12

Cerambycid Pests in Agricultural and Horticultural Crops

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CONTENTS

12.1 Introduction

Cerambycids as economic pests are not only important with respect to forest trees but also for various agricultural and horticultural crops. Damage to crops is usually caused by larval feeding and, occasionally, by adult feeding or oviposition. Larvae of most cerambycid species are borers, feeding on living, dying, dead, or rotten plant stems, branches, or twigs. Most wood-boring species feed on subcortical tissues—at least initially. Later, they may burrow further into sapwood and—even hardwood—to continue feeding. Herbaceous feeders usually bore in host stems. Root feeders may bore in the roots, hollowing out and killing the roots of the host plants, or they may live in the soil and feed on the roots. In some species, larvae damage fruit; adults cause economic damage to leaves and male flowers by feeding and to stems or branches by girdling.

Worldwide, more than 100 cerambycid species have been or currently are economic pests of crops. However, the pest status or identity of several species has not been confirmed, and several others are no longer considered economically important. Consequently, only 90 species are discussed in this chapter, of which 46 are from the Lamiinae, 34 are from the Cerambycinae, and 10 are from the Prioninae. Geographically, 48 species are considered endemic to Asia, 11 to South and Central America, 10 to Europe, 7 to North America, 6 to Africa, and 8 to Australasia.

Table 12.1 provides scientific names, common names, crop hosts, feeding sites, life cycle duration, overwintering stages, economic importance, and regions/countries where damage is considered to have an economic impact for these 90 species. Most common names are in general use in various parts of the world, and some are created here based on crops attacked, geographical distribution, morphological features, or combined information. Many species are extremely polyphagous, using a wide range of woody and herb plant species as their larval hosts; for example, the larvae of *Anoplophora chinensis* (Forster) feed on more than 100 species of living trees from 36 families (Lingafelter and Hoebeke 2002; Haack et al. 2010) and those of *Oemona hirta* (F.) on more than 200 host species from 81 families (EPPO 2013c). Therefore, the hosts listed for each cerambycid species in Table 12.1 are limited to major crops damaged rather than the full host record, and the pest status in plants other than crops is not discussed in this chapter. Feeding sites refer to the sites of plants where cerambycid larvae feed, including roots (R), main stems or trunks (M), branches (B), twigs (T), and shoots (S).

Most cerambycid species included in this chapter take at least one year to complete their life cycle. It is important to bear in mind that the information on life cycles provided in Table 12.1 is in summary form. The duration for completion of a generation may be dependent on the prevailing climatic conditions. For example, the South American species *Steirastoma breve* (Sulzer) has only one generation a year in southern Brazil but up to four generations a year in tropical areas (Kliejunas et al. 2001).

The assessment of economic importance mainly is based on literature and, to a lesser extent, on personal experience and personal communications. The countries or regions listed in Table 12.1 are limited to where damage to crops is reported for each species rather than complete geographical distribution, information about which is given in the text. Control measures, including those accepted by the growers as well as in laboratory and field trials, are provided for each species. Many synthetic insecticides used for control are not registered for cerambycid pests or have already been banned for crop pest control. Therefore, in describing chemical control available for each species, only the application method (such as spray, painting, injection, place-and-plug, and soil treatment) and chemical classes (such as organophosphate and carbamate) are given, with literature provided. Readers can make up their own minds in terms of what insecticides should be used and how to use them depending on pest species and local governmental regulations.

In this chapter, the major crops cerambycids damage are divided into eight categories on the basis of agricultural and horticultural traditions and for the convenience of workers in these sectors: (1) pome and stone fruit trees, (2) citrus trees, (3) tropical and subtropical fruit trees, (4) nut trees, (5) mulberry trees, (6) cacao, coffee, and tea crops, (7) vine crops, and (8) field crops. Many cerambycid species attack crops in more than one category; thus, the species included in each category are those that cause the most damage to crops in that category. The biology and management of cerambycid pests are discussed in individual crop categories. Under each category, the pest species are clustered according to their origins for readers' convenience.

12.2 Cerambycid Pests of Pome and Stone Fruit Trees

Pome and stone fruit trees refer to two major groups of deciduous species originating from the temperate zone of the Northern Hemisphere (Ebert 2009). The most abundant species in the first group comprise apple, pear, and quince, while those in the second group include cherries, peaches, plums, and apricots. Economically, apples, pears, peaches, and plums are ranked among the top 10 in terms of worldwide fruit production (Ebert 2009).

Dozens of cerambycid species have been recorded that attack pome and stone fruit trees, but only 20 species in the world are recognized as economic pests of these tree crops. Their biology and management measures are discussed in this section. Among these species, seven are endemic to Asia, six to Europe, four to North America, two to South America, and one to Africa.

TABLE 12.1

Cerambycid Pests of Crops in the World

Species[a]	Common Name	Crop Hosts[b]	Feeding Site[c]	Generation(s) per Year[d]	Overwintering Stage[e]	Economic Importance[f]	Countries Where the Species Is Recorded as a Pest[g]
Acalolepta cervina (Hope)	Coffee brown beetle	Coffee especially arabica coffee	M	1	L	++	China and Thailand
Acalolepta mixta (Hope)	Passion vine longicorn	Grape vine, passion vine, fig, mango, and citrus	R&M&B	1	L&P	+++	Australia
Aeolesthes holosericea (Fabricius)	Cherry stem borer	Apple, apricot, anhili, cherry, plum, peach, mulberry, and walnut	M&B	2 years	L	++	Northern India and southern China
Aeolesthes induta (Newman)	Silky gray-brown longhorn	Tea and oil tea	M&R	2–3	L&A	++	Southeastern China
Aeolesthes sarta Solsky	Apple stem borer	Apple, apricot, and walnut	M&B	2 years	L	+++	India and Iran
Agapanthia dahli (Richter)	Sunflower longicorn beetle	Sunflower	M	1–2 years	L	+	Hungary and western Russia
Analeptes trifasciata (Fabricius)	Cashew stem girdler	Cashew	M&B	2	L&P	+++	Nigeria
Anoplophora chinensis (Forster)	Asian starry citrus longicorn or Citrus longhorned beetle	Citrus particularly lime, lemon, and orange; stone and pome fruit trees	M&R	1–2 years	L	+++	Asia: China, Japan, Korea, Indonesia (Sumatra), Myanmar, Malaysia, Philippines, and Vietnam; EUROPE (introduced): France, Germany, Italy, The Netherlands, Switzerland, and UK
Anoplophora macularia (Thomson)	Macularian whitespotted longicorn	Citrus and lychee	M	1	L	++	China (Jiangsu, Taiwan) and southern Japan
Aphrodisium gibbicolle (White)	Striate-necked green longicorn	Citrus	M&B	1–2 years	L&P	+	Southern China
Apomecyna saltator (Fabricius)	Cucurbit vine borer	Vines of ridge gourd (*Luffa acutangula*), pointed gourd (*Trichosanthes dioica*) and melons, pumpkins, and vegetable marrow	M	2–3	L	++	India and China

(Continued)

TABLE 12.1 ***(Continued)***

Cerambycid Pests of Crops in the World

Species[a]	Common Name	Crop Hosts[b]	Feeding Site[c]	Generation(s) per Year[d]	Overwintering Stage[e]	Economic Importance[f]	Countries Where the Species Is Recorded as a Pest[g]
Apriona germari (Hope)	Brown mulberry longicorn	Mulberry, apple, walnut, fig	M&B	1–3 years	L	+++	India, southern China, and Southeast Asia
Apriona rugicollis Chevrolat	Mulberry tree borer	Mulberry and teyaki	M&B	2–3 years	L	++	China, Japan, and Korea
Aristobia testudo (Voet)	Lychee longicorn	Lychee, longan, cocoa, jackfruit, guava and citrus	B&T	1	L	++	Southern China and northern India
Aromia bungii (Faldermann)	Peach rednecked longicorn	Peach, apricot, plum, and cherry	M&B	2–3 years	L	++	China, Mongolia, Korea, Vietnam; Italy and Germany (introduced)
Bacchisa atritarsis (Pic)	Black-tarsused tea longicorn	Tea and oil tea	M&B	2 years	L	++	Southern China
Bacchisa fortunei (Thomson)	Blue-backed pear longicorn	Pear, apple, and peach	B&T	2 years	L	+	China
Batocera horsfieldi Hope	Large gray and white longicorn	Walnut	M&B	2–3 years	L&P	++	China and India
Batocera lineolata Chevrolat	Cloud-marking longicorn	Walnut	M&B	2–3 years	L&P&A	++	China
Batocera rubus (Linnaeus)	Lateral-banded mango longhorn	Mango and fig	M&B	1–3	L or P	++	China and India
Batocera rufomaculata (DeGeer)	Mango tree stem borer	Mango, fig, durian, jackfruit, apple, guava, pomegranates, mulberry, and cashew	M&B	1–2	L	+++	India, Thailand, Egypt, and Israel
Bixadus sierricola (White)	West African coffee borer	Coffee particularly robusta coffee	M&R	1–2	L	+++	Western African countries
Calchaenesthes pistacivora Holzschuh	Pistachio longicorn	Pistachio	B&T	2 years	L&A	++	Iran
Celosterna scabrator (Fabricius)	Grape stem borer	Grapevine	M&B	1	L	++	India
Cerambyx carinatus (Küster)	Ring-pediceled longicorn	Cherry	M	2–3 years	L	+	Turkey

(Continued)

TABLE 12.1 ***(Continued)***

Cerambycid Pests of Crops in the World

Species[a]	Common Name	Crop Hosts[b]	Feeding Site[c]	Generation(s) per Year[d]	Overwintering Stage[e]	Economic Importance[f]	Countries Where the Species Is Recorded as a Pest[g]
Cerambyx cerdo Linnaeus	Great capricorn beetle	Apple, pear, and cherry	M	3–5 years	L&A	+	Most European countries
Cerambyx dux (Faldermann)	Giant-eyed longicorn	Apple, pear, plum, peach, almond, cherry, plum, and almond	M&B	2–3 years	L&P&A	++	Malta, Middle East, and Mediterranean countries
Cerambyx nodulosus Germar	Nodulated longicorn	Cherry	M	3–4 years	L	+	Turkey
Cerambyx scopolii Fuessly	Capricorn beetle	Cherry, apple, plum, and walnut	M&B	2–3 years	L&P&A	+	France and Switzerland
Chelidonium argentatum (Dalman)	Greenish lemon longicorn	Citrus	M&B	1	L	++	Southern China and India
Chelidonium cinctum (Guérin-Méneville)	Lime tree borer	Citrus	B&T	1	L	+	Southern China and India
Chelidonium citri Gressitt	Green citrus longicorn	Citrus	B&T	1	L	+	Southern China
Coptops aedificator (Fabricius)	Albizia longicorn beetle	Mango and coffee	M&B	1	L	++	Middle East, Africa, and South Asia
Dectes texanus LeConte	Dectes stem borer	Sunflower and soybean	M	1	L	+++	USA (mainly southern Great Plains)
Diploschema rotundicolle (Audinet-Serville)	Brown-headed citrus borer	Citrus and peach	M&B	1	L&P	++	Brazil
Disterna plumifera (Pascoe)	Speckled longicorn	Citrus	M&B	1	L	+	Australia
Dorcadion pseudopreissi Breuning	Ryegrass root longicorn	Turf and pasture grasses	R	2 years	L&A	++	Turkey
Dorysthenes buqueti (Guérin-Méneville)	Sugarcane stem longicorn	Sugarcane	M	1–2 years	L	++	Thailand and Indonesia
Dorysthenes granulosus (Thomson)	Sugarcane root and stem longicorn	Sugarcane, citrus, mango, cassava, and longan	M&R	2 years	L	+++	Thailand and southern China
Dorysthenes hugelii (Redtenbacher)	Apple root borer	Apple but occasionally pear, peach, cherry, and plum	R	3–4 years	L&P	++	India

(Continued)

TABLE 12.1 ***(Continued)***

Cerambycid Pests of Crops in the World

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Dorysthenes hydropicus (Pascoe)	Sugarcane longicorn beetle	Sugarcane, pomelo, and reed	M&R	1–2 years	L	++	Mainland China and Taiwan
Dorysthenes paradoxus (Faldermann)	Bluegrass longicorn	Turf grass	R	3 years	L	++	Northern China
Dorysthenes walkeri (Waterhouse)	Long-toothed longicorn	Sugarcane	M&R	2 years	L	++	Southern China
Elaphidion cayamae Fisher	Spined citrus borer	Citrus (orange and mandrine)	B&T	1	L	++	Cuba
Hylettus seniculus (Germar)	Hylettus citrus borer	Citrus	M&B	1	L	++	Brazil
Linda nigroscutata (Fairmaire)	Apple twig borer	Apple	T&S	1	L	+	India and China
Macropophora accentifer (Olivier)	Harlequin citrus borer	Citrus and figs	M	1	L&P	++	Brazil
Macrotoma palmata (Fabricius)	Large brown longicorn	Apricot and citrus	M&B	3–4 years	L	++	Egypt
Monochamus leuconotus (Pascoe)	African coffee stem borer	Coffee especially arabica coffee	M&R	1–2 years	L	+++	Africa especially South Africa, Tanzania, and Uganda
Nadezhdiella cantori (Hope)	Gray-black citrus longicorn	Citrus	M&B	2–3 years	L&P&A	+++	China
Neoplocaederus ferrugineus (Linnaeus)	Cashew stem and root borer	Cashew	M&R	1–2	L	+++	India (particularly east and west coasts) and Nigeria
Neoplocaederus obesus (Gahan)	Cashew stem borer	Cashew and chironji	M&R	1	L	++	India, Vietnam, and southern China
Nitakeris nigricornis (Olivier)	Yellow-headed borer	Coffee especially arabica coffee	M&R&B&T	1–2 years	L	++	Eastern Africa
Nupserha vexator (Pascoe)	Sunflower stem borer	Sunflower	M	1	L	++	India
Nupserha nitidior Pic	Soybean girdle beetle	Soybean	M&R	1	L	+	India
Oberea posticata Gahan	Citrus shoot borer	Citrus	T&S	1	L&P	++	India
Oberea lateapicalis Pic	Orange shoot borer	Citrus	T&S	1–2 years	L	+	India

(Continued)

TABLE 12.1 ***(Continued)***

Cerambycid Pests of Crops in the World

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Obereopsis brevis (Gahan)	Girdle beetle	Soybean, rice bean, and sunflower	M&B	2	L	+++	India
Oemona hirta (Fabricius)	Lemon tree borer	Citrus, apple, persimmon, and grapevine	M&B&T	2 years	L	++	New Zealand
Oncideres cingulata (Say)	Pecan twig girdler	Pecan and hickory	B&T	1–2 years	L	++	USA
Oncideres dejeanii Thomson	Pear twig girdler	Pear	B&T	1	L	+	Brazil
Osphranteria coerulescens Redtenbacher	Rosaceae branch borer	Cherry, apricot, peach, plum, apple, pear, quince, almond, pistachio, and fig	B&T	1	L	++	Turkey and Iran
Plagiohammus colombiensis Constantino, Benavides and Esteban	Colombian coffee stem and root borer	Coffee	M&R	2 years	L&P	++	Colombia
Plagiohammus maculosus (Bates)	Speckled coffee stem and root borer	Coffee	M&R	2–3 years	L&P	++	Mexico and Guatemala
Plagiohammus mexicanus Breuning	Mexican coffee stem and root borer	Coffee	M&R	2–3 years	L&P	+	Mexico
Plagiohammus spinipennis (Thomson)	Lantana stem and root borer	Coffee	M&R	2–3 years	L&P	+	Mexico
Plagionotus floralis (Pallas)	Alfalfa root longicorn	Alfalfa and yellow sweet clover	M&R	1–2 years	L	++	Eastern Europe
Platyomopsis pedicornis (Fabricius)	Australian mango longicorn	Mango and shrubby stylo	M&B	1	L&P	+	Northern Australia
Praxithea derourei (Chabrillac)	Taladro longicorn	Apple	M&B	1	L	+	Argentina and Uruguay
Prionus californicus Motschulsky	California prionus	Cherry, peach, apricot, and citrus	R	3–5 years	L	+++	Western North America
Prionus imbricornis (Linnaeus)	Tilehorned prionus	Apple	R	3–5 years	L	++	Eastern North America

(Continued)

TABLE 12.1 *(Continued)*
Cerambycid Pests of Crops in the World

Species[a]	Common Name	Crop Hosts[b]	Feeding Site[c]	Generation(s) per Year[d]	Overwintering Stage[e]	Economic Importance[f]	Countries Where the Species Is Recorded as a Pest[g]
Prionus laticollis (Drury)	Broad-necked root borer	Apple	R	3–4 years	L	++	Eastern North America including USA and Canada
Psacothea hilaris (Pascoe)	Yellow-spotted longicorn beetle	Mulberry and figs	M	1–2	E&L	+++	China and Japan (adults also damage leaves by feeding)
Pseudonemorphus versteegi (Ritsema)	Citrus trunk borer	Citrus	M	1	L	+++	India and Myanmar
Psyrassa unicolor (Randall)	Pecan branch pruner	Pecan and hickory	B&T	1–2 years	L	+	USA
Rhytidodera bowringii White	Yellow-spotted ridge-necked longicorn	Mango	M&B&T	1–2 years	L&P	++	India and southern China
Rhytidodera simulans (White)	Mango trunk and branch borer	Mango, cashew, and rose apple	M&B&T	1	L&P	++	Indonesia and Malaysia
Rhytiphora diva (Thomson)	Alfalfa crown borer	Soybean and alfalfa	M	1	L	++	Northern Australia particularly Queensland and Western Australia
Saperda candida Fabricius	Roundheaded apple tree borer	Apple, pear, cherry, and plum	M&B	2–3 years	L&P	++	Canada (Quebec) and Eastern USA
Skeletodes tetrops Newman	Australian citrus longicorn	Citrus	B&T	1	L	+	Australia
Steirastoma breve (Sulzer)	Cacao longicorn beetle	Cacao (*Theobroma cacao*)	M&B	1–4	L	+++	South America and some Caribbean islands
Sthenias grisator (Fabricius)	Grapevine stem girdler	Mulberry and grapevine	T&S	1	L	++	India and Sri Lanka
Strongylurus thoracicus (Pascoe)	Pittosporum longicorn	Citrus	M&B&T	1	L	+	Australia
Tetrops praeustus (Linnaeus)	Plum longicorn	Apple and pear	T&S	1–2 years	L	+	European countries; introduced to northeastern USA, and northern Africa
Trachylophus sinensis Gahan	Four-ridged tea longicorn	Tea and oil tea	R&M&B	1	L	+	China

(Continued)

TABLE 12.1 ***(Continued)***

Cerambycid Pests of Crops in the World

Species[a]	Common Name	Crop Hosts[b]	Feeding Site[c]	Generation(s) per Year[d]	Overwintering Stage[e]	Economic Importance[f]	Countries Where the Species Is Recorded as a Pest[g]
Trichoferus griseus (Fabricius)	Fig longicorn	Fig	M&B	2–3 years	L	+	Egypt
Uracanthus cryptophagus Olliff	Australian citrus branch borer	Citrus	B&T	1	L	+	Australia
Xylotrechus arvicola (Olivier)	European grapevine borer	Grapevine	M&R&B	2 years	L	+++	Spain
Xylotrechus javanicus (Castelnau & Gory)	Asian coffee stem borer	Coffee particularly arabica coffee	R&M&B	1–3	L&P	+++	India, China, Thailand, and Vietnam
Xylotrechus pyrrhoderus Bates	Grape tiger longicorn	Grapevine	M&B	1	L	++	Japan, Korea, and China

[a] Synonyms are given in the text.
[b] The host plants listed here are important crops the pests damage rather than the complete range of host plants.
[c] Roots (R), main trunks or stems (M), branches (B), twigs (T), and shoots (S).
[d] Estimated number of generations/year: 1, 2, or 3 refer to 1, 2, and 3 generations per year; however, 2 years, 3 years, or 4 years mean that one generation takes 2, 3, or 4 years.
[e] Eggs (E), larvae (L), pupae (P), or adults (A).
[f] +, ++, and +++ represent occasional (or minor) pest, important (or moderate) pest, and key (or serious) pest, respectively.
[g] These are not exhausted distribution records.

12.2.1 Asia

12.2.1.1 Aeolesthes sarta Solsky

Common name: Apple stem borer

The adults of the cerambycine stem borer are 28–47 mm long and dark gray-brown, with the elytra covered with short silvery hairs; shiny silvery spots form two irregular bands crossing the elytra (Figure 12.1). This species is widely distributed in Central and South Asia including Afghanistan, Iran, India, Kyrgyzstan, Pakistan, Tajikistan, Turkmenistan, and Uzbekistan, and highly polyphagous with a host range of many tree species from Ulmaceae, Salicaceae, Platanaceae, Rosaceae, Juglandaceae, Sapindaceae, Betulaceae, Elaeagnaceae, Oleaceae, Fabaceae, Moraceae, and Fagaceae (Duffy 1968; EPPO 2005).

The longicorn beetle is one of the most important pests of many forest and ornamental trees such as *Populus, Platanus, Ulmus,* and other amenity trees in cities and parks in the region of its present distribution (EPPO 2005). Because this pest causes significant damage to trees in urban areas, it is also called the city longicorn beetle. In horticulture, this is a serious pest of apple and walnut trees in Asia and also impacts cherry, apricot, peach, and plum trees (Duffy 1968; Sengupta and Sengupta 1981; Shiekh 1985; Farashiani et al. 2001; Mir and Wani 2005; Bhat et al. 2010a; Khan et al. 2013). For example, *A. sarta* was first reported as a serious pest of apple and other temperate fruit trees in Jammu and Kashmir (northern India) in 1980s (Shiekh 1985). According to Bhat et al. (2010a), depending on apple cultivars and tree age, infestation rate ranges from 6.5% in American Apirogue to 23.2% in Red Delicious and from 5.5% in 10- to 15-year-old trees to 27% in those more than 30 years old in northern India. Khan and Qadri (2006) reported a 50% infestation rate in Indian apple and apricot orchards. The pest causes enormous damage to walnut trees, with a 30–40% infestation rate in northern India (Khan et al. 2013). In Iran, 40–100% of apple and walnut trees can be infested (Farashiani et al. 2001). Larvae bore into the large branches and trunks where sizable emergence holes and borings at the base of infested trees are indications of this pest's presence. Infested trees may not die for many years, but their vitality and

FIGURE 12.1 *Aeolesthes sarta* adult. (Courtesy of Xavier Gouverneur.)

productivity are impaired and leaves become wilted and dry. Usually, several generations develop on the same tree until it is eventually killed. So far, the distribution of this species still appears to be limited to Asia. However, if introduced, they can potentially become established in other parts of the world such as Europe where pome and stone fruit trees are widely grown (Vanhanen et al. 2008).

Biology of this pest is extracted from Duffy (1968), EPPO (2005), and Mazaheri et al. (2007). Pupation usually occurs in October and November, and the adults emerge from March to June. The eggs are usually laid in small batches of 5–10 on living trees, particularly in wounds in the bark, on broken ends of branches, and in pits gnawed down to the living bark. A female can lay about 50 (Duffy 1968), 123 (Mazaheri et al. 2007), or 240–270 eggs (EPPO 2005) in her lifetime. The eggs hatch in 10–14 days, and neonate larvae bore into the bark and sapwood. Frass is ejected through the entry hole. The grown larvae enter the wood and, at the end of the first season of development, make a long (about 25 cm) tunnel that first runs parallel to the axis of the trunk or branch and then turns to form a downward gallery about 15 cm long. At the bottom of this gallery, the larva overwinters, protected by a double plug made from frass. Next in the spring, the larvae continue to feed, making tunnels deep into the wood. At the end of July, they prepare pupation cells protected by double plugs made from borings. Pupation occurs in these cells, and the pupal stage lasts about two weeks. After eclosion, the adult remains in the pupation cells over the winter and then emerges in the spring. The life cycle lasts two years.

Cultural measures have been used to control the pest in orchards and gardens (Duffy 1968). For example, during outbreaks, adults can be trapped and killed using freshly cut logs of hosts. Heavily infested trees should be felled and removed before November. In a field trial, two entomopathogenic fungal isolates *Beauveria bassiana* and *Metarhizium anisopliae* gave some control (Mohi-Uddin et al. 2009). Bhat et al. (2010b) have tested the pathogenicity of three fungal isolates, *B. bassiana, B. brongniartii*, and *M. anisopliae*, in the laboratory and indicated that *B. bassiana* is most virulent against *A. sarta* larvae. Insertion of organophosphate insecticide-soaked small pieces of sponge into borer holes in the trunk achieved >60% larval mortality in the field (Khan and Qadri 2006). The similar application of organophosphate or aluminum phosphide can kill 70% of larvae within three weeks of application (Mohi-Uddin et al. 2009; Bhat et al. 2010c).

12.2.1.2 Aeolesthes holosericea (Fabricius)

Synonyms: *Pachydissus similis* Gahan, *P. velutinus* Thomson, *Ceramryx holosericeus* Fabricius
Common name: Cherry stem borer

The adults of this cerambycine species are 20–36 mm long and similar to *A. sarta* in morphology; the body is dark or reddish brown, covered with dense grayish or light brown silky pubescence; the elytra have a sheen of contrasting dull and bright areas that vary according to incidence of light (Figure 12.2). It is widely distributed in India (particularly northern India), Pakistan, Sri Lanka, southern China, Myanmar, Vietnam, Thailand, Malaysia, and Laos. So far, this species still appears to be limited to Asia. This longicorn is also highly polyphagous, attacking many tree species from Fabaceae, Rutaceae, Betulaceae, Combretaceae, Malvaceae, Phyllanthaceae, Meliaceae, Sonneratiaceae, Myrtaceae, Lythraceae, Euphorbiaceae, Anacardiaceae, Annonaceae, Moraceae, Myristicaceae, Diptocarpaceae, Pinaceae, Rosaceae, Fagaceae, and Tamiaceae (Beeson 1941; Duffy 1968; Regupathy et al. 1995; Mamlayya et al. 2009; Prakash et al. 2010; Bhawane and Mamlayya 2013; Salve 2014).

Duffy (1968) suggested that this species only attacks dead or felled trees. However, it also attacks living trees. This stem borer has become an increasingly important pest of apple trees in northern India (Tara et al. 2009; Gupta and Tara 2013, 2014) and a minor pest of mango, guava, peach, pear, and plum trees in China (Li at el. 1997). It also attacks cherry, apricot, guava, mango, mulberry, peach, pear, plum, and walnut trees in India (Tara et al. 2009). Similar to *A. sarta*, the larvae cause the damage, making horizontal zigzag tunnels into the trunk and main branches and thereby reducing the longevity and fruit yield of trees (Gupta and Tara 2014). Trees can be killed in successive years of damage.

The biology of this pest is similar to that of *A. sarta* (Duffy 1968; Tara et al. 2009; Gupta and Tara 2013). Pupation occurs in October in northern India, and adults emerge in the following March–May with

FIGURE 12.2 *Aeolesthes holosericea* adult. (Courtesy of Xavier Gouverneur.)

a peak in April. The females lay eggs in batches of four to six in the cracks or crevices under the bark during May–October. A female can lay about 200 eggs in her lifetime but, in confinement, can lay up to 92 eggs. The larvae bore into the bark, sapwood, and finally into heartwood. Their life cycle lasts about two years; the first winter is spent in the larval stage and the second in the larval or pupal stage in galleries.

So far, only chemical control appears to be effective for this pest. The application of organophosphate or aluminum phosphide in a way similar to that used for *A. sarta* can kill up to 100% of larvae (Gupta and Tara 2014).

12.2.1.3 Aromia bungii (Faldermann)

Synonyms: *Aromia cyanicornis* Guérin-Méneville, *Cerambyx bungii* Faldermann
Common name: Peach rednecked longicorn

The adults of this cerambycine species are 20–40 mm long and blue-black and shining—except for pronotum, which is bright red (Figure 12.3). It is widely distributed in eastern Asia including China, Japan, Korea, Mongolia, and Vietnam (Duffy 1968; Li et al. 1997; Anderson et al. 2013; EPPO 2013a, 2015). The larvae of this longicorn are reported to feed on a number of plant species from Rosaceae, Meliaceae, Poaceae, Ebenaceae, Oleaceae, Salicaceae, Juglandaceae, Lythraceae, and Theaceae with Rosaceae appearing most preferred (Anderson et al. 2013; EPPO 2013a, 2015). *A. bungii* has recently been introduced to Europe, including Germany and Italy (Anderson et al. 2013; EPPO 2013a), and may have become established in Italy (Garonna et al. 2013). Based on its known host range and distribution, this pest probably has the potential to establish in most parts of the Europe and presents a high risk (EPPO 2013a).

The peach rednecked longicorn is considered an important pest of stone fruit trees, such as peach, apricot, plum, and cherry in eastern Asia, particularly China (Duffy 1968; Li et al. 1997; Anderson et al. 2013; EPPO 2013a). Earlier references show that the larvae bore in both sapwood and heartwood of main trunks and large branches, weakening trees and occasionally killing them (Gressitt 1942; Duffy 1968).

FIGURE 12.3 *Aromia bungii* adult. (Courtesy of Antonio P. Garonna.)

More recent literature reports that the larvae mainly tunnel in the subcortical area beneath the bark and the sapwood and less commonly in the heartwood, leading to loss of fruit production and weakening of the trees (EPPO 2013a).

Pupation takes place at the end of June; the adults emerge from late June until early August, and winter is passed in the larval stage (Gressitt 1942; Liu et al. 1999). The females lay eggs in bark crevices on the trunk and main branches mainly in July (EPPO 2013a). Lifetime fecundity is unknown. This species has a life cycle of two to three years depending on climate (Liu et al. 1999; Ostojá-Starzewski and Baker 2012).

Gressitt (1942) recommended that the larvae be extracted by means of hook wire and adults collected during the daytime on branches, trunks, and flowers during July. Heavily infested trees should be felled and destroyed. Hong and Yang (2010) have tested the application of raw extracts and culture homogenates of a poisonous mushroom, *Lepiota helveola* Bresadola, to control larvae and achieved up to 80% larval mortality. There are also reports of trials using several entomophagous nematode species, *Steinernema* spp., as biological control agents against *A. bungii* (Liu et al. 1993, 1998b). However, it is not known how useful these treatments can be in the field.

12.2.1.4 Linda nigroscutata (Fairmaire)

Synonym: *Miocris nigroscutatus* Fairmaire
Common name: Apple twig borer

The adults of the lamiine longicorn are 15–20 mm long and bright orange-red; the pronotum has four small, round, black spots in the form of a trapeze on the disc; the elytra have an elongate scutum-shaped black mark behind the scutellum, reaching to the end of the basal quarter or basal third of suture, and the humeri generally are also marked with a black spot (Figure 12.4). This species occurs in southwest China and northeast India (Gressitt 1947; Duffy 1968; Sachan and Gangwar 1980; Cao 1981). So far, there is no report on occurrence of this lamiine outside Asia.

FIGURE 12.4 *Linda nigroscutata* adults, dorsal (left) and lateral (right) views. (Courtesy of Xavier Gouverneur.)

The apple twig borer is an apple tree pest of some economic importance in southwest China and northeast India (Fletcher 1919; Gressitt 1947; Duffy 1968; Sachan and Gangwar 1980; Cao 1981). The adult females girdle twigs and tender shoots and lay eggs in the wound subcortically, and the larvae bore in the twigs and shoots and eventually hollow them, reducing growth and yield (Beeson and Bhatta 1939; Duffy 1968; Sachan and Gangwar 1980; Cao 1981). Frass is ejected from holes made by larvae in twigs.

According to Cao (1981), the adults emerge from May to July, peaking during May. The eggs are laid singly in the girdled wounds of the current year's shoots. The larvae bore into the shoots and then continue to bore into one- and two-year-old twigs. Lifetime fecundity is unknown. This pest has one generation a year and overwinters as mature larvae that pupate in infested twigs.

Pruning and burning of infested twigs are probably the only effective measures for the control of this pest (Fletcher 1919; Cao 1981). These practices should be carried out during June–August. If the larger twigs are infested, a pesticide solution may be injected into larval tunnels.

12.2.1.5 Bacchisa fortunei (Thomson)

Synonyms: *Chreonoma fortunei* (Thomson), *C. fortunei obscuricollis* Pic, *C. fortunei flavicornis* Kano, *Plaxomicrus fortunei* Thomson
Common name: Blue-backed pear longicorn

The adults of this lamiine are 8–11 mm long; the body is orange-yellow with metallic blue elytra (Figure 12.5). *B. fortunei* (Thomson) is widely distributed in China, Japan, and Korea, and feeds on most cultivated pome and stone fruit species (Duffy 1968; Li et al. 1997). So far, this species only occurs in Asia.

This longicorn is considered a minor pest of apple, pear, and peach trees in China (Chang 1973; Qian 1987; Wei 1990; She et al. 2005). However, up to 45% infestation on apple trees has been reported in northwestern China (Xu et al. 2007). The larvae bore in twigs or small branches, making them vulnerable to wind breakage (She et al. 2005). The infested parts break open, exposing frass (Guan 1999). Growth and fruiting of damaged twigs and branches are significantly reduced.

FIGURE 12.5 *Bacchisa fortunei* adult. (Courtesy of Larry Bezark.)

Biology of this pest is summarized from Guan (1999) and She et al. (2005). Adults emerge during April–July with a peak in June. The adult females prefer twigs and branches 15–25 mm in diameter for oviposition. They gnaw oviposition slits on selected parts and lay eggs in the slits singly. A female can lay 10–30 eggs in her lifetime. Neonate larvae bore into the bark and then the sapwood. This pest takes two years to complete its life cycle and overwinters as larvae.

Cultural measures are recommended to control the pest, such as removal of eggs and neonate larvae using knives, killing larvae in tunnels using wire hooks (Guan 1999), and pruning damaged twigs and branches (She et al. 2005). Injection of organophosphate insecticides into larval tunnels is recommended for heavily infested twigs and branches (Guan 1999; She et al. 2005). Trials using a wasp (*Scleroderma guani* Xiao and Wu) parasitizing larvae and pupae have been carried out in northwestern China's Gansu Province, one of the major apple growing areas, and achieved a parasitism rate of 55.5–60.8% (Wei 1990).

12.2.1.6 Osphranteria coerulescens Redtenbacher

Common name: Rosaceae branch borer

The adults of this cerambycine borer are 16–22 mm long; body is elongate with a metallic violet color; the elytra are clothed with dense appressed golden pubescence (Figure 12.6). It is widely distributed in Iran, Iraq, Turkey, Pakistan, and Afghanistan, and larvae feed on various species from Rosaceae and other families (Sharifi et al. 1970; Kaplan 2013; Özdikmen 2014).

As an important pest in Iran (Sharifi et al. 1970; Abivardi 2001) and Turkey (Kaplan 2013), *O. coerulescens* damages the twigs and branches of many pome and stone fruit trees such as cherry, apricot, peach, plum, apple, pear, and quince, and several other crop species such as almond, pistachio, and fig. According to Sharifi et al. (1970), the neonate larvae immediately bore into the twigs, which start wilting with discolored leaves in two weeks. During the short period of movement up the twigs, the larvae cut the vascular bundles, reducing the amount of sap at the top of the twig. This activity apparently produces an environment

FIGURE 12.6 *Osphranteria coerulescens* adult. (Courtesy of Jiří Mička.)

favorable for the development of the larvae. After three weeks, when the larvae turn and proceed toward the base of the twig, the damaged tip of the twig falls off. The badly infested trees are quite obvious after 20–25 days because of the fallen twigs. About four weeks after penetration, the larval entrance is marked by a 10- to 15-mm-long, glutinous filament extruded from the branch at this point. On the trees, the tips of the broken branches are brownish and have irregularly cut surfaces. In addition to the central larval gallery, the branches have small holes. Fine frass is ejected through these openings. From the young branches, the larvae may continue boring into the trunks of six- to seven-year-old trees. These branches break off at the slightest pressure and, in heavily infested orchards, many may be seen on the ground in late summer, fall, and early spring. This breakage can result in severe crop reduction.

Biology of this longicorn is extracted from Sharifi et al. (1970) and Kaplan (2013). The adults emerge in May and June and prefer spring twigs for oviposition. The favored site for egg deposition is the angle between the petiole and the stem. The eggs are also laid on the twig surface—usually singly but occasionally in groups of two or three. A female can lay 30–75 eggs in her lifetime. This pest has one generation a year and overwinters as mature larvae.

Although larval parasitoids and chemical sprays may contribute to its control to some extent, the simplest, safest, and cheapest method of control is cutting the infested twigs during the summer (Sharifi and Javadi 1971).

12.2.1.7 Dorysthenes hugelii (Redtenbacher)

Synonyms: *Lophosternus falco* Gahan, *L. hügelii* Gahan, *L. palpalis* Gahan, *Cyrthognathus falco* Thomson, *C. hügelii* Redtenbacher

Common name: Apple root borer

The adults of this prionine root borer are very large beetles, about 29–53 mm long; the body generally is castaneous in color, with the head and prothorax slightly darker than the elytra. The species is recorded in India, Pakistan, and Nepal. There is no report on expansion of this species outside its native region. The larvae feed on roots of apple, pear, peach, cherry, and plum trees—with apple being the preferred host; adults do not feed (Singh 1941; Duffy 1968).

The apple root borer is a serious pest of apple trees in India (Singh 1941; Verma and Singh 1986) with an infestation level ranging from 2 to 16 larvae per tree. The pest infests all commercial cultivars and groups of apple plants (Sharma and Khajuria 2005; Singh et al. 2010). According to Singh (1941), the larvae bore into or girdle the roots and occasionally the stem below the surface of the ground. The infested trees generally are weakened and yield reduced. Heavily infested trees can die in a few years.

Biology of this pest has been studied by various authors (e.g., Singh 1941; Duffy 1968; Sharma and Khajuria 2005; Singh et al. 2010). The adult emergence peaks with the onset of monsoons in late June and early July. They live for a few days to about three months and are attracted to light. The female prefers sandy and sandy/loam soils for oviposition and, in her lifetime, lays 300–600 eggs, usually singly, at a depth of about 8 mm in the soil. The egg, larval, prepupal, and pupal stages occupy about 1, 42, 3 and 2–3 months, respectively. The neonate larvae move down and start feeding upon reaching the roots. The life cycle lasts three to four years, and overwintering occurs at the larval and pupal stages.

Control measures for killing adults using light trapping (Sharma and Khajuria 2005) or insecticides (Rana et al. 2004) should be directed during late June to mid-July (Singh et al. 2010). According to Sharma and Khajuria (2005), most larvae are present within a 90-cm radius and 30-cm depth of apple tree basins, where control measures should be directed.

12.2.2 Europe

12.2.2.1 Cerambyx carinatus (Küster)

Synonym: *Hammaticherus carinatus* Küster
Common name: Ring-pediceled longicorn

The adults of this cerambycine borer are 30–45 mm long and dark brown in color; the second antennal segment is in the shape of a ring, nearly three times as wide as long; the elytron has a spine at suture (Figure 12.7). It is widely distributed in Eastern Europe and the Middle East—such as in Bulgaria, Croatia, Iran, Macedonia, Malta, Serbia, and West Turkey, and its larvae feed on large stressed or sickly trees of the Rosaceae family (Bense 1995; Özdikmen and Turgut 2009; Hoskovec and Rejzek, 2014). So far, it has not been recorded in other parts of the world.

The ring-pediceled longicorn is a minor pest of cherry trees in Eastern Europe and the Middle East, particularly in western Turkey (Tezcan and Rejzek 2002). The larvae bore in the heartwood of the trunks, weakening the vigor of the infested trees.

The adults emerge during June–August and lay eggs in bark wounds or crevices along the trunks. The lifetime fecundity is unknown. The larvae bore in the superficial regions of the trunk in the first few months and then enter the sapwood and heartwood. The winter is passed in the larval stage. One generation takes two to three years.

Maintenance of tree health probably is the best control measure for this pest. Whitewash along the trunk may be useful in preventing oviposition.

12.2.2.2 Cerambyx nodulosus Germar

Common name: Nodulated longicorn

The adults are 26–46 mm long and dark brown to blackish in color; the pronotal disc bears irregular wrinkles, and the elytral apex is rounded (Figure 12.8). This species mainly occurs in southeastern Europe, Turkey, and the Near East, and its larvae feed on sickly trees of the Rosaceae family, particularly *Prunus* (Bense 1995; Hoskovec and Rejzek, 2014). So far, it has not been recorded in other parts of the world.

FIGURE 12.7 *Cerambyx carinatus* adult. (Courtesy of Jiří Mička.)

FIGURE 12.8 *Cerambyx nodulosus* adult. (Courtesy of Zoran Božović [image from Srećko Ćurčić].)

The nodulated longicorn is also a minor pest of cherry trees in Eastern Europe and the Middle East, particularly in western Turkey (Tezcan and Rejzek 2002). It also attacks *Pyrus, Malus*, and *Crataegus* trees (Bense 1995). The larvae bore in the trunks and expel large quantities of easily visible sawdust. In southeastern Bulgaria, even very small, stunted *Crataegus* shrubs growing on sandy soils of the Black Sea coastal region can serve as hosts (Tãuşan and Bucşa 2010).

The adults emerge during May–August and are active during the day. One generation lasts three to four years. The larval biology is similar to that of *C. carinatus*. The lifetime fecundity is unknown.

