Post-Graduate Degree Programme (CBCS)
in
ZOOLOGY

SEMESTER-IV

SOFT CORE THEORY PAPER

FOREST ENTOMOLOGY
ZDSE(MN)T-304

SELF LEARNING MATERIAL

DIRECTORATE OF OPEN AND DISTANCE LEARNING
UNIVERSITY OF KALYANI
KALYANI, NADIA,
W.B. INDIA

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Director's Message

Satisfying the varied needs of distance learners, overcoming the obstacle of distance and reaching the unreached students are the threefold functions catered by Open and Distance Learning (ODL) systems. The onus lies on writers, editors, production professionals and other personnel involved in the process to overcome the challenges inherent to curriculum design and production of relevant Self Learning Materials (SLMs). At the University of Kalyani, a dedicated team under the able guidance of the Hon'ble Vice-Chancellorhas invested its best efforts, professionally and in keeping with the demands of Post Graduate CBCS Programmes in Distance Mode to devise a self-sufficient curriculum for each course offered by the Directorate of Open and Distance Learning (DODL), University of Kalyani.

Development of printed SLMs for students admitted to the DODL within a limited time to cater to the academic requirements of the Course as per standards set by Distance Education Bureau of the University Grants Commission, New Delhi, India under Open and Distance Mode UGC Regulations, 2020 had been our endeavour. We are happy to have achieved our goal.

Utmost care and precision have been ensured in the development of the SLMs, making them useful to the learners, besides avoiding errors as far as practicable. Further suggestions from the stakeholders in this would be welcome.

During the production-process of the SLMs, the team continuously received positive stimulations and feedback from Professor (Dr.) Amalendu Bhunia, Hon'ble Vice- Chancellor, University of Kalyani, who kindly accorded directions, encouragements and suggestions, offered constructive criticism to develop it within proper requirements. We gracefully, acknowledge his inspiration and guidance.

Sincere gratitude is due to the respective chairpersons as well as each and everymember of PGBOS (DODL), University of Kalyani. Heartfelt thanks are also due to the Course Writers-faculty members at the DODL, subject-experts serving at University Post Graduate departments and also to the authors and academicians whose academic contributions have enriched the SLMs. We humbly acknowledge their valuable academic contributions. I would especially like to convey gratitude to all other University dignitaries and personnel involved either at the conceptual or operational level of the DODL of University of Kalyani.

Their persistent and coordinated efforts have resulted in the compilation of comprehensive, learner-friendly, flexible texts that meet the curriculum requirements of the Post Graduate Programme through Distance Mode.

All the Self Learning Materials are self-writing and collected from e-book, journals and websites.

Director

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SOFT CORE THEORY PAPER - ZDSE(MN)T -304

FOREST ENTOMOLOGY

Module	Unit	Content	Credit	Page No.
ZDSE(MN)T -304 (FOREST ENTOMOLOGY)	I	Indian forest types, their distribution and importance, forest insects (pests)- damage and sign categories.	2	
	II	Insect pests of timber yielding trees (Sal – *Shorea robusta*; Teak –*Tectona grandis*; Mahogony- *Swietenia macrophylla*). Bionomics and nature of damage of Borers – *Hoplocerambyx spinicornis*, Defoliators – *Hapalia machaeralis*.		
	III	Soil insects and their damage to forest plants and their management.		
	IV	Role of insects in tropical forest ecosystem.		
	V	General issues in forest entomology: a) Insect damages in plantation vs natural forest, b) Pest problems in plantation of indigenous vs exotic species. c) Pest problems in monoculture and mixed plantations.		
	VI	Management of tropical insect forest pests		
	Total counselling session 6 hrs.			

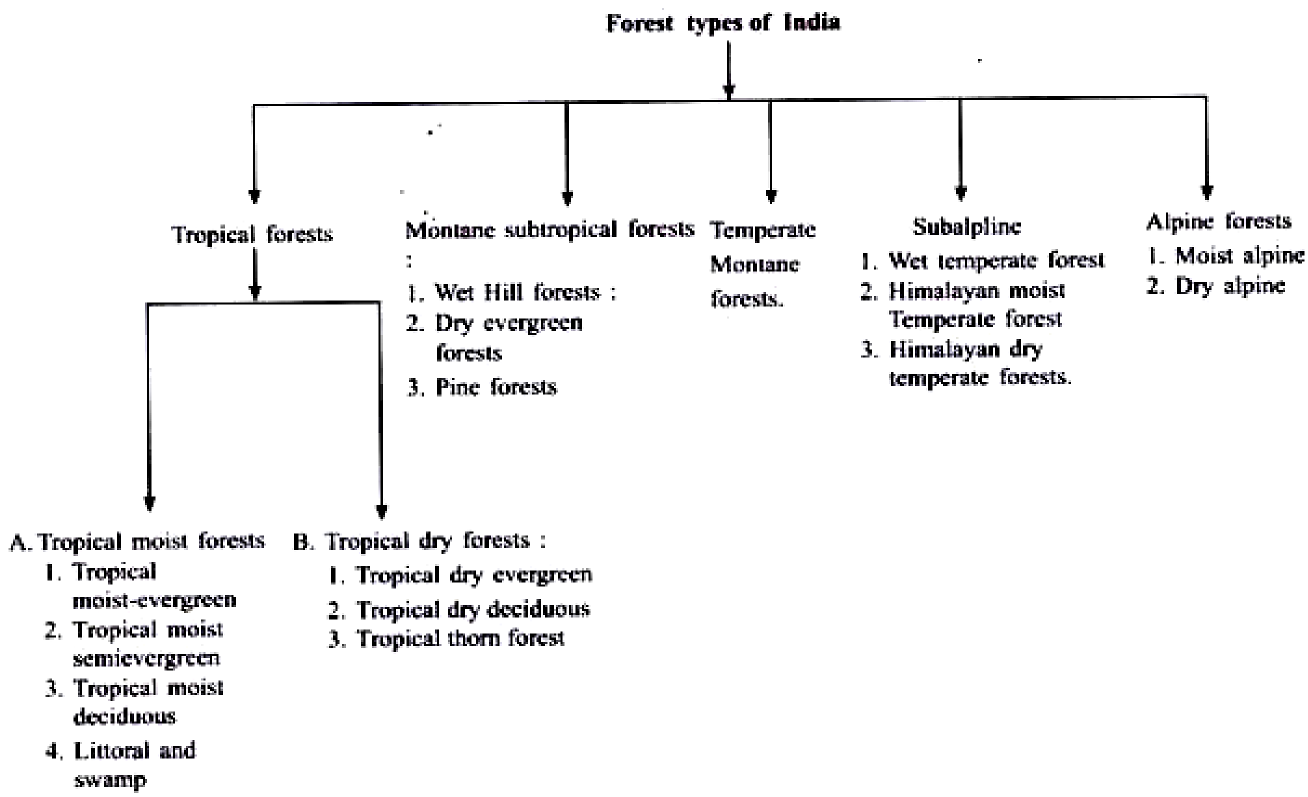
UNIT I

Indian forest types, their distribution and importance, forest insects (pests)- damage and sign categories

Objective: In this unit we will discuss about Indian forest types, their distribution and importance, forest insects (pests)- damage and sign categories.

INDIAN FOREST TYPES

Champion (1936) recognized 13 major types of forest in India. Champion and Seth (1968) recognized sixteen types of forest as listed below. Hanson (1962) defines forest as “a stand of trees growing close together with associated plants of various kinds”. The following types of forests are found in India which covers nearly 17 per cent of the total Indian Territory.



The relative extents of different types of forests in India:

Table 11.1. Relative extents of different types of Indian forest.

Forest type	*Area (in million hectare)*	*Percent of total forest area*
Tropical moist evergreen	4.5	5.8
Tropical moist semievergreen	1.9	2.5
Tropical moist deciduous	23.3	30.3
Littoral and Swamp	0.7	0.9
Tropical dry evergreen	0.1	0.1
Tropical dry deciduous	29.4	38.2
Tropical Thorn	05.2	6.7
Subtropical broad leaved montane wet forest	0.3	0.4
Subtropical dry evergreen	0.2	0.2
Subtropical pine	3.7	5.0
Montane wet temperate	1.6	2.6
Himalayan moist temperate	2.6	3.4
Himalayan dry temperate	0.2	0.2
Subalpine	3.3	4.3
Moist alpine	—	—
Dry alpine	—	—

I. Tropical forest:

A great majority of the forests found in India are of this type. Tropical forests are of two types:

A. Tropical moist forests.
B. Tropical dry forests.

A. Tropical moist forests:

These are further classified into the following types on the basis of relative degree of wetness:

i. Tropical moist evergreen forests,
ii. Tropical moist semi-evergreen forests, and
iii. Tropical moist deciduous forests.
iv. Littoral and swamp forests.

(i) Tropical moist evergreen forests:

These are also called tropical rain forests. In India such forests are found in very wet regions receiving more than 250 cm average annual rainfall. These are climatic forests having luxuriantly growing lofty trees which are more than 45 metres in height. The shrubs, lianas (woody climbers) and epiphytes are abundant because of high rainfall. These forests are found in Andaman and Nicobar Islands, Western coasts and parts of Karnataka (N. Canara), Annamalai hills (Koorj), Assam and Bengal.

(ii) Tropical moist semi-evergreen forests:

These forests are found along the western coasts, eastern Orissa and upper Assam where annual rainfall is between 200 and 250 cm. They are characterised by giant and luxuriantly growing intermixed deciduous and evergreen species of trees and shrubs. The important plants in these forests are the species of *Terminalia, Bambusa, Ixora, Dipterocarpus, Garcinia, Sterculia, Mallotus, Calamus, Albizzia, Elettaria, Pothos, Vitis, Shorea, Cinnamomum, Bauhinia, Albizzia*, etc. Orchids, ferns, some grasses and several other herbs are also common.

(iii) Tropical moist deciduous forests:

These cover an extensive area of the country receiving sufficiently high rainfall (100 to 200 cm) spread over most of the year. The dry periods are of short duration. Many plants of such forests show leaf-fall in hot summer.

The forests are found along the wet western side of the Deccan plateau, i.e. Mumbai, N-E. Andhra, Gangetic plains, and some Himalayan tracts extending from Punjab in the West to Assam valley in the East. The forests of Southern India are dominated by Teak (*Tectona grandis), Terminalia paniculata, T. bellerica, Grewia tilliaefolia, Dalbergia latifolia, Lagerstroemia, Adina cordifolia*, etc. are the other common species in forests of South India. In north, they are dominated by shal (*Shorea robusta*).

Some other common associates of shal are *Terminalia tomentosa*, *Dellenia* species, *Eugenia* species, *Boswellia* species and *Mallotus philippensis*. These forests produce some of the most important timbers of India. Grasses become important both in seral stages and in the areas under fire.

(iv) Littoral and Swamp Forests:

Littoral and Swampy forests include the following types:

1) Beach forests
2) Tidal forests or Mangrove forests
3) Fresh water swamp forests.

Beach Forests:

The beach forests are found all along the sea beaches and river deltas. The soil is sandy having large amount of lime and salts but poor in nitrogen and other mineral nutrients. Ground water is brackish, water table is only a few metres deep and rainfall varies from 75 cm to 500 cm depending upon the area. The temperature is moderate. The common plants of these forests are *Casuarina equisetifolia, Borassus, Phoenix, Manilkara littoralis, Callophyllum littoralis, Pandanus, Thespesia, Barringtonia, Pongamia, Cocos nucifera, Spinifex littoreus* and a number of twiners and climbers.

Tidal or Mangrove forests:

Tidal forests grow near the estuaries or the deltas of rivers, swampy margins of Islands and along sea coasts. The soil is formed of silt, silt-loam or silt-clay and sand. The plants are typical halophytes which are characterised by presence of prop roots with well developed knees for support and pneumatophores and viviparous germination of seeds.

Tidal forests one distinguished into the following four types with overlapping constituent species:

i. Tree mangrove forests
ii. Low mangrove forests,
iii. Salt water forests and
iv. Brackish water forests.

Tree Mangrove forests:

These forests occur on both east and west sea coasts. The best development occurs in Sundarbans. The forest floor is flooded with salt water daily. Plants may attain a height 10-15 metres and form almost closed evergreen forests. The common trees of these forests are *Rhizophora mucronata*, *R. conjugata*, *Avicennia alba*, *Bruguiera conjugata*, *B. parviflora*, *B. caryophylloides*, *Kandelia candel*, *Xylocarpus molluccensis*, *X. granatuns*, *Ceriops tagal*, *Avicennia officinalis*, *Excoecaria agallocha*, *Sonneratia acida*, *Lumnitzera racemosa*, *L. littorea*, *Aegiceras carniculatum* and two most frequently occurring palms *Nipafruticans* and *Phoenix paludosa*.

Low Mangrove Forests:

These forests grow on soft tidal mud near estuaries, which is flooded by salt water. Forest is dense but the trees with leathery leaves attain maximum height of 3-6 m. The vegetation consists of a few species which show gregarious growth habit. Important tree species are *Ceriops decandra, Avicennia alba*, *Aegialitis rotundifolia* and *Excoecaria agallocha*. Besides, a common shrub *Acanthus elicifolius* and some grasses also occur at places. Low mangrove forests are more developed on east sea coast than on west coast.

Salt water Mangrove Forests:

These forests occur beyond tree mangrove forests in big river deltas where the ground is flooded with tidal water. Silt deposition and salt content in soil are low. Tree height is upto 20 m or so but girth is not large. Forests are dense. Pneumatophores are common. The common plants are *Heritiera minor*, *Excoecaria agallocha, Ceriops decandra, Xylocarpus molluccensis, Bruguiera conjugata, Avicennia officinalis* and *Nipa* at places.

Brackish Water Mangrove Forests:

They grow near the river deltas where forest floor is flooded with water at least for some times daily. Water is brackish (salty) but during rains it is nearly fresh. Tree height may reach 30 m or so. Forest is dense. Common species of the forests are *Heritiera minor*, *Xylocarpus molluccensis*, *Bruguiera conjugata*, *Avicennia officinalis*, *Sonneratia caseolaris*, *S. acida*, *Excoecaria agallocha*, *Ceriops decandra*, *Cynometra ramiflora*, *Amoora cuculata*, *Pandanus*, and two palms; *Nipa* and *Phoenix paludosa.*

Fresh Water Swamp Forests:

These forests grow in low lying areas where rain or swollen river water is collected for some time. Water table is near the surface. Important plants include *Salix tetrasperma*, *Acer*, *Putranjiva, Holoptelia, Cephalanthus*, *Barringtonia*, *Olea, Phoebe*, *Ficus, Murraya*, *Adhatoda, Canna* and a variety of grasses.

B. Tropical dry forests.

These are classified into the following types:

(i) Tropical dry evergreen forests,

(ii) Tropical dry deciduous forests, and

(iii) Tropical thorn forests.

(i) Tropical dry evergreen forests:

These forests are found in the areas where rainfall is in plenty but dry season is comparatively longer. The trees are dense, evergreen and short (about 10 to 15 metres high). These forests are found in eastern part of Tamil Nadu, in east and west coasts. The common plant species are much the same as in Tropical moist evergreen forests. Species of *Maba, Calotropis, Pabatta, Feronia, Canthium, Zizyphus, Randia* etc. are most common. Bamboos are absent but grasses are common.

