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Taxonomy of parasitoid wasps in China: An overview

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HIGHLIGHTS

- We outline the taxonomic studies on parasitoid wasps in China for the first time.
- We provide a brief history of the studies of parasitoid wasps in China.
- We list the people, institutions and taxonomic groups involved in China.

GRAPHICAL ABSTRACT

Species of parasitoids known in China

Superfamily	family	Worldwide		China	
		genus	species	genus	species
Ichneumonoidea	Braconidae	1040+	18580+	256	1892
	Ichneumonidae	1547	23770+	320	1860+
Chalcidoidea	Aphelinidae	35	1160	15	220
	Chalcididae	85+	1455+	15	62
	Encyrtidae	460	3600	123	406
	Eulophidae	300+	4300+	54	341
	Eupelmidae	45+	965+	9	40
	Mymaridae	95+	1400+	25	130
	Mymarommatidae	1	10	1	1
	Pteromalidae	640	3450	98	372
	Tanaostigmatidae	9	90	1	1
	Trichogrammatidae	80	840+	45	170
Platygastroidea	Scelionidae	160	3000	2	34
Proctotrupoidea	Heloridae	1	12	1	2
	Proctorenyxidae	1	2	1	1
	Proctotrupidae	28	363	18	82
	Roproniidae	2	24	2	17
	Vanhorniidae	3	5	1	1
Ceraphronoidea	Megaspilidae	12	450	1	3
Diaprioidea	Diapriidae	150	2300	6	10
Trigonaloidea	Trigonalidae	15	90	6	18
Megalyroidea	Megalyridae	8	45	2	2
Evanioidea	Evaniidae	20	400	5	15
	Aulacidae	3	200	2	18
	Gasteruptiidae	9	500	1	5
Stephanioidea	Stephanidae	11	345	5	20
Chrysidoidea	Bethylidae	100	2400	10	51
	Chrysididae		3000		7
	Dryinidae		1400	16	214
	Sclerogibbidae	7	20	1	1
	Scolebythidae	9	13	1	1
	Embolemidae	2	33	2	6

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ABSTRACT

The parasitoid Hymenoptera are one of the most important groups of natural enemies of agriculture and forestry pests and have been used as biological control agents in IPM programs for a long time. The systematic research on parasitoids and their associations with hosts lays a solid base for biological control of pests. Here we summarize the taxonomic studies undertaken on the parasitoid wasps in China in the last eight decades. At present about 48 families in 12 superfamilies of parasitoid Hymenoptera are known in China, of which the majority of the families have been studied to some extent while a number of them are still poorly studied. Around 6000 species of 32 families which dealt with in this paper are known in China, and some of them have been successfully and widely used in the existing biological control while others are potentially useful in future biocontrol program. This overview provides the international audience a general idea about the current state of the systematic study of parasitoid Hymenoptera conducted in China, the known species of parasitoids and the native and introduced species used in biocontrol in China.

1. Introduction

Biologically China is one of the megadiverse regions of the world, lying in two of the world's major ecozones, the Palaearctic and Oriental regions, in term of numbers of endemic plant and animal species (Shi et al., 2005). This is reflected in the insect fauna of China in general and also in its parasitoid Hymenoptera or parasitoid wasps in particular (Chen, 1997; Chen et al., 2000a). The term parasitoid Hymenoptera or parasitoid wasp refers to a large evolutionary grade of hymenopteran superfamilies, mainly in the Apocrita, a group of insects that is both taxonomically and biologically poorly defined, despite the fact that members of the group utilize a parasitic lifestyle, that is, they parasitize other animals, mostly other arthropods. Many of them, such as the family Braconidae, are considered beneficial to humans because they are the very important agents in successful programs for the biological control of phytophagous insect pests.

However, compared with some other regions of the world, the comprehensive study of the Chinese parasitoid Hymenoptera began recently, but accelerated in the last several decades. The aim of this paper is (1) to outline the taxonomic studies undertaken on the parasitic wasps of China, (2) document the people, institutions and taxonomic groups involved in the effort, and (3) provide

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selected examples of the use of Chinese parasitoid wasps in biological control.

2. Brief history of parasitoid taxonomy in China

The multi-volume monograph "Hymenopterorum Catalogus" (Shenefelt et al., 1969, 1970a,b; Shenefelt, 1972, 1973a,b, 1974, 1975, 1978; Shenefelt and Marsh, 1976) clearly shows that the majority of studies on parasitoid wasps of China prior to the 1970's were undertaken by foreign experts, and that those by Chinese taxonomists mostly started more recently. However, there are some notable exceptions. Chu Joo-Tso, Li Feng-Swen and Chin Shin-Foon [=Zhao Shan-huan] are among the earlier pioneers who studied the parasitoids of agricultural pests for biological control in China. During 1933–1937 Chu published a series of papers on the parasitoids of agricultural and forestry pests, such as the rice skipper *Parnara guttata* Bremer & Grey, the Cabbage White *Pieris rapae* L. and the Masson pine caterpillar *Dendrolimus punctatus* Walker (Lepidoptera), and insect pests of Chinese mulberry *Morus alba* L. (Chu, 1935, 1936). Li (1935) published on the parasitoids of cotton pests, and Chin (1937) focused on the parasitoids of one of the insect pests of rice, the rice yellow stemborer *Scrirpophaga incertulas* (Walker) (Lepidoptera).

During the 1940's to 1960's, little work was undertaken on parasitoids in China. However, two authors of this time deserve mention. One is Hsich Sun-Yun [=Xia Songyun], who continued some preliminary work on parasitoid Hymenoptera attacking important pests of rice in Hunan province, China (Hsich, 1957). The other is Chao Hsiu-Fu [=Zhao Xiufu], who started a systematic study on the subfamily Doryctinae of Braconidae, mainly the genera *Spathius* and *Platyspathius* (Chao, 1957; Chao and Chen, 1965) and continued these studies into the 1970's (Chao, 1977, 1978).

