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A survey of parasitoid species within *Eriogyna pyretorum* (Lepidoptera: Saturniidae) in Fuzhou Region of China

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A survey of parasitoid species within *Eriogyna pyretorum* (Lepidoptera, Saturniidae) in Fuzhou Region of China

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Abstract

Eriogyna pyretorum Westwood is a notorious defoliator of *Cinnamomum camphora* (L.) J. Presl that causes large economic and ecological losses in planted forests. To understand the importance of suppress population of *E. pyretorum* on natural parasitoids, a three-years investigation was conducted in the field. Four parasitoid species were identified from *E. pyretorum*: *Gregopimpla himalayensis* (Cameron, 1899), *Theronia depressa* (Gupta, 1962), *Xanthopimpla konowi* (Krieger, 1899) and *Kriechbaumerella longiscutellaris* Qian et He. Both *G. himalayensis* and *T. depressa* are reported for the first time as parasitoid wasps of *E. pyretorum*. Parasitism rates were 18.76% for *K. longiscutellaris*, 2.10% for *G. himalayensis*, 7.55% for *T. depressa*, and 0.83% for *X. konowi*. Longevity, offspring, and sex ratio were compared in four hymenopteran species, and *K. longiscutellaris* was the most abundant parasitoid of *E. pyretorum* in Fujian Province.

Keywords: biocontrol, biological characteristics, parasitism rate, parasite, pests, silkworm

Introduction

Cinnamomum camphora (L.) J. Presl (Laurales: Lauraceae) is widely cultivated in South China as an ornamental avenue tree because it has a good shape, rapid growth and can purify air, reduce air and noise pollution, and maintain soil and water (Xiang et al. 2020). In addition, crude camphor extract from branches, leaves, and roots of *C. camphora* can be used as an insecticide or anticorrosive material (Yakefu et al. 2018; Tian et al. 2021). However, global climate change and rapid urbanization have facilitated the spread of pests, resulting in serious challenges to the biological security of China (Xiang et al. 2020).

Currently, several defoliators are damaging *C. camphora*, including *Pagiophloeus tsushimanus* (Chen et al. 2021, Samartsev et al. 2021), *Orthaga achatina* (Yan et al. 2018), and *Eriogyna pyretorum* (Yin et al. 2008). Among these pests, *E. pyretorum* causes serious damage to *C. camphora*, primarily by larvae feeding on leaves, which decreases photosynthesis and seriously affects normal tree growth and development (Zhou et al. 2021). Beta-cypermethrin and other insecticides can achieve 91.3% control of *E. pyretorum* larvae (Yin et al. 2008). However, chemical insecticides can negatively affect the environment by causing death of natural enemies and resistance in pests and leaving insecticide residues (Naqqash et al. 2016), so it is very important to find natural enemies that can control *E. pyretorum*. Research on natural enemies of *E. pyretorum* remains limited, and little is known about the species and their biological characteristics (Yin et al. 2008; Zhou et al. 2021). Therefore, *E. pyretorum* were collected in the field and then reared in the lab to obtain natural parasitoid enemies. Biological characteristics of these parasitoids were examined in order to preliminarily assess its potential for release as a biological control agent.

Materials and methods

Larvae and pupae (56 and 667, respectively) of *E. pyretorum* were collected in Fuzhou, Fujian Province, China, from January 2019 to December 2021; geographic and vegetation information are presented in Table 1. Larvae were reared at 24 ± 1°C and 60% ± 10% relative humidity (**R.H.**) on a daily supply of fresh leaves of *C. camphora* in rearing boxes (18 × 11 × 6 cm) until pupation. Then, samples were placed in an insectary to collect parasitoids.

After emergence, parasitoids were fed 30% honey solution in an artificial climate chamber (MGC-300H, Shanghai Yiheng Co., Ltd., Shanghai, China) at 24 ± 1°C and

60% ± 10% R.H. Adult parasitoids and exit holes were photographed with an SLR camera. Specimens were stored in 80% alcohol and then preliminarily identified according to the Qian et al. (1987), He (2004), and Yang and Chen (2018).

During the rearing process (24 ± 1°C and 60% ± 10% R.H.), after adults emerged, events such as the time of adults leaving from exit holes, male courtship, adults mating, and female ovipositing into the host were recorded. In addition, oviposition behavior was observed and the oviposition stages recorded. The number of offspring was recorded every day, distinguishing between male and female by the absence or presence of an ovipositor, number of offspring per pupa, and longevity of parasitoid wasps were recorded. Parasitism rate, offspring, and adult longevity were calculated as the mean ± standard deviation.

