

INSECT FAUNA ASSOCIATED WITH ECONOMICALLY IMPORTANT FOREST FLORA

Abstract

Forest is an important resource for sustaining the life in the earth. Most of the forests established in the tropical regions of the earth having high rainfall and temperature. This forest plays significant role for different climatic conditions, in hydrological cycle, sustaining biodiversity, environmental amelioration etc. Forest provides livelihood through supplying the food substances like edible fruits, nuts, flowers, leaves, rhizomes, corms, tubers etc which is collected by the tribal and rural people since ancient times. Besides supplying the food items forest plant species are the major sources of timber essential for constructions and making furnitures. Timbers are utilized since the human civilization for constructing their shelter. The plants have medicinal value, too. Different defoliator pests like lepidopteran caterpillars, miners, skeletonizers feed on the foliage and hamper the plant growth in the nursery as well as in the plantation. Several sucking insects, foliage feeders, gall formers reduce the growth of both edible and non-edible wild plants throughout the world. Different caterpillars, grasshoppers, and beetles are important defoliating pests of timber crops like teak, poplar, shisham, sal, tun, neem, sandalwood etc. where coleopteran beetles and their grub feed on the barks, bore inside the heartwood and soft wood and reduce the economic value of the timbers and also cause topple down of trees in the forest. Besides this several sucking pests like scales, bugs, mealybugs hamper the shoot growth in nursery and also devitalize the plants. This chapter deals with the occurrence, nature of damage and possible management practices of the major pests causing significant damage to those forest resources.

Keywords: Forest, Wild edible plant, Timbers, Insect pests, Management

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I. INTRODUCTION

Forests are of paramount importance to both the environment and human societies due to their multifaceted ecological, economic, and social roles. Forests are home to a staggering variety of plant and animal species. They provide habitat and shelter for countless species, contributing to global biodiversity. Many species, including some endangered ones, rely on specific forest ecosystems for their survival. Forests are vital for mitigating climate change by absorbing and storing carbon dioxide from the atmosphere through a process called carbon sequestration. Trees capture carbon during photosynthesis and store it in their biomass and soil, thus helping to regulate the earth's carbon balance and combating global warming. Through the process of photosynthesis, trees release oxygen into the atmosphere, providing the oxygen to the humans and many other organisms need to breathe. Forests play a crucial role in maintaining the earth's oxygen levels. Forests contribute to water regulation by absorbing and releasing water through their roots and leaves. The root systems of trees hold soil together, preventing erosion caused by wind and water. Deforestation can lead to soil degradation, loss of fertile land, and increased vulnerability to landslides. Forests contribute significantly to the global economy through industries such as timber and wood products, non-timber forest products (like fruits, nuts, and mushrooms), ecotourism, and recreational activities. Forests hold cultural and spiritual significance for many indigenous communities and societies worldwide. They are often associated with myths, traditions, and spiritual practices. Forests play a role in regulating local and regional climates by influencing temperature, humidity, and rainfall patterns. They help create microclimates that can support diverse plant and animal communities. As per the 2020 Global Forest Resources Assessment by the FAO, the earth's combined forest area accounts for 4.06 billion hectares (equivalent to 10.0 billion acres), encompassing about 31% of the overall landmass (Anonymous, 2020a). A majority (54%) of global forests are concentrated within five specific nations: Brazil, Canada, China, Russia, and the United States. Russia boasts the world's most extensive forested expanse, covering 815 million hectares (equivalent to one-fifth of the total global forest area). The remaining four countries each possess forested territories exceeding 100 million hectares. Interestingly, Gabon, a relatively small African country, holds just 0.58% of the world's forest coverage; however, it boasts the highest proportion of forest area in relation to its total land area, with a remarkable ratio of 91.3% (Ritchie and Roser, 2021). Forests exist worldwide, their distribution shaped by the interplay of temperature and rainfall patterns. There are four primary forest biome categories: tropical, temperate, subtropical, and boreal. The majority of the planet's forested areas (45%) are situated in tropical zones, characterized by elevated temperatures and humidity. Following closely, the boreal region, encompassing areas like Russia and the Arctic, holds the second-largest forest extent (33%), occupying the intermediary space between tropical and boreal regions, the temperate/subtropical zone accounts for 25%. Nearly half of the global forest cover (49%) forms a relatively cohesive expanse, while 9% occurs in disconnected fragments. Approximately 80% of the total forested area spans patches larger than 1 million hectares (equivalent to 2.5 million acres), leaving the remaining 20% scattered across over 34 million smaller patches worldwide (Anonymous, 2020b). In India total forest area occupies an area of 7, 13,789 square Km, which covers 21.71 % of India's total geographical area (Anonymous, 2021).

Forests are rich in edible plants and fruits that contribute to human diets. These include berries, nuts, seeds, and various types of fruits. For example, wild berries like blueberries and raspberries are often foraged from forested areas. Forests are home to a wide variety of edible mushrooms. Species like chanterelles, morels, and porcini are sought after

by foragers and used in cooking. Forests provide a natural habitat for bees and other pollinators. Honey and other bee products like pollen and royal jelly are collected from beehives placed in or near forests. Forests support a diverse range of wildlife, some of which are hunted for food. Indigenous and local communities often engage in traditional hunting practices to obtain meat from animals like deer, rabbits, and birds. Many forests contain plants with medicinal properties. While not always used as primary food sources, these plants are an essential part of traditional medicine and can be consumed for their health benefits. Non-timber forest products encompass a wide range of resources beyond food, including fibers, resins, and dyes. Some NTFPs, like rattan and bamboo shoots, are also consumed as food. Forests are a vital source of timber, serving as a cornerstone of the global wood and paper industry. Through the method of trial and error, human has been acquired various knowledge, including the skill to differentiate between edible and harmful parts of plants. Over 250 million indigenous individuals depend on traditional means of gathering wild food to sustain themselves. In South Asia alone, over 100 million people employ traditional practices like fishing, herding, and farming to meet their basic needs. A study indicated that approximately one billion individuals globally incorporate wild food into their daily diets (Aberoumand, 2009). Previous study has approximated that numerous tribal groups in India exploited over 3900 distinct types of wild food plants and vegetables. Among these, 1532 species are located within the Western Ghats and Himalayan regions (Arora and Pandey, 1996). Within India the majority of indigenous tribes reside in hamlets or villages that are situated near forests. These communities rely on the forests to fulfill their basic daily requirements. They engage in gathering wild food plants as well as various non-timber forest products (NTFPs) to sustain themselves both economically and for their survival.

Timber, also known as wood, harvested from trees, plays a significant role in various aspects of human society and the economy. The timber industry is a significant contributor to many economies, providing jobs, income, and revenue. Forestry and related industries support livelihoods in rural and forest-dependent communities. Timber production often involves sustainable management practices, including reforestation and responsible logging. These practices help maintain the ecological health of forests and ensure a continuous supply of timber. Sustainable timber production can be planned in a way that preserves biodiversity and supports ecosystems. Proper management practices aim to minimize negative impacts on wildlife and other forest-dependent species.

Negative impacts caused by insect pests in forests result in significant losses. Insect pests can infest and damage trees, leading to their eventual death. This can cause considerable reductions in forest cover and biodiversity. Pests that infest commercially valuable tree species can lower the quality and quantity of timber produced. This can affect industries dependent on high-quality wood. Pests can cause changes in the composition and structure of forests. This might lead to a shift in dominant species, affecting the overall ecological functioning of the forest. Insect-infested trees are often weakened and more susceptible to diseases, making them potential fire hazards, which can then lead to broader forest fires. Some insect pests can carry diseases that affect humans or other animals, posing health risks to forest users and nearby communities. Invasive insect pests can be introduced to new areas and cause rapid and widespread damage to native forests, disrupting ecosystems. A range of insect pests, such as leaf-eating insects, tunneling pests, sap feeders, root borers and pests that create abnormal growths, result in significant harm in nurseries, plantations, and established trees. Consequently, forest managers face a severe challenge.

In tropical forest ecosystems, insects have a crucial function. They impact the environment positively, neutrally, or even as nuisances. Insects engage with trees and the overall non-living and living aspects of their surroundings in intricate ways. Having a comprehensive grasp of these interactions that lead to the deterioration and demise of trees is essential before effective solutions can be implemented (Basu *et al.*, 2010). Numerous insects and illnesses have been identified as causing harm to both naturally replenishing forests and planted forests in India (Nair *et al.*, 1986).

