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Ahasan Ullah Khan
[a] Department of Entomology, Faculty of Agriculture, Sylhet Agricultural University, Sylhet, Bangladesh
[b] Climate-Smart Agriculture Lab, Department of Agroforestry and Environmental Science, Faculty of Agriculture, Sylhet Agricultural University, Sylhet, Bangladesh

Anayat Ullah Khan
Department of Science, Jashore University of Science and Technology, Jashore, Bangladesh

Saugat Khanal
Agriculture and Forestry University, Bharatpur, Chitwan, Nepal

Subodh Gyawali
Institute of Forestry, Tribhuvan University, Nepal

Corresponding Author:
Ahasan Ullah Khan
[a] Department of Entomology, Faculty of Agriculture, Sylhet Agricultural University, Sylhet, Bangladesh
[b] Climate-Smart Agriculture Lab, Department of Agroforestry and Environmental Science, Faculty of Agriculture, Sylhet Agricultural University, Sylhet, Bangladesh

Insect pests and diseases of cinnamon (*Cinnamomum verum* Presi.) and their management in agroforestry system: A review

Ahasan Ullah Khan, Anayat Ullah Khan, Saugat Khanal and Subodh Gyawali

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Abstract
Cinnamon (*Cinnamomum verum* Presi.) is important spice in the world which is cultivate in tropical and subtropical region of the world. It is widely used as beneficial spices and pharmacological agents from the inner bark of plants. The study is fully based on the use of secondary sources of data; related journals, government institutes, and related reports. Medically, this plant is very important but its production is humper due to insect pests and diseases are main barriers for the production of cinnamon fruit. The objective of this study was to document the insect pests and diseases of cinnamon and their management in agroforestry system compared to different cinnamon growing countries. Since many research works were done on these issues but all are not available to the policy makers, extension workers and public in a systematic manner to date. The major insects are jumping plant louse (*Trioza cinnamomic)*, mite *(Eriophyes boisi)*, common mime (*Chilasa clytia* Lankeswara, Moore), blue bottle (*Graphium sarpedon* Teredon), leaf and shoot Webber (*Orthaga vitialis)*, hairy caterpillar *(Euproctis fraternal* Moore), *wood boring moth* or hairy tussock moth *(Dasychira mendosa)*, fruit borer (*Alcides morio* Heller), leaf miner (*Acrocercops* spp.), and sorolopha semiculta (*Olethreutes semiculta*) and major diseases are leaf spot and die back (*Colletotrichum gloeosporioides)*, seedling blight (*Diplodia* sp.), grey leaf spots/blight (*Pestalotia cinnamomic*), black sooty mould (*Stenella* spp.), algal leaf spots (*Cephaleuros virescens*), stripe canker (*Phytophthora cinnamomi*), pink disease (*Corticium salmonicolor* B. and Br.), brown root rot (*Phellinus lamaensis* Murr.), and leaf spot/blight (*Colletotrichum gloesporioides*). The paper eventually would help to increase the productivity of *C. verum* through the management of its insect pests and diseases.

Keywords: *Cinnamomum verum*, insect pests, diseases, management, importance

Introduction
Cinnamomum verum, a plant belonging to Lauraceae family and genus Cinnamomum, is the hardiest tree among the spices (Mian *et al*., 2018) [1]. Since antiquity, it has been used as beneficial spices (Gruenwald *et al*. 2010) [2] and pharmacological agents which are obtained from the inner bark of plants. It has been in use for many years with multiple culinary usages to enhance the flavor of food. Predominantly, they are cultivated for their dried inner bark of the small evergreen tree (Ravindran, 2004) [3]. The major hubs of cinnamon cultivation in south Asia are India and Sri Lanka. Besides, it is cultivated commercially in the tropical regions like Brazil, Java, Madagascar, Vietnam, the West Indies and Zanzebar. Cinnamon can grow well in humid regions with typical temperature 27 ^{0}C and annual precipitation of 1500-2500 mm. It is popular with local name as 'Darchini'. Nearly 2000-2500 species and 32 genera fall under genus *Cinnamomum* trees of tropics and subtropics (Tiwari and Agarwal, 2004) [4]. These species are shrubs and small to medium-sized plants (Jantan *et al.* 1995; Braun, 2006) [5, 6] of rainforests thriving well at various altitudes from highland slopes to lowland forests. The most common species are *Cinnamomum zeylanicum*, *C. loureirii*, *C. burmanni* and *C. aromaticum*. The bark of *C. aromaticum* and *C. zeylanicum has high commercial use in Asia and Europe as well.* Some species are used in chocolate manufacturing industries, in many desserts' recipes, spicy candies, tea, hot cocoa and liqueurs worldwide. In the Middle East, it is usually used in savory dishes of chicken and lamb. 4000 years ago, Chinese literature has cited the traditional usage of cinnamon in manufacturing of naturopathic medicine (Qin *et al*., 2010) [7], ayurvedic medicine for treatment of diabetes during ancient times (Modak *et al*., 2007) [8].

