARTICLE INFO

*Article history:*
Available online 2 July 2013

*Keywords:*
China biological control
Insect pests

This Special Issue was first conceived by Professor Harry Kaya, a former Editor-in-Chief of *Biological Control*. Given his years of experience as Editor-in-Chief, Professor Kaya became well aware of the recent advancements made in biological control in China as his Chinese colleagues had slowly increased their publications in Western journals in English. Nevertheless, he was also aware that much of the research was published in Chinese journals in the Chinese language – which was inaccessible to many researchers who are not native Chinese speakers. Thus, in September 2010, he proposed the idea of publishing a Special Issue on Biological Control in China. Upon getting our group on board, a formal proposal for this Special Issue was submitted and accepted by Elsevier in November 2010. Following the proposal, we began to coordinate the production of manuscripts in China from our Chinese colleagues. The invited authors were asked to provide a comprehensive analysis of the development and implementation of biological control of insect pests in a given commodity crop and further address future directions. The commodities emphasized in this issue are rice, cotton, corn, greenhouse crops, brassica, litchi, citrus, apple, tea, and forest in general. Additionally, a detailed taxonomic review of parasitic wasps and fungal biological control agents were also added to this issue.

China has a long history of entomology and the use of biological control. Chou (1980) and Zou (1981) reviewed the history of entomology in China, based primarily on descriptions in old Chinese books as well as records of and relics unearthed in archaeological studies. These records indicate that the Chinese invented sericulture before 3000 BC, started the rearing of silk worms indoors on cultured mulberry plants before 1600 BC, recorded parasitic tachinid flies of silkworms around 300 AD, and presented a description of the life cycle of a parasitic tachinid fly of silkworms in 1096 (Chou, 1980; Zou, 1981; Wang, 1985; Cai et al., 2005). Thus, it is indicated that entomology originated in China and the earliest record of insect parasitoids also came from this country (van Lenteren, 2005).

In the recorded history of biological control, the earliest example appears to be the use of ants (yellow citrus ants, *Oecophylla smaragdina*) by farmers in southern China to prevent citrus fruit tree damage, described in a book entitled *Nanfang Cao Mu Zhuang* (Vegetations of the South) by *Ji Hang* in 304 AD (Chou, 1980; Zou, 1981; Peng, 1983). Peng (1983) also presents many other early examples of biological control in China using other ants (black ants), frogs, birds (wild and domesticated) and even plants; all of which are recorded in Chinese books from 300s to 1800s. Detailed studies of insect parasitoids and other natural enemies in recent times in China seems to begin in the 1920s, as recorded in two publications on parasitoids of mulberry tree insect pests by Chu (1934a, 1934b), a pioneer scientist in the field of biological control in modern China. Research and application of biological control of

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1049-9644/$ - see front matter 
http://dx.doi.org/10.1016/j.biocontrol.2013.05.005

insect pests in China have been continuously pursued since then. Due to interruptions mainly from wars, relatively little work was done during the 1930s–1940s. Since 1950s, activities of research and application of biological control of insect pests in China have been increasing steadily (Bao and Gu, 1998; Gu et al., 2000).

In this issue, Luo Y.G. et al. highlight the biological control of insect pests of rice paddy in China, a commodity that makes up the staple food to over 1.3 billion people in China thus making China to be one of the largest producers of rice in the world. Following the promulgation of "prevention first and then integrated control" as the national policy for plant protection by the Chinese Ministry of Agriculture in 1975, more effort and support was given to survey natural enemies and increase biological control in agricultural production. Due to its overarching importance of rice in China, the first nation-wide survey of natural enemies was conducted in the rice paddy fields from late 1970s to 1980s. Over 1300 species of natural enemies were recorded, and a dozen or so species have been well studied with regard to their biology and efficacy as biocontrol agents. Effort in enhancing conservation biological control as the core element of integrated pest management (IPM) in rice was initiated in early 1970s and has been pursued since then with varying degrees of success in a few localities of some rice-producing provinces particularly in Guangdong and Zhejiang. More recently, the concept of ecological engineering has been incorporated into rice IPM projects to further enhance roles of natural enemies in a sustainable manner. Long-term field implementation of biocontrol-based rice IPM in several rice ecosystems in southern China has shown that compared to chemical control-oriented management strategies, input of chemical insecticides can be reduced by 80% with no risk of loss in crop yield.

