Relevance of Botanicals for the Management of Forest Insect Pests of India

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R. Sundararaj

Abstract

Insect pests are major biological determinants of forest productivity, and integrated pest management is not new to Indian forestry. In this chapter, insect pests of economic importance in Indian forest scenario are summarized, and the possibility of managing them with botanical pesticides is discussed. Proper understanding of the biology and ecology of the tree species and their associated fauna and flora plays an important role in the pest management. In general, nurseries and monoculture plantations are much more susceptible to insect epidemics as compared to mixed plantations and natural forests. Besides, the number of insect species acquiring pest status is increasing day by day possibly due to environmental imbalances, climate change and bioinvasion. Large-scale spraying of chemicals, microbes or botanicals cannot be feasible in large-scale plantations and natural forest areas, but it is feasible to use maximum quantity of neem cake and other neem products as an integral component for pest management. Besides, it is essential to promote the use of plant products in the forest insect pest management programmes which will encourage the users to grow more trees in their homesteads and boost the greening India programme.

Keywords

Intergrated forest pest management • Botanicals • India

8.1 Introduction

Forests are vital for life on earth; without healthy, thriving forests, earth cannot sustain life. They have many functions integral for our survival and sustenance. They offer watershed protection, timber and non-timber products and various recreational options. They prevent soil erosion, help in maintaining the water cycle and check global warming by using carbon dioxide in photosynthesis. About 30 % of the world is forested today, but the ratio between forest and population varies immensely. The United States and Canada share 16 % of the world's forests; the former Soviet Union contains 21 %, Africa has

R. Sundararaj (✉)
Forest and Wood Protection Division, Institute of Wood Science & Technology, 18th cross, Malleswaram, Bangalore 560 003, India
e-mail: rsundararaj@icfre.org; rsundariwst@gmail.com

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Fig. 8.1 Raising of nurseries, an important activity for forest plantation

20 % and Latin America has 24 %. As per the estimate of FAO (2001), about 47 % of the world's total forests lie in the tropics and 8 % in the subtropics, together making up 55 % of the total. Of the tropical forests, the largest portion is in Latin America (52 %), centred on the Amazon river basin; followed by Africa (28 %), centred on the Congo river basin; and the rest in the Asia-Pacific (19 %), where it is more scattered. Forests provide habitat for many living organisms. The forest ecosystems deliver a vast array of products and services to the society. The most famous product from the forest is wood, which has an enormous diversity of applications and purposes. However, apart from that, there are a large number of non-timber forest products, like medicinal plants, honey, fruits, etc. The availability, the use and the importance of these products vary per region and per culture. Most often, the poorest and vulnerable part of society depends very much on the forest. Over the years, the area under forest cover has decreased steadily, as forests have been cleared for agriculture, industry, housing and other development activities like the construction of roads, railways and hydro-electric plants. Today tropical rainforests are disappearing from the face of the globe. Despite growing international concern, rainforests continue to be destroyed at a pace exceeding 80,000 acres (32,000 ha) per day, a concern for climate change. It is a global environmental problem and can manifest itself in gradual shifts in temperature, precipitation and a rise in sea level (Dubey 2009). New challenges due to climate change require increasing the forest cover and protecting environmentally important forests in the world. Reforestation is a way to help restore the balance. Planting trees, especially quick-growing native trees that will not be logged or burned, remove carbon from the cycle and sequester, or 'fix' it, within the wood itself. For these, raising forest nurseries (Fig. 8.1) which can supply plants for planting to many geographical areas is vital in which keeping pests out of nurseries is especially important. Forest nurseries use intensive management practices which, if not properly done, may promote pest buildup. The artificial environment of the nursery, such as planting density, species or clone choice and monoculture, can be favourable to pest development. To minimize damage, detecting and treating pests before they spread are essential. Some of the nursery IPM practices are also useful in managing planted forests.

8.2 Status of Indian Forest

Forest is the second largest land use in India next to agriculture. India's forest cover accounts for 23.84 % of the total geographical area of the country with very dense forest (more than 70 %) 2.54 %, moderately dense forest (between 40 % and 70 %) 9.71 % and open forest (between 10 % and 40 %) 8.77 %. In addition, tree cover accounts for 2.82 % of India's geographical area (Table 8.1). It constitutes one of the principal natural resource and occupies a permanent

Table 8.1 Forest and tree cover of India in 2007 (FSI 2009)

Class based on canopy density (%)	Area (million ha)	Geographical area (%)
Very dense forest (more than 70)	8.35	2.54
Moderately dense forest (between 40 and 70)	31.90	9.71
Open forest (between 10 and 40)	28.84	8.77
Total forest cover	69.09	21.02
Tree cover	9.28	2.82
Total forest and tree cover	78.37	23.84

place in enhancement of national economy, poverty alleviation and tribal development. Forests of India form a unique national treasure and are responsible for India's rich biodiversity making the country as one of the 12 'megadiverse' countries in the world. They play a vital role in harbouring more than 45,000 floral and 81,000 faunal species of which 5,150 floral and 1,837 faunal species are endemic. The panorama of Indian forests ranges from evergreen tropical rain forests in Andaman and Nicobar Islands, the Western Ghats and northeastern states to dry alpine areas in the Himalayas in the north, and between these two extremes, the country has semievergreen, deciduous, subtropical and thorn forests. These forests hold within them a unique wildlife, flora and fauna, and are also a source of sustainable livelihoods to over 200 million people in the country. With 17 % of the world's population and 18 % livestock population over 2.4 % of the world's total geographical area, India's forests are facing severe biotic pressures as nearly 40 % of domestic fuelwood needs of the people and 30 % of fodder needs of the cattle population in the country are met from forests. The demand and supply gap of timber, fuelwood and fodder are widening. Shifting cultivation (slash and burn cultivation) practised over about 1.2 m ha., though associated with sociocultural, legal and biophysical characteristics, is also a cause of degradation of forests predominately in eastern and northeastern India. Dealing with the stupendous task to overcome the problems forests are facing, the National Forest Commission has recommended an allocation of a minimum of 2.5 % of the national budget to the forestry sector. Besides, progressive national forestry legislations and policies in India aimed at conservation and sustainable management of forests have reversed deforestation. One of the primary objectives as laid in the National Forest Policy is to increase forest productivity per unit area and time. Accordingly, in the forestry research, the topmost priority has been enhancement of productivity. The average annual productivity of wood per ha. in India has been worked out at 0.7 cubic metres which is much less than the world average of 2.1 cubic metre (Gairola and Aggarwal 2005), whereas as per the reports of Sachin Kumar and Thakur (2011), the average potential productivity of Indian forests has been estimated at 6 cubic metres per ha. per annum. Concerted efforts are therefore required to bridge this large gap between the potential and realized productivity. Efforts were therefore directed to raise large-scale plantations under various forestation programmes. Insect pests and diseases are major biological determinants which limit forest productivity. Rising of large-scale plantations are bound to be fraught with alarming pest problems (Sachin Kumar and Thakur 2011). Many such a forestation programmes, at times, suffer total failures due to insect problems. Pests and diseases cause catastrophic damage that result in loss of the planting stock and failure of plantations and the associated economic losses. Hence, it is vital to maintain the health and vitality of forests, forest ecosystems particularly nurseries and trees outside forests with reference to pests and diseases.