II. CATEGORIES OF INSECT PESTS DAMAGING THE FORESTS

- 1. Defoliators:** Larvae of moths and butterflies, nymph and adult grasshoppers and coleopteran beetles fall under this category. They completely or partially feed the leaves or skeletonize and mine the leaves. Broader harmful consequences encompass diminished shoot and root growth, decreases in height and volume growth, as well as reduced flowering or seed production. While a tree might bounce back from a solitary instance of defoliation, repeated defoliation can lead to the tree's demise. Evaluating the extent of the impact is challenging. Several leaf rollers and webworms folds the leaves to hide and feed inside. Vitality of the tree is diminished, weakening the innate protection against herbivores, which makes the tree susceptible to various secondary pests such as borers of moths and beetles. Important defoliators include Teak defoliator (*Hyblaea puera*, Hyblaeidae, Lepidoptera), Teak skeletonizer (*Eutectona machaeralis*, Crambidae, Lepidoptera), Gamhar defoliator (*Calopepla leayana*, Chrysomelidae, Coleoptera), Ailanthus defoliators (*Atteva fabriciella*, Attevidae, Lepidoptera and *Eligma narcissus*, Nolidae, Lepidoptera), Khasi pine defoliator (*Eterusia pulchela*, Zygaenidae, Lepidoptera), Poplar defoliators (*Clostera fulgurita* and *Clostera cupreata*, Notodontidae, Lepidoptera), Shisham defoliator (*Plecoptera reflexa*, Noctuidae, Lepidoptera), Sal defoliator (*Lymantria mathura*, Lymantriidae), Tendu defoliator (*Hypocala rostrata*, noctuidae, Lepidoptera), Deodar defoliator (*Ectropis deodarae*, Geometridae, Lepidoptera), Chir defoliator (*Lebeda nobilis*, Lasiocampidae, Lepidoptera), Kadam defoliator (*Arthroschista hilaralis*, Crambidae, Lepidoptera), Pongamia leaf miner (*Acrocercops sp.*, Gracillariidae, Lepidoptera), Sal semilooper (*Achaea janata*, Noctuidae, Lepidoptera), Chafer beetle (*Apogonia coriacea*, Scarabidae, Coleoptera) etc.
- 2. Sap Suckers:** Different hemipteran sucking pests like aphids, psyllids, bugs, scale, mealy bugs, spittlebugs, cow bugs, cicadas, leaf hoppers are known as sap feeders and they are responsible devitalizing the trees and reduced vigour of the trees. Extracting primary production syntheses and organic nitrogen compounds by the sap suckers from the tree results in a noteworthy decrease in output, comparable to the losses incurred through defoliation. Additionally, the insect's feeding process could lead to direct foliage loss due to the injection of saliva containing toxins. They can transmit the viral diseases and induces the chances of sooty mould fungus infestation. Major sucking pests infesting wild forest flora are, mosquito bug (*Helopeltis antonii*, Miridae, Hemiptera), Pine wooly aphid (*Pineus pini*, *P. laevis* and *P. boernerii*, Adelgidae, Hemiptera), Champ bug (*Urostylis punctigera*, Urostylididae, Hemiptera), Tendu psyllid (*Trioza obsoleta*, Psyllidae, Hemiptera), Alstonia psyllid (*Pauropsylla tuberculata*, Psyllidae, Hemiptera), Teak membracid (*Cosmoscrata relata*, Membracidae, Hemiptera), Teak Pentatomid (*Agonoscelis pubercula*, Pentatomidae, Hemiptera) etc.

- 3. Borer Pests:** Larvae of different moths, adult beetles and their grubs generally bore inside the shoots or stems of the trees. Typically, the borers make tunnel within developing shoots, often starting with the main shoots and then moving on to the smaller branches. The size of the tunnel gets larger as the insect goes through its growth and development stages. The affected shoot's demise is succeeded by the halt of growth in young trees. In more mature saplings, there's potential for the emergence of one or multiple secondary branches. This results in the transformation of the tree into a dense and lifeless cluster of branches. Due to the attack of borers timber adopts a curved and bifurcated form, falling short of the anticipated height. Important borer insects found in the forests are Poplar borer (*Apriona cineria*, Cerambycidae, Coleoptera), Sal heartwood borer (*Hoplocerambyx spinicornis*, Cerambycidae, Coleoptera), Eucalyptus and Babul stem borer (*Cerosterna scabrator*, Cerambycidae, Coleoptera), Miliaceae shoot borer or Toon borer (*Hypsipyla robusta*, Crambidae, Lepidoptera), Pine shoot borer (*Dioryctria abietella*, Pyralidae, Lepidoptera), Sal root borer (*Dorysthenes huegelli*, Cerambycidae, Coleoptera), Bamboo borer (*Dinoderus brevis*, Cerambycidae, Coleoptera), Teak borer (*Dihammus cervinus*, Cerambycidae, Coleoptera), Tendu stem borer (*Plocaederus ferrugineous*, Cerambycidae, Coleoptera), Bamboo spine borer (*Estigmaena chinensis*, Chrysomelidae, Coleoptera), Gambhar shoot weevil (*Alcidodes ludificator*, Curculionidae, Coleoptera) etc.
- 4. Bark Eaters:** Larvae of lepidopteran moth families like Cossidae, Metarbelidae, grubs of beetle families like Scolytidae, Platypodidae, Cerambycidae, Buprestidae, some weevils and termites are mainly feed on the barks of forest plants. They consume bark materials, creating shallow tunnels that occasionally penetrate the inner layers. In case of younger plants, they might even completely strip off the bark. The tunnels created by the larvae become larger as they grow. Pupation happens within these tunnels, and adult insects emerge through distinct exit holes. Trees that lack vitality are more prone to such attacks. Distinct engraving patterns of galleries in sapwood are unique to each species and can lead to fatalities in cases of high infestation. In instances of severe infestation, weakened health or subsequent attacks by pests or diseases become evident in later stages. These deceased trees then serve as both sustenance and breeding grounds for borers in the future. Regionalized bark decay, the demise of juvenile seedlings are very common. Repetitive onslaughts by termites can lead to the mortality of young transplants, as observed in *Eucalyptus* species. Important bark feeders are bark eating caterpillar (*Indarbela quadrinotata*, Indarbelidae, Lepidoptera), Simul bark feeder (*Indarbela sp.*, Metarbelidae, Lepidoptera), Southern pine beetle (*Dendroctonus frontalis*, Curculionidae, Coleoptera), Acacia longicorn beetle (*Xystrocera festiva*, Cerambycidae, Coleoptera), Pine weevil (*Hylobius abietis*, Curculionidae, Coleoptera) and termites (*Odontotermus odobesus*, Termitidae, Isoptera).
- 5. Wood Feeders:** Various insects belong to the orders like Lepidoptera, Coleoptera and Hymenoptera feed on the woods. Among the lepidopterans larvae of hepialid moth, goat moths (Cossidae), red borers (Zeuseridae) mainly attack in the woods. Predominant coleopterans like round headed borers (Cerambycidae) and flat headed borer (Beuprestidae) mainly feed on the woods and larvae of wood wasp (Siricidae, Hymenoptera) attack the wild forest trees. Larvae create tunnels after entering from the outside, resulting in a wound on the surface of the bark. These tunnels can either continue within the timber's surface or delve into the core of the heartwood. Significant deterioration of wood occurs, even though the tree's external appearance seems healthy.

This deterioration impacts its economic worth. Termites and rapid moth infestations occur primarily through physical wounds (resulting from factors such as fire, pruning, or fungal infections). Attacks from wood wasps and certain beetles are secondary, often arising from stressful conditions. Important wood borers can be observed in the forests are beehole borer of teak (*Xyleutes ceramic*, Cossidae, Lepidoptera), Sal heart wood borer (*Haplocerambyx spinicornis*, Cerambycidae, Coleoptera), Acacia root and shoot borer (*Celosterna scrabrator*, Cerambycidae, Coleoptera), Teak sapling borer (*Sahyadrasus malabaricus*, Lepidoptera), Teak trunk borer (*Cossia cadambae*, Cossidae, Lepidoptera) etc.

- 6. Gall Formers:** Some mites and insect species like gall midges, gall wasps, sawflies and psyllids induce galls in the trees. They produce tumor like hypertrophied structures especially in the leaves. The leaves become twisted and fall off due to heavy galling. Some gall formers are Tendu leaf gall fly (*Trioza obsolete*, Triozidae, Hemiptera), Poplar gall former (*Pemphigus* sp., Aphididae, Hemiptera), Poplar bud gall mite (*Aceria parapopuli*, Acarina, Eriophyidae) and Eucalyptus gall wasp (*Leptocybe invasa*, Eulophidae, Hymenoptera).

III. IMPORTANCE OF WILD EDIBLE PLANTS AND ASSOCIATED INSECT FAUNA

A wide variety of consumable foods are present in forests, encompassing seeds, leaves, fruits, roots, gums, fungi, and wildlife such as insects, rodents, wild game, and fish. Frequently, these forest-sourced foods possess nutritional value that can match or even surpass that of cultivated alternatives. Despite this, these forest foods typically don't form the primary components of diets. Nevertheless, they play a vital role in enhancing the diversity and nutritional excellence of the diets of rural populations. Forests offer sustenance and nourishment during the distinctive periods of scarcity. A multitude of edibles are gathered from the forests, ranging from beetle larvae to nuts and honey. Several researches suggested that the nutritional worth of forest-derived foods indicates that often, the nutritional excellence of these forest foods matches or even surpasses that of cultivated alternatives. For instance, wild leafy greens, on average, possess significant riboflavin levels (0.4 - 1.2 mg/100 g of edible portion). These values observed in wild leafy greens exceed those found in eggs, milk, nuts, and fish. The vitamin C content of *Ziziphus jujube* var. *spinosa* is 1000 mg/100 g. In general terms, food products derived from forest plants can be classified into categories such as leaves, seeds and nuts, fruits, tubers and roots, sap, gum, fungi, salt, and medicinal items. Roughly 20,000 plant species are considered suitable for consumption worldwide and approximately 20 plant categories are responsible for meeting the calorie requirements of over 85% of the global population mainly in the poor, vulnerable and agrarian rural peoples of the developing countries. In India, the utilization and reliance on forest resources are notably extensive, particularly in areas along the forest periphery, where approximately 350 to 400 million rural inhabitants depend on wild plant resources as a way of sustaining their lives and livelihoods. Several tribal peoples are engaged in collecting wild edible herbs for food and medicinal purposes throughout the India. The following table (Table 1) represents the list of common wild edible plants exploited by the rural and tribal people of India along with their associated important insect community which are the menacing factors of the listed plant species.

