Chapter 12
Coconut Leaf Beetle *Brontispa longissima* Gestro

Baoqian Lu and Zhengqiang Peng

Abstract *Brontispa longissima* Gestro, known as the Coconut leaf beetle, is a leaf beetle that feeds on young leaves and damages seedlings and mature coconut palms. *B. longissima* has become an increasingly serious pest of coconuts in the Asian-Pacific region, especially over the last three decades. *B. longissima* broke out in Hainan Province, China in 2002. Quarantine and surveillance are the best prevention methods for introductions and further spread. Chemical spraying has been recommended, but foliar sprays pollute environments and are not suitable for certain areas and tall trees. To reduce pollution caused by chemical sprays, chemical sachets, Yejiaqing which is eluviation powder, were widely used to control *B. longissima* in scenic spots and cities in China. Great efforts have been put on biological controls. *Metarhizium anisopliae* which was isolated from *B. longissima* and formulated as a bioinsecticide was applied in China, as well as in Vietnam and Samoa. The larval parasite *Asecodes hispinarum* Bouček and pupal parasite *Tetrastichus brontispae* Ferrière were introduced into China in 2004 and have approved to be very functional. The parasitisation of *T. brontispae* and *A. hispinarum* was ~90% and ~100%, respectively. Field recoveries were made in some regions after parasitoids releasing however the parasitisation is not always so high. It is necessary to release substantial numbers of the parasite into suitable populations of *B. longissima* to ensure establishment. Environment and climate might effect on the survival and effectiveness of the parasitoid. Such information on control measure is necessary to study.

Keywords *Brontispa longissima* Gestro • Invasion biology • Chemical control • Biological control • *Metarhizium anisopliae* • *Asecodes hispinarum* Bouček • *Tetrastichus brontispae* Ferrière

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F. Wan et al. (eds.), *Biological Invasions and Its Management in China*,
Invading Nature - Springer Series in Invasion Ecology 11,
DOI 10.1007/978-94-024-0948-2_12

Fig. 12.1 *B. longissima* (from *left* to *right*: adult; pupa; 5th, 4th, 3rd, 2nd, 1st instar larvae; eggs)

12.1 Introduction

Palms, most of which are restricted to tropical, subtropical, and warm temperate zones, are among the best studied and most extensively cultivated plant families. They have been important to humans throughout much of the human being's history. Many common products and foods are made from palms, and palms are also widely used in landscaping for their unique appearance, making them one of the most economically important plants. For example, coconut palm (*Cocos nucifera* L.) is an important crop in the tropics supporting the livelihood of millions of people. Global production of coconut is around 61.2 billion nuts from an area of 12.1 million hectares. Approximately 78% of global production is contributed by Indonesia, Philippines, India and Sri Lanka (Rethinam and Singh 2007). The production value of coconut is about 0.5 billion RMB from an area of 40,000 ha in China, most in the Hainan Island.

The coconut leaf beetle, *Brontispa longissima* Gestro (Fig. 12.1) is one of the most serious pests of palms. It is native to Indonesia and possibly also to Papua New Guinea. The pest has spread to most regions of coconut production areas. Both adults and larvae damage the leaflets of young unopened fronds. They graze away the surface in streaks, which are typically parallel to the midrib. Destruction of young leaf spike tissues restricts growth for a long time and heavy attack may cause death (Fig. 12.2). Coconut production losses due to the damage of *B. longissima* have been recorded to be as high as 30–50% in Vietnam and 50–70% in Samoa (Tran 2004; Voegele 1989). The coconut hispid beetle has the potential to have drastic affects on the livelihoods of whole villages; in some localities 90% of the people rely on the coconut for their livelihood (Quirante 2007). Where the coconut hispid beetle has been left unchecked and coconut processing factories have been shut

Fig. 12.2 Symptoms of coconut tree damaged by *B. longissima*

down, thousands of workers have been let off and farmers have been left without work (Bernama 2007). To control this pest, extensive research has been conducted worldwide, including in China, to learn its biology and ecology. Moreover, great efforts have been exerted to the development of various control methods, in particular biological control. In this chapter, we reviewed pest status, distribution, biology, ecology and control measures to *B. longissima*.