8.3 Forest Insect Pests

Forest vegetation provides food and breeding sites for many insect species. A great diversity of forest insects adapted morphologically, physiologically and behaviourally to feed on almost all

Fig. 8.2 Termite infestation on sandal (*left*) and *Terminalia* sp. (*right*)

forest vegetation and organic matter derived from it. In general, insects are more numerous in the tropics than temperate forests. Insects, as a group, are capable of feeding on almost all parts of a tree – the leaves, flowers, fruit, seed, shoot, bark, sapwood, heartwood and the roots. All insect orders are present in the forest ecosystems. Almost all organic matter in the forest is eaten by one or other insect species. These insects play key roles in ecosystem processes at two trophic levels – as primary consumers and as decomposers. They also play minor roles as secondary and tertiary consumers. In addition, they interact with many other life forms in innumerable ways. These direct and indirect effects of insects on trees, other organisms and the physical environment can influence primary production, succession and evolution of plant communities. The diversity of forest insects is also reflected in their feeding habits. Among them, leaf feeders constitute a large proportion of forest insects. Members of the orders Lepidoptera, Coleoptera and Orthoptera are the common leaf-feeding insects. During outbreaks, they consume most or all the foliage and if it occurs over several successive years, causes reduced seed yields, growth loss, dieback and sometimes death of the tree itself. Sap feeders constitute a comparatively small proportion of species, but some are of economic significance because of population outbreaks and many act as vectors of disease. Most sap feeders belong to the order Hemiptera and a small scale of Diptera and Thysanoptera. They suck the plant juices, and heavy infestations can kill stems and premature defoliations, and they act as vectors. Stem feeders include shoot borers, bark borers, sapwood borers and sapwood cum heartwood borers. Shoot borers are mostly lepidopteran larvae of the families Pyralidae, Oecophoridae and Cossidae. Bark borers include the bark surface-feeding caterpillar *Indarbela quadrinotata* as well as the more economically important 'bark beetles' of the family Curculionidae (Scolytinae). Sapwood cum heartwood borers are mainly the coleopteran family Cerambycidae bore deep into the tree trunk and cause more serious damage. These wood-boring insects reduce the structural integrity of trees and structural damage to poles, fences and wooden buildings. Shoot- and stem-infesting insects kill growing portion of trees and cause growth reduction and tree deformity. Other economically important groups are flower, nectar, pollen and seed feeders which can reduce the seed yields. Gall inducers often kill branches and reduce seed production. Dead wood feeders are mainly termites (Fig. 8.2) and to some extent cerambycid beetles. Termites cause considerable destruction to plants from nurseries to trees in plantations and natural forests, and they probably do more damage to dry wood or seasoned timber

than any other insects in the tropics (Harries 1965). If the damage they cause is significant steps to be taken to reduce those losses so that human's dependent on these resources may continue to exist in comfort. Fortunately, only a small group of the insect species found in the world forests competes with humans for forest resources. However, that relatively small number can have a wide range of ecological, social, or economic impacts. Their damage can be significant, sometimes accounting for millions of US$ in resource losses and pest management costs (Ciesla 2011).

8.4 Forest Insect Pests of India and Their Impacts

Indian forests are mainly tropical, which are characterized by high species diversity and generally are free of pest outbreaks, although the trees may support small populations of phytophagous insects (Nair 2007). In tropical evergreen forests with their numerous species of trees and still more numerous hordes of insect species, the absence of epidemics is not surprising (Beeson 1941). Mixed stands are much safer from insect injury than are pure stands. This is true because the forests have a high degree of species diversity, and most insects have a narrow host range. When, however, single-species plantations are established, the probability of an outbreak of a defoliating insect increases substantially (Wagner et al. 1991). A large number of insects and diseases are known to damage both naturally regenerating forests and plantations in India, although little statistics are available on the area affected by these insects (FAO 2007).

8.4.1 Insect Pests in Natural Habitats

Nair et al. (1986a) reported that all the observed 20 tree species in moist deciduous forests and 18 tree species in evergreen forests in Kerala suffered different types of damage by insects like defoliation, sap sucking, gall inducing and wood boring. The annual defoliation percentage ranged from 0.1 to 6.7 for the different tree species. The mean monthly defoliation was 21 % for moist deciduous species and 17 % for evergreen species. In general, evergreen tree species suffered less damage than moist deciduous species. *Tectona grandis* (teak), one of the important tree species in the moist deciduous forest, showed more 50 % defoliation due to its defoliator *Hyblaea puera*. *H. puera* is also known to cause heavy defoliation in Karnataka, Andhra Pradesh and Madhya Pradesh. Teak is also affected periodically by teak skeletonizer *Paliga machaeralis* in India. Its outbreaks in natural teak areas in central India were reported as early as 1892–1898 (Thompson 1897; Fernandez 1898). *Pteroma plagiophleps*, a polyphagous bagworm, was known to outbreak in plantations of pine *Falcataria moluccana* in India (Nair and Mathew 1992) and also infest many other trees such as *Tamarindus indica*, *Delonix regia*, *Emblica officinalis*, *Syzygium cumini*, *Populus deltoides*, *Tectona grandis* and *Trema orientalis* (Mathew and Nair 1986).

In India, the incidence of cerambycid borer *Hoplocerambyx spinicornis* on Indian sal *Shorea robusta* is in epidemics in many times throughout the range of central and northern India. This is the most economically important pest of Indian forest. In 1997–1998, it has become an endemic pest of sal in Madhya Pradesh and has affected one-sixth of the total sal forests that cover an area of 300,000 ha inflicting a loss of Rs. 250 crores. The beetle, which has an annual life cycle, lays eggs under the bark of the trunk. The grubs bore into the sapwood and heartwood and remain active for 6–7 months, creating extensive galleries and causing partial or complete girdling, eventually killing the tree. In an epidemic in 1923–1928, about seven million sal trees were killed in Madla Forest Division in Madhya Pradesh (Roonwal 1978). Another epidemic in the same state from 1994 to 1998 which covered half a million ha of sal forests resulted in death of about three million trees, before it subsided naturally in 1999 (Dey 2001). The lesser leaf roller of bamboos *Pyrausta bambucivora* is injurious in bamboo forests of northwest Himalaya particularly in moist nullahs. Two bamboo weevils, viz.,

Fig. 8.3 Infestation of *Aristobia octofasciculata* (*left*) and *Zeuzera coffeae* (*right*) on sandalwood

Cyrtotrachelus dux and C. *longimanus* and the bamboo hispine beetle *Estigmena chinensis* are common shot and cum borers of bamboos in natural forests and young plantations. *Dinoderus ocellaris*, *D. minutus* and *D. brevis* are important borers of felled bamboos, and they cause immense damage, and their attack occurs when the bamboos are in the process of drying. Singh et al. (2001) reported heavy mortality of chir pine (*Pinus roxburghii*) in India which occurs in the subtropical mixed forest at Morni Hills in Haryana, patches comprising young and middle-aged trees, heavy mortality of pine trees. Four species of beetles, viz., *Sphenoptera aterrima* (Buprestidae), *Cryptorhynchus rufescens* (Curculionidae), *Platypus biformis* (Curculionidae, Platypodidae) and *Polygraphus longifolia* (Curculionidae: Scolytinae), were considered as causative organisms for the death of trees.

Sandalwood is infested by six species of stem borers, viz., *Aristobia octofasciculata* (Fig. 8.3), *Aeolesthes holosericea*, *Purpuricenus sanguinolentus*, *Capnolymma cingalensis*, *Zeuzera coffeae* (Fig. 8.3) and *Indarbela quadrinotata*. All these borers infest and damage standing sandalwood trees and often lead to mortality in young trees. The trees infested by these borers show poor growth and poor quality of wood. Sandalwood kotis in south India showed sandalwood logs with hollowed heartwood and an average loss of 198.6 kg of heartwood to every ton of wood produced by these trees (Remadevi et al. 1998). There are several important insect species causing qualitative as well as quantitative losses by making galleries in the bark and wood of trees. The affected tress show less resistance to diseases and natural calamities. Breaking of shoots by winds often facilitates entry of pathogens/microorganisms. Trees in a pool physiological state and stress become more liable to attack by xylophagous insects. *Hypsipyla robusta* is an important pest of Meliaceae and causes considerable losses to seeds, shoots and stem of *Toona ciliata*, *Swietenia macrophylla* and *S. mahagoni*. *Tonica niviferana* is a major shoot borer of semul. The beetle *Estigmena chinensis* (Chrysomelidae) is a serious pest of bamboo forests. The pentatomid bug, *Udonga montana*, feeds on the developing seeds of bamboos, and a very heavy build up of this bug was noticed periodically in bamboo forests coincident with gregarious flowering of bamboos.

