INSECT PESTS OF CASHEW
&
THEIR MANAGEMENT

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Technical Bulletin No 27

INSECT PESTS OF CASHEW & THEIR MANAGEMENT

ICAR- Directorate of Cashew Research
Puttur – 574 202,
Karnataka, India

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(Front cover:Life cycle of CSRB, shoot damage by TMB, leaf folder damage, leaf and blossom webber damage and Drosophila damage on fruits
Back cover: Cashew fruits without pest infestation, thrips damage on developing nuts and apples)

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FOREWORD

Cashew introduced into India from Brazil for afforestation is a popular commercial crop of great significance at present. Besides it is successful for rehabilitation of degraded soils. Initially it was planted as a soil conservation crop without much scientific consideration but over the year the area under cashew increased and currently covers ~10.11 lakh ha during 2013-14. However, a large portion of these plantations are senile and contribute less to the total pr duction (7.53 lakh MT). Inadequate plantation management, insect attack and low soil fertility further contribute to reduced productivity (700kg/ha) of cashew at National level.

Although, cashew is infested by ~ 180 insect pests in India; tea mosquito bug and stem & root borer are the most important. Sound knowledge on pest ecology, life history, host range, severity of damage and natural enemies are essential to devise appropriate pest management practices. Generally, cashew pests are managed using chemical pesticides but increasing awareness on food, environment and biosafety issues necessitate safe pest management practices. Over the years, considerable researches on ecology, host range and natural enemies of cashew has been carried out in different agro-climatic regions of the country and useful information generated to devise appropriate pest management practices.

I am happy that scientists of ICAR- Directorate of Cashew Research, Puttur have compiled the scientific information available on this aspect as a Technical Bulletin Insect Pest of Cashew and their Management . The scientific information on issues of topical interest like preparation of insecticide spray solutions, safe pesticide usage, list of banned/ restricted insecticides, pesticide poisoning and antidotes thereof etc. have been suitably been covered for the benefit of farmers and other stakeholders. I hope this publication will serve as reference manual on management of pests in cashew and be immensely useful to cashew farmers and other stakeholders.

Date: 5 December, 2015 (N. K. Krishna Kumar)

Place: New Delhi

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PREFACE

Cashew is an important tree nut crop, grown in traditional and non-traditional regions of the country. Production of cashew is hampered by several biotic as well as abiotic factors. Cashew is reported to be infested by more than 180 insect pests in India. In which, tea mosquito bug and cashew stem and root borer are the two important pests. Besides, there are also various insect pests that attack cashew at different stages of growth. While, some insect pests are of regional importance. The knowledge on pest ecology, their host range, damage intensity etc. is required so as to plan suitable management measures.

Considerable investigations have been carried out in the field of cashew Entomology since many years. But even today cashew growers are not adopting proper management practices for the control of cashew pests. This bulletin comprises detailed information on insect pests of cashew, their damage, seasonality, host range, biology and management measures. I hope this publication will be useful to the cashew researchers and farmers to save the crop from various insect pests so as to improve the income from cashew cultivation.

(P.L. SAROJ)

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1. INTRODUCTION

The cashew (*Anacardium occidentale* L.) is one of the important tree nuts grown for its delicious kernel. The tree is of medium height, evergreen woody perennial belonging to Anacardiaceae family. Though, 21 species of *Anacardium* are reported, *A. occidentale* is the only species cultivated for commercial purpose. Cashew is native of Brazil and was introduced in to India by the Portuguese travellers nearly five centuries ago. Apart from India, cashew is grown in Ivory Coast, Brazil, Indonesia, Vietnam, Nigeria, Benin, Guinea Bissau, Mozambique, Philippines etc., In India, it was first introduced in to Goa, from where it has spread to other parts of the country. In the beginning, it was mainly planted to prevent soil erosion and later for afforestation on degraded coastal ecosystem. Commercial cultivation of cashew began only during the early 1960s and over the years, it has become an important cash crop. Now cashew has attained the status of an export-oriented commodity, earning considerable foreign exchange for the country and generating employment opportunities by its cultivation and processing mainly for the rural mass and women folk.

