Chapter 8
Pests and Diseases of Cinnamon (*Cinnamomum zeylanicum* Blume)

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8.1 Introduction

8.1.1 Importance

Cinnamon (*Cinnamomum zeylanicum* Bloom), belonging to the Family Lauraceae, is indigenous to Sri Lanka and believed to have originated in the central hilly areas of the island. The tree is medium sized and evergreen and the flush is a bright light-red color. The bark of cinnamon, growing up to 10 mm thick, is light brown and possesses a strong, spicy, and aromatic but pleasant smell and a burning taste. The bark of the tree is used worldwide as a valuable spice. From the bark and the leaf, an essential oil is distilled (Kostermans 1996). Cinnamon is cultivated as low bush, about 2–3 m tall, to make harvesting easier. The extent of cinnamon cultivation in Sri Lanka is around 33,000 ha (Anonymous 2018). The country supplies almost 90% of the total true-cinnamon requirement to the world (Anonymous 2017).

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8.1.2 Insect Pests and Diseases of Cinnamon

In spite of the presence of a mixture of essential oils, with antimicrobial, antifungal, or insecticidal properties, in almost every part of the cinnamon (*C. zeylanicum*) (Singh and Maurya 2005), many arthropod pests and fungal pathogens are known to attack the plant. Over 70 species of insect pests have been reported from the cinnamon crop in Sri Lanka (Rajapakse and Kulasekara 1982) and India (Premkumar et al. 1994; Anandaraj and Devasahayam 2004). The majority of them are, however, not economically important. Understanding of the local pest complex is crucial for their management and to keep their population below a damaging economic threshold. The incidence and severity of pests and diseases are highly dependent on the growth stage of cinnamon. In the nursery stage, the young leaves are extremely susceptible to leaf blight and cinnamon thrips leading to collapse of plants and a higher rate of motility, especially during the rainy season. In addition, leaf miner, gall makers, and leaf eating caterpillars also attack young leaves at the nursery stage, the management of which is somewhat easier than that of thrips and leaf blight. The cinnamon crop, from nursery to the first harvesting stage, is susceptible to various pests, root grubs, thrips, leaf galls makers, shot hole borers (Scolytidae), and several diseases including white root disease. Leaf blight, leaf miner, leaf webber, and other minor pests can damage young plants, but the damage is not economically important.

Rough bark disease (RBD), caused by *Phomopsis* sp., is the most common and destructive fungal disease that lowers the yield and the quality of the cinnamon crop. The wood boring moth (*I. cinnamomumi*) is most devastating to mature cinnamon plantations lowering the productivity significantly. White root disease, brown root rot, thrips, stem and stripe cankers, shoot boring weevil, and vertebrate pests are identified as occasional pests that affect the cinnamon crop under conducive weather conditions. Leaf blight, leaf miner, leaf galls, leaf webbers, and leaf eating caterpillars, though present in mature cinnamon plantations, are also of minor importance (Jayasinghe et al. 2016).

Cinnamon thrips (*Dicromothrips* spp.), gall forming mites (*E. boisi)*, gall forming louse (*Trioza cinnamomi*), leaf miner (*Acrocercops* sp.), and root grubs are also occasional pests that damage cinnamon at different stages of cultivation. Red bark beetle (*Zeuzera coffeae*), shoot boring weevil (*Alcipes clauses*), leaf webber (*Sorolopa* sp.), cinnamon butterfly (*Chilasa clytia*), atlas moth (*Attacus atlas)*, seedling borer (*Xyleborus arquatus*), and leaf eating caterpillar, including the lappet moth (*Phyllodesma* sp.), are considered as minor pests.

Leaf, stem, and root diseases can inflict significant yield losses in cinnamon. Leaf blight (*Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc.) is a common disease at all stages of the crop when rainy and humid weather conditions prevail. White root disease (*Rigidoporus microporus* (Fr.) Overeem) and brown root rot (*Phellinus noxius* (Corner) G. Cunn) are very common during the dry seasons when the plants are under stress. The incidence of stem canker and stripe cankers (*Phytophthora cinnamomi* Rands) is occasional. Black sooty mold (*Stenella* sp.), blisters on fruits (*Exobasidium cinnamomi* Petch), horse hair blight (*Marasmius crinis-equi* F. Muell. ex Kalchbr.), and algal leaf spot (*Cephaleuros virescens* Kunze ex E.M.Fries) are common but of minor importance.

Several vertebrate pests, namely, barking deer, rat deer, stag, peacock, squirrels, and hares are also likely to cause significant damage when the cinnamon crop is in close vicinity to forest covers.

8.2 Insect Pests of Cinnamon

8.2.1 Major Insect Pests

8.2.1.1 Cinnamon Wood Borer (*I. cinnamomumi* Tosevskiis)

Level of Importance The larvae of several species of clearwing moth (Sesiidae) are important wood-boring pests (Duckworth and Eichlin 1978). Cinnamon wood boring moth (*Ichneumenoptera cinnamomumi*) Tosevskiis, also known as cinnamon clearwing moth, is native to Sri Lanka and is the most destructive to the cinnamon crop in Sri Lanka (Dharmadasa and Jayasinghe 2000; Jayasinghe et al. 2006).

Symptoms The larvae of the cinnamon clearwing moth feed and tunnel on the stem at ground level resulting in depletion of food reserves, weakening and breakage of stems, die-back of shoots, and rotting of the pruned stems without producing new shoots. Development of numerous adventitious roots, above the damaged point, is a common and characteristic symptom of cinnamon clearwing moth infestation (Jayasinghe 2013).

Life Cycle Females of CWBM deposit eggs in crevices on the base of cinnamon bushes. Eggs are reddish to dark brown and 1 mm long. The incubation period of eggs is about 1 week. Five larval stages span a period of 40–55 days. The larvae bore into the bark and later tunnel into the heartwood. Larvae have a light pink body with a dark brown head; hence, the pest is called pink stem borer. Pupation takes place beneath the bark which lasts about 35–40 days (Fig. 8.1). Emerged adult moths survive for about 3–7 days and male to female population ratio is 2:1. With the increase of air temperature during February to May in Sri Lanka, the population of male moths is reduced significantly (Dharshanee et al. 2008). The moth completes two to three life cycles per year.

Management Biological characteristics and the behavior of the pest make it rather difficult to adopt management practices. Three different management strategies have been introduced in Sri Lanka to manage the CWBM and each practice has its own strengths and weaknesses.

Cultural Methods Although heaping soil at the base of the cinnamon bush, referred to as earthing-up, minimizes laying of eggs on preferred sites and has been found to

Fig. 8.1 The damage caused by cinnamon wood boring moth (*Ichneumenoptera cinnamomumi* Tosevskiis) in cinnamon plants: (**a**) initial damage, (**b**) subsequent severe damage, (**c**) damaged bark, (**d**) development of adventitious roots above the damage point, (**e**) the adult moth, (f) larvae, (**g**) pupae, and (**h**) earthing-up prevents moth damage. (Photographed by G. G. Jayasinghe)

be highly (90%) effective in managing the pest (Jayasinghe and Wickramasinghe 2001; Jayasinghe 2013), the method is difficult to practice in sloping land and plantations with jutted out stem bases, owing to soil erosion.

Chemical Control Insecticides, effective in the control of the pest, are available. However, due to hazardous effect of synthetic chemicals to the environment and possible residual effects in the cinnamon bark to be exported, the use of chemical insecticides is not preferred (Jayasinghe and Wickramasinghe 2001).

Biological Control A novel alternative control method for cinnamon clearwing moth is the use of a pheromone, [(*E*,*Z*)-3,13-octadecadien-1-ol and (*E*,*Z*)-3,13-octadecadienyl acetate] (Grassi et al. 2002; Jayasinghe et al. 2006; Dharshanee et al. 2008), that disrupts the mating pattern of the moth. The slow rate of control and the length of the period taken to manage the pest are drawbacks in pheromone-based management.