12.2 Distribution and Impact

The beetle is capable of flight. Laboratory experiment showed that females were able to fly ~400 m (Zhou et al. 2004a). They might fly further far with strong wind. It is believed that human activities have largely contributed to its dispersal. This pest has probably been introduced frequently along with global trade. This is supported by the documented detection of *B. longissima* in products imported into southern China. For example, *B. longissima* was detected in ornamental palms imported from Vietnam by Guangdong Entry-Exit Inspection and Quarantine Bureau in 1999 (Huang et al. 2000). The pests were also found in Fanyu, Guangdong in same year (Huang and Liang 2000). *B. longissima* was detected in coconut trees imported from Vietnam by local authority in Guangxi in 2000 (Gong and Bai Zh 2001). *B. longissima* was discovered in Haikou, Hainan Province in June 2002 and more infested

Fig. 12.3 Current geographical distributions of *B. longissima* in China

palms in and around Haikou and Sanya cities were confirmed by field surveys. In the year later, the pests spread throughout the Hainan Island (Lu et al. 2005a). The pests also dispersed northwards and reached a number of regions, including Zhanjiang, Maoming and Shenzhen of Guangdong Province, Beihai and Wuzhou of Guagnxi Province, and Honghe of Yunnan province (Fig. 12.3). Modeling analysis indicated that the beetle could be established in most provinces in south China ranging from 16.53°N to 25.73°N and from 97.85°E to 118.91° (Lu et al. 2004; Li et al. 2005; Peng et al. 2006). China's coconut industry consists of smallholders with 40,000 ha. Survey in 2003 showed 100,000 palm plants were infested and 90% of them were coconuts. Infestation of *B. longissima* seriously reduces the income of coconut farmers, but also the rapidly developing tourism. In support of tourism industry, Hainan has commenced a "beautification campaign" which includes the planting of coconuts and many ornamental species in cities and along major roads. Yet, most of these palms have been affected by the beetle since 2002.

12.3 Biology and Ecology

Understanding the biological and ecological traits provides a basis for managing invasiveness. Researchers in China conducted a series of studies on biology and ecology of *B. longissima*, e.g., fecundity, generation time, and cold tolerance.

There are 4–5 overlapping generations per year in Hainan Province and about three overlapping generations per year in Guangdong Province (Zhong et al. 2005; Zhou et al. 2004a). Larval stages last for 30–40 days, and adults of *B. longissima* live up to 220 days. A female can lay more that 100 eggs. Both adults and larvae seem to avoid light and prefer to feed in young unopened leaflets (Zhou et al. 2004b). When facing harsh environmental conditions, adults can adjust their breeding efforts so as to increases the survival of their progeny. The beetle was able to live up to 6 days without food and starvation can enhance the beetle mature (Xu et al. 2007). Supercooling points of the beetle for all stage were below minus 5 °C indicating the pest had reasonable cold hardness (Xiao et al. 2006).

Up to 34 plant species in 25 genus have been recorded as hosts for *B. longissima*. However, various hosts may differ significantly in their suitability (Li et al. 2009). In China, *C. nucifera* is one of the most favorable hosts, on which the beetle has a higher population growth capacity as compared on other hosts (Zeng et al. 2003; Li et al. 2007). For this reason, *C. nucifera* is often very seriously damaged.

Palm plants are attacked severely in dry seasons, however, plants would recover in rainy seasons, as found in Hainan Province, China (Lu unpublished). Such a phenomenon had also been demonstrated in previous studies (Tjoa 1953; Kalshoven, 1981). There are some possible explanations. Firstly, rain might depress *B. longissima* density and dry periods favour the growth of its population. Secondly, palm plants can grow more rapidly in rain season than dry season. Thus, in rainy season hosts may compensate for the damage at a given pest density.