8.4.2 Insect Pests in Plantations

About 170 species have been tried in plantations forestry which is a major activity in forestry

Fig. 8.4 Infestation of gall wasp *Leptocybe invasa* in *Eucalyptus* sp. (*left*) and flower gall inducer *Asphondylia pongamiae* on *Pongamia pinnata* (*right*)

Fig. 8.5 Infestation of *Icerya* sp. on *Tectona grandis* (*left*) and *Rastrococcus iceryoides* on *Pongamia pinnata* (*right*)

sector in India (Ghosh 1977). It includes species of Acacias, Ailanthus, Bamboo, Casuarina, Dalbergia, Eucalyptus (Fig. 8.4), Pinus, Poplar, Pongam, Shorea, Swietenia and *Gmelina arborea*, *Leucaena leucocephala* and *Tectona grandis* (Fig. 8.5). These tree species are selected irrespective of the extent of the area planted and whether they suffer from serious pest problems or not. The pests associated with these plantation tree species fall under three major categories – nursery pests, sapling pests and pests of older, established plantations.

8.4.3 Nursery Pests

Forest nurseries in India are grown and maintained to overcome the problems of deforestation. Government of India is spending large amount of money to bring about afforestation and reforestation programmes, but the programmes are facing a lot of problems due to nursery pests. Generally, forest tree seedlings are raised in nursery beds and planted out in the field when they are 6–12 months old. Nursery pests include root-feeding white grubs and termites; shoot-cutting caterpillars, crickets and grasshoppers (Fig. 8.6); leaf-feeding caterpillars and beetles; sap-sucking bugs (Fig. 8.7); and shoot-boring scolytine beetles. White grubs are the immature stages of some beetles of the family Scarabaeidae which live in soil and feed underground on the roots of seedlings, and their adult beetles feed on the foliage of trees. White grubs of *Holotrichia consanguinea* and *H. serrata* are

Fig. 8.6 Grasshoppers affecting sandal nurseries

Fig. 8.7 *Pseudoregma bambusicola* infestation on *Bamboo* sp. and *Acaudaleyrodes rachipora* on *Prosopis cineraria*

serious pests of teak nurseries in some localities. Some species of termites attack the roots of seedlings, killing the plants. In well-managed nurseries, the problem of termite damage to young seedling, sampling transplants, or cuttings is almost insignificant. However, under unfavourable conditions, termite menace assumes alarming proportions, often resulting in the total loss and abandonment of nurseries (Thakur 1983, 1988). Caterpillars of some noctuid moths which are commonly known as 'cutworms' characteristically cut off the shoots of small seedlings at ground level. Crickets and mole crickets cause damage in forest nurseries which nest in tunnels made in the ground, come out at night and feed on seedlings, cutting them and dragging pieces to their tunnels. Seedlings of *Casuarina equisetifolia*, *Tectona grandis*, *Dalbergia sissoo*, eucalypts, etc., are damaged by these insects. Several species of grasshoppers and leaf-feeding caterpillars feed on the foliage of seedlings and saplings. Several species of leaf-

feeding caterpillars damage seedlings in forest nurseries. *Diacrisia obliqua* and *Spodoptera litura* are polyphagous. *Eutectona machaeralis* and *Hyblaea puera* attack teak (Ambika-Varma et al. 1996), and *Eligma narcissus* attacks *Ailanthus* spp. (Sivaramakrishnan and Remadevi 1996). *Strepsicrates rhothia* is a cosmopolitan pest which attacks seedlings of many species of eucalypts. Many species of chrysomelid and curculionid beetles also cause damage to forest nursery seedlings. The chrysomelids *Chrysomela populi* and *Nodostoma waterhousie* in poplar nurseries in Kashmir and Himachal Pradesh, respectively, are examples from India (Khan and Ahmad 1991; Singh and Singh 1995). Many species of psyllids cause serious damage to nursery seedlings. *Arytaina* sp. causes serious damage to seedlings of *Albizia lebbeck* in Karnataka (Sivaramakrishnan and Remadevi 1996), and an unidentified species attacks seedlings of *A. odoratissima* and *Pterocarpus marsupium* in Kerala (Mathew 1993).

The babul whitefly *Acaudaleyrodes rachipora* is known to attack the seedlings of species of *Prosopis*, *Acacia* and many other plants of Indian arid zone (Sundararaj and Murugesan 1996). In exceptional cases, losses up to 20–30 % of seedlings of teak due to white grubs, 80 % of eucalypts due to termites, 10–20 % of Albizia lebbeck or eucalypts due to cutworms, 40 % of eucalypts due to crickets, 40 % of *Acacia mangium* due to scolytines, 30–40 % of *Pericopsis elata* due to a pyralid, etc., have sometimes been reported (Nair 2007). The invasive gall-inducing *Leptocybe invasa* (Plate 4) was reported to take heavy toll on eucalyptus nurseries and plantations. Seedlings in nurseries and 6–8-month-old saplings are susceptible to *L. invasa*, which produces galls in young shoot terminals, petioles and midribs, while in mature trees the galls occur only on midribs. A heavy infestation of the wasp results in loss vigour and growth retardation. The spread of gall wasp is a huge concern to the country as eucalypts occupy 25 % of the plantation estate of the country (Jacob et al. 2007). Generally, serious damage in nurseries can usually be prevented by application of prophylactic or curative control measures.

8.4.4 Sapling Pests

The insects, which attack the sapling stage of trees, include root, stem, or terminal shoot borers, leaf-feeding caterpillars and sap-sucking bugs. Termites usually attack saplings of eucalypts, pines, casuarina, etc., during their establishment stage after transplanting into the field. The grub of the cerambycid beetle *Celosterna scabrator* bore into the root-shoot portion of the saplings of *Prosopis* spp., *Acacia* spp., *Eucalyptus* spp., etc., often causes death of host trees. Sandal plants of girth class 5–12 cm were found heavily infested by *Purpuricenus sanguinolentus*. The nature of attack was from the stem towards the basal portion of sandal causing death to the sandal saplings and posing threat to young sandal plantations (Raja Muthukrishnan et al. 2009). Larvae of the cossid moth *Zeuzera coffeae* bore into the stem of saplings of teak, sandal, eucalypts, etc., and some bostrichid beetles bore into the stem of saplings of *Acacia mangium*. Larvae of the moths *Hypsipyla robusta* bore into the terminal shoot of saplings of mahogany and other meliaceous trees, causing severe growth retardation. Leaf-feeding caterpillars of the moth *Eligma narcissus* cause defoliation of saplings of *Ailanthus* species. Kadam, *Anthocephalus cadamba*, commonly raised in large scale under agroforestry conditions suffers severe defoliation due to *Arthroschista hilaralis*. The defoliation retards growth of young trees in 2–5-year-old plantations result in stunned growth. *Pteroma plagiophleps* often defoliates albizias which are raised in large scale in various states. Hypocala rostrata causes large-scale defoliation in tendu (*Diospyros melanoxylon*) and makes the leaves unfit for making bidi wrapper (Khan and Bhandari 2001).