(ii) Tropical dry deciduous forests:

These forests are distributed in the areas where annual rainfall is usually low, ranging between 70 and 100 cm, such as, Punjab, U.P., and Bihar, Orissa, M.P. and large part of Indian peninsula. The largest area of the country's forest land is occupied by Tropical dry deciduous forests. The dry season is long and most of the trees remain leafless during that season. The forest trees are not dense, 10 to 15 m in height, and undergrowth is abundant. In north, the forests are dominated by shal and in south by teak

(Tectona grandis). The common constituents of these forests in South are *Dalbergia, Terminalia, Dillenia, Acacia, Pterospermum, Diospyros, Anogeissus, Boswellia, Chloroxylon, Bauhinia, Hardwickia, Gymnosporia, Zizyphus, Moringa, Dendrocalamus*, and so on. The other species of trees and shrubs of Sal dominated forests of northern region are *Terminalia, Semicarpus, Buchnania, Carissa, Modhuca, Acacia, Sterculia, Launea, Salmalia Adina, Bauhinia, Aegle, Grewia, Phyllanthus*, etc.

(iii) Tropical thorn scrubs:

These forests occur in the areas where annual rainfall is between 20 to 70 cms, dry season is hot and very long. They are found in South Punjab, most of Rajasthan and part of Gujarat. The vegetation in these regions occurs only along the rivers. The land away from the rivers and devoid of irrigation is mostly sandy and devoid of trees. The vegetation is of open type consisting of small trees (8 to 10 m high) and thorny or spiny shrubs of stunted growth. The forests remain leafless for most part of the year and are sometimes called thorn scrub or scrub jungles. There is luxuriant growth of ephemeral herbs and grasses during the rainy season. Towards the desert region the vegetation diminishes and in arid parts there is almost no vegetation. Species of *Acacia, Cassia, Calotropis, Randia, Albizzia, Zizyphus, Erythroxylon, Euphorbia, Cordia, Prosopis. Salvadora, Aegle, Gymnosporia, Atriplex, Grewia, Asparagus, Berberis, Butea, Kochia, Leptadenia, Capparis, Adhatoda*, etc. characterise the plant formations of semiarid regions of India.

Champion (1938) named the natural vegetation of desert as tropical thorny forest. Bharucha (1955) divided the Rajasthan desert into the following vegetational zones:

i. Area of shifting sand dunes at and around Jaisalmer and Bikaner.
ii. Area of established sand dunes near Jodhpur.
iii. Sand stone rocks covered by xerophytic plants like Euphorbia nerifolia.
iv. Area of halophytic vegetation.
v. Sandy-loam soil vegetation.

II. Subtropical montane forests:

These forests are found in the region of fairly high rainfall but where temperature differences between winter and summer are less marked. Winter generally goes without rains. They are found upto the altitude of about 1500 metre in south and up to 1800 metre in the north. In composition, subtropical forests are almost intermediate between tropical forests and temperate forests and a sharp demarcation can seldom be made between tropical and subtropical or subtropical and temperate forests.

These forests have been grouped into the following three types:

i. Wet hill broad leaved forests,
ii. Dry evergreen forests, and
iii. Pine forests.

(i) Wet hill broad leaved forests:

They are found in Mahabaleshwar, Coorg, Karnataka, parts of Assam, Panchmarhi and other parts of M.P. The important plants found in the wet hill forests of south are the species of *Eugenia, Randia, Terminalia, Eleganus, Murraya, Gymnosporia, Atylosia, Ficus, Pterocarpus, Lantana, etc. while those of the north are Castonopsis, Calamus, Alnus, Quercus, Betula, Schima phoebe, Cedrella, Garcinia, Populus* etc.

(ii) Dry evergreen forests:

They occupy the foot-hill areas of Himalayas. The common constituents of vegetation are *Acacia modesta*, *Olea cuspidata*, etc.

(iii) Pine forests:

They are found mostly in western and central Himalayas and in Assam hills. The forests are dominated by species of *Pinus* (*Pinus khasya* and *P. roxburghii*). Species of *Quercus, Berberis, Carissa, Bauhinia* may also occur rarely in pine forests.

III. Temperate Montane forests:

These forests occur in the Himalayas at the altitude from 1800 to 3800 metres where humidity and temperature are comparatively low.

Montane forests have been classified into the following three types on the basis of moisture regime:

i. Montane Wet temperate forest,
ii. Himalayan Moist temperate forest, and
iii. Himalayan Dry temperate forest

(i) Montane Wet temperate forests:

These are found in Himalayas extending from Nepal to Assam at the altitude from 1800 to 3000 m, as well as in some parts of South India (Nilgiris). The forests in south are evergreen and are called sholas. The forests are dense with closed canopy and the trees may be 15 to 20 m high. Epiphytes are in abundance. Important plants constituting the vegetation in Eastern Himalayas are species of conifers, *Hopea, Balanocarpus, Elaeocarpus, Artocarpus, Pterocarpus, Myristica, Hardwickia, Salmelia, Dioscoria*. The members of family Compositae, Rubiaceae, Acanthaceae and Leguminosae form the undergrowth.

(ii) Himalayan Moist temperate forests:

These forests develop in the areas of lesser rainfall. The trees are high, sometimes up to 45 metres tall. The dominant elements of vegetation are oak and conifers. Undergrowth is shrubby and consists of deciduous species of *Barberis, Spiraea, Cotaneaster*, etc.

(iii) Himalayan Dry temperate forests:

These forests dominated by Rhododendrons, oaks and conifers from a narrow belt at the altitude from 3000 to 4000 m in the western Himalayas extending from a part of Uttaranchal through Himachal Pradesh and Punjab to Kashmir. The other commonly found species belong to genera *Daphne*, *Desmodium, Indigofera, Artemisia, Cannabis, Plectranthus, Fraxinus*, several epiphytic mosses, Lichens, etc.

IV. Sub-alpine Forests:

The sub-alpine forests are found throughout Himalayas from Ladakh in the west to Arunachal in the east at the altitude from 2800 m to 3800 m. Annual rainfall is less than 65 cm. but snowfall occurs for several weeks in a year. Strong winds and below 0°C temperature prevail for greater part of the year. Trees are like those of temperate zone. Epiphytic mosses and lichens are in abundance.

Champion (1939) has recognized the following two types of forests in sub-alpine zone:

(a) Sliver Fir-Birch forests which are found on glacial moraines. *Abies spectabilis, Abies densa, Pinus wallichiana, Betula utilis, Quercus semecarpifolia, Pyrus spp. Rhododendrons, Juniperus recurva, J. wallichiana, Berberis, Salix fruticulosa* are common plants of these forests.

(b) Birch-Rhododendron forests which grow on rocky substrata. The common trees are *Betula utilis, Quercus semecarpifolia*, many species of Rhododendron *Pyrus* spp., *Acer* spp, *Salix, Juniperus* spp. etc.

V. Alpine forests:

Alpine vegetation has been classified into the following three types:

a) Alpine forests,
b) Moist Alpine scrubs, and
c) Dry Alpine scrubs.

(a) Alpine forests:

Plants growing at the altitude from 2900 to 6000 m are called alpine plants. In India, alpine flora occurs in Himalayas between 4500 and 6000 metres. At lower level, alpine forests consist of dwarf trees with or without conifers and at higher level scrubs and only scattered xerophytic shrubs are left to merge with alpine meadows. The common plants of alpine forests are *Abies, Pinus, Juniperus, Betula,* shrubby Rhododendrons, *Quercus, Pyrus, Salix* etc.

(b) Moist Alpine scrubs:

This type of vegetation is distributed extensively throughout the Himalayas above 3000 metres. It is most often dense and composed of evergreen dwarf Rhododendron species, some birch and other deciduous trees. Mosses and ferns cover the ground with varying amounts of alpine shrubs, flowering herbs and ferns. Alpine pastures include mostly mesophytic herbs with very little grasses.

(c) Dry Alpine scrubs:

These are open xerophytic formations spread in U.P., Himachal Pradesh, Punjab and Kashmir. Species belonging to *Artemisia, Potentilla, Kochia, Juniperus* predominate in the vegetation which develops generally on lime stone rock.

FOREST INSECT PESTS

(Source: FAO. 2007. Overview of Forest Pests – India. Forest Health and Biosecurity working papers: 1-24.)

India's forest cover is estimated to be about 67.701 million hectares, or 22.8 percent of the country's land area. Other wooded lands comprise 4.110 million ha. The dense forest in almost all the major states has been reduced, however and forest degradation is a matter of serious concern.

India has 3.226 million ha of forest plantations, representing 4.8 percent of total forest area. Principal plantation species include *Acacia* spp. *Eucalyptus* spp., and *Tectona grandis* are the main species planted having greater area in planted forests than other species. *Eucalyptus globulus*, *E. grandis* and *E. tereticornis* are most common, while among the acacias, *Acacia auriculiformis*, *A. catechu*, *A. mearnsii*, *A. nilotica* and *A. tortalis* are common. Other commonly planted broadleaf species are *Albizia* spp., *Azadirachta indica*, *Casuarina equisetifolia*, *Dalbergia sissoo*, *Gmelina arborea*, *Populus* spp. *Prosopis* spp., *Shorea robusta* and *Terminalia* spp. Among conifers, *Cedrus deodara* and *Pinus roxburghii* occupy a major area; *Pinus patula* and *P. caribaea* have been planted to a limited extent.

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. The figures are available mostly at local level or in some national reports or papers presented at conferences. One report estimated that 1,000,000 ha of forest was damaged by insect pests and 8 400 000 ha by diseases.

FOREST PEST

Naturally regenerating forests

Insects (Indigenous insects)

1. ***Asphondylia tectonae*** **Mani, 1974**

Diptera: Cecidomyiidae

Common names: Twig gall midge

Host type: broadleaf

Hosts: *Tectona grandis*

Asphondylia tectonae is a gall insect that is one of few insects recorded as pests of teak in naturally regenerating forests. It has been recorded in the natural forest in Kerala and Karnataka in southern India and in poor class teak forests in central India. It attacks new shoots of teak and causes formation of galls that coalesce, harden and surround the stem.

2. ***Cryptothelia crameri*** **Westwood**

Lepidoptera: Psychidae

Common names: Chir pine defoliator Host

type: conifer

Hosts: *Pinus roxburghii*

From 1989–1990, an outbreak of *Cryptothelia crameri* a defoliator of *Pinus roxburghii* was reported in the state of Jammu and Kashmir. The outbreak caused 5 percent tree mortality over 2 000 ha with 0.3 million trees lost resulting in a net loss of 22.5 million rupees. The first epidemic of this species was reported in 1885 from Tons Valley, Uttaranchal State. It was subsequently recorded from Himachal Pradesh State in 1928 and also in Kahhula, Pakistan.

3. Ectropis deodarae Prout

Lepidoptera: Geometridae

Common names: Deodar defoliator

Host type: Conifer

Hosts: *Cedrus deodara*

Large areas of deodar forests, *Cedrus deodara*, in the northwestern and western Himalaya regions are often defoliated completely by *Ectropis deodarae*, causing heavy mortality.

An outbreak was noticed in June 1994 in the Neldehra forest in Mashobra range and Badmain forest in Bhajji range near Shimla in Himachal Pradesh. The caterpillars feed on the needles from the tip to the base scraping the basal portion of the needles. As a result, the needles turn brown, dry up and fall to the ground prematurely. In the later stages of attack, the trees, branches and the undergrowth were covered with the webs and veils of silk, and the plantation had a brown, scorched appearance. The attack was so heavy that complete defoliation of 8–10 ha of a 60–70 year old stand occurred. Recently, an epidemic of this defoliator was reported from the Lolab Valley, Jammu and Kashmir. Tree mortality was as high as 30 percent. Epidemics occur at about 10 year intervals and may last for 2 or 3 years.

4. Eucosma hypsidryas

Lepidoptera: Tortricidae

Common names: Spruce bud worm Host

type: conifer

Hosts: *Picea* spp.

A budworm, *Eucosma hypsidryas*, is major cause of mortality of spruce trees in the Himalayas. Trees of all ages are attacked. Heavy and repeated infestation results in weakening of the host.

5. *Eutectona machaeralis* Walker, 1859

Lepidoptera: Pyralidae

Common names: Teak skeletonizer; teak leaf skeletonizer Host

type: broadleaf

Hosts: *Tectona grandis*

Eutectona machaeralis is a major pest of teak, occurring throughout South Asia and some parts of Southeast Asia. Complete defoliation by the pests results in more or less leaflessness during most of the growing period. Damage varies from almost negligible to as much as half of the total annual increment. Past studies estimate the losses due to this insect at approximately 0.051 million ha annually.

Outbreaks of this species occur in most years with exceptionally heavy build-up in some years. Although the insect is present throughout the year, outbreaks develop towards the end of the growing season before normal leaf shedding.

6. *Hoplocerambyx spinicornis* (Newman, 1842)

Other scientific names:

Coleoptera: Cerambycidae

Common names: sal heartwood borer; sal borer Host

type: broadleaf

Hosts: *Shorea robusta*; *S. siamensis*; *S. assamica*; *S. obtusa*; *Parashorea robusta*; *P. malaanonan*; *P. stellata*; *Anisoptera glabra*; *Hopea odorata.*

Hoplocerambyx spinicornis is widely distributed in Asia – Burma, Bhutan, India, Indo-China, Indonesia, Malaysia, Nepal, Papua New Guinea, Pakistan, Philippines, Singapore, Thailand. It is a pest of *Parashorea robusta, P. malaanonan, P. stellata, Shorea siamensis, S. assamica, S. obtusa, S. robusta, Anisoptera glabra* and *Hopea odorata.*

H. spinicornis causes severe damage in central and northern India on *Shorea robusta.* Outbreaks of this insect have been recorded periodically since 1897 in Chota Nagpur, India. In 1998, this insect damaged and killed about 1 million trees. The area of forest affected by this insect has not been clearly reported however, a conservative estimate was that at least 1 000 ha of forests were affected in 2000. Other reported outbreaks include Singhbhoom, Bihar in 1899, Assam (1906, 1961), Himachal Pradesh (1948-1952), Madhya Pradesh (1905, 1927-28, 1948-52, 1959-63, 1998), Uttranchal (1916-24, 1934-37, 1958-60, 1961, 1965), and West Bengal (1931-34). Its larvae girdle and kill trees and riddle the heartwood with large tunnels or galleries making it unfit for marketing as timber. It is normally a pest of felled and dying sal but during epidemics, it attacks healthy trees of all ages and girth. The borers prefer large, mature trees, where there is more chance of completing the life cycle. But during epidemics this borer is capable of infesting every tree above 0.3 m girth and is not confined to mature or over-mature trees. During such epidemics, millions of trees may be killed with losses totaling millions of rupees annually.

This borer has the habit of destroying the trees in patches. It produces characteristic symptoms: dying-off from the crown downwards by sudden withering of the foliage in autumn or spring; and profuse exudation of resin at points where the first stage larvae bore through the bark. The emergence of the adult beetle is closely synchronized with rainfall (June/July). The beetles lay eggs in the bark and sapwood and a heavily infested tree may contain as many as 900 living larvae.

Insects (Indigenous insects)

More than 143 species of insects infest both indigenous as well as exotic species of poplars, *Populus* spp. in northwestern India, with about 65 species infesting *Populus deltoides* alone. Random sampling surveys of poplar plantations (1984–2002) was undertaken in the lower hills and plains of six states (Uttar Pradesh, Uttaranchal, Haryana, Punjab, Himachal Pradesh, and Jammu and Kashmir) between 1984 and 2002. The survey included 36 nurseries, 84 large (≥ 3 ha) and 255 small (< 3 ha) plantations. Seven insect species were detected at outbreak levels. Among these, three species: *Clostera cupreata, C. fulgurita* and *Apriona cinerea* were ranked as major pests as they had relatively higher incidence (> 50 percent attack) and caused extensive economic loss during outbreaks, coupled with tree mortality which persisted for several years in succession over large areas.