The area under cashew cultivation in our country is around 10.11 lakh ha, which is the highest among cashew growing countries, and the annual total production is approximately 7.53 lakh tonnes during 2013-14. It is mostly grown in coastal belts of South-West and South-East India including the states like Maharashtra, Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, Odisha and West Bengal and also in the non-traditinal areas including inlands of central India and parts of North-Eastern regions. Cashew kernel contains proteins (21%), carbohydrates (22%), fat (47%), minerals and vitamins, which is considered as one of the healthy and safe foods. Cashew plays a vital role in nutritional security of the people worldwide. India is the first country in the world to exploit the international trade of cashew kernels in the early part of 20th Century. Owing to high nutritional value, the demand for cashew continues to increase globally. India exports 1.312 lakh tonnes of cashew kernels per annum to over 65 countries and is a leading exporter for over a century. The countries that import Indian cashew include United States of America, Netherlands, United Kingdom, United Arab Emirates, Japan, France, Saudi Arabia, Spain, Russia, Germany, Canada and Greece.

Globally, India's share in the cashew area and production is 20 per cent and 16 per cent, respectively. Though we have large area under cashew, our production as well as productivity are lesser compared to Vietnam and Nigeria. At present,

average productivity of cashew is 782 kg/ha in our country, which is lower than many cashew growing countries of the world. Furthermore, the productivity is almost standstill over the few years. This needs critical examination to identify the yield gaps so as to meet the needs of future. Production of cashew is being impaired by various factors including poor genetic make up of existing plantations, cultivation on marginal as well as less fertile lands, poor plant health management, damage by insects, diseases, weeds, climatic vagaries etc. Among these factors, insect pests are very important, causing marked damage even cent per cent yield loss in cashew during certain occasions.

Insects are extremely diverse and important in any ecosystem. Food plants of the world are known to be damaged by more than 10,000 species of insects, 30,000 species of weeds, 100,000 disease causing agents and 1000 species of nematodes. An insect is considered as a pest when it becomes detrimental so as to cause economic damage to crop. In India, approximately 23.3 % of the total crop yield is lost every year due to the ravages of insect pests. Every crop is affected by one or the other pest and cashew has no exception to that. Cashew plantations generally resemble "a single species forest", affording a relatively stable microclimate and food resources for various insect communities.

Cashew plantations are rich in biodiversity and globally, more than 400 species of arthropods are known to infest cashew till now. Among which, hemipteran pests are in huge numbers followed by coleopteran and lepidopteran pests. In India alone,

From left: Healthy cashew plants and a tree infested by TMB

there are 200 insect pests reported on cashew. Different insect pests attack cashew during different stages of crop growth both spatially and temporally. However, depending on the climate, location and age of the plantation, each geographic region may have its own distinctive pest complex. All parts of the plant *viz*., leaf, stem, bark, root, flower, apple and nut, are fed upon by at least one pest species, resulting in 11 – 55% loss in yield as an average, if left unchecked. These losses can be avoided, if regular monitoring and proper management measures are taken up.

Table 1. Pest diversity in cashew in terms of number of species

Insect pests		**Non-Insect pests**	
Insect orders	**No. of species reported**	**Class**	**No. of species reported**
Field condition			
Hemiptera	90	Nematoda	30
Coleoptera	84	Acari	18
Lepidoptera	83	Aves	15
Orthoptera	17	Other vertebrata	12
Thysanoptera	17	Gastropoda	02
Isoptera	10		
Hymenoptera	05		
Diptera	04		
Sub- total	310	Sub- total	77
Storage condition			
Coleoptera	20	Mammalia (Rodentia)	01
Lepidoptera	05		
Sub- total	25	Sub- total	01
Total	**413**		

Among the pests, a sucking pest namely, tea mosquito bug and a chewing pest *viz*., cashew stem and root borer are the two major pests of cashew in almost all cashew growing regions of the country as well as the world. These two pests are very severe in nature having potential of causing even upto total yield loss, if proper management measures are not taken up timely. The other important pests that damage cashew include leaf miner, leaf & blossom webbers, leaf & flower

thrips, shoot tip caterpillars, leaf beetles and apple & nut borer which require management measures under certain circumstances to prevent yield loss. Apart from these, there are plenty of minor pests that also feed on cashew sporadically, but the damage caused by them is meagre, hence management measures against these minor pests may not be required unless their attack exceeds threshold levels. Moreover, under field conditions there are plenty of natural enemies (biocontrol agents/ farmers' friends) like several parasitoids, predators and pathogens which take care of these minor pests. However on few occasions, intercultural operations like weeding, pruning of cashew, fertilizer application etc also influence insect pest activities. Hence, the knowledge on insect pests including their bio-ecology, season of occurrence, symptoms of pest damage, intensity of damage, natural enemies are important so as to plan the efficient management measures to have a good harvest.