Cotton is another commodity most widely cultivated in China, thus ranking the country to be one of the largest cotton producers in the world in recent years. The control measures in the past six decades have ranged from chemical to non-chemical based measures, followed by region wide IPM systems with transgenic Bt cotton and conservation biological control as the core elements (Wu and Guo, 2005). Luo S.P. et al. in this issue analyze the role of natural enemies and conservation biological control in cotton when incorporated into IPM systems. Insect pest control though heavily was chemical based from 1950s to 1970s, remained so until 1990's despite the apparent acceptance of the IPM concept in the country and records of hundreds of species of natural enemies of cotton insect pests from 1970s onwards. In the early 1990s, serious chemical control failures began to occur in many areas and efforts to increase use of biological control agents through both augmentative and conservation measures received more and more attention. A revolutionary change in cotton insect pest control has occurred since 1997 with the rapid increase of adoption of Bt cotton. The drastic, widespread decreases in populations of major lepidopteran pests brought about by Bt cotton have greatly reduced the use of chemical insecticides, which in turn enhanced the diversity and efficacy of natural enemies in the cotton and nearby non-cotton fields, particularly those attacking pests that are not targeted by Bt cotton such as aphids (Lu et al., 2012). The promotion of regional biocontrol service brought about by decreases of insecticides helped to increase the stability of cotton ecosystems and eventually cotton production in China.

A review by Wang Z.Y., et al. address the corn insect pests. While rice is the most important food crop in China, corn is ranked the first food crop in "planting area" and second in total yield. One of the most outstanding achievements in biological control in China in the last several decades is the large scale mass rearing and release of *Trichogramma* wasps against insect pests, and this success has been associated mainly with control of corn insect pests. Although the pioneering work of using large, factitious insect eggs (e.g., eggs of the eri-silkworm, *Philosamia cynthia ricini*) for the mass rearing of *Trichogramma* wasps was conducted in the south against lepidopteran insect pests of sugar cane in the 1950s (Bao and Gu, 1998; Gu et al., 2000), this idea was soon adopted in the research of mass rearing of *Trichogramma* wasps against the Asian corn borer, *Ostrinia furnacalis*, in corn in the north. In the 1970s, two *Trichogramma* species, *Trichogramma dendrolimi* and *Trichogramma chilonis*, were found to be particularly suited to mass-rearing with the eggs of the oak silkworm, *Antheraea pernyi*. Cost-effective rearing systems of *Trichogramma* with oak silkworm eggs were developed in 1980s–1990s, and still continue to date. This technology has exerted a most extensive impact in northeast China including the three provinces of Heilongjiang, Jilin and Liaoning. In recent years, the area of corn crops under management through the release of *Trichogramma* in northeast China has increased, reaching to 218 and 266 million ha in 2011 and 2012 respectively, according to the official statistics issued by the agriculture departments of the three provinces. In many locations, consecutive releases of *Trichogramma* year after year not only have offered good control of the insect pests in the years of release, but also have increased the diversity and abundance of natural enemies and enhanced the natural control at the regional level.

"Protected crop production" under greenhouses has increased dramatically in China in the last three decades, reaching up to 4.7 million ha by 2010, 95% of which are under vegetable cultivation. The greenhouses in China exhibit a remarkable diversity of structures, mainly depending on the geographic regions, and over 80% of them provide only semi-closed environments. Yang N.W. et al. take a look at the development and application of biological control of insect pests in greenhouse vegetable production in China. Biological control of insect pests in greenhouses in China began in the 1970s with the first introductions of *Encarsia formosa* and *Phytoseiulus persimilis* from the United Kingdom and Sweden for the control of greenhouse whitefly and spider mites in northern China. In the last three decades, with the rapid increase of protected crop cultivation, the diversity of insect pests has evolved but is always dominated by four groups of sucking insects including whiteflies, aphids, spider mites and thrips. Meanwhile, a dozen or so species of predators including predatory mites, ladybird beetles, stinkbugs and lacewings as well as several species of parasitoids in the families Aphelinidae and Aphidiidae have been successfully studied as potential candidates for use in greenhouses. Several others such as *Amblyseius cucumeris* and*Encarsia formosa* have been mass reared for commercial releases at varying scales in different locations. However, as a whole, augmentative biological control has not yet played a significant role in the insect pest control in greenhouses in China. This situation contrasts with that in the Netherlands where 90% of greenhouse vegetable production has been under an IPM system with use of augmentative biological control as the core component, as well as that in southern Spain where 20,000 ha of greenhouses are now routinely using biological control (Pilkington et al., 2010). Apparently augmentative biological control in China is a very profitable field to be explored in the years to come.

Liu et al. concentrate on the IPM practices in *Brassica* crops in China. Brassicas constitute the major group of vegetable crops in China particularly in the open field, accounting for 30–45% of all vegetable crops based on the region. In 2008, the area under brassica cultivation was over 4 million ha. The control of insect pests on brassica crops has largely relied on heavy use of chemical insecticides. Despite this, surveys in various regions indicated existence of a wide diversity of predators and parasitoids, many of which were shown to have great potential as biocontrol agents for the key pests such as the diamondback moth, *Plutella xylostella*, the cabbage white butterfly, *Pieris rapae*, and aphids. Efforts were then made in several areas to develop practical IPM systems with conservation biological control as the cornerstone. The results gener-