Table 1: Insect pests causing significant damage to the common edible wild plants found in India

Wild edible plant species	Associated major pest species with systematic position	References
Malabar kino (<i>Pterocarpus marsupium</i>)	<i>Neolithocolletis pentadesma</i> (Gracillariidae, Lepidoptera)	Senthilkumar and Murugesan (2015)
	<i>Eucosma</i> sp. (Eucosmidae, Lepidoptera); <i>Redoa</i> sp. (Lymantriidae, Lepidoptera); <i>Euproctis</i> sp. (Lymantriidae, Lepidoptera); <i>Aetheomorpha malayana</i> (Gallerucidae, Coleoptera); <i>Sphenoptera indica</i> (Buprestidae, Coleoptera); <i>Indomias hispidulus</i> (Curculionidae, Coleoptera); <i>Spanioneura</i> sp., <i>Arytaina</i> sp., <i>Padaukia kino</i> (Psyllidae, Hemiptera)	Mathew (1995)
Kusum tree (<i>Schleichera oleosa</i>)	<i>Icerya aegyptiaca</i> (Margarodidae, Hemiptera); <i>Aulacaspis</i> sp. (Diaspididae, Hemiptera); <i>Amrasca biguttulla</i> (Cicadellidae, Hemiptera); <i>Amblyrrhinus poricollis</i> (Curculionidae, Coleoptera); <i>Peltotrachelus</i> sp. (Curculionidae, Coleoptera); <i>Physomerus grossipes</i> (Coreidae, Hemiptera); <i>Leptocoris augur</i> (Rhopalidae, Hemiptera)	Singh <i>et al.</i> (2014)
Java plum (<i>Syzygium cumini</i>)	<i>Aonidiella aurantii</i> , <i>A. orientalis</i> , <i>Parlatoria pseudopyri</i> , <i>P. marginalis</i> (Diaspididae, Hemiptera); <i>Chloropulvinaria polygonata</i> , <i>C. psidii</i> , <i>Coccus discrepans</i> , <i>Vinsonia stellifera</i> (Coccidae, Hemiptera); <i>Megatrioza vitiensis</i> (Psyllidae, Hemiptera); <i>Artemidorus pressus</i> (Lygaeidae, Hemiptera); <i>Aleurocanthus rugosa</i> (Aleurodidae, Hemiptera); <i>Meridarchis reprobata</i> , <i>M. scyrodes</i> (Carposinidae, Lepidoptera); <i>Indarbela quadrinotata</i> , <i>I. tetraonis</i> (Cossidae, Lepidoptera); <i>Acrocercops phaespora</i> (Gracillariidae, Lepidoptera); <i>Hyposidra successaria</i> (Geometridae, Lepidoptera); <i>Trabala vishnou</i> (Lasiocampidae, Lepidoptera); <i>Orthaga</i> sp. (Pyralidae, Lepidoptera); <i>Bactrocera correcta</i> (Tephritidae, Diptera); <i>Retithrips syriacus</i> (Thripidae, Hemiptera); <i>Lymantria mathura</i> , <i>Orygia postica</i> (Erebidae, Lepidoptera); <i>Singhiella bicolor</i> (Aleurodidae, Hemiptera)	Butani (1979); CABI (2007)

Indian tragakanth (<i>Sterculia urens</i>)	<i>Sylepta balteata</i> [<i>Pleuroptya balteata</i>] (Crambidae, Lepidoptera)	Amin and Upadhyaya (1977)
Arjun (<i>Terminalia arjuna</i>) Haritaki (<i>Chebulic myrobalan</i> or <i>Terminalia chebula</i>)	<i>Atmetonychus peregrines</i> (Curculionidae, Coleoptera); <i>Apoderus tranquebaricus</i> (Curculionidae, Coleoptera); <i>Eucorynus crassicornis</i> (Noteridae, Coleoptera); <i>Rhiphiphorothrips cruentatus</i> (Thripidae, Thysanoptera); <i>Trioza fletcheri</i> (Psyllidae, Hemiptera); <i>Clovia</i> sp. (Aphrophoridae, Hemiptera); <i>Hishimonus indicus</i> , <i>H. viraktamathi</i> (Cicadellidae, Hemiptera); <i>Sphenoptera cupriventris</i> (Coleoptera: Buprestidae); <i>Indarbela quadrinotata</i> (Lepidoptera: Cossidae)	Beeson (1919); Singh and Thangavalu (1994); Mishra <i>et al.</i> (1995); Prakash <i>et al.</i> (2010); Chandrashekharaiyah <i>et al.</i> (2018)
Toothed leaf red creeper (<i>Ventilago denticulate</i>)	<i>Cosella ventilogi</i> (Eriophyidae, Acari)	Chakrabarti <i>et al.</i> (2008)
Indian plum (<i>Ziziphus mauritiana</i>)	<i>Carpomyia vesuviana</i> , <i>Dacus correctus</i> (Tephritidae, Diptera); <i>Meridarchis scyroides</i> (Carposinidae, Lepidoptera); <i>Achaea janata</i> (Noctuidae, Lepidoptera); <i>Maconellicoccus hirsutus</i> (Coccidae, Hemiptera); <i>Aubeus himalayanus</i> (Curculionidae, Coleoptera); <i>Scirtothrips dorsalis</i> (Thripidae, Thysanoptera); <i>Indarbela quadrinotata</i> , <i>I. watsoni</i> , <i>I. tetraonis</i> (Cossidae, Lepidoptera); <i>Dasychira mendosa</i> (Erebidae, Lepidoptera); <i>Adoretus decanus</i> , <i>A. kanarensis</i> , <i>A. stoliezkae</i> , <i>A. pallens</i> , <i>A. versutus</i> , <i>Holotrichia consanguinea</i> (Scarabaeidae, Coleoptera); <i>Eriophyes cernus</i> (Eriophyidae, Acari); <i>Larvacarus transitans</i> , <i>Eutetranychus orientalis</i> (Tetranychidae, Acari)	Verma <i>et al.</i> (1972); Mann and Bindra (1977); Sharma (1992); Pareek and Nath (1996); Balikai (1999); Yadav <i>et al.</i> (2003)
Elephant fern (<i>Angiopteris evecta</i>)	<i>Herpetogramma platycapna</i> (Crambidae, Lepidoptera)	Ghazali <i>et al.</i> (2014)
Indian chest nut (<i>Castanopsis indica</i>)	<i>Hormocerus reticulates</i> (Curculionidae, Coleoptera)	Beeson (1919)
Taro (<i>Colocasia</i> sp.)	<i>Spodoptera litura</i> (Noctuidae, Lepidoptera); <i>Monolepta signata</i> (Chrysomelidae, Coleoptera); <i>Aphis gossypii</i> (Aphididae, Hemiptera); <i>Bemisia tabaci</i> (Aleurodidae, Hemiptera); <i>Stephanitis typicas</i> (Tingidae, Hemiptera);	Sushil <i>et al.</i> (2016)

	<i>Thrips</i> sp. (Thysanoptera, Thripidae)	
Thorny coriander (<i>Eryngium foetidum</i>)	<i>Helopeltis theivora</i> (Miridae, Hemiptera)	Van den Bergh (2016)
Elephant apple (<i>Dillenia indica</i>)	<i>Thretra</i> sp. (Sphingidae, Lepidoptera)	Ashad-Uz-Jaman <i>et al.</i> (2022)
Common bamboo (<i>Bambusa</i> sp.)	<i>Odontotermes</i> sp. (Macrotermitidae, Isoptera); <i>Hieroglyphus banian</i> (Acrididae, Orthoptera); <i>Algedonia (Pyrausta) coclesalis</i> (Pyralidae, Lepidoptera); <i>Calmochrous pentasaris</i> (Cosmopterigidae, Lepidoptera); <i>Aleurocanthus</i> sp. (Aleyrodidae, Homoptera); <i>Oregma bambusae</i> (Aphidae, Hemiptera); <i>Estigmene chinensis</i> (Chrysomelidae, Coleoptera); <i>Cyrtotrachelus longimanus</i> (Curculionidae, Coleoptera)	Varma <i>et al.</i> (1988)
Jackfruit (<i>Artocarpus heterophyllus</i>)	<i>Glyphodes caesalis</i> (Crambidae, Lepidoptera); <i>Diaphania caesalis</i> (Pyralidae, Lepidoptera); <i>Latoia lepida</i> (Cochlididae, Lepidoptera); <i>Toxoptera aurantii</i> (Aphididae, Hemiptera); <i>Nipaeococcus viridis</i> (Pseudococcidae, Hemiptera); <i>Batocera</i> sp. (Cerambycidae, Coleoptera)	Little and Hills (1978); Chakraborty <i>et al.</i> (2011)
Neem (<i>Azadiracta indica</i>)	<i>Holotricha consanguinea</i> (Coleoptera, Scarabidae); <i>Helopeltis antonii</i> (Miridae, Hemiptera); <i>Aonidiella orientalis</i> (Diaspididae, Hemiptera); <i>Pulvinaria maxima</i> , <i>P. azadiractae</i> (Coccidae, Homoptera); <i>Heliothrips haemorrhoidalis</i> and <i>Taeniothrips longistylus</i> (Thripidae, Thysanoptera); <i>Laspeyresia koenigana</i> (Eucosmidae, Lepidoptera); <i>Achaea janata</i> (Noctuidae, Lepidoptera); <i>Cleora cornaria</i> (Geometridae, Lepidoptera); <i>Thosea bipartita</i> (Limacodidae, Lepidoptera); <i>Odites atmopha</i> (Xyloryctidae, Lepidoptera); <i>Mylloceris laetivirens</i> , <i>Cryptocephala aequalis</i> (Curculionidae, Coleoptera)	Sharma (2016)
Tamarind (<i>Tamarindus indica</i>)	<i>Cryptophlebia ombrodelta</i> (Tortricidae, lepidoptera); <i>Aonidiella orientalis</i> , <i>Aspidiotus tamarindi</i> , <i>Saissetia oleae</i> (Diaspididae, Hemiptera); <i>Holotrichia isularis</i> (Scarabidae, Coleoptera); <i>Nipaeococcus viridis</i> (Pseudococcidae, Hemiptera); <i>Toxoptera aurantii</i> (Aphididae, Hemiptera); <i>Scirtothrips dorsalis</i>	Gupta <i>et al.</i> (2017); Singh <i>et al.</i> (2021)