Control measures are similar to those for *C. carinatus*.

12.2.2.3 Cerambyx scopolii Fuessly

Synonyms: *C. piceus* Geoffroy, *C. niger gallicus* Voet
Common name: Capricorn beetle

The adults are 17–28 mm long and totally black in color; the elytra are rounded at the apex and covered with a fine gray pubescence (Figure 12.9). The longicorn is widely distributed in Europe, Caucasus, Transcaucasia, North Africa, and in the Near East (Bense 1995; Hoskovec and Rejzek 2014). It is polyphagous, with its larvae feeding on tree trunks and branches from the Rosaceae, Fagaceae, Juglandaceae, Betulaceae, Salicaceae, Ulmaceae, Grossulariaceae, Sapindaceae, and Oleaceae families (Duffy 1953; Hoskovec and Rejzek 2014). So far, it has not been recorded in other parts of the world.

This species is a minor pest of apple, cherry, plum, and walnut trees in Europe (Stahel and Holenstein 1948; Brauns 1952; Duffy 1953; Ferrero 1985). The larvae make large, broad tunnels deep in the heartwood of mature and often healthy trees (Figure 12.10), weakening them. When the damage occurs to the trunks, fruit drop prematurely, and the infested trees may eventually die. In the early stages of infestation, gumming and cracks and swellings in the bark can occur.

According to Duffy (1953), the adults emerge during April–July and lay eggs in the crevices in the bark of the branches and trunks of mature trees. The lifetime fecundity is unknown. The larvae initially

FIGURE 12.9 *Cerambyx scopolii* adult. (Courtesy of Boženka Hric [image from Srećko Ćurčić].)

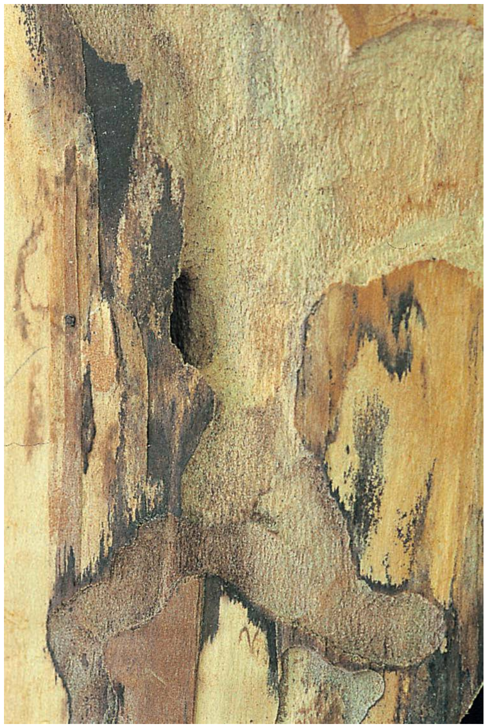

FIGURE 12.10 Galleries made by *Cerambyx scopolii* larvae. (Courtesy of György Csóka.)

feed under the bark and soon enter sapwood and then heartwood. Pupation occurs in the pupal cell in the heartwood either in August–September or in the spring. The life cycle lasts two to three years. Overwintering occurs at the larval stage, and depending on when pupation occurs, the winter can also be passed at the pupal or adult stage.

In orchards, maintenance of tree health is still probably the best control measure for this pest (Stahel and Holenstein 1948; Duffy 1953). Removal of infested branches and the use of trap-pans baited with molasses to catch adults may help reduce the pest population. When the trunks are infested, the introduction of cotton wool soaked in organophosphate insecticides into galleries and the subsequent sealing off of holes may be effective.

12.2.2.4 Cerambyx cerdo Linnaeus

Synonyms: *C. luguber* Voet, *C. heros* Scopoli
Common name: Great capricorn beetle

The adults are 24–55 mm long and blackish, with the elytra reddish brown toward the apex; the second antennal segment at the inner edge is as long as its width, not in the shape of a ring; the elytral apex has a spine at the suture (Figure 12.11). This species occurs in the Mediterranean region and is highly polyphagous on deciduous trees from the Rosaceae, Ulmaceae, Fagaceae, Juglandaceae, Salicaceae, Fabaceae, and Betulaceae families (Duffy 1953; Bense 1995; Hoskovec and Rejzek 2014). So far, it has not been recorded in other parts of the world.

The great capricorn beetle is a minor pest of apple, pear, cherry, and oak trees in Europe (Bruans 1952; Duffy 1953). The larvae make sizable tunnels in the sapwood and heartwood of large, mature tree trunks (Figure 12.12) and sometimes cause considerable damage. Reinfestation may continue for many years, weakening the trees that are affected.

The biology is summarized from Bruans (1952), Duffy (1953), and Hoskovec and Rejzek (2014). The adults emerge during May–August and lay eggs in the crevices of the bark. The larvae bore under the bark

FIGURE 12.11 *Cerambyx cerdo* adult. (Courtesy of György Csóka.)

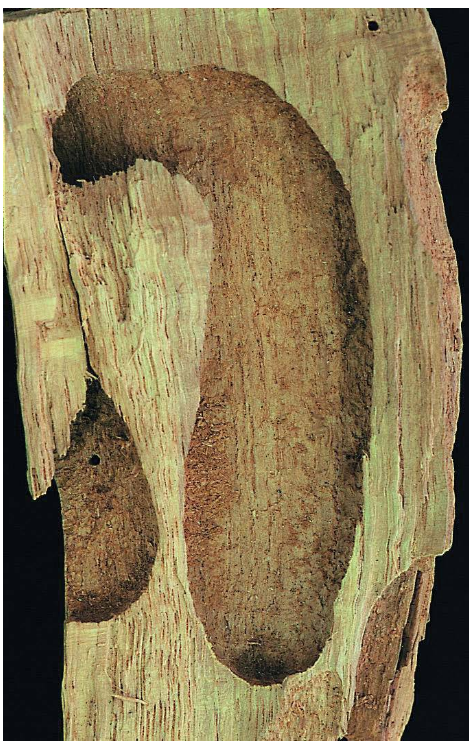

FIGURE 12.12 Galleries made by *Cerambyx cerdo* larvae. (Courtesy of György Csóka.)

for a few weeks, then enter the sapwood, and finally bore into the heartwood. They spend three to four years in the trunk. Pupation occurs in the pupal cell made in the heartwood in August. The adults overwinter in the pupal cells and emerge from May onward the next year. The life cycle lasts three to five years.

Control measures are similar to those for *C. scopolii*.

12.2.2.5 Cerambyx dux (Faldermann)

Synonym: *Hammaticherus dux* Faldermann
Common name: Giant-eyed longicorn

The adults are 25–45 mm long and dark brown to blackish, with the elytra being black only at the base and becoming paler, reddish brown toward the apex; the eyes are large with the lower edge nearly reaching the underside of the head; the elytral apex is more or less rounded (Figure 12.13). This species is widely distributed in Eastern Europe, the Middle East, and in the Near East, particularly in Bulgaria, Macedonia, Malta, Turkey, Greece, Crimea, Iran, and Jordan (Bense 1995; Sharaf 2010; Hoskovec and Rejzek 2014). So far, it has not been recorded in other parts of the world. Its larvae are polyphagous in fruit and ornamental trees or brushes (Hoskovec and Rejzek 2014).

The giant-eyed longicorn is an important pest of apple and pear trees in the Mediterranean and Middle East regions, and it also occasionally attacks apricot, plum, peach, and almond trees (Jolles 1932; Lozovoi 1954; Saliba 1972, 1974, 1977). In Jordan, it is a serious pest of stone fruit trees with about 24% of cultivated trees being infested; plum trees are more susceptible than peach trees, and almond trees are the least susceptible host (Sharaf 2010). The larvae bore in the branches and trunks, expelling a large quantity of sawdust from tunnels. Mature trees more than five years of age are usually attacked because younger trees do not have trunks thick enough to accommodate the fully grown cerambycine larvae.

The biology of *C. dux* has been relatively well studied (Jolles 1932; Saliba 1977; Sharaf 2010). The adults emerge during March–June and may be stimulated by rain. In Jordan, the adults emerge

FIGURE 12.13 *Cerambyx dux* adult. (Courtesy of Larry Bezark.)

at the time their hosts bloom. They live for about a month and lay eggs singly or in small patches of 10 arranged in two vertical rows, with each row of five eggs placed in the bark crevices or wounded lesions of the upper trunk or the shady side of the main branch. According to Saliba (1977), the average number of eggs laid per female is approximately 13. However, the fecundity appears to be much higher than 13 eggs (Sharaf 2010). The females are attracted to black-colored, previously infested, or mechanically injured trunks and branches. The larvae bore under the bark for a few months and then enter the sapwood and heartwood. The egg stage lasts one to three months; the larval stage, 15–16 months; the pupal stage, one to two months; and the dormant adult stage in pupal cell, seven months. *C. dux* overwinters as the partially grown larvae, pupae, and adults. The life cycle lasts about two to three years.

Several control measures have been practiced (Jolles 1932; Lozovoi 1954; Saliba 1972; Sharaf 2010). Removal of heavily infested and dead trees can effectively reduce the population size in the orchards. Plugging all borer holes with cement can kill a certain number of larvae but may not be effective enough. To reduce the infestation rate, mechanical injuries to the trunks and branches should be avoided. Sprays of insecticides in May and June may kill adults and young larvae before they enter the trees. The most effective control method appears to be the application of a white latex paint, by painting or spraying, to the trunks and branches to prevent oviposition and larvae from entering the trees. The paint can be mixed with insecticides to kill adults and neonate larvae.

12.2.2.6 Tetrops praeustus (Linnaeus)

Synonym: *T. praeusta* Linnaeus
Common name: Plum longicorn

The adults of this lamiine borer are 3–6 mm long; the head and pronotum are black; the elytra are yellow to yellowish brown; each elytron has a black spot at the apex but sometimes the elytra are entirely black (Figure 12.14). This species is widely distributed in Europe and has become established in

FIGURE 12.14 *Tetrops praeustus* adult. (Courtesy of Eugenio Nearns, Longicorn ID, USDA APHIS ITP, Bugwood.org [5516884].)

the northeastern United States and North Africa (Yanega 1996; Howden and Howden 2000). The larvae primarily feed on various species from Rosaceae but also attack trees from the Fagaceae, Malvaceae, Ulmaceae, Salicaceae, Celastraceae, and Rhamnaceae families (Duffy 1953; Bense 1995).

The plum longicorn is a minor pest of apple and pear trees. The larvae bore inside the twigs and shoots. Leaves on primary shoots later become dry and fall off, a symptom similar to fire blight caused by *Erwinia amylovora* (Burrill) (Jerinic-Prodanovic et al. 2012).

The biology is briefly described in Duffy (1953), Bense (1995), and Jerinic-Prodanovic et al. (2012). The adults emerge in May–July and lay eggs in oviposition slits made by females in the bark of the twigs and shoots. The lifetime fecundity is unknown. The larvae bore in and under the bark and pupate in the sapwood. In Europe, this species completes its life cycle in one to two years depending on climate, and overwinters at the larval stage.

Pruning of the infested twigs can reduce the pest population to some extent.

12.2.3 North America

12.2.3.1 Prionus californicus Motschulsky

Common name: California prionus

There are about 27 synonyms for this species (Linsley 1962), which are not listed here. The adults of this prionine root borer are 24–55 mm long, exclusive of mandibles, and reddish brown to piceous brown in color; the antennae are 12-segmented with segments 3–11 of males being distinctly produced externally at the apex; the pronotum is short (Figure 12.15). It is widely distributed in western North America from Mexico to Alaska and highly polyphagous, feeding on species from the Fagaceae, Juglandaceae, Rosaceae, Vitaceae, Salicaceae, Myrtaceae, Ericaceae, Rutaceae, Anacardiaceae, and Pinaceae families (Linsley 1962; Bishop et al. 1984; Steffan and Alston 2005; Alston et al. 2007, 2014).

FIGURE 12.15 *Prionus californicus* adult. (Courtesy of Steven Valley, Oregon Department of Agriculture and Bugwood.org [5449551].)

In the past two decades, *P. californicus* has become a serious pest of stone fruit trees, particularly sweet cherry, peach, and apricot, in the Intermountain West region (Alston et al. 2007, 2014), and also damaged citrus trees in Phoenix, Arizona (Jeppson 1989). The larvae spend three to five years underground, causing direct or indirect death of fruit trees due to girdling of the root cambium and introduction of secondary pathogens that lead to decay (Alston et al. 2014). The damage is more severe when the trees are grown in light, well-drained soil; sometimes, the trunks of the trees are completely girdled just below the ground level (Linsley 1962). In citrus trees, larvae bore in the trunks just below the ground surface (Jeppson 1989). Canopy death or sudden loss of tree vigor can be symptoms of *P. californicus* infestation.

The biology of this pest is summarized from Linsley (1962) and Alston et al. (2014). The adults emerge in early to mid-summer and are active crepuscularly. The females lay eggs in the soil. A female can lay 200–300 eggs in her lifetime; but, in some cases, up to 600 eggs are laid. The neonate larvae tunnel in the soil to seek out tree roots. The younger larvae begin feeding on smaller roots and gradually reach the tree root crown (stump, usually at or near the soil level) as mature larvae. In cherries, a greater proportion of the larvae found at the root crown are mature larvae, while younger larvae are found in smaller roots. Following three to five years of root and root-crown feeding while moving upward in the soil, the insect pupates in a pupal cell close to the soil surface. However, early reports show that pupation can occur in the soil 8–16 cm below the surface. The life cycle lasts three to five years and overwintering occurs in the larval stage.

Once an orchard is infested by this pest, it is difficult to control its population increase and spread to nearby trees, and the application of insecticides may only suppress the pest to some extent (Alston et al. 2014). Several insecticides registered for stone fruit may provide incidental suppression of the adults. Systemic insecticides such as imidacloprid may be effective on the younger larvae on the roots but not against the older larvae in the root crown or lower trunk. Imidacloprid may suppress the local population if used annually over several years. Heavily infested trees should be removed. Maintaining tree health and preventing stress are the best options for the control of prionus infestations. Fallowing an infested field for two or more years, planting annual crops that will be tilled under each year, and avoiding planting stone fruit trees in infested sites are also effective for managing the prionus in infested soils.

12.2.3.2 Prionus imbricornis (Linnaeus)

Synonyms: *P. robustus* Casey, *P. diversus* Casey, *Cerambyx imbricornis* Linnaeus
Common name: Tilehorned prionus

The adults are 24–50 mm long, exclusive of mandibles, and dark brown to reddish brown in color; there are 15–20 segmented antennae (Figure 12.16). This species is widely distributed in eastern North America along the Atlantic Coast from Florida to southern Canada, and from Florida west to the Great Plains, Nebraska, and Texas (Linsley 1962; Agnello 2013). Its larvae are polyphagous, feeding on roots of many species from Fagaceae, Rosaceae, Vitaceae, Salicaceae, Juglandaceae, Sapindaceae, Cornaceae, Tiliaceae, and Poaceae (Linsley 1962; Agnello 2013).

The tilehorned prionus has been recorded as a destructive pest of the living roots of oak, chestnut, pear, apple, grape, and several herbaceous crops (Linsley 1962). It has become an important pest of apple trees in recent years and, to a lesser extent, it also attacks cherry, peach, plum, quince, pear, and pecan trees (Agnello 2013). The aboveground symptoms of infestation are a gradual thinning and yellowing of foliage and limb-by-limb mortality. Young trees may be chewed off just below the soil surface and their root systems devoured. Mature trees may have only one or two functional roots left near the surface, keeping them alive until they are blown over by wind. The larvae are reported to also damage roots of maize (reviewed by Linsley 1962).

The biology of this pest is summarized from Craighead (1915), Linsley (1962), and Agnello (2013). The adults emerge from the soil in early to mid-summer but mostly in July. They fly at dusk and night and are attracted to lights. During the day, they hide beneath the loose bark or debris at base of trees. The females lay 100–200 eggs in groups in the soil around tree bases (Linsley 1962). Agnello (2013) stated that the females live for one to two weeks, during which time they each lay hundreds of eggs. The eggs hatch in two to three weeks. The neonate larvae dig down to the roots and begin feeding on the root bark. They move through the soil from one root to another, feeding on the surfaces of small roots.

FIGURE 12.16 *Prionus imbricornis* adult. (Courtesy of Nathan P. Lord, USDA APHIS ITP, Bugwood.org [5492072].)

Eventually, they enter the wood of larger roots, which they hollow, girdle, or sever. During the summer, the larvae feed on the roots in the upper 15–45 cm of soil but in the winter, are often located at nearly twice these depths. The feeding and developmental period lasts three to five years. When ready to pupate in early spring, larvae leave the roots and construct large oval pupal cells within 6–12 cm of the soil surface. Overwintering occurs at the larval stage, and the life cycle lasts three to five years.

Several control measures are recommended by Agnello (2013). Heavily infested trees that are beyond recovery should be removed and burned before the following spring to prevent developing borers inside from completing their life cycle. Keeping trees in a healthy, vigorous condition is one of the best preventive measures against attack. Foliage sprays of broad-spectrum insecticides during peak adult activity in July may be partially effective. Although the adults are attracted to light, no trials have been conducted to test whether light traps could be useful for controlling adults.

12.2.3.3 Prionus laticollis (Drury)

Synonyms: *P. oblongus* Casey, *P. frosti* Casey, *P. nigrescens* Casey, *P. densus* Casey, *P. beauvoisi* Lameere, *P. kempi* Casey, *P. parvus* Casey, *P. brevicornis* Fabricius, *Cerambyx laticollis* Drury
Common name: Broad-necked root borer

The adults are 22–44 mm long, exclusive of mandibles, and black or dark brown with an obscurely reddish cast in color; the antennae are 12-segmented (Figure 12.17). This species is widely distributed in eastern North America along the Atlantic Coast from southern Canada and New York and inland to Oklahoma (Linsley 1962; Agnello 2013). Its larvae are polyphagous, feeding on roots of many species from Fagaceae, Rosaceae, Salicaceae, Tiliaceae, Vitaceae, and Pinaceae (Linsley 1962; Agnello 2013).

The broad-necked root borer has recently become an important pest of apple trees, and to a lesser extent, it also attacks cherry, peach, plum, quince, pear, and pecan in eastern North America (reviewed by Agnello 2013). It is exclusively a root feeder. The aboveground symptoms of infestation are

FIGURE 12.17 *Prionus laticollis* adult. (Courtesy of Jon M. Yuschock, Bugwood.org.)

a gradual thinning and yellowing of foliage and limb mortality. Young trees are sometimes chewed off just below the soil surface and their root systems completely consumed. Established trees may be alive after infestation with one or two roots left near the soil surface but are easily blown over by wind. It is not unusual to find from several to 20 or more borers in one tree. In the past, this species was known to attack living roots of trees and shrubs, damaging fruit trees and grapevines in the central and northeastern United States, and also to attack lead telephone cables in subterranean wooden ducts, railway ties, and other timbers in contact with the ground (Linsley 1962).

According to Laurent (1905), Linsley (1962), and Agnello (2013), the adults emerge mainly in July and live for one to two weeks. Although Linsley (1962) reported a flight period of July–August, females have not been observed flying (Agnello 2013). The adults are active during dusk and night and remain inactive under the loose bark or debris at the base of the tree during the day. The females lay eggs in the soil near the tree base and produce an average of 363 eggs each. The eggs hatch in two to three weeks. Young larvae penetrate the soil and feed on surfaces of small roots and move through the soil from one root to another. They then bore into the wood of larger roots. Similar to the tilehorned prionus, the larvae feed on the roots in the upper 15–45 cm of the soil during the summer but are often located at nearly twice these depths in winter. In the early spring, mature larvae rise to within 6–12 cm of the soil surface to pupate. Overwintering occurs in the larval stage, and the life cycle lasts three to four years.

Control measures are similar to those for the tilehorned prionus (Agnello 2013).

12.2.3.4 Saperda candida Fabricius

Synonyms: *S. bipunctata* Hopping and *S. bivittata* Say
Common name: Roundheaded apple tree borer

The adults of this lamiine species are 13–21 mm long and brownish to black in color; the head, pronotum, and elytra have two longitudinal white stripes running the length of the body; the antennae and legs are usually reddish brown, and the entire body is covered with gray pubescence with the ventral

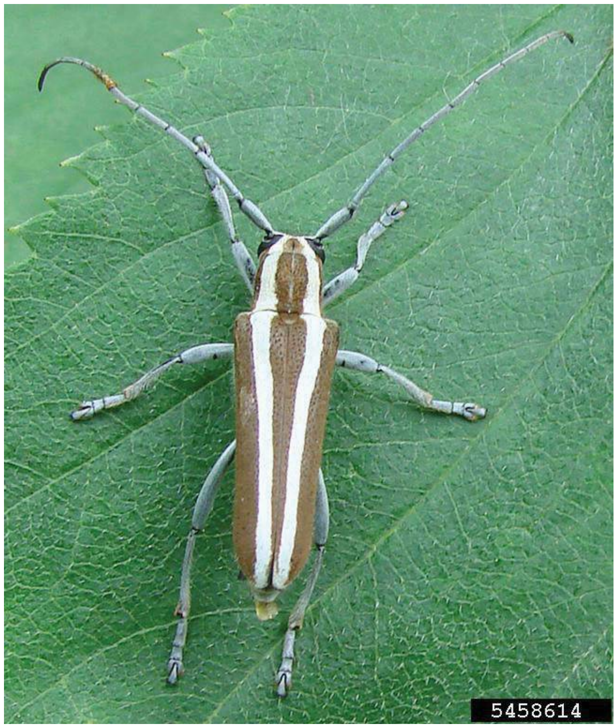

FIGURE 12.18 *Saperda candida* adult. (Courtesy of Dawn Dailey O'Brien, Cornell University, Bugwood.org [5458614].)

side silvery white (Figure 12.18). This borer is native to North America and distributed across the United States (particularly the eastern part) and southern Canada (Linsley and Chemsak 1995; EPPO 2008; Agnello 2013). It was accidentally introduced to the island of Fegmarn in Germany in 2008, causing serious concern to Europe (Nolte and Krieger 2008; EPPO 2008; Kehlenbeck et al. 2009; Baufeld et al. 2010; Eyre et al. 2013) and China (Yao et al. 2009). However, it is still not clear whether this species has become established and spread in Europe or elsewhere. *S. candida* has a broad range of hosts in Rosaceae including apple, cherry, peach, plum, quince, and pear, with the preferred host being apple (EPPO 2008).

In the eastern United States and southeastern Canada, it is considered an important pest of fruit trees, particularly apple, with trees of all sizes being attacked—but with those from three- to ten-years-old suffering the most (Agnello 2013). The adults feed on leaves, twigs, and fruit of host plants, but their injury to plants is not significant. The larvae bore in the main trunks and large branches and may completely girdle young trees. Infested trees look sickly, producing sparse, pale-colored foliage. The larval attacks can kill the trees or weaken them so that they are broken by wind. Sawdust-like frass can be found at the base of infested trees.

The biology of this pest is summarized from Linsley and Chemsak (1995) and Agnello (2013). The adults fly during May–August with an emergence peak of two to three weeks in June. Most emergences occur at night through round, pencil-sized holes from the bases of infested trees. The female lives about 40 days on average, normally hiding during day and laying eggs at night. The female makes a longitudinal cut in the bark with her mandibles near the base of the tree, inserting a single egg between the bark and xylem and sealing it in place with a gummy secretion. Oviposition mainly takes place in June and July but fecundity is not known in the field. The eggs hatch in 15–20 days. The larvae bore into the bark, moving upward or downward in the trunk depending on the year and stage of growth, feeding on the inner bark layer, and widening their tunnels as they feed. By the end of their third season of feeding, the larvae have bored straight up in the trunk and constructed pupal chambers just beneath the bark surface, within which they pass their final winter. This species requires two to three years to complete its development, depending on climate.

Agnello (2013) summarized the available control measures for this pest as follows: (1) tree destruction—remove and burn heavily infested trees that are beyond recovery before the following spring to prevent developing borers inside from completing their life cycle. (2) Larval killing by hand—during bloom and again in September, inspect the bark surface of the trunk between the lower 60 cm to just below the soil surface for small pinholes with sawdust exuding from them. Insert a stiff wire that is slightly hooked at the end to reach and impale the borer. (3) Injection—inject a mixture of pyrethrum in ethanol or *para*-dichlorobenzene moth flakes in cottonseed oil into the gallery using a grease gun to kill the borers that cannot be reached with the wire. (4) Foliage sprays—apply broad-spectrum insecticides at the beginning and end of June to kill adults. (5) Oviposition barriers—in early May, wrap protective coverings of various materials around the bottom 60 cm of the trunks to prevent the female beetles from reaching their preferred oviposition sites. (6) Surface deterrents—apply a deterrent wash (alkaline mixture of insecticidal soap plus caustic potash [lye] mixed to the consistency of thick paint) on the uninfested trunk surfaces using a paintbrush every two to four weeks, depending on rainfall, from late May through July to deter egg laying.

12.2.4 South America

12.2.4.1 Oncideres dejeanii Thomson

Synonym: *O. pustulata* Thomson
Common name: Pear twig girdler

The adults of this lamiine longicorn are 15–26 mm long and dark brown in color; the elytra have yellowish-brown pubescence at the base and a number of more or less round pubescent spots from near the base to the apex (Figure 12.19). This species is widely distributed in Brazil (from Maranhão, Ceará to Rio Grande do Sul),

FIGURE 12.19 *Oncideres dejeanii* adult. (Courtesy of Juan Pablo Botero [image from Marcela L. Monné].)

Paraguay, Argentina, and Uruguay (Duffy 1960; Monné 2002). Its larvae are highly polyphagous, feeding on a number of plant families including Anacardiaceae, Annonaceae, Bignoniaceae, Bombacaceae, Boraginaceae, Caesalpiniaceae, Casuarinaceae, Cecropiaceae, Cupressaceae, Euphorbiaceae, Fabaceae, Flacourtiaceae, Lauraceae, Meliaceae, Mimosaceae, Moraceae, Myrtaceae, Polygonaceae, Proteaceae, Rosaceae, Rutaceae, Salicaceae, and Tiliaceae (Link et al. 1994, 1996; Duffy 1960; Monné 2002).

In recent years, the pear twig girdler has become a minor pest of pear trees in southeastern Brazil, with a potential to become an important pest (Cordeiro et al. 2010). The adults girdle healthy tree branches before oviposition, which occurs under the green bark of the girdled parts. The larvae bore and complete their development in the girdled branches. The girdled twigs and branches eventually die. The average size of infested twigs/branches is 3.5 cm in diameter with a range from 1 to 3.6 cm.

According to Paro et al. (2012), the adults are present between November and January with a peak in February in southeastern Brazil. The larvae bore in the twigs and branches. The adults feed on the flowers and leaves of host plants, but adult feeding injury is not important. The winter is passed in the larval stage. The life cycle lasts about a year but can be longer depending on climate.

Pruning of the infested branches and twigs may reduce the pest population. Insecticide sprays while adults are active may contribute to a reduction in damage.

12.2.4.2 *Praxithea derourei* (Chabrillac)

Synonyms: *Elaphidium collare* Burmeister, *Xestia derourei* Chabrillac
Common name: Taladro longicorn

The adults of this cerambycine borer are 24–34 mm long, moderately slender, and reddish brown in color with sides being more or less parallel; the vertex and pronotum are covered with golden hairs; the elytra have fairly dense punctures with the apex bearing two sharp spines (Figure 12.20). The beetle occurs throughout South America, including Brazil, Bolivia, Paraguay, Argentina, and Uruguay (Duffy 1960;

FIGURE 12.20 *Praxithea derourei* adult. (Courtesy of Juan Pablo Botero [image from Marcela L. Monné].)

Monné 2001a). Its larvae feed on a number of plant species, including Betulaceae, Fagaceae, Meliaceae, Myrtaceae, Rosaceae, Salicaceae, and Tamaricaceae (Duffy 1960; Monné 2001a).

Although this species attacks a number of ornamental and forest trees in South America (Duffy 1960), it is considered a minor to important pest of apple trees in Argentina and Uruguay (Carbonell Bruhn and Briozzo Beltrame 1980; Di Iorio 1998). This species also attacks pear trees, but its significance to pear orchards is not clear (Carbonell Bruhn and Briozzo Beltrame 1980). The larvae make tunnels down from the branches to the bases of tree trunks (Duffy 1960; Di Iorio 1998). The infested parts are weakened and, at times, killed.

The biology is summarized from Bosq (1942), Duffy (1960), and Di Iorio (1998). The adults emerge during December and January. The females lay eggs among the terminal buds, particularly on the higher branches. The lifetime fecundity is unknown in the field. Young larvae bore into the branches and tunnel down to the trunks. The life cycle lasts about a year and the larvae overwinter.

According to Bosq (1942) and Duffy (1960), the infested branches should be cut off and burned or the borer holes injected with insecticide before summer.

12.2.5 Africa

12.2.5.1 Macrotoma palmata (Fabricius)

Synonyms: *M. valida* Thomson, *M. coelaspis* White, *M. humeralis* White, *M. böhmi* Reitter, *M. palmata rugulosa* Kolbe, *Prionus senegalensis* Olivier, *P. spinipes* Illiger, *P. palmatus* Fabricius
Common name: Large brown longicorn

The adults of this prionine are 25–65 mm long and brown to blackish brown in color; the antennae are 11-segmented with the inner side of several basal antennal segments bearing numerous granular outgrowths or spines; the sides of the pronotum have a number of small spines and granular processes (Figure 12.21). This longicorn occurs in many African countries including Egypt, Saudi Arabia,

FIGURE 12.21 *Macrotoma palmata* adult. Specimen from MNHN-Paris. (Courtesy of Jiří Pirkl, copyright MNHN-Paris, used with permission of T. Deuve and A. Taghavian.)

Morocco, Libya, Algeria Ethiopia, Kenya, Namibia, Nigeria, Rhodesia, Senegal, Sierra Leone, Ivory Coast, Cameroon, Burundi, Rwanda, Gambia, Guinea, Uganda, Mali, Mauritania, Niger, Guinea-Bissau, Benin, Mauritius, Mozambique, Botswana, Congo, and Uganda. Its larvae are highly polyphagous, feeding on many tree species from Aceraceae, Anacardiaceae, Casuarinaceae, Lauraceae, Mimosaceae, Moraceae, Myrtaceae, Piperaceae, Platanaceae, Rhizophoraceae, Rosaceae, Rutaceae, Salicaceae, and Tamaricaceae (Duffy 1957; Tadros et al. 1993; Sama et al. 2005; Delahaye et al. 2006).

The large brown longicorn attacks forest and ornamental trees and various fruit tree species including fig, citrus, and apricot in Northern Africa (Duffy 1957; Delahaye et al. 2006; Tawfik et al. 2014). It has become an important pest of apricot (Tadros et al. 1993) and citrus (Shehata et al. 2001) orchards in Egypt. The larvae bore in the trunks and main branches, weakening the trees. Older trees such as those more than 10 years old are more susceptible to this pest (Shehata et al. 2001; Tawfik et al. 2014) and can be infested by two to eight borers per tree. The highest level of the borer population (adult exit holes) occurs on the eastern side of the orchard (Shehata et al. 2001).

The biology of this beetle is summarized from Duffy (1957), EI-Sebay (1984), Tadros et al. (1993), Shehata et al. (2001), and Tawfik et al. (2014). The adults can be found between April and October, with an emergence peak in July and August. The females lay their eggs in the cracks and crevices in the bark of the trunks and main branches of healthy trees. The lifetime fecundity in the field is not known. However, in the laboratory, a female can lay an average of 50.9 eggs during the 12–18 days of the oviposition period. The larvae bore into the bark and then into the wood. The total larval period lasts two to four years, depending on temperature. The species takes three to four years to complete its life cycle and overwinters as mature larvae.

Control measures are still developing. Some laboratory tests on the effectiveness of fungus and synthetic insecticides have been made, but how useful these agents are for the control of the pest in the field is unknown.

12.3 Cerambycid Pests of Citrus Trees

The genus *Citrus* in the family Rutaceae contains some of the most commercially grown fruit species in the world—such as oranges, mandarins, and lemons. Oranges and other citrus fruit species are ranked among the top five in worldwide fruit production (Ebert 2009).

It has been widely believed that the origin of the *Citrus* genus was in the part of Southeast Asia bordered by northeast India, Myanmar, and southwest China (Scora 1975; Gmitter and Hu 1990). The fact that about 50% of cerambycid pests of citrus are endemic to Southeast Asia appears to support this hypothesis. However, some recent studies suggest that the genus could have originated in Australia, New Caledonia, and New Guinea (Liu et al. 2012a), even though relatively few cerambycids are economic pests of citrus in this region.

Jeppson (1989) listed and briefed 13 cerambycid species of some economic importance to the citrus industry; among them, *Stromatium barbatum* (Fabricius) in India and *Chloridolum alcmene* Thomson in Southeast Asia are no longer considered economically important and thus are not treated in this book; *Prionus californicus* and *Macrotoma palmata* are more important as stone fruit than as citrus trees and thus were discussed in the previous section of this chapter. In addition, *Aneflomorpha citrana* Chemsak was recorded as attacking orange twigs and small branches in Arizona in the 1950s (Gerhaedt 1961) but is not currently considered a pest of economic importance.

Although many cerambycids are reported to attack citrus trees, only 19 are considered economic pests in the world. Among these, 10 species are endemic to Asia, one of the world's largest citrus producing regions (USDA 2015). Australasia is one of the world's citrus-growing regions, but its production is relatively small compared to Asia, North and South America, Europe, and Africa (USDA 2015). Smith et al. (1997) listed five species that are distributed only in Australia and are considered economic pests of citrus in the eastern and southeastern regions of that continent. Among these species, *Acalolepta mixta* (Hope) [= *A. vastator* (Newman)] is an important pest of grapevines and thus is discussed in the section on vine crops later in the chapter; the remaining four species are detailed here. Furthermore, *Oemona hirta* (Fabricius), a New Zealand native, is a moderate pest of citrus and thus is discussed in this section—although it also attacks many plant species, including a number of fruit tree and grapevine species. South America, particularly Brazil, has become one of the major citrus growing regions in the world (USDA 2015). Many cerambycid species endemic to South America have broadened their host ranges to exotic citrus trees. For example, *Retrachydes thoracicus* (Olivier) (Penteado Dias 1980; Nascimento do et al. 1986), *Hexoplon ctenostomoides* Thomson, and *Phoebe phoebe* (Lep. & Serv.) (D'Araujo e Silva 1955) have been reported as infesting citrus and other fruit trees. However, these species are not currently considered economic pests of citrus. There are only four cerambycid species of economic importance in citrus orchards in South America, and they are discussed here. Cerambycids rarely cause any significant damage to citrus trees in Europe, North America, and Africa.

12.3.1 Asia

12.3.1.1 Anoplophora chinensis (Forster)

Synonyms: *A. malasiaca* (Thomson), *Melanauster chinensis* (Forster), *Cerambyx punctator* Olivier, *C. farinosus* Houttuyn, *C. chinensis* Forster
Common name: Asian starry citrus longicorn or citrus longhorned beetle

The lamiine adults are 20–40 mm long; the body is entirely shining black with the elytra marked with small, scattered, irregular, white pubescent batches; the basal halves of most antennal segments and tarsi have powdery blue pubescence; the ventral side has white pubescence; the elytra have numerous rounded tubercles on the basal fifth but lack abundant, long, suberect hairs on the surface (Figure 12.22). In rare cases, specimens do not appear to have any white patches on the elytra (Lingafelter and Hoebeke 2002). This species is primarily distributed in China, Korea, and Japan, with occasional records from Indonesia, Malaysia, Myanmar, the Philippines, and Vietnam (Duffy 1968; Lingafelter and Hoebeke 2002; CABI 2008; Haack et al. 2010). *A. chinensis* has been intercepted in many countries in Europe and North America and confirmed to have established in Europe, causing serious concern (Eyre et al. 2010; Haack et al. 2010; Peverieri et al. 2012; Schroder et al. 2012; Strangi et al. 2013). Its larvae feed on more than 100 tree species from at least 26 families including Aceraceae, Anacardiaceae, Araliaceae, Betulaceae, Elaeagnaceae, Fagaceae, Lauraceae, Oleaceae, Polygonaceae, Styracaceae, Rutaceae, Rosaceae, Salicaceae, Ulmaceae, Moraceae, Meliaceae, Leguminosae, Juglandaceae, Aquifoliaceae, Platanaceae, Euphorbiaceae, Casuarinaceae, Verbenaceae, Sapindaceae, Theaceae, and Taxodiaceae (Lingafelter and Hoebeke 2002; Haack et al. 2010; EPPO 2013b).

FIGURE 12.22 *Anoplophora chinensis* adult. (Courtesy of Steven Valley, Oregon Department of Agriculture and Bugwood.org [5445438].)

Although this longicorn attacks many tree species, it is considered a serious pest of citrus trees in China, being extremely abundant in all lowland orchards (Lieu 1945; Duffy 1968; Wang et al. 1996; You and Wu 2007; Haack et al. 2010; EPPO 2013b). It is also an important pest of many stone and pome fruit and mulberry trees there (Li et al. 1997). The adults feed on bark and leaves of host trees, but their injury is not significant. The larvae feed under the bark for about two months, after which time they bore into the woody tissues of the lowest portions of the trunks and the roots. Symptoms of infestation include frass and wood pulp extruding from frass holes, discoloration and deformation of the bark, and round emergence holes. A single larva can cause the death of a tree five- to six-years-old or younger. Mature trees can be significantly weakened by several larvae and eventually killed in successive years of infestation.

The biology of this pest is summarized from Lieu (1945), Duffy (1968), Adachi (1994), Wang et al. (1996), You and Wu (2007), Haack et al. (2010), and EPPO (2013b). The adults are present from late May to early October, with an emergence peak occurring in June and July. The females make oviposition slits with their mandibles in the living bark of lower trunks and exposed roots, lay eggs singly in the slits, and then seal the oviposition sites with secretions from the ovipositor. A female can lay an average of 70 eggs in her one- to three-month lifetime. The eggs hatch in one to three weeks, depending on temperature. The larval developmental period ranges from 10 to 15 months depending on climate. Pupation and adult development occur in the wood, and the adults exit the tree through a round hole on the bark surface. *A. chinensis* takes one year to complete its life cycle in southern China, one to two years in northern China and Japan, and probably up to three years in Northern Europe. Overwintering takes place at the larval stage.

Lieu (1945) recommended two effective control methods. First, the exposed roots and lower trunks up to 50 cm (particularly the lower 25 cm) from the ground are examined for egg slits and exuding frass at intervals of 10–14 days from early July to early October. The egg slits should be pressed with the thumb to crush the eggs, and the bark under the frass should be pared off so that the gallery can be uncovered and the larva killed. Second, whitewashing the exposed roots and lower trunks up to 50 cm from the ground with water-based pastes of quick-lime alone or mixture of quick-lime and sublimed sulphur proves to be very effective in preventing oviposition and killing the adults. The adults do not lay any eggs on treated trees, and those that visit the treated sites die in two to six days. The coating will remain for about two months. If the paste is washed away by heavy rain during the oviposition period, the trees should be retreated. Whitewashing is still the most practical and effective control method in China. Adachi (1990) has trialed the application of wire netting to prevent oviposition in a mature grove in Japan, achieving effective control. Heavily infested trees should be removed and destroyed. Chemical control is usually not very effective for this pest. However, Cavalieri (2013) trialed chemical control in Italy and achieved about 90% success. Briefly, in late May to early June, the basal trunks of trees should be sprayed or brushed with pyrethroid solutions, and then the trunks should be treated again 20 days later with a mixture of pyrethroid and neonicotinoid. Brabbs et al. (2015) summarized the literature on the biological control of this pest and discussed the potential of various biological control agents including entomopathogenic fungi *Beauveria brongniartii* Petch, parasitic nematodes *Steinernema feltiae* Filipjev and *S. carpocapsae* Weiser, and insect parasitoids *Aprostocetus anoplophorae* Delvare and *Spathius erythrocephalus* Wesmael. In China, three native parasitoids have been recorded that attack this pest, *A. prolixus* LaSalle & Huang, *Brulleia shibuensis* Matsumura, and *Scleroderma* sp. (Niu et al. 2014). However, to date, none of these agents has been used for the control of *A. chinensis* in commercial orchards. Because of this pest's invasive nature, EPPO (2013b) recommended various procedures for containing and eradicating the pest once intercepted and introduced.

12.3.1.2 Anoplophora macularia (Thomson)

Synonyms: *A. oshimana* Ohbayashi and *Calloplophora macularia* Thomson
Common name: Macularian whitespotted longicorn

The lamiine adults are 23–40 mm long. This species is very similar to *A. chinensis* in appearance, and they are not easily distinguished by the elytral maculation (Lingafelter and Hoebeke 2001). It differs from *A. chinensis* in having the ventral side covered with blue pubescence and the elytral surface with abundant, long, suberect hairs (Lingafelter and Hoebeke 2002). Unlike *A. chinensis*, the distribution range of *A. macularia* is limited to southern Japan, Taiwan, and southeast coast of China (Lee and Lo 1996; Lingafelter and Hoebeke 2002). So far, there has been no report of its invasion or expansion outside its primary region. It is also polyphagous with a host range of about 70 tree species from at least 19 plant families (Chang 1975).