Sandal saplings were infested by 73 species of hemipteran- and 2 species of thysanopteran-sucking pests. The hemipteran-sucking pests include 21 species of Cicadellidae followed by 7 species of Pentatomidae; 6 species each of Coccidae, Margarodidae, Membracidae and Pseudococcidae;

Fig. 8.8 Infestation of *Megapulvinaria maxima* on sandal (left) and *Pyrausta coclesalis* on *Bamboo* sp.

4 species of Aleyrodidae; 2 species each of Alydidae, Coreidae, Delphacidae, Diaspididae, Gerridae, Pyrrhocoridae and Scutelleridae; and 1 species each of Cercopidae, Eurybrachidae and Ortheziidae (Sundararaj and Raja Muthukrishnan 2008a). The sap-feeding bug *Tingis beesoni* attacks saplings of *Gmelina arborea* and causes dieback of shoots. The mealy scale *Megapulvinaria maxima* (Plate 8) and tea mosquito bug *Helopeltis antonii* are common sucking pests on Neem. Its infestation on sandal often leads to death of young plants. Various insect pests belonging to the orders Coleoptera, Hemiptera, Orthoptera and Lepidoptera attack bamboo in nurseries and plantations, and they are grouped as defoliators, borers and sap. Aphids were major pests on bamboo species damaging the sap from the lower surface of leaves. The major sap-sucking aphid pests are *Astegopteryx bambusae*, *Astegopteryx formosana*, *Hysteroneura setariae*, *Pseudoregma bambusicola* and *Melanaphis bambusae*. The bamboo bug, *Notobitus meleagris*, is a pest of bamboo, and the injection of its toxic saliva into bamboo shoot at feeding causes the death of plant cells and necrosis. *Estigmena chinensis* is the most important pests of standing bamboos in natural forests and plantations. Sometimes, 100 % culms in clump are attacked. *Pyrausta coclesalis* (Fig. 8.8) is a common defoliator of bamboo in Indian subcontinent. Depending on the tree species, sapling pests can cause serious economic loss, particularly where no effective control methods is available.

8.4.5 Pests of Older Plantations

Generally, a large number of insect species are associated with each tree species. The number of phytophagous insect species associated with a tree species ranges from 10 to 200 in general, with a mean of 65 with an exceptional 920 species associated with Eucalyptus (Nair 2007). The number of species of insects associated with a plantation tree species will be influenced by several factors – the chemical profile of the species, the extent and climatic diversity of the geographical area covered, the period over which the species has been cultivated on a large scale, etc. In most of the cases, although fairly large numbers of insects are associated with all tree species, many of them are casual or minor pests, and only a few species are major pests on a tree species. Major pests include defoliators, sapsuckers and stem borers. Leaf-feeding insects occur on all tree species, with serious pests occurring on *Ailanthus*, *Dalbergia sissoo*, eucalypts, *Gmelina arborea*, teak, oak sal, pine deodar and poplars. The insect *Atteva fabriciella* commonly known as Ailanthus webworm causes defoliation in plantations of *Ailanthus* species. *D. sissoo* suffers extensive damage due to attack of key pests known as shisham defoliator, *Plecoptera reflexa*, and shisham leaf roller, *Dichomeris eridantis*.

The epidemic by *Ascotis selenaria imparata* in sal forests often causes complete defoliation of

Fig. 8.9 Defoliated teak plantation

sal trees. Poplar is defoliated by two major defoliators, viz., *Clostera fulgurita* and *C. cupreata*. Large-scale defoliation due to these insects has been reported in poplar plantations in Uttar Pradesh. Khasi pine is defoliated by *Eterusia pulchella* and *Metanastria ampla*. *Lymantria obfuscate* commonly known as India gypsy moth or Kashmir willow defoliator attacks willow, poplars and oak (Khan and Bhandari 2001). Sap-sucking insects are major pests in *Leucaena leucocephala*. A sap-sucking bug, *Rederator bimaculatus*, is responsible for transmitting spike disease, caused by a mycoplasma-like organism in the sandal tree, *Santalum album*. Sundararaj and Raja Muthukrishnan (2008b) reported the presence of six species of stem borers in sandalwood trees. Remadevi and Raja Muthukrishnan (2008) observed significant difference in the distribution of *A. octofasciculata* and *I. quadrinotata* on different girth classes of sandal. Ghate et al. (2011) reported the incidence of *Capnolymma cingalensis* from sandal forest areas of Karnataka. Stem borers are major pests of *Shorea robusta*. *Celosterna scabrator* is a major pest of babul (*Acacia nilotica*), khair (*Acacia catechu*) and Eucalyptus plantations in Uttar Pradesh, Madhya Pradesh and Haryana. Combined defoliation of teak by *Paliga machaeralis* and *Hyblaea puera* is a major problem in India (Fig. 8.9). *Alcterogystia cadambae* is a major pest in teak plantations, and *Batocera rufomaculata* is a polyphagous pest species affecting the timber of many tree species.

8.4.6 Pest of Timber

Various groups of insects, belonging to several orders, commonly known as wood borers, confine their attack to various timber species under different conditions. Among these, the most important order is Coleoptera (or beetles). Wood wasps and ants belonging to Hymenoptera and termites (Isoptera) are the other major wood invaders. Timber in structures/houses is mainly attacked by insects belonging to the Coleopteran families, Platypodidae and Scolytidae (ambrosia beetles), Lyctidae, Bostrichidae, Cerambycidae and Anobiidae. Ghoon beetles/borers or bostrichids or shot hole borers particularly *Heterobostrychus aequalis* and *Sinoxylon* spp. also cause extensive damage to timber in service and storage. Termites are one of the

principle destroyers of wood in buildings in the tropics and the subtropics. The extent of financial loss due to termite damage has not been computed precisely due to the difficulties associated with such computations. Edwards and Mill (1986) estimated that US$ 1,920,000 was spent worldwide per annum by the pest control operations for the treatment of buildings against termites. In India itself, the cost of treatments as preventive and remedial measures comes to about Rs 28 million annually (Rawat 2004). Damage to constructional timbers and timber products in buildings can be caused either by dry wood termites which do not maintain soil connection for moisture requirements or by the soil-dwelling termites that obligatorily maintain soil connection for moisture requirements. However, *Coptotermes* spp. are known to survive without soil connection provided that moisture source is available near their colony sites. The soil-dwelling termites cause the maximum infestation and damage in India and other tropical countries. Timbers put in use in marine environment are commonly affected by marine wood borers which fall under two main classes, viz., Bivalvia of Mollusca and Crustacea of Arthropoda.