	(Thripidae, Thysanoptera); <i>Eublemma angaluifero</i> (Noctuidae, Lepidoptera); <i>Virachola Isocrates</i> (Lycaenidae, Lepidoptera); <i>Phycita orthoclina</i> (Phycitidae, Lepidoptera); <i>Cryptoph lebia</i> (Tortricidae, Lepidoptera)	
Safed musli (<i>Chlorophytum borivilianum</i> and <i>tuberosum</i>)	<i>Holotrichia serrata</i> (Scarabidae, Coleoptera)	Meshram (2004)
Crepe ginger (<i>Costus speciosus</i>)	<i>Acrida exaltata exaltata</i> and <i>Diabolocatanops pinguis</i> (Acrididae, Orthoptera); <i>Neorthacris acuticeps</i> (Pyrgomorphidae, Orthoptera); <i>Phanoptera gracilis</i> (Tettigoniidae, Orthoptera); <i>Oxyrachis tarandus</i> (Membracidae, Hemiptera); <i>Nisia nervosa</i> (Meenoplidae, Hemiptera); <i>Chrysocoris stollii</i> (Scutelleridae, Hemiptera); <i>Spilosoma obliqua</i> (Erebidae, Lepidoptera); <i>Altha nivea</i> (Limacodidae, Lepidoptera); <i>Mylocerus discolor</i> (Curculionidae, Coleoptera)	Swamy <i>et al.</i> (1993)
Satawar (<i>Asparagus racemosus</i>)	<i>Ophiomyia simplex</i> (Agromyzidae, Diptera); <i>Crioceris asparagi</i> , <i>Crioceris duodecimpunctata</i> (Chrysomelidae, Coleoptera); <i>Brachycorynella asparagi</i> (Aphididae, Hemiptera); <i>Popillia japonica</i> (Scarabidae, Coleoptera); <i>Euxoa scandens</i> (Noctuidae, Lepidoptera); <i>Lygus lineolaris</i> (Miridae, Hemiptera); <i>Spodoptera ornithogalli</i> (Noctuidae, Lepidoptera); <i>Lema downsei</i> (Chrysomelidae, Coleoptera)	Saravanan and Chaudhary (2011); Morrison <i>et al.</i> (2014)
Yam (<i>Dioscorea</i> sp.)	<i>Heteroligus meles</i> (Dynastidae, Coleoptera); <i>Aspidiella hartii</i> (Diaspididae, Hemiptera); <i>Euzopherodes vapidella</i> (Pyralidae, Lepidoptera); <i>Decadarchis minusculata</i> (Tineidae, Lepidoptera); <i>Dasytes rugosella</i> (Tineidae, Lepidoptera); <i>Araecerus fasciculatus</i> (Anthribidae, Coleoptera); <i>Phenacoccus</i> sp. (Pseudococcidae, Hemiptera); <i>Ansioarthra coerulea</i> (Tenthredinidae, Hymenoptera); <i>Galerucida bicolor</i> , <i>Lema lacordairei</i> (Chrysomelidae, Coleoptera); <i>Crioceris livida</i> (Chrysomelidae, Coleoptera); <i>Thrips crawfordi</i> (Thripidae, Thysanoptera); <i>Dasychira mendosa</i> (Lymantridae, Lepidoptera); <i>Aspidiella hartii</i> (Diaspididae, Hemiptera); <i>Ferrisia virgata</i> (Pseudococcidae,	Coursey (1967); Dina (1977); Nair <i>et al.</i> (1982); Plumbley and Rees (1983); Sauphanor and Ratnadass (1985); Akinlosotu and Kogbe (1986); Nwankiti <i>et al.</i> (1988); Pillai <i>et al.</i> (1993); Nakahara (1994); Vasu <i>et al.</i> (2000); Asiedu <i>et al.</i> (2001); Kumar (2007)

	Hemiptera); <i>Leucopholis coneophora</i> (Scarabaeidae, Coleoptera)	
Himalayan nettle (<i>Girardinia diversifolia</i>)	<i>Vanessa indica</i> , <i>Vanessa cardui</i> , <i>Kallima inachus</i> (Nymphalidae, Lepidoptera)	Nitin <i>et al.</i> (2018)
Glory lily (<i>Gloriosa superba</i>)	<i>Spodoptera litura</i> (Noctuidae, Lepidoptera); <i>Polytela gloriosae</i> (Noctuidae, Lepidoptera); <i>Anomis flava</i> (Erebidae, Lepidoptera); <i>Earias vitella</i> (Nolidae, Lepidoptera); <i>Dysdercus cingulatus</i> (Pyrrhocoridae, Hemiptera); <i>Aphis gossypii</i> (Aphididae, Hemiptera); <i>Plusia signata</i> (Noctuidae, Lepidoptera)	Suganthy and Sakthivel (2012); Suganthy and Sakthivel (2013); Meshram <i>et al.</i> (2015)
Muskmelon/ Sweetmelon (<i>Cucumis callosus</i>)	<i>Bactrocera cucurbitae</i> (Tephritidae, Diptera); <i>Aulacophora foveicollis</i> (Chrysomelidae, Coleoptera); <i>Henosepilachna septima</i> (Coccinellidae, Coleoptera); <i>Diaphania indica</i> (Lepidoptera: Crambidae)	Barma and Jha (2011); Choudhary and Patel (2012); Khan <i>et al.</i> (2012); Vinutha <i>et al.</i> (2017)
Kumarika (<i>Smilax zeylanica</i>)	<i>Tagiades litigiosa litigiosa</i> (Hesperiidae, Lepidoptera); <i>Kaniska canace</i> , <i>Phalanta phalantha</i> (Nymphalidae, Lepidoptera); <i>Spindasis lohita lazularia</i> , <i>Zesius chrysomallus</i> , <i>Loxura atymnus</i> (Lycaenidae, Lepidoptera)	Nitin <i>et al.</i> (2018)
Bael (<i>Aegle marmelos</i>)	<i>Papilio</i> sp. (Papilionidae, Lepidoptera); <i>Papilio demoleus</i> (Papilionidae, Lepidoptera)	Karuppaiah <i>et al.</i> (2010); Sharma <i>et al.</i> (2014)
Indian gooseberry (<i>Phyllanthus embilica</i>)	<i>Indarbela quadrinotata</i> (Cossidae, Lepidoptera); <i>Betousa stylophora</i> (Thyrididae, Lepidoptera); <i>Garcillaria acidula</i> (Gracillariidae, Lepidoptera); <i>Virachola Isocrates</i> (Lycaenidae, Lepidoptera); <i>Drepanococcus chiton</i> (Coccidae, Hemiptera)	Mann and Bindra (1977); Patel <i>et al.</i> (1996); Meshram and Soni (2017); Choudhary <i>et al.</i> (2022); Hua <i>et al.</i> (2022)
Bhui amla (<i>Phyllanthus amarus</i>)	<i>Paracoccus marginatus</i> (Pseudococcidae, Hemiptera)	Chellappan <i>et al.</i> (2013)
Red silk cotton (<i>Bombax ceiba</i>)	<i>Tonica niviferana</i> (Depressariidae, Lepidoptera); <i>Batocera rufomaculata</i> (Cerambycidae, Coleoptera); <i>Dinoderus bifoleolatus</i> , <i>D. minutus</i> , <i>Heterobostrychus aequalis</i> , <i>Sinoxylon atratum</i> (Bostrychidae, Coleoptera);	Sebastian (1969); Mathew (1995)