This longicorn is an important pest of citrus and lychee (litchi) in Taiwan and is particularly abundant in abandoned citrus and lychee orchards and in areas where casuarina and melia trees are present (Chang 1970, 1975; Hwang and Ho 1994; Ho et al. 1995; Lee and Lo 1996). Larval damage can weaken or kill trees. Damage symptoms are similar to those from *A. chinensis*.

The biology of *A. macularia* is summarized from Chang (1970, 1975), Ho et al. (1995), and Lee and Lo (1996, 1998). The adults emerge between early April and October with a peak in June, bite oviposition slits in the bark near the base of the trunks, and lay eggs singly in the slits. The females live for an average of 115 days and, in their lifetime, lay an average of 204 eggs each. Larval feeding usually occurs on the phloem and sapwood under the bark of the trunk. This species has one generation a year; overwintering occurs at the larval stage, and pupation often takes place in a tunnel made into the solid wood at the upper part of the feeding area.

Several control methods recommended by Ho et al. (1995) include the white-brushing (with lime and sulfur) of the trunks before adult emergence to prevent oviposition, chemical spraying on the tree base or canopy to kill adults during April–October, biological control using egg and larval parasitic wasps and fungus *Beauveria* spp., and cultural practices such as tree base sanitation, appropriate irrigation, fertilization, and the use of resistant cultivars. Earlier, Hou (1979) suggested that the application of fumigants through the borer's tunnel openings can kill larvae. However, the effectiveness of the above control measures needs further investigation.

12.3.1.3 Pseudonemorphus versteegi (Ritsema)

Synonyms: *Anoplophora versteegi siamensis* Breuning, *Monochamus glabronotatus* Pic, *M. albescens* v. *subuniformis* Pic, *M. albescens* Pic, *M. versteegii* Ritsema
Common name: Citrus trunk borer

Pseudonemorphus versteegi has been placed in the genera *Monochamus* and *Anoplophora* but transferred to the genus *Pseudonemorphus* by Lingafelter and Hoebeke (2002) in their major revision of *Anoplophora*. The adults of this lamiine species are 18–33 mm long and covered with bluish pubescence; the elytra are marked with black spots (Figure 12.23). The longicorn is distributed in India, Myanmar, China, Laos, Vietnam, and Indonesia, and its host range appears to be narrow (Duffy 1968). So far, the species has not been reported to have expanded outside its primary distribution range.

This species is a serious pest of citrus trees in northern India and Myanmar (Lingafelter and Hoebeke 2002), particularly the northeastern Himalayan region of India (Saikia et al. 2012). For example, about 68% of citrus trees were infested during 1992–1995 in Meghalaya, India (Shylesha et al. 1996). *P. versteegi* is only considered a minor pest of citrus trees in southern and southwestern China (Li et al. 1997). In several other southeastern Asian countries, it is not reported as a pest. The longicorn attacks almost all commercially grown citrus species but prefers mandarin and orange (Shukla and Gangwar 1989; Singh and Singh 2012). Although several tree species other than citrus have been recorded as hosts, such as *Aglaia spectabilis* (Miquel) (Beeson and Bhatta 1939), *P. versteegi* is recognized as a pest of citrus trees only (Phukam et al. 1993).

Most adults emerge in May with some variations in different reports: April and May (Beeson and Bhatta 1939), April to June (Banerjee and Nath 1971), and March to September with a peak in May (Shylesha et al. 1996). The adults feed on citrus leaves and young bark. Oviposition occurs on the main trunks (Beeson and Bhatta 1939). Females make oviposition slits in the living bark with their mandibles and then lay eggs singly in the slits. The lifetime fecundity ranges from 35–85 eggs (Banerjee and Nath 1971) and 40–50 eggs (Shylesha et al. 1996) to an average of 69 eggs (Chatterjee

FIGURE 12.23 *Pseudonemorphus versteegi* adult. (Courtesy of Larry Bezark.)

and Ghosh 2001). Young larvae feed on the outer sapwood, forming a horizontal gallery before tunneling toward the center of the trunk (Banerjee and Nath 1971). This cerambycid has one generation a year and overwinters at the larval stage (Beeson and Bhatta 1939; Banerjee and Nath 1971; Shylesha et al. 1996).

Whitewashing the base of trees about 80 cm from the ground can prevent most ovipositions, and a tie of straw or a cotton band can prevent the beetles from ascending the trunks (Mitra and Khongwir 1928). The larvae can be killed in their tunnels by the introduction of a flexible wire (Duffy 1968). Banerjee and Nath (1971) and Shylesha et al. (1996) recommended destruction of eggs and young larvae before penetration into wood using mechanical methods such as pressing oviposition slits to crush the eggs and neonate larvae. Injection of gasoline into larval holes (5–10 mL per hole), followed by the sealing of the hole with mud or cotton plugging twice at 15-day intervals, proves to be highly effective in killing the larvae, achieving up to 82% success (Shukla and Gangwar 1989; Chatterjee and Ghosh 2001; Kalita et al. 2003).

12.3.1.4 Aphrodisium gibbicolle (White)

Synonyms: *Chelidonium gibbicolle rubrofemoralis* Pic, *C. gibbicolle subgibbicolle* Pic, *C. gibbicolle* White
Common name: Striate-necked green longicorn

The adults of this cerambycine borer are moderately slender and 28–34 mm long; the body is bluish green and metallic with the head and thorax being more shining; the pronotum has a number of transversely arranged wrinkles; the ventral side is grayish-green or bluish-green, covered with silvery gray pubescence (Figure 12.24). The species is distributed throughout China and in several other Asian countries including Bangladesh, India, Cambodia, Vietnam, Laos, and Thailand (Tu et al. 2006). There is no

FIGURE 12.24 *Aphrodisium gibbicolle* adult. (Courtesy of Larry Bezark.)

report of its occurrence outside its primary distribution range. This is a polyphagous cerambycid with a host range of at least 11 plant species in Rutaceae, Juglandaceae, Pinaceae, Fagaceae, Umbelliferae, and Euphorbiaceae, and it recently has been considered an important pest of oak forests in southern China (Tu et al. 2006; Zhang et al. 2010).

Aphrodisium gibbicolle is a minor to moderate pest of citrus in southern China (Hoffmann 1934; Chien 1981; Li et al. 1997). In Guangdong, the adults prefer to lay eggs on citrus branches; the larvae bore under the bark of the branches and then into the wood of the main trunks, weakening the trees (Hoffmann 1934).

Based on observations by Hoffmann (1934), the adults emerge in April to August in southern China and the life cycle lasts one year. The lifetime fecundity is 15–54 eggs (Zhang et al. 2010). Tu et al. (2006) showed that the adults emerge during May and June with an emergence peak in mid-June; this cerambycid needs two years to complete its life cycle, with the third and fourth instar larvae overwintering in the first year and prepupae and pupae overwintering in the second year. Several other *Aphrodisium* species in southern China also have a life cycle of two years (Zhang et al. 2010). On oak trees such as *Cyclobalanopsis oxyodon* and *Lithocarpus glabra*, the eggs are laid in the crevices or wounds in the bark of the branches or in trunks of 6–12 cm in diameter (Tu et al. 2006).

There has been no control method specifically developed for this pest. However, the control methods utilized for other *Aphrodisium* species could be useful for the development of control measures for *A. gibbicolle*. Zhang et al. (2010) summarized several effective ways to suppress *Aphrodisium* populations: removing and burning infested branches and trunks during the winter, whitewashing main trunks in the spring, injection of insecticides into or plugging gallery openings with cotton buds soaked with insecticide in the winter, and spraying insecticides on oviposition sites in the late spring to early summer to kill adults.

12.3.1.5 Chelidonium argentatum (Dalman)

Synonym: *Cerambyx argentatus* Dalman
Common name: Greenish lemon longicorn

The adults of this cerambycine species are 24–27 mm long; the body is dark green and shining; the ventral side is green and covered with silvery gray pubescence, and the antennae and legs are dark blue to blackish purple (Figure 12.25). It is distributed in China, India, Myanmar, and Vietnam, and its host range appears narrow, feeding on plants from Rutaceae, particularly citrus species (Duffy 1968).

The greenish lemon longicorn is an important pest of citrus trees in southern China (Gressitt 1942; Chang 1958; Chen et al. 1959; Chien 1981; Li et al. 1997) and southern India (Beeson and Bhatta 1939; Ramachandran 1953; Singh et al. 1983). The larvae bore into the branches, which wither and become vulnerable to wind breakage, and continue to tunnel down to the trunks. Fine, dry, and yellowish-white frass is obvious on infested branches and trunks as well as on the ground. Young trees can be hollowed to the root and killed.

The biology of this pest is summarized from Gressitt (1942), Chang (1958), and Chen et al. (1959). The adults are diurnal and present between May and August, with an emergence peak during May–June. The females lay eggs on slender branches. The lifetime fecundity is about 22 eggs. The larvae bore into the tender bark and then the wood of main branches and the trunk. They become mature in six months, overwinter in the tunnels, and pupate in April. The life cycle lasts one year.

Several methods are recommended for the control of this borer. For example, the pruning and burning of all the branches containing larvae in August (before they enter the main trunk) can significantly reduce the damage caused by *C. argentatum* (Gressitt 1942; Singh et al. 1983). In addition, Singh et al. (1983) injected 15 mL of gasoline or insecticide solutions in larval tunnels to kill those *C. argentatum* larvae that have entered the trunk. Wang et al. (1999) tested the effectiveness of an entomopathogenic nematode, *Steinernema glaseri*, for the control of *C. argentatum* larvae in the field and achieved 70% larval mortality.

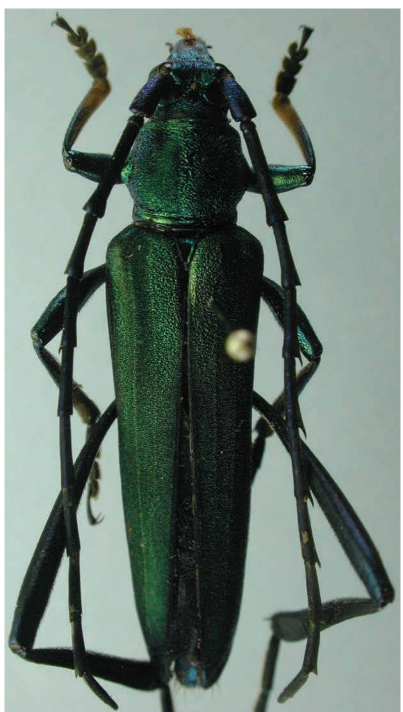

FIGURE 12.25 *Chelidonium argentatum* adult. (Courtesy of Larry Bezark.)

12.3.1.6 *Chelidonium cinctum* (Guérin-Méneville)

Synonym: *Callichroma cincta* Guérin-Méneville
Common name: Lime tree borer

The cerambycine adults are 21–32 mm long and metallic bluish green in color; the antennal segments 1–3 are metallic blue and the rest are blackish purple; the elytra are metallic bluish-green with an irregular, yellow band near the basal-middle region. The species occurs in southern China, India, Laos, Myanmar, and Cambodia, and so far, only citrus species are recorded as hosts of this borer (Duffy 1968; Chiang et al. 1985).

The lime tree borer is a minor to moderate pest of orange and lime trees in southern China (Gressitt 1942; Chien 1981; Li et al. 1997) and southern India (Kunhi Kannan 1928; Beeson and Bhatta 1939; Ramachandran 1953; Singh et al. 1983). Younger branches suffer the most damage, wilting and dying. When trees are three to four years old, a single larva can kill a tree. In older trees, the borers can significantly reduce the yield and may eventually kill the trees in several successive years of infestation. Frass from frass-ejection holes is also obvious.

Callichroma cinctum adults emerge in April–June (Beeson and Bhatta 1939) and lay eggs in the axils of young living twigs; larvae bore into the twigs, causing death, and eventually bore into the main branches (Fletcher 1919). Lifetime fecundity is unknown. Young larvae bore into the center of the twigs, turn upward for about 3 cm, and cut a complete spiral around the twigs. The life cycle lasts one year, and overwintering occurs at the larval stage.

Pruning and burning of all the branches containing larvae in November and January can be effective for the control of *C. cinctum* (Fletcher 1919; Kunhi Kannan 1928; Beeson 1941). The girdled twigs turn black and are easily recognizable (Beeson 1941). Other control measures used for *C. argentatum* may also be effective for this species.

12.3.1.7 *Chelidonium citri* Gressitt

Common name: Green citrus longicorn

The cerambycine adults are 22–25.5 mm long and dark green above and golden green on the head, extremities, and sides of the prothorax and ventral surfaces; the antennae are largely violet to purplish black; the legs are bluish green to violet; the ventral surface is covered with thin silvery pubescence. This species is recorded in southwest China and feeds on citrus (Gressitt 1942) and *Murraya* (Liu and Huang 2003) in Rutaceae.

The green citrus longicorn is a minor pest of citrus trees (Chien 1981; Zhang et al. 2002) and the ornamental plant, *Murraya paniculata* (L.) (Liu and Huang 2003) in southern China. Damage symptoms are similar to those from *C. cinctum*. Infestation often reduces productivity and fruit quality (Zhang et al. 2002).

The adults emerge during April–May and lay eggs in the axils of young living twigs or petioles (Liu and Huang 2003). The lifetime fecundity in the field is unknown. The larvae bore into twigs and then branches. This species has one generation a year and overwinters at the larval stage.

Liu and Huang (2003) recommended that insecticides be sprayed on the axils of young living twigs or petioles between late June and early July to kill newly hatched larvae of *C. citri*, before they enter twigs and branches, or injected into the branches to destroy those larvae that have entered the plant. Control measures used for the other *Chelidonium* species described earlier may also be effective for the control of this pest.

12.3.1.8 *Oberea posticata* Gahan

Common name: Citrus shoot borer

The adults of this lamiine borer are 15–21 mm long and slender; the antennae are shorter or slightly longer than the body, and the body is dull brown (Figure 12.26). This species occurs in India, Myanmar, Nepal, and Taiwan. The larvae feed on tree species from Rutaceae and Moringaceae (Duffy 1968; Sasanka Goswami and Isahaque 2001a).

FIGURE 12.26 *Oberea posticata* adult. (Courtesy of Larry Bezark.)

The citrus shoot borer is considered a moderate pest of citrus, particularly mandarin and orange, in India; its larvae bore into the twigs and growing shoots, causing death and substantially reducing yield (Isahaque 1978; Ghosh 1998; Sasanka Goswami and Isahaque 2001a, 2001b). Fresh frass ejected from the twigs is evidence of infestation. Infested seedlings can be killed.

According to Sasanka Goswami and Isahaque (2001a, 2001b), the adults are present from mid-March to early September. The females make oviposition slits in the tender bark of the shoots and twigs and lay eggs singly in the slits. The lifetime fecundity varies from 14 to 23 eggs per female. The oviposition period lasts from early April to mid-July, and the larval feeding inside the shoots (as indicated by fresh frass) takes place from mid-April to early October. The developmental period from eggs to adults ranges from 87 to 105 days. This borer has one generation a year and overwinters as the mature larvae and pupae inside the shoots or twigs.

Spraying insecticides such as pyrethroid on the shoots and twigs during the oviposition period may be effective for adult control. Pruning and burning the infested twigs and shoots before the spring may also be effective.

12.3.1.9 Oberea lateapicalis Pic

Synonym: *O. mangalorensis* Gardner
Common name: Orange shoot borer

The lamiine adults are 12–20 mm long and slender; the body is yellow with the antennae, eyes, and apical half of the elytra being blackish brown to black; the antennae are shorter than the body. It is only recorded in India and feeds on plants from Rutaceae (Duffy 1968; Bhumannavar and Singh 1983).

The orange shoot borer is a minor pest of citrus, particularly mandarin and orange, but in neglected orchards it can be a serious pest (Bhumannavar and Singh 1983; Singh et al. 1983). The larvae bore into shoots and twigs, weakening and killing them. Fresh frass ejected from shoots and twigs is obvious.

The life cycle is summarized from Bhumannavar and Singh (1983). Emergence occurs in April and May, and the females girdle the tender shoots before laying eggs in the bark of the girdled shoots. The lifetime fecundity is unknown. The larval stage lasts 304–385 days including 120–135 days in diapause, and pupation occurs at the onset of premonsoon rains in March. *O. lateapicalis* overwinters at the larval stage in diapause. The life cycle lasts one to two years.

Spraying insecticides on the shoots and twigs during the oviposition period may effectively kill the adults (Singh et al. 1983). Pruning and burning the infested twigs and shoots before the spring may also be effective.

12.3.1.10 Nadezhdiella cantori (Hope)

Synonyms: *Hammaticherus scabricollis* Chevrolat, *Hamaticherus cantori* Hope
Common name: Gray-black citrus longicorn

The cerambycine beetle is 41–52 mm long, grayish-brown to brownish-black, and covered with golden pubescence; the pronotum is deeply vermiculately strigose, and each side has a stout median tubercle or spine; the elytral apex has a small tooth at the suture (Figure 12.27). The species occurs in most parts of China—particularly in the south—and in Thailand, and its larvae are recorded from Rutaceae and Vitaceae (Duffy 1968; Hua 1982). The beetle has not been recorded outside Southeast Asia to date, making it potentially important for quarantine (Wang et al. 2002b).

The gray-black citrus longicorn is a serious pest of citrus in all citrus-growing areas of China, particularly southern China and Taiwan (Gressitt 1942; Li et al. 1997). It is also reported to attack species other than citrus, such as grapevines (Hua 1982). However, *N. cantori* is not considered an important pest in Thailand and in vineyards. The larvae bore into the main branches and trunks. The infested trees are significantly weakened and subject to wind breakage. The infestation significantly reduces the yield and increases secondary pest attack. When several larvae infest a single tree, which is common, the tree ultimately dies (Duffy, 1968).

FIGURE 12.27 *Nadezhdiella cantori* adult. (Courtesy of Xavier Gouverneur.)

Several independent studies in the past 70 years report similar biological characteristics of this species. Most adults emerge in June or July and a few appear in May and August; the females lay eggs singly between late May and late July in the crevices on the bark of the trunk and main branches (Lieu 1947) or on the trunk within one meter above the ground (Chen 1942). The reproductive and flight activities of this beetle mainly occur between 17:00 and 24:00 hours, and each activity has two peaks—with the first one taking place within the three hours before sunset (21:00 hours) and the second occurring within the three hours after sunset (Wang et al. 2002b). A female lays up to 57 eggs in the laboratory, but field-collected females carry 100–150 eggs each (Duffy 1968). The larvae feed on the inner bark of the trunk and main branches for about six weeks before entering the wood (Lieu 1947). Both Chen (1942) and Lieu (1947) reported that the life cycle of this pest lasts about two years, and the winter is passed at the larval stage. However, Lieu (1947) indicated that, in some cases, the life cycle can last three years—with the third winter being passed in the pre-emergence stage. Based on the work by Chang et al. (1963), the duration of a generation depends on the date of hatching. The larvae that hatch before mid-July pupate between August and October of the following year and give rise to adults that emerge in November but may remain in the pupal chambers until the end of the following April. The larvae that hatch after August pupate in August–September of the next year, and the adults do not leave the pupal chamber until the fourth year.

Gressitt (1942) suggested that the use of light traps in the late spring and the collection of mating pairs on trees during the day could be useful control measures. Because many adults hide in big holes (usually old damage holes resulting from larval boring) in the lower portions of the trunks between late May and early August, they should be collected from these holes and destroyed during this period (Lieu 1947). Chen (1942) reported that the best method of control is to prevent oviposition by covering the trunk with flat straw ropes or filling the holes and cracks with concrete or an adhesive substance. The trunks should be examined to a height of about 2.5 m for the eggs and exudations of fine wood dust five times in June and July, the eggs removed with a hard brush or by hand, and the young larvae killed by striking the bark at points where frass is seen (Lieu 1947). The trunks can also be brushed clean and then whitewashed with a freshly made mixture of quick-lime and water (1:6) during the hot sunny days in early June to discourage oviposition. However, Chen (1942) suggested that whitewashing the trunk is not very effective. The last resource is to cut down badly damaged trees and kill the insects. Furthermore, three parasitoids that attack *A. chinensis* also parasitize this pest in China: *Aprostocetus prolixus, Brulleia shibuensis*, and *Scleroderma* sp. (Niu et al. 2014), but their application for control of this pest in commercial orchards is not practiced.

12.3.2 Australasia

12.3.2.1 Uracanthus cryptophagus Olliff

Common name: Australian citrus branch borer

The cerambycine beetle is narrow in shape and 24–44 mm long; the body is reddish brown to blackish brown with the head, prothorax, and legs often darker; the pronotal disc and each elytron are covered with very dense, long, golden pubescence arranged in four longitudinal lines (Figure 12.28). It occurs in eastern and northeastern New South Wales, southeastern Queensland, and southwestern Western Australia, and its larvae feed on small branches of citrus and lychee trees (Thongphak and Wang 2007).

The Australian citrus branch borer is a minor to moderate pest of all commercially grown citrus species, particularly oranges (Smith et al. 1997). The typical symptom is made by larval ringbarking the twigs and branches, which become wilted and die beyond the ring point; frass is expelled from frass-ejection holes (Duffy 1963; Smith et al. 1997). Weakened branches may fall to the ground.

The life cycle is summarized from Duffy (1963), Smith et al. (1997), and Thongphak and Wang (2007). The adults are present from July to January and are attracted to mercury vapor (MV) light. The females lay their eggs in the cracks or crevices of twigs and small branches. The lifetime fecundity is not known. The eggs hatch in about 10 days, and the larvae immediately bore into the wood

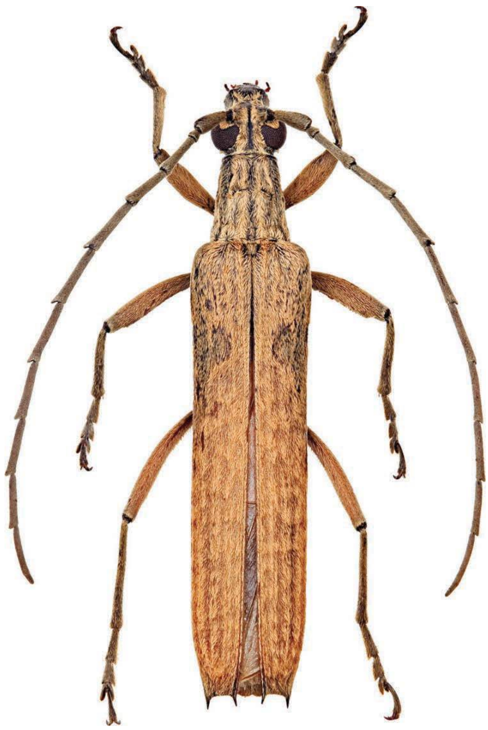

FIGURE 12.28 *Uracanthus cryptophagus* adult. (Courtesy of CSIRO, copyright CSIRO, used with permission of Adam Slipinski.)

and continue feeding in the hosts through the summer, fall, and winter. There is one generation per year. Overwintering occurs at the larval stage.

Duffy (1963) and Smith et al. (1997) provided some recommendations for the control of this pest. Trees should be inspected regularly for early signs of wilting. Infested twigs and branches should be cut as soon as possible and burned. Pruning wounds on larger branches are then sealed with wax or paint. Citrus orchards should not be established in former rain forest areas that are prone to attack by the pest. Good cultivation management to maintain the vigor of trees may be helpful. Evidence from other countries suggests that excessive use of fungicides may result in increased damage because these kill fungi that attack the borers. Infested trees may be treated by injecting insecticides into the uppermost frass-ejection holes, but the effectiveness of this chemical treatment is not clear. Furthermore, there is no insecticide that is registered for the control of this longicorn.

12.3.2.2 *Strongylurus thoracicus* (Pascoe)

Synonym: *Didymocantha thoracica* Pascoe
Common name: Pittosporum longicorn

Adults of the cerambycine borer are about 30 mm long; the body is light brown with a characteristic row of white spots on each side of the pronotum (Figure 12.29). It is found in eastern Queensland, New South Wales, and Victoria (Duffy 1963; Smith et al. 1997). The host range of this beetle is wider than that of the Australian citrus branch borer, and it feeds on tree species from the plant families Anacardiaceae, Malvaceae, Meliaceae, Pittosporaceae, Rosaceae, and Rutaceae (Duffy 1963; Smith et al. 1997).

The pittosporum longicorn is a minor pest of citrus trees, particularly orange trees in Australia (Smith et al. 1997). This species is attracted to older trees lacking vigor or to trees infected with disease. Damage is caused by larval boring inside the twigs and small branches, causing wilting. Frass ejected from plants is also evidence of infestation. Attacked twigs and branches die and snap off.

FIGURE 12.29 *Strongylurus thoracicus* adult. (Courtesy of CSIRO, copyright CSIRO, used with permission of Adam Slipinski.)

Duffy (1963) and Smith et al. (1997) described the general biology of this species. The adults emerge during October–February and lay eggs in the crevices of twigs and small branches throughout the summer. The larvae bore into, girdle, and amputate the twigs and small branches, and then they tunnel down the center of the branches for up to 1 m into the main trunk. During feeding, the larvae often come to the surface and eject frass. There is one generation per year. Overwintering occurs at the larval stage. Control measures are similar to those used for the Australian citrus branch borer.

12.3.2.3 Skeletodes tetrops Newman

Common name: Australian citrus longicorn

This is a cerambycine borer. The adults are 7–15 mm long; the body is straw yellow; the prothorax has two to three blackish to reddish-brown longitudinal stripes on each side, with two median stripes enclosing a short central straw-yellow stripe on the disc; each elytron has complicated longitudinal blackish to reddish-brown stripes (Figure 12.30). This longicorn occurs in southwestern Western Australia, northwestern Victoria, eastern New South Wales, eastern Queensland, and southeastern Papua New Guinea (Wang 1995). About 10 tree species from Araucariaceae, Fabaceae, Malvaceae, Meliaceae, and Rutaceae are recorded as its hosts (Duffy 1963; Webb 1987, 1988; Webb et al. 1988; Hockey and De Baar 1988; Wang 1995; Smith et al. 1997).

The Australian citrus longicorn is a minor pest of citrus trees, particularly orange, and prefers to attack older or weakened trees (Smith et al. 1997). Larvae feed under the bark of twigs and branches and make frass-ejection holes. Infested parts wilt and die.

Adults are present all year except in May and are attracted to light (Wang 1995). According to Smith et al. (1997), females lay eggs in the crevices of the bark during the summer. Lifetime fecundity is unknown. The life cycle lasts one year, and overwintering occurs at the larval stage. Control measures are similar to those used for the Australian citrus branch borer.

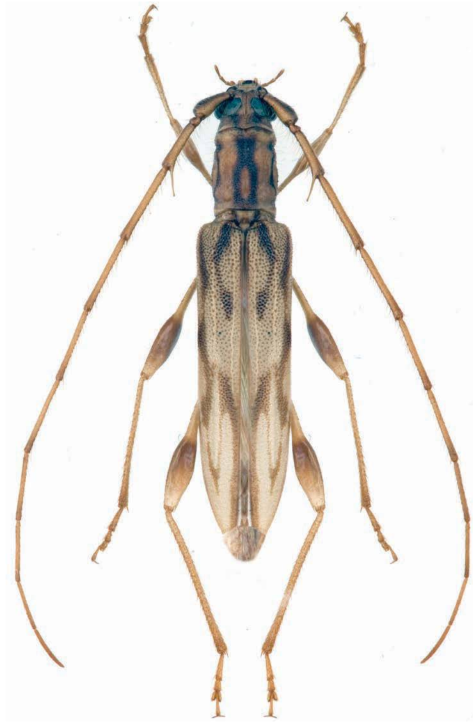

FIGURE 12.30 *Skeletodes tetrops* adult. (Courtesy of CSIRO, copyright CSIRO, used with permission of Adam Slipinski.)

12.3.2.4 *Disterna plumifera* (Pascoe)

Synonyms: *Zygocera plumifera* Pascoe, *Paradisterna plumifera* (Pascoe), *Parahybolasius fuscomaculatus* Breuning

Common name: Speckled longicorn

The adults of the lamiine borer are about 12 mm long; the body is robust and light or dark gray, speckled with brown marks (Figure 12.31). It is distributed in southeastern Australia, and its larvae feed on trees from Apocynaceae, Malvaceae, Meliaceae, Pinaceae, Rosaceae, and Rutaceae (Duffy 1963).

The speckled longicorn is a minor pest of citrus in eastern Queensland and northeastern New South Wales (Smith et al. 1997). All commercially grown citrus species and varieties are attacked, but the navel orange appears to be the preferred host. The larvae bore under the bark, producing a large amount of sawdust-like frass that falls to the bottom of the trunk. The infested parts are weakened, resulting in secondary rot caused by fungi. Trees more than 15 years old are usually affected the worst by this pest.

According to Smith et al. (1997), the adults start to emerge in mid-spring and continue to emerge throughout the summer. The eggs are laid on the bark of the trunk and lower sections of the main branches of citrus trees that are not vigorous due to either age or disease or both. This pest has one generation a year and overwinters as mature larvae.

Smith et al. (1997) recommended good orchard management that can maintain the vigor of trees as an ideal preventative measure for lessening the attack by this pest that prefers weakened trees. Old blocks of trees infested by this borer should be replaced. If the application of insecticides and fungicides is attempted, diseased and eaten bark is removed first and then the affected areas are sprayed with solutions containing both insecticide and fungicide. Spraying foliage with chemicals is not effective for the control of this beetle.

FIGURE 12.31 *Disterna plumifera* adult. (Courtesy of CSIRO, copyright CSIRO, used with permission of Adam Slipinski.)

12.3.2.5 Oemona hirta (Fabricius)

Synonyms: *O. humilis* Newman, *Saperda hirta* Fabricius, *S. villosa* Fabricius
Common name: Lemon tree borer

The cerambycine beetle is 11–31 mm long; the body is reddish brown to blackish brown, and the elytra are brown to reddish brown; the pronotal disc has distinct, long, transverse rugae and pale yellow hairs; the elytral surface is covered with pale yellow hairs and coarse and rugose punctures (Figure 12.32). This borer is distributed throughout New Zealand and, so far, only occurs there (Duffy 1963; Lu and Wang 2005). It was intercepted in the UK in the 1980s; in 2010, a number of *Wisteria* rootstocks imported to the UK from New Zealand were infested with larvae, which were immediately destroyed (Ostojá-Starzewski et al. 2010). The latter incidence has led to the performance of a detailed pest risk analysis organized by the European and Mediterranean Plant Protection Organisation (EPPO 2013c). *O. hirta* is extremely polyphagous, utilizing more than 200 tree and shrub species as its larval hosts—both endemic and exotic to New Zealand—from at least 63 families: Acanthaceae, Adoxaceae, Anacardiaceae, Apocynaceae, Araliaceae, Araucariaceae, Argophyllaceae, Asparagaceae, Betulaceae, Cannabaceae, Casuarinaceae, Celastraceae, Compositae, Coriariaceae, Cornaceae, Corynocarpaceae, Cruciferae, Cunoniaceae, Cupressaceae, Cyperaceae, Ebenaceae, Elaeocarpaceae, Euphorbiaceae, Fabaceae, Fagaceae, Gramineae, Grossulariaceae, Juglandaceae, Labiatae, Lauraceae, Loganiaceae, Lythraceae, Magnoliaceae, Malvaceae, Monimiaceae, Myrtaceae, Nothofagaceae, Nyssaceae, Oleaceae, Pandanaceae, Pennantiaceae, Pinaceae, Plantaginaceae, Piperaceae, Pittosporaceae, Platanaceae, Proteaceae, Phytolaccaceae, Ripogonaceae, Rhamnaceae, Rosaceae, Rubiaceae, Rutaceae, Salicaceae, Sapindaceae, Scrophulariaceae, Solanaceae, Tamaricaceae, Theaceae, Thymelaeaceae, Ulmaceae, Violaceae, and Vitaceae (Lu and Wang 2005; EPPO 2013c).

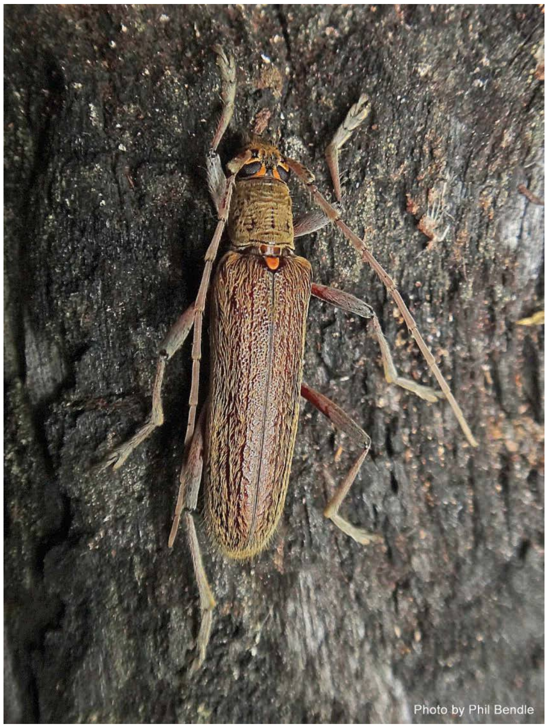

FIGURE 12.32 *Oemona hirta* adult. (Courtesy of Phil Bendle, Taranaki Educational Resource Research Analysis and Information Network.)

The lemon tree borer is an important pest of citrus, persimmon, and apple trees as well as grapevines, with citrus trees being the preferred hosts (Taylor 1957; Hosking 1978; Clearwater 1981; Clearwater & Muggleston 1985; Wang et al. 1998; Lu and Wang 2005). Almost all commercially grown citrus species in New Zealand are attacked. Dieback of the infested twigs and small branches may occur in the first year of infestation. In the second year, the larvae move downward and damage the main branches and trunk, weakening the tree. Sawdust-like frass is obvious at or around excretion holes.

The adults emerge between early September and early February with a peak occurring during October–November (Lu and Wang 2005). The eggs are usually laid singly at the leaf–twig junctions and in the crevices and wounds (particularly pruning wounds) of the twigs, branches, and trunk—with the twigs being preferred oviposition sites (Taylor 1957; Hosking 1978; Clearwater 1981; Clearwater & Muggleston 1985; Wang et al. 1998; Lu and Wang 2005). Each female produces an average of 82 eggs but only lays an average of 51 eggs in her lifetime (Wang et al. 1998). The larvae bore directly into the wood, first into the sapwood and then into the heartwood, normally along the twigs and branches toward the trunk (Hosking 1978; Wang et al. 1998). In rare cases, the larvae can enter the roots. The life cycle normally lasts two years in the field (Clearwater 1981; Wang et al. 1998; Lu and Wang 2005) but, at a constant temperature of 23°C in the laboratory, this insect can complete its life cycle within one year (Wang et al. 2002a). *O. hirta* normally overwinters as larvae.

Clearwater and Wouts (1980) injected a suspension of the nematode *Steinernema feltiae* Filipjev into frass holes and achieved more than 90% larval mortality. Pruning the infested twigs and branches and then covering the pruning cut surface with a paint containing insecticides are probably the most effective control measures for this pest (Clearwater and Muggleston 1985). Three species of parasitic wasps are found to attack the larvae of *O. hirta*, but the overall parasitism rate by these parasitoids is low (<5%), making their usefulness for the control of this pest questionable (Wang and Shi 1999, 2001).

12.3.3 South America

12.3.3.1 Hylettus seniculus (Germar)

Synonyms: *Nyssodrys ophthalmica* Lameere, *Lamia seniculus* Germar
Common name: Hylettus citrus borer

The lamiine adults are 18–45 mm long and robust; the antennae are 1.5 times as long as the body, which is reddish brown to dark brown and covered with grayish pubescence; each elytron has a subtriangular brown mark near the basal-sutural area (some specimens do not have this brown mark) and a larger triangular brown mark on the apical half (Figure 12.33). The borer is widely distributed in Costa Rica, Argentina, Brazil, and Bolivia, and it feeds on tree species in Anacardiaceae, Bombacaceae, Burseraceae, Flacourtiaceae, Pinaceae, and Rutaceae (Duffy 1960; Tavakilian et al. 1997; Monné 2001b, 2005b; Di Iorio 2006; Paz et al. 2008; Ferreira-Filho et al. 2014).

The hylettus citrus borer is an important pest of citrus trees in northern Brazil, particularly in old and neglected orchards (Moreira et al. 2003). It is also collected in large numbers in northern Brazilian mango orchards, but its pest status in mango is not clear (Paz et al. 2008). The larvae bore under the bark of the main branches and trunks of citrus trees, causing leaf wilting, drying, breaking of branches, and tree death (Moreira et al. 2003). Frass is packed in tunnels behind the boring larvae; the bark of infested tree parts turns dark and can be easily removed by hand, exposing sawdust-like frass (Moreira et al. 2003).

The life history of this borer is summarized from Duffy (1960), Puzzi (1966), and Moreira et al. (2003). The adults are present almost throughout the year. The females make oviposition slits with their mandibles in the bark of the branches and trunks and lay their eggs singly in the slits. They prefer thinner branches for laying eggs. The lifetime fecundity is not known. The larvae bore into the bark and tunnel down underneath to the main trunk. Pupation occurs in shallow pupal cells located in the inner side of the bark. Overwintering appears to occur at the larval stage, but larval feeding takes place throughout the year. The life cycle probably lasts one year.

FIGURE 12.33 *Hylettus seniculus* adult. (Courtesy of Juan Pablo Botero [image from Marcela L. Monné].)

Moreira et al. (2003) described several control measures for this pest: partially scraping the bark of infested branches and trunks to kill the larvae and then pasting fungicide and hydrated lime on the wounds to prevent diseases; pruning and burning the heavily infested branches and replacement of badly infested trees to prevent reinfestation, and spraying of organophosphate insecticides in late afternoon to kill adults and neonate larvae. For small orchards, injecting organophosphate insecticides into borer tunnels through the bark is recommended.

*12.3.3.2 Diploschema rotundicolle (*Audinet-Serville*)*

Synonyms: *D. flavipennis* Thomson, *Phoenicocerus costicollis* Audinet-Serville, *P. rotundicollis* Audinet-Serville

Common name: Brown-headed citrus borer

The cerambycine adults are 30–40 mm long; the antennae are shorter than the body; the head and prothorax are reddish to blackish brown and covered with coarse light brown pubescence; the elytra are glabrous and pale yellowish brown with a short sutural spine at the apex (Figure 12.34). This species is widely distributed in central to southern Brazil, Argentina, Paraguay, and Uruguay, and its larvae are polyphagous, feeding on at least 25 host species (both endemic and exotic to South America) from 10 plant families, Rutaceae, Bignoniaceae, Cupressaceae, Erythroxylaceae, Euphorbiaceae, Meliaceae, Myrtaceae, Rhamnaceae, Rosaceae, and Sapindaceae (Duffy 1960; Monné 2001a, 2005a).

In Brazil, the brown-headed citrus borer is a moderate to serious pest of citrus trees, particularly orange and lemon (e.g., Bondar 1913; Pinto da Fonseca and Autuori 1932; Puzzi and Orlando 1959; Nascimento do et al. 1986; Machado 1992; Machado et al. 1998; Machado and Berti Filho 1999, 2006), and a minor pest of peach trees (Bondar 1913). The damage is caused by the larval tunneling in the branches and trunks. Early in the infestation, young larvae cause wilting of the buds and young leaves. Once the larvae grow larger and enter the trunk, the tree can be severely damaged. For example, Bondar (1913) reported that a lemon tree trunk was almost completely destroyed by 16 larvae.

FIGURE 12.34 *Diploschema rotundicolle* adult. (Courtesy of Juan Pablo Botero [image from Marcela L. Monné].)

Although various authors have described some aspects of its biology (e.g., Duffy 1960; Ioneda et al. 1986; Link and Costa 1994; Di Iorio 1998), the most comprehensive appraisal of the biological features of *D. rotundicolle* is given by Bondar (1913). The adults are present between late spring (November) and late fall (May), and they lay eggs in the crevices near the apex of new and tender branches. The lifetime fecundity is not known. The larvae bore in the small branches downward through the larger branches to the trunk. After about eight months' feeding, the mature larvae turn and bore upward, enlarging a portion of the tunnel to make a pupal cell for pupation and an opening about 12 mm in diameter for adult emergence. In the field (Bondar 1913) and laboratory (Machado and Berti Filho 1999), this species has one generation a year. Overwintering occurs at the larval or pupal stage.

Several control methods are recommended by various authors. The most effective control method appears to be examination of the branches in May and June for any sign of frass and removal of the infested branches before the larvae enter the main branches and the trunk. Faria et al. (1987) trialed several methods, including the application of light traps and insecticides, but concluded that none of these measures could effectively suppress this pest's population. Machado et al. (1998) tested the application of the fungus *Metarhizium anisopliae* (Metsch.) in borer galleries by using larvae of pyralid moth *Galleria mellonella* L. as vectors, which resulted in effective control of this pest. Machado and Berti Filho (2006) evaluated the effectiveness of two measures, pruning the infested branches and, following the pruning, introduction of the previously mentioned fungus into the borer galleries using the moth vector or by direct powdering into the galleries. These control practices achieved greater than 90% larval mortality.