The available details on pest appearance, season, biology, symptoms of damage, alternate hosts and suitable management measures are presented here.

2. PRIMARY INSECT PESTS OF CASHEW

In cashew, still now two pests are considered as primary (key) insect pests which cause severe yield loss. They are tea mosquito bug & cashew stem and root borer which occur almost regularly and are persistent in nature. Timely management measures are essential to bring down their population so as to prevent economic damage.

2.1. Tea mosquito bug (TMB): *Helopeltis antonii* Sign., *H. bradyi* Waterhouse, *H. theivora* Waterhouse and *Pachypeltis maesarum* Kirkaldy (Miridae: Hemiptera).

Tea mosquito bug is a major pest of cashew causing very high damage during flushing, flowering and fruiting period. There are four species of tea mosquito bug attacking cashew. Among which, *H. antonii* is the dominant species all over India. The pest is a sucking insect feeding the plant sap from foliage, flowers, immature fruits and nuts, thereby developing a number of brownish black lesions which turn into necrotic spots, resulting in drying of affected plant parts. During outbreak situation, the entire flushes and panicles dry up and the trees exhibit a scorched appearance. The pest has got potential to cause as high as cent per cent loss in yield.

Pest appearance

Adult *H. antonii* is slender, elongate, 6-8 mm long, reddish brown in colour, with black head, reddish/ brownish/ blackish thorax and black & white abdomen. While, *H. bradyi* closely resembles *H. antonii*, but has a minute colour variation in the hind femur and abdominal region. While, *H. theivora* has longer antennae and yellowish pronotal ring and greenish patch in the abdomen. A pin-like knobbed scutellar process is present dorsally in both the nymphs (except first instar) and adults of all Helopeltis species, but not in *P. maesarum.* Nymphs are translucent

From left: *H. antonii, H. bradyi*, *H. theivora* and *P. maesarum*

reddish brown having long antennae. The nymphs of *H. antonii*, *H. bradyi* and *H. theivora* are light to brownish, greenish yellow and greenish in colour, respectively. The size of nymphs of *H. antonii* and *H. bradyi* are almost similar except slight variation in colour, whereas, the nymphs of *H. theivora* are comparatively smaller and slender. Eggs are inserted into the plant tissue, hence only the pair of tiny hair like chorionic processes of each egg are visible outside.

Distribution

It is distributed in most of the cashew growing regions of the country including Kerala, Karnataka, Goa, Maharashtra, Tamil Nadu, Andhra Pradesh, Gujarat, Chhattisgarh and Odisha. Among the TMB species, *H. antonii* is predominant in all regions except North-Eastern regions, where *H. theivora* is dominant. In general, occurrence of TMB is severe in West coast regions compared to East coast regions.

Biology

Eggs are tiny, elongate and are inserted into tender shoots, stalks of inflorescence, leaf midribs and petioles, either singly or in groups of 2-6. The presence of a pair of minute silvery hair like unequal chorionic processes of 0.4-0.6 mm length projecting outside is indicative of the presence of each egg inside the plant tissues. The nymph hatches in 6-8 days, undergoes five instars in a period of

Developmental stages of TMB

8-14 days and develops as adults in all three *Helopeltis* species. The preoviposition and oviposition periods of TMB range from 3-5 days and 5-10 days, respectively. The adults survive even more than a month and a female bug can lay up to 259 eggs during its life time. The nymphs develop even faster and survive better, when feed on immature fruits than flushes and panicles.

Season

In general, TMB activity is very less during monsoon period (June- September) and the build up of pest population commences during October - November synchronizing with the emergence of new flushes after the cessation of monsoon rains. The population reaches a peak during December-January, when the trees are in full bloom while, the pest activity is seen till May until harvest. But, the pest incidence may be noticed throughout the year in young plantations.