Results

In total, 723 *E. pyretorum* (56 larvae and 667 pupae) were collected in the field, of which 144 samples were parasitized. Three species of parasitoids were identified: *Gregopimpla himalayensis* (Cameron, 1899) (Fig. 1A), parasitized host stage is the larva and parasitoid emerging stage is pupa (Fig. 1B); *Theronia depressa* (Gupta, 1962) (Fig. 1C); *Xanthopimpla konowi* (Krieger, 1899) (Fig. 1E); and *Kriechbaumerella longiscutellaris* Qian et He (Fig. 1G) are pupal parasitoids (Fig. 1D, F, H). *Gregopimpla himalayensis* and *T. depressa* were new parasitoid recorded within *E. pyretorum*.

The wasp *G. himalayensis* parasitized *E. pyretorum* larvae and emerged in its pupal stage, with 11.33 offspring emerging per pupa. *Xanthopimpla konowi*, an eremoparasitic parasitoid wasp, oviposited within the pupae of *E. pyretorum*. The wasp *T. depressa* parasite percentage from *E. pyretorum* was 7.55% and offspring was 1.33. The parasitism rate of *K. longiscutellaris* was 18.76%, and the average number of offspring within *E. pyretorum* was 13.36. Thus, of the four species obtained, *K. longiscutellaris* had the highest parasitism rate, longest longevity, and highest number of offspring per host (Table 2).

Emergence of *K. longiscutellaris* resulted in an average of seven exit holes per pupa, with diameters ranging from 2.51 to 4.75 mm (Fig. 1H). After emergence, adults could fly and forage within 2.55 ± 1.19 min. Male wasps surrounded females in courtship until a female received a male, which typically required 16.70 ± 4.30 min, but a few required 40 min. Successful males mounted and mated with females, with mating occurring within 6.85 ± 2.32 min.

Oviposition behavior of *K. longiscutellaris* could be divided into three stages. In the search stage, female antennae drooped and the abdomen wiggled. In the investigation stage, after selecting a host, females extended the ovipositor to explore the best position for oviposition. If the host pupa wriggled in the cocoon, the female terminated the investigation and searched for the next position. In the spawning or oviposition stage, females inserted the ovipositor into the host gradually until the abdomen was close to the surface of the cocoon; this stage continued for 24.6 ± 4.78 min. With *E. pyretorum*, wasps only parasitized hosts within a cocoon shell.

Discussion

According to Fang and Lian (1980), Li et al. (1986), and Qian et al. (1987), insects parasitizing *E. Pyretorum* include ten species from nine genera, six families, and two orders. *Mesocomys albitarsis* (Ashmead, 1904) and a *Trichogramma* sp. are egg parasitoids, and an *Apanteles* sp. parasitizes larvae. Six parasitoid wasps attack pupae, including *Habronyx pyretorum* (Cameron, 1912), *X. konowi* (Krieger, 1899), *Xanthopimpla pedator* Fabricius, *Theronia zebra diluta* Gwpta, *K. longiscutellaris* Qian et He, and *Brachymeria* sp. In addition, the parasitic fly *Exorista sorbillans* Wiedemann attacks *E. pyretorum* larvae (Lian and Fang 1980; Qian et al. 1987). In this work, we identified four species of parasitoid wasps, of which *T. depressa* and *G. himalayensis* were discovered as the first reported parasitoids of *E. pyretorum* in Fujian province of China.

Gregopimpla himalayensis is widespread in North Korea, Japan, and India and has been recorded in 14 provinces of China (Yang and Chen 2018). This parasitoid has multiple host species, including *Philosamia cynthia* Walker et Felder, *Dendrolimus punctatus* Walker, and *D. spectabilis* Butler (Yang and Chen 2018). *Theronia depressa* was present in the Philippines and three provinces of China (Lin et al. 2017). The parasitoid has multiple host species, including *Artona funeralis* (Butler) and *Dendrolimus houi* Lajonquiere. *Xanthopimpla konowi* was also distributed in Asia, including in Japan, Myanmar, Vietnam, India, Thailand, Malaysia, and Indonesia. It has also been recorded in 13 provinces of China (Lian and Fang 1980). Lian and Fang (1980) and He (2004) identified ten host species, including *P.*