The response of this beetle to *C. nucifera* leaf volatiles was investigated in laboratory bioassays (Fang et al. 2011). Both sexes are attracted to a mixture of beta -myrcene, (−)-limonene and E-2-hexen-1-ol (1: 6: 1), which are key components of coconut palm leaf volatiles. A blend of beta -myrcene and (−)-limonene (0.7: 1–1: 0.7) in low amounts (100 ng) elicits aggregation and oviposition in females. Chemical analyses of food-deprived, gravid female *B. longissima* show high concentrations of beta -myrcene and (−)-limonene in their accessory glands, suggesting that female beetles sequester both compounds and release them during oviposition.

12.4 Control

12.4.1 Quarantine and Cultural Control

Quarantine is the first step in blocking the pest, and keeping the community aware that the control program is essential to ensure substantial control of pest. International collaboration is important as the pest is relating to more than one nation responsibility.

A surgical method of control was ever attempted in the Solomon Islands which involved cutting out and destroying the central unopened frond which harbours the pest (Brown and Green 1958). This procedure must be conducted over a large area at same time to reduce re-infestation from neighbouring palms. It also has to be repeated fairly often to be effective. Palms which were 3–6 years old could stand the loss of one leaf every 6 months, but younger palms could not as this caused too much reduction in growth rate. However, this method is expensive and will not greatly affect the Brontispa population as a whole unless mature palms (more than 5 years) are also treated. Mechanical control of the pest by removing affected heart leaves is laborious and has very little effect (Kalshoven, 1981). In China, this measure was taken when the isolated infested spot were detected.

Coconut varieties in the Solomon Islands considerably varied in their susceptibility to Brontispa attack. Some varieties from the Ivory Coast and Fiji also show high degrees of resistance (Stapley 1973, 1980). Six local coconut cultivars were tested in Western Samoa, five of which were highly susceptible, and green dwarf was fairly resistant (FAO 1983). The preference of adult *B. longissima* to six local varieties in China was investigated by Yu et al. (2009). The development of *B. longissima* was the longest on the Red Dwarf and the shortest on the Hainan Tall; Female *B. longissima* laid the lowest eggs on Mawa and the highest on Hainan Tall; survival were the highest on Hainan Tall and the lowest on Aromatica Green Dwarf. The trend index of experimental population of *B. longissima* fed on the 6 coconut cultivars was 96.07 (78F1), 82.34 (Hainan Tall), 73.93 (Yellow Dwarf), 60.16 (Red Dwarf), 60.07 (Mawa) and 55.26 (Aromatica Green Dwarf). The resistant variation needs to be further tested in the filed.

12.4.2 Chemical Control

For emergency method, chemical control is first choice at early stages of *B.longissima* invasions. Particularly for young palms which are vulnerable to damage, chemical control has to be applied in time. Chemicals used to control the pest must reach the insect in the narrow crevices between leaflets and chemical treatment must be maintained throughout the year because *B. longissima* breeds continuously, with several generations a year. If beetles start breeding as soon as they reach young palms, larvae will probably be present after about 1 week; if there has been any residual effect from insecticide treatment, it will be considerably longer before the larval population presents a serious risk (Brown and Green 1958). Insecticide resistance in *B. longissima* has been documented by Georghiou and Lagunes-Tejada (1991).

Chemicals originally recommended for control include nicotine sulphate, lead arsenate, dichlorodiphenyltrichloroethane (DDT) and dieldrin, but carbaryl, trichlorfon and lindane are now advocated (Maddison 1983; Stapley 1973, 1980; Wu and Tao 1976). In Australia, carbary was recommended to be sprayed on unopened fronds thoroughly (Waterhouse and Norris 1987). In China, Cypermethrin, ethiofencarb, Acetamiprid, Fipronil and imidacloprid were recommended as they are highly efficient and much less toxic to untargeted organisms. Trichlorfon eliminated Brontispa from isolated areas of young palms in Western Samoa (Bourke 1981). There were attempts to develop botanical pesticide, however the application of botanical pesticide was at the laboratory stage (Qin et al. 2007; Feng et al. 2010; Zhang and Feng 2010).