	<i>Xylothrips flavipes</i> (Thripidae, Thysanoptera); <i>Platypus cavus</i> , <i>P. latifinis</i> (Curculionidae, Coleoptera); <i>Trachelizur bisulcatus</i> (Brentidae, Coleoptera)	
Charoli nut (<i>Buchanania lanzan</i>)	<i>Plocaederus obesus</i> (Cerambycidae, Coleoptera); <i>Rhipiphorothrips</i> spp. (Thripidae, Thysanoptera); <i>Sitotroga cerealella</i> (Gelechiidae, Lepidoptera); <i>Rhyzopertha dominica</i> (Bostrychidae, Coleoptera)	Meshram (2009); Meshram and Soni (2017)
Golden shower tree (<i>Cassia fistula</i>)	<i>Catopsilia pomona</i> , <i>C. pyranthe</i> , <i>Eurema blanda</i> (Pieridae, Lepidoptera); <i>Indarbela quadrinotata</i> , <i>Zeuzera coffeae</i> , <i>Xyleutes persona</i> (Cossidae, Lepidoptera); <i>Nephoterix rhodobasalis</i> (Pyralidae, Lepidoptera); <i>Aonidiella orientalis</i> (Diaspididae, Hemiptera); <i>Acaudaleyrodes rachipora</i> (Aleurodidae, Hemiptera); <i>Amblypelta lutescens</i> (Coreidae, Hemiptera); <i>Phenacoccus solenopsis</i> (Pseudococcidae, Hemiptera); <i>Thrips flavus</i> (Thripidae, Thysanoptera)	Beeson (1941); Datiles and Rodríguez (2013)
Coromandel ebony (<i>Diospyros melanoxylon</i>)	<i>Trioza obsoleta</i> (Psyllidae, Homoptera); <i>Hypocala rostrata</i> (Noctuidae, Lepidoptera); <i>Miresa albipuncta</i> (Limacodidae, Lepidoptera)	Kumar <i>et al.</i> (1989); Joshi and Meshram (1991); Kumar <i>et al.</i> (1991)
Bollygum (<i>Litsea glutinosa</i>)	<i>Bactrocera dorsalis</i> (Tephritidae, Diptera); <i>Chilasa clytia</i> (Papilionidae, Lepidoptera)	Allwood <i>et al.</i> (1999); Prasada Rao and Solomon Raju (2021)
Mahua (<i>Madhuca longifolia</i>)	<i>Selitrichodes madhucae</i> , <i>Aprostocetus madhucae</i> , <i>A. dehradunensis</i> , <i>Quadrastichus manmohani</i> , <i>Chrysonotomyia madhucae</i> (Eulophidae, Hymenoptera)	Singh <i>et al.</i> (2021)
Velvet bean (<i>Mucuna pruriens</i>)	<i>Spodoptera litura</i> (Noctuidae, Lepidoptera); <i>Maruca vitrata</i> (Crambidae, Lepidoptera); <i>Coptosoma cribraria</i> (Plataspidae, Hemiptera); <i>Aiolopus thalassinus</i> (Acrididae, Orthoptera); <i>Aphis craccivora</i> (Aphididae, Hemiptera); <i>Anticarsia gemmatalis</i> (Erebidae, Lepidoptera)	Oudhia (2001); Rich <i>et al.</i> (2003); Rani and Sridhar (2004)
Karanja (<i>Pongamia pinnata</i>)	<i>Asphondylia pongamiae</i> (Cecidomyiidae, Diptera)	Devaraj and Sundararaj (2014)

IV. MAJOR PESTS OF ECONOMICALLY IMPORTANT FOREST TREES, THEIR SYMPTOMS OF DAMAGE AND MANAGEMENT

1. **Poplar (*Populus tremula*):** Eight bug species that are significant poplar pests in Indian agroforestry systems have been identified from poplar. Five species namely *Ascostis sclenaria*, *Eucosma glaciata*, *Phlantha phalantha* and *Nodostoma* have also been classified as important pests, along with three species viz. *Clostera fulgurita*, *C. cupreata*, *Apriona cinerea*, *Indarbela quadrinotata* and white grubs have been noted as possible poplar pests (Singh and Singh, 1986).

- **Defoliators:** *Clostera fulgurita*, *Clostera cupreata* (Notodontidae, Lepidoptera)
- **Damage Symptoms:** The initial three developmental stages exhibit a social behavior and display a strong appetite for eating. They remove the outer layer of the leaf and create a skeletal appearance. As the larvae mature into the fourth and fifth stages, they become sequestered and consume all parts of the leaves, leaving only the veins behind.

2. **Leaf Webber: *Asphadistis Cryphomycha* (Crambidae, Lepidoptera)**

- **Damage Symptoms:** The immature larvae wrap two or three leaves in silken threads and consume the epidermis, which causes the leaves to dry out. When viewed from below, the webbed leaf folds appear burned. In extreme circumstances, 60% of the leaves may be webbed.
- **Management of Defoliators and Leaf Webbers:** Spotting the eggmass containing leaves and mechanical destruction of the eggs are effective. Plucking of the leaves containing the gregarious larvae and killing of the larvae prevents further population build up. In nurseries and poplar plantations, the poplar clones L 47/88 and L 48/89 are relatively resistant to defoliator damage. Burning of the fallen leaves that *A. cryphomycha* has webbed and damaged is also effective. The leaf eating pests can be controlled by the application of quinalphos 25 EC @ 4 ml or profenofos 50 EC @ 2 ml/L of water.

3. **Poplar stem borer: *Apriona cinerea* (Cerambycidae, Coleoptera)**

- **Damage Symptoms:** The apodous grubs pierce the stools and create winding passageways that lead to the roots in the nursery. In mature trees larvae create approximately 8 to 10 winding openings in the branches of the main stem. These openings serve for expelling waste and the chewed wood fibers. They are spaced around 10 to 12 cm apart. The larvae use these openings to move from the branches to the trunk. Over time, the interior of the branches, stem, and trunk is eroded, resulting in hollowness. As a consequence, the trees lose strength and are prone to breaking during powerful winds.
- **Management:** In August-September the damaged branches should be removed to prevent the grubs from reaching the main stem. Identifying and sealing of all the active expulsion openings caused by infestation in every tree using clay is effective except for the bottommost hole. Chlorpyrifos 20 EC (2 ml) dissolved in kerosene oil

into the lowest aperture caused by the pest may be administered. Different collateral hosts like mulberry, apple should not be planted near the plantation of poplar tree.

4. Bark Eating Caterpillar: *Indarbela Quadrinotata* (Cossidae, Lepidoptera)

- **Damage Symptoms:** The caterpillars consume the bark of the tree while enveloping themselves in a web constructed from wood particles and their excrement pellets. The harm is noticeable from the outside, appearing as dense, band-like, silky webs running along the bark of the main stem and branches, particularly near the junctions. Additionally, the larvae create L-shaped burrows in the trunk, typically at the points where branches meet. If this insect's persistent and intense infestation persists over 2-3 years, it ultimately leads to the total destruction of the plants.
- **Management:** Application of a spray solution containing either Chlorpyrifos 20 EC or Quinalphos 25 EC) at a concentration of 0.05 percent can manage the pest effectively. Application of the spray can be carried out using either a manual foot-operated sprayer or a mechanized power sprayer attached to a tractor trailer. If the issue continues to exist even after a 10-15 day interval from the initial spraying, a secondary application can be performed using alternative insecticides. It's important to focus the spraying solely on the trunk of the tree.

5. Gamhar (*Gmelina arborea*)

- **Gamar Defoliator: *Calopepla leayana*, (Chrysomelidae, Coleoptera):** *Calopepla leayana* is a species with a specialized diet, exclusively consuming the *Gmelina arborea* plant. This species has been observed in Meghalaya for the first time in India (Kumar *et al.*, 1995).
- **Damage Symptoms:** The beetle undergoes winter hibernation. It becomes active when the premonsoon rain begins in April and May. This pest shows its activity from the middle of March to the middle of November. Both the larvae and adult beetles commence vigorous feeding, resulting in the complete skeletonization of leaves, leaving only the midrib.
- **Management:** Capturing adult beetles within their hibernation shelters and manually removing beetles afterwards as they return to the plantation after winter are quite effective. The beetles can be lured towards a white cloth, gathered, and then eliminated using mechanical methods. Insecticides, a commercial product containing *Bacillus thuringiensis* subsp. *kurstaki*, and the fungus *Beauveria bassiana* have demonstrated efficacy in controlling the larvae. Application of neem seed kernel extract, such as Neemazal at a concentration of 5% (5 ml per liter), or neem oil at a concentration of 2% (2 ml per litre), combined with a binding agent (3 gm of Khadi bar soap per liter of suspension), three times with a 15 day gap in between, can be employed to mitigate the harm. Spraying the leaves with a solution containing 0.05% Chlorpyrifos, 0.04% Monocrotophos or 0.05% Malathion has proven to be efficient in targeting both larvae at different stages and adult beetles.

6. **Gamar Shoot Weevil: *Alcidodes ludificator* (Curculionidae, Coleoptera):** It is an important pest of early plantation. It can cause substantial damage to the tree crop (Nair, 2007).

- **Damage Symptoms:** The insects are widespread during the rainy season, typically from May-June to September-October. These pests, in their adult stage, chew into the developing tips, delicate branches, and the stalks of leaves, creating a series of lateral depressions. Each plant can exhibit a population of 6 to 21 of these weevils. The beetles deposit their eggs in these depressions, particularly on the primary growth points and branches. They consume the soft inner material dug out from the pits. Initial signs of infestation include drooping upper leaves and the withering of growing tips. After a few days, the affected leaves and ends dry out and turn brown, making them easily noticeable from a distance. In the case of young trees, this results in a significant inhibition of growth.
- **Management:** To decrease the weevil population, it is recommended to apply 10 kg of high-quality neem cake per hectare as a foundational treatment.