1. *Apriona cinerea* Chevrolat, 1852

Coleoptera: Cerambycidae

Common names: poplar stem borer Host type: broadleaf

Hosts: *Populus* spp.

The poplar stem borer, *Apriona cinerea* is another pest of poplars. Young plants, 1–3 years old, are most prone to attack. This insect is common in the northwest Himalayas and the adjoining plains region.

2. *Calopepla leayana* (Latreille, 1807)

Other scientific names: *Craspedonta leayana*; *Imatidium leayanum* Latreille; *Cassida leayana* Olivier; *Calopepla leayana ab. nigriventris* Weise

Coleoptera: Chrysomelidae

Common names: Gamar defoliator; Gamhar defoliator; Yemane defoliator; Yemane tortoise beetle

Host type: broadleaf

Hosts: *Gmelina arborea*

The defoliator *Calopepla leayana* appears to be most important insect pest of *Gmelina arborea* in plantations within the natural range of the tree. It is perhaps the most widely reported and studied defoliator of *G. arborea* in Asia.

Young larvae feed mainly on the undersurface of gamar (*Gmelina arborea*) leaves, leaving only the mid-ribs and main veins intact. The adult beetle feeds on the leaf, cutting large circular holes, and also eats young buds and shoots. Heavy infestation leads to drying up of shoots of young trees and the trees remain leafless for about 4 months of the growing season leading to ultimate death. *C. leayana* was reported for the first time on gmelina in Meghalya, India in 1995, indicating an apparent expansion of its range to the northeast of India. It is considered a serious pest of gamhar plantations in Assam, Trefru.

3. Chrysomela populi Linnaeus 1758

Other scientific names: *Melosoma populi*

Coleoptera: Chrysomelidae

Common names: poplar defoliator; poplar leaf beetle; willow leaf beetle Host type: broadleaf

Hosts: *Populus* spp.; *Salix* spp.

Chrysomela populi is a pest of both poplars and willows in the temperate Himalayas from Jammu and Kashmir to Arunachal Pradesh.

4. Clostera cupreata Butler

Other scientific names:

Lepidoptera: Notodontidae

Common names: poplar defoliator

Host type: broadleaf

Hosts: *Populus* spp.

Clostera cupreata has been an important pest of poplar plantations in the Tarai Region of Uttar Pradesh since 1966 and in Punjab State since 1986. Epidemics typically develop three years after plantation establishment.

5. Clostera fulgurita (Walker)

Lepidoptera: Notodontidae

Common names: poplar defoliator

Host type: broadleaf

Hosts: *Populus* spp.

Clostera fulgurita has been an important pest of poplar plantations in the Tarai Region of Uttar Pradesh since 1966 and in the Punjab since 1986. Epidemics typically develop three years after plantation establishment.

6. Eutectona machaeralis Walker, 1859

Other scientific names:

Lepidoptera: Pyralidae

Common names: teak skeletonizer; teak leaf skeletonizer Host

type: broadleaf

Hosts: *Tectona grandis*

Eutectona machaeralis is a major pest of teak, occurring throughout South Asia and some parts of Southeast Asia. Complete defoliation by the pests results in more or less leaflessness during most of the growing period. Damage varies from almost negligible to as much as half of the total annual increment. Past studies estimate the losses due to this insect at approximately 0.051 million ha annually.

Outbreaks of this species occur in most years with exceptionally heavy build-up in some years. Although the insect is present throughout the year, outbreaks develop towards the end of the growing season before normal leaf shedding.

7. *Hyblaea puera* (Cramer, 1777)

Other scientific names: *Phalaena puera*; *Noctua saga*; *Noctua unxia*; *Heliothis apricans*

Lepidoptera: Hyblaeidae

Common names: teak defoliator

Host type: broadleaf

Hosts: *Alstonia scholaris*; *Avicennia* spp.; *Callicarpa* spp.; *Pterocarpus macrocarpus*; *Rhizophora* spp.; *Tectona grandis*; *Vitex* spp.

The larvae of this moth species feed on the leaves of a wide range of plants including *Avicennia* spp., *Callicarpa* spp., *Rhizophora* spp., *Vitex* spp. and *Tectona grandis*. It is considered to be a major pest of teak plantations in areas of Asia. In India, *H. puera* causes one or more near-total and additional partial defoliations of teak over extensive areas annually. At Nilambur in southern India, this has resulted in a loss of 44 percent of the potential volume increment in young planted forests. In Kerala, defoliation of teak was often over 50 percent.

The larvae create shelters for themselves by cutting pieces of leaves and rolling them together. They come out of the shelters to feed by night. *Hyblaea puera* is widespread throughout the tropics occurring in Asia, Australia, the Pacific Islands, Africa, Central America and South America.

8. *Hypsipyla robusta* Moore, 1886

Other scientific names: *Epicrocis terebrans* Oliff, 1890; *Magiria robusta* Moore, 1886; *Hypsipyla scabrusculella* Ragonot, 1893; *Hypsipyla pagodella* Ragonot, 1888 Lepidoptera: Pyralidae

Common names: mahogany shoot borer; cedar tip moth; toon shoot fruit borer Host type: broadleaf

Hosts: *Khaya* spp.; *Cedrella* spp.; *Cedrela toona*; *Toona ciliata*; *Tectona grandis*; *Swietenia macrophylla* .

Hypsipyla robusta caterpillars bore into the tips and shoots of several species of high quality timber species. They feed on a range of plants in Meliaceae and Verbenaceae including *Swietenia macrophylla, Toona cilata*, *Cedrella* spp. and *Tectona* spp. In India, it is a particular pest of of toon, *Cedrela toona*, and mahogany and is capable of causing 100 percent mortality of seedlings and young plantations. The caterpillars destroy the apical shoot causing the tree to form many side branches and frequently a deformed trunk leading to a decreased value of the timber. This insect can destroy plantations.

The mahogany shoot borer mainly attacks trees in high light areas, hence the biggest effects are observed in young planted forests, particularly those planted with a single species. Young understorey trees in naturally regenerating forests suffer far less damage. Plantings of mahogany have been almost completely abandoned in some areas because of the damage caused by this insect. This species has also been reported to cause damage in Australia, Bangladesh, Nigeria, Pakistan, Sri Lanka and West Indies.

9. Lymantria mathura Moore, 1865

Other scientific names: *Porthetria mathura* (Moore), *Ocneria mathura* (Moore), *Lymantria aurora* Butler, *Lymantria fusca* Leech, *Lymantria mathura aurora* Butler Lepidoptera: Lymantriidae

Common names: pink gypsy moth; rosy gypsy moth; Russian gypsy moth; sal defoliator Host type: broadleaf

Hosts: *Antocephalus cadamba*; *Mangifera indica*; *Quercus incana*; *Q. serrata*; *Shorea robusta*; *Syzygium cuminii*; *Terminalia arunja*; *T. myriocarpa*

Lymantria mathura is a serious defoliator found in China, the Democratic People's Republic of Korea, India, Nepal, Japan, Republic of Korea, and the Russian Federation. It is polyphagous and feeds on a variety of deciduous trees including Fagaceae (oaks and beeches), Salicaceae (willows), Rosaceae (fruit trees) Betulaceae (birches), Juglandaceae (hickories and walnuts), Oleaceae (ashes) and a number of tropical families of trees.

Recorded hosts in India include *Antocephalus cadamba*, *Mangifera indica*, *Quercus incana*, *Quercus serrata*, *Shorea robusta*, *Syzygium cuminii*, *Terminalia arunja* and *Terminalia myriocarpa*.

In India outbreaks are infrequent but extensive when they do occur. No significant tree mortality occurs after defoliation of the sal tree, *Shorea robusta*, but tree vigor may be reduced and susceptibility to attack from other insect species may increase. However, successive defoliations on *Shorea robusta* in Assam and north India have been known to kill trees.

10. Lymantria obfuscata Walker

Other scientific names:

Lepidoptera: Lymantriidae

Common names: Indian gypsy moth; apple hairy caterpillar; leaf eating caterpillar; Kashmir willow defoliator

Host type: broadleaf Hosts:

Salix spp.

Lymantria obfuscata is a damaging defoliator of willows and defoliation causes loss of increment. Trees may be killed if they are severely defoliated for more than one year.

Introduced insects

1. Heteropsylla cubana Crawford,1914

Other scientific names: *Heteropsylla incisa* (Sulc.)

Homoptera: Psyllidae

Common names: leucaena psyllid Host type: broadleaf

Hosts: *Leucaena leucocephala*

Leucaena leucocephala is a tree grown extensively in community forestry and agroforestry ecosystems for fodder and fuel throughout the tropics including India. The tree was almost pest free in India until 1988, when the leucaena psyllid, *Heteropsylla cubana*, appeared in

Chengalpetu (Tamilnadu), South India and caused severe defoliation and extensive death of young trees. By 1990, it had attacked all the *Leucaena* plantations in the country.

2. Icerya purchasi Maskell

Other scientific names: *Pericerya purchasi* (Maskell)

Homoptera: Coccidae

Common names: cottony cushion scale; fluted scale; Australian bug; mealy scale; white scale

Host type: broadleaf

Hosts: *Acacia decurrens*; *A. dealbata*

Icerya purchasi, the cottony cushion scale, was accidentally introduced into India in 1921. It damages *Acacia decurrens* and *A. dealbata* in addition to numerous other forestry and agricultural plant species. The scale has done serious damage to plants in the Nilgiri hills in South India, and in the Anamallai hills in Tamilnadu, and has since become well established throughout the country (FAO, 2005b). *Rodolia cardinatis* (Coleoptera: Coccinellidae) was introduced for the control of this scale, and it has proven to be a very effective predator.

3. Leptocybe invasa Fisher & LaSalle, 2004

Other scientific names:

Hymenoptera: Eulophidae

Common names: blue gum chalcid Host type: broadleaf

Hosts: *Eucalyptus camaldulensis*; *E. tereticornis*; *E. grandis*; *E. deanei*; *E. globulus*; *E. nitens*; *E. botryoides*; *E. saligna* ; *E. gunii*; *E. robusta*; *E. bridgesiana*; *E. viminalis*

The blue gum chalcid is a gall-inducing wasp native to Australia. It has become a pest of planted eucalypt forests in various parts of the world including Kenya, Morocco, New Zealand, Tanzania and Uganda. Recently it has been reported from India in planted forests and nurseries of *Eucalyptus camaldulensis* and *E. tereticornis* (Jacob, Devaraj and Natarajan, 2007). This gall wasp is also known to attack other eucalypt species including

E. botryoides, *E. bridgesiana*, *E. deanei*, *E. globulus*, *E. gunii*, *E. grandis*, *E. nitens*, *E. robusta*, *E. saligna* and *E. viminalis*.

L. invasa lays eggs in the bark of shoots or the midribs of leaves. The eggs develop into minute, white, legless larvae within the host plant. Damage is caused when the developing larvae produces galls on the leaf midribs, petioles and twigs. The galls can cause the twigs to split, destroying the cambium. Small circular holes indicating exit points of adults from pupae are common on the galls. Repeated attacks lead to loss of growth and vigour in susceptible trees. Severely attacked trees show gnarled appearance, stunted growth, lodging, dieback and eventually tree death. The blue gum chalcid has a relatively narrow host range.

4. Pineus pini

Other scientific names: *Pineus laevis* (Maskell, 1885) Börner, 1907; *Aphis pini* Gmelin, 1790; *Kermes pini* Macquart, 1819; *Anisophleba pini* Koch, 1857; *Kermaphis pini* var. *laevis* Maskell, 1885; *Pineus pini* (Macquart, 1819) Börner, 1907; *Pineus sylvestris* Annand, 1928; *Pineus havrylenkoi* Blanchard, 1944; *Pineus simmondsi* Yaseen & Ghani, 1971; *Pineus boerneri* Annand, 1928

Hemiptera: Adelgidae

Common names: pine woolly aphid; red pine adelgid; pine twig chermes; pine aphid

Host type: conifer

Hosts: *Pinus* spp.; *Pinus patula*

The pine woolly aphid feeds on the shoots of *Pinus* spp., at times causing tip dieback. It occurs in Africa, Australia, Europe, New Zealand and North and South America. First introduced to India in the 1970s, *Pineus pini* has caused severe damage to *Pinus patula* plantations in the Nilgiri hills of South India (FAO, 2005b). Since only trial plantations had been established, the damage has been restricted to *Pinus patula* and its further spread has been contained by discontinuing the planting of *P. patula* (FAO, 2005b).

Control of this pest by biological control is variable – in some areas this method has been highly successful and significantly less so in others. This aphid has moved into new areas mostly by movement of infested planting stock.

5. Quadraspidiotus perniciosus (Comstock)

Other scientific names: *Aspidiotus perniciosus* Comstock; *Comstockaspis perniciosa* (Comstock); *Diaspidiotus perniciosus* (Comstock)

Homoptera: Coccidae

Common names: San José scale; California scale Host type: broadleaf

Hosts: *Populus* spp.; *Salix* spp.; *Aesculus* spp.; *Alnus* spp.; *Betula* spp.; *Celtis* spp.; *Fagus* spp.; *Fraxinus* spp.; *Morus* spp.

A native of China, *Quadraspidiotus perniciosus* or the San Jose scale reached India in 1911, and by 1933 had attained pest status in fruit orchards and plantations of poplars and willows (FAO, 2005b). The San Jose scale also damages species of *Aesculus*, *Alnus*, *Betula*, *Celtis*, *Fagus*, *Fraxinus* and *Morus*.

All surface parts of young hosts are infested. Attacks are generally on wood but, in severe infestations, leaves and fruits may also be penetrated. Bark often cracks and exudes gum, resulting in a surrounding dark-brown gelatinous area. Heavy infestation causes cessation of growth and loss of yield.

Probable questions:

Suggested reading:

Forests and Forestry, K.P. Sagreiya, (First edition 1 January 1967), National Book Trust, India.
2. Indian Forestry, K. Manikandan S. Prabhu, (7th edition 1 February 2021); Jain Brothers-New Delhi; Jain Brothers.

UNIT II

Insect pests of timber yielding trees (Sal – *Shorea robusta*; Teak –*Tectona grandis*; Mahogony- *Swietenia macrophylla*). Bionomics and nature of damage of Borers – *Hoplocerambyx spinicornis*, Defoliators – *Hapalia machaeralis*.

Objective: In this unit we will discuss about Insect pests of timber yielding trees (Sal – *Shorea robusta*; Teak –*Tectona grandis*; Mahogony- *Swietenia macrophylla*). Bionomics and nature of damage of Borers – *Hoplocerambyx spinicornis*, Defoliators – *Hapalia machaeralis.*

Insect pests of Timber Yielding trees & bionomics and nature of damage of borers and defoliators

(Source: ICFRE, 2020. A User Manual on Forest Insect Pests and Diseases Indian Council of Forestry Research and Education, Dehradun, India.)

1. **SAL (*Shorea robusta*)**

Sal Heart-wood borer, *Hoplocerambyx spinicornis* . (Coleoptera: Cerambycidae) (Figs148-151)

Distribution: In India Sal is distributed in two main regions viz. Northern and Central regions bisected by Gangetic plains occupying an area of about 11.6 million hectares (105,790 sq. km area in Northern and Central region) approximately, 14.2% of the total forest in the country.

Sal trees when attacked by the borer shows symptoms which are categorized as follows:

Category 1. Leafless crown (c), epicormics (e) dead, resin spots (r) on stem and plant with heap of wooddust (w) more than 7 cm.