It was reported to be used as stomachic and carminative for gastrointestinal complaints as well as other ailments (Teuscher, 2003) [9]. Plants health and soil quality are the determining components for ecological production of the cinnamon that keep the agroforestry system working well. Only healthy soil can help upgrade the crop yield. Soil microorganisms (MOs), invertebrates, and other biotic agents play continuous role in maintaining soil fertility level as they respond differently to external agents and help undergoes biochemical reactions (McIntyre, 2000) [10]. According to Chang *et al*. (2013) [11], the flavor of cinnamon is because of 0.5 to 1% perfumed in essential oil. It has antioxidant attributes that may reduce the risk of heart diseases or stroke and has strong antidiabetic effects and lower sugar level (Anonymous, 2015) [12]. It has economic importance as well. Global trade indices show that *C. burmannii* (Indonesian cassia) has substituted the more luxurious true or Ceylon cinnamon (*C. verum*) in recent days in Europe, the United States, and Canada (UN comtrade, 2011; BfR, 2006; Sproll *et al*., 2008; Raters and Matissek, 2008; Lungarini 2008) [13, 14, 15, 16, 17]. *C. burmannii accounted for more than 90%* of the "cinnamon" trade in the U.S. during the last five years in previous decade (UN comtrade, 2011) [13]. In view of extensive export and import prospects, cinnamon has high economic and trade value in an international market. Nonetheless, several constraints hold up the remarkable breakthrough in production of cinnamon throughout the world.

The most important restraint that has hindered the breakthrough in cinnamon production globally is failure to effective control of pests, insects, and diseases associated with the plants. Cinnamon, although a hardy plant, is susceptible to infect by variety of pests and diseases during its various stages of development (Rajapakse and Kumara, 2007) [18]. Lower yield is related with aging of crop, improper crop maintenance, severe pests and diseases incidence, climate changes, etc. Pests and diseases were found to cause severe damage to cinnamon in different regions. These pests and diseases are accountable for notable reduction in the production of cinnamon bark, the economic product and also for declining the quality of other products like leaf oil, bark oil and root bark oil even though, they are not economically significant. Keeping these points in view, this paper solely aims to review the information on the existing pests and diseases of cinnamon production, their impacts and role in yield decline, and the possible management strategies in agroforestry ecosystem.

Methodology

The review is primarily based on literature search in different web-based databases such as Google scholar, Web of science (www.thomsonreuters.com/web-of-science), Research gate (www.researchgate.net), full text search of Science Direct (www.sciencedirect.com), related websites, and blogs. The methodological approach is illustrated in Figure 1. The search was focused on pest and diseases infestations during cinnamon production, their impacts, and management strategies in agroforestry ecosystem. The key terms used during the search were Cinnamon, Pests and diseases, Impacts, Management. Furthermore, several kinds of word combinations were also taken during search to find more articles. First-round screening was performed with a quick review of title, abstract, and keywords. Moreover, a review of the existing journal literature, books, report, blogs and newspaper were carried out to assess the current state of the research on insects and diseases of cinnamon.

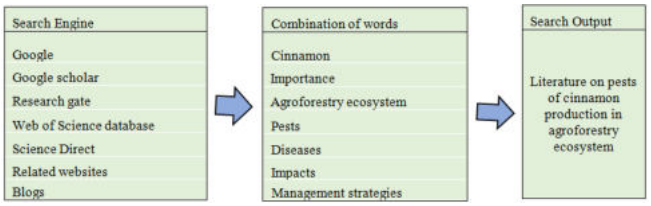

Fig 1: Methodology adopted for literature search using words in web-based databases

Reviews on insect pests of cinnamon (*Cinnamomum verum*)