Host range

Variety of plants (more than 50) are infested by tea mosquito bug, mostly by *H. antonii* and *H. theivora*. Important host plants include neem (*Azadirachta indica*), cocoa (*Theobroma cacao*), guava (*Psidium guajava*), drumstick (*Moringa oleifera*), cotton (*Gossypium* spp.), Singapore cherry (*Mutingia calabura*), black pepper (*Piper nigrum*), allspice (*Pimenta dioica*), henna (*Lawsonia inermis*), mahogany (*Swietenia mahogoni*), eucalyptus (*Eucalyptus* sp.), apple (*Malus domestica*), avocado (*Persea americana*), camphor (*Cinnamomum camphora*), cinchona (*Cinchona* sp.), cinnamon (*Cinnamomum zeylanicum*), grapes (*Vitis vinifera*), red gram (*Cajanus cajan*), tamarind (*Tamarindus indica*), tea (*Camellia sinensis*) etc. *P. maesarum* also infests *Careya arborea*, *Pogostemon parviflora* and *Leea sambucina*.

(Alternate host plants of TMB) From left: Neem, Singapore cherry and Henna

Apart from these, a few weed plants that are existing in the cashew plantations of West coast region also support the life of TMB during off season of cashew. Recently, 14 weed species including *Chromolaena odorata, Terminalia paniculata, Acalypha wilkenesia, Leea* sp., *Melastoma malabathricum, Macaranga peltata, Solanum torvum, Calycopteris floribunda* etc have been recorded to be infested by species of TMB between July - October.

Symptoms of damage

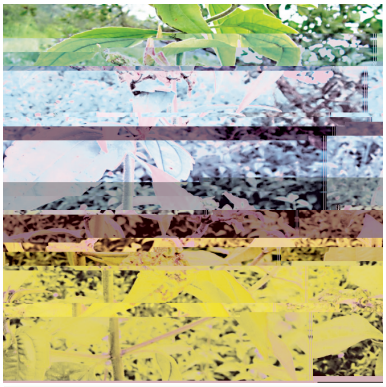
The nymphs and adults suck the sap from the tender leaves, shoots, inflorescences, immature nuts as well as immature apples. Water soaked lesions appear at the feeding sites after 10-15 min of feeding. These lesions become prominent within 3-6 hours, turn pinkish brown in 24 hours, and scabby black in 2-3 days. Feeding also causes exudation of gummy substances from the plant parts. Later, the lesions coalesce and ultimately results in drying of shoots. The infestation on inflorescences results in blossom blight, wherein the flowers and stalks of inflorescences completely dry up.

Upon severe damage, most of the flushes and inflorescences dry up and the tree develops a scorched appearance. Generally, one month old nuts and apples of all stages are attacked by TMB. As a result of injury, immature nuts drop off. If older ones are attacked, they survive with injury and attain maturity. Kernels are usually unaffected except when the attack occurs in very early stage of nut development. Each insect can damage up to 3-4 shoots or inflorescences during its life time leading to heavy loss in nut yield.

From left: TMB damage lesions on tender shoot, dried cashew inflorescence and feeding of *H. antonii* on cashew apple

Management measures

a. Cultural means



C. odorata- a common weed

Monitoring at regular intervals for the occurrence of damage symptoms on cashew as well as other alternate host plants present in the surroundings of cashew plantations are required so as to initiate the management measures. During offseason of cashew, TMB could survive also on a few plants including weeds that exist in and around the cashew plantations especially in the borders. Recently, 14 species of weeds have been recorded to sustain the life of TMB at DCR, Puttur. Among which, *C. odorata* is very common in cashew plantations of West coast region. Therefore, monitoring followed by weed as well as TMB management on the infested weeds especially just before flushing of cashew has to be taken care to prevent the spread of TMB from weeds to cashew.