7. **Tea Twig Caterpillar: *Ectropis bhurmita* (Geometridae, Lepidoptera) (Kumar and Chandra, 2017)**

- **Damage Symptoms:** The caterpillar of the looper, which measures around 3cm in length, exhibits varying coloration but is primarily grayish green with brownish dots and lines. It is an exposed feeder on the foliage of its host plants, consuming young leaves almost completely and leaving the leaves with a network-like pattern. In instances of limited leaf availability, it has been observed to also nibble on the bark of young twigs. The pupal stage occurs within the soil. Multiple generations occur throughout the year in India, with the shortest life cycle lasting about a month, typically taking place during the southwest monsoon period. This moth larva is a general feeder and consumes the foliage of various dicotyledonous trees. Noteworthy hosts within India include *Aleurites montana*, *Bombax malabaricum*, *Dalbergia latifolia*, *Grevillea robusta*, *Schleichera oleosa*, *Shorea robusta*, *Syzygium cumini*, *Taxodium distichum*, *Tectona grandis* and *Terminalia tomentosa* across different regions of its distribution.
- **Management:** The larvae can be handpicked and killed. Synthetic pyrethroids are most suitable for controlling the pest as they have quick knock down effect. Cypermethrin and deltamethrin display high efficacy in controlling defoliating insects.

8. **Tingid Bug: *Tingis beelsoni* (Tingidae, Hemiptera)**

- **Damage Symptoms:** Both the nymphs and mature forms of this insect primarily feed near the leaf base on the underside of the leaf blade and within the leaf axils. This results in the appearance of spots and a brownish hue near the leaf's base. The leaves that are affected lose their vitality, eventually dropping off, and the plant experiences complete defoliation. Furthermore, the shoots dry out darken, and a dark mold spreads

across the plants. This progression leads to the upper parts of the plant withering, eventually causing the plant to die off (Harsh *et al.*, 1992).

- **Management:** The sucking pest can be effectively controlled by applying monocrotophos 0.05% + ridomil 0.2% followed by decis 0.005% + ridomil 0.2%.

9. Teak (*Tectona grandis*)

- **Teak Defoliator: *Hyblaea puera* (Hyblaeidae, Lepidoptera):** It is an important pest of teak and mainly feed on the leaves. It is found in almost all teak growing regions (Nair and Sudheendrakumar, 1986).
- **Damage Symptoms:** During their first and second developmental stages, the insects primarily consume the leaf's external surface. In their third stage, the larvae take a leaf segment, fold it over, secure it with silk, and consume it from within. They consume the entirety of the leaf except for the main veins on delicate leaves. *H. puera* poses a significant threat to *T. grandis*, resulting in substantial losses in both growth and quality. These larvae construct protective enclosures by cutting and rolling leaf fragments together, emerging from these shelters to feed during the night. Initially, they defoliate young plants and significantly strip leaves from trees aged 2 to 5 years within the plantations. Periodic outbreaks usually transpire in March-April and September-October. The larvae enter the pupal stage while nestled within the leaves, curling the leaf tips around their bodies.
- **Management:** Consistent observation throughout the cultivation period, especially right after the rainy season, is essential. Setting up light traps is recommended to monitor and capture adult moths belonging to the *Hyblaea puera* species. Detecting leaves that are folded at the edges allows for the identification and removal of *Hyblaea puera* larvae every 10 days, and these should be eliminated. Employing Neem oil or Pungam oil mixture as a spray every 15-20 days can deter the caterpillars. Alternatively, spraying with 0.05% Monocrotophos is an option. Another effective measure is to use *Bacillus thuringiensis* at a concentration of 1.5%.

10. Leaf Skeletonizer: *Eutectona Machaeralis* (Pyralidae, Lepidoptera):

Among the most destructive leaf-eating pests, the teak skeletonizer, scientifically known as *Eutectona machaeralis*, is abundantly present and has the potential to inflict substantial harm to teak trees.

- **Damage Symptoms:** Named for its behavior, the teak skeletonizer devours leaves, leaving only the veins behind, creating a skeletal appearance. The larvae consume the leaf's entire green tissue, leaving the network of veins untouched, thus skeletonizing the leaf. When these pests cause complete defoliation, the trees are nearly devoid of leaves for a significant portion of their growing phase. This species experiences outbreaks nearly every year, with particularly intense infestations occurring in certain years. Despite being present year-round, these outbreaks tend to emerge towards the conclusion of the growing season, just before the natural shedding of leaves occurs.

- **Management:** Consistent monitoring is advised throughout the cultivation period, especially following the monsoon rains. Utilizing light traps to oversee and capture adult moths is recommended. Locating leaves that are folded at the edges allows for the discovery of insect larvae, which can be removed every 10 days and destroyed. Spraying with Neem oil or Pungam oil mixture can be conducted at intervals of 15-20 days to discourage the caterpillars. The potent remedy against the teak skeletonizer was identified as freshly derived leaf extracts from *Calotropis procera*, *Datura metal*, and *Azadirachta indica*. For control purposes, it is suggested to apply a foliar spray of 0.01% Alphamethrin or 0.02% Cypermethrin (2 ml/ 5 litres of water), or 0.005% Deltamethrin (9 ml/ 5 litres of water). Introducing the egg parasitoid, *Trichogramma raoi*, at a rate of 1.25 lakhs per hectare, distributed in five stages from June to October, is also recommended.

11. Teak Beehole Borer Moth: *Xyleutes ceramic*, *Zeuzera coffeae* (Cossidae, Lepidoptera)

- **Damage Symptoms:** This particular moth species is regarded by certain individuals as the "most damaging and inadequately comprehended pest" of teak trees. The caterpillars of this moth penetrate the central wood of teak, resulting in notable harm. Additionally, it is noted for feeding on various plant species including *Callicarpa*, *Clerodendrum*, *Gmelina*, *Tectona* (Verbenaceae), *Erythrina*, *Sesbania* (Leguminosae), *Spathodea* (Bignoniaceae), and *Duabanga* (Sonneratiaceae).
- **Management:** Administering 0.2% Quinalphos directly to the affected area after clearing away the excrement proves to be exceptionally efficient.

12. Canker Grub of Teak: *Dihammus Cervinus*, *Acalolepta Cervina* (Cerambycidae, Coleoptera) (Baksha, 1996)

- **Damage Symptoms:** Mature beetles encircle the teak stem close to its base, causing an injury that triggers the tissue to thicken. This ongoing thickening leads to the development of a rounded, bulging callus. Cankers are typically located near the base of the stem, although they can also appear at points 3-4 feet above the ground.
- **Management:** Placing a robust wire into the bored opening is beneficial. Infusing insecticides such as 0.1-0.25% Monocrotophos or Dimethoate, along with Quinalphos at 0.2%, into the affected area, followed by sealing with wax or mud, is an effective technique. Additionally, introducing a fumigant into the hole and sealing it can also effectively eliminate the borer. The larvae consume the roots in the nursery. That's why Phorate 10 G or Carbofuran 3G at a quantity equivalent to two teaspoons, combined with finely textured sand can be administered.

13. Teak Fruit Borer: *Dichocrocis punctiferalis* (Pyralidae, Lepidoptera): *Dichocrocis punctiferalis* is a primary threat to teak's flowering shoots and early-stage fruits. The application of 0.2% Quinalphos directly onto the infected area after eliminating the excrement is a notably successful method.

14. Sissoo/ Shisham (*Dalbergia sissoo* / *D. latifolia*)

- **Shisham Leaf Miner: *Dichomeris eridantis* (Glechiidae, Lepidoptera):** The leaf miner *Dichomeris eridantis* has been documented for infesting *Dalbergia sissoo* (Roxb.) (Leguminosae)
- **Damage Symptoms:** In early March, moths emerge from overwintering pupae and begin laying eggs within two to three days on the lower side of leaves. Hatching occurs within two to three days between May and September, and within five days in March and October. The larva feeds on shisham leaves within protective structures formed by rolling either one leaf or, more commonly, by binding two leaves together using silk. The internal surface of the leaf gets scraped or small holes emerge at the leaf blade edges, primarily during the nighttime. Often, the caterpillar abandons one shelter and creates a new one. To navigate the foliage, the caterpillar frequently employs a thread of silk. This results in defoliation of both fresh and mature leaves.
- **Management:** *Anthia sexguttata* is a versatile predator that preys on the caterpillars, pupae, and moths of *Plecoptera reflexa* and *Dichomeris eridantis*. Another effective natural enemy is *Chrysoperla carnea* (Neuroptera: Chrysopidae), which targets the eggs and larvae of *D. eridantis*. Significant insect predators, such as *Hierodula ventralis* and *Canthecona furcellata*, also play a role. Controlling this leaf-eating insect can be achieved by using a 0.1% water-based Fenitrothion emulsion spray.

15. Shisham Defoliator: *Plecoptera Reflexa* (Noctuidae, Lepidoptera): The defoliator *Plecoptera reflexa* has the potential to cause economic damage to shisham tree (Beeson, 1941).