12.3.3.3 Macropophora accentifer (Olivier)

Synonyms: *Prionus accentifer* Olivier, *Acrocinus accentifer* (Olivier), *Macropus accentifer* (Olivier)
Common name: Harlequin citrus borer

Adults of this lamiine borer are 18–31 mm long; the body is reddish brown and covered with a mixture of dark brown, brown, gray, pale, and white pubescence, showing harlequin patterns; the antennae are almost twice as long as the body; the pronotum has a robust spine on each side; and the elytral apex has a sharp spine at the margin (Figure 12.35). The borer is widely distributed in South America, including Brazil, Paraguay, Argentina, Uruguay, Bolivia (Monné 2001b, 2005b), and Peru (Carrasco 1978). This species is polyphagous, with at least 15 tree species from nine families being recorded as hosts: Anacardiaceae, Boraginaceae, Euphorbiaceae, Lauraceae, Meliaceae, Moraceae, Myrtaceae, Rosaceae, and Rutaceae (Monné 2001b; Machado et al. 2012).

The harlequin citrus borer has been considered an important pest of citrus trees over the past 100 years in South America, particularly in Brazil (Bondar 1913, 1923; Pinto da Fonseca and Autuori 1932; Puzzi and Orlando 1959; Duffy 1960; Zajciw 1975; Carrasco 1978; Nascimento do et al. 1986; Machado and Raga 1999). The damage is caused by larval boring inside the main trunks. If not controlled, the pest can destroy a citrus orchard in three to four years of infestation. It is also reported as a pest of fig trees in Peru (Carrasco 1978).

Although the biology of this pest is mentioned by many authors, the most comprehensive information is given by Bondar (1913, 1923) and Duffy (1960). The adults mainly emerge during August–October and lay eggs between September and January. They make oviposition slits in the bark using their mandibles before laying their eggs. The females prefer the lower portion of the trunk for oviposition. The lifetime fecundity is unknown. The larvae bore in subcortical tissues before entering the wood for pupation between July and September. The life cycle lasts about a year, and the overwintering occurs at the larval and pupal stages.

Bondar (1913, 1923) and Duffy (1960) described the effective measures for killing the larvae that should be performed during May–June: carefully examine the lower parts of the trunks of the trees, inject gasoline or insecticides into the borer holes, and block the holes with plugs. Machado and Raga (1999) have trialed applications of the fungus *M. anisopliae* and two chemicals. They show that the fungus or imidacloprid can kill about 90% of larvae in 15 days after treatment.

FIGURE 12.35 *Macropophora accentifer* adult. (Courtesy of Juan Pablo Botero [image from Marcela L. Monné].)

12.3.3.4 Elaphidion cayamae Fisher

Common name: Spined citrus borer

The cerambycine adults are 12–17 mm long; the body is dark reddish brown and irregularly covered with long, recumbent, gray pubescence; the fourth antennal segment is very short with a very long spine; the elytral apex has a very long spine at the margin and a short spine at the suture. This longicorn is widely distributed in Cuba, and its larvae feed on citrus trees (Castellanos et al. 1990; Grillo-Ravelo and Valdivies 1990, 1992; Castellanos and Jimenez 1991; Dominguez and Dominguez 1991; Vicente 1991).

Since the 1980s, the spined citrus borer has been considered an important pest of citrus trees—particularly orange and mandarin—in Cuba, resulting in yield loss (Castellanos and Jimenez. 1991). For example, in a citrus orchard, the infestation rate can be as high as 90% (Grillo-Ravelo and Valdivies. 1990). Up to 1,053 larvae/ha are found in August (Vicente 1991). The larvae feed on the branches and twigs of citrus trees, which wilt and become dry after the infestation (Grillo-Ravelo and Valdivies 1990).

The life cycle is summarized from Grillo-Ravelo and Valdivies (1990, 1992). The adults emerge from March to May and are active nocturnally. However, an attempt to use light traps for monitoring failed to catch any adults in the field. The adults can live for more than 90 days. Females lay their eggs on the twigs and branches. The lifetime fecundity in the field is not known. Larvae bore into twigs and branches and feed inside for about 10 months. The life cycle lasts one year, and overwintering occurs at the larval stage.

Pruning infested branches appears to the most effective measure for the control of this pest (Castellanos et al. 1990; Grillo-Ravelo and Valdivies 1990; Dominguez and Dominguez. 1991). To achieve the best result, pruning should take place during September–October. Pruned branches and twigs should be burned.

In recent years, a new *Elaphidion* species (unnamed) has been found causing a similar level of damage to citrus branches and twigs in Cuba (González-Risco et al. 2011, 2013). Although the harm caused by the new pest is similar to that of *E. cayamae*, the larval biology of these two species appears to be different. The new pest makes a ring around a green branch or twig in the area of the cambium, which prevents the movement of nutrients and causes symptoms of wilting, drying leaves and branches above the ring. This brings the fall of flowers and/or fruit that they hold. Control measures used for *E. cayamae* could also be effective for the new pest.

12.4 Cerambycid Pests of Tropical and Subtropical Fruit Trees

A number of tropical and subtropical fruit crops are commercially grown around the world, such as banana, mango, pineapple, lychee, figs, longan, durian, jackfruit, guava, and pomegranate. Among these crops, banana, mango, and pineapple are ranked number one, six, and nine, respectively, in worldwide fruit production (Ebert 2009).

A very large number of insect species are recorded as pests of tropical and subtropical fruit trees, but relatively few cerambycid species are of economic importance to these crops (Li et al. 1997; Hill 2008). There is no confirmed economic cerambycid pest in major herbaceous fruit crops such as bananas and pineapples. Six cerambycid species are of economic importance to tropical and subtropical fruit tree crops in Asia, one in Australasia, and one in Africa. Although some cerambycid species have been recorded attacking tropical and subtropical fruit tree crops in the New World, none is considered an economic pest of these crops in that region.

Some cerambycid species that attack tropical and subtropical fruit trees as very minor pests are considered serious pests of other crops. For example, a minor mango pest in Australia, *Acalolepta mixta* (Hope) [= *A. vastator* (Newman)], is an important vineyard pest, and thus is discussed in the Cerambycid Pests in Vine Crops section.

12.4.1 Asia

12.4.1.1 Aristobia testudo (Voet)

Synonyms: *Aristobia clathrator* (Thomson), *Celosterna clathrator* Thomson, *Lamia reticulator* Fabricius, *Cerambyx testudo* Voet
Common name: Lychee longicorn

The lamiine adults are 20–35 mm long and black in color; the vertex and pronotal disc are covered with yellow pubescence and two longitudinal black pubescent stripes; the elytra are covered with black pubescence and a number of yellow pubescent spots; the antennal segments 1–2 are black and segments 3–11 yellow, with segments 3–4 or 3–5 bearing black tuft hairs at the apex (Figure 12.36). The beetle is distributed in northern India, Myanmar, Thailand, Laos, Vietnam, and southern China, and its larvae feed on tree species from Annonaceae, Lythraceae, Myrtaceae, and Sapindaceae (Chen et al. 1959; Duffy 1968; Hua 2002; Shylesha et al. 2000). The species has not been recorded outside its primary distribution area.

The lychee longicorn is a moderate to serious pest of lychee, longan, cocoa, and jackfruit (Li et al. 1997)—particularly lychee (Ho et al. 1990; Li et al. 1997; He 2001; Waite and Hwang 2002) in southern China where it is also recognized as a minor pest of citrus (Li et al. 1997). The damage is caused by the adult ring-barking and larval boring. The infested twigs and branches wilt and die. In severe infestation, the tree can be killed. The twig ring-barking by ovipositing adults causes the extremities to die and snap off. In addition, this pest can cause minor to serious damage to guava in India. For example, in northeastern India, the infestation rate ranges from 8% to 76% in different guava orchards; although the pest prefers older trees (10 years old), young trees may be killed within one year of infestation (Shylesha et al. 2000).

According to Ho et al. (1990) and Waite and Hwang (2002), the adults emerge during June–August. They girdle the branches and twigs by chewing off strips of bark and then lay eggs singly in the wound, covering the wound and eggs with exudate. The lifetime fecundity in the field is unknown. The eggs hatch in August and September. The larvae initially bore under the bark and then into the xylem in January, making tunnels in the wood up to 60 cm long. These tunnels have openings packed with frass at regular intervals for aeration. The tunnels are blocked with wood fiber and frass just before pupation in June. This pest has one generation a year and overwinters at the larval stage.

FIGURE 12.36 *Aristobia testudo* adult. (Courtesy of Larry Bezark.)

Shapiro-Ilan et al. (2005) discussed the possible application of entomophagous nematodes to control cerambycid larvae, including *A. testudo*. In practice, Xu et al. (1995) trialed the injection of the nematode *Steinernema carpocapsae* (Weiser) (Agriotes strain) into larval tunnels and achieved 73–100% larval mortality under experimental conditions. Ho et al. (1990) suggested that, apart from injecting tunnels with dichlorvos (DDVP), chemical control is generally unsuccessful. The most effective control measures for this pest (Ho et al. 1990; Waite and Hwang 2002) include: (1) regular inspection of orchards during the adult activity period and removal of the beetles manually when they "play dead," (2) removal of eggs and young larvae from branches and twigs during July–September, and (3) identification of larval location based on the presence of tunnel openings packed with frass and removal of larvae with wire hooks or a knife. A skilled worker can kill 112 larvae in 2 hours.

12.4.1.2 Batocera rubus (L.)

Synonyms: *B. sarawakensis* Thomson, *B. sabina* Thomson, *B. mniszechii* Thomson, *B. formosana* Kriesche, *B. bipunctata* Kriesche, *B. albofasciata* Stebbing (nec DeGeer), *Lamia downesii* Hope, *L. 8maculata* Fabricius, *Cerambyx albofasciata* DeGeer, *C. albomaculatus* Retzius, *C. rubus* Linnaeus

Common name: Lateral-banded mango longicorn

The lamiine beetle is 30–60 mm long; the body is grayish brown with two orange or red marks on the pronotum ranged longitudinally; each elytron has about four whitish or yellowish spots with the median third spot being the largest; sometimes, an additional one or two much smaller spots may be present on the elytron (Figure 12.37). This species is widely distributed in southern and southeastern Asia (Duffy 1968) and has recently been intercepted in France and Italy (EPPO 2011, 2012). The borer is polyphagous, attacking many tree species from Anacardiaceae, Apocynaceae, Burseraceae, Fabaceae, Malvaceae, Moraceae, and Phyllanthaceae (Duffy 1968) in tropical and subtropical regions, but its main hosts relevant to the scope of this book are mango, fig, jackfruit (EPPO 2011), and mulberry (Butani 1978).

FIGURE 12.37 *Batocera rubus* adult. (Courtesy of Xavier Gouverneur.)

This beetle is considered a minor to moderate pest of mango and fig, particularly mango, in India (Atwal 1963; Hill 1975, 2008) and China (Li et al. 1997). The larvae bore into the trunk and main branches and mainly pupate in the branches. On the damaged branches, the foliage may die and fruit set may be impaired (EPPO 2011); severely infested trees may die.

In India, the adults emerge in May–June and lay eggs singly in the crevices or under the loose bark of the trunk and branches. The fecundity is unknown. This beetle has one to three (EPPO 2011) generations a year depending on climate. Overwintering occurs at the larval or pupal stage.

Pruning and burning all infested branches appear to be the most effective control measures for this pest (Butani 1978). Injection of insecticides or petroleum products into tunnel openings and sealing them also may be effective.

12.4.1.3 Batocera rufomaculata (DeGeer)

Synonyms: *B. diana* Nonfried, *B. polli* Gahan, *B. thysbe* Thomson, *B. chlorinda* Thomson, *Cerambyx cruentatus* Gmelin, *C. rufomaculatus* DeGeer

Common name: Mango tree stem borer

Adults of this lamiine borer are 26–52 mm long and similar to *B. rubus* in appearance but differ in each elytron with six orange–yellow or pale yellow spots; sometimes an additional one or two much smaller spots may be present on the elytron (Figure 12.38). This beetle is distributed throughout its primary regions, including India, Bangladesh, Nepal, Pakistan, Myanmar, Thailand, Laos, Vietnam, Malaysia, Indonesia, Sri Lanka, Andman, and southern China, and has been introduced into Lebanon, Israel, Iran, Iraq, Turkey, Egypt, Madagascar, Comoros, Mauritius, the Virgin Islands, and Puerto Rico (Duffy 1968; CABI 1994; Ben-Yehuda et al. 2000; Tozlu-Goksel 2000; Batt 2004; Potting et al. 2008). It is highly polyphagous, attacking at least 50 plant species from Anacardiaceae, Annonaceae, Apocynaceae, Arecaceae, Burseraceae, Caricaceae, Dipterocarpaceae, Euphorbiaceae, Fabaceae,

FIGURE 12.38 *Batocera rufomaculata* adult. (Courtesy of Jiří Mička.)

Lauraceae, Lecythidaceae, Malvaceae, Moraceae, Moringaceae, Musaceae, Myrtaceae, Platanaceae, Rosaceae, and Rubiaceae, but its main hosts relevant to the scope of this book are mango, fig, durian, guava, jackfruit, pomegranate, cashew, apple, walnut, and mulberry (Haq and Akhtar 1960; Atwal 1963; Duffy 1968; Palaniswami et al. 1977; Butani 1978; Sharma and Tara 1984, 1986, 1995; CABI 1994; Ben-Yehuda et al. 2000; Godse 2002; Sundararaju 2002; Batt 2004; Sudhi-Aromna et al. 2008; Swapna and Divya 2010; Maruthadurai 2012; ZetaBoards 2012; Ahmed et al. 2014).

Over the past five decades, this species has become a serious pest of a number of tropical and subtropical fruit tree crops—particularly mango, fig, durian, and jackfruit—causing significant production loss in India, Bangladesh, Thailand, Nepal, Egypt, and Israel (Palaniswami et al. 1977; Ben-Yehuda et al. 2000; Batt 2004; Sudhi-Aromna et al. 2008; Upadhyay et al. 2013; Ahmed et al. 2014). Considering its invasive ability, this species should be listed as an important quarantine pest in all subtropical and tropical regions where it has not become established. Attack by *B. rufomaculata* often leads to the death of trees.

The life cycle is summarized from Browne and Foenander (1937), Beeson (1941), Duffy (1968), Sudhi-Aromna et al. (2008), and Maruthadurai et al. (2012). The adults can be found throughout the summer when they chew small oviposition slits in the bark of branches and trunk and lay eggs singly in the slits. Most oviposition occurs during July–August. The lifetime fecundity is up to 200 eggs. The larvae initially feed under the bark, then bore into the phloem tissue, and finally bore into the heartwood to pupate. In the tropical regions, the larval feeding occurs throughout the year; and in subtropical regions, the larvae overwinter. The life cycle lasts from six months to one year depending on climate.

Various mechanical and chemical measures are recommended for the control of this pest. Pruning infested branches and covering the cuts with pruning paste may be highly effective before the larvae enter the trunk (Butani 1978; Ben-Yehuda et al. 2000). However, heavily infested trees should be felled and burned (Haq and Akhtar 1960; Duffy 1968). Spraying insecticides on the main branches and trunk (Haq and Akhtar 1960), or even entire trees (Upadhyay et al. 2013), during the oviposition period can also be effective. The injection or insertion of insecticides into the tunnels made by the larvae can lead to satisfactory control by contact or fumigant or by both modes of action (Haq and Akhtar 1960; Palaniswami et al. 1977; Butani 1978; Sharma and Tara 1986; Ben-Yehuda et al. 2000).

12.4.1.4 Coptops aedificator (Fabricius)

Synonyms: *C. quadristigma* Fåhraeus, *Lachnia parallela* Audinet-Serville, *Cerambyx fuscus* Olivier, *C. villica* Olivier, *Lamia aedificator* Fabricius
Common name: Albizia longicorn beetle

The lamiine adults are 13–19 mm long; the body is brown, speckled with black and gray spots, and has angular black and dark brown markings on the elytra (Figure 12.39). It is widely distributed in southern, southeastern, and western Asia and throughout Africa, and has been introduced to Taiwan and Hawaii (Duffy 1957, 1968; Dawah et al. 2013; Saha et al. 2013). Its host range is very wide, attacking about 90 plant species from Anacardiaceae, Annonaceae, Apocynaceae, Burseraceae, Caesalpiniaceae, Cannabaceae, Combretaceae, Dipterocarpaceae, Euphorbiaceae, Fabaceae, Lecythidaceae, Malvaceae, Meliaceae, Moraceae Rubiaceae, Olacaceae, Rutaceae, and Ulmaceae (Duffy 1957, 1968; Dawah et al. 2013).

Over the past century, this species has hardly been considered an important pest of any tree crops but has been treated as a quarantine pest in regions where this species does not occur, such as in the New World (Dawah et al. 2013). Recently, Dawah et al. (2013) reported that *C. aedificator* has become a serious pest of mango trees in Saudi Arabia. The damage mainly is made by larval feeding on branches and trunks. Frass expulsion holes are made at intervals, and sometimes sap oozes out of the holes, making the symptoms of the infestation obvious (Dawah et al. 2013). The pest also has caused minor damage to coffee plantations in Africa and South Asia.

In India, the adults appear almost throughout the entire year, but the peak activity period is in June (Duffy 1968). The females lay their eggs singly in oviposition slits made with their mandibles in main branches and trunks. The lifetime fecundity in the field is unknown. Larval feeding occurs throughout

FIGURE 12.39 *Coptops aedificator* adult. (Courtesy of Larry Bezark.)

the year. Larvae bore subcortically or in the inner bark (Beeson and Bhatia 1939) or into the sapwood under the bark (Dawah et al. 2013). The life cycle lasts one year, and overwintering occurs at the larval stage (Beeson and Bhatia 1939; Duffy 1968).

Careful inspection and early detection of damage may allow preventive measures to be taken and may reduce the likelihood of its spread to other regions (Dawah et al. 2013). So far, removal and destruction of infested branches or entire trees are probably the only effective control methods for this pest (Chandy 1986). The application of insecticides recommended for *Batocera* spp. may not be effective for the control of *C. aedificator* (Dawah et al. 2013).

12.4.1.5 *Rhytidodera bowringii* White

Common name: Yellow-spotted ridge-necked longicorn

This cerambycine beetle is 25–40 mm long and generally dark brown in color; the antennae are slender and slightly shorter than the body; the pronotum has regular, longitudinal ridges; the elytra are covered with gray pubescence and a number of yellow pubescent markings arranged longitudinally; the elytral apex is truncated obliquely (Figure 12.40). The species is distributed in southern China, northern India, Nepal, and Myanmar (Duffy 1968; Hua 2002). The record in Java (Duffy 1968) is not confirmed. It was intercepted in Florida in 2006 (NAPPO 2006). However, there is no evidence of its establishment outside its primary distribution region. The host range of this longicorn appears to be narrow, with only several species recorded as its hosts—including mango and cashew (Fletcher 1930; Gressitt 1942; Duffy 1968; Hua 2002; NAPPO 2006; Wang 2006).

The yellow-spotted ridge-necked longicorn is a moderate to serious pest of mango in northern India and southern China (Fletcher 1930; Gressitt 1942; Duffy 1968; Luo et al. 1990; Wang 2006; Ding et al. 2014). According to Luo et al. (1990), about 25 mango orchards were completely destroyed by this pest in 1988 in China's Hainan Province. The larvae bore into the center of shoots, branches, and trunks

FIGURE 12.40 *Rhytidodera bowringii* adult. (Courtesy of Larry Bezark.)

(Duffy 1968; Luo et al. 1990), causing death of the infested parts (Gressitt 1942; Luo et al. 1990; Wang 2006). They keep their tunnels clear by means of frass-ejection holes. However, early infestation is difficult to detect because the bored branches continue to look healthy, bear green leaves, and develop side shoots until they die back and drop off the tree.

The adults emerge during May–June. The females lay their eggs on the living shoots and branches of eight- to ten-year-old trees, and the larvae bore right down their center, making clear circular tunnels (Beeson and Bhatia 1939; Duffy 1968). The fecundity in the field is unknown. Pupation occurs in the tunnel. The life cycle lasts one year in India (Beeson and Bhatia 1939) and China's Hainan Province (Luo et al. 1990) and two years in Yunnan Province (Zhou et al. 1995). Overwintering occurs at the larval or pupal stage.

Because the adults are nocturnal and attracted to light, Gressitt (1942) suggested that the most effective measure for the control of this pest probably is the application of light traps in the orchards. The pruning and destruction of infested branches and shoots can be highly effective in preventing further damage by this pest (Luo et al. 1990). Insertion of cotton wool saturated with insecticides into frass-ejection holes and then sealing them results in effective control (Luo et al. 1990; Ding et al. 2014). Ding et al. (2014) indicated that two applications of this method during the season achieve 100% control, but injection of insecticides into the holes is less effective. Pan et al. (1997) described an integrated approach to the management of this pest including cultural measures to increase the vigor of trees, pruning infested parts to remove the larvae, and application of insecticides to kill the larvae. Shen and Han (1985) tested the effectiveness of a nematode*, Steinernema carpocapsae* (Weiser), for the control of the larvae in the laboratory, achieving 80–100% larval mortality. However, these authors suggested that the method may not be practical for large-scale control in the field. In addition, Zhang (2002) has evaluated the resistance of various mango varieties in China and suggested growing potentially resistant varieties in regions where *R. bowringii* is abundant.

12.4.1.6 Rhytidodera simulans White

Common name: Mango branch and trunk borer

This species is similar to *R. bowringii.* Its adults are about 30 mm long and dark brown in color; the antennae are more or less flattened and substantially shorter than the body; the pronotum is irregularly wrinkled; the elytra are covered with gray pubescence and a number of orange and gray pubescent markings arranged longitudinally; the elytral apex is toothed at the margin (Figure 12.41). This cerambycine is distributed in Indonesia, Malaysia, Thailand, and Myanmar (Duffy 1968; Anonymous 1986; Muniappan et al. 2012). To date, it has not been recorded outside Southeast Asia. Similar to *R. bowringi*, the host range of this species is narrow, with fewer than 10 species recorded as its hosts and mango, cashew, rose apple, and star fruit being the most common (Muniappan et al. 2012).

The mango branch and trunk borer is considered a moderate pest of mango trees in Indonesia (Franssen 1949, 1950) and Malaysia (Ithnin and Shamsudin 1996; Abdullah and Shamsulaman 2008). The damage is caused by the larvae boring inside twigs, branches, and trunks, usually girdling the twigs or branches just beneath the bark (Franssen 1949; Muniappan et al. 2012). Infested tree parts may die or break off.

The adults and all immature stages are present throughout the year, and the life cycle lasts about one year (Franssen 1949; Kondo and Razak 1993; Muniappan et al. 2012). The eggs are laid singly on or near the tips of the twigs of mango trees; the larvae enter the twigs and bore through the branches toward the trunk. The fecundity in the field is unknown. Pupation occurs in the tunnels after six months' larval development. The females prefer to oviposit on older trees that are weakened by diseases or other insect pests, and trees under six years old are rarely attacked.

Franssen (1949) recorded three parasitic wasp species belonging to three families—Encyrtidae, Eupelmidae, and Pteromalidae—attacking eggs of *R. simulans* but indicated that their parasitism rates are not high. There is no recommended chemical control measure for this pest, but the methods used for the control of *R. bowringi* might be effective. Because the infestation by *R. simulans* usually is secondary to the primary damage by other insect pests or diseases, control of the primary pests that precede *R. simulans*, cultural measures to promote vigorous growth of the trees, and regular inspection and

FIGURE 12.41 *Rhytidodera simulans* adult. (Courtesy of Xavier Gouverneur.)

removal of damaged branches are recommended by Franssen (1949, 1950). Kondo and Razak (1993) tested the effectiveness of a nematode, *S. carpocapsae*, in killing *R. simulans* larvae under laboratory conditions. However, the use of *S. carpocapsae* to control *R. simulans* does not appear to be practical.

12.4.2 Australasia

12.4.2.1 Platyomopsis pedicornis (Fabricius)

Synonyms: *Saperdopsis obscura* Breuning, *S. bispinosa* Breuning, *Rhytophora tuberculata* Hope, *Lamia pedicornis* Fabricius
Common name: Australian mango longicorn

The adults of the lamiine borer are 15–20 mm long; the body is brown and covered with grayish to brown pubescence; the elytra have a number of long erect hairs and a submedian, zigzag, grayish, pubescent band; the elytral apex is bitoothed. The beetle is distributed throughout the Australian continent except for South Australia, Victoria, and Tasmania (McKeown 1947; Hall 1980; Smith 1996), and its larvae feed on mango (Smith 1996) and shrubby stylo [*Stylosanthes scabra* (Vog.)], a legume pasture crop introduced from South America (Hall 1980).

The Australian mango longicorn is a minor pest of mango trees (Smith 1996) and shrubby stylo (Hall 1980) in northern Australia. The larvae bore into the bark and later penetrate deeper into the sapwood of the branches and trunks of mango trees, weakening the trees and reducing the yield. In shrubby stylo, the larvae tunnel into the lower main stems and tap roots and eventually kill the plants, usually after they have been weakened by fire.

Little is known about the biology of this species. The adult beetles probably lay their eggs singly into oviposition slits made by mandibles in the bark of the trunk or main branches of mango trees. It is thought that the life cycle of this species is spread over 12 months but that the larval damage is most likely to be noticed in the late wet to early dry season from March to May (Smith 1996).

Smith (1996) described a control measure for this pest on mango trees in northern Australia. Injection of a solution of organophosphate insecticides mixed with petroleum oil into the holes of larval tunnels may be effective. For small infestations involving only one or two trees on the property, the insecticide mix should be liberally painted over the suspected tunnels with a paint brush after scrubbing the area with a wire brush. Larger infestations may be treated with the same mixture but applied with a hand-operated backpack-style sprayer. The nozzle of the sprayer should be placed over one of the breather holes and a quick squirt of insecticide injected under pressure into the tunnel. Follow-up treatments may be necessary for several months.

12.4.3 Africa

12.4.3.1 Trichoferus griseus (Fabricius)

Synonyms: *Hesperophanes griseus* (Fabricius), *H. tomentosus* Lucas, *Callidium griseum* Fabricius
Common name: Fig longicorn

The fig longicorn is a cerambycine borer. Its adults are 10–20 mm long; the body is reddish brown and covered with a mixture of grayish and brownish pubescence (Figure 12.42). The beetle has been recorded in Algeria, Morocco, Tunisia (Duffy 1957), Egypt (El-Nahal et al. 1978; Ismail et al. 2009), and Turkey (Aksit et al. 2005). It probably is widely distributed in the Mediterranean region. Its larvae feed on trees from Anacardiaceae, Apocynaceae, Betulaceae, Fabaceae, Fagaceae, Lythraceae, Moraceae, Sapindaceae, Myrtaceae, Rosaceae, Salicaceae, and Taxaceae (Duffy 1957; Aksit et al. 2005).

This species is a minor to moderate pest of fig trees in Egypt (El-Nahal et al. 1978; Ismail et al. 2009; Imam and Sawaby 2013). The damage is caused by the larval boring into large branches and trunks. Most frass remains in the larval tunnels, but some is ejected through the holes in the bark made by the larvae. Infested trees are weakened and even killed.

The life cycle is summarized from Duffy (1957), El-Nahal et al. (1978), and Imam and Sawaby (2013). The adults emerge during June–August, with a peak in July. They do not feed and can live for only six

FIGURE 12.42 *Trichoferus griseus* adult. (Courtesy of György Csóka.)

or seven days. The females lay their eggs singly or in groups of 2–18 eggs in bark cracks, under lichens on the bark, or under loose bark on large branches and trunks. Each female lays an average of 94 eggs in her lifetime. The hatch rate is highest (98%) at 30°C as compared to 70% at 20°C. The larvae bore into the bark and later enter the wood. This borer takes two to three years to complete its life cycle in the field but can complete a generation in one year in the laboratory. Overwintering occurs at the larval stage.

Rubbing the bark to remove lichens and cutting off all infested and dead branches may suppress the pest population to a great extent (Duffy 1957). Pruning infested branches and killing larvae in the tunnels using wires may reduce the pest population by about 55% (Ismail et al. 2009). Civelek and Çolak (2008) and Ismail et al. (2009) have tested the application of aqueous extracts of several plant species to kill the larvae and have obtained some positive results. However, it is not clear whether it is practical to use these extracts for controlling this pest in the field.

12.5 Cerambycid Pests of Nut Trees

Nut trees in this chapter do not meet the botanical definition but are those that produce nuts in the culinary sense—including walnut, pistachio, almond, cashew, hickory, pecan, chestnut, sheanut, and hazelnut. Major tree nut producers are concentrated in Asia, North America, Europe, and Africa, although most countries in the world produce some nuts. For example, China and Iran are among the largest producers of walnuts, the United States and Spain of almonds, Vietnam and Nigeria of cashew nuts, Iran and the United States of pistachios, and the United States and Mexico of hickory nuts and pecans.

A large number of cerambycid species are recorded that attack nut trees around the world. However, only eight species are considered economically important to walnut, pistachio, almond, cashew, hickory, and pecan trees in Asia, North America, and Africa. There is no record of economically important cerambycid pests of chestnuts, sheanuts, and hazelnuts.

12.5.1 Asia

12.5.1.1 Batocera horsfieldi Hope

Synonyms: *B. adelpha* Thomson, *B. kuntzeni* Kriesche
Common name: Large gray and white longicorn

This lamiine borer is one of the largest longicorns, and its adults are 32–65 mm long. The body is dark brown to black and covered with gray and grayish brown pubescence; the pronotum has a pair of kidney-shaped white to yellowish pubescent markings; each elytron has two to three lines of irregularly shaped and arranged white pubescent markings; the basal quarter of the elytra has granular processes; the elytral apex is rounded. The large gray and white longicorn is widely distributed in China, Japan, Korea, northern India, Nepal, Vietnam, and Myanmar, and attacks at least 66 plant species from 25 families (Duffy 1968; Hua 1982, 2002; Anonymous 2013). This species has not been reported to occur or been intercepted outside its primary distribution range.

It is a moderate pest of walnut and several forest and fruit tree species in China (Li et al. 1997; Jia et al. 2001; Wang et al. 2004; Li 2009) and India (Rhaman and Khan 1942; Duffy 1968). In some Chinese walnut orchards, the infestation rate can be as high as 70% (Wang et al. 2004). Infested walnut trees are significantly weakened but rarely killed. Infested branches can often be killed.

The biology and control of this longhorn have been studied by various individuals (e.g., Beeson and Bhartia 1939; Gressitt 1942; Rhaman and Khan 1942; Duffy 1968; Wang et al. 2004). The adults emerge between May and August but can be found as late as November, depending on climate. The females make transverse oviposition slits in the bark of the living trunk and main branches and lay their eggs singly in the slits. Each female lays 55–60 eggs in her lifetime. The larvae initially bore into the bark and sapwood and later into the heartwood. Pupation occurs in the larval tunnels. The life cycle lasts two to three years, depending on climate. Overwintering is passed at the mature larval or pupal stage.

Careful inspection of individual trees for symptoms caused by oviposition and young larval feeding is highly recommended. These symptoms are transverse cuts and black patches of liquid and frass on the bark. In these early damage stages, destruction of eggs and young larvae can be achieved by cutting into or probing the affected bark using a knife or a wire. Heavily infested or dying branches and trunks should be removed and burned. In the later infestation stage, insertion of cotton-wool soaked in insecticides or a solution of the nematode *S. carpocapsae* into the larval tunnels via frass holes and then closure of these holes with clay mud or other material can be effective. Furthermore, a polyphagous parasitoid, *Dastarcus helophoroides* (Coleoptera: Bothrideridae), that attacks many cerambycid species—including *Anoplophora glabripennis* (Motschulsky) and *Monochamus alternatus* Hope (Urano 2006; Ren et al. 2012)—has been used for the control of *B. horsfieldi* on walnut and other trees, achieving between 40% and 80% control (Li 2009; Li et al. 2009a, 2009b). This parasitoid can be mass-reared artificially (Ogura et al. 1999).

12.5.1.2 Batocera lineolata Chevrolat

Synonyms: *B. catenata* Vollenhoven, *B. chinensis* Thomson, *B. flachi* Schwarzer, *B. hauseri* Schwarzer
Common name: Cloud-marking longicorn

This species is very similar to *B. horsfieldi* in morphology and size and once was considered a synonym of the latter. However, using external morphological and genitalia characteristics, Liu et al. (2012) confirmed that *B. lineolata* and *B. horsfieldi* are two valid species. Briefly, this beetle differs from *B. horsfieldi* in its pronotal markings (which are white) and in the wider distance between the pair of the pronotal markings. Also, this beetle's elytral apex is truncated with a small tooth at suture (Figure 12.43).

The cloud-marking longicorn is widely distributed in China, Japan, Korea, India, Myanmar, and Laos (Duffy 1968; Hua 1982, 2002; Anonymous 2013). It has been intercepted in Hawaii (Nishida 2002), Australia (Biosecurity Australia 2006), France (Menier 1992), Germany, Belgium, Austria, and the Netherlands (Anonymous 2013), causing quarantine concerns in many countries. However, there is no evidence of the establishment of this beetle outside Asia. This lamiine is also highly polyphagous,

FIGURE 12.43 *Batocera lineolata* adult. (Courtesy of Jiří Mička.)

attacking at least 47 species of trees from 15 families (Duffy 1968; Hua 1982, 2002; Anonymous 2013; Yang et al. 2013), including some important forest trees, such as oaks (Xu et al. 2010b) and poplars (Yu et al. 2007a). In recent years, it has become a moderate pest of walnut trees in China, causing damage to walnut orchards similar to that caused by *B. horsfieldi* (Yang et al. 2012, 2013).

The biology of this species is also very similar to that of *B. horsfieldi* (Kojima, 1929; Duffy 1968). The adults start to emerge at the end of April (Xia et al. 2005). The life cycle lasts two to three years, and overwintering occurs at the larval, pupal, or adult stage (Duffy 1968; Yu et al. 2007a).

Control measures used for *B. horsfieldi* could be attempted for this species. The release of *D. helophoroides* can achieve some control but appears to be less effective compared to *B. horsfieldi* (Li et al. 2013). No other tested method, including the application of insecticides, is confirmed to be effective.

12.5.1.3 Calchaenesthes pistacivora Holzschuh

Common name: Pistachio longicorn

The cerambycine adults are 9–12 mm long; the antennae, head, and legs are black; the pronotal disc is yellowish to reddish, with a large black marking that may be enlarged to cover the entire disc; the elytra are yellowish to reddish with two pairs of black spots (basal pair is larger) (Figure 12.44). The pistachio longicorn was first collected from Iranian pistachio orchards in 1999 and later described as a new species by Holzschuh (2003). So far, *C. pistacivora* is only found in Iran and on pistachio trees (both cultivated and wild) (Rad 2005).

Iran is the largest pistachio producer in the world. This species has recently become an increasingly important pest of pistachio trees in Iran (Rad 2006; Mehrnejad 2014), threatening production. The pest prefers trees weakened by water stress and by extreme salinity in water and soil (Achterberg and Mehrnejad 2011). The damage is caused by larval boring inside the twigs and branches. The infested twigs and branches eventually die.

FIGURE 12.44 *Calchaenesthes pistacivora* adult on pistachio flowers. (Courtesy of M. R. Mehrnejad.)

According to Rad's (2006) study in the field, the adults start to emerge in early April and feed on pistachio leaves. The females usually lay their eggs on pruned sites of branches in mid-April. Each female lays 40–45 eggs in her lifetime. The larvae bore under the bark and then into the wood of the twigs and branches. Larval development takes 16 to 18 months. Pupation occurs in the larval tunnels. The life cycle lasts two years. This species overwinters at the larval and adult stage. It passes the first winter as a larva that develops into an adult in the second fall, but the adult remains in the feeding tunnel between October and late March before emergence (Achterberg and Mehrnejad 2011).

Due to the nature of host preference by this pest, Mehrnejad (2014) suggested that maintenance of tree vigor through appropriate and regular irrigation and fertilization regimes is considered the most effective control measure. In general, removal of infested parts of trees would also be a useful measure to consider. Achterberg and Mehrnejad (2011) described a new parasitoid species, *Megalommum pistacivorae* (Hymenoptera: Braconidae), that attacks the final instar of *C. pistacivora* larvae and achieves about a 23% parasitism rate. Rad et al. (2005) tested the effectiveness of spraying insecticides to kill adults in the field during the adult activity period and suggested that, if these insecticides are used during April, the adult beetles could be effectively controlled in the field.

12.5.1.4 Neoplocaederus ferrugineus (Linnaeus)

Synonyms: *Plocaederus ferrugineus* (Linnaeus) and *Cerambyx ferrugineus* Linnaeus
Common name: Cashew stem and root borer

The cerambycine beetle is 25–40 mm long; the head and prothorax are blackish brown and most of the remaining parts of the body are reddish brown; the pronotal disc has irregular ridges or wrinkles; the pronotum has a pair of sharp spines at sides (Figure 12.45). It is widely distributed in southern and southeastern Asia, particularly in India, Sri Lanka, Myanmar, Thailand, Vietnam, and Cambodia (e.g., Duffy 1968; Devi and Murthy 1983; Punnaiah and Devaprasad 1995; Senguttuvan and Mahadevan 1997a, 1997b;

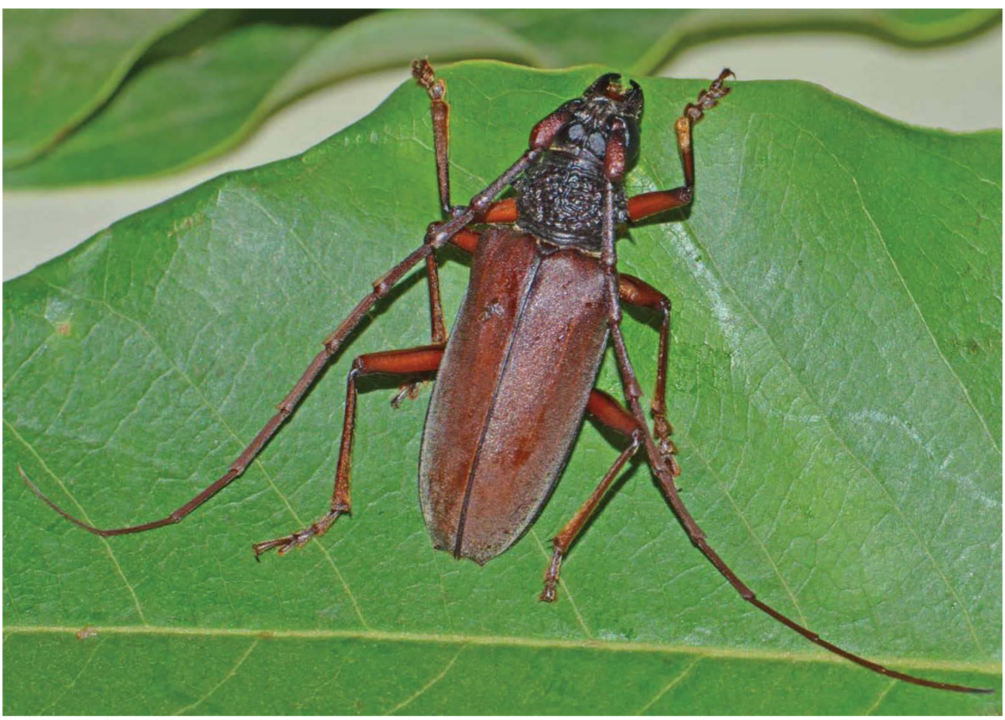

FIGURE 12.45 *Neoplocaederus ferrugineus* adult. (Courtesy of Narasa Reddy, SRF, NBAIR, used with permission of NBAIR director.)

Chaikiattiyos 1998; ChauIn 1998; Lay 1998; Surendra 1998). It also occurs in Nigeria (Anikwe et al. 2007), where it probably was introduced from Asia. Cashew trees were first recorded as hosts of this longhorn by Bhasin and Roonwal (1954). So far, about nine plant species are recorded as its hosts, of which four (including cashews) belong to Anacardiaceae (Duffy 1968; Mohapatra and Jena 2007; Asogwa et al. 2009a). Among five plant species tested in the laboratory, the cashew clearly is the favorite host of *N. ferrugineus* (Mohapatra and Jena 2007, 2008a).

In the past few decades, this species has become a serious pest of cashew trees in India and in several southeastern Asian countries, evoking massive studies on its biology and control. In India, this pest is particularly damaging on the east and west coast, with the infestation rate being up to 40%, and severely infested trees die within two years, causing substantial losses (Bhaskara Rao 1998; Sahu and Sharma 2008; Maruthadurai et al. 2012; Naik et al. 2012; Sahu et al. 2012; Vasanthi and Raviprasad 2013a, 2013b). Furthermore, *N. ferrugineus* has recently emerged as a serious pest of cashew trees in Nigeria, causing the sudden death of mature trees within a few weeks (Anikwe et al. 2007; Hammed et al. 2008; Asogwa et al. 2009a, 2009b). The infestation rate in Nigeria ranges from 13% to 36% (Anikwe et al. 2007; Asogwa et al. 2009a, 2009b). The major damage symptoms include extrusion of frass through the holes at the root collar region, oozing of gum at the base of the tree trunk, leaves turning yellow and falling off, and death of the tree. Affected trees may also tilt on one side due to loss of anchorage if the injury to anchoring roots is severe (Maruthadurai et al. 2012).