b. Chemical means

Proper surveillance for initial pest damage symptoms during flushing, flowering and fruiting period of cashew are essential to decide on the spraying time for effective pest management. Since, Economic Treshold Level (ETL) is not arrived for TMB, first round of insecticidal spray need to be given, whenever the incidence occurs at 5 - 10 % damage. Second spray may be repeated within 3 - 4 weeks and third spray can be given as and when required. If inflorescence damage is severe (beyond 50 %) further sprays can not help. Chemicals that can be sprayed in rotation are: lambda cyhalothrin (0.6 ml/lit), profenophos (1.5 ml/lit), acetamiprid (0.5 g/lit), triazophos (1.5 ml/lit), imidacloprid (0.6 ml/lit) and carbaryl (1g/lit).

c. Host plant resistance

All the released varieties are susceptible for TMB attack and there is no evidence on the existence of a completely tolerant / resistant cashew type against TMB infestation. But the continuous field screening of common varieties at DCR revealed that Dhana, Bhaskara and the accession VTH 153/1 had comparatively less TMB infestation. Under low to moderate pest incidence, variety 'Bhaskara' escapes TMB damage because of its mid season flowering nature. In Bhaskara, non-overlapping of cropping period and the peak TMB population occurs in most of the years. Besides, this variety produces significant mixed phase of bisexual and

male flowers in the first two weeks leading to early fruit set within 15-20 days after initiation of flowering. While in Kerala, varieties like Amrutha, Damodar and Raghav are comparatively less susceptible to TMB, while, Priyanka and Anagha are highly susceptible.

d. Biological means

Though the eggs of *Helopeltis* spp. are laid deep and concealed, they are often attacked by a range of parasitoids. There are five species of egg parasitoids [*Telenomus cuspis* (Platygasteridae), *Erythmeles helopeltidis* (Mymaridae), *Chaetostricha* sp. (Trichogrammatidae), *Ufens* sp. (Trichogrammatidae) and

A spider, *Telamonia dimediata* Simon predating a TMB

A parasitoid, *Telenomus cuspis* parasitizing TMB eggs

A reduviid, *Cydnocoris gilvus* Brum. predating a TMB

A praying mantid, *Hierodula membranacea* predating a TMB

Gonatocerus sp. (Mymaridae)] parasitize the eggs of TMB, and thus take care of TMB population to certain extent in field conditions especially at low pest density. Among which, *T. cuspis* is the major parasitoid which could cause even up to 50 % egg parasitism in TMB during certain months. Nymphal parasitoid of genus *Leiophron* (Hymenoptera: Braconidae) has also been reported on *H. antonii.* Besides, a parasitic mite namely, *Leptus* sp. (Erythraeidae) also kills TMB adults, but occurs at very low intensity. Moreover, mass rearing of any of these parasitoids could not be successful in laboratory since they are host specific, hence they can not be exploited for TMB control at present. Besides, specific strains of the entomopathogenic fungi namely, *Beauveria bassiana* and *Metarizhium anisopliae* are found effective against TMB, but the availability of the fungal culture to the farmers needs to be ensured.

On the other hand, the predatory fauna of TMB includes a wide number of spiders, reduviid bugs, ants, praying mantids, mantispid flies, robber flies, pentatomid bugs etc that exist in field especially under unsprayed condition. The aggressive predators namely, red ants (*Oecophylla smaragdina*) actively predate on TMB and other pests of cashew, thus providing service to farmers in reducing the pest attack. Hence the trees having ant nests must be spared of insecticidal sprays so as to conserve them for natural pest management.

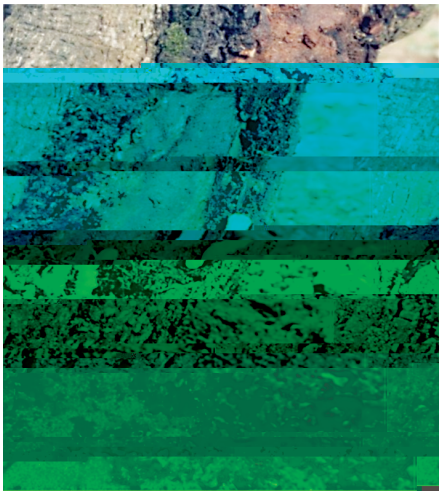
e. Botanical means

A few plant products have been tested for their insecticidal activities against TMB. The water emulsions of pongamia oil (3%) could cause high mortality of TMB up to 7 days after spraying followed by Neem oil (3 %). Seed extracts of *Annona reticulata and A. squamosa* could cause mortality of TMB to some extent, but not *Strychnos nuxvomica*. However, 5 % leaf extracts of *A. reticulata, Tephrosia vogelii* and *S. nuxvomica, Butea frondosa, Adathoda vasica* are not found effective against TMB. The commercial neem pesticides like Nimbecidine, Gogrej Achook, Limanool and RD-9 Repellin at 1 % are not effective in causing mortality of TMB, but have noticeable ovipositional deterrency effect similar to Pongamia oil and neem oil.