8.5 Insect Pest Management

In natural tropical forests where serious pest attack is exceptional, most tree species raised in plantations are attacked by one or more serious pests. For some tree species, pests have a devastating impact in plantations, much more serious than in the mixed species natural stands. Integrated pest management practices are well recognized in the management of forest insect pests. It largely depends upon the sound knowledge of forest nature and the natural regulating forces operating in it. Strategy of wood protection is by avoiding all chemical and adopting natural ways to prevent the attack of insect pests by adopting physical and cultural methods or by employing the biocontrol methods. Naturally, many timbers are durable timbers but which account for only 10 % of the total volume of wood used in the industrial sector (Purushotham 1975). The presence of various chemical compounds and lignin are the factors which account for the natural resistance of timbers (Walcott 1946, 1947; Abushama and Abdel Nur 1973; Behr et al. 1972). The cultural methods include avoiding sapwood, following safe-felling period, debarking, starch depletion and following proper storage methods. Surface protection like polishing, lamination, as well as sterilization is very effective natural methods. The concept of integrated pest management (IPM) exploits all the available options so that the insecticide load to the environment can be minimized. The IPM practices are adopted from raising nurseries, seed sowing, bed preparation, etc., but most of the control operation in forestry is limited to the nursery stage in the form of chemical inputs. However, the use of synthetic pesticides during the last half century has often been careless and indiscriminate which resulted in malicious effects on the environment and leads to 'ecological backlash' (Sundararaj 1997). Concern about this has led to a surge of research into alternative pest control technologies. One of the efforts is the development of botanical insecticides as a novel and safer alternative strategy. It is this place where these botanical insecticides could be of great use along with other options to minimize the use of chemicals. Botanical insecticides, which contain plant extracts as active components, are safer as well as environmentally friendlier than synthetic insecticides. The use of these chemicals of plant origin, commonly called 'botanicals' or 'phytochemicals', has attracted particular attention because of their specificity to insect pests, their biodegradable nature and their potential for commercial application (Bishop and Thornton 1997; Shukla et al. 2000). These materials have been, since time immemorial, reported to be devoid of the various disadvantages, which are associated with the use of synthetics. Bioactivity of plant-based compounds is well documented in literature and is a subject of increasing importance. Knowledge of the toxic plants, their toxic principles and their biological activity is of paramount importance not only to enable them to be utilized as natural pest control

agents and replace the commercial synthetic pesticides but also to enable us to understand the nature of their toxicity to nontargeted animals (Shukla et al. 2001). The efficient use of such renewable natural resources is becoming increasingly important worldwide. There is no doubt that many plant secondary metabolites affect insect behaviour, development and reproduction. Characterization and identification of these substances is an important first step in understanding the effect of plants on insect life. The botanicals thus obtained offer better compatibility with other biological pest control agents than that of the synthetics, and this has brought them to a sudden prominence in pest management programme.

8.5.1 Neem Products for the Management of Forest Insect Pests

Neem (*Azadirachta indica*) products are known in use in India from time immemorial against noxious insects. Because of its legendary insect repellent and medicinal properties, it is being identified as 'the most promising of all plants', and at the present moment, it is the source of the most promising pesticides. More than 100 protolimonoids, limonoids, or tetranortriterpenoids and some nonterpenoid constituents have been isolated from various parts of neem (Koul et al. 1990; Lim and Dale 1994). From the neem seed extract alone, over 57 components (Table 8.2) have been isolated and identified (Jacobson 1988). It is now well established that azadirachtin, the most important phagorepellent of neem kernels, protects plants against insect attack. Bernays and Chapman (1977) indicated azadirachtin as the most potent antifeedant against insects like *Locusta migratatoria migratorioides* and *Schistocerca gregaria*. It exhibits strong antifeedant activity against locusts as well as growth-inhibiting properties (Rembold et al. 1980). Neem kernel extracts or their oil repel insects act as antifeedant, cause growth disruption, deformities or mortality and impair egg production (Sieber and Rembold 1983).

Table 8.2 Some of the important biologically active chemicals from *A. indica*

Compound name	Molecular formula	Activity
Azadirachtin	$C_{35}H_{44}O_{16}$	AF, GR, OR
Azadiradion	$C_{28}H_{43}O_5$	AF
Azadiron	$C_{28}H_{36}O_4$	AF
Deacetyl azadirachtinol	$C_{32}H_{42}O_{15}$	AF, GR
6-Deacetylnimbinen	$C_{26}H_{32}O_6$	AF
Nimbinen	$C_{28}H_{34}O_7$	AF
3-Deacetylsalannin	$C_{32}H_{42}O_8$	AF, GR
Salannin	$C_{34}H_{44}O_9$	AF
1, 3-Diacetyl vilasmin	$C_{30}H_{40}O_7$	AF, GR
Eposyazadiradion	$C_{28}H_{34}O_6$	AF
Gedunin	$C_{28}H_{34}O_7$	AF
Meliantriol	$C_{30}H_{50}O_5$	AF
Nimbandiol	$C_{26}H_{32}O_7$	AF

AF Antifeedant activity, *GR* Growth and development regulation, *OR* Ovipositional repellent

This chapter offers further evidence for the impact of neem products against the major forest insect pests of India. The control of forest pests like poplar defoliator, *Pygaera cupreata* (Bhandari et al. 1988); babul defoliator, *Taragama siva* (Sundararaj et al. 1995); the rohida defoliator, *Patialus tecomella* (Sundararaj and Murugesan 1995); the babul whitefly, *Acaudaleyrodes rachipora* (Sundararaj et al. 1995, 1996; Sundararaj 1999a, b); and the teak defoliators, *Eutectona machaeralis* and *Hyblaea puera* (Kulkarni et al. 1996; Remadevi and Raja Muthukrishnan 1998; Murugan et al. 1999; Sree et al. 2008) using different neem products have been tested and found useful. Dubey and Sundararaj (2004) demonstrated neem oil as effective like that of commercial neem formulations and Chlorpyrifos in containing the nymphal populations of *A. disperses*-infesting trees of *Michelia champaca* and *B. variegata*. Neem seed kernel suspension as effective repellent against the polyphagous desert locust *Schistocerca gregaria* was demonstrated (Pradhan and Jotwani 1971; Singh 1985; Sundararaj et al. 1995). Ramarethinam et al. (2002a, b) reported insecticidal property of azadirachtin against *Eurema hecabe* on *Cassia fistula* Ambika et al. (2007). The application of

neem cake alone or in combination with other seed cakes and VAM was recommended to control whiteflies in nurseries (Sundararaj 2010). As the neem products proved its practical utility, they are recommended for large-scale application in forestry. The types of neem products and their effect on the insect pest of forest importance and their host spectrum are given in the Table 8.3. The reports confirm that the neem constituents are effective against forest insect pests. Neem products particularly neem cake form an integral component of potting mixture in raising seedlings. It is mixed with other potting mixtures along with other biofertilizers. The number of neem trees in India is estimated to be around 18 million with potential of 54,000 t of seeds/year, and only 25 % of the seeds are used (Gahukar 2010) and hence its full potential to be exploited. Besides, neem-based pesticides can further be fortified against dynamic pests by optimizing their use with microbial agents. From the standpoint of safety, neem-based pesticides, with their low mammalian toxicities, offer attractive alternatives to many hard conventional pesticides in use today. However, as per the report of the Directorate of Nonedible Oils and Soap Industry, Khadi and Village Industries Commission, Bombay, 1976 (Rajasekaran 1991), less than one-fourth of the neem seeds produced in this country is collected for utilizations purpose (Table 8.4). Hence, it is the right time to make more awareness to use neem products more as well as the users should be encouraged to grow more neem trees on their domestic homesteads and educated about its value in pest control.

8.5.2 Other Plant Products for the Management

Considerable amount of research is carried out in India with emphasis on screening and development of plant products, phytochemicals and natural products. Over 2,000 plant species have been reported to possess pesticidal activity (Crosby 1971; Chakraboraty and Basu 1997) out of about 2,500,000 angiosperms so far documented. A perusal review indicated that other than neem, about 64 plant species were reported to have pest management properties on forest insect pests (Table 8.5). In these plants, mostly crude extracts were found to have different type of pest management properties in laboratory condition against defoliating pests of teak, poplar, subabul, bamboo, etc., without identifying the active principles in the plant products. Shukla et al. (2001) commented that only a fraction of pesticidal plants have been analysed for active principles. Defoliating insects were mostly used as test insects except for the report of Sharma et al. (1992) who reported insecticidal properties of 15 plant oils against the sap-sucking psyllid *Heteropsylla cubana*. Cashew nut shell liquid has been found effective in protecting the wood for shorter durations against termites (Remadevi et al. 2002). These plant products are probable sources of some biologically active agents for pest management for the future. However, since almost all plant products other than neem and cashew nut shell liquid were evaluated in the laboratory condition as of now, they were not practically used in pest control.