Ayyar (1940) [19] first reported that nymphs and adults of Homopteran pest *Pauropsylla depressa* (Triozidae) produced galls on leaves and shoots of cinnamon plants in India. Mani (1973) [20] found out 5 species of insects and mites forming leaf galls and another unrecognized insect species causing inflorescence galls. Rajapakse and Kulasekera (1982) [21] have studied about the pest associated with cinnamon in Sri Lanka. Devashayam and Koya (1997) [22] reported that important insects and pests of cinnamon include cinnamon butterfly (*Chilasa clytia* Lankeswara), Moore and leaf miner (*Conopomorpha civica)* in India. Major pests infesting cinnamon in South East Countries and their possible control techniques have been summarized in this study. Different researchers have studied on different insect pests of cinnamon. Table 1 shows the involvement of scientists in study of several diseases.

a. Jumping plant louse (*Trioza cinnamomic)*

A jumping plant louse (Homoptera: Triozidae) is mainly associated with the leaf galls of cinnamon. Hollis and Martin (1997) [23] noted that 48 species of psylloids are allied with lauraceous swarm plants and 72% of significant of these insects. According to Rajapakse and Kulasekera (1982) [21], *T. cinnamomi* is the most important insect pest of cinnamon in Sri Lanka. Mani (1973) [20] also reported an indefinite psyllid also causes creation of galls in cinnamon in India.

Management: Jumping louse is serious pest in the cinnamon field. Mainly leaves infested by this insect and related to the leaves gall. Removal and burning the infested leaves and shoot. Perfect mass trapping of these pests could probably reduce the damage to a cinnamon crop. Some agrochemicals also can decrease the incidence of pests to some extent.

Table 1: Review of literature on the major insect pests and diseases of cinnamon

Insects	References
Jumping plant louse	Mani (1973); Rajapakse and Kulasekera (1982); Hollis and Martin (1997) [20, 21, 23]
Mite	Mani (1973), Perera *et al.* (1985); Rajapakse and Ratnasekera (1997); Warren and Moran (1978) [20, 24, 25, 26]
Mime	van der Poorten (2004); Bell (1912), Butani (1983) [27, 28, 29]
Blue bottle	van der Poorten (2004); Bell (1912) [27, 28]

Leaf and shoot Webber	Singh, *et al.* (1978) [30]
Hairy tussock moth	Dharmadasa and Jayasinghe (2000) [31]
Leaf miner	Butani (1983); Anandaraj *et al.* (2001); Devashayam and Koya (1993) [29, 32, 33]
Sorolopha semiculta	Rajapakse and Kulasekera (1982); Singh, *et al.* (1978); Bhumannavar (1991) [21, 30, 34]
Butterfly	van der Poorten (2004) [27]
Leaf miner	Ayyar (1940); Mani (1973); Rajapakse and Kulasekera (1982); Devashayam and Koya (1997) [19, 20, 21, 22]
Diseases	**References**
Grey leaf spots/blight	Anonymous (1996); Karunakaran *et al.* (1993); Ciferri (1926), Ciferri and Fragoso (1927) [35, 36, 37, 38]
Algal leaf spots	Weiss (2002); Hosagoudar (1984); Prakasam (1991) [39, 40, 41]
Rough bark disease	Kumara (1999a) [42]
Stripe canker	Ciferri and Fragoso (1927); Rands (1922); Anandaraj and Devasabayam (2004); Mehrlich, (1934) [38, 43, 44, 45]
Pink disease	Weiss (2002) [39]
Brown root rot	Chang (1992); Da Graca *et al.* (1980) [46, 47]
Stem and root diseases	Weiss (2002) [39]
Leaf spot/blight	Prakasam (1991); Anandaraj and Devasabayam (2004); Kumara, (1999b); Karunakaran and Nair (1980); Bhat, *et al.* (1988) [41, 44, 48, 49, 50]