f. Behavioural means

With the increasing awareness on eco-friendly approaches, it is also desirable to explore the opportunities of pest management by behavioural means. In that angle, presence of sex pheromone activity in female TMB is confirmed in studies conducted at DCR, wherein mated as well as unmated female TMB tend to attract more males throughout its life time. The research is underway to identify the chemical nature of pheromone and to investigate the possibility of synthesizing it so as to use it under field conditions.

2.2. Cashew stem and root borer (CSRB): *Plocaederus ferrugineus* L., *P. obesus, Batocera rufomaculata* De Geer (Cerambycidae: Coleoptera)



CSRB grubs and their damage

Cashew stem and root borer is another important pest of cashew, capable of killing even the grown up trees within a short period. It is a kind of hidden pest, where aerial symptoms of damge become visible only at the later stages of infestation. It is serious both in East and West coasts of India. Among the two species of *Plocaederus*, *P. ferrugineus* is the commonly occurring species. Apart from these, mango stem borer, *Batocera rufomaculata* also attacks the cashew trees at later stage of CSRB infestation. This pest is present throughout the year.

Pest appearance

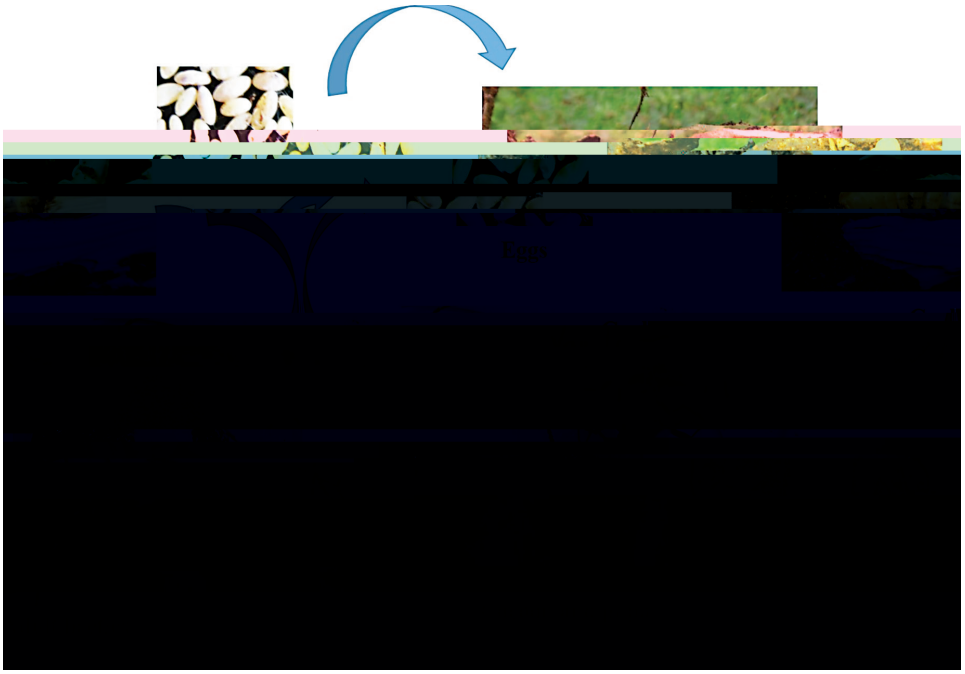
Eggs are small, slender, ovoid, smooth, creamy white in colour and look similar to rice grains measuring about 4.5 × 2.0 mm. The creamy grubs have 3 pairs of thoracic legs and grow from 6 cm to about 10 cm in length. Grub spins calcareous cocoon inside the tree bark and hardwood itself and pupates inside. Adult beetles make a circular exit hole of 1.5 cm width for their emergence. The adults of *P. ferrugineus* are dark reddish brown, medium sized beetles (25 to 40 mm in length) with long antennae. Adults of *P. obesus* are chestnut coloured, longicorn beetles, measuring about 4.0 cm with a waxy cuticle. While, adults of *B. rufomaculata* are greyish, measuring 5.0 cm in length and have yellowish or orange spots on the forewings. The grubs of this species are apodous (legless) and pupate without forming any calcareous cocoon.