Integrated Approaches It is often difficult to rely upon individual strategies to manage the CWBM. Selection of a suitable combination of strategies, depending upon the prevailing climatic conditions, the land size, topography, etc., is advantageous. The most profitable strategy for managing the cinnamon clearwing moth is combining field application of insecticides, immediately after harvest, with "earthing-up" (heaping soil at the base of the bush) and selective pruning, about 3 months after harvest. In well-managed fields with flat terrain, the most suitable and sustainable singular practice is "earthing-up," twice a year (Jayasinghe 2013).

CWBM infestation at certain levels can bring about 50% yield loss through reduced dry-bark yield and a reduced number of harvestable stems per bush or of bushes lost due to pest damage. Two "economic injury levels" (EIL), based on the percentage of damaged bushes (8%) and the number of pests in 100 bushes (10), were established using Benefit Cost Ratio. This can be used in decision-making concerning the management of wood boring moth in cinnamon fields (Jayasinghe 2015).

8.2.1.2 Cinnamon Leaf Gall Makers

Level of Importance Gall forming pests generally cause little damage to plants, as such they do not adversely affect the bark yield since the affected plant parts continue to photosynthesize with near normal efficiency. The yield and the quality of leaf oil might be changed significantly due to gall formation. However, leaf gall infestation represents a prominent pest damage in young cinnamon cultivations and nurseries.

Taxonomy Forty-eight species of psyllids are reported (Hollis and Martin 1997) from lauraceous host plants and a significant majority (72%) of them belongs to the family Triozidae. Mani (1973) reported an unknown psyllid that also induces gall formation in cinnamon in India. Jumping plant louse (*T. cinnamomi*; Homoptera: Triozidae) is principally associated with the foliage of cinnamon causing leaf galls.

Symptoms In cinnamon, two conspicuous leaf gall types are observed:

(i) Upper surface leaf galls, caused by jumping plant louse (*T. cinnamomi*), a homopteran (Rajapakse and Kulasekara 1982)
(ii) Lower surface leaf galls, induced by *Eriophyes boisi*, a mite belonging to the family *Eriophyidae* (Perera et al. 1985)

Both pests are plant suckers and form galls on the leaf blade as their habitat. Feeding by *Eriophyes boisi* or *T. cinnamomi* causes abnormal cell division and formation of galls. Each gall type is identical in shape, but their dimensions are variable. The galls caused by the psyllid (plant louse) and the mite can be distinguished easily by their morphology.

Oil distillation requires cinnamon leaves without galls or with lower levels of galls, in order to maximize a quality product, as leaf gall infestation not only reduces the quantity but also the eugenol content of oil which is required to be maintained above 85% for higher returns at the international market (Dalandawatta et al. 2015). The use of infested cinnamon leaves with galls as raw materials in the cinnamon oil industry will only increase the cost of production per unit weight of oil, and will not render maximum yields in distillation terms.

Management

Cultural Methods The use of healthy plant material and resistant varieties and improving sanitary conditions in nurseries would reduce gall formation. In mature plantations selective pruning helps to reduce pest population.

Chemical Control In situations of intense infestation, a systemic insecticide may be used (Sahabandu et al. 1998)

8.2.1.3 Upper Surface Leaf Galls: The Jumping Plant Louse (*T. cinnamomi*) or Psyllids

Homoptera: Triozidae

Symptoms The insect galls are solitary and widely spread on the upper surface of the leaf (epiphyllous) but not on the veins. They are conical shaped, unilocular, hard, and yellowish-green. The galls measure 2–3 mm in height and 1–2 mm in thickness at the base (Mani 1973). Only one insect lives within each gall until it reaches maturity and the mature insects leave the gall, making a hole on the lower surface of the leaf which turns the gall brown and dry (Fig. 8.2).

Taxonomy and Life Cycle Upper surface leaf galls are caused by the jumping plant louse (*T. cinnamomi*) belonging to Homoptera: Triozidae). Numerous generations are found within a year, each generation lasting for 35–40 days.

T. cinnamomi prefers younger, growing, and incompletely expanded leaves to mature or over matured leaves. Therefore, the gall initiation in cinnamon appears to be largely restricted to young and tender leaves. *T. cinnamomi* also exhibits a strong preference for the top crown level of the tree (Rajapakse and Ratnasekera 1997).

In a study, conducted to determine the nutrient composition of various categories of leaves, it was found that there was no significant relationship between crude protein level and the abundance of galls (Rajapakse and Ratnasekera 1997). However, significant differences were observed in crude fats in young leaves. Although a relationship between a preference for young leaves and crude proteins which is well known for other Homoptera (Warren and Moran 1978) this study has not supported the same.

Fig. 8.2 Insect galls in cinnamon leaf: (**a**) galls formed on the upper surface of cinnamon leaves, (**b**) the upper leaf gall maker (*Trioza cinnamomi*) (×400), (**c**) dried galls after the insects had left the galls. (Photographed by G. G. Jayasinghe)

8.2.1.4 Lower Leaf Galls (*Eriophyes boisi*; Acarina; Eriophydae)

Symptoms Mite-infested galls, mostly formed on the lower leaf surface, that is, hypophyllous, are comparatively larger, more irregular, and softer than the insect galls that are present on the veins and the apical bud. Sometimes the entire apical bud becomes a mite gall and does not develop into a leaf. The mite-infested galls, initiated on the lower surface of young leaves, are ovoid or irregularly conical with a ridged surface, pinkish in color initially and becoming green on maturity. The gall cavity has long hairs and a rugose surface, the color is greenish or yellowish and somewhat ridged. The lower surface is covered by a thin layer of cells which ruptures to permit emergence of the adult (Mani 1973).

Life Cycle Large numbers of four-legged, worm-like Eriophyes mites live in a single gall (Fig. 8.3). Mature mites are spread out of split-dried galls by wind during the dry season. There may be numerous generations per year whose length varies according to the season. After emergence of the adult, the gall dries up and turns dark brown in color. The gall cavity is lined by a small but closely packed mass of cells that lack chlorophyll, surrounded by sclerenchyma and parenchyma cells which also lack chlorophyll. The gall formation results in retardation of growth of plants at young and nursery stages.

Infestation by either the mite or gall insect significantly reduces the leaf oil content by 18 to 43% and lowers the oil quality (Perera et al. 1985). The decline of cinnamon oil content is greater with the increase in the severity of infestation, that is, 10.5% reduction at 25.6% severity which increases to 74.26% at 97.26% severity following mite infestation; 25.9% reduction at 22.7% severity increases to 66.5% at 62.9% severity, after insect gall infestation. Leaf infestation reduces the eugenol content of cinnamon oil that needs to be maintained above 85% for higher returns in the international market (Dalandawatta et al. 2015).

Management The severity of the incidence of leaf galls in cinnamon and the extent of damage vary with the degree of plant resistance and the season. The possibility

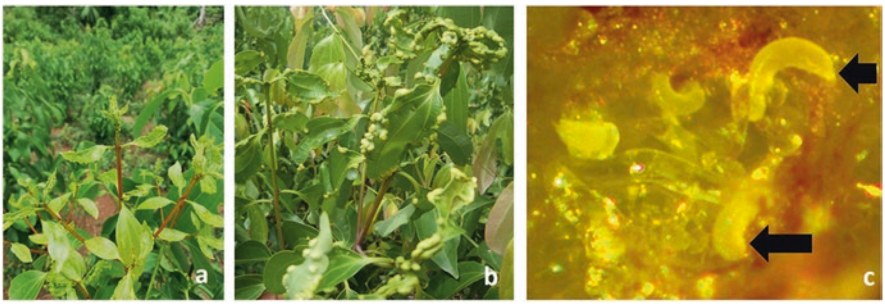

Fig. 8.3 Mite galls in cinnamon: (**a**) initial stage of damage, (**b**) galls formed on lower surface of cinnamon leaves, (**c**) lower leaf gall maker (*Eriophyes boisi*) in cinnamon (×400). (Photographed by G. G. Jayasinghe)

of initiation of both types of galls is greater with the development of new flush with the rain. Infestation becomes critical mostly in nurseries and also in young plantations as the affected plants show retardation of growth. Similar infestations will not cause much economic damage in mature plantations.

Once the initial injury is evident, control measures will have to be implemented before the mites and psyllids become established within the plant, since the damage, once caused, cannot be reversed.