Fig. 12.4 Parasitoids breeding (*Top left*: two parasitoids; *Top right*: *B. longissima* breeding; *Bottom left*: parasitoids breeding; *Bottom right*: artificial diets

The pesticide is applied to the central spike of the palm. Satisfactory control can be achieved at low cost using a fine, low-volume spray applied from above to the central spike of each individual palm (Brown and Green 1958). The application of chemicals at 10-day intervals was more effective than 3-weekly applications (Hollingsworth et al. 1986; Peters et al. 1984).

Chemicals applied through foliar spray may pollute environments through drifts and kill both harmful and beneficial insects. Foliar sprays were also limited for high palms or plant parts where were inaccessible. To overcome these disadvantages, several specific chemical-applying methods have been developed. For example, crown application with carbofuran sachets produced the most effective results, even for tall palms (Choo-Toh 1999). A new pesticide powder mixture (Thiosultap sodium and acetamipri), developed by South China Agriculture University, was mainly used in China (Lu et al. 2012a). The eluviation powder put into bags and then hung on the palm shoots can work with the rainfall (Fig. 12.4). Treatment with this pesticide powder could not only effectively control the beetle with long duration and little side-effect to environment, but also effectively prevent the beetle from spreading. Satisfactory control could be achieved if insecticide bags were used in tourist areas, on sides of street and isolated areas. There are some shortcomings for insecticide sachets. Firstly, eluviation powder depends on rainfall. Therefore it does not work well in dry seasons or dry areas. Secondly, placing the sachets onto palm shoots is labour intensive with high cost.

Researchers have attempted to develop other delivery methods and optimum dosages to control the beetle. Experiments of soil drenching of systemic insecticides and trunk injection were conducted (He et al. 2005; Zhao et al. 2003; Zheng et al. 2010). All methods were effective in delivering the chemicals for beetle control, however soil drench and trunk injection were not applied in field widely.

12.4.3 Biological Control

The history of biological control of this pest was reviewed by Waterhouse and Norris (1987). The prospects for control are also discussed. In China, studies have been focused on natural enemies and entomopathogenic fungus of this pest and their use for biological control.

12.4.3.1 *Metarhizium anisopliae*

A suspension of *Metarhizium anisopliae* was used in the 1980s in Samoa for a pest on young coconut seedlings in fields and in nurseries, but its application to tall trees was difficult and impracticable. In Taiwan, a domestic strain of *M. anisopliae* var. *anisopliae* (MA-1) was isolated from infected coconut leaf beetles (Liu et al. 1989). Two field trials of microbial control of *B. longissima* were conducted in the Pingtung area (southern part of Taiwan) in 1986 and 1987. *B. longissima* could not be detected after three applications of MA-1 formulated as a homogeneous biomass, in granules or in a conidial suspension. In Vietnam, *M. anisopliae* was isolated from naturally infected *B. longissima*, which exhibited the highest virulence to pest, particularly to larvae (Nguyen et al. 2004). The field test showed *M. anisopliae* had good control to the beetle and long persistence, even up to 21 days.

In mainland China, high efficient strains of *M. anisopliae* were selected after strain screening (Qin et al. 2006; Song et al. 2006; Ding et al. 2006). A fermentation technology was also developed and *M. anisopliae* was produced 10 tones per year. To be easily applied, powder, solutions and powder sachet of *M. anisopliae* were developed. In the field, *M. anisopliae* could kill 80% *B. longissima* after 1 week. Laboratory tests showed *M. anisopliae* mixed with Monosultap improved efficacy (Qin et al. 2008). Similarly, *M. anisopliae* mixed with *Bacillus thuringiensis* showed synergic control (Bian et al. 2009).