Category 2. Crown and epicormics brown, resin spots on stem and heap of wood dust more than 7 cm.

Category 3. Crown brown, epicormics green, resin spots on stem and heap of wood dust more than7 cm.

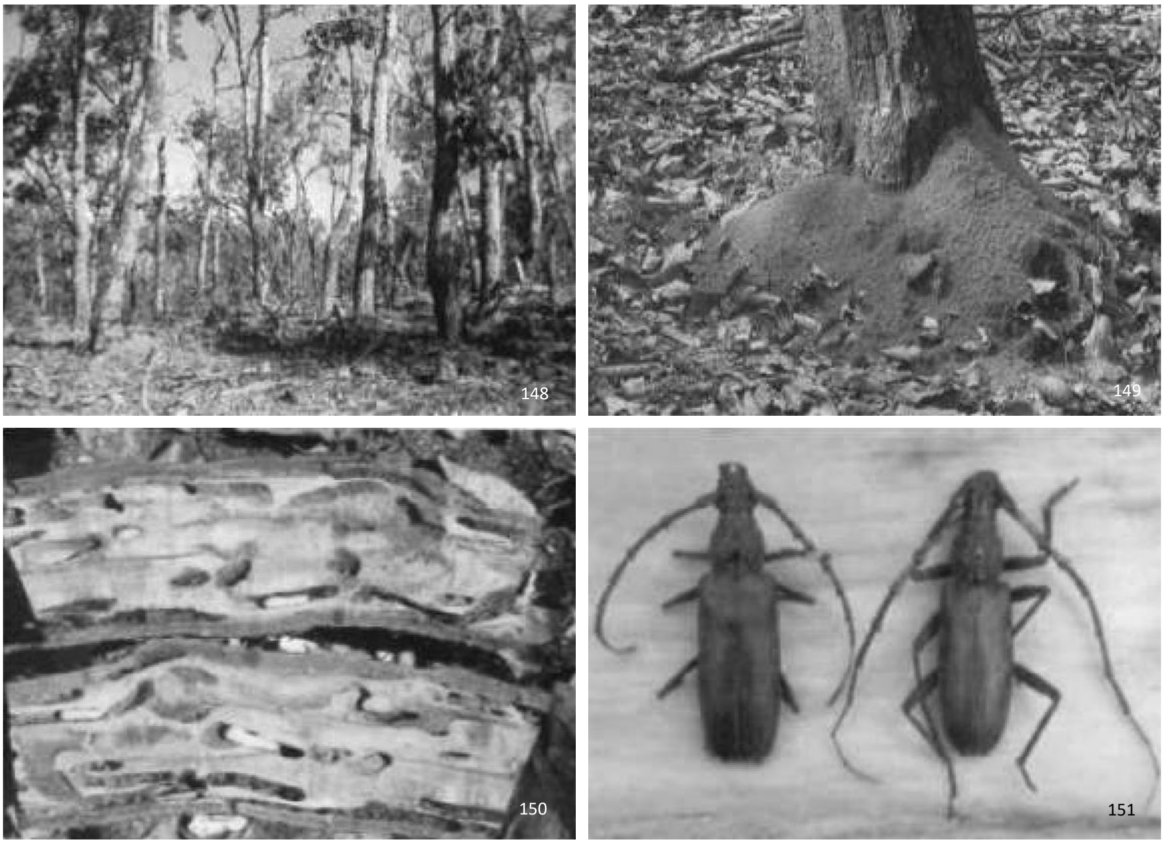
Category 4. Crown and epicormics green, resin spots on the stem and plant with scattered heap of wood dust, less than 7 cm, at the base of tree.

Category 5. Half crown dead and rest of half crown and epicormics green, resin spots on stem and heap ofwood dust less than 7 cm at the tree base.

Category 6. Stumps attacked by the borer with heap of wood dust at the base of stump.

Category 7. Crown and epicormics green, resin abundant and wood dust scattered or scanty. Healthy Sal Tree.

Female Beetle is about 6 cm long, uniformly dark brown. The elytra are shiny black to reddish- brown. The antennae of males are longer than the body while in females it is equal or shorter than the body. The beetle feed on the oozing sap of the Sal tree and lays about 200 eggs in the crevices of bark. Larvae when reaches the bast, the tree exudes resin which flow out and can be seen on the stem. Freshly oozed resin is pinkish brown in color which becomes light yellow after sometime. The larva feed on the bast by making irregular tunnels. Later it enters the sapwood and riddles it with zigzag tunnels. In the process of feeding and tunneling a large heap of wood dust is deposited at the base of attacked tree. The mature larva then enters the heart wood. Affected Sal trees are invariably killed outright due to girdling caused by criss-cross larval tunnels.



Figures 148-151. Sal Heart-wood borer, *Hoplocerambyx spinicorni*: 148, infested sal forest; 149, heap of sawdust at the base of sal tree; 150, galleries by larvae and 151, beetles, left female and right male

Management: Management of Sal heart-wood borer in attacked forest is done mainly through following measures:

i) Monitoring of attacked trees: After the end of monsoon season the infested trees should be enumerated and marked as per the described damage categories. Category 1 and 2 of infested tree should be removed from the forest before the onset of next monsoon and should be stored at least 3-4 kmaway from the edge of the sal forest.

ii) Trap tree operation (Fig. 152): Trap tree operation is based on the fact that adult beetles are strongly attracted to the smell of exuding sap from the freshly injured tree. It has been reported that the adults fly tonewly felled trees from as far as 800 m away within five minutes and can smell the sap from a distanceof 2 km.

a) Selection of unsound trees for making traps

Unsound trees like top broken, crooked and category 7 trees, as described above, are selected for making thetraps.

b) Preparation of logs

Depending upon the intensity and incidence of attack one or two such trees per hectare are felled and commercial logs are prepared.

Bark at both the cut ends is beaten up to 30 cm with the help of back of an axe or hammer to provide sap and shelters for the beetles. The beaten ends are covered with the twigs and leaves of undergrowth to avoid quick drying.

Figure. Trap tree operation of SalHeart-wood borer, *Hoplocerambyx spinicornis*: Preparation of a log for trapping beetles

c) Collection and killing of beetles

The beetles which are attracted to the sap should be handpicked regularly at dawn and dusk and killed by

immersing them in water to which kerosene it added to form a top layer.

On the 10th day, the dried bark should be removed and further 30 cm bark should be beaten for fresh exudation of sap.

When trap work is over logs should be immediately removed, shifted to the depot and converted into

planks.

SOME IMPORTANT POINTS

Trap tree operations should first be concentrated on heavily affected coupes of forests.

Record of daily catches must be maintained and the laborers engaged should be suitably paid for the catches as incentive.

All the collected beetles should be burnt and buried in the presence of responsible forest officer.

After felling and removal of category 1 and 2 sal trees, the timber should be kept in depots, which are situated at least 3 km away from the edge of the nearest sal forest.

2. **TEAK (*Tectona grandis*)**

Canker grub of Teak- *Dihammus cervinus*

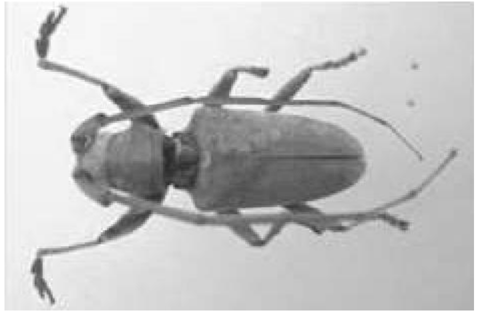


Figure 182. *Dihammus cervinus*

Adult beetles girdle the teak stem near the base, this injury results in hypertrophy of the tissue. Continued hypertrophy results in formation of a round bulbous callus. Cankers are found usually near the base but sometimes 3-4 feet above the ground.

Management: Insertion of thick wire through the bore hole or injecting insecticides like 0.1-0.25% Monocrotophos or dimethoate, quinophos or 0.2%. Paradichlorobenzene in kerosene oil and plaster them with wax or mud.

Introducing any fumigant and plugging the borerhole also kills the borer.

Leaf skeletonizer- *Eutectona machaeralis*

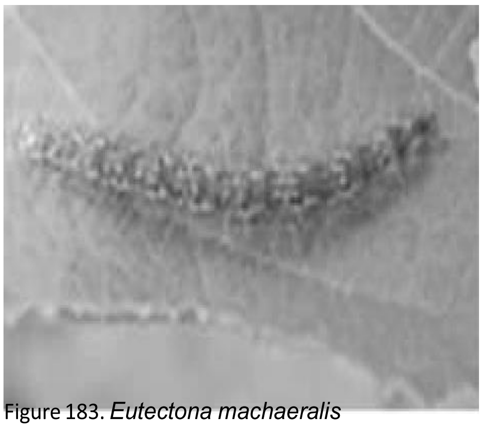


Figure 183. *Eutectona machaeralis*

Infestation period of insects is July-October. Larvae feed on green tissue of leaf and skeletonize it. Leaf skeltonizing retards the seedling growth and during severedamage seedlings dries.

<u>Management</u>: Regularmonitoring throughout the raising period particularly soon after the monsoon rains. Install light traps to monitor and trap adult moths. Leaves folded at the margins can be located and insect larva can be plucked every 10 days and destroyed. Spray of Neem oil or

Pungam oil emulsion can be done 15-20 days interval to deter the caterpillars. Foliar spraying of 0.01% alphamethrin or 0.02% cypermethrin (2 ml /5 Lt. water) or 0.005% deltamethrin (9 ml /5 Lt. water) is recommended for control. Introduction of egg parasitoid, Trichogramma raoi @ 1.25 lakhs/ ha between June to October in 5 installment should be done.

i. White grubs- *Holotrichia* spp.

Infestation period of insects is June-September. Wilting of the seedlings; Grubs feed roots.

Management: Sandy soil should be avoided for raising seedlings. Semi decomposed FYM should not beused. Soil working should be avoided during monsoon i.e. June –July. Soil mixing of Phorate 10 G @ 200 gm/ bed (size 10 x 1 m) should be used.

ii. Teak defoliator- *Hyblaea puera* (Fig. 184).

Infestation period of insects is June-October. Larvae defoliate seedlings, young and old trees. Early larval stages feed by scraping on the leaf surface. Late stages feed on the whole leaves. They also cut flaps of leaf edge, ties up with silk, remain inside and feed from within. Defoliation leads to complete drying of seedlings.

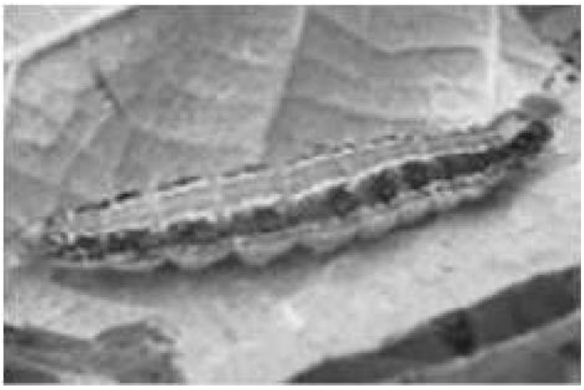


Figure 184. *Hyblaea puera* larva

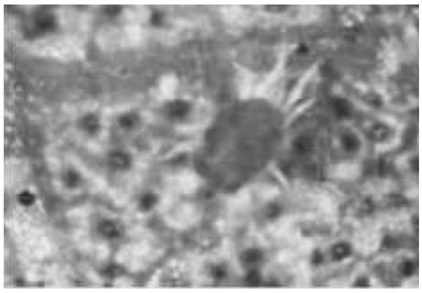
Management: Regular monitoring throughout the raising period particularly soon after the monsoon rains. Install light traps to monitor and trap adult moths of *Hyblaea puera*. Leaves folded at the margins can be located and

Hyblaea puera larva can be plucked every 10 days and destroyed. Spray of Neem oil or Pungam oilemulsion can be done 15-20 days interval to deter the caterpillars. 0.05% monocrotophos or 0.076% dicholrvos can be sprayed. *Bacillus thuringiensis* at 1.5% concentration is effective.

iii. Sap sucker- *Tetranychus urticae* (Fig. 185).

Infestation period of insects is June-September. Presence of chlorotic spots which coalesce into pale

patches. There will be extensive webbing underneath the leaves. Leaves start drying from the edges and slowlywither away.



Management: Application of 2 % Neem oil emulsion pointed towards the under-side of the leaves can reducethe population level. 2.5 ml of dicofol per liter of water canbe applied during severe infestation.

iv. Tingis beesoni

Infestation period of insects is march-November. The leaflamina becomes spotty with brownish patches near the base. Leaf ultimately withers and leading to complete defoliation of the plant. Stunty growth with side shootgrowth and plant become bunchy.

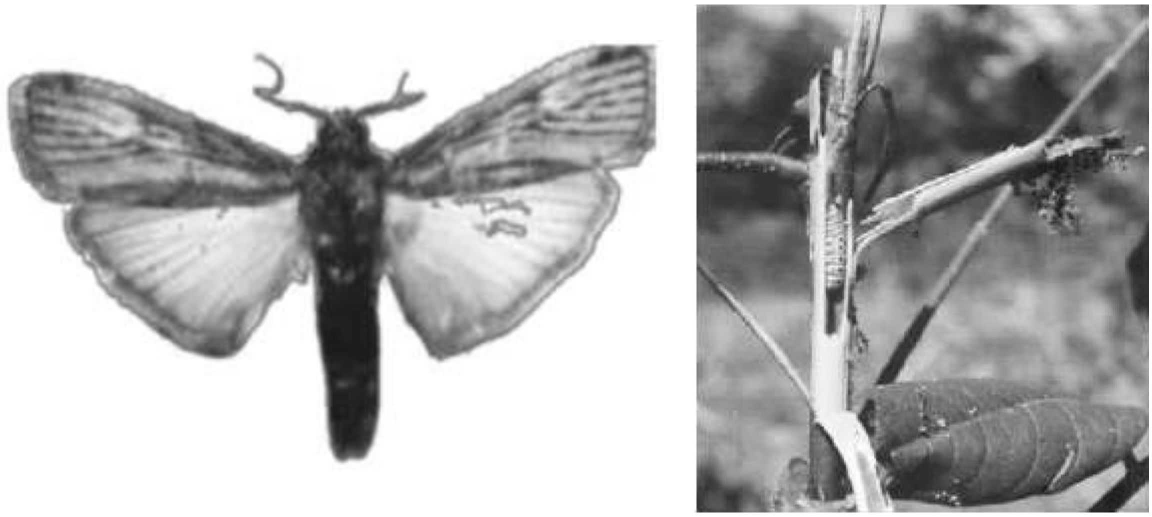
Management: Application of 2 % Neem oil emulsion pointed towards the under-side of the leaves can reduce the population level. 2.5 ml of dicofol per liter of water can be applied during severe infestation. Spraying of foliage with 0.05 to 0.075 % water emulsion of Dimethoate (Rogor) 2-3ml/liter or methyl demeton 20 EC 2 ml/liter or monocrotophos 36 EC 1.5 ml/liter or phosphamidon 40 SL 2ml/liter. control thepest.

3. **MAHOGANY (*Swietenia* spp.)**

Meliac eae/ Toon or Mahogany

fruit and Shoot-Borer, *Hypsipyla robusta* (Lepidoptera: Pyralidae)

Major Host Plants: *Cedrela toona, Chickasha tabularis, S. macrophylla, S. mahagoni*



Distribution: Sub-tropical and tropical forests of Indo-Malayan region, Australia, Africa, West Indies and South America.