Cultural Methods Periodical selective pruning is the best management practice to remove *Trioza* and *Eriophyes*-infested, gall-bearing shoots, in addition to application of chemicals.

Biological Control Biological control of eriophyid mites and psyllid is difficult because they live inside and feed on galls, which protects the mites from predators. In addition, effective natural enemies for eriophyid mites are not known.

Chemical Control Insecticides/miticides must be applied to prevent further infestation, when initial symptoms become apparent in a few newly emerged flushes (Sahabandu et al. 1998). However, only a limited number of effective miticides are available for controlling eriophyid mites.

8.2.1.5 Cinnamon Thrips

Level of Importance Infestation by cinnamon thrips may result in significant yield losses in mature cinnamon plantations while severe growth retardation can occur in nurseries and plants at young stage. The thrips that infest cinnamon crops have not been identified and their taxonomy is not known.

Symptoms Thrips damage results from the piercing and rasping action of their cone-shaped mouth parts. Thrips damage can be easily identified by the symptoms. Initially minute, dark green spots appear on the leaf and with time these turn into white or silver. If widespread, these can give a silvery and streaked appearance (Fig. 8.4).

Life Cycle The life cycle of thrips from egg to adult may be completed within 2 weeks. Thrips damage is greatest after periods of hot, dry weather. Cool, rainy weather reduces thrips populations and damage.

Management

Cultural Methods Good crop management and field sanitation generally keep thrips damage to a minimum. Thrips have a wide range of hosts including numerous weed species. Weed management in and out of cinnamon plantations reduces the level of thrips.

Fig. 8.4 Thrips damage in cinnamon: (**a**) thrips infestation of new shoots emerged after a harvest, (**b**) damage to young shoots, (**c**) die-back of the plant after thrips damage, (**d**) leaf shedding after thrips damage, (**e**) damage to nursery plants, (**f**) nymph (×10) sucking sap underside the leaves, (**g**) adult thrips (×100). (Photographed by G. G. Jayasinghe)

Biological Control Effective biological control methods using natural predators and parasitoids need to be developed.

Chemical Control Management practices involving treatment with an effective insecticide have been developed for nurseries and younger plantations. Use of synthetic insecticides in mature plantations is not, however, desirable because of possible environmental effects and residual issues concerning the final product.

8.2.1.6 Cinnamon Red Borer (*Z. coffeae* Nietn. Thysanoptera: Cossidae)

Cinnamon red borer (*Z. coffeae* Nietn.) is a generalist pest, that is, one found in a vast range of crop plants. This is one of the earliest known pests, first described in 1861 by John Nietner and was first recoded in Sri Lanka by Rutherford (1913).

Symptoms The damage to the host plant is caused by the caterpillars of the cinnamon red borer. The caterpillars bore into the bark and twigs of different host plants and make tunnels inside the stem and the root. When tunneling is in progress, withering of leaves is common in the cinnamon plant and at severe stage, the stems or whole bushes die off. Dark brown excreta, coming out of the holes made by the pest, is characteristic for identification of the pest. The feces are globular in shape and 3–5 mm in diameter, bigger than the excreta of the cinnamon wood boring moth.

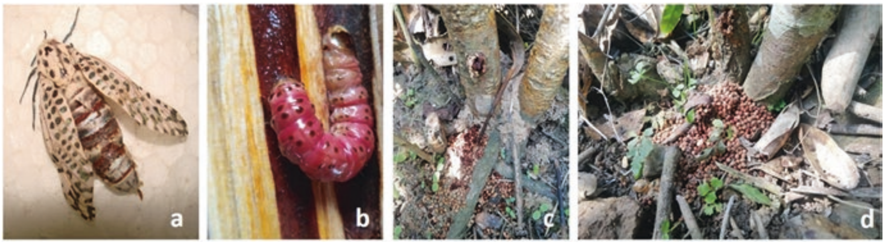

Fig. 8.5 Cinnamon red borer: (**a**) adult borer (*Zeuzera coffeae*), (**b**) larvae living inside the cinnamon stem, and (**c**, **d**) nature of the damage. (Photographed by G. G. Jayasinghe)

Life Cycle Adult moth is white in color and 30–40 mm in size when the wings are expanded. Males are comparatively smaller in size than females. Small black dots are present in the forewings and the outer margin of hind wings (Fig. 8.5). The abdomen is long and posteriorly tapering. Bipectinate antennae are present and proboscis absent in both sexes. Emerging young larvae are slender, soft, and red in color. The eggs that are deposited by copulated female moths in rows on host plants are hatched after 10 days. The larvae bore into the stems or twigs start making tunnels after feeding on the pith of plants. Larvae become fully matured in 4–5 months and are dark red in color and 40 mm long. After 3–4 weeks of pupation, the emerging moth comes out from a hole that the larvae make before pupation. It takes 5–6 months to complete the life cycle (Chang 1984).

Management

Cultural Methods Removing and burning of severely infested branches or twigs is effective in reducing the pest population.

Chemical Control Since larvae live safely inside the stem or twigs in host plants, chemical spraying will not be very effective. Instead a cotton bud, soaked with an insecticide, may be inserted into the tunnel through the hole that the larvae have made in cinnamon stems.

Integrated Approach An integrated management system, using larval parasitoids with chemical, mechanical and cultural methods, has been developed (Ahmad 2017).

8.2.1.7 Cinnamon Root Grubs (*Anomala* sp. Scarabaeidae)

White grubs are among the most destructive pests in certain cinnamon growing areas, especially when the cinnamon plants are at young stage.

Life Cycle Some beetle grubs, including *Anomala* species, feed on the roots of grasses, and younger plants. Population of root grubs might be very high in soils rich in organic matter. Though mature cinnamon plants show resistance to root grub,

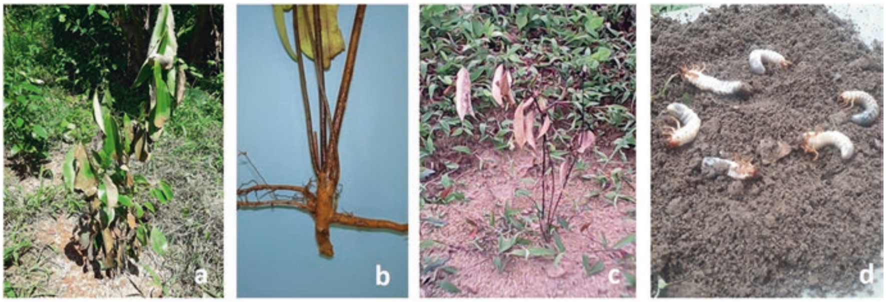

Fig. 8.6 Root grubs (*Anomala* sp.) damage in cinnamon, (**a**–**c**) nature of the damage and (**d**) grubs living in soil. (Photographed by G. G. Jayasinghe)

newly established young cinnamon plants are most vulnerable to the pest (Fig. 8.6). Damage can be more severe with the onset of the rainy season, after a long dry period, because starving grubs start feeding on roots voraciously after spending an inactive period during the dry spell.

Management

Cultural Methods Clean weeding is not recommended when grubs damage is severe.

Chemical Control Soil drenching with a suitable chemical where new cinnamon seedlings are established after removing all damaged plants is recommended. Alternatively, the chemical may be added to the planting sites, a day before planting. These are effective in managing root grubs, when the cinnamon plants are still at young stage. Repeated application of the chemical after 2 weeks kills newly hatched larvae since eggs tend to resist the insecticide to a certain extent.

8.2.1.8 Cinnamon Shot-Hole Borer (Scolytidae)

Shot-hole borer damage is very common in cinnamon when the seedlings are overmatured more than 2 years at nurseries. Though the exact species of the shot-hole borer in cinnamon is not known, the morphology of the shot-hole borer, the symptoms of infested plants and the damage caused are almost same as those of *Xylosandrus compactus* (Eichhoff).