12.4.3.2 Natural Enemies

Despite the habit to hide in leaflets of unopended fronds, *B. longissima* is attacked by a number of natural enemies, including many species of ants, earwigs and parasitic hymenopterans. There are two parasitoids of coconut leaf beetle *Tetrastichus brontispae* and *Asecodes hispinarum,* which have been successfully used in several countries to control the beetle (Table 12.1).

Table 12.1 Introdutions for the biological control of *B. longissima*

Country	Species	Liberated	From	Result
Cambodia	*A. hispinarum*	2005	Vietnam	?
China	*T. brontispae*	2004	Taiwan	+
China	*A. hispinarum*	2004	Vietnam	+
Thailand	*A. hispinarum*	2004	Vietnam	+
Maldives	*A. hispinarum*	2004	Vietnam	+
Lao PDR	*A. hispinarum*	2004	Vietnam	+
Vietnam	*A. hispinarum*	2003	Western Samoa	+
Nauru	*A. hispinarum*	2004	?	?
American Samoa	*T. brontispae*	1985	Western Samoa	+
American Samoa	*T. brontispae*	1984	Guam	?
Australia	*T. brontispae*	1984	New Caledonia	+
Taiwan	*T. brontispae*	1983	Guam	+
Western Samoa	*T. brontispae*	1982	Tahiti	
Western Samoa	*T. brontispae*	1982	Papua New Guinea	+
Western Samoa	*T. brontispae*	1981–1982	New Caledonia	+
Tahiti	*T. brontispae*	1979	New Caledonia	?
American Samoa	*T. brontispae*	1978	New Caledonia	?
American Samoa	*T. brontispae*	1978	Vanuatu	?
American Samoa	*T. brontispae*	1975	Vanuatu	–
American Samoa	*T. brontispae*	1974	Vanuatu	–
American Samoa	*T. brontispae*	1973	New Caledonia	–
American Samoa	*T. brontispae*	1973	Vanuatu	–
Vanuatu	*T. brontispae*	1969–1970	New Caledonia	+
Solomon Island	*T. brontispae*	1968	Java	+
Solomon Island	*T. brontispae*	1968	Tahiti	+
Tahiti	*T. brontispae*	1962–1963	Sulawesi	+
New Caledonia	*T. brontispae*	1963	Saipan	+
New Caledonia	*T. brontispae*	1947	Java	–
Papua New Guinea	*T. brontispae*	1939	Solomon Island	+
Solomon Island	*T. brontispae*	1935	Java	+
Sulawesi	*T. brontispae*	1932	Java	+

+ represent positive results; – represent negative resutls; ? represent unknown results

However, in most of the invaded regions in China, only a few natural enemy species were detected so far. For example, in Hainan Island where *B. longissima* were found in 2002, only a few predators (earwigs, ants and mantis) have been found. As local natural enemies were not efficient, the pest broke out and spread throughout the Hainan Island quickly. To reduce outbreak of *B. longissima*, China mainland has introduced several natural enemies from overseas. Both *T. brontispae* and *A. hispinarum* were introduced to the Hainan Island in 2004, from Taiwan and Vietnam, respectively. To breed at a large scale and release in the field, Lu et al. (2005a, b, c, 2006) conducted a series of experiments on the two parasitoids, including the comparison of their biology. *A. hispinarum* and *T. brontispae* were found to have some similar

Table 12.2 Comparison of two parasitoids biology

Biological characteristics	*A. hispinarum*	*T. brontispae*
Stage attacked	Larval stage	Pupal stage
Adult body length (mm)	Female, 0.5–0.85;male, 0.35–0.65	Female,0.85–1.4;male, 0.98–1.25
Adult longevity (hr)	47.4	84.0
Fecundity per female	43.0	20.6
Adult emergence per host	60.3	21.5
Female percentage	74.8%	77.4%
Development in Hainan (d)	19.5	21.0
Initial development temperature (°C)	10.7	10.9
Effective accumulated temperature (day degree)	261.2	298.8
Generations a year in Hainan	19	17
Phototaxis	Attracted to light	Attracted to light
Parthenogenesis	Arrhenotoky	Arrhenotoky

biological characteristics such as phototaxis and parthenogenesis. Meanwhile, they do have their own biological traits. Generally, *T. brontispae* has a lower fecundity, bigger body size and a longer life cycle than *A. hispinarum* (Table 12.2).