8.6 Conclusion

The forest is a dynamic ecosystem constituting of principal natural renewable resources of multifarious uses which fulfill the requirement of the society and sustainability of the earth. Insect pests are major biological determinants of forest productivity, and integrated pest management is not new to Indian forestry. Adoption of wood protection technologies alone has the potential to save approximately 2 m^3 of wood for every 3 m^3 and because of increase in average life of timber from 5 to 15 years would save at least 5.6 m ha of forests raising the forest cover by 2 % in India. A good and ideal silviculture system means healthy, resistant, tolerant and vigorous tree. Proper understanding of the biology and ecology of the tree species and their associated fauna and flora plays an important role in the pest management. The nurseries and monoculture plantations are much more susceptible to insect

Table 8.3 Effect of neem products on insect pests having the host spectrum of forest trees

Pest species	Neem products	Host plant	Effects	References	Known host spectrum of forest trees
Achaea janata	NSKE	Castor	Antifeedant	Chari and Muralidharan 1985; Ramarethinam et al. 2002a	*Acacia arabica*, *Albizia amara*, *Anogeissus latifolia*, *Bauhinia vahlii*, *Grewia microcos*, *Phyllanthus emblica*, *Ziziphus jujuba*
	NSO and neem formulations		Insecticidal		
Agelastica alni	NSKE	Alder	Fecundity reduction	Speckbacher 1977	–
Aphis gossypii	NSO	Brinjal	Insecticidal	Cherian and Gopal 1944	*Tecomella undulata*
Bemisia tabaci	NSKE	Black gram	Insecticidal	Mariappan et al. 1987; Natarajan and Sundaramurthy 1990	*Clerodendron infortunatum*
	NSO	Cotton	Growth suppression		
Bupalus piniarius	NSKE	*Pinus sylvestris*	Insecticidal	Speckbacher 1977	–
Callosobruchus spp.	NKP	Pulses	Grain protection	Jotwani and Sircar 1967	Many tree species
Caryedon serratus	Nimbicidin	Seeds	Antifeedancy and growth regulation	Murugesan et al. 2008	*Acacia nilotica*, *Pongamia pinnata*
					Tamarindus indica
Choristoneura fumiferana	Margosan-O	Spruce	Antifeedant, growth regulation, insecticidal	Thomas et al. 1992	–
Diprion pini	NSKE	Forest trees	Insecticidal	Speckbacher 1977	–
Drosicha mangiferae	NC	Mango	Insecticidal	Tandon and Lal 1980	*Artocarpus integrifolia*, *Dalbergia sissoo*, *Ficus benghalensis*, *F. religiosa*, *F. glomerata*
Dysdercus cingulatus	NSKE	Cotton	Insecticidal and juvenile hormone mimic activity	Abraham and Ambika 1979	*Bombax malabaricum*, *Thespesia populnea*
Dysdercus koenigii	NSKE	–	Growth inhibitor	Jaipal et al. 1983	*Grewia tiliifolia*, *Sida rhombifolia*
	NSO	–	Antifeedant, growth inhibitor	Gujar and Mehrotra 1990	–
Euproctis lunata	NSKE	Castor	Repellant	Babu and Beri 1969	*Acacia nilotica*, *Terminalia tomentosa*, *Ziziphus jujuba*
Euproctis fraterna	NSKE	Castor	Antifeedant	Kareem et al. 1988	*Terminalia tomentosa*, *Tectona grandis*, *Shorea robusta*, *Ziziphus jujuba*, *Ougeinia dalbergioides*
Euproctis chrysorrhoea	NSKE	Oak	Antifeedant	Speckbacher 1977	–
Eurema hecabe	Azadirachtin	*Cassia fistula*	Insecticide	Ramarethinam et al. 2002b	–
Eutectona machaeralis	NSE	Teak	Antifeedant	Kulkarni et al. 1996	*Tectona grandis*, *Callicarpa* spp., *Tectona hamiltoniana*
	NSO	Teak	Antifeedant	Remadevi and Rajamuthukrishnan 1998	
Fenusa pusilla	NSKE	Birch trees	Insecticidal	Larew et al. 1987	–
Fenusa pusilla	Margosan-O	*Betula papyrifera*	Insecticidal	Marion et al. 1990.	–
Helicoverpa armigera	NSKE	Bengal gram and red gram	Insecticidal	Srivastava et al. 1984	*Albizia* sp., *Pinus* sp.
	NSO	Chickpea	Crop protectant	Sinha 1993	
Heteronygmia dissimilis	NSKE	Khayanyasica	Insecticidal	Rwamputa and Schabel 1989	–

(continued)

Table 8.3 (continued)

Pest species	Neem products	Host plant	Effects	References	Known host spectrum of forest trees
Hieroglyphus banian	NSKE	Rice	Crop protection	Dhaliwal et al. 1993; Mohan et al. 1991	*Dendrocalamus strictus*
	NSO, NC		Crop protection		
Holotrichia consanguinea	Neem cake	Groundnut	Crop protection	Rao and Bajaj 1984	Forest nurseries
Holotrichia insularis	NC	Chilli	Insecticidal	Sachan and Pal 1976	Nursery pest of many species
Hyblaea puera	NSKE	Teak	Antifeedant ovipositional deterrent	Murugan et al. 1999	*Tectona grandis*, *Tecomella undulata*, *Millingtonia hortensis*, *Callicarpa* spp., *Vitex* spp.
	NSO	Teak	Antifeedant	Remadevi and Rajamuthukrishnan 1998	
Hylobius abietis	Azadirachtin-enriched product	Spruce	Repellent	Beitzen-Heineke and Hofmann 1992	–
Hyloicus pinastri	NSKE	*Pinus sylvestris*	Insecticidal	Speckbacher 1977	–
Lipaphis erysimi	NSKE	Mustard	Insecticidal	Sharma et al. 1984	*Tecomella undulata*
Locusta migratoria	NSKE	–	Protected maize, cabbage and sorghum plants	Pradhan and Jotwani 1971	Many tree species
Lymantria dispar	NSKE	Oak	Insecticidal	Skatulla and Meisner 1975	–
L. monacha	Azadirachtin-enriched product	–	Insecticidal	Beitzen-Heineke and Hofmann 1992	–
Melolontha hippocastani	Azadirachtin-enriched product and NSO	Oak	Fecundity reduction	Schmutterer and Kaethner 1988	Many tree species
M. melolontha	Azadirachtin-enriched product and NSO	Oak	Fecundity reduction	Kaethner 1991	–
Nephotettix virescens	NSKE	Rice	Antifeedant	Krishnaiah and Kalode 1991	*Santalum album*
	NSO	Rice	Insect growth disruptant	Kareem et al. 1988	
	NKP	Rice	Insecticidal		
Paliga machoeralis	LE	Teak	Insecticidal	Sree et al. 2008	–
Panolis flammea	NSKE	*Pinus sylvestris*	Insecticidal	Speckbacher 1977	–
Pericallia ricini	NSO	–	Antifeedant	Mala 1987	*Cassia tora*, *Santalum album*, *Bombax ceiba*
	NOE		Antifeedant and growth regulation	Mala and Muthalagi 2008	
					–
Phyllocnistis citrella	NSO	Citrus	Insecticidal	Dhara Jothi et al. 1990	*Aegle marmelos*, *Murraya koenigii*
	NC				
Pityogenes chalcographus	Neem oil, NSKE	Spruce	Sterilizing effects	Wulf and Scheidemann 1990	–
Pristiphora abietina	Azadirachtin-enriched product	Spruce	Insecticidal	Schmutterer 1995	–

(continued)