Emergence and oviposition occur almost all year round in the field (Mohapatra and Mohapatra 2004); there are two peaks, one in March–May and another in December–February (Senguttuvan and Mahadevan 1997b, 1999a; Mohapatra and Jena 2009). However, Raviprasad and Bhat (2010) reported that most eggs are laid during December–June. The life cycle lasts six months to one year, depending on climate. For example, this longhorn has two generations a year with some overlaps in southeastern India (Senguttuvan and Mahadevan 1997b; Mohapatra and Mohapatra 2004), while it has only one generation a year in southwestern India (Maruthadurai et al. 2012). In the laboratory, this beetle can complete one generation a year on a natural or semisynthetic diet (Rai 1983; Senguttuvan and Mahadevan 1998; Vasanthi and Raviprasad 2013b). The larvae continue to feed and develop throughout the year. According to Maruthadurai et al. (2012), the females prefer to lay their eggs in the bark crevices or physical wounds caused by previous borer damage or heavy pruning on the trunk and roots exposed above the soil; the larvae bore into the fresh tissue of the bark, feeding on the subepidermal tissues, and then into phloem and xylem. Each female lays 60–90 eggs in her lifetime. Portions of the trunk below 50 cm are most frequently attacked (Mohapatra and Mohapatra 2004). Furthermore, the females prefer trees older than four to five years (Maruthadurai et al. 2012) or more than 10 years old (Kumar et al. 1996; Senguttuvan and Mahadevan 1999a) for oviposition. Pupation occurs in the heartwood (Beeson and Bhatia 1939).

Many studies have been carried out for the development of control measures for this pest including chemical, cultural, and biological control. Control actions taken at the early stage of infestation are essential if they are to work at all, and trees with moderate and severe infestation cannot be saved (Devi and Murthy 1983; Sundararaju 1985; Senguttuvan and Mahadevan 1997a, 1997b; Mohapatra and Jena 2008b; Asogwa et al. 2009b). Cultural measures recommended include (1) removing eggs during oviposition peaks and also subsequent early instar larvae (Rao et al. 1985; Bhaskara Rao 1998; Chaikiattiyos 1998), (2) removing heavily infested and dead trees (Chaikiattiyos 1998; Lay 1998; Anikwe et al. 2007; Mohapatra and Jena 2008b), and (3) cleaning the bases of infested trees (Mohapatra and Jena 2008b). Among these cultural practices, destruction of eggs and early instar larvae appears to be the most effective. In addition, evidence shows that the level of resistance and tolerance against the pest differs substantially among cashew cultivars (Kumar et al. 1996; Sahu et al. 2012), providing opportunities for further investigation into plant breeding programs for the control of *N. ferrugineus*. Chemical methods consist of (1) swabbing, painting, or spraying the exposed roots and trunk up to a height of 1–2 m (depending on trunk length) with synthetic (such as chlorpyriphos), botanical (such as neem oil), or fossil fuel (such as kerosene) insecticides and repellents two to four times a year (Rao et al. 1985; Senguttuvan and Mahadevan 1997a, 1997b; Bhaskara Rao 1998; Lay 1998; Mohapatra and Satapathy 1998; Senguttuvan and Mahadevan 1999b; Mohapatra et al. 2000, 2007; Chakraborti 2011; Anikwe et al. 2007; Mohapatra and Jena 2008b; Raviprasad et al. 2009); (2) application of chemical dust or granules around the tree base and incorporation into the soil (Devi and Murthy 1983; Rao et al. 1985), and (3) insertion of chemicals in cotton wool under the bark (Sundararaju 1985) or injection of chemicals into the larval tunnels (Chaikiattiyos 1998). The first method is the most effective, and the synthetic insecticides are superior to others. So far, no effective predators or parasitoids have been found for *N. ferrugineus*. Biological control only involves painting the trunk with a saturated conidial-mud slurry of two fungus species, *Beauveria bassiana* (Bals.-Criv.) Vuill. and *Metarhizium anisopliae* (Metchnikoff) Sorokin (Mohapatra et al. 2007; Sahu and Sharma 2008; Mohapatra and Jena 2008b; Raviprasad et al. 2009; Ambethgar 2010), or pouring a saturated aqueous suspension of conidia through larval entry holes and soil incorporation of fungal spawn (Ambethgar 2010). However, biological control using these fungi is not very effective for the control of this pest (Mohapatra and Jena 2008b; Raviprasad et al. 2009). In conclusion, a combination of multiple tactics, particularly cultural measures followed by chemical treatment, is more effective than the use of only one tactic (Rao et al. 1985; Senguttuvan and Mahadevan 1997a, 1997b; Bhaskara Rao 1998; Lay 1998; Anikwe et al. 2007; Mohapatra et al. 2007; Mohapatra and Jena 2008b).

12.5.1.5 Neoplocaederus obesus (Gahan)

Synonyms: *Plocaederus pedestris* Cotes, *P. obesus* Gahan
Common name: Cashew stem borer

This cerambycine species is similar to *N. ferrugineus* in appearance. The adults are 27–45 mm long; the body is pale brown to light reddish-chestnut or testaceous, clothed with short pubescence (Figure 12.46). The borer is also widely distributed in southern and southeastern Asia, including India, the Andaman Islands, southern China, Thailand, Myanmar, Vietnam, Sri Lanka, and Bangladesh (e.g., Duffy 1968; ChauIn 1998; Liu et al. 1998; Hua 2002). So far, it has not been recorded outside its primary distribution region. *N. obesus* is more polyphagous than *N. ferrugineus.* At least 28 plant species from 12 families are recorded as its hosts, of which 7 species, including cashew, mango, and chironji, belong to Anacardiaceae (Duffy 1968; Hua 1982; Meshram 2009; Maruthadurai et al. 2012; Vasanthi and Raviprasad 2013a, 2013b).

FIGURE 12.46 *Neoplocaederus obesus* adult. (Courtesy of Larry Bezark.)

The cashew stem borer is considered an important pest of cashew trees in India (Khan 1993; Maruthadurai et al. 2012; Vasanthi and Raviprasad 2012, 2013a, 2013b), Vietnam (ChauIn 1998), and southern China (Pan and van der Geest 1990; Li et al. 1997; Liu et al. 1998). It is also an important pest of chironji trees in India (Meshram 2009; Meshram and Soni 2011a, 2011b). Infestation eventually kills the trees if no action is taken.

The biology of this species is very similar to that of *N. ferrugineus*, with damage caused to trunks and roots. It has only one generation a year in the field (Meshram 2009; Maruthadurai et al. 2012) and the laboratory (Vasanthi and Raviprasad 2013b). Each female lays 40–50 eggs in her lifetime.

Several studies have evaluated the effectiveness of cultural, biological, and chemical control methods for this pest. Gressitt (1942) recommended trimming and destroying infested branches as well as the removal of bark, frass, and larvae from attacked trunks followed by an application of tar. Pan and van der Geest (1990) suggested that manual removal of the beetle larvae from the infestation sites is probably the most effective control measure. Vasanthi and Raviprasad (2012) evaluated the effectiveness of three entomopathogenic nematodes, *Heterorhabditis indica* Poinar, *Steinernema abbasi* Elawad, and *S. bicornutum* Tallosi, against the borer and concluded that all these tested nematodes can kill the larvae about two weeks after exposure. However, it is not known whether these nematodes can successfully control the pest in the field. Meshram and Soni (2011a, 2011b) tested the effectiveness of two fungus species, *Metarhizium anisopliae* (Metsch.) Sorok. and *Beauvaria bassiana* (Bals) Vuill., and insecticides for the recovery of trees infested by the borer in the field. After removing the larvae and cleaning the frass materials, they evaluated three application methods: swabbing saturated conidial-mud slurry over the tree trunk, pouring a saturated aqueous suspension of conidia through borer entry holes, and soil incorporation of fungal spawn. Results show that pouring the conidial suspension has achieved a recovery rate of 16.0–25.0%, followed by swabbing with a conidial slurry (17.0–20.0%), and soil application (13.0–14.0%). Using the same delivery methods, conventional insecticides achieve the highest recovery rate (38.0–43.0%). However, implementation of fungal application in the integrated control of *N. obesus* should be considered because the fungi would not only be safer to nontarget organisms but also more effective in a long-term pest control program. Finally, Liu et al. (1998) suggested that cut-end coating, trunk whitewashing with a lime solution, and injection of insecticides into borer tunnels also can give effective control.

12.5.2 North America

12.5.2.1 Psyrassa unicolor (Randall)

Synonym: *Stenocorus unicolor* Randall
Common name: Pecan branch pruner

The cerambycine adults are slender and 7.5–13 mm long; the body is light to reddish brown, covered with short pubescence (Figure 12.47). This species occurs throughout the eastern United States from Minnesota south to Alabama and west to Texas (Linsley 1963). This branch pruner attacks pecan and hickory trees and, to a lesser extent, the oaks and a few other species (Linsley 1963; Solomon 1985).

The pecan branch pruner is only considered a minor pest of pecan trees in the United States. Linsley (1963) and Solomon (1985) described the damage made by this pest. The larvae are twig and branch pruners, usually girdling at or near a node. They tunnel in pecan twigs 2–4 mm in diameter for a distance of 12–36 cm until intersecting a larger branch, which they girdle. Branches 10–50 mm in diameter and 0.6–3.6 m long are severed with a smooth concentric cut and fall to the ground from January to May. Twenty-nine percent of the larvae are in the severed portion of the branch, 13% in the branch stub, and the remaining larvae are dislodged and lost during the break.

According to Solomon (1985), the adults emerge from late April to early June. The eggs are deposited on small twigs that arise from a larger branch 10–50 mm in diameter. The young larva tunnels down the center of the twig toward its base but does not hollow out the small twig completely. Upon reaching the larger branch, it bores into the branch and begins to girdle it. The girdle is completed during late winter and spring when the larva makes a smooth, uniform concentric circular cut, often completely severing the wood but leaving the bark intact. Pupation takes place within the gallery just beneath the bark.

FIGURE 12.47 *Psyrassa unicolor* adult. (Courtesy of James Solomon, USDA Forest Service, Bugwood.org [3066006].)

The adult chews an irregularly shaped hole through the bark to emerge. The life cycle lasts one to two years, and overwintering occurs at the larval stage.

Severed branches on the ground under trees in orchards and ornamental plantings should be picked up in early spring and destroyed before the adults emerge in late spring and early summer. To be most effective, the pick-up and destruction practice should be undertaken for the entire orchard, woodlot, or neighborhood. Direct control in natural forest stands rarely is needed. Two icheumonid parasites, *Labena grallator* Say and *Agronocryptus discoidaloides* Viereck, may help reduce infestations (Linsley 1963).

12.5.2.2 Oncideres cingulata (Say)

Synonyms: *O. cingulatus pallescens* Casey, *O. proecidens* Casey*, and Saperda cingulata* Say
Common name: Pecan twig girdler

The adults of this lamiine girdler are 12–16 mm long; the body is cylindrical and generally grayish brown in color with a broad, ashy-gray band across the middle of the elytra (Figure 12.48). This longicorn is distributed throughout the eastern United States, from New England to Florida and as far west as Kansas and Arizona, and is highly polyphagous, feeding on trees from Anacardiaceae, Betulaceae, Caesalpiniaceae, Combretaceae, Cornaceae, Corylaceae, Ebenaceae, Fabaceae, Fagaceae, Juglandaceae, Lauraceae, Myricaceae, Myrtaceae, Nyssaceae, Rosaceae, Rutaceae, Salicaceae, Tiliaceae, and Ulmaceae (Bilsing 1916; Rogers 1977a; Linsley and Chemsak 1984; Rice 1995; Coppedge 2011; Day 2015).

The pecan twig girdler is a moderate pest of pecan and hickory trees in the United States (e.g., Bilsing 1916; Forcella 1984; Linsley and Chemsak 1984; Baker and Bambara 2001; Day 2015). The damage is caused by adult girdling. The females girdle the twigs and small branches using mandibles before oviposition to create proper conditions for the development of their larvae. The girdled twigs and branches break off or hang loosely on the trees. Usually, the ground under infested trees is covered with twigs

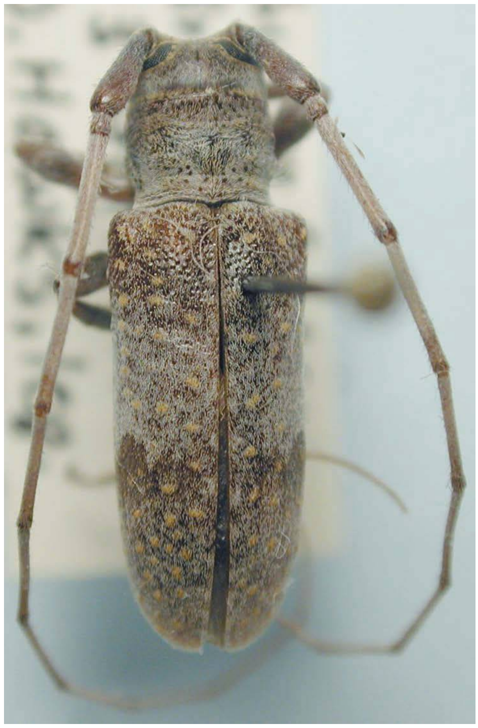

FIGURE 12.48 *Oncideres cingulata* adult. (Courtesy of Larry Bezark.)

and branches cut off by the longicorn. In pecan orchards, the fruiting twigs of heavily infested trees are often reduced, resulting in lower nut yields in the following year or years. This type of injury causes the development of many offshoots that adversely affect the symmetry of the trees. Pecan nurseries located close to heavily infested woodlots may suffer considerable losses from girdled seedlings. Severed twigs lodged in the tree canopy or on the ground often retain leaves even after the tree sheds its foliage in fall. Large trees usually sustain the most girdling, but young trees are sometimes heavily damaged.

The biology of this pest is summarized from Bilsing (1916), Rogers (1977a), Linsley and Chemsak (1984), Rice (1995), and Baker and Bambara (2001). The adults emerge from late August to early October. They feed on the tender bark near branch ends. The females girdle living twigs and small branches 0.6–2.0 cm in diameter and 25–75 cm long with their mandibles, make oviposition slits in the bark of girdled hosts, and then lay their eggs singly in the slits. Each female lays 50–200 eggs in her lifetime. The larvae bore into the host immediately after hatching. After the first instar, the larvae develop rapidly in the girdled portions of the host, boring toward the severed end of the twigs or branches by feeding only on the woody portion and leaving the bark intact. Pupation occurs during August and September, and the pupal stage lasts 12–14 days. Most larvae complete development within one year and pass the winter, but a small percentage of mature larvae pass a second winter in the galleries of girdled branches.

Baker and Bambara (2001) and Day (2015) summarized available control measures for this pest. In orchards, nurseries, and ornamental plantings, severed twigs and branches on the ground as well as those lodged on the trees should be gathered and destroyed during the fall, winter, and spring. The same practice should be applied in nearby woodlots containing oak and hickory trees if they have a history of serious damage from this pest. This practice can substantially reduce the pest population in one or two seasons. Insecticides only may be necessary to prevent damage from heavy infestations in some hardwood tree nurseries. These may be applied once or twice in September and again in October as a protectant to reduce the majority of the twig girdlers. The parasites, *Eurytoma magdalidis* Ashmead, *Iphiaulax agrili* Ashmead, and *Horismenus* sp., and a checkered flower beetle, *Cymatodera undulata* Say, may help reduce the girdler populations naturally.

12.5.3 Africa

12.5.3.1 Analeptes trifasciata (Fabricius)

Synonyms: *Lamia obesa* Voet, *L. trifasciata* Fabricius
Common name: Cashew stem girdler

The lamiine adults are 25–42 mm long and black in color; the elytra have three orange bands that may enlarge to cover most areas of the elytra in some specimens (Figure 12.49). This insect is widely distributed in Angola, Benin, Cameroon, the Central African Republic, the Democratic Republic of Congo, Ethiopia, Ghana, Ivory Coast, Kenya, Liberia, Niger, Nigeria, Senegal, Sierra Leone, and Togo, and attacks trees from Anacardiaceae, Lamiaceae, Malvaceae, and Myrtaceae (Duffy 1957; Wagner et al. 1991; Asogwa et al. 2011).

In the past decade or so, the cashew stem borer has become a serious pest of cashew trees in Nigerian orchards, particularly in the south (Hammed et al. 2008; Asogwa et al. 2011; Adeigbe et al. 2015). The infestation rate ranges from 40% to 80%, causing up to 55% cashew nut yield loss. Damage is caused by adult feeding on and girdling branches and young trunks, with the latter causing the most destruction. Both sexes feed by scraping the bark of cashew branches and young trunks, making V-shaped grooves, and then girdling them to provide dying sites for larval development. The stumps of the affected trees usually regenerate and produce many side shoots, giving an untidy appearance and producing no nuts. In some cases, the girdled branches and trunks recover by producing a lot of gum exudates around the girdled portion, followed by an outgrowth to heal the wound.

Information on the biology is extracted from Wagner et al. (1991) and Asogwa et al. (2011). The adults emerge in January–March and September–December. The females lay their eggs in the bark above the girdled portion that will hang on the tree or fall to the ground. The lifetime fecundity in the field is unknown. Dying and dead wood tissue provides a breeding site for the larvae, which bore inside the wood and develop to pupae and adults. This pest has two generations a year and overwinters at the larval and pupal stages.

FIGURE 12.49 *Analeptes trifasciata* adult. (Courtesy of Larry Bezark.)

The control measures are summarized from Asogwa et al. (2011) and Adeigbe et al. (2015). Cultural control appears to be the only effective measure at present. All the hanging girdled branches and those that have fallen to the ground are removed from the cashew plots on a monthly basis and burned. However, the large number of the girdled branches hanging on treetops and beyond reach by hand makes it very difficult to eradicate this pest from cashew orchards. It may be difficult for growers to afford the extra costs required to remove hanging branches from the treetops. The regenerated side shoots due to girdling attract foliar pests, which damage the apical portion and reduce photosynthetic activities of the tree. Such side shoots should be pruned immediately. Finally, removal of alternative hosts, such as *Adansonia digitata* and *Ficus mucosa*, in addition to burning the infested twigs may be necessary to effectively control the spread and damage by this pest.

12.6 Cerambycid Pests of Mulberry Trees

Mulberry trees (*Morus* spp.) are native to warm regions of Asia, Africa, and the Americas, with most species native to Asia. The fruits are red to dark purple in color, edible, and sweet with a good flavor. The leaves of several mulberry species are used as food for silkworms [*Bombyx mori* (L.)]. Silk is extracted from the cocoons of silkworms for making garments and other textile products.

Sericulture, the rearing of silkworms using mulberry leaves for the production of silk, has become one of the most important industries in many countries, particularly China, Japan, India, Korea, Brazil, Russia, Italy, and France (Sánchez 2000). At present, China and India are the two main sericultural countries, together producing more than 60% of the world's silk each year.

Mulberry trees are subject to attacks by a number of cerambycid species. For example, more than 30 longicorn species are recorded that infest mulberry trees in China (Gao et al. 1988). However, only about four species are considered economic pests of mulberry trees in the world, and all occur in Asia.

Batocera rufomaculata (DeGeer) is also an important pest of mulberry trees, but it is more severe in mango trees; thus it is treated in Section 12.4 on tropical and subtropical fruit trees. A North American species, *Dorcaschema wildii* Uhier, distributed from the eastern United States to Texas, causes very minor damage to mulberry and several ornamental trees (Solomon 1968; Linsley and Chemsak 1984), and thus is not discussed further here.

12.6.1 Asia

12.6.1.1 Psacothea hilaris (Pascoe)

Synonym: *Monohammus hilaris* Pascoe
Common name: Yellow-spotted longicorn beetle

The adults of this lamiine borer are 13–31 mm long; the body is dark brown with a longitudinal yellow stripe on the vertex, a longitudinal yellow stripe on each side of the pronotal disc, and a number of yellow spots on the elytra; the antennae are extremely long, about 2.5 times as long as the body in males and twice as long as the body in females (Figure 12.50). The primary distribution range of this beetle includes Japan, Korea, and China (Duffy 1968; CABI 2012). It has been intercepted in Europe and North America in warehouses, on wood and wooden spools imported from Asia, and has been confirmed as established in Italy (Lupi et al. 2013). Its host range appears to be narrow with only several plant species from Araliaceae, Asteraceae, and Moraceae being recorded as hosts (Duffy 1968; Hua 1982; Li et al. 1997).

The yellow-spotted longicorn beetle is one of the most serious pests of mulberry trees in Japan and China (Emori 1976; Masaki et al. 1976; Kawakami 1987; Gao et al. 1988; Sakakibara and Kawakami 1992; Sakakibara 1995; Shintani and Ishikawa 1999a, 1999b; CABI 2012). It can also seriously damage fig trees (Sakakibara and Kawakami 1992; Sakakibara 1995; CABI 2012). The damage is caused by larval boring in tree trunks. Severely attacked trees become weakened and eventually die (Lupi et al. 2013).

FIGURE 12.50 *Psacothea hilaris* adult. (Courtesy of Junsuke Yamasako.)

Both mulberries and figs belong to the family Moraceae. This cerambycid is also recorded as a minor pest of citrus trees in southern China (Li et al. 1997).

Studies show that there are at least two ecotypes in this species (Sakakibara and Kawakami 1992; Shintani and Ishikawa 1999a), allowing it to adapt to a wide range of environmental conditions through diapause or quiescence at the egg or larval stage under unfavorable conditions such as cold winters (Sakakibara 1995; Shintani and Ishikawa 1999a; Watari et al. 2002). This feature makes *P. hilaris* a potentially important invasive pest, and its recent establishment in Italy (Lupi et al. 2013) is a testament.

The adults can be found from May to November (Masaki et al. 1976) or from June to October (Duffy 1968; Lupi et al. 2013). Like many other lamiines, the females gnaw the bark of trees, making oviposition slits before laying eggs. They lay most of their eggs singly in oviposition slits in the basal portion of the trunk. The larvae feed on the cambial region, making irregular tunnels and ejecting dust-like frass from the crevices in the bark (Duffy 1968). Depending on climate and ecotypes, this species may have one or two generations a year (Watari et al. 2002). On an artificial diet in the laboratory, it can complete one to two generations a year depending on environmental conditions (Emori 1976). Overwintering occurs at the egg and/or larval stage.

Kawakami and Shimane (1986) described the process of producing a biopesticide containing conidia of an entomogenous fungus, *Beauveria tenella*. They have conducted field trials to determine its effectiveness for the control of adults, achieving cumulative adult mortality of 60–90% 30 days after application. Another entomogenous fungus, *Beauveria brongniartii*, was tested by Kawakami (1987) with similar killing efficiency. However, it is not known whether these fungus-based insecticides are effective in large-scale control programs. Gao et al. (1988) sprayed or brushed the trunk with synthetic insecticides, achieving between 80% and 90% control. Caution should be taken to avoid a negative impact on silkworms when synthetic chemicals are applied to mulberry trees. Although not reported for *P. hilaris*, cultural measures used for other cerambycids (see Chapter 9) could be considered and modified for the control of this species.

12.6.1.2 *Apriona germari* (Hope)

Synonyms: *A. plicicollis* Motschulsky, *A. deyrollei* Kaup, *A. cribrata* Thomson, *Lamia germari* Hope
Common name: Brown mulberry borer

The lamiine longicorn beetle is 26–50 mm long; the body is black and almost entirely covered with dense tawny brown, slightly greenish pubescence; the antennae are blackish brown, with bases of most segments ringed with grayish white pubescence; the prothorax has a pair of spines at the sides; the elytra have coarse granular processes on the basal fifth (Figure 12.51). The primary distribution range of this species includes China, Korea, India, Pakistan, Nepal, Laos, Myanmar, Thailand, and Vietnam (Duffy 1968; EPPO 2013d). Although Japan is mentioned in several publications on *A. germari* (Ibáñez Justicia et al. 2010), this pest probably is not present in Japan (EPPO 2013d). In the past two decades, *A. germari* has been intercepted in several European countries and probably also in the United States from goods imported from China, but there is no evidence that it has established outside its primary distribution range (Ibáñez Justicia et al. 2010; EPPO 2013d). This species is polyphagous, feeding on more than 30 species from Betulaceae, Bombacaceae, Fabaceae, Fagaceae, Juglandaceae, Lauraceae, Meliaceae, Moraceae, Rosaceae, Rutaceae, Salicaceae, Theaceae, and Ulmaceae (Duffy 1968; Huang et al. 2009; EPPO 2013d). Most host plant species are from Moraceae. The list of host plants of this longicorn given by Duffy (1968) and repeated by Huang et al. (2009) should be treated with some caution because Duffy (1968) did not distinguish between *A. germarii* and *A. rugicollis*, and some records appear to relate to *A. rugicollis*.

The brown mulberry borer is a serious pest of mulberry trees used for silkworm production in China (Gao et al. 1988; Zhao et al. 1994; Zhu et al. 1995) and northern India (Hussain et al. 2007, 2009; Hussain and Chishti 2012), causing significant economic loss. The infested trees are weakened and even killed. It is also considered an important pest of apple (Yang et al. 2005), fig (Qin et al. (1997), paper mulberry (Jin et al. 2011), walnut (Zhang et al. 1999), and poplar (Li 1996; Shui et al. 2009) trees. Furthermore, this species is recorded as a minor pest of many other fruit and forest trees (Li et al. 1997;

FIGURE 12.51 *Apriona germari* adult. (Courtesy of Eric Jiroux.)

Ibáñez Justicia et al. 2010; EPPO 2013d). Like many other lamiine species, *A. germari* adults need complemental nutrition for ovary development. Qin et al. (1994) showed that adults feeding on mulberry tree tissues produce normal ova, but those on apple or poplar tree tissues do not, suggesting that this species may not be able to establish in an environment where appropriate adult hosts are not present.

The adults emerge from May to October with a peak during June–August in China (Gressitt 1942). In India, they emerge from June to September, with a peak in mid-July in the subtropical region, while in the temperate region, the adult population peaks in the second fortnight of August (Hussain et al. 2007). The females use their mandibles to make oviposition slits and lay their eggs in the bark 20 cm above ground level (Duffy 1968), with a preference for primary branches 0.8–1.1 cm (Hussain and Buhroo 2012) to 1.3–1.9 cm (Yoon et al. 1997a) in diameter. They lay an average of 117 eggs each during the mean oviposition period of 43 days (Hussain and Buhroo 2012). The larvae bore into the sapwood first and then into the heartwood. Most larvae bore and move downward through the branches to the trunk (Yoon et al. 1997a), damaging the trunk and even the roots (Gressitt 1942). As the larvae tunnel downward, the larvae eject fine, wet, and sawdust-like frass at about 10 cm intervals (Duffy 1968). This species has one generation a year in southern China (Gressitt 1942; Chen et al. 1959) and northern India (Hussain and Buhroo 2012); in northern China, a life cycle lasts two to three years depending on climate (Yang et al. 2005; Huang et al. 2009). In the laboratory, this beetle can complete one generation a year on an artificial diet (Yoon et al. 1997b; Yoon and Mah 1999). Overwintering occurs at the larval stage (Ibáñez Justicia et al. 2010).

As a preventative measure, culture control can significantly reduce the damage by this borer. For example, summer pruning of the infested branches can stop further damage to the trunks, and removal of heavily infested trees can reduce infestation on mulberry farms by about 60% (Hussain and Chishti 2012). Studies showed that the level of resistance against *A. germari* varies among tree species (Zhang et al. 1999) and mulberry cultivars (Hussain and Chishti 2012), providing foundations for the development of resistant plant breeding programs for the control of this borer. An egg parasitoid, *Aprostocetus fukutai* Miwa & Sonan, is found to be an important natural enemy of *A. germari,* with a parasitism rate of about 50% in China (Yan et al. 1996). However, there is no evidence that this parasitoid is useful for large-scale biological control programs. Li et al. (2011) have tested the potential of a fungus, *Beauveria bassiana*, for biological control of *A. germari* in China. They showed that more than 95% larval mortality is achieved 10 days after inoculation in the laboratory. In the field, almost 70% of the larvae are killed 20 days after application. They suggested that this fungus has great potential to be used for the control of this pest. However, chemical control measures are still the most effective for the control of *A. germari*. For example, Gao et al. (1988) sprayed or brushed the trunk with synthetic insecticides, achieving between 80% and 90% control. In a trial on the spray effectiveness of different insecticide formulations for the control of this borer, Zhu et al. (1995) found that the controlled release microcapsule is more effective, persists longer, and has lower environmental toxicity than the emulsifiable concentrate. Yang et al. (2005) demonstrated that spraying insecticides in a microcapsule solution on the trunk and large branches during peak adult activity and then again in 20 days gives successful control. Furthermore, the injection of insecticides into borer holes can achieve >90% control (Pan, 1999), and inserting one fumigation rod into a borer tunnel that is then sealed with mud results in >97% larval mortality (Zhao et al. 1994). More recently, Shui et al. (2009) demonstrated that inserting zinc phosphide sticks into borer tunnels is a feasible method for controlling *A. germari*.

It is worth noting that, in the most recent taxonomic revision on *Apriona* (Jiroux 2011), *A. germari* is only reported from southern China (Guangdong, Hainan, Yunnan, and Tibet), India, Vietnam, Laos, Myanmar, Nepal, Bangladesh, Cambodia, and Thailand. Therefore, much of the aforementioned biology for *A. germari* outside these areas may well refer to the next species, *Apriona rugicollis* Chevrolat.

12.6.1.3 Apriona rugicollis Chevrolat

Synonym: *A. japonica* Thomson
Common name: Mulberry tree borer

The adults of the mulberry tree borer are 40–60 mm long; the body is dark gray to greenish in color; the basal fifth to sixth of the elytra has blackish tubercles (Figure 12.52). This species is widely

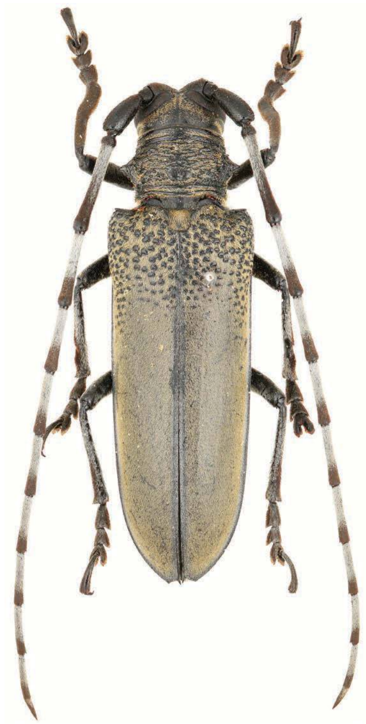

FIGURE 12.52 *Apriona rugicollis* adult. (Courtesy of Junsuke Yamasako.)

distributed in China, Korea, and Japan (Jiroux 2011). In 2009, it was intercepted in a Dutch port in a consignment of *Enkianthus* trees from Japan but did not establish (Ibáñez Justicia et al. 2010). *A. rugicollis* infests more than 26 plant species, including mulberry, fig, poplar, willow, beech, and keyaki (Japanese zelkova) trees from Cornaceae, Ebenaceae, Ericaceae, Fabaceae, Fagaceae, Juglandaceae, Lauraceae, Lythraceae, Malvaceae, Moraceae, Ulmaceae, Platanaceae, Rhamnaceae, Rosaceae, Rutaceae, and Salicaceae (Yamanobe and Hosoda 2002; Ibáñez Justicia et al. 2010; EPPO 2013d). *Apriona rugicollis* is a moderate pest of mulberry (Kikuchi 1976; Esaki 1995) and keyaki trees (Esaki 1995; Esaki 2006, 2007a), with the latter species being widely used for ornamental purposes in Japan. However, as mentioned earlier, much of the described biology and pest status for *A. germari* may refer to this species.

The adults are present from early July to early September with an oviposition peak in August (Esaki 2007a). The females prefer the main branches and trunks >10 mm in diameter for oviposition (Esaki 2007a), with most eggs being laid in the oviposition slits made on tree trunks 40–50 mm in diameter (Esaki 1995). The female lays an average of 60 eggs in her lifetime (reviewed by Yamanobe and Hosoda 2002). The adults feed on leaves and tender bark. The larvae bore under the bark and then into the heartwood. The life cycle lasts two to three years in the field (Esaki 2007a) and about one year in the laboratory (Esaki 2001). Overwintering appears to occur at the larval stage.

Esaki (2006) suggested that the removal of weeds around trees can reduce oviposition by *A. rugicollis* because the females prefer to oviposit on sites covered by weeds. Pruning the infested branches may also be effective for the control of this species. Esaki and Higuchi (2006) have tested the effectiveness of a fungus, *Beauveria brongniartii* (Saccardo) Petch, for the control of this borer in the field, demonstrating that the application of fungus-containing sheets on trees where the adults congregate for feeding can kill adults effectively. Spraying the branches with synthetic insecticides twice at an interval of three weeks during the early stage of the adult activity period can achieve 100% adult mortality over a period of nine weeks (Esaki 2007b).

12.6.1.4 *Sthenias grisator* (Fabricius)

Synonym: *Lamia grisator* Fabricius
Common name: Grapevine stem girdler

The adults of the lamiine grapevine stem girdler are 15–22 mm long; the body is stout in shape and blackish brown in color and is covered with a mix of gray and brown pubescence; the elytra have a grayish white spot in the middle at the suture and an oblique grayish white band across at the apical third margined with a thinner blackish-brown stripe at the apical side; in some specimens, the blackish stripe can expand to cover most of the apical area (Figure 12.53). This species occurs in India and Sri Lanka (Duffy 1968; Sengupta and Sengupt 1981; Bhaskar and Thomas 2010). The host range of this longicorn is quite broad, with more than 30 tree species recorded as hosts from Anacardiaceae, Apocynaceae, Casuarinaceae, Euphorbiaceae, Fabaceae, Menispermaceae, Moraceae, Moringaceae, Nyctaginaceae, Rosaceae, Rutaceae, and Vitaceae (Duffy 1968; Satyanarayana et al. 2013).

The grapevine stem girdler is considered a minor to moderate pest of mulberry, grapevine, jatropha (a crop grown for producing biodiesel), mango, almond, jackfruit, and several ornamental plant species such as roses (Singh and Singh 1962; Duffy 1968; Butani 1978; Sengupta and Sengupt 1981; Rahmathulla and Kumar 2011; Satyanarayana et al. 2013; Mani et al. 2014). In rare cases, it can be a serious pest of mulberry plantations (Bhaskar and Thomas 2010). The major damage is done by the adult girdling for egg laying (Sanjeeva Raj 1959; Duffy 1968). Portions above the girdle wilt and die.

The adults emerge almost all year round but mainly in July and August (Beeson and Bhatia 1939). The females completely girdle the shoots, tree branches up to 2 cm in diameter, vines, or bushes and then lay eggs singly in the wound (Sanjeeva Raj 1959; Duffy 1968). The lifetime fecundity in the field is unknown. The larvae bore in the portions above the girdle to avoid contact with ascending flow of sap. The life cycle may be completed within five months but, under dry conditions, a generation may take a year.

The most commonly used practice for the control of this pest is pruning and destruction of girdled apical portions from the point just below the girdle as soon as girdles are found or shoot withering is noticed (Duffy 1968; Bhaskar and Thomas. 2010). Swabbing the base of the trunks or branches with insecticides may also be effective (Butani 1978).

FIGURE 12.53 *Sthenias grisator* adult and girdle. (Courtesy of Sangamesh Hiremath.)

12.7 Cerambycid Pests of Tea, Coffee, and Cacao Crops

Tea, coffee, and cacao are the three most important crops for the production of beverages in the world. Cacao is also the key component of chocolate. Leaves of tea trees and seeds of coffee and cacao trees are harvested and consumed. Trees producing these products are small trees or bush-like woody plants. Tea is thought to originate from Asia, coffee from Africa, and cacao from Central and South America. These crops are now grown both inside and outside the regions of their origins.

Tea probably is the most popular drink in the world in terms of consumption, equaling all other manufactured drinks in the world put together—including coffee, chocolate, soft drinks, and alcohol (Macfarlane and Macfarlane 2004). China and India are the biggest tea producers in the world. Coffee is grown in most tropical regions, with Brazil and Vietnam being the top two producers. Cacao is also grown in many tropical countries, with the top two producers being Ivory Coast and Ghana in Africa.

In various books and catalogs, many cerambycid species are listed as pests of these beverage crops. For example, about 90 cerambycid species reportedly attack commercially grown coffee trees alone (Waller et al. 2007). However, only 13 species are considered pests with economic importance for these crops: three infesting tea and two impacting coffee trees in Asia, three damaging coffee trees in Africa, and one injuring cacao trees and four attacking coffee trees in Central and South America.

12.7.1 Asia

12.7.1.1 Bacchisa atritarsis (Pic)

Synonym: *Chreonoma atritarsis* Pic
Common name: Black-tarsused tea longicorn

The adults of the lamiine borer are 9–11 mm long; the head, pronotal disc, and ventral side are reddish to orange brown; the antennae are black with the basal two-thirds of segments 1–4 being reddish to yellowish brown; the elytra are metallic blue or purple; the legs are reddish brown to orange brown with the tarsi and apical third of tibia being blackish (Figure 12.54). This longicorn is only distributed in Taiwan and southern parts of China (Hua 2002). The number of plant species recorded as its hosts appears to be small: tea (*Camellia sinensis*), oil tea (*C. oleifera*), willow, Chinese wingnut, walnut, apple, pear, peach, and plum (Chen et al. 2002; Hua 2002; Tan et al. 2003). Of the infested species, *C. sinensis* is used in the production of tea for drinks, while seeds of *C. oleifera* are harvested for edible tea oil.

The black-tarsused tea longicorn is a moderate pest of tea and oil tea crops in southern and southeastern China and Taiwan (Chen 1958; Chang 1973; Qian 1984; Chen et al. 2002; Tan et al. 2003; Lv et al. 2011). In Zhejiang Province, it appears be a serious pest of oil tea trees (Hua et al. 2012). The damage is caused by larval tunneling in branches and trunks. The infested parts are weakened and may be broken off in the wind. The yield can be significantly reduced by this pest.

According to Qian (1984) and Chen et al. (2002), adults emerge from May to July. The females make oviposition slits in the bark of the main branches and trunks where they lay their eggs singly. The lifetime fecundity is unknown. Most oviposition occurs on branches and trunks 10–20 mm in diameter where larvae first bore under the bark, making spiral-shaped swollen marks, and then continue into the heartwood. The life cycle lasts two years, and overwintering occurs at the larval stage.

Chen et al. (2002) have practiced cultural and chemical control measures in the field and made recommendations for control methods. Careful examination of plants for characteristic symptoms (spiral-shaped swollen marks) and then pruning and destroying the infested portions can reduce further damage and infestation. However, when the main trunks are infested, chemical control probably is the only option. Swabbing the trunk below the damage marks with a systemic organophosphorous insecticide during August kills almost all larvae 20–30 days after application.

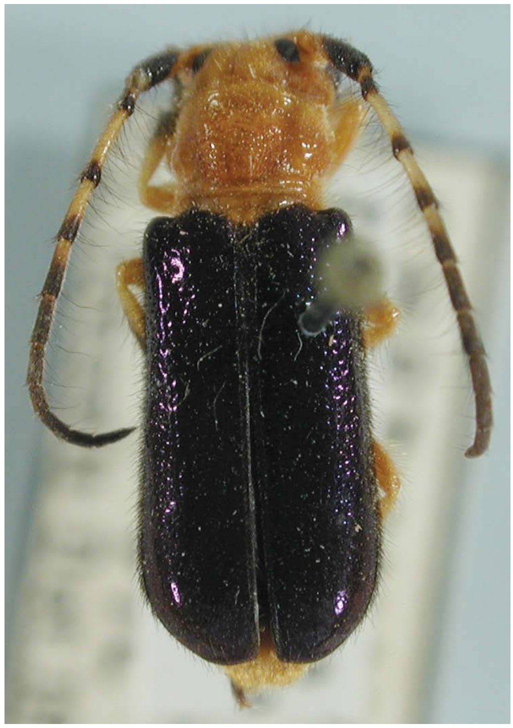

FIGURE 12.54 *Bacchisa atritarsis* adult. (Courtesy of Larry Bezark.)

According to Chen et al. (2002), *Dolichomitus mclanomcrus tinctipcnnis* (Camcron) is reported to be a larval parasitoid of this longicorn, but whether this wasp species can be used for the control of this pest is unknown.

12.7.1.2 Trachylophus sinensis Gahan

Synonym: *T. piyananensis* Kano
Common name: Four-ridged tea longicorn

The cerambycine adults are 25–38 mm long; the body is blackish brown and covered with dense, shining, golden pubescence; the pronotal disc has irregular wrinkles and four longitudinal and oblique ridges (Figure 12.55). This longicorn mainly occurs in southern and southeastern China and in Myanmar where *Camellia* spp. have been reported as hosts (Duffy 1968; Liau 1968; Hua 1982; Qian 1984).

This longicorn attacks tea and oil tea, causing minor to moderate damage to these economic crops (Liau 1968; Qian 1984; Tan et al. 2003; Hua et al. 2012). The damage is caused by larval tunneling in branches, trunks, and roots. The infested plants are weakened and their yield reduced.