b. Mite *(Eriophyes boisi)*

A mite (Acarina: Eriophyiidae) is important pest in Sri Lanka and some other countries in Southeast Asia (Rajapakse and Kumara 2007) [18]. This pest has been considered to be form morphological galls in cinnamon leaves (Mani, 1973) [20]. in Sri Lanka, Perera *et al.* (1985) [24] reported the mite, is an important pest producing leaf galls and the number of new galls found on young leaves were greater than on mature leaves. The nymphs and adult mites suck sap from young leaves that turn yellow and drop. The infested plant obtained the mean oil content (18-43) % of leaves with galls. The lower surface of leaf is enclosed by a thin layer of cells which disagreements to permit the emergence of the adult. The leaf galls caused by psyllids are epiphyllous, conical, unilocular, hard yellowish green. Galls develop on both sides of the leaf blade (Mani, 1973) [20]. Rajapakse and Ratnasekera (1997) [25] reported that in a spatial distribution study, the *T. cinnamoni* preferred young, growing incompletely expanded leaves than mature and over mature leaves and there was a positive significant correlation be-tween gall counts and the proportion of young leaves. This study was determined the nutrient composition of various leaves (Rajapakse and Ratnasekera, 1997) [25], it was found no significant relationship of crude protein to abundance of galls. Another study has stated the relationship between young leaves and crude protein (Warren and Moran, 1978) [26] in cinnamon plant.

Management: Application of Dicofol 18.5EC @ 2 L/ha or Ethion 46.5 EC @ 1.26 L/ha is effect to control of mite in the plant. Precautions should be taken during the application to avoid under or over dose than recommended by plant experts.

c. Common mime (*Chilasa clytia* Lankeswara, Moore)

The common mime (Lepidoptera: Papillionidae) is a swallowtail butterfly. This butterfly species first reported in Sri Lanka (van der Poorten, 2004) [27]. It flies very slowly however, during menace it flies fast. Predominantly, may become serious insect pests in young plantations and abundant from December to June. Bell (1912) [28] reported that the fly is seen in large numbers in monsoon months and spends the dry months. Eggs are heavily parasitized by the egg parasitoid *Telenomus remus*.

Management: Hand picking the larvae and pupae from the field with the help of light trap. Application of quinalphos 0.05% on tender and partly mature leaves in severe infestations can minimize the pest.

d. Blue bottle (*Graphium sarpedon* Teredon)

The blue bottles (Lepidoptera: Papililionidae) are noted throughout year in cinnamon cultivating areas. The common blue bottle and Tailed Jay, *G. agememnon* are the fastest nectar feeders of the butterflies in Sri Lanka (van der Poorten, 2004) [27]. The larvae of this bottle were reported to feed on Cinnamon tender leaves and stem (Bell, 1912) [28].

Management: Remove and destruction of infested leaves. Hand picking of larvae of blue bottle is method to minimize this pest. Pesticides like Ethion, cumbush, and bavistin are commonly applied to control this pest.

e. Leaf and shoot Webber (*Orthaga vitialis)*

The leaf and shoot Webber (Lepidoptera: Pyralidae) are very active and web the leaves and the terminal shoots. The webbed cluster of leaves harbors several larvae. Singh, *et al.,* 1978[30] reported that the major pest mainly infested by the shoot and leaf webber in India.

Management: The damaged leaf and shoot webs with larvae should be collected and destroyed. Pheromone traps have been used to monitor pest populations in the cinnamon. Spraying Carbaryl (0.1%), or Quinalphos (0.05%) or Endosulphan (0.05%) and repeated either thrice at 10-12 days interval.

f. Hairy caterpillar *(Euproctis fraternal* Moore)

Hairy cater pillar (Lepidoptera: Lymantriidae) larvae feed voraciously on leaves. Initially the larvae scrape the green matter in skeletonization. Later the larvae move in to the other parts of the plant and defoliate (Rajapakse and Kumara, 2007) [18].

Management*:* Hand picking of egg masses, early instar larvae and killing them by burning/keratinized water. Light traps are also effective method to destroy the moths. Application of Diazinon 60EC @ 2ml/L of water or Cymbush 10EC @ 1ml/L of water are effectively control the moth.

g. Wood boring moth or hairy tussock moth (*Dasychira mendosa)*

The Clearwing moth (Lepidoptera: Sesiidae) of these larvae was first reported in Sri Lanka Dharmadasa and Jayasinghe (2000) [31]. The symptoms were the dying branches, rough bark and insect excreta in infested plant with wood boring insect. These larvae feed on phloem of live trees and tend to mine horizontally. Repeated feeding weakens the branches or kill branches and that may break and fall during rainy weather.