Distribution

The pest is distributed in most of the cashew growing regions of the country including Kerala, Karnataka, Goa, Maharashtra, Tamil Nadu, Andhra Pradesh, Gujarat, Chhattisgarh, Odisha, Jharkhand, West Bengal and North-East regions.

Biology

Adults are sluggish on the day of emergence, mating starts on the second day, and repeated matings occur during its life time. Eggs are usually deposited in the



Life stages of CSRB: eggs, grub, pupa and adults

crevices of the bark of main trunk up to one metre height from ground level and also on the exposed roots as well as in soil close to collar region of the tree.

Eggs are pale white, ovoid and smooth, Young grubs hatch in 5-7 days and immediately start boring into bark. The nascent first instar grubs feed on the tissue near the site of oviposition and extrusion of fine dusty frass is noticed within few days of hatching. Grub remains inside the tree and the grub period continues for 6-7 months. The fully grown grub measures about 100 mm in length. Pupation occurs in a calcareous cocoon and adult beetle emerge out through exit hole. Though the adults form within 40 to 60 days, they lie quiescent within the cocoon and emerge out after 45-60 days. Since adults are active only during night and rest below dried leaves, they are normally not seen during day time in the field conditions.

Seasonality

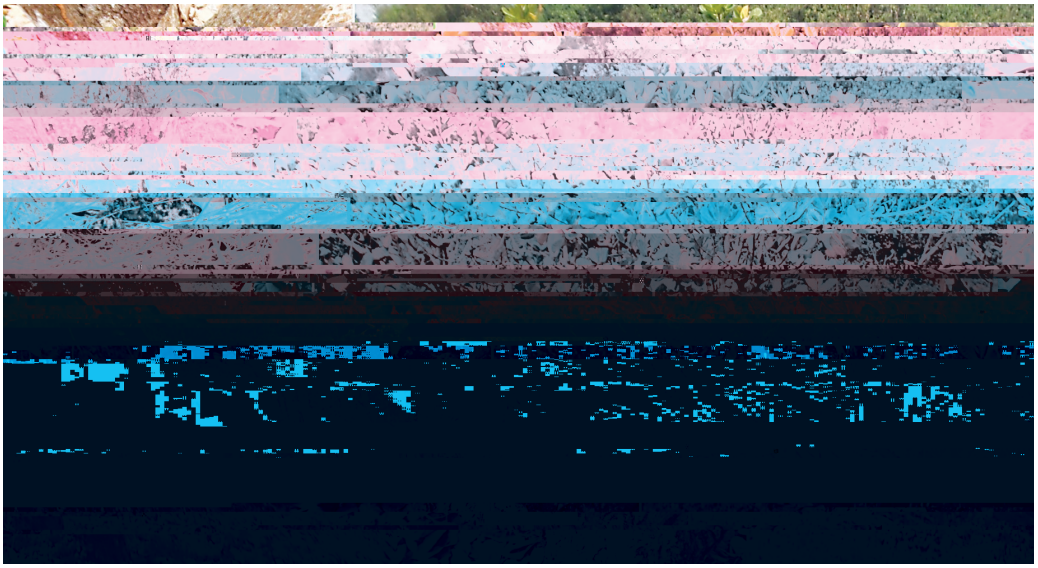
Since, emergence of adult beetles starts around November-December, the pest incidence in terms of damage symptoms is noticed during the months of December to May in different cashew growing tracts of the country. But, different stages of infestation are generally seen all round the year. During the onset of monsoon, the healthy trees turn dark green, whereas, the infested trees remain yellowish.