Adults emerge between March and June and lay their eggs on the trunk surface just above the soil level, on mosses and lichens attached to the bark (Liau 1968), or on the bark of the trunk and branches (Tan et al. 2003; Hua et al. 2012). Each female lays 29–30 eggs in their lifetime. The larvae bore into the trunk and roots (Liau 1968) or into the trunk and branches (Tan et al. 2003; Hua et al. 2012). The life cycle lasts about one year, and overwintering occurs at the larval stage (Liau 1968).

Because the main damage occurs in the trunk and roots, chemical control is the only option that has been considered to date. Injecting insecticides into larval tunnels in October or spraying insecticides on the lower trunk between the ground and upward to 30 cm during June–July has is effective for the control of this pest (Liau 1968). In addition, the chemical control method for *B. atritarsis* (Chen et al. 2002) may also be effective for this pest.

FIGURE 12.55 *Trachylophus sinensis* adult. (Courtesy of Xavier Gouverneur.)

12.7.1.3 Aeolesthes induta (Newman)

Synonym: *Hammaticherus indutus* Newman
Common name: Silky gray-brown longhorn

The cerambycine adults are 23–38 mm long; the body is brown to blackish brown and covered with dense, shining, light brown pubescence, giving a satin look; the ventral side is covered with grayish brown pubescence; the pronotal disc has irregular wrinkles on the sides and a rectangular area in the middle that is arranged longitudinally (Figure 12.56). This longicorn is widely distributed in southern and southeastern Asia, including India, Sri Lanka, China, the Philippines, Indonesia, Myanmar, Thailand, and Laos, and it attacks a number of woody species in Anacardiaceae, Dipterocarpaceae, Euphorbiaceae, Fabaceae, Malvaceae, Meliaceae, Myrtaceae, Pinaceae, Rubiaceae, Rutaceae, and Theaceae (Chen 1958; Duffy 1968; Hua 1982; Qian 1984; Tan et al. 2003; Lv et al. 2011). Duffy (1968) cited a 1920s' report on serious damage caused by this species to cocoa in the Philippines. However, further details about its current pest status for this crop are unknown.

The silky gray-brown longhorn is a moderate (occasionally serious) pest of tea and oil tea crops in southeastern China (Chen 1958; Qian 1984; Tan et al. 2003; Liu et al. 2010; Lv et al. 2011). The infestation rate varies depending on the distance of trees from the road, the landscape where tea plantations are located, and whether roots are exposed to the air. For example, about 30% of trees near the roadside are infested, while less than 10% of trees 70–100 m away from the road are attacked (Liu et al. 2010; Yang and Liu 2010; Yang et al. 2011). Liu et al. (2010) reported an infestation rate ranging from 7% to 50% in a tea orchard in Zhejiang Province, with more serious damage occurring near a hilltop rather than midway along the hillside. According to Yang and Liu (2010), higher infestation rates (51%) occur in trees planted in shallow soil with their roots partially exposed to the air, while infestation rates are lower (17%) in those planted in thick soil with their roots completely covered. Infestation can cause trunks to decay (Chen 1958). The infested trees are generally weakened, and heavily damaged ones die.

FIGURE 12.56 *Aeolesthes induta* adult. (Courtesy of Larry Bezark.)

The adults emerge between April and July and lay their eggs in crevices or joints on trunks or branches that are 2–3.5 cm in diameter and 7–35 cm above the ground. Most oviposition occurs in late May. The lifetime fecundity in the field is unknown. The larvae first bore under the bark and then into the heartwood. They bore downward and make tunnels extending to at least 35 cm below the ground's surface, leaving holes 2–3 cm aboveground for frass expulsion. The life cycle lasts two to three years depending on climate. Overwintering occurs at the larval stage in the first year or first and second years and at the adult stage in the pupal cells in the second or third year.

Yang et al. (2011) indicated that the use of light traps during the adult activity period can substantially reduce the infestation on tea trees by this pest in Zhejiang Province. Covering exposed roots with soil can increase the vigor of trees and prevent oviposition, thereby reducing infestation rate (Yang and Liu 2010; Lv et al. 2011). Insertion of cotton wool saturated with organophosphate insecticides into borer holes near the ground and sealing those holes with mud can also effectively control this pest (Yang and Liu 2010; Lv et al. 2011).

12.7.1.4 Acalolepta cervina (Hope)

Synonyms: *Dihammus cervinus* (Hope), *Monohammus cervinus* Hope
Common name: Coffee brown borer

The lamiine adults are 15–27 mm long; the body is uniformly covered with dense, grayish brown pubescence; pubescence on the basal portions of most antennal segments is grayish; the scutellum is covered with golden pubescence; the pronotum has a spine on each side (Figure 12.57). The coffee brown borer is widely distributed in Asia including China, India, Myanmar, Thailand, Vietnam, Nepal, Laos, Japan, and Korea (Duffy 1968; Hua 1982; Waller et al. 2007). Its larvae feed on at least 16 forest tree species in Adoxaceae, Bignoniaceae, Combretaceae, Daphniphyllaceae, Lamiaceae, Lythraceae, Moraceae, Rubiaceae, Salicaceae, Scrophulariaceae, and Theaceae (Duffy 1968). Chen et al. (1959) listed coffee (family Rubiaceae) as a host that is not listed in Duffy (1968).

FIGURE 12.57 *Acalolepta cervina* adult. (Courtesy of Larry Bezark.)

In the past two decades, the coffee brown borer has been recognized as a moderate (Loh and Zhang 1988; Kuang et al. 1997; Li et al. 1997; Yu and Kuang 1997) to serious pest (Wei and Yu 1998; Rhainds et al. 2002; Waller et al. 2007; Lan and Wintgens 2012) of Arabica coffee in China and Thailand. The infested trees are seriously weakened with leaves turning yellow and falling off and the trunk and main branches breaking up. In severe cases, trees die. Coffee plants of different ages, ranging from three to seven years, have a similar level of infestation (Rhainds et al. 2002). In southwestern China, this pest is much more prevalent than *Xylotrechus javanicus* (Castelnau & Gory), another coffee pest in Asia (see the following section), although the latter is a more serious pest (Kuang et al. 1997; Rhainds et al. 2002).

The adults emerge between April and October in India (Duffy 1968) and between March and June in China (Kuang et al. 1997; Yu and Kuang 1997). The females cut transverse oviposition slits in the bark of the trunk where they lay their eggs singly during April–June. A female lays 40–60 eggs in her lifetime. The larvae bore into the bark and then the sapwood (Rhainds et al. 2002). Larval tunnels in the trunk usually are spiral upward (Lan and Wintgens 2012). This longicorn has one generation a year and overwinters at the mature larval stage (Loh and Zhang 1988; Waller et al. 2007; Lan and Wintgens 2012).

Lan and Wintgens (2012) summarized several commonly used control measures. Swabbing the trunk with contact insecticides from the base to 1 m aboveground during the oviposition period can reduce egg laying and, during May–July, may kill neonate larvae and prevent them from boring into the trunk. These authors also recommend cultural practices including removing heavily infested trees in August and September, planting shade trees, avoiding moving infested trees to noninfested areas, and proper pruning and fertilizer application. Wei and Kuang (2002) have tested the efficiency of biological control using a fungus, *Beauveria bassiana,* against the pest in both the laboratory and the field. In the field trials, they pushed “fungus mud” containing fungal spores into larval tunnels and achieved more than 90% larval mortality 20 days after application. However, it is not known whether this biological control method can be used successfully on a large scale.

12.7.1.5 *Xylotrechus javanicus* (Castelnau & Gory)

Synonyms: *X. lyratus* Pascoe, *X. quadripes* Chevrolat, *Clytus sappho* Pascoe, *C. javanicus* Castelnau & Gory
Common name: Asian coffee stem borer

The adults of this cerambycine borer are 13–17 mm long and black in color; the head, prothorax, and bands on the elytra are covered with grayish or yellowish pubescence; the pronotal disc has a round, subasperate, medial black spot and a pair of smaller sublateral black spots; the elytra have a basal transverse band, an oblique band on the shoulder, a band beginning immediately behind the scutellum—running close to the suture and then diverging posteriorly and turning outward, a transverse or slightly oblique band behind the middle that gradually widens toward the suture, and an apical band with an oblique front margin (Figure 12.58). *Xylotrechus javanicus* (as *X. quadripes*) was erroneously reported by several authors as occurring in Africa (Venkatesha and Dinesh 2012), but it is only distributed in southern and southeastern Asia—including China, India, Sri Lanka, Bangladesh, Cambodia, Indonesia, Laos, Myanmar, the Philippines, Thailand, and Vietnam (Duffy 1968; CABI 1998). So far, about 20 plant species from Anacardiaceae, Bignoniaceae, Burseraceae, Cannabaceae, Fabaceae, Lamiaceae, Moraceae, Oleaceae, and Rubiaceae have been reported as its hosts with a preference for Arabica coffee trees as hosts (Duffy 1968; Waller et al. 2007; Lan and Wintgens 2012; Venkatesha and Dinesh 2012). This pest's enormous economic importance has triggered massive studies over the past 100 years, particularly in India and China. Venkatesha and Dinesh (2012) provided an excellent review of those studies with more than 100 references cited.

The Asian coffee stem borer is a serious pest of Arabica coffee trees in India, China, Thailand, and Vietnam, causing substantial losses in production (Duffy 1968; Visitpanich 1994; Li et al. 1997; Yu and Kuang 1997; Rhainds et al. 2002; Waller et al. 2007; Lan and Wintgens 2012; Venkatesha and Dinesh 2012). About two months after infestation, an early external symptom may appear—ridges on the surface of the trunk or main branches, each caused by a larva tunneling under the bark. With continued larval tunneling, the damaged tree withers, showing yellowing and wilting symptoms. Severely damaged trees die.

FIGURE 12.58 *Xylotrechus javanicus* adult. (Courtesy of Kwan Han.)

This pest prefers to attack older trees. For example, in southwestern China, five- to seven-year-old plants are 10 times more heavily infested than three- to four-year-old plants (Rhainds et al. 2002).

The emergence period varies in different countries probably because of different climatic conditions (Venkatesha and Dinesh 2012). For example, emergence occurs in April–May and September–December in India; most beetles emerge during May–July and some during February–March and November–December in Vietnam; and three emergence peaks take place in May, October, and December in China. The females lay their eggs singly or in small batches of several eggs in the cracks and crevices of bark on the trunk and main branches. They prefer to lay eggs in bright sunlight. The lifetime fecundity is 50–103 eggs. The larvae bore into the bark and then into the sapwood and heartwood, making tunnels downward with some extending into the roots. About 80% of adults emerge from the trunk and the rest from the roots. In the warm coffee-growing regions, larval development continues all year round, and overwintering occurs at the larval or pupal stage. This pest may have one generation a year in India (Venkatesha and Dinesh 2012) and two or three generations a year in China (Kung 1977; Loh and Zhang 1988; Lan and Wintgens 2012), depending on climate. The borer can be reared successfully in the laboratory using cut trunks and branches of Arabica coffee trees (Gowda et al. 1992) or with an artificial diet (Raphael et al. 2005). It can complete development from eggs to adults in 71–90 days on cut Arabica coffee trunks (Seetharama et al. 2005).

Many tactics have been developed and practiced for the control of this pest (reviewed by Duffy 1968; Waller et al. 2007; Lan and Wintgens 2012; Venkatesha and Dinesh 2012). Venkatesha and Dinesh (2012) listed 33 species of natural enemies that attack *X. javanicus,* of which 29 are parasitic wasps, two are avian predators, and two are fungal pathogens. Although various trials in the laboratory and field using some of these natural enemies demonstrate promising outcomes in terms of killing the borer, there appears to be no large-scale application of any of these agents for the control of the pest. Venkatesha and Dinesh (2012) suggested that because the larvae and pupae are well protected in tunnels, application of their natural enemies may not be highly successful; but further investigation into the application of biological control agents that attack eggs may be useful. A number of field trials using a synthetic male-produced sex pheromone have also been carried out for the control of this pest (Venkatesha and Dinesh 2012). While Hall et al. (2006) and Jayarama et al. (2007) suggested that pheromone traps may be able to contribute to successful control of the female beetles, the application of pheromone traps does not seem to be a viable strategy in China (Rhainds et al. 2001). Further studies on the application of semiochemicals are warranted.

The commonly used control measures (Waller et al. 2007; Lan and Wintgens 2012; Venkatesha and Dinesh 2012) are summarized as follows:

1. *Cultural control:* Before the beginning of adult emergence, scrubbing the scaly bark of the trunk and main branches with a brush, a piece of metal, or with gloves made from thick fabric (to make the bark's surface smooth) can prevent females from laying eggs and can destroy eggs and young larvae. This measure is highly effective but labor-intensive. Examination for the characteristic borer ridges and then removal of the infested parts or uprooting of entire trees can reduce further infestation of healthy trees. The removed trees or branches should be burned. If the uprooted trees are used for firewood, they should be submerged in water for 7–10 days to kill the borers, which can otherwise complete development in the cut trunks and branches. Because the females prefer to lay eggs in bright sunlight, planting appropriate shade trees alongside coffee trees can reduce infestation.
2. *Chemical control:* Swabbing or painting the trunk and main branches with a coal tar distillate, a lime solution, or an insecticide solution before the beginning of adult emergence can reduce oviposition to some extent and kill eggs and young larvae. However, swabbing systemic insecticides on the plants is not effective for the control of larvae that have already bored into the plant tissue.
3. *Resistant cultivars:* A number of attempts have been made to develop cultivars resistant to this borer. For example, a new Arabica cultivar in India, Chandragiri, has good yield potential and a high tolerance to the pest because the drooping branches of these plants cover the entire trunk and act as a barrier against borer attack (Jayarama 2007).

12.7.2 Africa

12.7.2.1 Monochamus leuconotus (Pascoe)

Synonyms: *Phygas fasciatus* Fåhraeus, *Anthores leuconotus* Pascoe
Common name: African coffee stem borer

The lamiine adults are 17–35 mm and dark brown in color, with yellowish-brown patterns; the elytra have an extensive area of white pubescence that forms a very wide band across the subbasal and medial regions and a narrower band in the apical region; these two white bands are connected along the suture (Figure 12.59). This borer occurs throughout Central, South, and East Africa—including Angola, Burundi, Cameroon, Congo, Congo Democratic Republic, Ethiopia, Kenya, Malawi, Mozambique, Namibia, Rwanda, South Africa, Sudan, Tanzania, Uganda, Zambia, and Zimbabwe. To date, it has not established in West Africa or any continents other than Africa (Duffy 1957; CABI 2005a). However, a recent study (Kutywayo et al. 2013) suggests that the areas suitable for *M. leuconotus* infestation will increase significantly in African countries due to climate change. About a dozen woody plant species in Erythroxylaceae and Rubiaceae are listed as its hosts by Duffy (1957), including all coffee species (Rubiaceae), with Arabica coffee being the preferred host (Duffy 1957; CABI 2005a; Rutherford and Phiri 2006).

The African coffee stem borer has been a serious pest of coffee trees in South and East Africa since the 1930s (Duffy 1957; Hill 1975; Hillocks et al. 1999; Waller et al. 2007; Crowe 2012). In southern Africa, yield losses as high as 25% have been reported with more than 80% of coffee farms affected (Rutherford and Phiri 2006). Ringbarking in the trunks by the early instar larvae in the first two to three months after hatch causes severe damage to trees, which become weakened and display yellowing foliage, shoot dieback, and defoliation (Duffy 1957; Waller et al. 2007; Crowe 2012). Other signs include frass-ejection holes, from which frass is extruded. Young trees with small trunk diameters can be killed by these larvae, although infestation of older trees reduces production but rarely kills them. When the larvae become older, they bore into the heartwood, but their damage to trees is not as serious as that caused by younger larvae.

FIGURE 12.59 *Monochamus leuconotus* adult on a coffee tree. (Courtesy of Dumisani Kutywayo.)

Adults usually emerge during November–January with a peak in mid-December, and most oviposition occurs in mid-January (Tapley 1960; Schoeman et al. 1998). The females use their mandibles to make oviposition slits (usually horizontally) in the bark of the lower trunk (usually the lower 50 cm) and deposit eggs singly in these slits (Duffy 1957). According to Schoeman et al. (1998), a female lays an average of 80 eggs during her life span; the larvae bore into the bark and feed on phloem and cambium tissue for three to four months before entering the heartwood, feeding on xylem tissue for about 12 months. The larvae usually bore spirally downward to the roots (Duffy 1957). At warmer, lower altitudes, larvae are found mostly at the base of the trunks and main root systems, while at higher, cooler altitudes and also in heavy shade, more larvae develop well above the ground level (Tapley 1960). The adult beetles usually do not cause significant damage, although shoots and twigs are occasionally ringbarked (Schoeman et al. 1998). The life cycle lasts 12–25 months, with most individuals requiring 16–20 months (Tapley 1960). More recently, Waller et al. (2007) suggested that it takes between 18 and 24 months depending on the latitude and altitude. The larvae appear to continue developing all year round when the temperature is suitable, and overwintering usually occurs at the larval stage.

Although a number of control measures have been developed and practiced over the past century, this pest is still difficult to control (Rutherford and Phiri 2006; Waller et al. 2007). The most effective control method has been the brush or spray application of chemical pesticides to the trunk as a band around the lower 50 cm section and the root collar region. In past years, organochlorides achieved outstanding success in the control of this pest (Tapley 1960; Da Ponte 1965; Crowe 1966; Bigger 1967; McNutt 1967; De Villiers 1970; Schoeman 1991, 1995; Schoeman and Pasques 1993a, 1993b). However, these pesticides are no longer used due to their hazardous effects on the environment and on nontarget organisms and also their risk to the users (Rutherford and Phiri 2006). Alternative pesticides including organophosphates (Schoeman and Pasques 1993; Waller et al. 2007), pyrethroids (Schoeman 1995), phenylpyrazoles, and natural lime solution (Rutherford and Phiri 2006) can also provide effective control. The timing of the applications is extremely important, that is, the insecticides should be applied just before the start of the monsoon rains (Rutherford and Phiri 2006). Schoeman (1990, 1991, 1995) and Rutherford and Phiri (2006) summarized cultural control methods currently practiced. For example, well-maintained coffee trees are less likely to be attacked by this stem borer because it usually attacks weakened or debilitated plants. Planting resistant species or cultivars may suppress the pest population to some extent. Destruction of heavily infested plants (uprooting) before the onset of rains, and hence before the adults emerge, can reduce further infestation. Although labor-intensive, the removal of loose bark at the base of trees and wrapping tree trunks with banana fiber reduce oviposition and thus infestation. Jonsson et al. (2015) suggested that lowering coffee tree density and removing shade trees in or around the orchards can reduce damage because this pest avoids sun-explored trees. Several wasp species parasitizing *M. leuconotus* (including an egg parasitoid, *Aprostocetus* sp.) may contribute to high mortality rates for this pest in the field (Tapley 1960). Although there is no report on the commercial use of these parasitoids for pest control, further investigations into their potential and application may be warranted. Massive application of chemical pesticides could be one of the reasons why these natural enemies do not control the pest (Rutherford and Phiri 2006). Preliminary testing of the fungus *Beauvaria bassiana* for biological control has been investigated in South Africa with some promising results (Schoeman and Schoeman 1997). However, no commercial biological control products appear to be available (Rutherford and Phiri 2006).

12.7.2.2 Bixadus sierricola (White)

Synonym: *Monochamus sierricola* White
Common name: West African coffee borer

The lamiine beetle is 20–30 mm long, chestnut brown in color, and covered with grayish white pubescence; the elytra have a more or less V-shaped brown mark near the middle. It occurs throughout Western and Central Africa, including Angola, Benin, Cameroon, Central African Republic, Ivory Coast, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Nigeria, the Republic of the Congo, Sierra Leone, and Uganda (Duffy 1957; CABI 2005b; Waller et al. 2007). To date, it has not become established on any other continents. Duffy (1957) listed all coffee species and two other plant species as the hosts of *B. sierricola* but mentioned that some earlier authors have suggested that this longicorn beetle could be polyphagous.

The West African coffee borer is a moderate to serious pest of coffee trees in West and Central Africa (Padi and Adu-Acheampong 2001; Crowe 2012) depending on latitude and altitude. In Uganda, up to 80% of trees can be infested by this pest (Padi and Adu-Acheampong 2001). *B. sierricola* attacks all commercially grown coffee species (Crowe 2012). However, there is still controversy as to which coffee species is preferred as a host by this pest. For example, Fonseca Ferrão (1965) reported that it prefers to attack Robusta coffee, although Waller et al. (2007) suggested that Arabica coffee suffers the most damage. Ringbarking in the trunks by early instar larvae during the first two to four weeks after hatch causes serious damage to coffee trees, leading to loss of branches in older trees and the death of young trees (Duffy 1957; Fonseca Ferrão 1965; Waller et al. 2007). Although older trees often survive attacks, they are frequently broken by wind or attacked by secondary pests such as termites or by fungal diseases (Padi and Adu-Acheampong 2001; Waller et al. 2007). According to Waller et al. (2007), this pest prefers to attack trees four to five years old. Following ringbarking, the older larvae bore into the heartwood, producing large amounts of frass that drops at the base of the tree. Borer holes occur exclusively on the trunk up to 3 m from the ground level (Padi and Adu-Acheampong 2001).

This species has one or two generations a year depending on latitude and altitude (Duffy 1957; Fonseca Ferrão 1965). For the beetles with two generations a year, most adults of the first generation emerge between late August and early September, and most adults of the second generation emerge between late January and early February. For those with only one generation a year, the adults emerge in greatest numbers at the beginning of the long rains (Fonseca Ferrão 1965). The adults are active at dusk, searching for mates and laying eggs, and can live for two to three weeks. The eggs are laid singly in crevices or wounds in the bark of the trunk, usually 15–20 cm above the root collar. One female can lay 50–60 eggs in her life span. The larvae bore into the bark and ring it for a few weeks before entering the heartwood. They tunnel downward in the trunk through the root collar to the level of the second bundle of secondary roots. The larvae appear to continue developing all year round, and overwintering usually occurs at the larval stage.

Crowe (2012) suggested that the chemical control measures used for *M. leuconotus* can also be effective for the control of *B. sierricola* but does not give any details. Several cultural control measures are summarized by Duffy (1957) and Waller et al. (2007): (1) uproot and burn infested trees, (2) keep the base of the tree free of lichen and other covers to facilitate early detection of the pest, and (3) separate the coffee trees from the edge of the forest with a 30 m belt of food crops. The use of light traps is also suggested for catching adults but their practicality and effectiveness are not known. Two parasitoid species, one wasp (*Gabunia ruficoxis* Kriechbaumer) and one fly (*Phorostoma* sp.), were reported in earlier references (cited by Duffy 1957) as attacking the pest, but information about their usefulness in the control of this species is unknown. In the 1960s, the same organochlorides used to control *M. leuconotus* were used to paint lower sections of trunk (up to 50 cm) and the root collar region during adult emergence peaks; they provided excellent control for six months (Fonseca Ferrão 1965). More recently, an aluminum phosphide paste has been tested for its effectiveness in the control of *B. sierricola* larvae (Padi and Adu-Acheampong 2001). The paste is squeezed into fresh borer holes, and then those holes are sealed off with plasticine. Results show 100% larval mortality within 15 days after treatment, with no subsequent reinfestation by the beetle recorded within nine months.

12.7.2.3 Nitakeris nigricornis (Olivier)

Synonym: *Dirphya nigricornis* Olivier
Common name: Yellow-headed borer

This species was called *Dirphya nigricornis* Olivier until the recent revisional work by Teocchi et al. (2014). The adults of this lamiine borer are slender, 20–31 mm long, and yellowish to orange brown in color; the antennae, eyes, at least three-quarters of the elytra (from the basal one-quarter to the apex), and the tibiae and tarsi are dark brown to black (Figure 12.60). The yellow-headed borer is distributed only in eastern and southern Africa including Kenya, Mozambique, South Africa, Tanzania, and Malawi

FIGURE 12.60 *Nitakeris nigricornis* adult. (Courtesy of Larry Bezark.)

(Rutherford and Phiri 2006; Waller et al. 2007). Earlier, this species was recorded in both East and West Africa (Duffy 1957). However, more recent studies show that the borer in West Africa is *Neonitocris princeps* (Jordan) rather than *N. nigricornis* (Waller et al. 2007). *N. princeps* is a very minor pest of coffee trees and thus is not treated further in this chapter. The yellow-headed borer only attacks plants in Rubiaceae, including *Rytigynia schumanii* in Tanzania and *Vangueria rotundata* in Kenya in addition to *Coffea* spp. in many African countries (Duffy 1957; Waller et al. 2007). However, *D. nigricornis* prefers Arabica coffee as a host (Crowe 1963, 2012; Rutherford and Phiri 2006; Waller et al. 2007).

The larvae of this species cause minor to moderate damage to Arabica coffee in eastern Africa (Crowe 2012). However, serious damage to coffee plantations has been recorded in Kenya and in northern Malawi (Crowe 1963; Wanjala 1988; Wanjala and Khaemba 1988; Rutherford and Phiri 2006; Waller et al. 2007). The oviposition activity at the tips of the fruiting branches can be destructive, causing them to wilt and die. The larvae bore inward into the branches and then downward to the trunk and main roots. On the way downward, the larvae leave a series of flute-like holes along the branches and down the side of the trunk, where sawdust-like frass is ejected. Affected branches are weakened and may break under the weight of developing coffee berries; green shoots may wilt and die.

Adults may be collected almost all year round, with two emergence peaks—one in April–May and another in November–December (Crowe 1963). The females gnaw oviposition slits in the bark with their mandibles and lay their eggs singly inside the slits, mainly on the green distal and immature internodes, with the tertiary or primary shoots being preferred (Wanjala 1990). Each female can lay 20–30 eggs in her lifetime (Wanjala 1988). The larvae enter the wood, tunnel toward the trunk, and may eventually reach the main roots. This pest prefers weakened trees to healthy ones for oviposition, and the larval development can be completed in dead wood (Crowe 1963). The life cycle lasts one year (Wanjala 1988; Crowe 2012) to 20 months (Wanjala 1988), depending on local climates. The borer continues to develop all year around and overwinters at the larval stage.

Cultural control appears to be the most effective measure for the control of this pest. At the first signs of infestation (branch tip wilting and flute holes at the top of the branches), the affected branches should be removed and destroyed before the larvae reach the trunk (Crowe 1963, 2012; Rutherford and Phiri 2006; Waller et al. 2007). According to Crowe (2012), reinfestations only occur in areas where there are numerous shrubs of the coffee family Rubiaceae growing near coffee plantations, and a campaign to eradicate these shrubs may be necessary if the pest is particularly troublesome. Piercing the larvae with wire is also suggested (Crowe 1963). Wanjala (1988) listed 12 species of parasitoids and predators that attack this pest, but the role these natural enemies may play in its control is not known. If the larvae reach the trunk, chemical control may be undertaken. For example, the lowest frass-ejection holes can be enlarged using a knife, and then a persistent insecticide can be injected with an oil can or other suitable applicator (Waller et al. 2007; Crowe 2012).

12.7.3 South America

12.7.3.1 Steirastoma breve (Sulzer)

Synonyms: *S. depressum* Hart, *Cerambyx depressus* Fabricius, *C. brevis* Sulzer
Common name: Cacao longicorn beetle

The lamiine adults are 12–30 mm long and stout; the body is reddish or blackish brown and covered with grayish pubescence; the pronotum has three longitudinal, raised ridges on the disc and five short, blunt tubercles at each side; each elytron has a longitudinal carina from the base to near the apex (Figure 12.61). The longicorn is widely distributed in Latin America from the West Indies and Guatemala to Argentina. Its larvae feed on about 25 tree species in Arecaceae, Bombacaceae, Cecropiaceae, Fabaceae, Lecythidaceae, Malvaceae, Myrtaceae, Salicaceae, and Sterculiaceae, with a preference for Malvaceae—the species to which cacao (*Theobroma cacao* L.) belongs (Duffy 1960; Monné 2001b, 2005b).

The cacao longicorn beetle has been recorded as the most serious cerambycid pest of cacao trees in the New World since the nineteenth century (Guppy 1911; Duffy 1960; Entwistle 1972; Sánchez and

FIGURE 12.61 *Steirastoma breve* adult. (Courtesy of Juan Pablo Botero [image from Marcela L. Monné].)

Capriles 1979; Mendes and Garcia 1984; Liendo-Barandiaran et al. 2010). The adults feed on the thin bark and underlying soft tissues of young branches, leaving scarring that can be readily seen. However, the main damage is caused by larval tunneling in the branches and trunks. The larvae feed subcortically, making irregular spiral-like galleries and resulting in a ringed branch or trunk. Depending on the age and location of the damage, these events can kill the apical area. If the trunk is attacked, the entire plant can be killed. The larvae eject frass from oval holes. In dry weather, the ejected frass, together with gummy, gelatinous sap from the wound, can be found attached to the bark of trunks and branches, but this may be washed away by rain. When the larvae bore into the heartwood, they weaken the branches and trunks, making them liable to break off in windy conditions.

The life history is summarized from Guppy (1911), Duffy (1960), Mendes and García (1984), Kliejunas et al. (2001), and Liendo-Barandiaran et al. (2005, 2010). The adults are present all year round. The females make oviposition slits with their mandibles in the bark around the preferred root collar or lower trunk of the host trees and then lay their eggs singly in the slits. The lifetime fecundity in the field is unknown. The larvae bore into the bark and feed subcortically most of the time and then enter the wood. The adults are attracted to semiochemicals released from males and cacao trees. The number of generations this borer has depends on the local climate. For example, the species has one generation a year in southern Brazil but up to four generations a year in the tropical areas of northern Brazil. Overwintering, if any, takes place at the larval stage.

Preventative cultural control probably still is the most effective measure for this pest (Guppy 1911; Duffy 1960; Entwistle 1972). Traps composed of fresh branches (3–12 cm in diameter and 90–120 cm long) of *Pachira aquatica* Aublet, one of the borer's preferred hosts, are hung on cacao tree branches 150–250 cm above the ground to attract adults to lay eggs. The attracted adults can then be collected and destroyed. The traps should be replaced with newly cut branches every 2–3 weeks in the rainy season and every 10–12 days in the dry season. The used trap branches should be burned. Larvae found underneath tree bark can be cut out with a knife or killed with a piece of wire. Because unshaded plants are preferred for oviposition, adequate shade cover is important. Several parasitoid and predator species reportedly attack the cacao longicorn (reviewed by Duffy 1960), but their application for pest control has not been practiced in commercial cacao orchards. At present, it is not known whether the semiochemicals associated with this species can be used to control adults. Chemical control has achieved good results (Garcia et al. 1985). For example, endosulfan had been sprayed onto trunks and branches but that organochlorine insecticide is now banned. However, because the adults are active all year round in tropical regions, chemical sprays may provide only limited control.

12.7.3.2 Plagiohammus maculosus (Bates)

Synonym: *Hammoderus maculosus* Bates
Common name: Speckled coffee stem and root borer

The lamiine adults are 25–34 long; the body is reddish to blackish brown and covered with yellowish-green pubescence; the pronotal disc has a wide, longitudinal, yellowish-white stripe at each side; each elytron has six regular yellowish-white maculae that may be divided into eight or more smaller spots (Figure 12.62). The longicorn occurs from Mexico to Nicaragua (Monné 2005b) and feeds on Arabica coffee trees in Mexico, Guatemala, El Salvador, and Honduras (Barrera et al. 2004; Avila 2005; Barrera 2008).

The speckled coffee stem and root borer has been a moderate coffee pest since 1935 in Guatemala, with the infestation levels ranging between 5% and 25%. In Mexico, 34.8% of 23 sampled highland coffee plantations were infested, with levels ranging from 0.8% to 24.5%. Producers consider this borer one of the most important pests of coffee trees in Mexico (Constantino et al. 2014). According to Barrera (2008), the damage is caused by larval tunneling in the trunk and main roots. Borer attack reduces plant growth and eventually causes death either directly by root damage or indirectly by facilitating trunk breakage by wind. White to yellowish sawdust-like frass is present at the base of the infested coffee plants, which may become wilted, yellow, and decayed. The abundance of this longicorn is greater in high-altitude coffee plantations (>1,000 m above the sea level) and in places with long summers or low rainfall. Abandoned coffee plantations are more severely impacted.

FIGURE 12.62 *Plagiohammus maculosus* adult. (Courtesy of José Rafael Esteban [image from Luis M. Constantino].)

Barrera (2008) summarized the general biology of the coffee pests *P. maculosus, P. spinipennis*, and *P. mexicanus*. The adults are more visible at the beginning of the rainy season (April–June), which is the period when egg laying occurs. The females lay their eggs on the bark of the coffee trunks between the ground and 30 cm above. The lifetime fecundity is unknown. The larvae penetrate the trunk and bore all the way down to the roots. Pupation occurs in a chamber in the trunk near the ground where an adult exit opening is made. The larval period lasts from two to three years. Overwintering occurs at the larval and pupal stages.

Control measures (Espinosa 2000; Barrera 2008) are summarized as follows. The coffee plants with frass at the base of their trunks should be located. If damage is recent (the frass is white or pale yellow), the infested trunks should be removed. Weeds should be managed by shading, mulching, ground cover, and mechanical removal. In places where the pest appears yearly, a preventive insecticide applied with a brush or manual pump is recommended, treating from the trunk base up to 60 cm. The application may be repeated once or twice every 20 days. In order to kill the larvae within the trunk, a cotton ball soaked in an insecticide can be inserted through the respiration and excretion openings made by the larvae, or an insecticide solution can be injected into the openings with a syringe. With this manner of treatment, the orifice is enlarged, the insecticide applied, and the orifice sealed with mud or clay.

12.7.3.3 Plagiohammus spinipennis (Thomson)

Synonyms: *Hammoderus spinipennis* Thomson, *Hammatoderus jacoby-i* Nonfried
Common name: Lantana stem and root borer

This species is similar to *P. maculosus* but differs in that each elytron has three to four white maculae (Constantino et al. 2014) (Figure 12.63). It is distributed from Mexico to Panama and southward

FIGURE 12.63 *Plagiohammus spinipennis* adult. (Courtesy of José Rafael Esteban [image from Luis M. Constantino].)

to Colombia, Venezuela, and Peru (Monné 2005b; Esteban-Durán et al. 2010; Constantino et al. 2014). The larvae feed on several plant species from Asteraceae, Lamiaceae, Rubiaceae, and Verbenaceae (Maes et al. 1994; Arguedas and Chaverri 1997; Barrera 2008). Because some of its preferred hosts, *Lantana* spp. (Verbenaceae), have become important weeds in Hawaii and Australia, this longicorn has been introduced to these two areas as a biological control agent for weed control (Harley 1969, 1973).

The lantana stem and root borer is a minor to moderate pest of coffee trees in the highland coffee growing region (≥1,000 m above sea level) of the Mexican Pacific Coast (Barrera et al. 2004; Barrera 2008). The damage symptoms, biology, and control measures are similar to those of *P. maculosus*. When attacking *Lantana*, the larvae girdle the trunks, causing a swollen area to form, and then bore downward into the trunks and roots, killing the plants. In *Tectona grandis* L.f., the larvae feed on the phloem, resulting in trunk bulges at the point of attack and giving rise to new buds below that point (Arguedas and Chaverri 1997).

12.7.3.4 *Plagiohammus mexicanus* Breuning

Common name: Mexican coffee stem and root borer

The adult body is about 25–30 mm long and blackish brown in color; the elytra have very dense white dots throughout. This longicorn is only recorded in Mexico (Monné 2005b; Barrera 2008). The preferred host is Arabica coffee (Barrera 2008).

The Mexican coffee stem and root borer is a minor pest of coffee trees in the highland coffee growing region (≥1,000 m above sea level) of the Mexican Pacific Coast (Barrera et al. 2004; Barrera 2008). The damage symptoms, biology, and control measures are similar to those of *P. maculosus* (Barrera 2008).

12.7.3.5 Plagiohammus colombiensis Constantino, Benavides, and Esteban

Common name: Colombian coffee stem and root borer

Adults are 25–26 mm long and grayish brown in color; the pronotal disc has dense golden yellow pubescence except for two longitudinal light brown lines; each elytron has six large golden yellow spots and 50–55 small and very small golden yellow spots scattered over the surface (Figure 12.64). It occurs in Colombia and attacks Arabica coffee (Constantino et al. 2014). The primary host plant of *P. colombiensis* is presumed to be a native forest species because the main borer attacks have occurred in Colombia in the coffee plantations that used to be forests. The destruction and removal of native forest species may be the main cause of adaptation of this borer to coffee plantations (Constantino et al. 2014).

According to Constantino et al. (2014) and Constantino and Benavides (2015), the Colombian coffee stem and root borer is an important pest of coffee plantations in that country. The adults emerge in May and lay their eggs on the bark of the trunk near the base. The lifetime fecundity is not known. The larva (Figure 12.65) bores into the central portion of the trunk and tunnels down toward the main roots (Figure 12.66). Affected trees are recognized by piles of white sawdust-like frass that have accumulated at the base of the trunk. When the larvae reach the main roots, they tunnel upward to a height of about 10–30 cm above the soil where pupation takes place in a chamber. The life cycle takes 18 months from egg to adult. The adults are nocturnal.

Constantino and Benavides (2015) recommended the following measures for the control of this pest: (1) inspection of trees—looking for sawdust at the base of the trunks; (2) removal of dead, withered, or unproductive trees with adult emergence holes (Figure 12.67), including stumps; (3) injection of organophosphorus or pyrethroid insecticide solutions into the base of infested but not dying trees through the larval holes, which are then immediately sealed with clay, mud, or wax.

FIGURE 12.64 *Plagiohammus colombiensis* adult. (Courtesy of Luis M. Constantino.)

FIGURE 12.65 *Plagiohammus colombiensis* larva. (Courtesy of Luis M. Constantino.)

FIGURE 12.66 Gallery made by a *Plagiohammus colombiensis* larva in a trunk. (Courtesy of Luis M. Constantino.)

FIGURE 12.67 *Plagiohammus colombiensis* adult emergence hole. (Courtesy of Luis M. Constantino.)

12.8 Cerambycid Pests in Vine Crops

In general, the term vine refers to any plant with a growth habit of trailing and climbing stems or runners. Many vine species currently are grown as crops in gardens and commercial farms or orchards around the world for fresh fruit, vegetables, and wine making. There is little information on cerambycid pests in kiwifruit and legume vines. Therefore, vine crops in this chapter refer to grape and cucurbit vines where cerambycid stem borers are recorded as pests.

A number of cerambycid species use these plants as hosts, and some may be pests. For example, about seven species are recorded as attacking grapevines (Mani et al. 2014). Most species listed currently are not considered economically important, such as *Chlorophorus varius* Müller in North Africa (El-Minshawy 1976), while some species not listed have become highly important pests of grapevines such as *Xylotrechus arvicola* (Olivier) in European vineyards. Some cerambycid species that also attack grapevines are considered more important pests of other crops, such as *Oemona hirta* in citrus and *Sthenias grisator* in mulberry trees, both of which are discussed in the earlier sections on citrus and mulberry crops, respectively. A South American species, *Adetus analis* (Haldeman), that was recorded as a minor pest of chayote vine (*Sechium edule*) in Brazil (Pigatti et al. 1979; de Souza Filho et al. 2001) is not significant enough to be treated in this chapter. In this section, five species are considered economic pests of vine crops throughout the world.

12.8.1 Asia

12.8.1.1 Xylotrechus pyrrhoderus Bates

Common name: Grape tiger longicorn

The cerambycine adults are 9–14 mm long; the prothorax is dark brown to orange, the elytra are black with thick yellowish to whitish bands on the basal and subapical areas; the basal band is connected

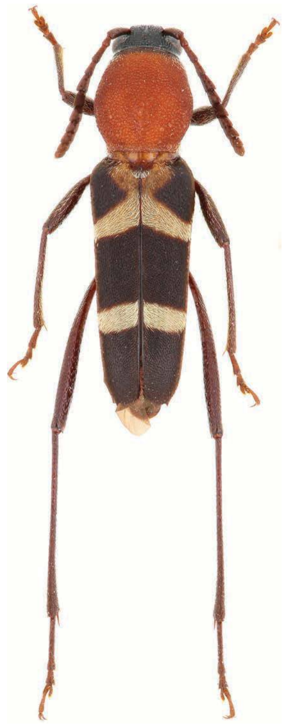

FIGURE 12.68 *Xylotrechus pyrrhoderus* adult. (Courtesy of Junsuke Yamasako.)

by a sharp angle with the subbasal band along the elytral suture; the subapical area has a transverse whitish pubescent band (Figure 12.68). This longicorn is distributed in East Asia including Japan, Korea, and China (Hua 2002; Han and Lyu 2010). To date, there is no record of its occurrence in other regions. The main host plants are from the family Vitaceae, including *Vitis vinifera* L. and *Ampelopsis brevipedunculata* (Maxim.) (Han and Lyu 2010).

The grape tiger longicorn is considered a moderate to serious pest of grapevines in Japan (Matsumoto 1920; Ashihara 1982; Sakai et al. 1982; Kiyota et al. 2009), Korea (Kim et al. 1991), and China (Miao 1994; Guo 1999; Li 2001; Huang and Yang 2002). The newly hatched larvae bore into the young stems and bud base and make tunnels transversely inside. Frass is packed in the tunnels and not ejected, making detection of larvae difficult. The infested areas turn dark or black late in the season. The infested stems may become wilted and easily broken by wind after the larvae enter the heartwood. In some Chinese vineyards, between 20% and 90% of grape plants are infested by this pest, depending on management level and plant age, with older and poorly managed plants suffering more severe damage than well-managed and younger plants (Huang and Yang 2002). However, according to Kim et al. (1991), the injury level caused by the larvae is higher in vigorous shoots than in weak ones. Most larval damage occurs during May–June. The adults feed on young shoots, buds, and leaves, but their damage is not significant (Guo 1999).