To breed and produce parasitoid wasps at large scale to control *B. longissima*, *techniques of mass rearing of B. longissima* using coconut leaf were developed. Leaflets of coconut spears were cut into small 5–7 cm pieces and kept inside a plastic container (20 cm length, 13 cm width, 7 cm high) covered with a screened and ventilated lid. To reduce the cost, coconut new leaves were mixed with old leaves. Adult *B. longissima* were introduced into the container and continuously reared at rearing rooms. The rearing rooms are maintained at temperature from 22 to 26 °C, 70–80% RH (Relative Humidity) with natural lighting. Adults of *A. hispinarum* or *T. brontispae* were introduced into the container at the stages of 4th-instar larvae or pupae (host : parasitoid = 1 : 1). A piece of tissue paper saturated with honey solution 10% (w/v) was fixed to the wall of the box to provide food for adult wasp. Parasitized hosts were then collected and stored at 14 °C for less than 10 days. To get large numbers of hosts required for parasitoid production, the artificial diet had been developed for mass rearing of *B. longissima* (Ichiki et al. 2009; Lu et al. 2005c, 2012b). When reared on this diet, the beetle has a survival rate of approximately 40% from hatching to adult stage. *B. longissima* larvae produced from this diet performs well as hosts for both *A. hispinarum* and *Tetrastichus brontispae*. So far five beneficial insectaries have been established in Danzhou, Haikou and Wenchang for mass culture of *A. hispinarum* and *T. brontispae*. These insectaries can produce a total of 300,000 *T. brontispae* and 1,200,000 *A. hispinarum* per day.

To release the two parasitoids in the fields, a container was design (Fig. 12.5). The container can protect parasitoids from rain and predators. One container was hanged for every 15 palm plants. Before releasing, *B. longissima* population density was investigated, and the number of parasitoids to be released was double of the