Management*:* Hand picking of egg masses, early instar larvae and killing them by burning/keratinized water. Light traps may be used to destroy the moths. Sex pheromone use to control male moth. Destruction of alternate host and plant debris of cinnamon. Application of Diazinon 60EC @ 2ml/L of water.

h. Fruit borer (*Alcides morio* Heller)

The cinnamon fruit borer (Coleoptera: Curculionidae) feed the inner contents of the seed and tunnels into the cinnamon seeds. The damage is of considerable economic importance since cinnamon is propagated through seeds. Mature grub has a brownish head with a whitish body and attains the length of 8-10 mm. The pupation takes place inside the seed and lasts for 7-9 days. The resultant weevil cuts a circular hole on the seed coat. They are dirty black in color and not active. The females are larger than the males. The longevity of the beetle is 5-7 days (Biotech and Limited 2011) [51].

Management: Removal and destruction of all infested shoots, all fallen dry leaves and other debris from the field. Releasing *Trichograma* (egg parasitoid) @ 1gm (about 25,000 egg) at first weekend and *Bracon* (larval parasitoid) @ bunker (800-1200 larvae) at next weekend are found most effective. Application of Spinosad @ 0.4 ml/l of water is effectively controlling this borer.

i. Leaf miner (*Acrocercops* spp.)

The adult is a tiny silvery moth (Lepidoptera: Gracillaridae). The larvae enter the leaf tissue by mining. They feed on the tissues between the upper and lower epidermis of tender leaves resulting in linear mines that end in blister like patches. The infested leaves become crinkle 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. Infestation by leaf miners *Conopomorpha civica* (Anandaraj *et al.,* 2001) [32] and *Phyllocnistis chrysophthalma* Meyer has been reported in India (Butani, 1983) [29]. Devashayam and Koya (1993) [33] reported that *C. civica* has infested 20.2% of the seedlings of cinnamon in Kerala, India.

Management: Neem cake soaked in water and the decantation when sprayed also controls the pest. Application of dimethoate 0.03% or methyl demeton 0.025% or imidacloprid 0.01% is effect to control the pest.

j. Sorolopha semiculta (*Olethreutes semiculta)*

The larva of this tortricid moth (Lepidoptera: Tortricidae) rolls the young leaves together. This study also reported the presence of the tortricid *Sorolopha archimedias* (syn. *Eudemiopsis archimedias*) in cinnamon in South Andaman in India (Bhumannavar, 1991) [34].

Management: Ploughing and cultivation of the soil before sowing reduce the pest burden and there is a modern trend to restrict the use of pesticides as far as possible. It can be achieved by regulating the crop, just using insecticides when necessary, and by cultivating varieties and crops which are resistant to Sorolopha semiculta. The infested leaves and shoot should be removed and burned to minimize this pest from the field. Light trap is the best way to manage adult caterpillar from cinnamon field.

Reviews on diseases of cinnamon (*Cinnamomum verum*)

Serious diseases reported from cinnamon are less compared to insects and mite damages and also are less economic importance. There has been no significant work done on diseases of cinnamon specially in Sri Lanka although this crop has been under cultivation for centuries. Cinnamon is considered as one of the hardy plants among other spice crops and therefore, chances are comparatively less for severe pathogenic infections. Some of the diseases which have taken considerable attention in South East Asian countries have been described. The major diseases are leaf spot and die back, seedling blight, grey leaf spots/blight, black sooty mould, algal leaf spots, stem and root diseases, rough bark disease, stripe canker, pink disease, brown root rot and so on (Table 1).

a. Leaf spot and die back (*Colletotrichum gloeosporioides*)

Leaf spot and die back disease is caused by *Colletotrichum gloeosporioides*. Small deep brown specks appear on the leaf lamina, which later coalesce to form irregular patches. In some cases, the affected portions are shed leaving shot holes on the leaves. Later the entire lamina is affected and the infection spreads to the stem causing die back. Pruning the affected branches and spraying Bordeaux mixture 1% are recommended to control the disease. Karunakaran and Nair (1980) [49] leaf spot and die back disease of *Cinnamomum zeylanicum* caused by *Colletotrichum gloeosporioides*.

Management: Sowing healthy and disease-free seeds. Destroy residues and remove infected leaves. Crop rotation should be followed and avoid excess irrigation. Spraying Bordeaux mixture @ 5% or Ridomi/ Dithane M-45 @ 0.2% for 3-4 times at 8-10 days interval has been found effective in reducing the spread to some extent.

b. Seedling blight (*Diplodia* sp.)

Seedling blight caused by *Diplodia sp.* occurs on seedlings in the nursery. The fungus causes light brown patches which girdle the stem resulting in mortality.