Biology Tiny Scolytidae beetles deposit eggs only in sufficiently matured stems, that is, when the stems reach the girth of more than 5 mm which is needed for establishment of beetle galleries. Galleries are infected with a symbiotic fungus that the beetle carries in its mouth parts. Females lay eggs in galleries. Eggs hatch and larvae feed on the fungus. Off-white tiny eggs, typical C-shaped legless larvae of weevil,

Fig. 8.7 Shot-hole borer damage in cinnamon: (**a**–**c**) nature of damage, and (**d**) adult beetle. (Photographs courtesy Janaka Chandana)

and white colored pupae can be seen in the galleries. Newly emerged adults, with fungus inoculums, come out from galleries and spread to new host plants.

Symptoms Infested seedlings show leaf and stem necrosis extending from the entrance hole. Five to seven days after gallery formation, the twigs, branches, or the entire plants start wilting (Fig. 8.7). Cinnamon seedlings collapse due to the breakdown of the stem at the point of pest damage.

Management

Cultural Practices Removal and destruction of infested plants is the most effective and recommended cultural practice.

Chemical Control Chemical control is essential when the infestation is severe.

Biological Control Biological control and breeding for resistance would be economically feasible and ecofriendly, but only a few efforts on these lines have been reported (Walgama 2012).

8.2.2 Minor Insect Pests

8.2.2.1 Cinnamon Butterfly, the Common Mime (Lepidoptera: Papilionidae) (*Papilio clytia* (Synonym: *C. clytia*)

P. clytia is a species belonging to the swallow tail butterfly family, Papilionidae, which is common in Sri Lanka, India, and some South East Asian countries. The larvae feed on young leaves of cinnamon. There are two different color forms for each sex, “clytia” and “dissimilis” (van der Poorten and van der Poorten 2011).

Level of Importance Cinnamon butterfly is not an economically important pest in Sri Lanka. However, *C. clytia*, is one of the major pests in cinnamon in India, responsible for severe damage (Singh et al. 1978).

Life Cycle The butterfly lays eggs singly on the upper and lower surfaces of young leaves. The eggs are spherical, waxy looking, and orange-yellow in color. The larvae feed on tender and slightly mature leaves. In cases of infestation, only the midribs of leaves with portions of veins are left behind or the entire plant is defoliated. The larval period (five instars) lasts for 11–17 days. The fully-grown larvae are pale yellow with dark stripes on the sides and measure about 2.5 cm in length. The caterpillars resemble bird droppings (defensive mimicry) at initial stages. The pupae are cylindrical and remarkably well camouflaged by fixing on to a branch so that they resemble the end of a broken twig. The pupal period lasts for 11–13 days and the total life cycle takes 24–36 days (Rajapakse and Wasantha Kumara 2007). Bell (1912) reported that the moth is seen in large numbers during monsoon months in India and spends the dry months as pupae (Fig. 8.8). Eggs are heavily parasitized by the egg parasitoid *Telenomus remus* (Rajapakse and Wasantha Kumara 2007).

Management

Cultural Practices Hand removal of larvae and pupae in lighter infestations is effective (Butani 1983).

Chemical Control Spraying tender and partly matured leaves with an effective insecticide may control the pest in severe infestations.

8.2.2.2 Atlas Moth, *A. atlas* (Linnaeus 1758)

Level of Importance The Atlas moth is said to be the world's largest moth and was first described by Linnaeus (1758) as a pest in cinnamon. Giant larvae voraciously feed on younger and semi-mature leaves of cinnamon, causing heavy damage to

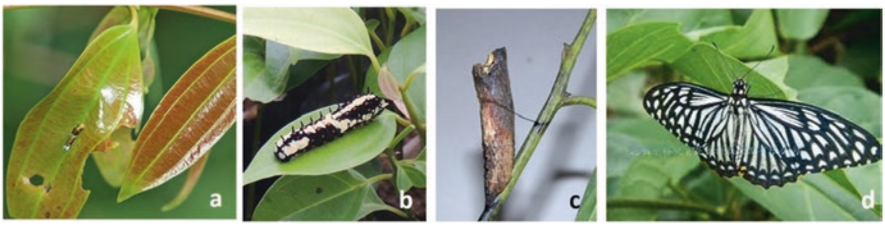

Fig. 8.8 Cinnamon butterfly (*Papilio clytia*): (**a**) initial damage to cinnamon, (**b**) mature larvae, (**c**) pupae, and (**d**) the adult. ((**b**, **d**) Photographed by G. G. Jayasinghe; (**a**) (http://krishimala.com/catalogue/cinnamon-butterfly); and (**c**) (https://commons.Wikimedia.org/wiki/File:Chilasa_clytia_pupa.jpg))

cinnamon plants. Since the number of larvae is limited, the damage is not economically significant. The Atlas moth is present in Asian countries, including India, Sri Lanka, and Philippines, and depends on a wide variety of host plant range, including cinnamon (Ahmed 2013).

Life Cycle The lack of mouth parts in adult moths makes them incapable of feeding on leaves, but they survive for a few days until fertilization takes place and eggs are laid, using food reserves built up during the larval stage. A powerful pheromone-mediated mating system helps fertilization and production of eggs. Oval-shaped eggs are deposited on the leaves of host plants and caterpillars are hatched from eggs after a few days. Larvae are grown gradually up to a length of 40 mm which, after five moltings within 60 days, are moved to a suitable place to pupate (Fig. 8.9).

Pupae start making strong silken cocoons around a suitable leaf and about 12 days after the pupae are formed the final molting takes place inside the cocoon. Eclosion occurs 25–30 days from pupating. Emerging adults spend 2 hours hanging out their wings, by pumping air through them, until their wings become fully functioning. The male moth remains within the pupal case until a night before flying off to seek a virgin female to mate with.

8.2.2.3 The Leaf and Shoot Webber (*Orthaga vitialis*): (Lepidoptera: Pyralidae)

Level of Importance The leaf and shoot webber (*Orthaga vitialis*) infests cinnamon crop but the damage caused is not significant or economically important in Sri Lanka. In India, the damage by the shoot and leaf webber, *Sorolopha archimedias*, has been reported as a major pest (Singh et al. 1978).

Life Cycle The adult leaf and shoot webber (*Orthaga vitialis*) is a yellow brown to dark brown moth and the larvae are very active, brown in color, and web the leaves and the terminal shoots into clusters (Fig. 8.10).

A webbed cluster of leaves harbors several larvae. The larvae are gregarious at the beginning and feed by scraping the leaf surface. Pupation takes place within the webbed-up cluster for 11–14 days. The larval period extends to about 28–30 days (Rajapakse and Wasantha Kumara 2007).

Fig. 8.9 Atlas moth (*Attacus atlas*): (**a**) adult moth, (**b**) larva, and (**c**) with pupal case. ((**a**, **c**) Photographed by G. G. Jayasinghe and (**b**) Photograph caurtesy Chinthaka Vidhanapathirana

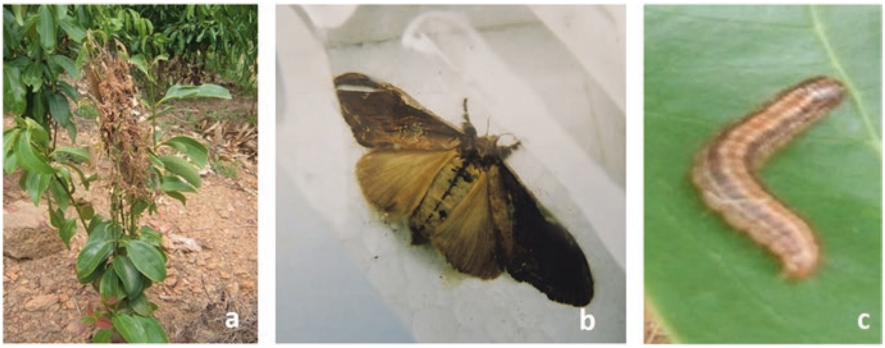

Fig. 8.10 Cinnamon leaf and shoot webber (*Orthaga vitialis*): (**a**) nature of damage, (**b**) adult moth, and (**c**) larvae. (Photographed by G. G. Jayasinghe)

Management

Cultural Practices Regular inspection of the plantation and pruning infested clusters followed by destruction is a good cultural control method. Since the leaf and shoot webber is not an economically important pest in cinnamon in Sri Lanka, removing and destruction of nests are sufficient to manage the pest.