Fruit or seed pest is capable of destroying the greater part of the seed crop of *cedrela tona* and *Carapamolucccensis* in India. As a shoot borer of young trees of Cederela and Swietenia, it attacks seedling ofvarious growth when they are as young as three months and less than on foot high; in plantations a 100 % infestation may be raised in the second year; later on the liability of the sapling or pole depends not so muchon each age as on the density of stocking and on each rate of growth and less frequent production of soft green shoot; older trees in which height growth has ceased are less liable to serious attack because the production and elongation of the terminal shoot is seasonally restricted and the borer cannot breed continuously in older stand. The combined work of the shoot generations on young cedar and mahogany trees may completely nullify the season growth; not only are the leaders of the current year killed of the laterals which have made progress on the woody stems of the previous years. The growth of the sapling appears to be completely checked but in the course of time, occasional shoots escape the borer and become lignified so that some upward progress made. Frequent bifurcation produces a dense bush plant.

Infestation period of insects is April-June in trees and most of the year in young plants. The life cycle and sequence of generation vary with the food plant and the climate of the region. It can be found on thespecies throughout the year feeding on different parts of the tree with following generations:

1. Flower generation: The eggs of the first generation are laid on the flowering shoots, early in March. Each female lays about 400-600 eggs the larva feed on the all parts of the inflorescence binding together individual adjacent flowers into bunches with loose silken network. A panicle in which a colony of larva hasfed remains a ragged mass of shriveled floral fragments long after the dispersal of the larvae. The life cycle lasts for 24- 29 days. Egg 4-5 days, larval stages 4+2+2+4, pupa 8 –12 days; the earliest moths appear in the last week of March. This generation lasts for 8 to 9 weeks.

2. Fruit generation: This is the second generation, which starts after the falling of all the flowers and settingof fruit pods. The second-generation larvae feed on the young and soft fruits. Older larvae feed on themature fruits and feed inside them and hollowing them. Feeding habit is the same as in flower generation four to seven fruits are bound together with the silken network. The larva inside the seed seals the exit holewith the excrement and silken threads. The life cycle lasts for 28-29 days. The moths appear in the last halfof April.

The pupation of the first and second generation takes place in the crevices of the tree trunk. The larvae descend the branches with the silken threads and search for the suitable place in the bark for pupation. In the heavy infested trees, the pupation takes place in mass. There may be two to three layered, the concentration of pupae may run into 1000 per square foot.

3. The shoot generations: The third, fourth and fifth generations are passed on the shoots. Larvae feed on the soft tissue of the new branches. Eggs are laid on the new unopened leaves, larva on hatching descends to the stouter part of the growing shoots and feeds by removing the epidermis by irregular patches, at the same time testing the shoot for a suitable spot to enter. If too vigorous tissue is selected as the site of entrythe attack fails and a flow of sap or gum drowns or entraps the larval; constant tapping of the sap weakens the shoot and the larva eventually gain an entry. Once established with in the shoot it excavates a central tunnel in the pith and increases it gradually until it may be two feet long. The larva usually remains in one shoot throughout each life but, in the later instars, may abandon a stunted shoot and attack second one at the axil of smaller twig. A gummy mass of frass bound with silk marks the entrance hole. The shoot above the entrance hole dies or shrivels, eventually falling over or breaking off. Below the site of entry, the shoot with each ends and lateral shoots dies and dries up as far downwards as the tunnel extends. Pupation of these generations take place inside e the shoot tunnel. Third and fourth generations last for 65- 80 days. The fifth generation over winters as fourth and fifth instar and lasts for 150-170 days.

Management: Application of thimet 10G @ 5-10 grams per polypot in soil or spray 0.01%-0.02% dimethoate or monocrotophos.

Probable questions:

Suggested reading:

1. Forests and Forestry, K.P. Sagreiya, (First edition 1 January 1967), National Book Trust, India.

2. Indian Forestry, K. Manikandan S. Prabhu, (7th edition 1 February 2021); Jain Brothers-New Delhi; Jain Brothers.

UNIT III

Soil insects and their damage to forest plants and their management

Objective: In this unit we will discuss about soil insects and their damage to forest plants and their management.

Soil insects damaging forest trees and forest nurseries:

1. Termites (Isop.: Termitidae)
2. Cockchafers (Col.:Scarabaeidae)

Over 22 per cent or 783,962 sq. km of our country's land is covered with forests. Forests, as we know, are not only the most important natural resource for mankind but also the best protector of our climate and our earth's ecology. Any excessive damage to forests is a threat to our own survival. This, notwithstanding, we are destroying our forests @ 13 lakh hectares or 13 thousand sq. km. per year. Next to man, the greatest destroyer of forests is insects who damage them to the tune of Rs. 125 lakhs per year. The major categories of insect-destroyers of forests are listed above.

The important soil dwelling insects that cause appreciable damage to our forest trees are termites and cockchafers. Termites cause damage to forest nurseries and young plantations by attacking the roots. The common genera injurious to forest are: Captotermes, Odontotermes and Cryptotermes. Termites also attack felled trees if they are left uncared for a long time and timber used in the construction of buildings, bridges and furniture. The cockchafers or white grubs which cause injury to seedlings and nursery are *Lachnosterna consanguinea*, *Granida albosparsa* and *Melolontha spp.* (Col.: Scarabaeidae).

<u>Examples</u>: -

- Termites – *Odontotermes obesus, Microtermes mycophagus* causes damage to *Acacia nilotica* & *Dalbergia sisso*. They mainly attack the nursery plants; they are the root feeders where the workers feed on underground roots & stem.

- Chafers/white grubs - They mainly cause damage to seedlings & nurseries. *Halotrichia consonguinea* causes damage to *Acacia nilotica, Albizia lebbeck*, the grubs feed on rootlets & cortical tissues of seedlings.

Probable questions:

Suggested reading:

1. Forests and Forestry, K.P. Sagreiya, (First edition 1 January 1967), National Book Trust, India.

2. Indian Forestry, K. Manikandan S. Prabhu, (7th edition 1 February 2021); Jain Brothers-New Delhi; Jain Brothers

UNIT IV

Role of insects in tropical forest ecosystem

Objective: In this unit we will discuss about Role of insects in tropical forest ecosystem.

The foundation of any ecosystem is always represented by the flow of energy and matter from one subsystem or trophic level to the next. The energy from the sun is trapped by plants or primary consumers in both terrestrial and aquatic systems and is passed on to primary consumers (herbivores) and then to secondary and tertiary consumers. Subsequently the energy reaches the decomposers and finally is either trapped in matter that is difficult to decompose or dissipated as heat. Insects, especially soil insects, in the ecosystem are never primary producers, they are important primary, secondary and even tertiary consumers in some ecosystems. Moreover, they are fundamental participants in the decomposition process in terrestrial and aquatic ecosystems. In the tropical forest ecosystem, the insects play the following important roles-

Insects as decomposers -

Dead and decaying plant and animal tissues or waste products serve as sources of food for many kinds of decomposers including insects, mites, fungi and bacteria. As decomposers process these tissues, carbon dioxide is released into the atmosphere completing the major part of the carbon cycle in the food web. Blowflies and flesh flies (Diptera: Calliphoridae and Sarcophagidae respectively) are some of the common examples of insects.

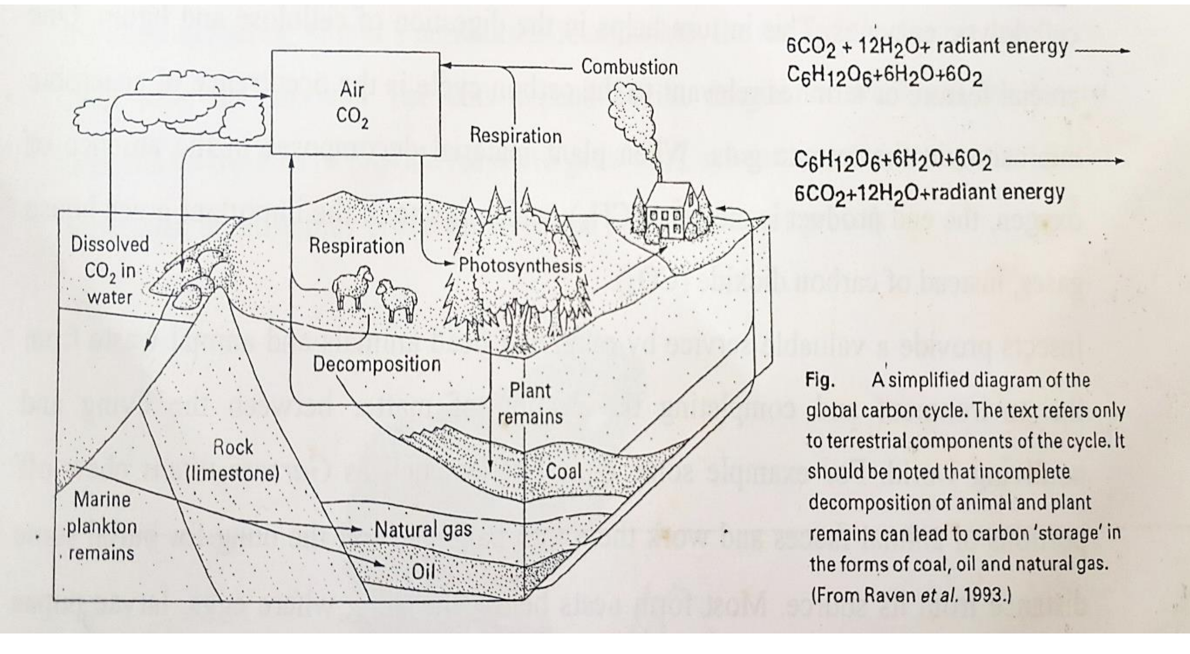


Fig. A simplified diagram of the global carbon cycle. The text refers only to terrestrial components of the cycle. It should be noted that incomplete decomposition of animal and plant remains can lead to carbon 'storage' in the forms of coal, oil and natural gas. (From Raven *et al.* 1993.)

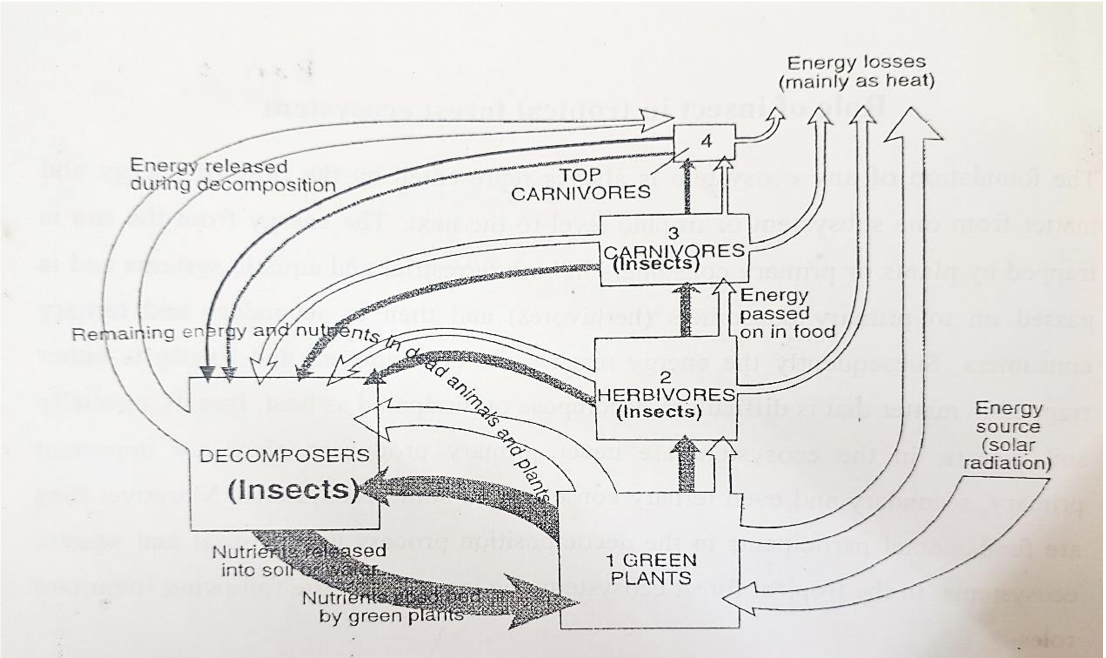


Fig. Diagrammatic representation of a general tropical food web. Boxes represent organisms of a particular trophic level (forest insects occur mainly in the herbivore trophic level, though many borers and termites may be included amongst the decomposers). White arrows indicate the one-way flow of energy; dark arrows indicate the cycling of nutrients; wider arrows indicate greater flows. (From Pomeroy and Service, 1986.)

The most impressive decomposers in the insect world are the termites (Isoptera) and extremely beneficial to the tropical forest ecosystem, being vital components in the breakdown of dead timber and the recycling of scarce nutrients through detritivore food chain Their symbiotic association with micro-organisms (like flagellate protozoans and some species of bacteria) that live in the guts of termites and produce cellulolytic enzymes. This in turn helps in the digestion of cellulose and lignin. One crucial feature of termites relevant to the carbon cycle is the occurrence of anaerobic microsites in the termite guts. When plant material decomposes in the absence of oxygen, the end product is methane (CH4), which is one of the important greenhouse gases, instead of carbon dioxide (CO2).

Insects provide a valuable service by removing dead animals and animal waste from the environment and completing the cycling of matter between the living and non-living world. For example, some dung beetles such as Garreta nitens chew off portions of animal faeces and work them into balls and roll the dung for burial some distance from its source. Most form nests below the dung where eggs, larvae, pupae and adults develop.