Management: Healthy and resistant variety seed use to minimize the seedling blight. Seed treated within Thirum and Vitavax 0.25% at 2.5-3.0 g/kg seed is effective against seedling blight. The disease can be controlled by spraying Bordeaux mixture 1%.

c. Grey leaf spots/blight (*Pestalotia cinnamomi*)

Grey blight is caused by *Pestalotia palmarum* and is characterized by small brown spots which later turn grey with a brown border. *P. cinnamomi* causing grey blight is also considered as one of the commonest dis-ease of cinnamon (Anonymous, 1996) [35]. In India, the disease was

reported to be caused by *P. palmarum* on *C. verum* causing foliar damage up to 90% (Karunakaran *et al.,* 1993) [36]. *Pestalotia furierea* causing similar leaf spot symp-toms were reported from Dominican Republic and also from Pakistan (Ciferri, 1926; Ciferri and Fragoso, 1927) [37, 38]. This disease can cause severe damage and defoliation.

Management: Removal of infested plant parts from the field. Spraying Dithane M-45 @0.2% or Bavistin @0.25% at 15 days interval for 2 times. Spraying 1% Bordeaux mixture during May and September in field.

d. Black sooty mould (*Stenella* spp.)

The disease is not considered as economically important among cinnamon cultivators and therefore, seldom warrant control measures. *Stenella* spp. has been stated as the causal agents of the disease. Blackish growth on the leaf due to sooty mould fungus is the typical symptom of the disease. The fungal growth is narrowed only to the surface and no penetration into the leaf tissues has been observed.

Management: Removal and destruction of infested leaves and use of balance fertilizer dose in the field. Eco-oil and eco-neem are used to check a wide range of sap-sucking insects and black sooty mould. Spray with two times to kill the pests. Ensure proper coverage to all the plants so that no pest is missed.

e. Algal leaf spots (*Cephaleuros virescens*)

Another disease which considered as economically less important, is the algal leaf spot disease caused by *Cephaleuros virescens.* This disease is not currently present very seriously in Sri Lanka and other southeast Asian countries although reported in the past. Orange or brownish colored spots with velvet appearance are seen on the leaf surface. Leaf spots are rather small in size and enlargement of the spots are also not common or very slow. Three other minor leaf diseases caused by *Aecidium cinnamomi, Leptosphaeria* spp. and *Gloeosporium* spp. have been reported but, the extent of damage was not described (Weiss, 2002) [39]. *Caeoma keralensis* causing hypertrophy and witches' broom on young shoots was de-scribed by Hosagoudar (1984) [40] and red leaf spots caused by *Colletotrichum capsici* was recorded in India Prakasam (1991) [41].

Management: There are no control measures recommended for this disease. Removal and destruction of infested leaves and use of balance fertilizer dose in the field. Often, leaf spot caused by *Cephaleuros virescens* is not threatening enough to the cinnamon yield and thus usually does not need more management. If the plant is highly susceptible, a form of IPM can be used to check the spread and severity of the disease. This includes proper sanitation and pruning of diseased plant parts. The lower branches and debris should be removed since they are usually infected. Reducing humidity or increasing air flow can help mitigating the algae effectively. Use of a tolerant variety of plant, and if required, intercropping, can lessen the rate of infection. Copper fungicides may help but needed to be used every 2 weeks if the surrounding remains wet.

f. Rough bark disease

One of the important diseases in Sri Lanka that has drawn grower's attention at present is the rough bark disease. The causal agent is still unidentified. The disease is found in many cinnamon growing areas in Matara district of Sri Lanka and could leads to severe damages to young and mature plants. Kumara (1999a) [42] also reported scab like appearance in cinnamon similar to this, affecting quilling efficiency considerably however, causal organism of the disease was not reported. Sandy soil, slopy lands, long weeding intervals and low dose of fertilizer applications correlate with increasing disease condition (Kumara, 1999a) [42].

Black/brown spots appear on the bark of stems and later become large patches. These spots are enclosed by a dark brown/ black border. Affected area of the bark appeared irregular nature giving scab like appearance. These scabby areas lengthy over the bark with crop maturity reducing yield quality. Interveinal chlorosis of leaves of young shoots is common in affected plants. Affected young shoots die in later stages giving heavy yield losses.