8.2.2.4 Common Blue Bottle (*Graphium sarpendum*); Lepidoptera; Papilionidae)

The blue bottles are common butterflies and seen year-round in cinnamon growing areas.

Life Cycle In flight, the beautifully contrasting fluorescent blue and black are unmistakable and the sexes are similar (Fig. 8.11). The common blue bottle and Tailed Jay, *Graphium agememnon*, are among the fastest nectar feeders of butterflies found in Sri Lanka (van der Poorten and van der Poorten 2011).

Eggs are laid on the lower surface of tender leaves and are completely round, smooth and yellow when they are first laid. The eggs last for 5–6 days. The first instar caterpillar is very spiny and of a smoky color. They are very sluggish and at first keep to the undersurface of leaves, feeding on them, and later they seem to favor the midrib on the upper surface of the cinnamon leaf. As the caterpillar grows older, it becomes green and quite well concealed by its green camouflage. The larval stage (five instars) lasts 29–31 days. They pupate on the underside of the leaves, stalks or small branches and the pupal period lasts for 19–20 days. The life cycle is about 59–60 days. The larvae of the Common Jay *G. dosonis* are also reported to be feeding on the tender leaves of cinnamon (Bell 1912).

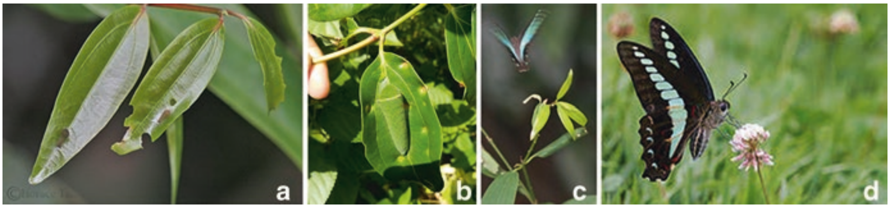

Fig. 8.11 Common blue bottle (*Graphium sarpendum*): (**a**) young larvae (http://butterflycircle.blogspot.com/2009/01/life-history-of-common-bluebottle.html), (**b**) mature larvae Photograph caurtesy Chinthaka Vidhanapathirana, (**c**, **d**) adults (https://en.wikipedia.org/wiki/Graphium_sarpedon#/media/File:Common_bluebottle,_Keitakuen,_Osaka.jpg)

8.2.2.5 The Leaf Miner, *Acrocercops* spp. (Lepidoptera: Gracillaridae)

Level of Importance Leaf miner (*Acrocercops* spp.) is listed in Sri Lanka as a minor pest of cinnamon. However, *Conopomorpha civica* and *Phyllocnistis chrysophthalma* Meyer are considered as major leaf mining pests in India (Devashayam and Koya 1997; Butani 1983) where *C. civica* infestation of cinnamon seedlings has caused over 20% loss.

Life Cycle The adult is a tiny silvery moth. The females lay minute flat eggs singly on the lower surface of th.3e leaves, close to the midrib. The eggs are hatched in about 2–6 days. The pale gray larvae enter the leaf tissue by mining (Fig. 8.12). They feed on tissues between the upper and lower epidermis of tender leaves resulting in linear mines that end in blister like patches.

Symptoms The infested leaves become crinkled and the mined areas dry up, leading to formation of large holes on the leaves. The mined leaves turn pale and curl up and the development of young leaves is retarded.

Management Appropriate insecticide sprays, at nursery and young stages of plants and during the emergence of new flush, are generally effective in preventing leaf miner infestations.

8.2.2.6 Shoot Boring Weevil: *A. clauses*: Curculionidae

This is a localized weevil, found in hilly areas like Ratnapura District (Sabaragamuwa Province) in Sri Lanka, where relatively cooler weather conditions prevail.

Life Cycle The shoot boring weevil (*A. clauses*) feeds on young shoots, emerging after a harvest and also pruning. They lay eggs inside young, developing shoots. Larvae emerging after 5–6 days also start feeding on young shoots and the larval period ends after four moltings. Larvae pupate within 20–30 days and pupae take another 15–20 days to become adults. The male weevil is slenderer than the female. Each female lays a single egg in a day and 10–20 eggs in its life time of 30–40 days. Multiple mating can occur during the life time of a weevil. Weevils complete –three

Fig. 8.12 Cinnamon leaf miner (*Acrocercops* spp.): (**a**) mild damage, (**b**) severe damage. (Photographed by G. G. Jayasinghe)

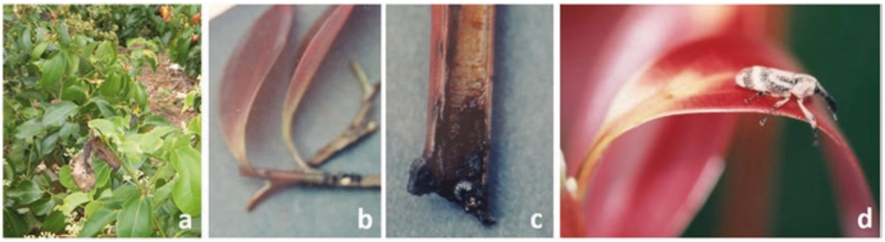

Fig. 8.13 Cinnamon shoot boring weevil (*Alcipes clauses*): (**a**) symptoms of damage, (**b**) eggs inside the stem, (**c**) the larvae, and (**d**) adults living freely. (Photographed by G. G. Jayasinghe)

to four life cycles within a year when young shoots are available (Fig. 8.13) (unpublished data).

Symptoms Damaged plants take a rosette-like appearance where multiple stems and branches do not become straight enough for processing into cinnamon sticks of good visual quality.

Management

Cultural Practices Pruning or removal of damaged shoots followed by their destruction will lower the pest population and infestation of plants. Depending on the population size, hand picking of adults, and their destruction may be carried out.

Chemical Control When the damage is likely to be severe, application of an effective insecticide would be needed.

8.2.2.7 Fruit Borer (*Alcides morio* Heller) (Coleoptera: Curculionidae)

Level of Importance Grubs (*A. morio* Heller) bore tunnels leading to the cinnamon seed and feed on the inner contents of the seed. The damage is economically significant since cinnamon is propagated through seeds.

Life Cycle The mature grub has a brownish head with a whitish body which attains 8–10 mm in length. The females are larger than the males. Pupation takes place inside the seed and lasts for 7–9 days. The weevil makes a circular hole on the seed coat to emerge. They are dirty black in color and not active. The longevity of the beetle is 5–7 days (Premkumar 1988).

8.2.2.8 Leaf Eating Caterpillar *Euproctis fraterna* (Lepidoptera: Lymantriidae)

The larvae of *E. fraterna* feed voraciously on leaves. Initially the larvae scrape the green matter leading to skeletonization of leaves. Later the larvae move into other parts of the plant and finally defoliation occurs. The larval stage of this hairy caterpillar lasts for 13–29 days and the pupal period is 9–20 days, making the total life cycle lasting for 6–7 weeks (Rajapakse and Kulasekara 1982).

8.2.2.9 Leaf Eating Caterpillar *Dasychira mendosa* (Lepidoptera: Lymatriidae)

Due to the broader nature of their host range, the larvae of the moth *D. mendosa* feed on the foliage of a range of plant species, including cinnamon. Breeding continues throughout the year during which there are probably five or six generations. The moth, with pale yellow hind wings and forewings, is irregularly patterned with various brown shades. The female lays large masses of eggs. Feeding by larvae results in defoliation and the larval period lasts for 21–28 days. A fully grown hairy larva has a reddish head and a grayish or yellowish body, striped with red and long, dense dorsal tufts of whitish hairs. They pupate in loose cocoons, made of silk and hairs and the pupal period lasts for 11–12 days (Rajapakse and Kulasekara 1982). Application of insecticides would keep most of the caterpillars under control.

8.2.2.10 Looper Caterpillar (*Thalassodes* spp.) Lepidoptera: Gracillaridae

Thalassodes species are looper caterpillars, found feeding on developing cinnamon leaves. The larval period lasts for 17–18 days. Larvae possess a color the same as that of newly emerging shoots, and assume a characteristic pose on the twig, which is often mistaken for a leaf petiole. The pupal period lasts for 7–8 days (Rajapakse and Kulasekara 1982).