Table 8.3 (continued)

Pest species	Neem products	Host plant	Effects	References	Known host spectrum of forest trees
Pygaera cupreata	NSKE	Poplar	Antifeedant	Bhandari et al. 1988	*Populus* sp., *Salix* spp.
Schistocerca gregaria	NSKP	Fed with diet	Repellant toxicity	Singh 1985	Many tree species of Indian arid zone
Spodoptera litura	NSKE	Tobacco	Antifeedant	Joshi et al. 1984	*Cassia tora*, *Diospyros montana*, *Tectona grandis*
	NSO	–	Antifeedant and gustatory repellant	Koul 1987	
	NC	Tobacco	Insecticidal	Murthy et al. 1990	
	Azadirachtin	Sugar beet	Larvicidal	Shivankar et al. 2008	
Stilpnotia salicis	Neem leaf	Willow	Antifeedant	Speckbacher 1977	–
Thaumetopoea pityocampa	NSKE	*Pinus sylvestris*	Insecticidal	Speckbacher 1977	–
White grub	NKP	Groundnut	Insecticidal	Raodev 1973	*Shorea robusta*, *Tectona grandis*, *Cassia* sp., *Lagerstroemia sp.*
Yponomeuta padellus	NSKE	*Prunus spinosa*	Antifeedant	Speckbacher 1977	–

NSKE Neem seed/neem seed kernel extract, *NSO* Neem seed oil, *NKP* Neem kernel powder, *NOE* Neem oil extractive, *NC* Neem cake, *LE* Leaf extract

Table 8.4 Distribution of neem trees in India and the potential collection

State	No. of trees ('000)	Total seed potential ('000 t)	Total oil potential ('000 t)	Actual collection (%)
Andhra Pradesh	653.9	12.2	2.5	27
Gujarat	636.2	21.0	4.2	1
Madhya Pradesh	735.6	18.2	3.6	2
Tamil Nadu	2,544.1	57.1	11.4	29
Maharashtra	710.1	28.2	5.6	1
Karnataka	790.6	20.1	4.0	20
Orissa	48.7	1.2	0.2	-NA-
Punjab	391.3	12.0	2.4	-NA-
Rajasthan	183.8	3.9	0.8	-NA-
Uttar Pradesh	7972.6	265.9	53.2	-NA-
West Bengal	273.0	2.5	0.5	27
Total	14,939.90	442.3	88.5	24

Source: Directorate of Nonedible Oils and Soap Industry, Khadi and Village Industries Commission, Bombay, 1976; Rajasekaran 1991
NA Not available

epidemics as compared to mixed plantations and natural forests. Besides, the number of insect species acquiring pest status is increasing day by day possibly due to environmental imbalances. Climate change and bioinvasion are expected to bring extension in the host range of many pests and diseases. Shift in population growth rate among insect species due to global warming will have profound ecological effect by altering species composition and disrupting food webs. Forest managers realize that large-scale spraying of chemicals, microbes, or botanicals cannot be feasible in large-scale plantations and natural forest areas. However, they find it is feasible to use a maximum quantity of neem cake as an integral component of potting mixture for raising nurseries. Also, the herbal product cashew nut shell liquid is commonly used for short-term wood protection. Most of the control operation in forestry is limited to the nursery

Table 8.5 Effect of plant products other than neem against forest insect pests of India

Plant species	Product	Pest species	Host plant	Effects	References
Acacia mangium	Leaf extract	*Hyblaea puera*	*Tectona grandis*	Antifeedant	Ramanna and Bhat 2006
Acacia auriculiformis	Leaf extract	*Hyblaea puera*	*Tectona grandis*	Antifeedant	Ramanna and Bhat 2006
Acorus calamus	Plant oil	*Heteropsylla cubana*	*Leucaena leucocephala*	Insecticidal	Sharma et al. 1992
Aegle marmelos	Seed oil	*Hyblaea puera*	*Tectona grandis*	Insecticidal	Krishnakumar et al. 2011
Adina cordifolia	Leaf extract	*Clostera cupreata*	Poplar	Antifeedant	Ahmad et al. 1997
Adhatoda vasica	Leaf extract	*Atteva fabriciella*	*Ailanthus* sp.	Antifeedant	Ahmad et al. 1991
Aloe vera	Leaf extract	*Paliga machaeralis*	*Tectona grandis*	Antifeedant	Kulkarni et al. 1997a
Amarphophallus componata	Tuber extract	*Hyblaea puera*	*Tectona grandis*	Larvicidal	Javaregowda and Naik 2006
Anacardium occidentale	Cashew nut shell liquid	Termites	*Hevea brasiliensis*	Wood protection	Remadevi et al. 2002
Angelica glauca	Plant oil	*Heteropsylla cubana*	*Leucaena leucocephala*	Insecticidal	Sharma et al. 1992
Annona squamosa	Leaf extract	*Crypsiptya coclesalis*	*Bamboo* spp.	Antifeedant	Kulkarni et al. 2003
Apium graveolens	Plant oil	*Heteropsylla cubana*	*Leucaena leucocephala*	Insecticidal	Sharma et al. 1992
Bassia latifolia	Plant oil	*Heteropsylla cubana*	*Leucaena leucocephala*	Insecticidal	Sharma et al. 1992
Bixa orellana	Leaf extract	*Paliga machaeralis*	*Tectona grandis*	Growth inhibition	Sree et al. 2008
Butea frondosa	Plant oil	*Heteropsylla cubana*	*Leucaena leucocephala*	Insecticidal	Sharma et al. 1992
Calophyllum inophyllum	Plant oil	*Heteropsylla cubana*	*Leucaena leucocephala*	Insecticidal	Sharma et al. 1992
Calotropis procera	Leaf extract	*Paliga machaeralis*	*Tectona grandis*	Antifeedant	Meshram 1995
Carum capticum	Essential oil	*Odontotermes obesus*	'*no choice bioassay*'	Mortality	Gupta et al. 2011
Cassis fistula	Leaf and bark extract	*Hyblaea puera*	*Tectona grandis*	Larvicidal	Javaregowda and Naik 2006
Cassia siamea	Leaf extract	*Hyblaea puera*	*Tectona grandis*	Larvicidal	Javaregowda and Naik 2006
Casuarina equisetifolia	Leaf extract	*Hyblaea puera*	*Tectona grandis*	Antifeedant	Ramana and Bhat 2006
Catharanthus roseus	Leaf extract	*Paliga machaeralis*	*Tectona grandis*	Growth inhibition	Sree et al. 2008
Cedrus deodara	Plant oil	*Heteropsylla cubana*	*Leucaena leucocephala*	Insecticidal	Sharma et al. 1992
	Essential oil	*Odontotermes obesus*	'*no choice bioassay*'	Mortality	Gupta et al. 2011
Chromolaena odorata	Leaf extract	*Termites*	*Bambusa balcooa*	Resistant to degradation	Borthakur and Gogoi, 2009
Cinnamomum camphora	Camphor oil	*Calopepla leayana*	*Gmelina arborea*	Antifeedant	Singh and Sushilkumar, 1998
		Eupterote geminate			

(continued)

Table 8.5 (continued)