- **Damage Symptoms:** In its early stages, the juvenile caterpillar consumes the underside of the leaf, but as it matures, it devours the entire leaf, including the leaf stalk and the fresh shoots. Instances of widespread infestations are frequent and occur on a predictable basis in irrigated stands of *D. sissoo*. Furthermore, this species has been documented as a significant pest for Indian rosewood, *D. latifolia*. Significant leaf loss usually commences around April. The final generation enters a hibernation phase from October to November. Frequent instances of leaf loss during the active growth period severely hinder the plant's growth rate. This can result in the withering of branches, the decline of main shoots, and the emergence of new shoots from dormant buds on the main stem. Consistent leaf loss can even lead to the demise of young plantations.
- **Management:** Cultural techniques can be employed to reduce the impact of the leaf-eating insect. By implementing practices like providing early irrigation, the emergence of moths can be out of sync with the appearance of fresh foliage on the plants. This ensures that the leaves mature before the larvae emerge. These larvae often referred to as loopers due to their looping movement, have been observed to be parasitised by organisms like *Disophrys sissoo* and *Microgaster plecopterae*. Beyond parasitic species, predators such as *Hierodula ventralis*, *Deiphobe* spp. (Orthoptera: Mantidae), *Anthia sexguttata* (Coleoptera: Chrysomelidae), *Canthecona furcellata* (Hemiptera: Pentatomidae), and *Chrysoperla carnea* (Neuroptera: Chrysopidae) play

a crucial role in curbing outbreaks of these leaf-eating pests. Among the various natural enemies, the eulophid known as *Euplectrus parvulus* exhibits high efficiency by targeting early larval stages. Braconid species like *Disophrys sissoo* and *Microgaster plecopterae* focus on larvae, whereas tachinids such as *Exorista civiloides*, *E. picta*, and *Podomyia setosa* attack both larvae and pupae. The chalcidid *Brachymeria nursei* specializes in pupae parasitism. Recorded rates of parasitism have been observed to vary from 2% to 24%. Typically, the extent of parasitic activity increases as the growth season progresses, especially when the pest population density is lower. Furthermore, a range of approximately twelve predator species, including carabids, mantids, reduviids, and ants, have been documented. Research aimed at determining the optimal *Bacillus thuringiensis* (Bt) dosage for controlling larvae has found that a concentration of 1.5% with B.t. (containing 90-102 billion spores per gram) is the recommended amount for achieving maximum larval mortality within 72 hours of application. This dosage remains effective regardless of the presence of varietal toxins and the form of Bt, whether in wettable powder or emulsifiable concentrate. Application 0.1% water emulsion of Fenitrothion has been demonstrated as an effective method to manage the population of *Plecoptera reflexa*. Again, applying a solution containing 0.003% Deltamethrin, or alternatively 0.05% Chlorpyrifos, has been suggested by Joshi and Jamaluddin (2007) as a method for managing *P. reflexa* larvae.

16. Shisham Leaf Roller: *Apoderus Sissu* (Attelabidae, Coleoptera): *Apoderus sissu* is a well-known insect pest recognized for its significant harm to shisham trees (*Dalbergia sissoo* Roxb.). Commonly referred to as the leaf rolling weevil, this pest is notorious for causing extensive foliage damage in shisham nurseries and plantations alike (Beeson, 1941).

- **Damage Symptoms:** The female beetle curls the leaf tips and deposits a solitary egg within the central coil. The larvae develop within these rolled leaves and eventually mature into adult beetles. Both the adult beetles and the larvae are significant agents of defoliation for shisham trees. The pest consumes leaf tissues, leading to considerable harm to the foliage. The most intense period of activity for this insect spans from June to October.
- **Management:** To manage the pest, application of a solution of Profenofos 50 EC at a rate of 1 milliliter per liter of water through spraying can be effective.

17. Siris (*Albizia odoratissima*)

- **Defoliator: *Strigina Scitaria* (Thyrididae, Lepidoptera)**
- **Damage Symptoms:** The caterpillars create folded shelters using leaves, where they consume their food from within. Occasionally, they also weave together adjacent leaflets to form a protective enclosure while feeding.
- **Management:** A satisfactory outcome could be achieved by employing a spray containing 0.05% Monocrotophos or 0.076% Dichlorvos.

18. Psyllid: *Psylla oblonga* (Psyllidae, Homiptera)

Damage Symptoms and Management: Psyllid infestation poses a significant issue, leading to the emergence of epicormic shoots, stunted growth, and the regression of seedlings. Applying 0.05% Monocrotophos every two weeks efficiently manages this pest.

19. Bark Eater: *Albizia odoratissima* (Cerambycidae, Coleoptera)

Damage Symptoms and Management: The beetle consumes young shoots, causing bark damage. It has a subdued metallic bluish or bronzy green color above and a vibrant red hue below, with its elytra featuring a circular spot and two transverse bands of intense black. The antennae are adorned with clusters of long, silky black bristles. The utilization of phorate granules as soil application has been proven to be effective in countering these beetles.

20. Eucalyptus

Eucalyptus gall wasp: *Leptocybe invasa* (Eulophidae, Hymenoptera)

- **Damage Symptoms:** The presence of the Eucalyptus gall wasp becomes evident through the appearance of raised gall formations on the midribs, petioles, stems, and leaves. These growths are observable on both sides of the leaves. This wasp targets Eucalyptus nurseries, young plantations, and coppices. The adult female lays eggs within young meristems, which encompass the midribs of juvenile leaves. Evidence of egg deposition can be seen on both sides of the midribs, especially on tender leaves. Upon hatching, the larvae develop within plant tissues within a designated chamber, sustaining themselves with nutrients from the surrounding plant material. Distinctively, cylindrical galls emerge on young stems, petioles, or midribs, with mature galls taking on shades of deep pink or red. Pupation occurs within these galls, and adult emerges by cutting the gall wall. The infestation of the gall wasp leads to the presence of galls on leaves, resulting in leaf deformation and reduced size, as well as the development of multiple shoots within the canopy. Severely affected plants bend and droop towards the ground. Growth is stunted, and in severe cases, the plants may die.
- **Management:** Blending of various genetic varieties for making plantation is required. Clones that display resistance should be opted. Eucalyptus variants like C-413 and C-288 exhibit a level of tolerance towards gall wasp infestations. These specific clonal plants can be acquired from PAU, Ludhiana. Consistent surveillance, trimming, and removal of impacted shoots in nursery seedlings and young trees within plantations are required to control the issue. Hanging a light trap above a water trough containing a small amount of kerosene is helpful to eliminate emerging adults and curb subsequent egg laying. Application of 5 grams (equivalent to 2 teaspoons) of Phorate per polybag and use 10 grams of Phorate per pit may be effective. On a monthly basis, application of Imidacloprid or Monocrotophos solution at a concentration of 0.03%, along with 1-2 drops of liquid soap is beneficial. For effective control of this wasp, systemic insecticides such as Acetamiprid 20 SP at a rate of 0.2 grams, Thiamethoxam 25 WG at 0.3 grams, and Imidacloprid 17.8 SL at 0.5 ml per liter of water demonstrate promising outcomes. Applying these insecticides can be repeated at 15-day and 30-day intervals to sustain a gall-free nursery environment.

21. Stem Borer: *Celosterna Scabrator* (Cerambycidae, Coleoptera)

Damage Symptoms and Management: The period of insect infestation spans from September to March. The larvae create tunnels within the primary shoots and roots. To address the issue, it is advised to eliminate the grubs from the affected roots by cutting them sideways at a depth of approximately 40 centimeters in the soil. Subsequently, a small amount of petrol, kerosene, or a solution containing 0.1% Dichlorvos should be poured into the exposed opening. Afterward, the hole should be sealed with the surrounding soil.

22. Termites: *Odontotermes* spp. (Termitidae, Isoptera)

Damage Symptoms and Management: Termite infestations occur year-round, with their severity peaking in July to August and again in April to May. The outcome is the wilting and eventual demise of seedlings. In the months of June-July, it is recommended to incorporate 40 to 60 kg/ha of Chlorpyrifos dust at a concentration of 5% into the soil. Additionally, soil drenching with a water emulsion containing 0.05% Chlorpyrifos, equivalent to 2.5 ml per liter of water, should be performed.

23. Neem (*Azadirachta indica*)

- **Soft Scale: *Megapulvinaria Maxima* (Coccidae, Hemiptera)**
- **Damage Symptoms:** Tiny scale insects take up residence near the leaf veins shortly after hatching from eggs. Nymphs extract plant sap through sucking. Male scales undergo pupation, appearing as white spots on leaves. Female scales relocate to the stem's base and cluster together. Winged male scales emerge and mate with females. A gravid female lays up to 300 to 500 eggs. Shortly after laying eggs, the female died. The nymphs usually suck the sap leading to complete drying of plants. Peak infestation period has been observed during January- March and June-August.
- **Management:** The infestation by this scale insect often starts from nearby trees in the vicinity. Infested branches of such trees should be pruned and eliminated by burning. Severely affected seedlings should be separated and disposed of. During minor infestations, leaves showing white patches (egg masses) can be manually removed and discarded. Spraying a solution of 5% tobacco extract, or a 2% emulsion of Pungam or Neem oil, can be carried out at 15-20 day intervals for managing the pest. If the pest is at the stage of egg-laying (visible as elongated white patches on leaves), a spray of 2% neem oil emulsion or Pungam oil can be applied to deter nymphs from settling on the leaves. In the case of severe infestations, a spray of 0.06% Dimethoate or 0.05% Methyl demeton can be employed. Care should be taken to prevent the extract from being washed away during watering.