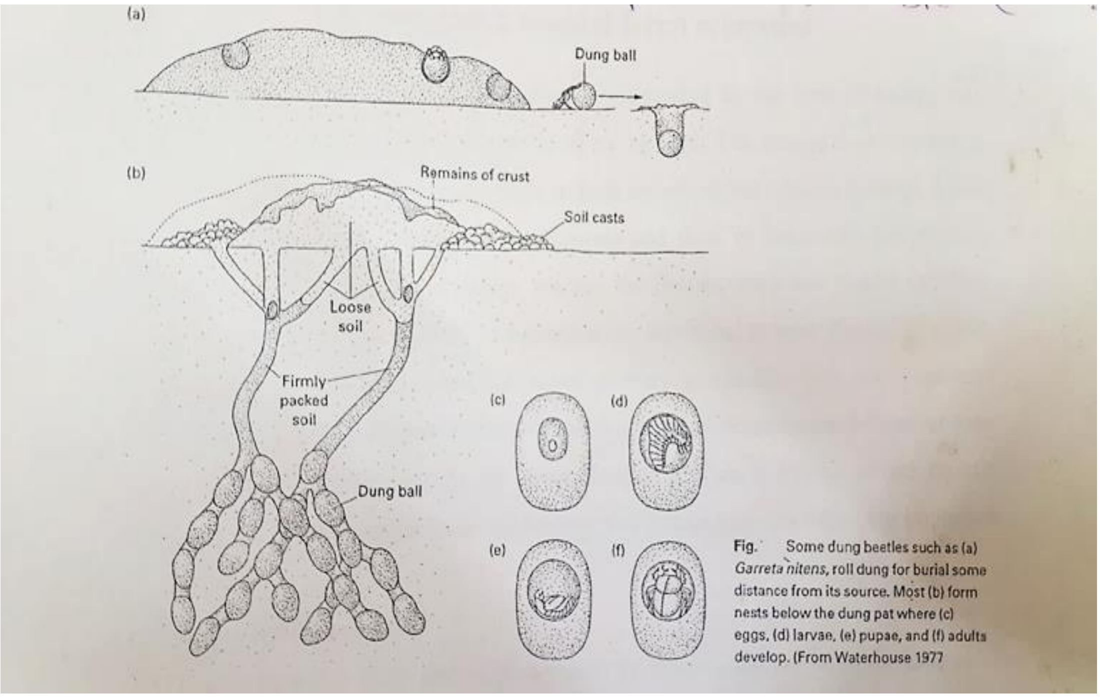
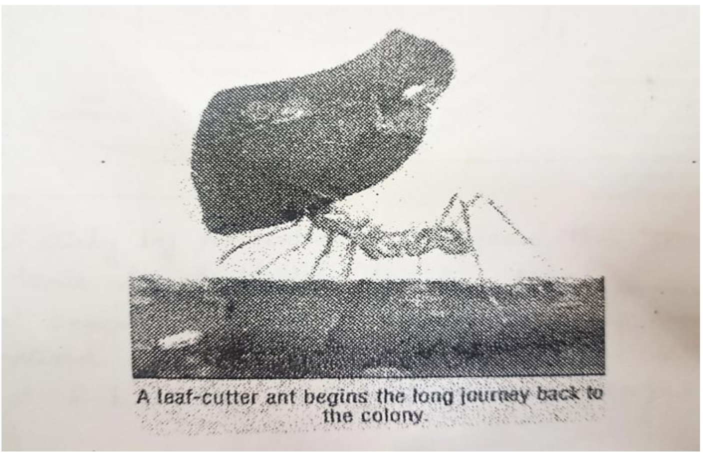


Fig. Some dung beetles such as (a) *Garreta nitens*, roll dung for burial some distance from its source. Most (b) form nests below the dung pat where (c) eggs, (d) larvae, (e) pupae, and (f) adults develop. (From Waterhouse 1977

Insects as stimulator of forest growth-

Tropical forests are home to a number of species of leaf cutter ants. They are often called as 'rain forest farmers'. The worker leaf cutter ants climb the trees of the rainforest and cut pieces of leaves from the canopy. They carry these leaf bits on their backs to their underground colony. Back at the colony, different ants chew the leaves and place them in a pile called a fungus garden. The ants eat the fungus that grows on the chewed leaves. This is a mutualistic relationship; the ant and the fungus depend on each other for survival. The ants depend on the fungus for food and the fungus depends on the ants to provide leaves to grow on. Leaf-cutter ants are important to the ecosystem because they prune the trees and stimulate forest growth.



A leaf-cutter ant begins the long journey back to the colony.

Probable questions:

Suggested reading:

1. Forests and Forestry, K.P. Sagreiya, (First edition 1 January 1967), National Book Trust, India.

2. Indian Forestry, K. Manikandan S. Prabhu, (7th edition 1 February 2021); Jain Brothers- New Delhi; Jain Brothers

UNIT V

General issues in forest entomology: a) Insect damages in plantation vs natural forest, b) Pest problems in plantation of indigenous vs exotic species. c) Pest problems in monoculture and mixed plantations.

Objective: In this unit we will discuss about general issues in forest entomology. It includes Insect damages in plantation vs natural forest, Pest problems in plantation of indigenous vs exotic species and Pest problems in monoculture and mixed plantations.

Introduction

Based on their ecological status, we can distinguish the forest stands as undisturbed natural forests, disturbed or degraded natural forests, and plantations. The plantations can be further categorised into those of indigenous or exotic species, and those consisting of a single species (usually called monoculture) or more than one species (usually called mixed plantation). Foresters, forest entomologists and plant ecologists have strong traditional views on the risk of pest susceptibility of these different types of natural and man-made forest stands. Speculation was unavoidable in the past because the practice of forestry could not wait for conclusions based on long-term experiments. Now that fairly adequate data have accumulated, it is possible to make a critical assessment of the hypotheses and their theoretical foundations. Three commonly held views and their underlying hypotheses are examined here. These views are (1) that natural, mixed-species tropical forests are free of pest problems (in contrast to forest plantations); (2) that plantations of exotics are at greater risk of pest damage than plantations of indigenous species and (3) mixed plantations are at lesser risk of pest damage than monocultures.

Do plantations suffer greater pest damage than natural forests? And if so, why?

That plantations suffer greater pest damage than mixed-species natural forests is a well-accepted axiom in forestry, although contrary to the conventional wisdom, tropical forests are not free of pests. Empirical data presented in

damage ranging from minor

showed that all gradations of insect

feeding with no significant impact to occasional large-scale outbreaks resulting

in massive tree mortality may occur in natural tropical forests. However, the

most common insect outbreaks in natural forests occurred in high-density stands approaching monoculture.

A detailed analysis of the plantation effect on pest incidence in tropical tree species was made by Nair (2001a). He compared the pest incidence in natural forests and plantations of several species for which relevant published literature was available—*Eucalyptus* spp., *Gmelina arborea*, *Hevea brasiliensis*, *Swietenia macrophylla* and *Tectona grandis*, and found that all of them suffered greater pest damage in plantations. In a meta-analysis of 54 individual studies reported in the literature, Jactel *et al.* (2005) also concluded that, overall, forest monocultures are more prone to pest infestation than more diverse forests. Thus the greater pest incidence in plantations is an undisputed scientific fact.

Two main hypotheses have been proposed to explain the lower pest incidence in natural forests – the 'enemies hypothesis' and the 'resource concentration hypothesis' (Root, 1973; Carson *et al.*, 2004). Recently, Nair (unpublished) proposed a third hypothesis called the 'pest evolution hypothesis'.

Enemies hypothesis

According to the enemies hypothesis, the lower pest incidence in the mixed-species stand is due to greater action of the pests' natural enemies. This is thought to be facilitated by the diverse plant community providing (1) alternative prey or hosts on which the natural enemies can sustain themselves and build up during periods when the pest is not present in the habitat, (2) a better supply of food such as pollen, nectar and honeydew for the natural enemies that enhances their fecundity and longevity and therefore overall effectiveness and (3) greater variation in microhabitats and microclimate that provides a larger variety of shelters for natural enemies. The increased natural enemy effectiveness therefore is thought to prevent pest build-up in the natural forest.

be the most important factor. This 'trapping effect' of monocultures on

Resource concentration hypothesis

According to the resource concentration hypothesis (Root, 1973), also called host concentration hypothesis (Carson *et al.*, 2004), monoculture favours pest build-up by providing (1) a larger absolute supply of food resources,

[illegible]

specialized pests may largely account for the greater pest load of monocultures (Root, 1973). Reduced dispersal also ensures less exposure to the risk of mortality during dispersal.

Experimental studies in agriculture have given strong support to the resource concentration hypothesis. In a comprehensive study of the insect fauna of collard (*Brassica oleracea*) in a pure crop in comparison to the same crop surrounded by miscellaneous meadow vegetation, Root (1973) found no evidence of greater effectiveness of natural enemies in the mixed vegetation, suggesting that the host concentration hypothesis offers a better explanation. In a test of the two hypotheses in the corn–bean–squash agroecosystem, Risch (1981) also found that there were no differences in the rates of parasitism or predation of pest beetles between monocultures and polycultures. On the other hand, it was found that the pest beetles tended to emigrate more from polycultures that included a non-host plant than from host monocultures, supporting the host concentration hypothesis.

Pest evolution hypothesis

According to Nair (unpublished), pest evolution might account for the greater pest incidence in forest plantations. He argues that natural selection of the pest genotypes most adapted to the planted host and the plantation environment is the major cause. This is facilitated by the large pest populations built up in large-scale plantations, the fast turnover rate of the pest generations and the inability of plantation trees to counterevolve.

In plantations of indigenous species, all pests originate from the natural forest. Most tree species in natural forests have a large number of associated insect species, of which only some become serious plantation pests. For example, out of over 174 species of phytophagous insects associated with the teak tree *Tectona grandis* in Asia, only three, the defoliator *Hyblaea puera*, the skeletonizer *Eutectona machaeralis* and the beehole borer *Xyleutes ceramicus* are serious pests of plantations (for details see under teak in Chapter 10). The major pest *H. puera* is widely distributed across the tropics and subtropics, covering Asia-Pacific, Africa, Central America, the Caribbean and South America, but its population dynamics on teak shows differences between the major regions. It has not attacked teak plantations in Africa so far and only recently has it attacked teak plantations in Latin America (in 1995 in Costa Rica and in 1996 in Brazil), in spite of its presence on other vegetation and the long history of teak planting in these regions. *H. puera* has been recorded on at least 45 host plants but outbreaks are common only on teak and rarely on some mangrove hosts. *H. puera* is suspected to be a species-complex (CABI, 2005). These observations show that there is large variation in the biological characteristics of *H. puera* populations and that the insect which infests teak in Asia might be a teak-adapted genotype. Enormous numbers of *H. puera* moths are produced every year on teak plantations and it is logical to assume that over the more than 100 years since it was first recognized as a pest of teak plantations in India, the species has become adapted to teak through natural selection. The teak skeletonizer *E. machaeralis* also seems to be adapted to teak through natural selection. Until recently it was thought that the skeletonizer which attacks teak in India, Bangladesh, Myanmar and other counties in Asia is the same species, but Intachat (1998) showed that the teak skeletonizer present in Malaysia, Indonesia and possibly Thailand is a closely related species, *Paliga damastesalis*. The differences between the two species are very slight and it is obvious that this also represents an evolving species-complex.

Obviously, out of the many species of insects associated with a tree species in the natural forest, only some have the greater potential to adapt to the particular host species and the plantation environment and become serious plantation pests. This is shown by the spectrum of pests attacking *Eucalyptus* spp. in natural forests and plantations in Australia. Only some of the pests that occur in natural forests are found in plantations; the most notable difference is the near absence of phasmatids and the preponderance of leaf-feeding beetles (chrysomelids and scarabaeids) in plantations (Wylie and Peters, 1993; see also Nair 2001a). It is evident that species and genotypes which can better adapt to the plantation environment will be selected in the plantations.

In plantations of exotic species, new pests may originate by adaptation of indigenous insects. The number of indigenous insect species attacking the exotic *Leucaena leucocephala* in India and *Acacia mangium* in Malaysia showed an increase over time (see Chapter 10). Wylie (1992) noted that rapid expansion of eucalypt plantations in China has been accompanied by a substantial increase in the number of insect species feeding on them. The bagworm *Pteroma plagiophleps*, which has been an insignificant pest of some native species, has become a major pest of the exotic *Falcataria moluccana* in India, with expansion of plantations of the latter (see Chapter 10). Other examples of such host-adapted insects are wingless grasshoppers on pines in Africa (Schabel *et al.*, 1999); several defoliating lepidopteran caterpillars also on pine in Africa (Gibson and Jones, 1977); the myrid bug *Helopeltis* spp. on *Acacia mangium* in Indonesia, Malaysia and the Philippines and on *Eucalyptus* in India (Nair, 2000); and the noctuid *Spirama retorta* on *Acacia mangium* in Malaysia (Sajap *et al.*, 1997). These insects became serious pests of exotics over time because insects, with a shorter generation time than trees, can adapt more quickly, and the trees in plantations have no chance of developing resistance mechanisms through natural selection, unlike those in natural stands. Insects can overcome the chemical defences of exotics through adaptive evolution using population genetic mechanisms, in the same way as they develop resistance to insecticides. All these examples of newly adapted pests in exotic plantations indicate the role of pest evolution in the origin of plantation pests.

Evolution is an ongoing process which enhances the fitness of pests in plantations. This pest evolution is invisible when it does not lead to changes in the physical appearance of the pests. It has therefore gone unrecognized although it is logical to expect that genotypic variation among individual insects will result in some individuals faring better than others on a particular host species, and that large-scale and long-term monoculture of the species will lead to natural selection of the best adapted insect genotypes. Adaptive evolution must be taking place in pest insects even when it is not physically visible, as in the case of development of insecticide resistance, particularly when large populations are built up repeatedly in plantations of selected tree species within the plantation environment, which differs from the natural forest environment in many respects. While a negative selection pressure is exerted by an insecticide on individuals not possessing resistant characteristics, a plantation crop exerts a positive selection pressure on individuals better adapted to the crop. The result is the same – survival and selection of better adapted individuals, i.e. differential survival and large-scale multiplication of certain genotypes, aided by a virtually unlimited food source offered by the plantations. Indeed, formation of demes (groups of individuals of a species that show marked genetic similarity) within populations of phytophagous insects in response to isolation, variation in host quality and other stochastic events is a well-recognized phenomenon (Speight *et al.*, 1999). There is little doubt that development of pest status by an insect is an evolutionary process. Pest evolution must be the main reason for the greater pest problems of monoculture plantations compared with mixed-species natural forests. Natural forests have the advantage that the trees can also evolve defensive mechanisms by differential survival of better-adapted tree genotypes, but this cannot take place in plantations. In the tropics where a typical insect pest can complete its life cycle in less than a month and breeding may take place throughout the year, the turnover rate of pest generations, and therefore the chances of natural selection, is very high compared with that of the long-lived trees. The narrowing of the genetic base of plantation trees due to human selection and inbreeding has been recognized as a factor favouring pest susceptibility (see e.g. Gibson and Jones, 1977) but pest evolution must be playing a more crucial role.

The pest evolution hypothesis is not an alternative to the host concentration hypothesis and the enemies hypothesis, but complementary to both. Pest evolution and host concentration appear to be the more important mechanisms although all three mechanisms might be operating with varying degrees of relative importance in different situations. The biological attributes of the pest insect are also important in determining whether it attains serious pest status in a plantation in contrast to a mixed-species natural stand. For example, where the adult female of a pest is flightless, as in bagworm moths, or has limited powers of dispersal, as in the psyllid bug *Phytolyma* spp., proximity of host trees, i.e. host concentration, might be necessary for precipitating an outbreak. On the other hand, a species like the elm bark beetle may spread the tree-killing Dutch elm disease to isolated elm trees. The importance of an insect's specialiced host-finding mechanism in its successful exploitation of a monoculture vs. mixed-species stand is discussed further in Section 8.4.5.

Pest problems in plantations of indigenous vs. exotic species

The issues

A substantial percentage of forest plantations in the tropics is made up of exotic species, notably eucalypts and pines, and more recently acacias (see Chapter 1). The success of exotics in plantations has generally been attributed, apart from the adaptability of the chosen species to the site, to the absence of their native pests. While many plantations of exotic species continue to be free of major pests, there is a fear that catastrophic outbreaks of pests may occur suddenly as in the case of leucaena psyllid and pine aphids (see Chapter 10). As mentioned earlier, it is generally believed that exotics are more prone to pest outbreaks. Some typical expressions of opinion include the following.

> The world-wide distribution of forest trees is being continuously changed as exotic species are used more and more in plantation forestry . . . We should expect trouble from insects in these exotic plantations (Berryman, 1986, p. 249)

> The [indigenous] species is adapted to the environment and already filling an ecological niche. This may render it less susceptible to serious damage from diseases and pests since controlling agents (predators, viruses, climatic factors) are already present . . . As a rule, where a native species meets the need, there is no reason to choose an alternative. Indeed, for reasons of conservation, if the choice lies between two species of comparable growth and quality, one of which is native and one exotic, . . . the native species is to be preferred. (Evans, 1992, p. 103–4)

> Some important biological advantages are present with indigenous species . . . They deserve more attention: It is possible to predict their

> performance in plantations based on their performance in natural stands; the species fills an existing ecological niche – it may therefore be less susceptible to diseases and pests, since the natural enemies are already present . . . (Appanah and Weinland, 1993, p. 28)

It can be seen from the above that two main reasons are given for the presumed lesser pest damage of indigenous species – (1) they have developed resistance or tolerance against the local pests through coevolution, and (2) natural enemies of the pests are present to keep them under check.