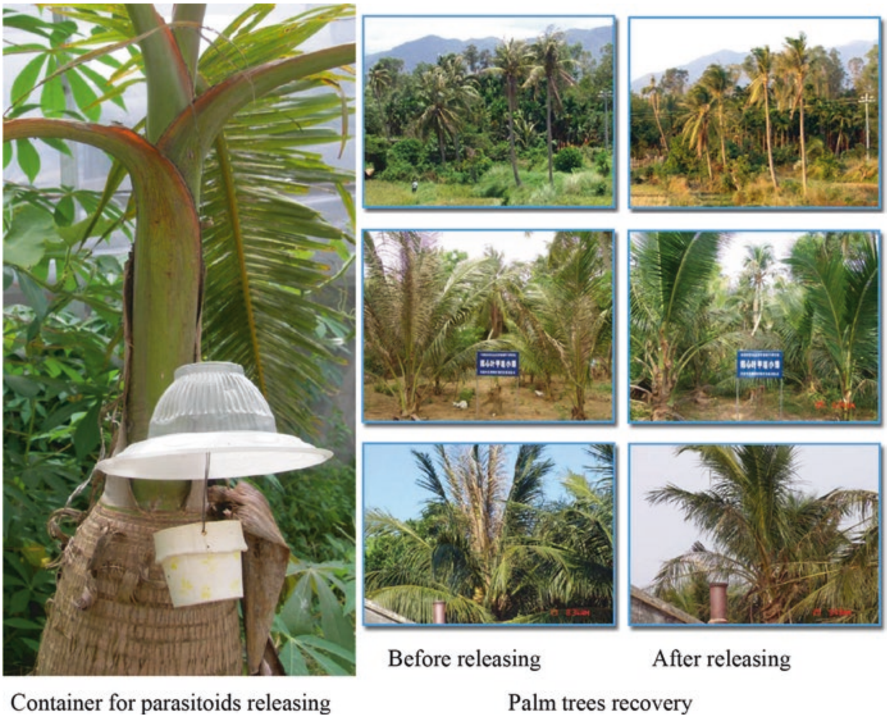

Fig. 12.5 Parasitoid releasing

pest. *A. hispinarum* and *T. brontispae* can be released at same time with 3:1 ratio. The release is normally performed 4–6 times at 1 month intervals. From 2004 to now, parasitoids have been released at more than 50 spots in Hainan, Guangdong, Yunnan, Guangxi Province. Almost all of the parasited larvae died within 3–4 days after hatching. To integrate chemical control and biological control, parasitoids should be released after chemical residue is below sub-lethal. It was suggested in China that 1 month was safe to release parasitoids after chemical spraying and 3 months were safe after pesticide sachet applying. Field recoveries made in some regions in following year after parasitoids releasing showed substantially reduced injury to coconut plantations by the beetle (Fig. 12.5). The parasitisation of *T. brontispae* was up to 100% and the parasitisation of *A. hispinarum* was up to 90%. However, the level of simultaneous parasitisation by two parasitoids is not always so high.

Earwigs are common predators of *B. longissima* as reported in many countries. In China, *Chelisoches morio* was the dominant species (Fig. 12.6). This predator takes 100 days for development from egg to adult in Hainan. One female lays 138 eggs on average, and one adult can consume about seven 2nd-instar *B. longissima* larvae per day. There was a new species, *Paralabella* sp. which is much smaller than *C. morio* in China.

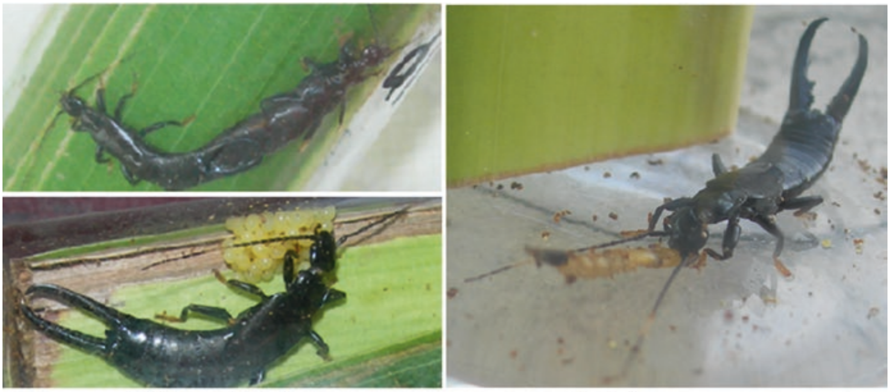

Fig. 12.6 *Chelisoches morio*

12.5 Conclusion and Perspectives

The breakout of the coconut leaf beetle in Southeast Asia is a typical example of pest invasions into a new area where no or few natural enemies exist. Quarantine technologies need to be further developed, such as fumigation for import or export palm plants.

Based on monitoring, IPM is key to control the pest substantially. There are advantages and disadvantages for each control strategy. For example, chemical control might cause resistance, resurgenee and residue of pest and biological control is unstable as natural enemies are affected by environmental and biotic factors. In the future, culture control, chemical control and biological control should be integrated.

Parasitoids introduction and releasing achieved positive results in many countries. However, parasitisation is not always high and it is hard to establish population of parasitoids in some regions. In Hainan, winter season is relative cold and dry which might have negative effects on the survival and effectiveness of the parasitoids. The landscape might affect parasitoids establishment. Scatted palm plants might limit the parasitoids dispersal and establishment. Therefore, more information on control measures is necessary.

Local enemies is suitable to local whether and environment. Great efforts should be put to find and test local natural enemies. Although *A. hispinarum* and *T. brontispae* were widely introduced and released, we could find local natural enemies to suppress the pest. In Hainan, earwigs are very common on damaged palm crown and its consumption of *B. longissima* is high. Collection, assessment, rearing and releasing of local natural enemies need to be conducted in the future.

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