cynthia Walker et Felder and *Antheraea pernyi* (Guerin-Meneville, 1855). *Kriechbaumerella longiscutellaris* was first recorded in Zhejiang Province, China, by Qian et al. (1987). Then, it was successively collected from *E. pyretorum*, *P. cynthia*, *D. punctatus*, *D. houi*, and *Cerura menciana* in China (Qian et al. 1987; He 2004). *Xanthopimpla konowi* and *T. depressa* are present in south China and other southeast Asian countries (Lin et al., 2017; He 2004). Both *G. himalayensis* and *K. longiscutellaris* are mainly distributed in north China (Yang and Chen 2018; Qian et al. 1987). These results show that wasps have a large latitudinal distribution and strong adaptabilities to different climates in a wide latitudinal range.

Most *K. longiscutellaris* emerged within a span of 1–5 days, but a few emerged on day 55. The two sets of offspring might be from different females. Further dissection of host pupae revealed that parasitoids developed irregularly. In addition, 30.15% of pupae contained more than one dead adult. Female parasitoids likely oviposit many eggs, but the nutrition provided by host pupae may not be sufficient to satisfy growth and development of all parasitoid wasps (DaSilva et al. 2016).

Kriechbaumerella longiscutellaris has long adult longevity, and *E. pyretorum* has a relatively long pupal stage (240 days; Zhou et al. 2021). Consequently, females have sufficient time to search for suitable hosts in the field. Moreover, *K. longiscutellaris* has a high female:male ratio, which increases the diffusion rate and parasitism efficiency (Wang et al. 2014; Nava-Ruiz et al. 2021). Therefore, *K. longiscutellaris* has good potential for biological control of *E. pyretorum*.

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Table 1. Summary of collections sites of *C. camphora* and *L. formosana* forests in Fuzhou, Fujian Province, China

No.	Survey sites	Longitude/E	Latitude/N	Above Sea Level/m	Overview of Surrounding Vegetation
1	Fujian Agriculture and Forestry University, Cangshan District (FAU)	119°14′13″	26°5′3″	ca. 110	Mainly *Acacia confusa*, with *C. camphora* scattered
2	Jinniushan Park, Gulou District (JNP)	119°15′45″	26°5′6″	ca. 100	Most *C. camphora* and bamboo forest
3	Houmei Village, Minhou County (HMV)	119°11′58″	26°5′52″	ca. 40	Mixed forests of *C. camphora* and *Eucalyptus robusta*
4	Xiyuangong Road, Minhou County (XYR)	119°10′42″	26°3′3″	ca. 30	Avenue trees of *C. camphora*
5	Xiyuan Villager, Minhou County (XYV)	119°7′36″	26°3′36″	ca. 30	Mainly *Pinus massoniana*, with *C. camphora* scattered
6	Guanzhong Villager, Minhou County (GZV)	119°10′59″	26°12′27″	ca. 50	Forests of *C. camphora*
7	Chenjia Villager, Yongtai County (CJV)	118°54′20″	26°0′54″	ca. 600	Mainly *Pinus massoniana*, with *L. formosana* scattered

8	Baidou Villager, Yongtai County (BDV)	118°55′47″	25°54′55″	ca. 80	Forests of *C. camphora*
9	Dangyun Villager, Yongtai County (DYV)	119°0′53″	25°59′32″	ca. 670	Mixed forests of *P. massoniana* and *L. formosana*

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Table 2. Percent parasitism and biological characteristics of parasitoids in Fuzhou, Fujian Province, China. FAU = Fujian Agriculture and Forestry University, JNP = Jinniushan Park, HMV = Houmei Village, XYR = Xiyuangong Road, XYV = Xiyuan Villager, GZV = Guanzhong Villager, CJV = Chenjia Villager, BDV = Baidou Villager, DYV = Dangyun Villager