An exception where exotics were considered to be at lesser risk from pests is the following.

> . . . the argument that establishing a species outside its natural habitat (i.e. as an exotic) increases its susceptibility to pests has not been proven . . . Growing a species as an exotic may actually release that species from its natural pests and thus improve its health and performance. (Zobel *et al.*, 1987, pp. 160–161)

Alternatively, it can be argued that the risk of pest outbreaks is associated with monocultures, irrespective of whether a species is indigenous or exotic. The question has become important in the context of the ongoing, rapid expansion of exotic plantations in the tropics, particularly large-scale industrial plantations aimed at production of pulpwood for medium-density fibreboard. The issue was examined in detail by Nair (2001a) and the following account is mainly based on that evaluation. He made detailed case studies of nine tree species commonly planted as exotics in the tropics. For each species, the pest problems in three situations were examined and compared; (1) in natural forests in countries where the species is indigenous, (2) in plantations in countries where the species is indigenous (native plantations) and (3) in plantations in countries where the species is exotic (exotic plantations). The species chosen were *Acacia mangium*, *Eucalyptus* spp., *Falcataria moluccana*, *Gmelina arborea*, *Hevea brasiliensis*, *Leucaena leucocephala*, *Pinus caribaea*, *Swietenia macrophylla* and *Tectona grandis*. The results are described below, following a brief consideration of the definition of exotics.

Defining the exotic

The term 'exotic' is generally used in relation to a country, to indicate a species introduced from outside, in contrast to 'indigenous' or 'native' species that grow naturally within the country. Since the political boundary of a country is the unit of area, a species is considered indigenous even when it occurs only in some parts of the country. Thus teak is indigenous to India, Myanmar, Thailand

and Laos, although it does not occur in all parts of these countries. This definition is not scientifically rigorous, particularly when the natural distribution of a species is limited to small parts of a big country. For example, *Acacia mangium*, *Falcataria moluccana* and *Eucalyptus deglupta* occur naturally in very small pockets in the eastern islands of Indonesia, and to say that they are indigenous to Indonesia is misleading as they do not form part of the natural vegetation for most of the country. For practical purposes, an exotic species is defined here as an introduced species that does not occur naturally over a large part of a country.

Empirical findings

When an exotic species is grown in monoculture, it becomes difficult to distinguish between the 'monoculture effect' and the 'exotic effect' contributing to pest problems. Analysis of the pest problems in the three habitats, that is the natural forest, native plantations and exotic plantations facilitated the segregation of monoculture and exotic effects. Comparison of the pest problems of native plantations with those of natural forests gave a measure of the monoculture effect, and comparison of the problems of exotic plantations with those of native plantations gave a measure of the exotic effect. A summary of the results from the case studies (for details see Nair (2001a)) is presented in Table 8.1.

In all the five cases for which data are available, monoculture practice itself led to greater pest damage. The species were *Eucalyptus*, *Gmelina arborea*, *Hevea brasiliensis*, *Swietenia macrophylla* and *Tectona grandis*. Data for exotic effect on pest susceptibility are available for eight species. Five of them (*Acacia mangium*, *Eucalyptus*, *Gmelina arborea*, *Hevea brasiliensis* and *Tectona grandis*) suffered lesser damage in exotic locations and two (*Leucaena leucocephala* and *Pinus caribaea*) suffered greater damage. One species (*Swietenia macrophylla*) suffered equal damage in some exotic places and greater damage in others. This shows that pest susceptibility is not exclusively determined by the exotic or indigenous status of a tree species.

It is also interesting to look at the number of insect species associated with native and exotic plantations (Table 8.2). The number of species found in exotic plantations was greater for four species, less for three and equal for one.

In summary, the empirical data shows that *neither the intensity of pest damage nor the number of insects associated with a tree species is determined by its exotic status*. While plantations are at greater risk of pest attack than natural forests, plantations of exotics are at no greater risk than plantations of indigenous tree species. They are in fact at lesser risk initially. Exotic status is only one among the many determinants of pest incidence.

Table 8.1. *Segregation of the monoculture effect[a] and exotic effect in pest susceptibility of tropical forest plantation species[b]*

Tree species	Monoculture effect	Exotic effect
Acacia mangium	No data	Lesser damage
Eucalyptus spp.	Greater damage	Lesser damage
Falcataria moluccana	No data	No data
Gmelina arborea	Greater damage	Lesser damage
Hevea brasiliensis	Greater damage	Lesser damage
Leucaena leucocephala	No data	Greater damage
Pinus caribaea	No data	Greater damage
Swietenia macrophylla	Greater damage	Equal damage in some places, greater in others
Tectona grandis	Greater damage	Lesser damage

[a]Monoculture effect indicates whether monoculture plantations in regions where the species is indigenous suffer greater or lesser pest damage compared to natural stands. Exotic effect indicates whether monoculture plantations in regions where the species is exotic suffer greater or lesser pest damage compared to monoculture plantations in regions where the species is indigenous.

[b]Data from Nair (2001a)

Theoretical explanations

When an exotic tree species is introduced into a new environment, it comes without its associated insect pests. Pests may originate from indigenous or exotic sources through the following mechanisms.

(*a*) *From indigenous sources*

1. Generalist feeders

This category accounts for most of the insects associated with exotics in a new location. Many insects are polyphagous and their host selection mechanism permits acceptance of a wide variety of plants. Probably they arrive on a host plant by random exploratory movements and accept it when they come in contact with it, based on some general criteria which may include absence of deterrents rather than presence of specific attractants. Thus a number of indigenous insects colonize an exotic. Examples of generalist feeders are root-feeding cutworms and whitegrubs; stem-boring hepialids and cossids; and leaf-feeding grasshoppers and caterpillars of noctuid, geometrid and lymantriid moths. Generally they are incidental feeders and therefore only minor pests, although some species like root-feeding termites on eucalypts and trunk-dwelling termites on teak in Indonesia have become serious pests of exotics.

Table 8.2. *Comparison between the numbers of insect species associated with native and exotic tree plantations*[a]

	Score[b] for number of insect species in		Whether exotic plantation has greater or lesser no. of associated insect species
Tree species	Native plantations	Exotic plantations	
Acacia mangium	1	8	Greater
Eucalyptus spp.	11[c]	40	Greater
Falcataria moluccana		5	
Gmelina arborea	10	2	Lesser
Hevea brasiliensis	6	3	Lesser
Leucaena leucocephala	1	4	Greater
Pinus caribaea	3	3	Equal
Swietenia macrophylla	1	2	Greater
Tectona grandis	23	2	Lesser

[a]Data from Nair (2001a)

[b]Scores are used instead of actual numbers as the number of associated insects is only approximate. One score is assigned to one to ten species. Thus, for example, score ten indicates 91–100 species and score 40 indicates 390–400 species

[c]Excluding those in the temperate region

2. Newly adapted insects

As mentioned earlier (Section 8.2.3) some indigenous insects adapt and become serious pests of exotic tree species over time. Examples are the bagworm *Pteroma plagiophleps* on *Falcataria moluccana* in India, wingless grasshoppers on pines in Africa, the myrid bug *Helopeltis* spp. on *Acacia mangium* in Southeast Asia and on *Eucalyptus* in India, the noctuid *Spirama retorta* on *Acacia mangium* in Malaysia etc. They become adapted in a short period because of their shorter generation time than trees, and trees in plantations, unlike those in natural stands, have no chance of developing resistance mechanisms through natural selection.

3. Specialized insects preadapted to closely related plant species

The examples of *Hypsipyla robusta* on mahogany and the shoot moths *Dioryctria* spp. and *Petrova* spp. on pines in Southeast Asia (see Chapter 10) show that an introduced tree species may encounter insects already adapted to closely related tree species in the location of introduction. This leads to quick attack of the exotic by these specialized oligophagous insects because the same or a closely related host selection mechanism developed over evolutionary time may operate. This results in serious pest problem as soon as the exotic tree is introduced.

(*b*) *From exotic sources*

In this case, well-adapted pests are introduced unintentionally from the native habitat of the exotic tree. Examples are the psyllid *Heteropsylla cubana* on *Leucaena leucocephala*; the beetles *Phoracantha* and *Gonipterus* on eucalypts; and the aphids *Cinara cupressi, Pinus pini* and *Eulachnus rileyi* on pines (see Chapter 10). These introduced pests can cause havoc, as in the case of the leucaena psyllid in Southeast Asia because they come without the natural enemies that often keep them in check in the pest's native habitat. However, the initial outburst may be tempered in the course of time as the native generalist natural enemies catch up with the pest.

Among the exotic tree species examined by Nair (2001a), the number of associated insect species ranges from about 20–400 (Table 8.2). This number is determined by several factors; distance from the native habitat, the extent and diversity of the geographical area of introduction, the time elapsed since introduction and the chemical characteristics of the tree species.

The major factors that determine the risk of pest incidence on exotics are the following.

1. Presence of other closely related tree species in the location of introduction.

Closely related species, particularly of the same genus, may harbour preadapted insect pests. In some cases, plants of closely related genera may serve the same purpose (e.g. *Toona* and *Swietenia*). Similar phytochemical profile is the deciding factor.

2. Extent of area occupied by the exotic plantations

The risk of pest problems increases with an increase in the extent of planted area, for the following reasons: (1) greater numbers of indigenous insects from diverse habitats come into contact and interact with the exotic species and adapt to it; (2) the greater the area of planting, the greater is the chance of mismatched planting sites which lead to plant stress. This could promote the outbreak of some pests like bark beetles which build up on stressed trees and then spread; (3) greater habitat heterogeneity increases the chances of matching with the habitat requirement of invading exotic pests and (4) a larger planted area provides a larger receptacle for randomly dispersing preadapted exotic pests.

3. Genetic base of the introduced stock

A narrow genetic base increases the risk of pest outbreaks. The risk increases over time, due to inbreeding.

4. Distance between location of introduction and the native habitat of the tree species

The longer the distance, the less the risk of pest problems as shown by the example of teak in Asia, Africa and Latin America.

5. Existence of serious pests in the native habitat

This is important in two ways. Their absence indicates that the tree species has innate resistance to most insects and therefore indigenous insects in the new location are unlikely to adapt to it easily and acquire pest status (e.g. *Hevea brasiliensis*). Secondly, the existence of serious pests in the native habitat indicates the chance of their unintentional introduction through one or other means.

6. Time elapsed since introduction

The risk of pest outbreak increases with time due to adaptation of indigenous insects and the greater likelihood of invasion by exotic pests.

7. Chemical profile of the exotic species

Some species are less prone to pest attack due to the presence of toxic or deterrent chemicals.

8. Innate biological attributes of the insects associated with the tree species

Populations of some insect species characteristically display outbreak dynamics while others display non-outbreak dynamics (r- and K-adapted insects, see Chapter 7).

As pointed out earlier, the two main reasons postulated for the presumed lower pest risk of native plantations are resistance of trees to indigenous pests developed through coevolution and increased natural enemy action. Both are not fully valid. The first is valid to the extent that an indigenous tree species will not be wiped out by a pest because it has evolutionarily outlived such an eventuality. However, this is of little value in the plantation system of tree management because economic damage can still occur, as shown by the many examples covered in Chapter 10. The second is valid in some cases, but not in all. Although natural enemies constitute an important factor regulating the population increase of many insects, and decisively so in some, empirical observations show that pest outbreaks occur in spite of their presence, sometimes even in natural forest stands. This shows that outbreaks occur due to other reasons as well. The theoretical principles of population dynamics discussed in Chapter 7 show the possibility of complex patterns of outbreak behaviour through the interplay of endogenous and exogenous factors. While natural enemies do regulate pest population build up in some cases and in some situations, in many cases the exact causes of population outbreak remain unknown.

The theoretical considerations support the empirical findings that the risk of pest damage in plantations is not exclusively or even predominantly dependent on the exotic or indigenous status of a tree species. It depends on the interplay of a number of factors mentioned above.

Pest problems in monocultures vs. mixed plantations

As indicated in the introduction, there is a traditional view that pest problems can be reduced by raising mixed-species plantations instead of monocultures. It is argued that there is a relationship between diversity and stability and that the more diverse an ecosystem, the more stable it is. This assumption has not been subjected to adequate empirical verification. In Chapter 4 we saw that mixed natural stands are not always free from pest problems. The available evidence for and against the claim and the theoretical backing are examined here.

Refining the hypothesis

First, let us take a closer look at the hypothesis itself. We are in fact dealing with many hypotheses here. The overriding hypothesis is that there is a relationship between diversity and stability such that a more diverse ecosystem is more stable. This has led to the hypothesis that natural mixed tropical forest which has a high diversity of tree species is stable and is free from pest outbreaks. This concept has been further extended to mixed forest plantations. So the hypothesis under consideration here is that mixed forest plantations suffer lesser pest damage than pure plantations of the same species. The simplifying assumptions do not end here. What do we mean by a mixed forest plantation? Natural mixed forests in the tropics are mixtures of many species. More than 100 tree species per hectare is the norm (see Chapter 1). But most artificial mixtures tried in plantations consist of only two tree species. This is shown by the FAO documentation of mixed plantation trials across the world, covering many countries in the tropics and subtropics and involving many tree species (FAO, 1992). In theory mixtures can take many different forms because there are several variables. These include the number of tree species in the mixture, canopy layers (single, double or multi-layered), percentage composition of the different tree species, spatial arrangement (mixing within the planting line which is often called intimate mixture, line mixture, block mixture etc.), age of the tree species and choice of tree species. The most common mixed plantation is a mixture of two species, in equal proportion, planted in intimate mixture or line mixture, forming a single canopy layer. The choice of tree species in the mixture varies; it can be a combination of any two species. So, more specifically, the hypothesis under consideration is that a mixed plantation consisting of any two or more species in intimate mixture, forming a single canopy layer, suffers less pest damage than a single species plantation.

Direct evidence from pure and mixed plantations of trees

Though a large number of casual or incidental observations are available, systematic, well-planned observations on pest incidence in pure versus mixed tree plantations are rare. Available data from the tropics are summarised in Table 8.3. Excluded are several papers in which only casual observations have been made or essential details are missing. In these studies, plantations of selected species have been raised in monocultures or in mixture with other tree species and the pest incidence compared. The other tree species (one or more) constituted various percentages of the total number of stems in the plantation, as shown in the table. It may be seen that the response of pests to mixed planting was variable; the severity of their incidence was either the same as in monoculture, lower, higher or variable. In general, we can only conclude that the response of pests to mixed planting was variable. A typical example is the shoot borer of mahogany. Suharti *et al.* (1995) reported that in Indonesia, when mahogany was planted in mixture with the neem tree *Azadirachta indica*, shoot borer incidence in mahogany was much reduced. But Matsumoto and Kotulai (2002) found that in Malaysia, the same mixture did not prevent economic damage by the mahogany shoot borer. In another study, Matsumoto *et al.* (1997) reported that when mahogany plantations were surrounded or enclosed by *Acacia mangium* plantations, mahogany was not attacked by the shoot borer. It is obvious that factors other than mixing of species influenced the results. Overall, the data presented in Table 8.3 does not support the hypothesis that mixed plantations of trees suffer less damage than monocultures. There are probably several confounding factors which influence pest incidence.