Management: Remove and destruction of affected seedlings/leaves/shoots help to reduce the disease incidence. The recommended dose of pesticides can be used as per the suggestions of the plant experts. Pruning should be practiced. Application of 1-2% Bordeaux mixture to reduce the disease incidence.

g. Stripe canker (*Phytophthora cinnamomi*)

Phytophthora cinnamomi causing stripe canker attacks shoots and young stems of cinnamon. Rands (1922) [43] first stated *Phytophthora cinnamomi* initiating severe losses to forest trees and avocado, as causal agent of stripe canker of *C. verum*. The fungus also affects *C. campora, C. culitlawan* and *C.* sintok (Ciferri and Fragoso, 1927; Rands, 1922) [38, 43]. The fungus *P. cinnamomi* from pineapple was also reported pathogenic on cinnamon, but with reduced virulence (Anandaraj and Devasabayam, 2004) [44].

Stripe canker is found on the trunks and branches, particularly of young trees of *C. verum* and *C. burmannii* in Indonesia (Mehrlich, 1934) [45]. Vertical stripes are seen on the stems with amber colour exudates at the advancing margins and hardens later. Vertical stripes of dead bark are most numerous near ground level. The disease is prevalent on ill-drained soils and causes up to 42% bark damage. Fungus produces chlamydospores and characterized by nonpapilate sporangia which can be obtained by incubating a nonsterile percolate of field soil (Mehrlich, 1934) [45].

Management: Well drainage is important to minimize the disease incidence at a lower level. Phytosanitation such as removal and destruction of affected parts and wound dressing with tar have also been recommended as manage this disease.

h. Pink disease (*Corticium salmonicolor* B. and Br.)

Pink disease caused by *Corticium salmonicolor* B. & Br. (syn. *C. javanicum*) has been stated on cinnamon and considered as an important disease in Sri Lanka, India and Indonesia (Weiss, 2002) [39].

Formation of pale pinkish white covered areas on stems or branches is the visible symptoms at the beginning. Later contagion spreads destroying bark and finally leading to the death of the smaller shoots. Pathogen also reported to attack mango, jackfruit, custard apple and other fruit trees often

grown in the vicinity of cinnamon plantations (Weiss, 2002) [39].

Management: Burning of affected pruning and other plant parts need to be practiced to reduce the disease incidence. The suggested fungicides for management of this disease are not available in the market. BIO-C is an economical and ecologically sound fungicide for control of pink disease. The application interval is once a week quarterly. The dose of each application is nearly 50 cc / plant depending on the extent of the infection of pink disease.

i. Brown root rot (*Phellinus lamaensis* Murr.)

This disease is caused by *Phellinus lamaensis* (Murr.) Heim, damages cinnamon plants. Chang (1992) [46] reported brown root disease caused by fungus *P. noxius* on *C. camphora.* Wilting and death of the aerial portions can be observed in these plants. The fungus was found to affect adjacent shade and ornamental trees such as *Dilonix regia*, *Annona* sp. and *Prunus* sp. (Da Graca *et al.,* 1980) [47].

Management: The host plant should be removed from the field and also from near about field area. There is no effective fungicide recommended for control use. Plants may be treated with fungicides, if infection is not severe. Fungicides will suppress but not cure brown root rot.

j. Stem and root diseases

A stem disease caused by *Exobasidium cinnamomi* has been recorded in Sri Lanka (Weiss, 2002) [39]. This disease can also spread into leaves producing small yellowish concave spots whose underside bears grayish white spore bodies. *Diplidia* spp. causing stem blight on young twigs in the nursery, produce small light brown covers on stems.

Management: Control is hard because once symptoms are noticed; infection to the stem or roots is often severe. For cinnamon, use a soil drench of a recommended dose of fungicide. A fungicide could also be incorporated with soil before planting as recommended by the manufacturer.

k. Leaf spot/blight (*Colletotrichum gloesporioides*)