Species	Percent parasitism of *Eriogyna pyretorum*									Parasitism rate (%)	Offspring	Ratio female: male	Female longevity (d)	Male longevity (d)
	FAU	JNP	HMV	XYL	XYV	GZV	CJV	BDV	DYV					
G. himalayensis	1.54 (2/130)	-	-	-	-	-	7.69 (1/13)	-	-	2.10	11.33±2.49	1.43: 1	9.1 ± 0.48	6 ± 0.76
T. depressa	-	-	-	-	8.33 (2/24)	-	-	-	6.90 (2/29)	7.55	1.25 ±0.43	5:0	13.80±3.76	-
X. konowi	-	-	-	0.52 (2/388)	-	2.13 (2/94)	-	-	-	0.83	1	3: 1	10.50±0.50	7
K. longiscutellaris	10.00 (13/130)	8.33 (2/24)	7.41 (2/27)	26.29(102/388)	4.17 (1/24)	11.70(11/94)	7.69 (1/13)	11.11 (1/9)	-	18.76	13.36±7.74	1.09: 1	47.75±26.74	30.77±14.20

Note: Average number of offspring or longevity ± standard deviation, number of parasitised pupae/ number of pupae in brackets.

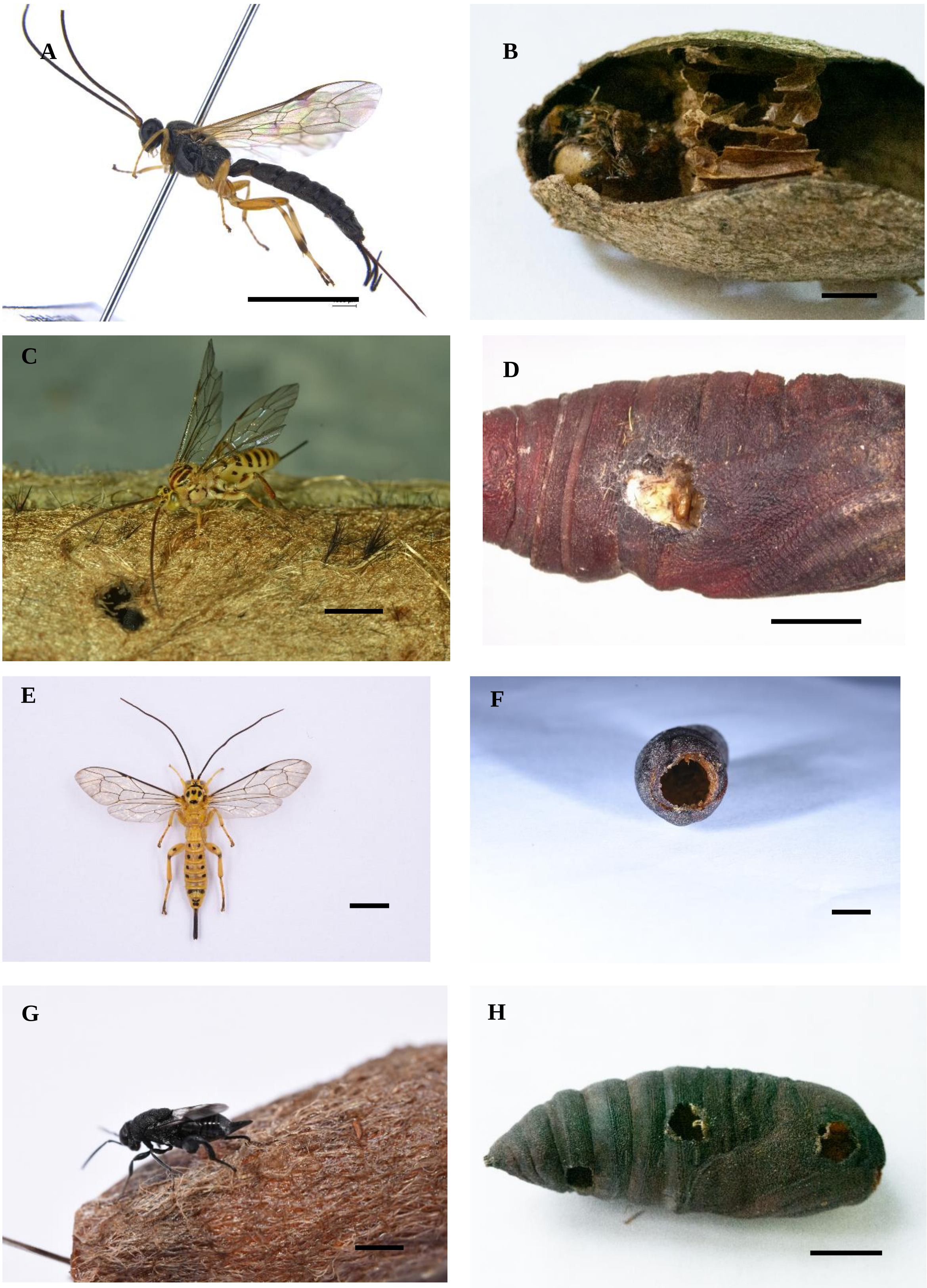
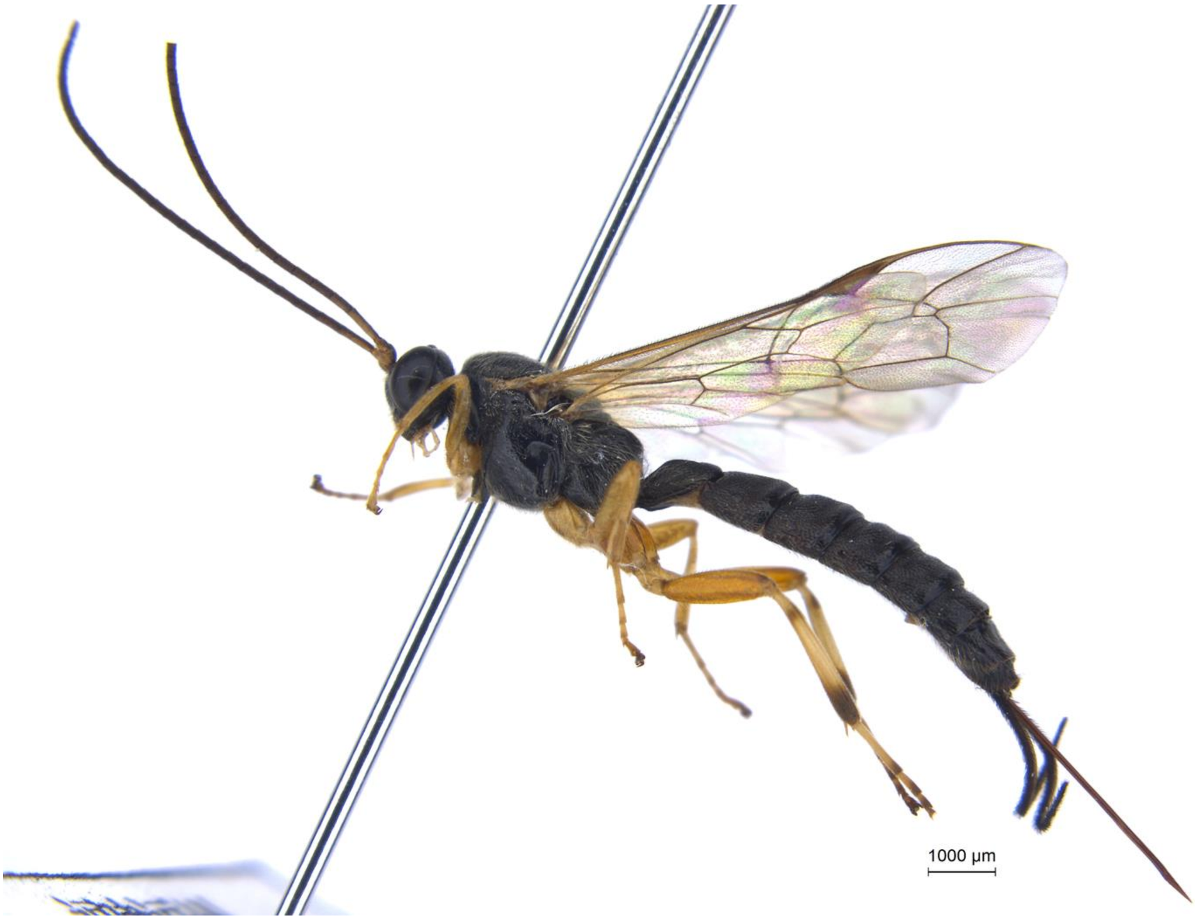


Figure 1. A Female of *G. Himalayensis* **B** Cocoons of *G. himalayensis* **C** Female of *T. depressa* **D** Exit hole of *T. depressa* **E** Female of *X. konowi* **F** Exit hole of

X. konowi **G** Female of *K. longiscutellaris* and **H** Exit holes of *K. Longiscutellaris*. Scale bars: 5 mm.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