Recently Jactel *et al.* (2005) made a meta-analysis of 54 observations of various authors who compared pest incidence between mixed species stands and single species stands. The data set comprised 17 observations from tropical, 32 from temperate and five from boreal forest regions. The analysis indicated that planting or managing a tree species as a pure stand, *on average* significantly increased the rate of insect pest damage as compared to a mixed stand. Among the 54 observations, the pure stand effect was an increase in pest damage in 39 cases and a decrease in 15. Further analysis showed that the overall effect was the same irrespective of forest region (boreal, temperate or tropical, although the magnitude of the effect was higher in boreal), insect order or feeding guild, but that there was difference between oligophagous and polyphagous pests.

Table 8.3. *Comparative pest incidence in pure versus mixed plantations*

Tree species	Pest	Pest incidence in: Monoculture	>75% mix	50% mix	20–25% mix	Unknown mix	Comp. incidence in mixture	Reference
Swietenia macrophylla	*Hypsipyla robusta*					Lower	Lower	1
Do	Do			Attacked			Attacked	2
Milicia excelsa	*Phryneta leprosa*	Attacked				No attack	Lower	3
Sonneratia apetala	*Zuezera conferta*	51%			32%		Lower	4
Albizzia odoratissima	Psyllid	40%		6–8%	13%		Lower	5
Grewia tiliaefolia	Caterpillar	20%			38–74%		Higher	5
Do	Gall insect	37%		37%	37%		Same	5
Haldina cordifolia	Defoliator	39%		37–57%	45–49%		Higher	5
Pterocarpus marsupium	Gall insect				Higher		Attacked	5
Xylia xylocarpa				Higher	Lower		Variable	5
Pinus massoniana		Lower	Higher				Higher	6
Ailanthus triphysa	*Atteva fabriciella*	Attacked		Attacked			Same[a]	7
Do	*Eligma narcissus*	Attacked		Attacked			Same[a]	7
Vochysia guatemalensis	Defoliator	5%			18.9%		Higher	8
Virola koschnyi	Defoliator	13.2%			17.3%		Higher[b]	8
Dipteryx panamensis	Defoliator	20.3%			21.9%		Same	8
Vochysia ferruginea	Leaf-cutting ant	2.5%			3.1%		Same	8

[a]Seasonal incidence was studied over a period of 3 years; no difference was noted between monoculture and mixed culture with teak

[b]Although the percentage incidence was higher in mixed plantation, the severity of damage was higher in pure plantation

References: 1, Suharti *et al.* (1995); 2, Matsumoto and Kotulai (2002); 3, Gibson and Jones (1977); 4, Wazihullah *et al.* (1996); 5, Mathew (1995); 6, Chao and Li (2004); 7, Varma (1991); 8, Montagnini *et al.* (1995)

Contrary to the general trend, about half of the polyphagous pests caused more damage in the mixed stands. Although Jactel *et al.* (2005) concluded that the meta-analysis substantiated the widespread belief that forest monocultures are overall more prone to pest insect infestation than more diverse forests, we should not ignore the exceptions. It must also be noted that in their study no distinction was drawn between naturally occurring mixed forest stands and the more simplified mixed plantations. In addition, the number of observations from the tropical region, where it is natural for forests to occur as mixed-species stands, was small compared to those from the temperate region.

Indirect evidence from natural forests and agricultural experiments

Natural forests

Occasionally, in some natural forests, a particular tree species may occur at different densities, with some stands approaching a monoculture at one extreme. Pest incidence has been studied on some species in such stands. A well-studied example is the balsam fir *Abies balsamea* in Canada. It was found that as the percentage of broadleaf trees in the balsam fir stands increased, defoliation caused by the spruce budworm *Choristoneura fumiferana* decreased (Su-Qiong *et al.*, 1996). In Spain, pure stands of the oak *Quercus suber* suffered greater damage from the fruit-boring weevil *Curculio elephas* compared to stands mixed with *Q. rotundifolia*, another host of the weevil (Soria *et al.*, 1995). In Bulgaria, pure stands of the beech *Fagus orientalis* are more susceptible to geometrid defoliators than mixed beech/oak stands (Stalev, 1989). These examples, although from the temperate rather than tropical region, lend support to the hypothesis that mixed stands suffer lesser pest damage than pure stands. In the tropics also, particularly in the cooler tropics, although no strict comparison between pure and mixed stands has been made as above, many insect outbreaks, though not all, have been associated with high host density. Examples of such outbreaks include *Eulepidiotis phrygiona* on *Peltogyne gracilipes* in Brazil, bagworms on pines in Indonesia, *Ophiusa* spp. on *Palaquium* and on *Excoecaria agallocha* in Indonesia, *Hoplocerambyx* on sal in India, bark beetle on pines in Honduras and sawfly on *Manglietia conifera* in Vietnam, as described in Chapter 4. In spite of the occasional occurrence of insect outbreaks in mixed tropical forests, it is generally agreed that they are relatively free of persistent pest problems compared with natural stands dominated by a single species.

Agricultural experiments

Numerous experiments with agricultural crops support the hypothesis that mixed stands suffer less pest damage than monocultures.

Speight *et al.* (1999) have cited many such examples. Planting carrot with onion reduces attack by the carrot fly *Psila rosea* (Diptera, Psyllidae). Broccoli when mixed with beans shows substantially reduced infestation with the flea beetles *Phyllotreta* spp. (Coleoptera, Chrysomelidae). Maize intercropped with cowpea reduces incidence of stem-boring Lepidoptera by 15–25%. In a comprehensive, three-year study carried out in New York, Root (1973) clearly demonstrated that *Brassica oleracea* grown in pure stands had substantially higher (often more than double) herbivore biomass per unit weight of foliage than when the crop was surrounded by miscellaneous meadow vegetation. He also found that the higher herbivore load of the pure crop was concentrated on a few specialized insect species. In another detailed study, Risch (1981) found that in polycultures in which at least one non-host plant was mixed, the numbers of six chrysomelid beetle pests of squash or bean were significantly lower than the numbers of these beetles on host plants in monocultures. Jactel *et al.* (2005) reviewed the various studies in agroecosystems reported in the literature and concluded that pest densities were significantly lower in mixed crop than in monocultures in 60–62% of cases. Here again, although the majority of cases supported the hypothesis under test, the exceptions which constituted 38–40% of the cases cannot be ignored. In the 150 independent studies examined by Risch *et al.* (1983), in 18% of cases pests were more abundant in the more diversified system, in 9% there was no difference and in 20% the response was variable. It appears that the response depended on the crop combination.

Inference from the evidences

The overall conclusions from direct and indirect evidences can be summarised as follows.

1. There is no consistent evidence to assert that pest problems are less severe in mixed-species forest plantations than in single-species forest plantations.
2. In contrast, there is clear evidence that in naturally occurring mixed-species stands of trees the pest problems are less severe compared with natural single-species dominated stands, although there are exceptions.
3. In the agriculture system, there are many examples where the insect pest damage in mixed cultures is lower than in monocultures. However, the exceptions were as high as 38–40% of the cases examined.

The first conclusion is not unexpected because, as pointed out earlier, the application of the diversity–stability principle to a simple mixed-species tree plantation is an unjustified oversimplification. Although we do not know exactly how diversity brings about stability, the ecological interrelationships that exist in a mixed-species natural forest in which the biotic components have coevolved over a long period of time is qualitatively and quantitatively very different from what we can expect in a random artificial mixture of two or more tree species. Therefore the second conclusion of lower pest incidence in mixed-species natural stands is in agreement with the general expectation in the context of the overriding hypothesis of the relationship between diversity and stability. The difference between mixed-species forest plantations and mixed-species agricultural crops comes as a surprise. Why should mixed-species stands of forest trees behave differently from mixed-species stands of agricultural crops?

The theoretical basis

The difference between mixed-species forest plantation and mixed-species agricultural crop appears to be the effect of host spatial scale. For an insect, a tree canopy which occupies a large volume of space is comparable to a monoculture patch of an agricultural crop. A single tree canopy is made up of thousands of shoots spread over a fairly large area. A large host patch arrests the movement of a host-seeking insect more effectively than a small host patch (Miller and Strickler, 1984). Even in a mixed-species tree plantation, the sensory stimuli offered to the insect by the odour plume of a tree is high because of the higher resource volume, perhaps as intense as that offered by a patch of agricultural crop. Therefore the insect tends to remain on the tree longer than on the individual plants in a mixed agricultural crop. Host selection involves not only the insect finding and accepting a host but also its remaining on the host once it has arrived. Insect pests easily disperse away from a mixed-species agricultural crop because of low resource concentration but a host tree species in a mixed forest plantation acts more like a patch of agricultural monocrop because of higher resource concentration, and retains the insects. Therefore the difference in pest response between a mixed-species and a single-species forest stand is not as contrasting as between a mixed-species and a single-species agricultural stand.

The mechanisms proposed to explain the postulated difference in pest incidence between mixed plantation and monoculture include increased natural enemy action and difficulty in host finding in the mixed plantation, reducing pest build-up, and effect of host concentration in the monoculture, encouraging pest build-up. These hypotheses, which are more applicable to the natural forest situation were discussed in Section 8.2 above. It is obvious that natural enemy action will be effective in the mixed natural stand but its effectiveness in an artificial mixed stand will depend on crop composition. From the empirical facts, it is clear that none of the above theoretical explanations is able to accommodate all the observed facts. There are far too many exceptions to each of the generalisations we tried to formulate, whether it is a comparison of natural mixed-species stands versus natural single-species stands, mixed-species tree plantations verus single-species tree plantations or mixed-species agricultural planting versus single-species agricultural planting. According to Jactel *et al.* (2005), the exceptional instances of increased pest damage in mixed forest caused by some polyphagous pests were attributable to heteroecious pests and the contagion process. Heteroecious pests are those that have an obligate alternate host which is essential for completing the development of the insect, as in the case of adelgids which have sexual and asexual stages on different host species. The mixed forest in which both hosts occur is more favourable for pest multiplication than the single species stand. Contagion process refers to a situation where a pest builds up on a more favourable host and then spills over to a less favourable host, when both are present in a mixed forest. In this case, the less favourable host in a single-species stand is more likely to escape infestation. However, the majority of the exceptions do not fall under the above two categories. Thus the theoretical basis for the presumed freedom from pests in artificial mixtures of trees is weak.

Difficulty in host finding has been assumed to reduce pest incidence in a mixed stand. But this will again depend on the pest species. Host finding is a highly evolved behavioural mechanism in many insects which have a narrow food range. These insects have very efficient, fine-tuned host finding mechanisms, usually mediated by secondary plant chemicals characteristic of a group of plants and specialised sensory receptors in the insects. Usually, host volatiles attract these insects from a long distance through receptors in their antennae and once they land on the plant gustatory receptors trigger a sequence of host acceptance behaviour. So it is unlikely that the presence of non-host trees can confuse them. On the other hand, there are polyphagous insects in which host acceptance behaviour is more complex, involving a series of step by step, yes or no behaviour options. In such species there is a random search for hosts during which a large number of plant species will be probed. Some trees may attract the insect towards them and provide an acceptable food source but will not elicit egg laying. In this process of host selection, a mixed-species stand can hinder or delay the host finding of a polyphagous insect. Thus the response of an insect to monoculture and mixed stands will also depend on the insect's biological attributes. Serious infestation can occur either in a mixed-species stand or single-species stand, depending on the characteristics of a particular insect species. Our inability to extract a valid generalization, applicable to all cases

not only the majority, on pest susceptibility of natural mixed-species stands, mixed-species plantations, monoculture etc. is not surprising because the driving force is not the stand composition, but the biology of the insect species, with stand composition modifying the severity of infestation.

Probable questions:

Suggested reading:

1. Forests and Forestry, K.P. Sagreiya, (First edition 1 January 1967), National Book Trust, India.
2. Indian Forestry, K. Manikandan S. Prabhu, (7th edition 1 February 2021); Jain Brothers-New Delhi; Jain Brothers

UNIT VI

Management of tropical insect forest pests

Objective: In this unit we will discuss about Management of tropical insect forest pests.

Control of forest pests is much more difficult than the control of agricultural pests because it is more costly, detection of incipient infestation is difficult and it needs highly skilled labour. Following methods, however, can be adopted for keeping the forest pest populations low:

1. Regular patrolling of forests should be carried out to detect infestations as also to fell and remove the infested trees from the forest areas.

2. Manual collection of eggs, larvae, diapausing pupae and adult beetles for being killed in kerosinised water or by insecticides.

3. Adoption of clean culture to remove alternate host plants of pests.

4. Maintenance of natural mixed undergrowth flora to encourage breeding of parasites and predators of the forest pests.

5. Search and introduction of bio-control agents - parasites, predators and pathogens is the most rewarding method of forest pest control because of their self-sustaining ability

6. Many insect pests undergo diapause for which they look for protected places. Artificial shelter traps could be provided to collect such insects for being destroyed.

7. Pheromones could be employed either to collect one of the sexes in pheromone-baited traps or to disrupt chemical communication between sexes and thus prevent mating The advantages of pheromonal control are: (1) the insects are forced to come to the chemicals (pheromones) and the chemicals are not to be carried to in- sects as in the case of insecticides, and (ii) for disruption of chemical communication, pheromone dispensers are now available for being scattered over forests by aircrafts, thus saving both labour and time.

8. In many cases (e.g., sal heartwood bower), insects are attracted in the trees by the smell of their sap. Therefore, if an infested tree is felled and fogged and the logs scattered in infested areas, fresh sap would attract the pests to the logs sparing to a great extent the trees.

9. Felled trees have to be removed from the forest to storage depots as quickly as possible to minimize exposure to pests. The cut-end may also be swabbed with creosote to give further protection. In the storage depots also, the logs should be sold or exported as soon as possible.

10. Soil insects could be controlled by sterilizing soil and using insecticides with irrigation water wherever possible.

11. Lastly, insecticides could be employed for quicker results with the help of aircraft.

Components required for tropical forest pest management:

The requirements for post limitation are laid out under three related topics or perceptions. These are:

i. The need for basic research into carefully selected and prioritized problems;
ii. The requirement for financial and moral support not only to carry out the research, but also to disseminate the results in a fashion which is of significant and practical use to entomologists and foresters on the international scene; and
iii. The acceptance by the industry that such research and the lessons learned from it are of crucial value in all types of tropical forestry, from the simplest tree-growing forest in a village, to the largest industrial plantation.

Components required for efficient tropical pest management:		
i. RESEARCH	**ii. SUPPORT**	**iii. INDUSTRY**
Basic ecology, taxonomy and impact of insects, aswell as pathogens. Provenance trials and resistance selection of trees, promotion of indigenous species in high-yield silviculture. Economically viable, appropriate technology systems for pest management Easy collaboration within and between research workers in tropical countries.	Databases of pest biology and impact; literature retrieval. Extension or advisory services readily available to commercial and subsistence growers, using well-trained local expertise. Incorporation of entomology and pathology In International aidschemes. Enhanced funding for R & D and the provision of support systems.	Recognition of the equal importance of entomologyandpathology in tropicalforestry, relative toeconomics and silviculture. Recognition of theimportance of preventionrather than cure in pestmanagement, with awillingness to alterforest practices accordingly. Consultations withentomologists andpathologists at theplanning stages of newand continuing afforestationprojects.

Probable questions:

Suggested reading:

1. Forests and Forestry, K.P. Sagreiya, (First edition 1 January 1967), National Book Trust, India.

2. Indian Forestry, K. Manikandan S. Prabhu, (7th edition 1 February 2021); Jain Brothers- New Delhi; Jain Brothers

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