Plant species	Product	Pest species	Host plant	Effects	References
Clerodendrum inerme	Leaf extract	*Hyblaea puera* and *Paliga machaeralis*	*Tectona grandis*	Antifeedant	Sundararaj et al. 2004
	Leaf extract	*Hyblaea puera*	*Tectona grandis*	Larvicidal	Javaregowda and Naik 2006
	Leaf extract	*Hyblaea puera*	*Tectona grandis*	Ovicidal	Ramana 2005
Cymbopogon citratus	Essential oil	*Odontotermes obesus*	'*no choice bioassay*'	Mortality	Gupta et al. 2011
Eucalyptus hybrid	Leaf extract	*Clostera cupreata*	Poplar	Antifeedant	Ahmad et al. 1997
Eucalyptus globulus	Essential oil	*Odontotermes obesus*	'*no choice bioassay*'	Mortality	Gupta et al. 2011
Eugenia caryophyllata	Essential oil	*Odontotermes obesus*	'*no choice bioassay*'	Mortality	Gupta et al. 2011
Daucus carota	Plant oil	*Heteropsylla cubana*	*Leucaena leucocephala*	Insecticidal	Sharma et al. 1992
Dalbergia stipulacea	Bark and Root extract	*Clostera cupreata*	Poplar	Antifeedant	Ahmad et al. 1997
Derris indica	Leaf extract	*Hyblaea puera*	*Tectona grandis*	Larvicidal	Javaregowda and Naik 2006
Datura metel	Leaf extract	*Paliga machaeralis*	*Tectona grandis*	Antifeedant	Meshram 1995
	Leaf extract	*Plecoptera reflexa*	*Dalbergia sissoo*	Antifeedant	Kulkarni et al. 1997b
	Leaf extract	*Paliga machaeralis*	*Tectona grandis*	Growth inhibition	Sree et al. 2008
Dirca palustris	Seed extract	*Paliga machaeralis*	*Tectona grandis*	Antifeedant	Murugesan et al. 2003
Dodonaea viscosa	Leaf extract	*Lamprosema niphaelis*	*Pongamia pinnata*	Growth inhibition	Deepa and Remadevi 2007b
		Hyblaea puera	*Tectona grandis*		Deepa and Remadevi 2008
Dryopteris sp.	Leaf extract	*Termites*	*Bambusa balcooa*	Resistant to degradation	Borthakur and Gogoi 2009
Eucalyptus hybrid	Leaf extract	*Plecoptera reflexa*	*Dalbergia sissoo*	Antifeedant	Meshram 2000
Gnidia glauca	Leaf and bark extract	*Hyblaea puera*	*Tectona grandis*	Larvicidal	Javaregowda and Naik 2006
Hevea brasiliensis	Plant oil	*Heteropsylla cubana*	*Leucaena leucocephala*	Insecticidal	Sharma et al. 1992
Holigarna arnottiana	Leaf and bark extract	*Hyblaea puera*	*Tectona grandis*	Antifeedant	Ramana et al. 2004
Ipomea carnea	Leaf and flower extract	*Crypsiptya coclesalis*	*Bamboo* spp.	Antifeedant	Kulkarni and Joshi 1998
Jatropha curcas	Plant oil	*Heteropsylla cubana*	*Leucaena leucocephala*	Insecticidal	Sharma et al. 1992
	Leaf extract	*Papilio demoleus*	*Feronia elephantum*	Antifeedant	Meshram et al. 1996
	Leaf and seed extract	*Hyblaea puera*	*Tectona grandis*	Larvicidal	Javaregowda and Naik 2006
Juniper communis	Plant oil	*Heteropsylla cubana*	*Leucaena leucocephala*	Insecticidal	Sharma et al. 1992
Lantana caftera	Leaf extract	*Hyblaea puera*	*Tectona grandis*	Larvicidal	Javaregowda and Naik 2006

(continued)

Table 8.5 (continued)

Plant species	Product	Pest species	Host plant	Effects	References
Lantana camara	Leaf extract	*Atteva fabriciella*	*Ailanthus* sp.	Antifeedant	Ahmad et al. 1991
		Plecoptera reflexa	*Dalbergia sissoo*		Kulkarni et al. 1997b
	Leaf extract	*Paliga machaeralis*	*Tectona grandis*	Antifeedant	Kulkarni et al. 1997a
	Leaf and flower extract	*Crypsiptya coclesalis*	*Bamboo* spp.	Antifeedant	Kulkarni et al. 1999
Lobelia nicotianaefolia	Leaf extract	*Hyblaea puera*	*Tectona grandis*	Larvicidal	Javaregowda and Naik 2006
	Leaf extract	*Lamprosema niphaelis*	*Pongamia pinnata*	Growth inhibition	Deepa and Remadevi 2007a
Persea macrantha	Solid colouring matter from the bark	*Hyblaea puera* and *Paliga machaeralis*	*Tectona grandis*	Antifeedant	Sundararaj et al. 2004
Melia azedarach	Leaf extract	*Atteva fabriciella*	*Ailanthus* sp.	Antifeedant	Ahmad et al. 1991
	Leaf extract	*Plecoptera reflexa*	*Dalbergia sissoo*	Antifeedant	Meshram 2000
	Leaf and seed extract	*Hyblaea puera*	*Tectona grandis*	Antifeedant	Senthilnathan and Sehoon 2006
Mentha arvensis	Essential oil	*Odontotermes obesus*	'*no choice bioassay*'	Mortality	Gupta et al. 2011
Nerium oleander	Leaf extract	*Paliga machaeralis*	*Tectona grandis*	Growth inhibition	Sree et al. 2008
Parthenium hysterophorus	Leaf extract	*Paliga machaeralis*	*Tectona grandis*	Antifeedant	Durairaj 2009
Polygonum glabrum	Leaf extract	*Termites*	*Bambusa balcooa*	Resistant to degradation	Borthakur and Gogoi 2009
Pongamia pinnata	Leaf extract	*Plecoptera reflexa*	*Dalbergia sissoo*	Antifeedant	Meshram 2000
Pterocarpus marsupium	Wood Extract	*Hyblaea puera*	*Tectona grandis*	Antifeedant	Deepa and Remadevi 2006
Ricinus communis	Leaf extract	*Hyblaea puera*	*Tectona grandis*	Larvicidal	Javaregowda and Naik 2006
Saussurea lappa	Plant oil	*Heteropsylla cubana*	*Leucaena leucocephala*	Insecticidal	Sharma et al. 1992
Semecarpus kathalekanensis	Leaf extract	*Hyblaea puera*	*Tectona grandis*	Ovicidal	Ramana 2006
				Antifeedant	Ramana et al. 2007
Sesamum indicum	Plant oil	*Heteropsylla cubana*	*Leucaena leucocephala*	Insecticidal	Sharma et al. 1992
Strychnos nux-vomica	Leaf, bark and seed extract	*Hyblaea puera*	*Tectona grandis*	Larvicidal	Javaregowda and Naik 2006
	Leaf extract	*Paliga machaeralis*	*Tectona grandis*	Growth inhibition	Sree et al. 2008
Trachyspermum ammi	Plant oil	*Heteropsylla cubana*	*Leucaena leucocephala*	Insecticidal	Sharma et al. 1992
Valeriana wallichii	Plant oil	*Heteropsylla cubana*	*Leucaena leucocephala*	Insecticidal	Sharma et al. 1992
Vitex negundo	Leaf extract	*Hyblaea puera*	*Tectona grandis*	Larvicidal	Javaregowda and Naik 2006
	Leaf powder	*Bruchidius sp.* and *Caryedon serratus*	*Tamarindus indica* and *Acacia nilotica*	Insecticidal	Murugesan et al. 2008

stage mainly in the form of chemical inputs. However, the consequent pollution jeopardizes the agricultural as well as forestry business. So usage of botanical insecticides could be of great use along with other options to minimize the use of chemicals in the future. Botanicals used as insecticides presently constitute 1 % of the world insecticide market, while currently Indian market for plant product is less than 1 %. Therefore, it is essential to promote the use of plant products in the insect pest management programmes for the benefit of users who are mainly the plantations growers, environmentalists, State Forest Departments, industries, farmers, etc. It will encourage the users to grow more trees in their homesteads and boost the greening India programme.

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