8.2.2.11 Other Minor Pests

Agroploce aprobola (Lepidoptera: Encosmidae), the scale *Ceroplastes rubens* Maskell (Homoptera: Coccidae), the sucking bug *Coptosoma pygmaeum* Mont (Heteroptera: Plataspidae), and *Leptocentrus obliquus* Walker (Homoptera: Membracidae) are considered as minor pests of cinnamon in Sri Lanka (Rajapakse and Kulasekera 1982). The chrysomelid beetles, *Coenobium lateralis* Weise, *Cryptocephalus snillus* Suffr, *Cryptocephalus virgule* Suffr, and *Podagric abadia* Harold were also found feeding on developing cinnamon leaves and shoots in Sri Lanka (Rajapakse and Kulasekara 1982). Damage by the larvae of *Leucopho lispinguis* Burmeister (Coleoptera: Scarabeidae) in nurseries of cinnamon has been reported.

Bhumannavar (1991) reported the presence of the tortricid *Sorolopha archimedias* (syn. *Eudemiopsis archimedias*) in cinnamon in South Andaman, India. Damage by the chaffer beetle *Popillia complanata* and a leaf beetle *Singhala helleri* has been reported in India (Singh et al. 1978). *Oecophylla smaragdina* F. (Hymenoptera: Formicidae) are a nuisance as the adult ants form nests from the leaves (Rajapakse and Wasantha Kumara 2007).

8.3 Diseases of Cinnamon

Despite the higher number of diseases reported in *C. zeylanicum*, only a few are significantly affecting the yield or the quality of cinnamon. Among them, rough bark disease (*Phomopsis* sp.), stripe canker (*Phytophthora cinnamomi* Rands), foot rot (*Fusarium oxysporum* Schltdl.), stem canker, leaf blight (*C. gloeosporioides* (Penz.) Penz. & Sacc.), white root disease (*R. microporus* (Fr.) Overeem.), and brown root rot (*P. noxius* (Corner) G. Cunn.) are common in cinnamon causing significant yield losses.

Diseases like blisters on fruit (*E. cinnamomi* Petch), gray leaf blight (*Pestalotia* sp.), thread blight (*Marasmius equicrinis* F. Muell. ex Berk.) (Dassanayake et al. 2009), witches' broom (Phytoplasma), and algal leaf spot (*C. virescens* Kunze ex E.M.Fries) are considered minor, occurring mostly in badly managed cultivations.

8.3.1 Major Diseases in Cinnamon

8.3.1.1 Rough Bark Disease (*Phomopsis* sp.)

Level of Importance Rough Bark Disease (RBD) has become a major threat to the cinnamon industry in Sri Lanka, causing severe losses of yield and quality of the product.

Pathogen The causal agent has been identified as *Phomopsis* sp. (Jayasinghe and Ratnasoma 2013). In another study, the involvement of several fungal species has been shown (D. M. de Costa, Personal communication). A scab-like condition, similar to RBD and affecting the quilling efficiency, was also reported (Kumara 1999a).

Symptoms Disease development initiates with the appearance of tiny black dots in 4–6 months old, greenish, semi-hardwood stems. With the advancement of disease, the black dots enlarge and turn into brown color lesions with a prominent black color margin which is characteristic of RBD (Fig. 8.14c). Within 2–3 months, the disease reaches a critical or irrecoverable stage where the fungus invades the xylem tissues of the stem causing blockage of water uptake, and also minerals, and interveinal chlorosis of foliage (Fig. 8.14e) (Jayasinghe et al. 2017).

The infected plants at a critical stage may exhibit branch die-back, leaf shedding, and/or poor stem growth above the diseased tissues. Symptoms of deficiency of nutrients, N, P, K, Mg, Ca, or Fe, appear when the disease progresses, although the soil nutrient levels remain unchanged at different stages of disease progression, suggesting that RBD infection blocks the upward movement of mineral nutrients in the plant. RBD reduces the quality, color, thickness, and the moisture content of bark and the quantity of bark oil (Jayasinghe et al. 2018). The efficiency of peeling is also adversely affected as diseased barks are difficult to be peeled off.

Though the pattern of progression of rough bark disease resembles a typical growth curve, it shows a slower disease progress within the first 10 weeks after initiation (Jayasinghe et al. 2018). This lengthy initial period of slower disease progress appears to be the easiest stage for management of the disease with lesser effort and cost.

Fig. 8.14 Rough bark disease (*Phomopsis* sp.) in cinnamon: (**a**) Initial stage of the damage, (**b**) and (c) moderate level of damage, (**c**) severe damage with bark splitting, (**d**) final stage of the disease, the leaves show interveinal chlorosis with leaf necrosis. (Photographed by G. G. Jayasinghe)

Disease Management

Cultural Practices The fungus survives on diseased crop residues. The spread of RBD can be controlled by removing and destroying diseased plants and by adoption of appropriate cultural practices such as harvesting at correct intervals and removing infected branches periodically.

Chemical Control Protectant fungicides, 1% Bordeaux mixture, copper-based fungicides, copper hydroxide or copper oxychloride and systemic fungicides have been tested with considerable success (Jayasinghe and Ratnasoma 2013).

8.3.1.2 Leaf Blight (*C. gloeosporioides*)

Level of Importance Leaf blight, caused by *C. gloeosporioides* (Anandaraj and Devasahayam 2004; Kumara 1999a), can be observed in almost every cinnamon growing area in Sri Lanka. The disease directly affects the foliage.

A moderate level of foliar damage (18%) had been reported due to this disease in Matara District (Southern Province, Sri Lanka); however, any significant correlation between the cinnamon yield and the disease severity has not been established (Kumara 1999a).

Critical Factors Affecting the Disease The fungus initiates infections in younger leaves during rainy weather. Shady and humid conditions can predispose the plants to infection and increase the severity of disease. Although the disease appears in cinnamon crop at all stages of growth, the plants bearing new flush and those at the nursery or young stages can be heavily affected, resulting in the collapse of seedlings and retardation of growth. A considerably higher disease incidence was observed in poorly weeded lands with greater shade and planting densities, and improper pruning practices (Kumara 1999a, b).

Symptoms The symptoms in young leaves include the development of small, brown specks on the leaf lamina which later coalesce to form larger, irregular necrotic lesions. These may be spread further giving to the entire leaf a scorched appearance (Fig. 8.15). The lesions remain as large, brownish areas on older leaves. The entire diseased areas may later become papery with dark brown margins. Sometimes the central portion of the spot is shed, giving the lesion a shot-hole appearance. Lesions may extend from either the tip of the leaf or from the leaf margins. With severe infections, lesions may become larger than a half of the leaf. In some seedlings, the infection spreads to the stem causing the leaves to be shed and finally leading to die-back (Karunakaran and Nair 1980).

Fu and Chang (1999) have reported the occurrence of brown to black spots on *Colletotrichum*-infected leaves of *Cinnamomum verum* in Taiwan. These spots later coalesce into larger areas and the infected leaves are shed. The pathogen was identified as *C. gloeosporioides* or its sexual form, *Glomerella cingulata*. Partial drying

Fig. 8.15 Leaf blight disease (*Colletotrichum gloeosporioides*) in cinnamon, (**a**) initial symptom, (**b**) damage in young plantation, (**c**) severe damage, (**d**) nursery plants severely affected in the rainy season. (Photographs (**a**, **b**, **d**) by G. G. Jayasinghe and (**c**) by K. L. Wasantha Kumara)

of the seedlings due to *C. gloeosporioides* (*G. cingulata*) was also demonstrated, 7 days after artificial inoculation of healthy cinnamon seedlings with the pathogen (Bhat et al. 1988). This can be another stage of the disease or a symptom under the prevailing conditions.

Pathogen The genus *Colletotrichum* comprises a highly diverse group of pathogens infecting a wide range of plant hosts. Recent molecular studies have enabled researchers to identify many new *Colletotrichum* species and understand the taxonomical position of species that were known for decades and identified using morphological characteristics.