Adult emergence occurs between July and October, with a peak in August (Matsumoto 1920; Ashihara 1982; Kim et al. 1991; Huang and Yang 2002). The adults live for 7–40 days and, between August and early November, lay eggs on the buds and on the young shoots that are 8–10 mm in diameter. Each female lays 17–90 eggs in her lifetime; these hatch in a week or two depending on temperature. The larvae stop developing when they reach about 4 mm in length (usually in late November) and then overwinter. The larvae become active again in the spring. Pupation occurs in the stems during July–August, and the pupal stage lasts 10–14 days; the newly eclosed adults remain in the pupal cells for 9–12 days before chewing an exit hole and emerging. The life cycle lasts one year.

The most common management measures for this pest are cultural and chemical control (Kim et al. 1991; Miao 1994; Guo 1999; Huang and Yang 2002). The main cultural control method is pruning infested branches/stems after the harvest season and burning pruned materials before June. Buds are carefully examined in summer, and any larvae found are killed using a knife. Spraying insecticides during August–October can be effective in killing adults and newly hatched larvae. In addition, a parasitoid wasp, *Odontobracon bicolor* Ashmead, has been identified as one of the natural enemies of *X. pyrrhoderus*, and its emergence period is from late July to mid-August, which is earlier than that of the grape tiger longicorn (Kim et al. 1991). However, the effectiveness of this parasitoid in the control of the grape tiger longicorn is unknown.

12.8.1.2 Celosterna scabrator (Fabricius)

Synonyms: *C. scabrator griseator* Aurivillius, *Aristobia murina* Nonfried, *Psaromaia renei* Pascoe, *Lamia gladiator* Fabricius, *L. spinator* Fabricius, *L. scabrator* Fabricius
Common name: Grape stem borer

The adult of this lamiine borer is 30–40 mm long and dull, yellowish brown in color; the sides of the body and legs are bluish; the elytra are yellowish gray with a large number of black spots varying in size from pinheads to minute specks (Figure 12.69). This south Asian species occurs in India, Pakistan, Sri Lanka, and Nepal (Beeson, 1941; Duffy 1968). It has been introduced into Madagascar and Réunion. The borer attacks a wide range of host plants, including genera *Eucalyptus, Acacia, Cassia, Casuarina, Pithecellobium, Prosopis, Tectona, Shorea, Pyrus, Mangifera, Zizyphus* (Beeson 1931, 1941; Chatterjee and Singh 1968; Duffy 1968), and *Vitis* (Upasani and Phadnis 1968).

This species has been recognized as a pest of forest trees; the eggs are laid on young living plants, and the larvae bore into the trunks and the roots, which are hollowed out. The infested tree stops growing and frequently dies (Beeson 1931, 1941; Chatterjee and Singh 1968; Duffy 1968). This borer generally attacks living trees, but its larvae can develop inside cut and stacked timber. The larval stage lasts about

FIGURE 12.69 *Celosterna scabrator* adult. (Courtesy of Larry Bezark.)

nine months. According to Chatterjee and Singh (1968), the adults feed on the bark of young eucalypt trees, causing death or breakage of the shoots, lay eggs under the bark of one- to four-year-old trees, and the larvae tunnel downward in the pith to the roots, causing cessation of growth or death. This species is also reported to attack citrus, apple, and mango trees, but its significance for these tree crops is not known (Mani et al. 2014).

Since the late 1960s, this borer has become a moderate to serious pest of grapevines in India (Upasani and Phadnis 1968; Azam 1979; Ranga Rao et al. 1979; Jagginavar et al. 2006, Mani et al. 2014). For example, up to 30% damage was reported in a vineyard in Karnataka, India (Jagginavar et al. 2006). The larvae bore into the vines, tunneling upward and downward until maturation and pupation. The damage caused by this borer to grapevines comprises holes in the main stem and branches, discoloration, withering and premature leaf drop, shriveling of the grape clusters before maturity, and injuries to the vascular bundles, eventually resulting in the withering of the vines above the site of attack (Upasani and Phadnis 1968; Mani et al. 2014). Previously, the borer was considered problematic only in old and neglected vineyards but, in recent years, severe damage has also occurred in one-year-old vineyards (Mani et al. 2014). The adults may also cause some damage to the tender shoots by scraping. Extrusion of frass from holes on the trunk and branches is a common sign with sawdust-like frass on the ground. Gummosis (oozing of a resinous substance from the hole) is also observed on damaged areas.

The adults emerge from early July to late October, with a peak between mid-July and late August (Beeson 1931, 1941). According to Mani et al. (2014), the females make slits on the bark of trunks and branches of vines, lay their eggs singly in the slits, and cover them with a gummy substance. The eggs hatch in 10 days. A female can lay 12–15 eggs in her lifetime, but this fecundity could be underestimated. The larval period lasts six to eight months and overwintering takes place during the larval stage. The mature larvae remain in the vine until May when pupation occurs. The pupal period is 25–35 days, and adults live for 20–25 days. A complete life cycle lasts from 10 months (Mani et al. 2014) to 1 year (Beeson 1941).

Chemical control is by far the most commonly used measure for the management of this pest (Azam 1979; Ranga Rao et al. 1979; Gandhale et al. 1983; Chandrasekaran et al. 1990; Jagginavar et al. 2008). Spraying insecticides on the crops during July–August can be effective in the control of adults (Azam 1979; Ranga Rao et al. 1979). The application of insecticides by immersing one or two roots per plant can control larvae (Chandrasekaran et al. 1990). Furthermore, Jagginavar et al. (2008) reported that injection of insecticides into stems results in more than 90% larval mortality. During August–September, the trunks and branches should be carefully examined, and the eggs and young larvae in the oviposition slits in the bark can be mechanically removed using a knife. This cultural measure can be used to effectively control this pest (Azam 1979; Ranga Rao et al. 1979).

12.8.1.3 Apomecyna saltator (Fabricius)

Synonyms: *A. subuniformis* Pic, *A. excavaticeps* Pic, *A. multinotata* Pic, *A. niveosparsa tonkinea* Pic, *A. pertigera* Thomson, *A. neglecta* Pascoe, *Lamia saltator* Fabricius
Common name: Cucurbit vine borer

The lamiine beetle is 10–12 mm long and slate-gray in color, with several white spots arranged in three evenly shaped “V” markings across the elytra (Figure 12.70). It is widely distributed in tropical and subtropical China (Qian 1985; Li et al. 1997), India, Bangladesh, and Sri Lanka (Duffy 1968). This species also occurs in Hawaii (Tavakilian and Chevillotte 2013), where it probably was introduced. The borer attacks a range of species in the family Cucurbitaceae (Khan 2012). The record of this species in Australia (May 1946) is likely another *Apomecyna* species, *A. histrio* (F.), which also infests cucurbits but is not considered an economic pest.

The cucurbit vine borer is a minor to moderate pest infesting vines of gourds, cucumbers, pumpkins, squashes, and watermelons in China (Qian 1985; Li et al. 1997) and India (Shah and Vora 1973, 1974; Samalo 1985; Sontakke and Satpathy 1993; Singh et al. 2008; Khan 2012). According to Singh et al. (2008), neonate larvae bore into the vines at the nodal joints and damage nodal regions; late instars enter the main vines, causing swelling and oozing of sap. The tunnels in the stems are filled with glutinous waste material. Young plants die due to severe infestation.

FIGURE 12.70 *Apomecyna saltator* adult. (Courtesy of Larry Bezark.)

The adults emerge two to three times in a year, depending on climate. The females make oviposition slits on the internodes into which they lay eggs (Shah and Vora 1974; Sontakke 2002). A female lays 38–52 eggs in her lifetime. The eggs are laid singly and hatch in five to eight days. There are six distinct larval instars with a total larval period of 31–42 days. The pupal period is 8–10 days with 2–3 days as prepupae. The adults live for 35–44 days. The total life cycle of this pest ranges from 80–98 days (Shah and Vora 1974) to 85–107 days (Sontakke 2002). Overwintering occurs during the larval stage. There are two to three generations a year.

Chemical control measures have been evaluated in India. For example, insecticide sprays can effectively control this pest (Samalo 1985; Sontakke and Satpathy1993), but granular or dust insecticides applied to the soil can only achieve 60–76% control (Samalo 1985). Singh et al. (2008) tested the potential resistance of various pointed gourd cultivars against the pest but found that none of them is sufficiently resistant. Both Samalo (1985) and Qian (1985) recommended that seedlings be carefully examined, infested stems removed, and postharvest residues destroyed.

12.8.2 Australasia

12.8.2.1 Acalolepta mixta (Hope)

Synonyms: *A. vastator* (Newman), *Monohammus vastator* Newman, *M. mixtus* Hope
Common name: Passion vine longicorn

The adults of this lamiine longicorn are about 30 mm long and speckled gray-brown; the prothorax has a prominent spine on each side, and the antennae are about twice as long as the body (Figure 12.71). It is widely distributed in mainland Australia, Lord Howe Island, Samoa (Duffy 1963; Slipinski and Escalona 2013), and Solomon Islands (Vitali and Casadio 2007; Chin and Brown 2008). A previous distributional record in the Philippines (Duffy 1963) is questionable. This borer has a wide range of host plants, including the genera *Mangifera* (mango) (Smith 1996), *Citrus* (Smith et al. 1997), *Agathis, Araucaria,*

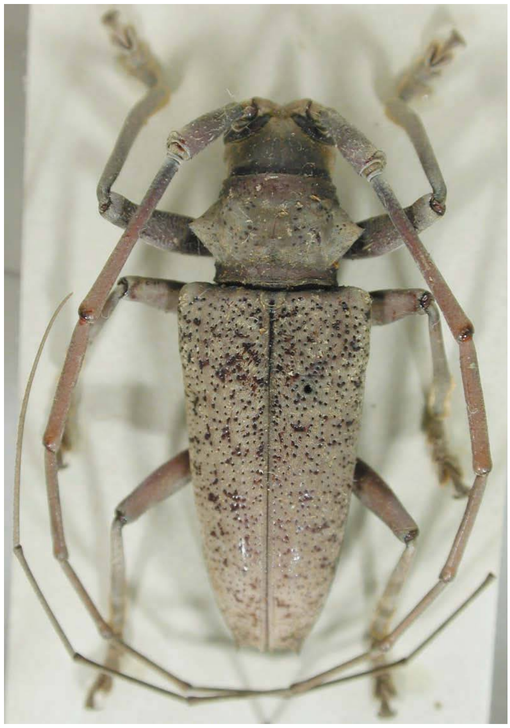

FIGURE 12.71 *Acalolepta mixta* adult. (Courtesy of Larry Bezark.)

Cassinia, Cymbidium, Diospyros, Ficus (fig)*, Flindersia, Laportea, Ozothamnus, Passiflora* (passion vine), *Pinus, Vitis* (grapevine)*, Toona,* and *Wisteria* with preferred hosts being fig trees, passion vines, and grapevines (Slipinski and Escalona 2013).

Acalolepta mixta is a serious pest of grapevines in southeastern Australia (Dunn and Zurbo 2014), infesting up to 70% of vines in some vineyards in New South Wales (Goodwin et al. 1994). It is also considered an important pest of fig trees and passion vines (Duffy 1963) and a minor pest of mango (Smith 1996) and citrus trees (Smith et al. 1997) in Australia. In vineyards (Dunn and Zurbo 2014), the larvae bore into the vine wood and tunnel throughout the trunk and into the roots. Sawdust-like frass is often visible in tunnels and around the infested vine trunk. Extensive damage to the vine trunk can lead to dieback and significant crop losses. Damage symptoms in passion vines are similar to those of grapevines (Duffy 1963). In the case of fig trees, the larvae penetrate the bark and then the sapwood; circular pieces of the bark die and fall out, leaving round pits and exposing the sapwood (Duffy 1963).

Goodwin and Pettit (1994) provided a detailed description of the life history of this pest in vineyards. The adults emerge between October and March with an emergence peak in January–February and an oviposition peak in January–March. The adults can live for up to six months. The females prefer to lay their eggs singly on the vine trunks and the base of young vine canes on the main or secondary arms. On average, a female lays 2.25 eggs per vine but only 0.8 larvae per vine survive to maturation. However, the total number of eggs a female can lay in her lifetime is unknown. The larvae develop under the surface of the bark during the first four instars and then bore into the wood in the later five instars. About 75% of mature larvae occur in the trunks, with more than 60% of all larvae completing their development in the area proximal to the fork in the grapevine. They complete their development in about 38 weeks. The pupal developmental period is about 20 days. The winter is passed during the mature larval and pupal stages. This borer has one generation a year. The adults can disperse up to 150 m by flight and by walking along the vine rows (rather than randomly) in the vineyards (Goodwin et al. 1994).

No parasites or predators have been recorded for this pest, but *Beauvaria bassiana* infects a small number of larvae during wet conditions in the field (Goodwin and Pettit 1994). Several control measures used on fig trees and passion vines are summarized by Duffy (1963). For example, the infested branches are cut off and burned, infested or loose bark is scraped away and the surface painted with bluestone paint or a lime/sulphur wash, and when necessary, chemical pesticides are injected into the vines. In vineyards, careful pruning and destruction of the infested vines may remove many larvae, but retraining of vines may be necessary following the pruning of those vines with serious infestations (Dunn and Zurbo 2014). Seasonal spraying in vineyards of organophosphate insecticides at two- to four-week intervals to control adults and young larvae is also widely practiced, but insecticide residues detected in grapes and wines are a concern (Goodwin and Ahmad 1998). Furthermore, the immediate reduction in the pest population made by a seasonal spraying scheme is followed by pest resurgence (Goodwin 2005a). To reduce the number of sprays and increase control effectiveness, Goodwin (2005b) recommended a single application of insecticide at dormancy. Two insecticides, fipronil (a phenylpyrazole) and bifenthrin (a pyrethroid) are registered for this purpose.

12.8.3 Europe

12.8.3.1 Xylotrechus arvicola (Olivier)

Synonyms: *Clytus heydeni* Stierlin, *C. arvicola* (Olivier), and *Callidium arvicola* Olivier
Common name: European grapevine borer

The adults of this cerambycine borer are 8–20 mm long and reddish brown to dark brown in color; the antennae and legs are reddish yellow, and the forehead bears distinct yellowish pubescence; the pronotum has yellow frontal and basal angles; the elytra are reddish brown with yellow transverse stripes (Figure 12.72). It is widely distributed in the Holomediterranean region including Europe, North Africa, and West and Central Asia (Bense 1995; Ocete et al. 2002b; Tavakilian and Chevillotte 2013; Ilic and Curcic 2013). This species is polyphagous, with its larvae feeding on at least 15 broadleaf plant genera

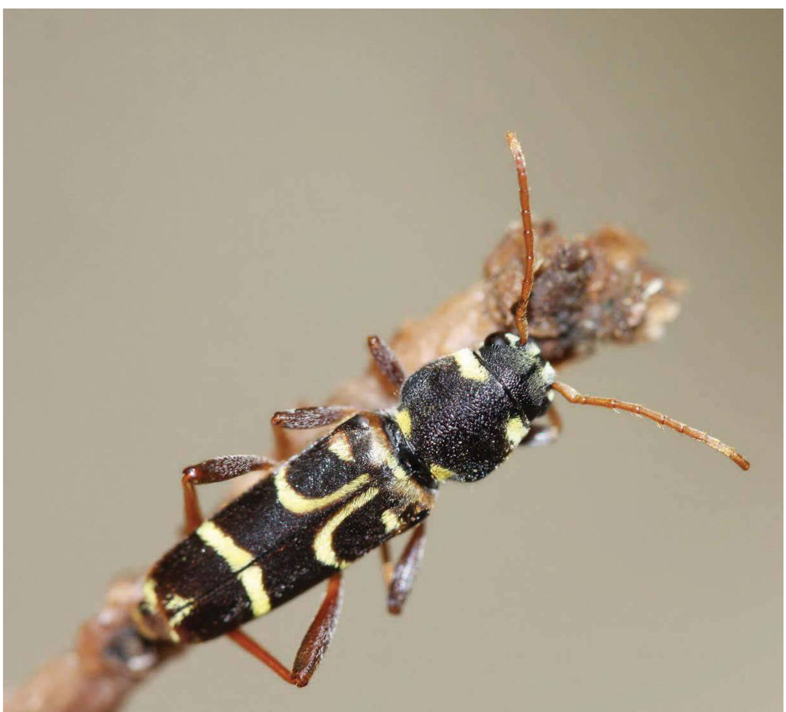

FIGURE 12.72 *Xylotrechus arvicola* adult. (Courtesy of Boženka Hric [image from Srećko Ćurčić].)

in Betulaceae, Fagaceae, Malvaceae, Moraceae, Rosaceae, Ulmaceae, Salicaceae, and Vitaceae (Bense 1995; Ocete et al. 2002a, 2002b, 2004, 2008, 2010; Soria et al. 2013).

This species was considered a minor pest of various tree species. However, it has become an increasingly serious pest of grapevines in Spain since the 1990s (Ocete et al. 2002a, 2002b, 2004, 2008, 2010; Soria et al. 2013). For example, in the vineyards of northern and central Spain, the infestation rate increased from 51% in 2004 to 96% in 2008; the vines started to die in 2005; and the death rate increased to 17% in 2008 (Ocete et al. 2010). The continuous use of nonselective chemical controls and the consequent changes in entomofauna could explain the origin and increase of this pest in Spanish vineyards (Soria et al. 2013). Garcia Calleja (2004a, 2004b) detailed the significant increase in damage and economic loss caused by this borer. Ocete et al. (2008) reported that, due to the damage by this borer, the inflorescence size and number of flowers are considerably reduced and that, during harvest, the grape clusters are smaller and looser, weighing on average five times less than those collected from the sound branches. Moreover, the wine made from the grapes on the infested branches has a significantly lower alcoholic percentage and a higher organic acid concentration.

The larvae bore into the vine branches, trunks, and roots. They excavate large and numerous galleries inside the wood, and infestations are difficult to detect and control (Ocete et al. 2008). Furthermore, Ocete et al. (2002a) indicated that the borer may be associated with pathogenic fungal species affecting the vine wood. More recent studies suggest that this borer, in addition to causing a progressive decay of the branches, could facilitate the transmission of plant fungus diseases—further threatening the vineyards by spreading grapevine decline pathogens (Benavides et al. 2013; Soria et al. 2013). The destruction by the borer and then the fungal diseases progressively weaken the affected vine as indicated by drastic reduction in yield and premature death. During the dying period, the shoots are without vigor; they look quite similar to those infected by the Eutypa dieback complex (Ocete et al. 2002b).

The adults emerge during May–August (Bense 1995; Benavides et al. 2013), and the females lay most of their eggs in the first two weeks after emergence (García-Ruiz et al. 2012). The female that emerges from grape wood collected from the field lays about 196 eggs in her lifetime (García-Ruiz et al. 2012). In the field, the life cycle lasts two years and the winter is passed at the larval stage (Bense 1995). However, in the laboratory, the developmental period from larvae to adults ranges from 269 to 321 days, depending on diet (García-Ruiz et al. 2012). The optimal temperature for the development of this borer is estimated to be from 31.7°C to 32.9°C (García-Ruiz et al. 2011).

So far, no effective control measures have been developed. Ocete et al. (2002b) suggested that to eliminate the sources of the infestation and infection, it is necessary to cut back the trunk of vines to enable regrowth and to cover the wounds with sealing paste. In vineyards, it is also recommended that this borer should be managed using an integrated pest management program (Ocete et al. 2008). For example, Soria et al. (2013) suggested that integrated pest management measures should be performed in mid-June and the end of July to reduce adult populations. Urgent investigations into the development of cultural and chemical control measures are warranted.

12.9 Cerambycid Pests in Field Crops

Field crops refer to any of the herbaceous plants grown on a large scale in cultivated fields—primarily grain, forage, sugar, oil, or fiber crops. Field crops are of ultimate importance for human survival. Future trajectories of food prices, food security, and crop land expansion are closely linked to future average crop yields in the major agricultural regions of the world.

Hundreds of insect species damage these crops, causing significant loss in yield and income and threatening food security. However, cerambycids that damage field crops are relatively rare. To date, only about 17 cerambycid species have been reported to be of economic importance in sunflower, soybean, sugarcane, and pasture and grain crops throughout the world. Among these species, *Oxymerus aculeatus* Dupont adults damage corn plants by feeding on the male flowers in Brazil, reducing seed production (Pires et al. 2011). However, this species is not considered further in this chapter because little is known about its larval biology. *Rhytiphora diva* (Thomson) [= *Zygrita diva* (Thomson)] and *R. stigmatica* (Pascoe) [= *Corrhenes stigmatica* (Pascoe)] (Slipinski and Escalona 2013) attack legume crops including soybean and lucerne (alfalfa) in northern Australia, but *R. diva* is far more common than *R. stigmatica* (Anonymous 2010). Therefore, only *R. diva* is discussed here. In North America, *Dectes texanus* LeConte, *Ataxia hubbardi* Fisher, and *Saperda inornata* Say were recorded as pests of sunflowers by Rogers (1977b). However, the latter two species are no longer considered pests of economic importance to field crops today. Therefore, only *D. texanus*, which is also a major pest of soybeans, is detailed in this chapter.

In this section, 13 cerambycid species that infest bean, sunflower, sugarcane, rice, sorghum, and pasture crops are discussed, including 1 in North America, 3 in Europe, and 9 in Asia. There is no record of any cerambycid that causes economic damage to wheat, tomato, and potato crops.

12.9.1 Asia

12.9.1.1 Obereopsis brevis (Gahan)

Synonyms: *Obereopsis subbrevis* Breuning, *Oberea brevis* Gahan
Common name: Girdle beetle

The girdle beetle is a lamiine widely distributed in India and Myanmar. The body is 9–9.5 mm long; the head, prothorax, and basal one-half to four-fifths elytra are yellowish; the antennae and apical one-half to one-fifth elytra are dark blue to black (Figure 12.73). This is a highly polyphagous species, feeding on numerous herbaceous species from Fabaceae (or Leguminosae), Asteraceae (or Compositae), Euphorbiaceae, Phyllanthaceae, and Malvaceae (Shrivastava et al. 1989).

Quite some time ago, this beetle reportedly attacked soybeans in India but was not a concern until the late 1960s and early 1970s, when serious damage to soybeans was reported (Srivastava et al. 1972; Gangrade and Singh 1975). Since then, it has become an increasingly serious pest of soybeans in India, causing substantial losses (Singh et al. 1976; Singh and Dhamdhere 1983; Kundu and Trimohan 1986;

FIGURE 12.73 *Obereopsis brevis* adult. (Courtesy of Prakash Kumar, CAD Chambal Agriculture Research Station, NBAIR, used with permission of NBAIR director.)

Rai and Patel 1990; Singh and Singh 1996; Upadhyay et al. 1999; Kumar et al. 2012; Netam et al. 2013; Jayanti et al. 2014; Sharma et al. 2014). It is also a moderate pest of garden beans *Lablab purpureus* (L.) Sweet, cowpeas *Vigna unguiculata* (L.) Walp. (Singh and Singh 1966), and rice beans *V. umbellata* (Thunb.) Ohwi & H. Ohashi (Verma and Singh 1991). The damage to these legume crops is caused by both adults and larvae. Adult females girdle the stems, petioles, petiolets, and branches before laying eggs. The parts above the girdle wilt and die. The larvae tunnel upward and downward in the stem, which weakens or even kills the whole plant. According to Jayanti et al. (2014), the girdle formation by the adult females results in a significant reduction in the number of pods and seeds and in seed weight. Losses caused by this pest are also associated with crop stage and different infestation levels. For example, up to a 10% infestation level does not reduce yield at all crop stages, but between 37 and 44 days after germination, the crop appears to be most vulnerable to infestation. Severe yield reduction occurs in those plants infested in the last week of August (40.0%) followed by the first and second weeks of September (37.6% and 32.3%, respectively). No further yield reduction takes place in the plants infested during the fourth week of September and the first week of October. Singh and Singh (1996) have examined the plant parts the beetle prefers to attack and the relationship between the parts attacked and yield loss. They note that the beetle inflicts maximum girdle formation on the petiole (43.1%), followed by the branch (22.6%), stem (21.5%), and petiolet (12.8%). Plants with girdles on the main stem suffer 15.74% premature mortality and the highest grain weight loss (47.2%), followed by girdles on the petiole, branch, and petiolet, which account for a grain weight loss of 40.3%, 39.9%, and 30.2%, respectively.

Furthermore, *O. brevis* has expanded its host range to attack sunflowers, with the infestation rate ranging from 60% (Pachori and Sharma 1997) to about 95% (Veda and Shaw 1994) in different regions of India, causing significant losses. The damage to sunflowers is made by girdling and tunneling the stems, damaged plants wilt, turn black, and look sickly (Veda and Shaw 1994).

The adults emerge twice a year, once between late July and early September and again between early September and mid-October, with an activity peak occurring in late August (Netam et al. 2013). In an earlier study, Rai and Patel (1990) examined the incidence of *O. brevis* in soybean plots sown on July 15, 1988, in India, and showed that the pest first appeared on August 10, and activity continued until October 12. A female girdles the plant at two levels, cuts a slit in between using her mandibles, and lays an egg in the slit (Dutt and Pal 1982; Pal 1983; Gautam 1988). A female produces 31–60 eggs but appears to lay only 7–13 eggs in her lifetime (Singh and Singh 1966). On soybean plants in the laboratory, the egg stage lasts 3–4 days, the larval stage 34–47 days, and the pupal stage 8–11 days (Gangrade et al. 1971). The developmental periods for all stages may be longer in the field, especially in the fall when some of the larvae enter hibernation. In another laboratory study (Dutt and Pal 1984), the egg stage is 3–4 days and the larval stage 24–44 days at 29–30°C. The beetle has two generations a year, and the larvae of both generations can enter diapause (Gangrade and Singh 1975). According to Singh and Singh (1966), the pest overwinters as mature and diapausing larvae in the feeding tunnel; the larvae become active again after the first rains in late June or early July and pupate soon afterward; the pupal stage lasts up to a month, and the adults emerge in time to breed on the monsoon crop. Dutt and Pal (1988) reported that the termination of larval diapause and emergence of adults can be forecasted on the basis of premonsoon precipitation and temperature. For example, exposure of larvae to 90–100% relative humidity and 30°C in the laboratory can terminate diapause in the following summer but not in the preceding winter. A premonsoon precipitation of 200 mm in the rainy season but not in the winter at 30°C secures the release of larvae from diapause and leads to adult emergence.

Because of its economic significance, a lot of effort has been made to control this pest, and many measures have been developed in the past 50 years. To date, the use of insecticides appears to be the most effective control measure for this pest (Chaudhary and Tripathi 2011). The classes of insecticides used for the control of this pest range from organochloride, organophosphate, organothiophosphate, organophosphorus, carbamate, benzamide, and pyrethroid to anthranilic diamide. Some of these insecticides have now been banned for use in agriculture (such as organochlorides). These insecticides can be sprayed once at the crop age of 30–45 days, depending on the infestation rate (Singh and Singh 1966; Singh 1986; Pande et al. 2000; Upadhyay and Sharma 2000; Yadav et al. 2001). In general, the spray should be made within 7–10 days of the presence of girdling symptoms (Sharma et al. 2014). If the infestation continues two weeks after the spray, a second spray is recommended (Parsai et al. 1990;

Purwar and Yadav 2004; Gupta 2008; Chaudhary and Tripathi 2011; Jain and Sharma 2011; Sharma et al. 2014). If the infestation is observed 75–80 days after sowing, spraying will not improve yield (Sharma et al. 2014). Organophosphate (Singh 1986; Singh and Singh 1989; Patil et al. 2002; Dahiphale et al. 2007) or carbamate (Singh 1986) insecticides in granular formulations can be used to treat the soil at the time of sowing or about 25 days afterward.

Crop resistance against the beetle has been investigated over the past 30 years, with attempts made to find highly resistant cultivars and to reduce insecticide applications (Bhattacharjee and Goswami 1984; Sharma 1994, 1995; Gupta et al. 1995; Salunke et al. 2002; Gupta et al. 2004; Manoj et al. 2005; Patil et al. 2006; Sinha and Netam 2013; Sharma et al. 2014). However, these attempts have only achieved limited success. Further investigations are warranted.

Several cultural control measures have been practiced and been demonstrated to be effective to a large extent. For example, soybeans should not be sown before the arrival of the monsoon period (July). Research shows that sowing in July results in the lowest infestation rate and the highest yield (Singh and Gangrade 1977; Singh and Dhamdhere 1983; Parsai and Shrivastava 1993; Meena and Sharma 2006). Soybean fields should be closely monitored, and the infested parts of the plants that have wilted as a result of attack should be collected at least once every 10 days and destroyed to get rid of the eggs and young larvae (Singh and Singh 1966; Singh and Dhamdhere 1983; Sharma et al. 2014). Intercropping soybean with maize or sorghum should be avoided because such an arrangement increases the infestation of soybeans by the beetle (Singh et al. 1990; Sharma et al. 2014). Sharma et al. (2014) suggested the use of *Dhaincha* as the trap crop for the girdle beetle, but the effectiveness of this measure is not known. Finally, deep summer plowing and crop rotation may also reduce the pest population.

Attempts have been made to explore biological control of this pest. Initially, a hymenopteran parasitoid (*Dinarmus* sp.) was found to parasitize *O. brevis* larvae (Singh and Singh 1966; Gangrade et al. 1971). However, no follow-up work has been undertaken, probably due to the low parasitism rate. Also used for the control of several other cerambycid pests mentioned earlier, the fungus pesticide *Beauveria bassiana* has been sprayed twice at 35 and 64 days after sowing, achieving only moderate success (Purwar and Yadav 2004). In an experiment where cultural and biological control measures were integrated for the management of this beetle and a lepidopteran pest on soybeans, Chaudhary et al. (2012) reported that the program involving removal of infested plant parts plus release of *Trichogramma* sp. at 30 days after sowing plus *Bacillus thuringiensis* (Bt) sprays at 50 days after sowing was highly effective.

Despite these efforts, the pest is still causing significant losses. This might well be due to the overuse of pesticides. More research is badly needed.

12.9.1.2 *Nupserha nitidior* Pic

Synonyms: *N. malabarensis* var. *nitidior* Pic, *N. nitidior* m. *atripennis* Breuning, *N. nitidior* m. *atroreductipennis* Breuning
Common name: Soybean girdle beetle

The lamiine adults are 6–7 mm long and dark yellowish in color without any specific patterns. This species appears to occur only in India. The host range is not very clear but appears to include herbaceous species from Asteraceae and Fabaceae (Duffy 1968; Anonymous 1973; Kashyap et al. 1978).

The soybean girdle beetle is considered a minor pest of soybeans in India (Thakur and Bhalla 1980; Chandel et al. 1995). Similar to *O. brevis*, this species damages the crops by adult girdling of the stems and larval tunneling in the stems and roots, causing similar symptoms (Anonymous 1973).

The adults emerge in July and August, girdle plants, and lay a single egg in an oviposition slit. The larvae bore into the stem and roots and enter diapause in the roots or soil between September and November, depending on climate. Diapaused larvae overwinter. This species has one generation a year.

Control measures are similar to those developed for *O. brevis*, including cultural and chemical control and use of resistant cultivars (Anonymous 1973; Kashyap et al. 1978; Thakur and Bhalla 1982; Chandel et al. 1995).

12.9.1.3 Nupserha vexator (Pascoe)

Synonym: *Glenea vexator* Pascoe
Common name: Sunflower stem borer

Because the identification of this lamiine species is not 100% certain, (Patil and Jadhav (2009) and Patil et al. (2009) who reported the occurrence of the damage tentatively used the name *Nupserha* sp. near *vexator* (Pascoe) (Figure 12.74). *Nupserha vexator* is distributed in India, Sri Lanka, and Myanmar. The species, formerly referred to as *N. antennata* Gahan (Duffy 1968; Slipinski and Escalona 2013), was introduced to Australia to control the noxious weed *Xanthium pungens* Wallr. in Queensland (Wapshere 1974) but apparently did not become established (Slipinski and Escalona 2013). Known hosts include species of Asteraceae.

In the early 1990s, the beetle was first noticed to damage sunflowers in central-western India. Since 1998, it has become a moderate to serious pest of sunflower crops in this region (Patil and Jadhav 2009; Patil et al. 2009). The infestation rate ranges from 10% to 70%, depending on year and sampling area, causing up to 17–31% yield loss (Patil et al. 2009). Patil et al. (2009) also reported that the infestation rate in July-sown sunflower crops is twice as high as that in August-sown sunflowers. The damage is caused by larval tunneling in the stem. The infested plants break easily, look sickly, and produce few or no seeds.

The information on biology mainly is extracted from Duffy (1968), Wapshere (1974), and Patil et al. (2009). The adults emerge during the first monsoon rains in June–July and lay their eggs singly in leaf axils. The adult males live for <1 month while females survive for up to 2.5 months. A female lays 30–260 eggs in her lifetime. The larvae enter the stem 7.5–9.0 cm above the root collar region and bore upward through the internal pith tissue. The first five larval instars last about 1.5 months, and the final two instars require several months. Before becoming mature, the larvae move downward, make an exit hole near the ground, and enter the soil for pupation. Some mature larvae remain in the stem and pupate there. Overwintering occurs at the mature larval stage. There is one generation a year.

FIGURE 12.74 *Nupserha vexator* adult. (Courtesy of Larry Bezark.)

Measures for the control of this pest are still being developed. The screening of cultivars resistant to the pest is promising. For example, Patil and Jadhav (2009) reported that the stem borer infestation rates on sunflowers varied from 0% to >80% in various germplasms under investigation over a five-year period, suggesting that it is possible to select for resistant cultivars for the effective control of this borer. Three chemical insecticides have been tested for control of the exposed stages of the pest—the eggs, newly hatched larvae, and the adults (Patil et al. 2009). Results show that spraying an organothiophosphate insecticide 40 days after the adult emergence achieves effective and economic control of the borer, followed by the organophosphate and organochlorine insecticides. However, organochlorines are being phased out globally.

12.9.1.4 Dorysthenes granulosus (Thomson)

Synonyms: *Paraphrus granulosus* (Thomson) and *Cyrthognathus granulosus* Thomson
Common name: Sugarcane root and stem longicorn

The prionine adults are 25–62 mm long; the body is reddish brown with a blackish-brown head and antennal segments 1–3, and each side of pronotum has three saw-like processes (Figure 12.75). It resembles *D. buqueti* (Guérin-Méneville) (see the next entry) but differs in having a shorter distance between the antennal tubercules; the lateral processes (spines) of pronotum are longer and sharper, and the lower side of antennal segments 3–5 have numerous granular processes. It is widely distributed in southern and southeastern Asia including southern China, Thailand, Vietnam, Laos, Myanmar, and India (Duffy 1968; Pu 1980; Li et al. 1997; Hua 2002; Thongphak and Hanlaoedrit 2012). *D. granulosus* and *D. buqueti* are often confused in reports from Thailand where both species occur (Thongphak and Hanlaoedrit 2012; D. Thongphak 2014, personal communication; W. Lu 2014, personal communication). According to Thongphak (2014, per. comm.), *D. granulosus* is a more abundant and more important pest of sugarcane than *D. buqueti* in northern Thailand. Based on photos in Thongphak and Hanlaoedrit (2012),

FIGURE 12.75 *Dorysthenes granulosus* adult. (Courtesy of Nathan P. Lord, USDA APHIS ITP, Bugwood.org [5491724].)

Anonymous (Fig. 5 beetle on the left, 2014), and personal communications with Thongphak and Lu in 2015, the Thai species mentioned in Sommartya and Suasa-ard (2006), Pliansinchai et al. (2007), Sommartya et al. (2007), and Suasa-ard et al. (2008, 2012) should be *D. granulosus* rather than *D. buqueti*. The host range of *D. granulosus* appears to be very wide, including numerous species from Poaceae, Sapindaceae, Anacardiaceae, Euphorbiaceae, Rutaceae, Myrtaceae, Fagaceae, Pinaceae, Arecaceae, and Meliaceae.

Since the 1970s, *D. granulosus* has become an increasingly more serious pest of sugarcane in southern China, particularly in Guangxi, Guangdong, Hainan, and Yunnan (Plant Protection Group of Guangxi Sugarcane Research Institute 1975; Zeng and Huang 1981; Yang et al. 1989; Liao et al. 2006; Yu et al. 2006, 2007, 2008, 2009, 2010; Long and Wei 2007; Gong et al. 2008; Xiong et al. 2010), and in northern Thailand (Sommartya and Suasa-ard 2006; Pliansinchai et al. 2007; Sommartya et al. 2007; Suasa-ard et al. 2008, 2012; Thongphak and Hanlaoedrit 2012). In the late 1970s, the infestation rate reached 5–40% in southern Guangxi, Hainan, and Yunnan (Zeng and Huang 1981). In the past decade, frequent outbreaks have occurred in the major sugarcane growing regions of Guangxi, with infestation rates of 15% to more than 60% (Liao et al. 2006; Yu et al. 2006, 2007; Long and Wei 2007; Gong et al. 2008), causing 10–50% yield loss (Liao et al. 2006). Young larvae feed on tender roots and then bore into main roots, tunnel upward in the stems up to 30–60 cm above the ground, and hollow out the stems (Zeng and Huang 1981; Liao et al. 2006; Long and Wei. 2007). As a result of larval feeding, sugarcane leaves turn yellow to brown, stems are easily broken by wind, and the whole plant eventually dies. Various authors reported that the damage by this pest is more severe to sugarcane planted in sandy soil and/or grown from the ratooning of the stubble for successive years (Zeng and Huang 1981; Long and Wei 2007; Yu et al. 2007). In northern Thailand, *D. granulosus* is considered a major pest of sugarcane, but much research remains to be done for better understanding of its pest status and biology in that region (Thongphak and Hanlaoedrit 2012).

This pest also damages roots and stumps of various other economic plants in southern China. For example, about 10% of less-than-one-year-old mango seedlings are infested, becoming wilted and dying (Zhang 1992). Longan seedlings and young citrus trees are heavily damaged, with up to 12% mortality in longan seedlings and about 30% of citrus trees losing economic value (Zhu and Xu 1996; Zhu 2012). More recently, it caused economic damage to cassava (*Manihot esculenta* Crantz) (Chen et al. 2012). The infestations on those crops occur mainly because they are planted on previous sugarcane farms without proper treatment of cane residues and soil. Since the 1990s, many farmers have replaced their sugarcane crops with fruit trees and other crops for high economic gain, but they have suffered huge economic losses due to this pest (Zhu and Xu 1996). Studies recommend that deep plowing, destroying cane residues, and soil treatment using pesticides be performed before planting other crops. *D. granulosus* larvae feed on roots and stumps of young citrus and *Eucalyptus citriodora* (Hook.) K.D. Hill & L.A.S. Johnson trees—weakening and even killing the trees (Zhu 1995)—and on stumps of harvested pine trees, causing economic losses (Wang 1994). However, these trees are not planted on previous sugarcane farms. In addition, Qin et al. (2010) reported that *D. granulosus* larvae are found to feed on rhizomes of coconut trees in southern China.

Long and Wei (2007) and Gong et al. (2008) have suggested possible reasons for the recent outbreaks of *D. granulosus* on sugarcane in southern China. These include (1) increase in sugarcane growing area, (2) increase in ratoon cropping, (3) decrease in rotation with rice, (4) planting susceptible varieties for high yield and sugar content, (5) increase in pesticide resistance, (6) lower rainfall in the past decade, and (7) increase in eucalypt growing area causing drought and providing more food for the pest.

Zeng and Huang (1981) gave an excellent description of the general biology of this longicorn. The adults emerge from April to June, with a peak in May. They mate on the emergence day or the next day and then lay eggs in soil 10–30 mm below the surface. The adults are nocturnal and attracted to light. A female can lay up to 783 eggs, with an average of 251 eggs in her lifetime. The eggs hatch in 10–18 days—most during early to mid-June. The larvae have 15–18 instars and last almost two years. The larvae go through 18 instars (Yu et al. 2012). The mature larvae leave the sugarcane stumps and overwinter in the soil. During March–April, they make large pupal cells near the stumps or 10–20 cm away from stumps and pupate in the cells 20–30 cm below the surface. The life cycle lasts two years. Yu et al. (2007) demonstrated that a female lays an average of 300 eggs in her lifetime and the pupal period lasts 15–31 days. In Thailand, the eggs are laid singly around the root zone at a depth of 6–35 mm;

each female lays approximately 160–310 eggs, with an incubation period of 14–23 days (Pliansinchai et al. 2007). Furthermore, Long and Wei (2007) tested larval resistance against starvation and indicated that the young larvae survive for more than two months without feeding and that the mature longicorns survive for more than four months with no food. They start feeding and damaging immediately after the food is available. This feature, together with the wide host range, makes the pest highly likely to be transported to other areas and become established. The biology described in China is very similar to that in Thailand (Pliansinchai et al. 2007). The authors show that the larvae are found throughout the year, with the highest population occurring in October and the lowest in April.