24. Shoot Borer: *Laspeyresia Aurantiana* (Eucosmidae, Lepidoptera)

- **Damage Symptoms:** Infestation of the pest occurs during May to June and again from November to December. The larvae bore into shoots, causing the defoliation of the uppermost leaves on seedlings. This leads to the development of forked branching

in the growing shoot. The affected seedlings exhibit slow growth and some may experience partial or complete drying.

- **Management:** The larvae fold the top leaves and take shelter within. To mitigate the damage to some degree, manually collecting and eliminating these folded leaves is recommended. In cases of significant infestation, spray application of 0.06% Dimethoate or 0.076% Dichlorvos can provide effective control.

25. White Grub: *Holotrichia* sp. (Scarabidae, Coleoptera)

- **Damage Symptoms:** The pest is active during the monsoon season. Adult beetles emerge from the soil after receiving the first shower of monsoon. Grubs feed on the roots and rootlets of seedlings, resulting in wilting of foliage. Adult beetles gregariously feed on the foliage during night time.
- **Management:** Sandy soil is favorable for white grub population build up so the seedling should not be raised in sandy soil. Application of unrotted or partially decomposed FYM should be avoided. During the monsoon season, which spans from June to July, it's advisable to refrain from any soil cultivation activities. Instead, for a bed with dimensions of 10 x 1 meters, incorporating Phorate 10 G at a rate of 200 grams per bed through soil mixing is recommended.

26. Tea Mosquito Bug: *Helopeltis Antonii* (Miridae, Hemiptera)

- **Damage Symptoms:** Neem trees face significant impact during the winter season. Trees that are affected display a scorched appearance. The insect extracts sap from delicate leaves and stems, leading to the desiccation of shoots. Frequently, this damage is mistakenly attributed to drought conditions.
- **Management:** Application of Malathion @ 0.1%, succeeded by Monocrotophos @ 0.04%, neem oil @ 2%, pinnai oil derived from *Calophyllum inophyllum* @ 2%, and pungam oil from *Pongamia pinnata* @ 2%, administered in two rounds of spraying with an additional application 15 days later, yielded a notable reduction in pest populations.

27. Sal (*Shorea robusta*)

- **Sal Heartwood Borer: *Hoplocerambyx spinicornis* (Cerambycidae, Coleoptera):** It is the most destructive pest of sal in India (Bhandari and Rawat, 2001) and first reported from Singhbhum division in Chota Nagpur, Bihar (Stebbing, 1906).
- **Damage Symptoms:** The borer insect is fatal to trees of various age groups measuring more than 20 cm in girth. However, trees with girths ranging from 91 to 150 cm, specifically those within the 121-150 cm girth range, are the most favored targets, displaying the highest mortality rate. The sal borer infestation is categorized as an epidemic when the number of trees impacted by these insects surpasses the economic threshold level (ETL), exceeding 1% of the total tree population.

Following a few monsoon showers, typically from the third week of June to the end of August, the beetles become active. They are attracted to the scent of recently cut inner bark and sapwood of sal trees. After mating, the beetles lay eggs that are white or cream in color, placing them in cracks on the tree's bark. These eggs hatch within a period of 3-7 days. The newly hatched larvae tunnel through the bark and reach the sapwood, where they create intricate pathways. Once they finish consuming the sapwood, the larvae transition to the heartwood, where they construct larger chambers for pupation. This pupation process generally begins in December. The larvae transform into immature beetles between April and May and eventually emerge starting from the middle of June, coinciding with the monsoon season. They not only damage the weak standing tree, also attack the logs fallen on the ground.

- **Management:** The beetles can be trapped using trap tree operation. In this procedure, a healthy sal tree with a circumference ranging from 60 to 90 cm is cut down and divided into logs measuring 2 to 3 meters in length. These logs are subsequently struck at their ends to release sap, creating a refuge for the beetles. The beetles are enticed by the scent of the sap, which they consume, causing them to become inactive, facilitating their collection and easier extermination. The process involves gathering the beetles from these logs during morning and evening from onset of monsoon. Application of a solution containing 0.4% Cartap hydrochloride (8 g per litre of water) and 0.4% Monocrotophos (11 g per litre of water) is effective for using tree traps to eliminate sal borer beetles. Treating logs with chemical pesticides showed complete beetle mortality within 20 days when using 0.7% Dichlorvos. Alternatively, 0.05% concentrations of Cartap hydrochloride, Chlorpyrifos, Monocrotophos, and Cypermethrin led to 100% beetle mortality within 30 days. Applying a solution of 0.05% chlorpyrifos (with a concentration of 10 ml of insecticide per litre) onto sal stacks that have been affected by borers, and subsequently covering them with polythene sheets prior to the onset of the monsoon in June is very much effective. This procedure aims to eliminate the beetles that emerge from the sal logs.

28. Indian Sandalwood (*Santalum album*): Sandal wood is attacked by several insects including stem borers and other sucking pest which causes serious damage in the nursery as well as in the plantation.

- **Bark Eating Caterpillar: *Indarbela quadrinotata* (Inderbelidae, Lepidoptera)**
- **Damage Symptoms:** The primary infestation occurred mainly at the point where branches meet, with the tunnels extending into the sapwood. Young saplings displayed signs of dieback and produced new shoots from dormant buds. The presence of the borers was marked by silk-lined pathways on the bark, ranging in numbers from 1 to 20. The mature larvae reached a length of 4-5 cm and underwent pupation within the protective tunnels. The life cycle of these insects spans a year, with adult moths emerging between May and July. This cycle is repeated annually.
- **Management:** Administering a solution of 0.1% Monocrotophos or 0.08% Fenvalerate, or 0.1% Quinalphos in the bore hole and encasement of the nearby bark

can be effective. Application of Entomopathogenic fungi like *Metarhizium anisopliae* or *Beauveria bassiana* is also found effective.

29. Red Stem Borer: *Zeuzera Coffeae* (Cossidae, Lepidoptera)

- **Damage Symptoms:** The red borer is a versatile pest that tunnels into the tender sapwood of young trees and saplings. Occasionally, this attack results in the destruction of young saplings.

The passageways created by juvenile larvae are cylindrical, while those formed by more mature larvae are broader and feature irregular hollow spaces. The larvae do not attack heartwood.

- **Management:** Trimming and incinerating infested branches or shoots should be done. Inserting a metal wire through the bore hole or introduction of insecticides like 0.1-0.25% Monocrotophos or Dimethoate, Quinophos, or a mixture of 0.2% Paradichlorobenzene and kerosene oil, then sealing them with wax or mud can be helpful. Employing any fumigant and sealing the borer hole is also effective in exterminating the borer. Spraying Fenthion, Fenitrothion, Phosalone, Monocrotophos, Etofenprox, Cartap hydrochloride, Chlorpyrifos, Phenthoate, or Spinosad @ 0.5 kg a.i./ ha, or applying Flubendiamide @ 25g a.i./ ha or Indoxacarb @ 0.30 kg a.i./ ha has been found effective. Incorporating Carbofuran @ 2 kg a.i. into the soil, or applying Phorate @ 1 kg a.i./ ha can be done for nursery raising.

30. Heartwood Borer: *Aristobia Octofasciculata* (Coleoptera: Cerambycidae)

- **Damage Symptoms:** This borer is exclusive to sandalwood regions and exclusively feeds on sandalwood. The infestation by this pest results in the withering of branches and, in some cases, even the death of young trees and saplings. Numerous living trees harbor multiple bore holes that extend into extensive hollow chambers within the heartwood. In mature trees, the heartwood can be partially or completely hollow. Young trees and saplings are susceptible to branch drying and potential mortality due to the impact of this pest.
- **Management:** Same as stem borer

31. Tun (*Toona ciliata*)

Tun Fruit and Shoot Borer: *Hypsipyla robusta* (Pyralidae, Lepidoptera)

- **Damage Symptoms:** Larvae of the moth mainly infest the shoot, flower and fruits. They complete five generation on the tun trees. During 2-3 generation they mainly cause damage by binding and feeding on the flowers and fruits. The next 3-5 generations are more destructive. Generation evolved from fruits shifted to the shoots. The larvae proceed to move downward and enter pupation within the crevices of the bark, enclosed by a silky web. In instances of intense assault, the entire tree trunk becomes enveloped in this webbing. Damage in the shoots results in forking of main stem and staggered head which provide poor economic return.

- **Management:** Active bore holes in the tree can be noticed by spotting the frassy materials extruding from the bore holes. After identifying them, application of 2 ml Chlorpyrifos 25 EC or Profenofos 50 EC per hole can provide good management of pest.

V. CONCLUSION

Wild plants are sustaining the different life forms from ancient times. Till date they are the base of livelihood for several tribal and rural people in all over the world. Insect pest are not a major concern for economically important forest plants until they are grown commercially or under agroforestry or social forestry system. Under such situation if heavy pest outbreak occurs, management schedule should be adopted in time. It is well known that parasitoids and predators including avian predators may take a significant role in controlling insect pests in natural ecosystem and besides pests forest is also a habitat of most of the natural enemies. In a nutshell, pest identification in time and early management for the respective pest through available biointensive approaches including conservation of natural enemies, using botanicals and biopesticides are crucial for managing the forest pests.

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