It was during the 1970's that research on biological control and associated studies on parasitoid Hymenoptera began in earnest. In the early part of this decade Chu & He published a series of four papers dealing with the identification of parasitoids of rice pests (Chu and He, 1973; Chu et al., 1976). In 1978, a book entitled "Atlas of natural enemies of economic insects" was published. This was the first publication that enabled workers to identify common species of natural enemies, both parasitoids and predators, in China. Soon after, the book "Atlas of natural enemies of rice pests in Zhejiang province, China" edited by He (1979a) was published. During this time and into the early 1980's several other provinces published similar studies dealing with natural enemies. Concurrently, a large number of individual papers on the biology of natural enemies appeared. In 1986 a general book "Atlas of natural enemies of rice pests in China" edited by He and Pang (1986) was published. As a result of these publications substantial information on common species of natural enemies was documented that greatly encouraged the systematic studies of parasitoids in China.

In 1973, a meeting sponsored by the Chinese Academy of Sciences was held to plan and coordinate studies on the taxonomy of the Chinese parasitoids under the frame of the long-term project "Fauna Sinica". This led to the publications of four volumes of "Economic Insect Fauna of China" on Chalcidoidea (I), Pteromalidae, Ichneumonidae and Sphecidae, respectively, in the following two decades (Liao et al., 1987; Huang, 1993; He et al., 1996a; Wu and Zhou, 1996). In 1992, these series were replaced by "Fauna Sinica", and presently four volumes on Braconidae (I), Dryinidae, Braconidae (II), Pteromalidae and Braconidae-Agathidinae, respectively, have been published (He et al., 2000; He and Xu, 2002; Chen et al., 2004b; Huang and Xiao, 2005; Chen and Yang, 2006a).

Since the resumption of recruiting graduate students in 1978 to undertake advanced studies on biological control and insect systematics, more than twenty students have completed their master and Ph.D. theses on the systematics of parasitic Hymenoptera. The first MS and Ph.D. degrees were conferred to graduates who majored in the systematics of parasitoids in 1984 and 1989 by Zhejiang University and Institute of Zoology, the Chinese Academy of Sciences, respectively.

The collections of parasitic Hymenoptera are also growing in the country. The Zhejiang University in Hangzhou, the Institute of Zoology of the Chinese Academy of Sciences in Beijing, the Taiwan Agricultural Research Institute in Taichung and the Fujian Agriculture and Forestry University in Fuzhou are the four leading institutions paying special attention to building collections of parasitoid Hymenoptera of China. The total number of pinned specimens in the four collections may exceed two million specimens. The Shanghai Entomological Museum of the Chinese Academy of Sciences in Shanghai, the South China Agricultural University in Guangzhou, the Hunan Agricultural University in Changsa, the Northwest A&F University in Yangling, and the Sun Yat-sen University in Guangzhou also have moderately large collections of parasitoid Hymenoptera.

3. Taxonomic studies

Historically, the classification system of Hymenoptera included two divisions or infraorders within the suborder Apocrita: one of these is the "Parasitica" containing the parasitoid wasps (with an exception of a few groups containing phytophagous species, mainly living in galls). The superfamilies united in the "Parasitica" are: Ceraphronoidea, Chalcidoidea, Cynipoidea, Diaprioidea, Evanioidea, Ichneumonoidea, Megalyroidea, Mymarommatoidea [= Serphitoidea], Platygastroidea, Proctotrupoidea, Stephanoidea and Trigonaloidea (Sharkey, 2007; Sharkey et al., 2012). Other than the "Parasitica", there are a few Apocrita that are also sometimes called "parasitic wasps": most of the members of the superfamily Chrysidoidea, as well as part of the families of superfamily Vespoidea. Most of these groups are ectoparasitoids. Among the sawflies or Symphyta, which are not Apocrita, there is only one small parasitic family, Orussidae. This is the Apocrita's closest living relative. It thus appears that the ancestors of ants and bees were parasitoids too (Gauld and Bolton, 1988; He et al., 1999).

In the account given below, a brief treatment is given on the significant families of parasitic Hymenoptera in China.

3.1. Ichneumonoidea

Ichneumonoidea is the largest superfamily within Hymenoptera and most of its members develop on other arthropods, especially the immature stages of other insects (Gauld and Bolton, 1988; Wahl and Sharkey, 1993). The superfamily includes two extant families, Ichneumonidae and Braconidae (Sharkey and Wahl, 1992; He et al., 1999).

The Braconidae is one of the most species-rich families of parasitic insects and the second largest of the Hymenoptera with 1040+ genera and 18,580+ species known in the world and 256 genera and 1892 species known to China (Yu et al., 2012). Nearly all braconids are primary parasitoids on other insects, especially upon the larval stages of Coleoptera, Diptera, and Lepidoptera. Parasitism of adult insects, especially of Hemiptera and Coleoptera, is also known (Shaw and Huddleston, 1991; Wharton, 1993).

He Jun-hua, Chen Xue-xin and their colleagues in Zhejiang University, Hangzhou have been engaged in the study of the Chinese braconids for a long time and published a number of papers (Chai et al., 2011; Chen, 1991; Chen and He, 1991, 1992a,b, 1996a,b, 1997; Chen et al., 1987, 1991, 1992b, 1993, 1994, 1997, 1998, 2000b; 2001a,b,c,d,e, 2002a,b,c, 2004a,b,c; Chen and van Achterberg, 1997a,b; Chen and Whitfield, 2002, 2003; He,