The entry and infection of host tissues by *Colletotrichum* spp. generally starts with the germination of conidia and the formation of infection structures, appressoria, that facilitate entry through the host cuticle, and epidermal cell walls. Infected leaves, twigs, etc., function as sources of inoculum which is generally dispersed by rain splash.

Disease Management

Cultural Practices Removal and destruction of infected parts improve sanitary conditions and lower fresh *Colletotrichum* infections.

Chemical Control Many effective, systemic fungicides are available to combat *Colletotrichum* infections in the field. Copper-based fungicides are also recommended to control the disease. Application of water-soluble sulfur on the emerging new flush, prior to initiation of leaf blight symptoms at nursery stage as a preventive measure, was found to be very effective in preventing *C. gloeosporioides* infection (Dharshanee et al. 2010).

8.3.1.3 White Root Disease (*R. microporus;* syn. *R. lignosus*)

Level of Importance White root disease, caused by *R. microporus* (Fr.) Overeem (Syn. *Rigidoporus lignosus*), is regarded as one of the most destructive root diseases in rubber (*Hevea brasiliensis*) plantations. The fungus, causing white root rot of tropical crops, was first described as a pathogen of rubber.

Critical Factors That Affect the Disease The disease is commonly found in cinnamon when it is planted in lands that had previously been used for rubber cultivation. The cinnamon tree is somewhat resistant to the fungus. However, under stress conditions during dry periods or when the cinnamon crop is cultivated in close vicinity to rubber plantations or in lands where cinnamon was planted after uprooting rubber, the plant is vulnerable to white root disease. *R. microporus* persists in dead or live root debris for a long time and causes new infections in healthy plants.

Symptoms Externally, yellowing and subsequent shedding of leaves, wilting, and die-back of branches or the whole tree are the main above ground symptoms of white root disease. The external white rhizomorphs are firmly attached to the root and the collar which become yellowish and later reddish. The leading edge of mycelium that is advancing appears as a continuous sheath, like a fan on the bark surface.

Pathogen The fungus belongs to the Phylum Basidiomycota and is classified under Agaricomycotina, Agaricomycetes, Polyporales, and the Family Meripilaceae. Fruit bodies or basidiocarps are formed at advanced stage of the disease or after the death of the infected trees (Fig. 8.16). The basidiocarp is brownish-orange with a bright yellow margin when fresh, while the lower surface appears reddish-brown and shows characteristic concentric zones (Omorusi 2012). The fungus has a wider host range, extending to over 100 woody plant species (Jayasuriya and Thennakoon 2007).

Disease Management Integrated approaches are vital for long-term management of white root disease in cinnamon.

Cultural Practices Application of sulfur dust to planting holes is recommended at the time when cinnamon cultivations are established, especially when in close vicin-

Fig. 8.17 Brown root rot disease (*Phellinus noxius*) in cinnamon, (**a**) above ground symptoms, (**b**) root symptoms, (**c**) leaf symptoms, and (**d**) basidiocarp development in dead trees or stumps. (Photographed by G. G. Jayasinghe)

ity to rubber plantations or lands where rubber was cultivated previously. Infected, dead plants and their roots must be uprooted and burned as a preventive measure to stop spreading the disease.

Chemical Root bases should be cleaned and an effective fungicide must be applied to the base of infected plants.

Biological Possible use of *Trichoderma harzianum* isolates, antagonistic to *R. microporus*, in the control of white root disease has been investigated and some *T. harzianum* strains collected from rubber established soils have shown significant control of pathogen in vitro (Jayasuriya and Thennakoon 2007).

8.3.1.4 Brown Root Rot (*P. noxius* (Corner) G. Cunn.)

Brown root disease is caused by the fungus, *P. noxius* (Chang and Yang 1998), especially when *C. zeylanicum* plants are grown under unsatisfactory drainage conditions or in shade. The fungus is known to have a wide host range (Ann et al. 2002). Brown root disease caused by *P. noxius* is also reported in *Cinnamomum camphora* (Chang 1992).

The fungus belongs to Basidiomycota and classified under the Phylum Basidiomycota, Agaricomycotina, Agaricomycetes, Hymenochaetales, and the Family Hymenochaetaceae.

Symptoms Leaves in infected trees turn brown and show wilting symptoms, and some bushes immediately die. Leaf wilting in brown root rot affected trees takes place faster than those in plants with white root disease. The fungus produces thin, hard and uneven basidiocarps which are initially yellowish-brown with a white margin and later on become brown and then dark gray when the host plant dies (Fig. 8.17).

Disease Management

Cultural Lands which were previously used for rubber cultivation or lands in close vicinity to established rubber plantations should be avoided for cinnamon cultivation. Provision of sufficient sunlight to the cinnamon crop by removing nearby trees, branches, etc., that cut off the sun and improving drainage would help reduce the incidence of disease. Infected and dead plants must be uprooted with the root system and burnt to destroy the pathogen.

Chemical Root bases of plants, suspected to be infected, or plants with initial symptoms, should be cleaned and treated with an effective fungicide. Alternatively, sulfur may be applied to the bases of infected plants.

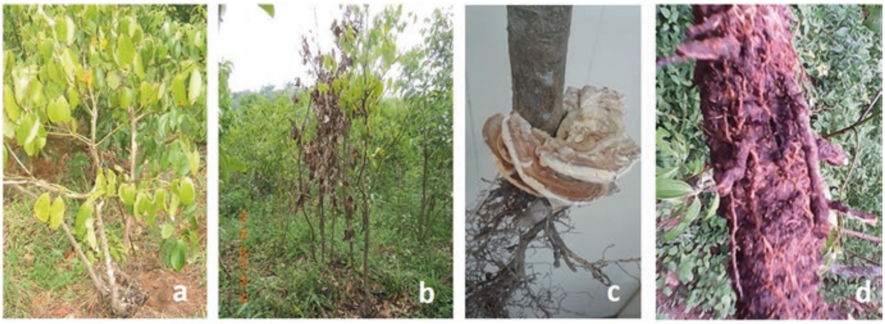

Fig. 8.16 White root disease (*Rigidoporus microporus*) in cinnamon: (**a**) initial symptom, (**b**) a plant that died due to the disease, (**c**) basidiocarps develop at the final stage of the disease, and (**d**) clearly visible fungal mycelium in infected roots. (Photographed by G. G. Jayasinghe)

8.3.1.5 Stripe Canker (*Phytophthora cinnamomi*)

Stripe canker of cinnamon is caused by an Oomycete, *Phytophthora cinnamomi* (Rands 1922). *P. cinnamomi* attacks shoots and young stems of cinnamon. Rands (1922) first reported *P. cinnamomi* causing severe losses to forest trees and avocado (*Persea americana*) and as the causal agent of stripe canker of *C. verum*. The pathogen also infects other cinnamon species, *C. camphora, C. culitlawan* and *C. sintok* (Rands 1922; Djafaruddin and Hanafiah 1975).

P. cinnamomi, isolated from pineapple, was also reported pathogenic on cinnamon, but with reduced virulence (Anandaraj and Devasahayam 2004). This may indicate the possibility of cross infection by *P. cinnamomi.*

Symptoms Stripe canker is found on the trunks and branches of *C. verum* and *C. burmannii*, particularly of young trees in Indonesia (Mehrlich 1934). Vertical stripes are seen on the stems with amber color exudates at the advancing margins which harden later. Vertical stripes of dead bark are most numerous near ground level (Fig. 8.18). The disease is prevalent mostly on ill-drained soils.

Pathogen *P. cinnamomi*, belonging to the Phylum Oomycota, is no longer considered a true fungus to be grouped within the Kingdom Fungi. Oomycota members that produce motile spores and grow as hyphae with cellulose containing walls, are included within the Kingdom Chromista together with brown algae and diatoms. *P. cinnamomi,* is largely a pathogen of woody plants.

Disease Management Improving soil drainage may keep the disease incidence at a lower level. In India, field sanitation such as removal and destruction of affected parts and wound dressing with tar have been recommended as control measures (Anandaraj and Devasahayam 2004).