The leaf spots/blight caused by a fungus *Colletotrichum gloeosporioides* is found in almost all cinnamon growing areas in Sri Lanka mainly affecting the foliage (Anandaraj and Devasabayam, 2004; Kumara, 1999b) [44, 48]. It appears in all growth stages of the plant and the entire foliage can be affected in severe infections. Kumara (1999b) [48] reported 18% foliar damage due to this disease in Matara, Sri Lanka however, with no significant correlation detected between cinnamon yield and the disease severity. Considerably, higher disease incidence was observed in lands with high shades, high planting densities, poor weeding, and improper pruning (Kumara, 1999 a and b) [42, 48]. The symptoms in young seedlings include, small brown specks on leaf laminae which, later coalesce to form irregular patches. Small, brownish, leaf spots on older leaves can be seen, especially in shaded areas. These small specks coalesce to form large necrotic blotches giving scorching appearance. Spots later become papery with dark brown margins. In other cases, the central portion is shed, forming shot hole appearance. Lesions may extend from tip of the leaf or from the margins. At severe infections, lesions may be larger than the half of the leaf. In some seedlings, the infection spreads to the stem causing a dieback (Karunakaran and Nair 1980) [49]. In India, reddish elongated spots were observed arising from the margin and resulting in defoliation (Prakasam, 1991) [41]. This also caused shot hole symptoms in later stages. However, the fungus caused this disease has been identified as *Phytophthora capsici* (Prakasam, 1991) [41]. Fu and Chang (1999) [46] also reported brown to black spots on *C. verum* leaves in Thaiwan. These spots later coalesced and the infected leaves were shed. The pathogen was identified as *C. gloeosporioides* (Syn. *Glomerella cingulata*). Partial drying of the seedlings is another symptom due to this pathogen as reported in India Bhat, *et al.* (1988) [50]. In this study, those seedlings yielded *C. gloeosporioides* and symptoms were reproduced 7 days after inoculation of healthy seedlings.

Management: Avoid overcrowding of plants, prune trees to improve light penetration and enable air circulation throughout the canopy, frequent irrigation is necessary to keep the plant moist, and destroy the fallen infected leaves. Reducing shades specially during nursery stages may reduce the disease severity. Application of Chlorothalonil 75% WP, Carbendazim 50% WP, Mancozeb 80% WP at 7-10 days intervals.

Medicinal significance of cinnamon

The plant essential oils and extracts have been rummage-sale for many thousands of years, in food preservation, pharmaceuticals, alternative medicine and natural therapies. Cinnamon is used widely in food industry and medicine. It is essential to study those plants scientifically which have been used in traditional medicine to progress the quality of healthcare. Plant extracts and oils are potential sources of novel antimicrobial compounds especially against bacterial pathogens. The cinnamon plants are one of them and it have been used as traditional medicines. The plants have been used as antibacterial (Abdalla *et al* 2017) [52], antimicrobial agents (Mukhtar and Ghori, 2012) [53], antibiotic (Ciftci *et al* 2010) [54], antiviral (Bishop 1995) [55], antimycotic (Azzouz and Bullerman, 1982; Akgul and Kivanc, 1988; Jayashree and Subramanyam, 1999; Mari *et al*, 2003) [56, 57, 58, 59], antitoxigenic (Akgul *et al*, 1991; Ultee and Smid, 2001; Juglal *et al*. 2001) [60, 61, 62], antiparasitic (Pandey *et al*. 2000; Pessoa *et al*. 2002) [63, 64], and insecticidal (Karpouhtsis *et al*. 1998) [65] properties and so many. The cinnamon plant also used as inflammation, cough, toothache, antiseptics expectorant, and some fungal infection. The cinnamon spices exhibition insulin-enhancing activity to antidiabetic *in vitro* culture (Khan *et al.,* 1990; *Broadhurst et al.,* 2000) [66, 67]. Botanical products can improve glucose metabolism and the overall condition of individuals with diabetes not only by hypoglycemic effects but also by improving lipid metabolism, antioxidant status, and capillary function (Bailey and Day, 1989) [68].

Conclusions and Recommendations

The cinnamon is a very important spice in the world market and also renowned for its medicinal properties, powerful antioxidants, anti-inflammatory properties, anti-diabetic, and anti-bacterial attributes for thousands of years. It has economic importance too. The spice of bark is very sensitive to insect pests and diseases that have decreased the yield in many countries. Physical, chemical, biological, and cultural methods of management have been practiced by

growers. However, chemical application of pesticides and insecticides is the most effective one as it responds quickly but has an effect in the environment as well as human life. So, the grower should follow the cultural method *viz* pruning, avoiding overcrowding, frequent irrigation, destruction of infected plant parts soon after the pest infestations, and training of plants is essential to control the diseases. Fertilization at the recommended dose at the right time is necessary. Biological control via trap crops is best to control some of the pests.

Development of insect and disease resistant varieties and upscaling of IPM and INM approach are necessary for increasing the productivity of cinnamon. Further research recommends quality production of percentage on yield loss due to insect pests and diseases in the agroforestry system and should be used in future research as bio-rational and botanical insecticides in agroforestry ecosystem to consider the environment issue in cinnamon plants.

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