A number of measures have been developed for the control of *D. granulosus* in the past two decades and they are summarized here. (1) Light and/or pitfall traps can be used to attract adults during April–June when most of them are active. The light traps are set up about 100 m apart and 1.5 m high. Under each light trap, a pitfall trap (40 cm by 40 cm by 60 cm) is dug in the soil and filled with water (Yu et al. 2007). Lights are turned on between 19:30 and 23:00 hours (Mai 1988) or between 19:00 and 21:00 hours (Yu et al. 2009), depending on temperature. Pitfall traps (30 cm long by 20 cm wide by 40 cm deep) of higher density (4 m apart) are made if the light traps are not used (Yu et al. 2008). The trapped adults are destroyed every day. Pliansinchai et al. (2007) also suggested that the adult trapping practice should be carried out during April–June in Thailand. (2) Cultural control includes irrigation by flooding to drown larvae, crop rotation with rice or sweet potato to reduce infestation (Yu et al. 2007), and deep plowing (Gong et al. 2008) using a rotary cultivator (Yang 1992) to destroy sugarcane stumps and to kill the larvae after harvest or before planting. (3) Resistant cultivars are planted to suppress the pest population. Pliansinchai et al. (2007) indicated that some cultivars, such as Uthong 3 and K 88-92, are resistant to pest attack and should be grown in the pest outbreak areas. (4) Chemical control involves the use of carbamate, phosphorus, or organophosphate insecticides in granular formulation for soil treatment. Yang (1992) and Yu et al. (2007) recommended that, following plowing and before planting new crops, the soil be treated with insecticides. Gong et al. (2008) suggested that the insecticides should be used twice a year, first at planting time and second at the egg hatch peak period to kill young larvae. Pliansinchai et al. (2007) also suggested that the larval populations could be controlled at the early stages in April–July in Thailand. (5) Biological control involves the applications of fungus and nematode insecticides. Zeng and Huang (1981) first suggested that the fungus *M. anisopliae* may be used for the control of this pest. Yu et al. (2010) have then screened and obtained a highly virulent strain against *D. granulosus* in China. Sommartya et al. (2007) and Suasa-ard et al. (2008, 2012) also demonstrated that this fungus is effective for the control of *D. granulosus* larvae in Thailand. Wang et al. (1999) have tested the effectiveness of the nematode *Steinernema glaseri* for the control of *D. granulosus* in the laboratory but found this nematode caused little mortality of the beetle.

12.9.1.5 Dorysthenes buqueti (Guérin-Méneville)

Synonym: *Lophosternus buqueti* Guérin-Méneville
Common name: Sugarcane stem longicorn

This prionine species (Figure 12.76) is very similar to *D. granulosus* (see earlier) but differs in having a wider distance between the antennal tubercules, the lateral processes (spines) of the pronotum are shorter and blunter, and the lower side of antennal segments 3–5 is smooth without granular processes. This species is recorded in Thailand, Indonesia (Java), India (Assam), Myanmar, Malaysia, Nepal, Laos, and China (Yunnan) (Duffy 1968; Chiang et al. 1985; Pitaksa 1993; Pramono et al. 2001a, 2001b; Thongphak and Hanlaoedrit 2012). The main hosts are recorded from Poaceae (Duffy 1968; Pitaksa 1993; Pramono et al. 2001a). Pramono et al. (2001a) have tested host preference of this species among 11 plant species from Anacardiaceae, Euphorbiaceae, Fabaceae, Malvaceae, and Poaceae, and found that sugarcane from Poaceae is the preferred host.

In the past, *D. buqueti* was only considered a minor pest of bamboo, feeding on rhizomes of bamboo clumps in Southeast Asia (Duffy 1968; Chiang et al. 1985). However, it has become an increasingly important pest of sugarcane in Thailand since the mid-1980s (Prachuabmoh 1986; Pitaksa 1993; Charernsom and Suasa-ard 1994; Leslie 2004) and in West Java, Indonesia, since the 1990s (Pramono et al. 2001a,

FIGURE 12.76 *Dorysthenes buqueti* adult. Specimen from Natural History Museum (London). (Courtesy of Jiří Pirkl, copyright Natural History Museum [London], used with permission of M.V.L. Barclay.)

2001b; Anonymous 2014). *D. buqueti* appears to be less damaging than *D. granulosus* in Thailand (Thongphak and Hanlaoedrit 2012; Thongphak 2014, per. comm.) although sugarcane weight losses to the pest by up to 43% (Prachuabmoh 1986) and 51% (Pitaksa 1993) have been reported. In the laboratory, the larval feeding can reduce sugarcane stem weight by 41.4% in 10–12 days (Pramono et al. 2001a). According to Pramono et al. (2001b), since 1995, when *D. buqueti* was first reported attacking 100 ha of sugarcane in Indonesia, the infestation area had expanded to 6,000 ha in 1999, suggesting that this pest has the potential to threat the entire Indonesian sugar industry. The larvae do not attack the cane roots but bore directly into the base of stems and then tunnel the stem upward to 20–30 cm above the ground (Pramono et al. 2001a). One larva can attack more than one stem. Canes of all ages are attacked, but the infestation rate on ratoon canes is much higher than on plant canes (Prachuabmoh 1986; Pitaksa 1993; Pramono et al. 2001a). Similar to *D. granulosus,* this pest causes more severe damage to sugarcanes in sandy soil (Prachuabmoh 1986). The infested crops turn yellow and suffer poor growth. The plants ultimately die, and crops fail to ratoon properly in cases of severe infestation (Pramono et al. 2001a).

In Thailand, the adults emerge from the soil in April, live for 15–20 days, and each female lays 500–600 eggs that hatch in 15–18 days (Prachuabmoh 1986). Pramono et al. (2001a) have made detailed observations on the biology of *D. buqueti* in Indonesia, which is summarized here. The adults are nocturnal, attracted to light, and live for an average of 31.3 days. Each female lays 180–287 eggs in her lifetime. The eggs are laid in the soil around the root zone and hatch in 15–32 days. The total larval duration ranges from 20 to 21 months with 10 instars, and different larval instars and pupae coexist at the same time. Pupation occurs in a 5.0 by 4.2 cm mud chamber in the soil about 20 cm below the surface. The pupal stage lasts 17–31 days. The fully developed adults usually remain in the pupal chamber for about 7–10 days before emergence. In Thailand, the larval stage lasts about one year (Prachuabmoh 1986) and life cycle takes one to two years to complete (Pitaksa 1993), although in Indonesia one generation takes two years (Pramono et al. 2001a). The winter is passed at the larval stage. Like *G. granulosus*, the larvae and pupae of *D. buqueti* can survive for a long time under unfavorable conditions, making it possible for the species to spread to other areas with the aid of transportation (Pramono et al. 2001a).

Similar measures that are used for the control of *D. granulosus* could be applied to manage this pest. Prachuabmoh (1986) and Pitaksa (1993) described some chemical and cultural control methods used in Thailand. Pramono et al. (2001a) have experimentally tested an integrated set of control measures in Indonesia, which includes the intensive cultivation, hand-collection of larvae and adults, cane sanitation in the stubble, and application of an entomopathogenic fungus (*Metarhizium flavoviride* Gams & Roszypal [Pramono et al. 2001b]). These authors show that the integrated pest management strategy can reduce the pest population by 60% and increase millable cane yield by 25.8%.

12.9.1.6 *Dorysthenes hydropicus* (Pascoe)

Synonyms: *Cyrtognathus breviceps* Fairmaire, *C. chinensis* Thomson, *Prionus hydropicus* Pascoe
Common name: Sugarcane longicorn beetle

The adults of this prionine longicorn are 25–47 mm long; the body is shiny and chestnut brown to blackish brown with a pair of large and long, knife-shaped mandibles which are curved backward and crossed against each other at about an apical third when resting (Figure 12.77). This species is widely distributed in China (from Jilin to Guangdong, Taiwan) and Korea (Chen et al. 1959; Toepfer et al. 2014). Earlier, only sugarcane from Poaceae was recorded as its host (Chen et al. 1959; Tseng 1962; Duffy 1968). With further studies, the host range of *D. hydropicus* is in fact very wide, with its larvae feeding on plants from Poaceae, Fabaceae, Rutaceae, Salicaceae, Thymelaeaceae, Santalaceae, Cupressaceae, Pinaceae, Ulmaceae, Rosaceae, Theaceae, and Myrtaceae (Fan and Liu 1987; Chiang 1989; Qiao et al. 2011; Toepfer et al. 2014). Qiao et al. (2011) have investigated the suitability of three host plant species from Rutaceae, Thymelaeaceae, and Fabaceae, respectively, and found that the larvae feeding on pomelo [*Citrus maxima* (Burm. f.) Merr. = *C. grandis* (L.) Osbeck] from Rutaceae perform the best.

FIGURE 12.77 *Dorysthenes hydropicus* adult. (Courtesy of Meiying Lin.)

It is a moderate pest of sugarcane in Taiwan, Jiangxi, Hunan, and Guangxi (Chen et al. 1959; Tseng 1962, 1964; Pemberon 1963; Jiang 1991; Li et al. 1997). However, its damage to sugarcane appears to be severe in central Taiwan (Tseng 1962, 1964), with a yield loss of 30–50% cited by Fei and Wang (2007). In the late 1950s and early 1960s, yield loss to *D. hydropicus* damage was reported to be as high as 40% in Taiwan (Tseng 1962). According to Jiang's (1991) description, the larvae feed on the roots first, then bore into the stumps, and tunnel the main stems upward up to the ground level. The stumps and stems are hollowed up, resulting in wilting and death of entire plants. The infested canes are easily pulled out and broken. The damage to the ratoon cane is more severe than to the plant cane, and the infestation rate is higher in the unirrigated fields (Tseng 1962).

In the 1980s, *D. hydropicus* was reported to seriously damage common reeds [*Phragmites australis* (Cav.) Trin. ex Steud.] in Hubei Province, China, with its larvae feeding on the reed stems below the surface (Fan and Liu 1987). The infestation rate usually is 20–40% and could reach 70% in some areas. The infestation weakens and eventually kills the plants. Reed is widely used for paper making and building materials, and its root is a common ingredient in Chinese medicine. Since 2000, thousands of pomelo (*C. maxima*) trees have been killed by *D. hydropicus* in orchards in Guangdong Province (Qin et al. 2008). Authors reported that about 25% of the 40,000 trees in one pomelo orchard were killed by this pest. Trees usually die one to two years after infestation. Almost 100% of young trees (one to two years old) are killed. One to seven larvae are extracted from the stump of each dead tree. The pomelo plants are widely used for altar decoration and the fruits for eating and Chinese medicine.

In sugarcane fields, the adults emerge and mate after spring–summer rains between April and June, depending on when a reasonable rain (20–30 mm) occurs (Chen et al. 1959; Jiang 1991). The adults are nocturnal and attracted to light. According to Jiang (1991), the females lay their eggs in the soil about 3–4 cm below the surface, usually near the sugarcane plants, with each female ovipositing about 200 eggs. The larvae initially feed on roots and then bore into the stumps and stems. The mature larvae leave the canes, make pupation chambers in the soil 4–6 cm below the surface, and pupate in March–April. Overwintering occurs at the larval stage. There is one generation a year in Taiwan.

In reed fields in Hubei (Fan and Liu 1987), the adults emerge in May–June and lay their eggs in the soil 2–3 cm below the surface; each female lays an average of 180 eggs. The larvae feed on subterranean stems or bore into stems up to the ground surface and cut the stems at the ground level. They may move in the soil to feed on other stems when one stem is completely consumed but do not feed on stems above the surface. The mature larvae make large pupal chambers 3–7 cm below the surface and pupate there in April–May. The life cycle takes two years, and overwintering occurs at the larval stage in Hubei. In the pomelo orchards in Guangdong (Qin et al. 2008), the adults emerge between late April and late June, with an emergence peak during late May. Oviposition occurs between May and July with a peak during early to mid-June. The eggs are laid in the soil 1–3 cm below the surface. The female egg load ranges from 73 to 543 eggs depending on a female's body size, with an average of 296 eggs per female. Most eggs hatch during late June to early July. The damage by larvae takes place almost all year round. The adults are attracted to light, with one lamp being able to trap more than 2,000 adults per night. The larvae feed on small and tender roots and then bore into the main roots. After they consume all internal contents of the main roots, they move to another plant and continue boring. The larvae only feed on the roots between 15 and 60 cm below the surface. The mature larvae make pupation chambers in the soil 20–30 cm below the surface and pupate there during late March to early April. The pupal stage lasts 15–25 days. The larvae can survive for several months without food. Both Qin et al. (2008) and Qiao et al. (2011) showed that one generation takes one to two years, and overwintering is passed at the larval stage.

Control measures are still being developed, particularly for infestation by this pest in citrus orchards. Several tactics are recommended: (1) using light or pitfall traps to attract adults during the peak adult activity period (Fan and Liu 1987; Qin et al. 2008)—this tactic should be suitable for all types of crops that this pest infests. (2) Chemical control involves the use of organophosphate insecticides in granular formulation for soil treatment. The method has only been recommended for sugarcane fields so far. In the 1960s, the chemicals used were organochlorines (Tseng 1964, 1966), which have now been phased out. Before planting, one treatment is sufficient for the planted cane fields, but two treatments (second application in January–February) may be necessary for the ratoon cane fields (Fei and Wang 2007). For citrus orchards, once damage symptoms occur, any control measure cannot save the infested trees (Qin et al. 2008). (3) Biological control involves applications of fungus and nematode insecticides. In Guangdong, Ma et al. (2013) have screened the virulence of 36 strains of entomopathogenic fungi *Metarhizium* spp. against *D. hydropicus* larvae feeding on *C. grandis* and found that two strains are highly virulent to the pest. However, there has been no report on the field application of these fungi for control of this pest. Xu et al. (2010) have tested the effectiveness of three entomopathogenic nematodes, *Heterorhabditis bacteriophora* Poinar, *Steinernema scapterisci* Nguyen & Smart, and *S. carpocapsae* (Weiser) for killing *D. hydropicus* larvae feeding on *C. grandis*. They showed some promising results, but whether these nematodes could be used in the field is unknown.

12.9.1.7 Dorysthenes walkeri (Waterhouse)

Synonyms: *Cyrtognathus siamensis* Nonfried, *Baladeva walkeri* Waterhouse
Common name: Long-toothed longicorn

The adults of this prionine beetle are very large in size, ranging from 37 to 65 mm long; the body is blackish brown to black and shiny; the mandibles are very long and curved downward and backward (Figure 12.78). This longicorn is distributed in Myanmar, Vietnam, Laos, Thailand, and in southern China (Fujiang, Guangdong, Yunnan, and Hainan) (Gressitt 1940; Chien 1982; Hua 1982) and were introduced into Iran (Özdikmen et al. 2009). The larvae of this species feed on various species from Arecaceae, Marantaceae, and Poaceae (Chien 1982; Qin et al. 2010).

The long-toothed longicorn was first found to attack sugarcane in the late 1970s and became an important sugarcane pest in Hainan and southwest Guangdong, causing substantial losses (Chien 1982; Mai 1983). The larvae feed on the roots in early instars and the stems in late instars. The damaged canes turn brown and are easily broken by wind. The damage to the ratoon canes usually is more severe than to the plant canes. Sugarcane grown in sandy soil is subject to more severe damage. Between 32% and 60%

FIGURE 12.78 *Dorysthenes walkeri* adult. (Courtesy of Jiří Mička.)

yield loss has been recorded in some ratoon cane growing regions in Hainan (Mai 1983). Qin et al. (2010) reported that this pest also attacks coconut in southern China.

Both Chien (1982) and Mai (1983) have made observations on the general biology of *D. walker*. The adults emerge between May and September, with a peak in June–August depending on when a reasonable rain occurs. Drought or lack of rain during this period of the year may delay emergence. Mating occurs on the same day as emergence. Two to three days after mating, the females start laying eggs. The eggs are laid singly (or two at a time) in the soil 1.5–5 cm below the surface. The average egg load per female is 288 eggs, but many of these eggs have not been laid when the female dies. The adults live for 6–14 days, are nocturnal, and are most active between 20:00 and 01:00 hours. The young larvae move downward in the soil, approach the cane stumps or ratoons, and feed on the roots. Three to four instars later, they bore into the ratoon cane or plant cane stems below the surface and tunnel the stems upward up to 30 cm (usually 10 cm) above the surface. The larvae can also make tunnels up to 80 cm (usually 20–30 cm) long in soil 20–40 cm below the surface. The mature larvae make pupation chambers in the soil and pupate there. The pupal stage lasts 13–22 days, but emerged adults can stay in the pupation chambers for more than 10 days waiting for rain before emerging from the soil. Overwintering occurs at the larval stage. One generation takes two years.

Several control methods are recommended by Chien (1982) and Mai (1983, 1988). (1) Cultural control involves plowing the sugarcane field and rotating with soybean and peanut crops every two to three years. (2) Adult trapping can be carried out during the adult emergence season, particularly after a rain. Light traps can be set 100 m apart and 4–6 m above the ground with lights on between 19:30 and 23:00 hours. (3) Soil treatment with *Metarhizium* or organophosphate insecticides is another method. Mai (1983) showed that the fungus-based insecticide can kill 94% of larvae of all instars, but the chemical insecticides can be only effective when used for the early instar larvae.

12.9.1.8 Dorysthenes paradoxus (Faldermann)

Synonyms: *Cyrthognathus aquilinus* Thomson, *Prionus paradoxus* Faldermann
Common name: Bluegrass longicorn

The prionine adults are 33–41 mm long; the body is chestnut brown to blackish brown (Figure 12.79). It resembles *D. hydropicus* but differs in having the external angles of antennal segments 3–10 sharper and the anterior process at the pronotal side smaller and closer to the mid process. The species is widely distributed from Heilongjiang in northern China to Guizhou in southwestern China (Chen et al. 1959; Hua 1982; Wang et al. 2009) and also in Mongolia and eastern Russia (Tavakilian and Chevillotte 2013). The bluegrass longicorn larvae feed on plants from Poaceae, Fagaceae, and Ulmaceae (Chen et al. 1959; Yan et al. 1997; Wang et al. 2009).

The crop species recorded as host plants of *D. paradoxus* include sugarcane and rice in southern China, and maize, sorghum, and turfgrass (*Poa annua* L.) in northern China (Chen et al. 1959; Yan et al. 1997). More than half a century ago, Chen et al. (1959) stated that the larvae of this species cut the stems of maize and sorghum at the ground level. However, little information on its current pest status with regard to sugarcane, rice, maize, and sorghum is available, suggesting that it is not a concern for those crops at present. Yan et al. (1997) and Hao et al. (1999) reported that *D. paradoxus* has recently caused serious damage to *P. annua* turfgrass in Shanxi Province, resulting in patched death. Larvae cause the damage by feeding on grass roots.

According to Yan et al. (1997), adults emerge from the soil during early July to early September with an emergence peak in late July to late August. The newly eclosed adults stay in pupation chambers for days and wait for rain before emerging from the soil. Mating occurs within a few minutes after emerging from the soil. The females lay eggs in the soil 2–3 cm below the surface. The average egg load per female is 121 eggs but only about 36 eggs are laid before death. The eggs hatch 7–10 days after being laid. The adults live for five to seven days. The larvae make tunnels in the soil and move upward and downward. The early instar larvae overwinter among the roots and late instars in vertical tunnels 45–65 cm below the surface. The overwintered late instar larvae move upward to 3–5 cm below the surface during April–May and start feeding on the roots again. The mature larvae make pupation chambers in the tunnels and pupate there during June and July. The pupal stage lasts 20–25 days. It takes three years to complete a life cycle.

FIGURE 12.79 *Dorysthenes paradoxus* adult. Specimen from Natural History Museum (London). (Courtesy of Jiří Pirkl, copyright Natural History Museum [London], used with permission of M.V.L. Barclay.)

Yan et al. (1997) recommended several control measures for this pest during late July to late August: (1) scattering mixtures of soil, organophosphate insecticides, and fertilizers on the lawn surface and then watering to kill the neonate larvae or spraying organophosphate insecticides in the rain to kill adults and (2) hand-collection of adults. The adults should also be nocturnal and attracted to light. Therefore, light trapping could also be used.

12.9.2 Australasia

12.9.2.1 Rhytiphora diva (Thomson)

Synonym: *Zygrita diva* Thomson
Common name: Alfalfa crown borer, or Lucerne crown borer

The lamiine adults are about 15 mm long and bright orange in color, with black or dark brownish legs and antennae; the elytra have two black spots near the apex but may have no spots or more spots (Figure 12.80). This species occurs in all Australian states except South Australia, Victoria, and Tasmania (Duffy 1963), and in Papua New Guinea (Tavakilian and Chevillotte 2013). Several legume genera are recorded as its host plants (Jarvis and Smith 1946).

This species has been a minor to serious pest of soybeans and alfalfa in northern Queensland since the 1940s (Jarvis and Smith 1946; Williamson 1976; Romano and Kerr 1977) and in northern Western Australia since the 1970s (Strickland 1981; Heap 1991). It is also of some economic importance to soybeans grown in northern New South Wales (Goodyer 1972). Brier (2007) and Bailey and Goodyer (2007) summarize the damage caused by this pest. In some soybean fields in northern Queensland, more than 80% of plants may be infested. The major damage occurs when the mature larvae ringbark the plants internally before making pupal chambers. This activity causes plant death above the girdle. In southern Queensland, this usually occurs after seeds are fully developed with no yield loss. In tropical regions, however, the larval

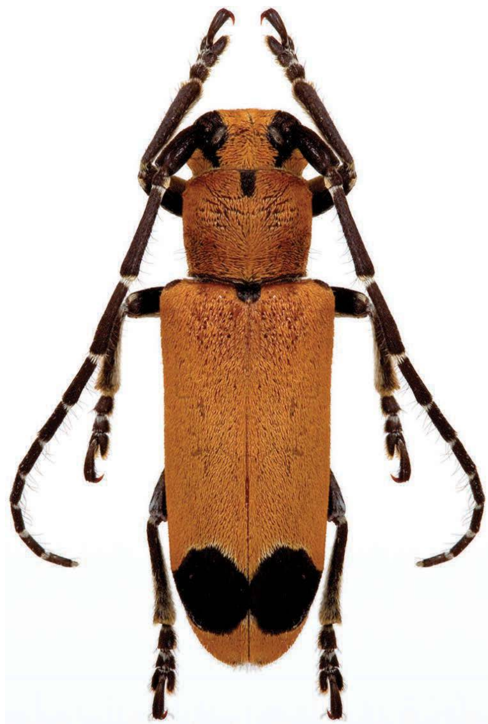

FIGURE 12.80 *Rhytiphora diva* adult. (Courtesy of CSIRO, copyright CSIRO, used with permission of Adam Slipinski.)

development is more rapid, and there can be considerable crop losses. In addition, *R. diva* is very damaging to edamae (soybeans) where green immature pods are harvested by mechanical pod pluckers. The stems of infested plants are weakened and snapped off, contaminating the harvested product.

The infestations usually occur from flowering onward. The adults lay their eggs in the stems of young soybeans. The larvae tunnel up and down through the pith in the stems and usually pupate in the tap roots (Brier 2007). According to Jarvis and Smith (1946), the larval development lasts three or more months, and pupation takes place in the end of the larval tunnel, from which the adult beetle cuts its way to the surface. There probably is only one generation a year, although the larvae of different instars occur together in the same field. The winter usually is passed at the larval stage.

Cultural control appears to be the most commonly used control measure for this pest. Jarvis and Smith (1946) recommended deep plowing of infested alfalfa fields before sowing. It is best to plough the infested legume field and to sow another crop in the farm rotation (Duffy 1963). Brier (2007) and Bailey and Goodyer (2007) also recommended cultural measures. For example, planting susceptible crops close to alfalfa should be avoided. In at-risk regions, later soybean plantings should be considered to shorten crop development, and in tropical regions, winter plantings would be an option to reduce loss. Shepard et al. (1981) have screened soybean lines for the alfalfa crown borer-resistant genotypes and obtained some promising results. So far, there are no pesticides registered for the alfalfa crown borer in soybeans.

12.9.3 Europe

12.9.3.1 Agapanthia dahli (Richter)

Synonyms: *A. dahli theryi* Pic, *A. dalhi erivanica* Pic, *Saperda dahli* Richter, *S. nigricornis* Fabricius
Common name: Sunflower longicorn beetle

The adults of this lamiine borer are 9.5–22 mm long; the body dorsum has greenish yellow pubescence of an unclear pattern and rusty erected hairs; the antennal segments 1–2 are black and the rest yellowish

FIGURE 12.81 *Agapanthia dahli* adult. (Courtesy of Milan Djurić [image from Srećko Ćurčić].)

or reddish yellow in the basal part and black in the apical part, and the pronotum has three yellowish longitudinal bands (Figure 12.81). It is widely distributed in Southern and Eastern Europe (including western Russia and Turkey), northern Iran, Kazakhstan, and Mongolia, and its host range appears to be limited to a number of herbaceous species from Asteraceae and Apiaceae (Horvath and Bukaki 1988; Bense 1995; Horvath and Hatvani 2001; David'yan 2008).

The sunflower longicorn beetle is a minor pest of sunflower crops in Eastern Europe, particularly in Hungary and western Russia (Horvath and Bukaki 1988; Horvath and Hatvani 2001; David'yan 2008). It damages sunflowers by the larval tunneling in the stems. Late sown crops usually suffer more severe damage. The infested stems are often cracked, resulting in lower seed yield and seed-oil content.

The adults are present from April to July and are active during the day (Bense 1995; David'yan 2008). The females gnaw sunflower stems up to 90 cm above the ground to make oviposition slits and lay their eggs in the slits singly. A female can lay about 50 eggs in her lifetime. The larvae bore into the stems and tunnel downward. Most larvae overwinter in the stems 8–80 cm above the ground but may overwinter in the stem below the ground surface. Some larvae pupate in the following spring but others overwinter twice. One generation lasts one to two years. For the control of this pest, David'yan (2008) recommended removal of sunflower stems from the field after harvest and deep plowing the field during the fall.

12.9.3.2 Dorcadion pseudopreissi Breuning

Common name: Ryegrass root longicorn

The adults of the lamiine longicorn (Figure 12.82) are robust beetles and brown to dark brown in color; the vertex and pronotal disc have a white to gray longitudinal pubescent stripe in the middle; each elytron has a white to gray pubescent stripe along the suture and one near the margin;

FIGURE 12.82 *Dorcadion pseudopreissi* adult. (Courtesy of I. A. Susurluk.)

the antennae reach the apical fifth of the elytra in males and the middle of the elytra in females. This species appears to occur only in central and western Turkey (Özdikmen 2010). Several turf and pasture grass species from Poaceae are recorded as the host plants of this longicorn beetle (Kumral et al. 2010, 2012).

The ryegrass root longicorn has become a major turf and pasture grass pest in western Turkey since 1996, causing up to 30% loss (Kumral et al. 2010). The pest has spread into urban landscapes, home lawns, and football fields (Kumral et al. 2012). The main economic damage is caused by larval feeding on the roots, and the damaged grasses turn yellow and die (Kumral et al. 2010; Susurluk et al. 2011). Kumral et al. (2012) have tested the susceptibility of five common grass species (*Lolium perenne* L., *Poa pratensis* L., *Festuca rubra* L., *F. arundinacea* Schreb, and *Agrostis stolonifera* L.) to this pest in western Turkey. Their results show that *F. arundinacea* is a turf species that is tolerant to *D. pseudopreissi* larvae, and *A. stolonifera* is not a suitable host of this pest.

Kumral et al. (2012) showed that the females lay their eggs in the soil in May, the eggs hatch in early June, and the larvae feed on grass roots for more than one year. The lifetime fecundity is unknown. One generation takes two years, and overwintering occurs at the mature larval and adult stages. Due to the nature of the two-year life cycle, the adults are present all year round except June–July, the eggs are present in May, the immature larvae in May–July, the mature larvae all year round except June, and the pupae appear in May–August.

There is no report on cultural and chemical control measures for this new pest. However, Susurluk et al. (2009) have tested the potential of an entomophagous nematode species for the control of *D. pseudopreissi* in the laboratory and have obtained some promising outcomes. A field test of the nematode *Heterorhabditis bacteriophora* Poinar against *D. pseudopreissi* larvae shows that the application of this nematode at 0.5 million infective juveniles per m^2 to the turf after *D. pseudopreissi* adults lay eggs significantly reduces the damage caused by this pest (Susurluk et al. 2011). However, it is still unknown whether this control measure is practical for large-scale use.

12.9.3.3 Plagionotus floralis (Pallas)

Synonym: *Echinocerus floralis* Pallas
Common name: Alfalfa root longicorn

The adults of this cerambycine longicorn are 6–20 mm long and black in color; the pronotum has a yellow pubescent front margin and a transverse yellow pubescent stripe behind the middle; the elytra have five transverse yellow pubescent stripes (Figure 12.83). It is widely distributed in Middle and Eastern Europe to the Caucasus Mountains, Iran, Syria, and Middle Siberia (Kaszab, 1971). *Plagionotus floralis* is polyphagous, with the larval host range being a number of species from Fabaceae, Asteraceae, Amaranthaceae, Theaceae, and Euphorbiaceae (Bense 1995; Toshova et al. 2010).

This species is a moderate pest of alfalfa in Eastern Europe (Mészáros 1990; Toshova et al. 2010; Bozsik 2013) and has become increasingly important in recent years (Zhekova and Petkova 2010). It also damages yellow sweet clover *Melilotus officinalis* (L.) (Toshova et al. 2010). The damage is caused by larval feeding on the main roots and stumps, resulting in yellow shoots and leaves and even death, especially in dry conditions. Toshova et al. (2010) suggested that the larvae may also bore into the lower section of the stems. According to Jermy and Balázs (1990), the damage by this longicorn is more severe in older alfalfa plants (three to four years old or more), causing up to 70–90% plant mortality in the European part of Russia. In eastern Azerbaijan of Iran, most damage also occurs in greater than three-year-old alfalfa and nonirrigated fields (Noushad and Kazemi 1995).

Using CSALOMON® ARb3z fluorescent yellow traps with a floral attractant in Bulgarian alfalfa fields, Toshova et al. (2010) reported that the adults are present from late May to late July. More recently, Imrei et al. (2014) have used the traps modified from CSALOMON® to monitor the adult activity period in Bulgaria and Hungary and have found that adults are active from May to August. The eggs are laid singly on the base of stems. The lifetime fecundity in the field is not known. The larvae bore into the main roots and tunnel in the middle. According to Toshova et al. (2010), this longicorn has one generation a year and overwinters at the larval stage in Bulgaria, but the life cycle may last two years in

FIGURE 12.83 *Plagionotus floralis* adult. (Courtesy of Boženka Hric [image from Srećko Ćurčić].)

the southern Urals and in western Siberia. The phenology of this pest in Iran is similar to that in Bulgaria (Noushad and Kazemi 1995).

Mitrjuskin (1940) reported that a parasitic wasp (*Bracon lautus* Szepl.) may be an effective natural enemy of *P. floralis*, which could be used for the control of this pest. The author also suggests that the removal of infested plants may be an alternative control measure. Plowing older fields and crop rotation with nonhost crops currently are considered the most effective measures (Imrei et al. 2014). Petkova and Zhekova (2012) have recently tested the resistance and tolerance of several alfalfa hybrids against the pest and concluded that those with the highest forage and seed productivity are attacked the least. Finally, the adult traps mentioned earlier are reasonably effective in adult monitoring and trap-and-kill programs (Toshova et al. 2010; Imrei et al. 2014).

12.9.4 North America

12.9.4.1 Dectes texanus LeConte

Common name: Dectes stem borer

The adults of this lamiine species are 5–16 mm long and pale gray in color, with long gray and black banded antennae (Figure 12.84). It is widely distributed from the eastern United States to Montana and Arizona, and southward to central Mexico and the Cape region of Baja California (Linsley and Chemsak 1995). So far, it has not been recorded outside its native range in North America. The larvae of *D. texanus* feed on a number of herbaceous species from Asteraceae, Brassicaceae, Cucurbitaceae, Fabaceae, Malvaceae, Solanaceae, and Zygophyllaceae (Linsley and Chemsak 1995).

This species is now a serious pest of both soybeans and sunflowers in the United States, particularly in the Midwest (Michaud and Grant 2010; Sloderbeck and Buschman 2011). It infested soybeans in Missouri, Arkansas, Louisiana, and Tennessee in the early 1970s but was not considered important at

FIGURE 12.84 *Dectes texanus* adult. (Courtesy of Whitney Cranshaw, Colorado State University, Bugwood.org [UGA5024026].)

the time (Patrick 1973). A few years later, this species started causing economic losses to soybean crops by larval girdling of the stem prior to harvest (Campbell and Vanduyn 1977). In the meantime, the stem borer has become a serious pest of sunflower crops in the southern Great Plains (Rogers 1977b) by larval burrowing within and internal girdling of the stalks (Rogers 1985). Nearly 40% of soybean plants are infested in Tennessee and Arkansas, with the infestation rates from individual fields varying greatly (0–100%) within states (Tindall et al. 2010). This pest has recently been receiving increased attention as a pest of soybeans in the North American Great Plains and is now well established as a pest of soybeans in at least 14 states across eastern North America (Buschman and Sloderbeck (2010). More recently, serious damage to soybeans was recorded in Kansas (Harris and McCornack 2014) and Nebraska (Rystrom and Wright 2013, 2014). Economic injury occurs when soybean plants become susceptible to late season lodging due to the larval girdling. About 80–90% of sunflower plants in cultivated varieties are infested (Michaud and Grant 2009). The mature larvae girdle the stalks at the base in preparation for overwintering, a behavior that reduces stalk breakage force by 34–40% (Michaud et al. 2007a), leading to significant yield losses through lodging. In Kansas, >70% of sunflower plants are infested, and planting date has no effect on infestation rate (Michaud et al. 2009). The pest also has caused damage to sunflowers in North and South Dakota in recent years (Knodel et al. 2010). According to Michaud and Grant (2005, 2010), the stem borer prefers sunflower to soybean plants if given a choice, and the adults from sunflower plants are heavier and live longer than those from soybean plants.

Biological information is extracted from several studies of soybean and sunflower fields (Patrick 1973; Hatchett et al. 1975; Rogers 1985; Knodel et al. 2010; Crook et al. 2004; Michaud and Grant 2005; Rystrom and Wright 2013). Depending on regions, the adults emerge from June to August and live for about a month. The females start to lay their eggs four to eight days after mating. The eggs are laid singly in the pith of the leaf petioles, side branches, and primary stems of soybeans and in the leaf petioles of sunflowers. Each female lays about 50 eggs in her lifetime. The eggs hatch in 6–10 days. The larvae bore into the pith and tunnel throughout the stem. The larvae are cannibalistic, and only one survives in a single plant. Before overwintering and at about the time when the plants are mature and ready for harvest, the mature larvae girdle the stems near ground level, causing the plants to break off at the slightest pressure. The overwintered larvae pupate from late May to early August. The stem borer has one generation a year.

A number of measures have been developed or tested for the control of this important pest, which are summarized here.

1. *Cultural control:* For the control of this pest on soybeans, winter burial of stems with deep plowing or row bedding methods has proved to be effective in reducing larval survival and adult emergence. Burial of stems at a depth of about 5 cm is sufficient to decrease the larval survival and adult emergence (Campbell and Vanduyn 1977). Because the females prefer sunflowers over soybeans for feeding and oviposition, sunflowers can be planted as the trap crops in the soybean fields to control the pest on soybeans (Michaud et al. 2007b). Michaud et al. (2007b) demonstrated that the females do not avoid ovipositing in plants already containing their own eggs or those of the conspecific females. As a result, sunflower plants can accumulate multiple eggs and subsequent larval combat typically results in the survival of only one. For example, planting sunflowers in the nonirrigated corners of a center pivot irrigated soybean field in 2005 reduced infestation of soybeans by 65% compared with a control field without adjacent sunflowers. In 2006, surrounding a 0.33 ha soybean field with six rows of sunflowers reduced soybean infestation to <5% of plants, compared with 96% of sunflower plants.

   Several cultural measures for the control of this pest in sunflowers are recommended. For example, planting sunflowers before mid-April or after late May in Texas significantly reduces stalk infestation (Rogers 1985). It is also indicated that delayed planting can be a reliable and effective management tool for growers in the central (Charlet et al. 2007a) and southern Great Plains (Knodel et al. 2010). However, planting date has no effect on the pest population in Kansas (Michaud et al. 2009). Ensuring adequate moisture by irrigation during the growing season can assist in reducing stem-infesting insect densities (Charlet et al. 2007b) and irrigated sunflowers have thick stalks, which may reduce lodging and yield losses from the stem borer

(Knodel et al. 2010). Rogers (1985) showed that a single disk and sweep tillage of the sunflower stubble in October and January can cause up to 73.5% and 39.7% mortality of the overwintering larvae, respectively. Finally, reduced plant spacing potentially can delay the onset of girdling behavior by the borer larvae and thus mitigate losses that otherwise result from the lodging of girdled plants (Michaud et al. 2009). In response to doubts as to whether the stem borers attacking soybeans and sunflowers are the same species, Niide et al. (2006) reconfirmed that these borers are the same species and that farmers should not plant soybeans and sunflowers in rotation.

2. *Chemical control:* Chemical control of this pest is difficult because the larvae spend about 10 months inside the stems or in stubbles (Campbell and Vanduyn 1977; Rystrom and Wright 2013). In soybean fields, insecticide sprays and granules prove to be ineffective against the larvae (Campbell and Vanduyn 1977), leaving the potential of chemical control measures to adults. However, sprays of an IGR and a pyrethroid, applied at two-week intervals, are not effective (Andrews and Williams 1988), probably due to a prolonged window of adult activity (Rystrom and Wright 2013). Sloderbeck and Buschman (2011) carried out three-year large-scale field trials in central Kansas to determine whether the stem borer can be controlled at its adult stage. They concluded that the aerial applications of a pyrethroid on July 6, 12, and 15 were successful in significantly reducing adults but that the applications on July 1, 20, and 24 were less successful. These data suggest that, for central Kansas, two aerial applications may be required to control the stem borer in soybeans. Due to the lack of effective sampling methods, treatment thresholds and timing have not yet been established for this pest. Rystrom and Wright (2014) attempted to establish the annual trends in the adult emergence and activity using field cages and regular sweep net sampling in Nebraska for 2013 and 2014. However, these measures can be time-consuming and unreliable. To establish a more reliable monitoring system, Harris and McCornack (2014) have shown some promise in the use of aerial imagery to track and monitor plant health in soybean fields. This may eventually lead to better understanding of *D. texanus* biology, which will aid in developing and implementing site-specific management strategies.

   Chemical control of the stem borer in sunflower fields also proves to be difficult due to the similar reasons described for soybean fields (Knodel et al. 2010), although Charlet et al. (2007a) suggested that chemical control is often reliable in protecting the sunflower crop from the stem pest and relatively insensitive to application timing.

3. *Application of plant resistance:* Richardson (1976) found some evidence of soybean plant resistance against the stem borer over a three-year study. In a more recent study, Niide et al. (2012) have found that no soybean cultivars have resistance to the larval damage. However, these authors show that one of the genotypes tested has plant antibiosis to the larvae and two tested have oviposition antixenosis.

   Michaud and Grant (2009) have investigated why the infestation of wild sunflowers by *D. texanus* is remarkably rare, whereas 80–90% of plants may be infested in the cultivated varieties. They conclude that a combination of physical and chemical properties of wild sunflowers confers substantial resistance to oviposition by *D. texanus* and that this natural antixenosis has been inadvertently diminished in the course of breeding cultivated varieties. In another study, Charlet et al. (2009) also found some potential for developing resistant genotypes in cultivated varieties for this pest in the central Great Plains. Furthermore, in the southern Great Plains, the perennial sunflower species are resistant to stalk infestation by the stem borer, indicating the possibility of breeding cultivars resistant to the pest (Knodel et al. 2010). Further studies are warranted before the plant resistance—including both antixenosis and antibiosis—can be used in the field.

4. *Biological control:* Hatchett et al. (1975) recorded seven species of hymenopteran parasites (representing the families Braconidae, Pteromalidae, and Ichneumonidae) that were reared from *D. texanus* larvae. More than three decades later, a dipteran parasitoid, *Zelia tricolor* (Coquillett) (Tachinidae) (Tindall and Fothergill 2010), and a hymenopteran wasp, *Dolichomitus irritator* (Fabricus) (Ichneumonidae) (Tindall and Fothergill 2012), were reported as attacking *D. texanus* in soybeans. However, to date, none of these natural enemies has been commercially applied for the control of this stem borer in the field.

12.10 Concluding Remarks

This chapter probably is the most comprehensive treatment of cerambycid pests on crops from a global view. It covers 90 cerambycid species of economic importance in Africa, Eurasia, North and South America, and Australasia. Species are ordered based on the main crops they damage, which are divided into eight categories: pome and stone fruit trees; citrus trees; tropical and subtropical fruit trees; nut trees; mulberry trees; cacao, coffee, and tea crops; vine crops; and field crops. Under each species, known distribution, biology, and control measures are provided. Effective measures for management of insect pests usually are developed and designed on the basis of our understanding of their biology. However, essential knowledge of biology of many cerambycid pests is still lacking. Future work should focus on biology of cerambycid pests of crops.

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