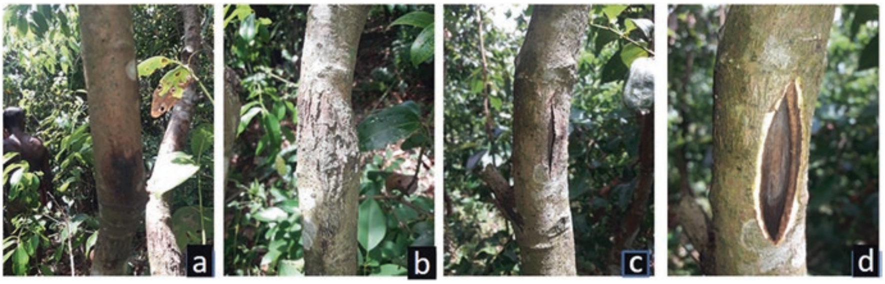

Fig. 8.18 Cinnamon Stripe Canker (*Phytophthora cinnamomi*): (**a**) initial stage of infection, (**b**) rupturing of the bark, (**c**) longitudinal split of bark, (**d**) final stage of the disease and the start of the die-back. (Photographed by G. G. Jayasinghe)

8.3.2 Minor Diseases

8.3.2.1 Gray Leaf Spots/Blight (*Pestalotia* sp. Petch)

Causal Organism Gray blight, caused by *Pestalotia* sp. was reported as one of the commonest diseases of cinnamon in Sri Lanka and it has been reported in India as well (Narendra and Rao 1972). A disease with similar symptoms on *C. verum,* causing foliar damage up to 90% was reported from India and the causal agent was identified as *Pestalotia palmarum* (Karunakaran et al. 1993). Similarly, in the Dominican Republic and Pakistan, the disease with similar leaf spot symptoms was reported to be caused by *Pestalotia furierea* in bay leaves (*cinnamomum tamala*) (Ciferri and Fragosa 1927; Wadud et al. 2017).

Symptoms Small, yellowish brown spots appear as initial symptoms on the cinnamon leaves and later on the spots turn gray with a sharp border and spread into the leaf lamina. In older lesions, dark acervuli are produced which appear as black dots in the center of the lesion. The disease causes severe damage and defoliation in cinnamon.

8.3.2.2 Black Sooty Mold (*Stenella* spp.)

Sooty molds are saprophytic fungi, living epiphytically on leaves and stems, forming black mycelial mats. They belong to several different families of Dothideales (Ascomycota) and are particularly abundant in the tropics. *Stenella* spp. appear to be the sooty molds in cinnamon and do not show any host preference. Colonies may consist of mixed populations of eight or more species. The disease is not economically important and therefore, fungicidal control is not recommended in Sri Lanka (Bavappa et al. 1996).

Since the sooty molds do not cause any damage to plants, except for reducing sunlight falling on leaves and reducing photosynthesis, their presence in cinnamon

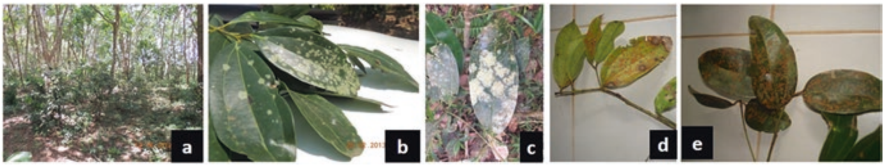

Fig. 8.19 Sooty molds and algal leaf spots that appear under unsatisfactory crop management conditions, (**a**) cinnamon growing under shade, (**b**, **c**) sooty mold (*Stenella* spp.) on cinnamon leaves, (**d**, **e**) algal leaf spots (C. virescens). (Photographs (**a**, **b**, **d**, **e**) by G. G. Jayasinghe, and (**c**) by K. L. Wasantha Kumara)

is not considered as an adverse situation. Sooty molds are very common in cinnamon, especially under shady condition (Fig. 8.19a–c).

8.3.2.3 Red Rust or Algal Leaf Spots (*C. virescens*)

Growth of algal colonies on leaves is common, especially when proper field sanitation practices have not been adopted in the cultivation. Algal growth is not considered important in terms of any damage to the host plant. The condition is referred to as red rust caused by the brown alga, *C. virescens*. Small, orange or brownish spots with a velvet appearance are seen on the leaf surface and their enlargement is not common or is very slow (Fig. 8.19d–e). Algal growth on leaf surface is generally encouraged by shady conditions (Bavappa et al. 1996).

Red rust can be avoided by adopting proper sanitation practices and by clearing nearby large trees and reducing shade. There are no other control measures practiced as the condition is observed occasionally in cinnamon lands.

8.3.2.4 Pink Disease (*Corticium salmonicolor* Berk. & Broome)

This disease has been reported from cinnamon in Sri Lanka, India, and Indonesia and the causal organism is identified as *C. salmonicolor* (Weiss 2002).

Symptoms The diseased areas appear first as pale pinkish white encrusts on stems and branches which later spread into larger areas in the bark. Pink disease can lead to death of smaller shoots at advanced stages of the disease.

Pathogen Pathogen has a wide host range and infects large trees, mango, jackfruit, custard apple, etc. The fungus is classified under the Phylum Basidiomycota, Agaricomycotina, Agaricomycetes, Corticiales, and the Family Corticiaceae. The spread of the disease can be slowed down by removing and burning of affected plants.

Fig. 8.20 Swollen fruit disease (*Exobasidium cinnamomi*) in cinnamon: (**a**) initial stage and (**b**, **c**) advanced stage of the disease. (Photographs by G. G. Jayasinghe)

8.3.2.5 Other Diseases

E. cinnamomi infects leaves and fruits cinnamon in Sri Lanka (Weiss 2002). Initially the fungus infects the leaves producing small, yellowish concave spots. Grayish-white spore bodies are produced on the lower surface of the leaf. Infected fruits show large, swollen, multiple blisters which make the fruits shrink and wrinkle (Bavappa et al. 1996) (Fig. 8.20). The disease is described as swollen fruit.

In another report, *Diplidia* spp. were reported as causing small light brown patches on cinnamon stems leading to stem blight and subsequent death of young seedlings in the nurseries (Da Camera Edes 1933).

Aecidium cinnamomi, Leptosphaeria spp., and *Colletotrichum capsici* cause leaf spots in cinnamon (Weiss 2002; Prakasam 1991). Further, Hosagoudar (1984) has described a fungus, *Caeoma keralense* (Syn. *Caeoma keralensis*), causing hypertrophy and witches' broom on young shoots of cinnamon trees in India.

8.4 Vertebrate Pests and Their Management in Cinnamon

Vertebrate pests also often pose problems to cinnamon cultivations. Different strategies need to be employed against vertebrate pests as most of them are protected animals. The strategies need to be economically viable, environmentally sound, and socially accepted.

Most vertebrate pests damage the newly generated shoots after a harvest (Fig. 8.21a). Damage to shoots can significantly slow down plant growth and reduce the yield. After damage to young shoots, the coppiced cinnamon plant does not have the erect stems that are essential for the preparation of cinnamon quills.

Peacock (Fig. 8.21f), mouse deer (Fig. 8.21g), barking deer (Fig. 8.21h), squirrels, hares, and stag are the most common vertebrate pests in cinnamon cultivations that are in close proximity to forest reserves. Most vertebrates are nocturnal, making identification difficult. The nature of the damage is often used to identify the pest. Ultrasonic sound devices with different frequencies (Fig. 8.21e) that were tested in

Fig. 8.21 Vertebrate pests in cinnamon and their management: (**a**) nature of damage (most vertebrate pests eat newly emerged shoots that develop after a regular harvest), (**b**) hiding new shoots behind the remaining twigs, (**c**) temporary fencing using locally available material, (**d**) sound devices used for repelling animals, (**e**) ultrasonic sound devices used to repel animals, (**f**) peacock (*Pavo cristatus*), (**g**) mouse dear (*Moschiola kathygre*), and (**h**) barking dear (Muntiacus muntjak malabaricus)

repelling peacock from cinnamon cultivations provided a significant reduction of damage to cinnamon.

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