Host range

Incidence of *P. ferrugineus* has been recorded also on sapota (*Manilkara zapota*), *Bombax malabaricum, Boswelia serrata, Buchanania latifolia, Buchanania lanzan*, *Diospyros melanoxylon, Hardwickia binata, Lannea grandis* and *Holigarna* spp. Likewise, *P. obesus* infests also on *Shorea robusta,* while, *B. rufomaculata* has been reported on mango (*M. indica*), silkcotton (*Ceiba pentandra*), jack (*Artocarpus heterophyllus*), rubber (*Hevea brasiliensis*), fig (*Ficus carica*), guava (*P. guajava*), pomegranate (*Punica granatum*), apple (*M. domestica*) and walnut (*Juglans regia*).

Symptoms of damage

During the initial stages of pest attack, exudation of gum and frass can be noticed in small quantities at the base of CSRB infested trees. During later stages of attack, the infested tree canopy shows a sickly appearance with yellowish leaves and premature dropping of leaves occurs. During the severe stages of attack, the twigs dry off and the bark on the trunk starts splitting. At this stage, large quantity of chewed fibres and gum, as well as frass can be seen as huge lumps at the base of the infested trees and the tree finally succumbs to death.



From left - top: Gummosis and extrusion of frass at tree base; Bottom - damage by grub showing the pupation hole, CSRB infested tree showing yellowing and premature leaf fall

Sometimes, the unexposed stout lateral and taproots are extensively damaged without any external symptoms and such trees may look very healthy or with slight sickly appearance, and suddenly die without any yellowing of leaves. A single grub

can tunnel around one square foot area of the bark wood tissue. In young trees of 1-3 years, infestation mostly occurs at collar region and damage occurs below the soil surface. Hence, exudation of frass and gum can not be noticed at initial stages of attack and heart heart wood as well as tap root of those trees get damaged. Those trees will die suddenly and a single grub is sufficient to kill such a tree.

Management measures

Controlling this pest is a tough job, as the borer remains in a concealed condition in the interface of bark and hard wood, and normally it escapes from the attack of the natural enemies.

a. Biological means

Later stages of CSRB grubs are infested sometimes by an entomopathogenic fungus namely *Metarhizium anisopliae* in few trees, however, the intensity of natural infection is very less. The eggs of CSRB are recorded to be parasitized by *Avetianella batocerae* Ferriere (Encyrtidae: Hymenoptera) which, however is not commonly encountered. Mycopathogen like *Beauveria bassiana* also causes mycosis in grubs of CSRB. Mixing of spawn of these mycopathogens with organic matter like FYM, neem cake and cashew apple can enhance the spore load under the field condition. The spores could survive for three months under field condition. In addition, the entomopathogenic nematodes belonging to *Steinernema* and *Heterorhabditis* are found to be effective in inducing mortality of grubs in lab conditions, which need to be further evaluated for their field efficacy.

b. Cultural means

Infestation of CSRB is severe in unattended plantations and infested trees act as source of inoculum. For this reason, it is important to intercept early and to take up prophylactic management measures so as to reduce pest intensity. Phytosanitation of the cashew plantation help to reduce the pest population in a given location and leads to lesser fresh incidence of the pest in the subsequent years. Deep planting of cashew grafts / seedlings can be done to prevent exposure of roots for egg laying by CSRB adults. The newly planted grafts should be trained to have branching at a height of 0.75-1.0 m from ground level for facilitating better inspection and adopting pest management techniques effectively. Once, the larvae enter into heartwood to turn into pupa, it is difficult to locate and kill them. Hence, a gear wire/ any bending metal wire may be inserted through the hole to reach the grub or pupa so as to kill it.

c. Chemical means

Several insecticides have been evalauted at various research centres, for over two decades. It is to be noted that any insecticidal treatment without removing the pest stages will not be effective as the grubs remain inside a thick protective

layer. Hence, the pest stages have to be carefully removed by careful chiseling of the tunnels in the infested portion especially with the fress frass and destroyed. Then, the chiseled portion should be swabbed thoroughly with chlorpyriphos (0.2 % *i.e.* 10 ml / lit) and subsequently the base should also be drenched with insecticidal solution. Repetition of the treatment should be done, if fresh pest infestation symptoms occur after 30-45 days. Another important consideration is not to damage more than 50 % of the bark circumference, as this will lead to girdling and death of the treated trees. In case, more than 50 % of the bark circumference has been damaged or the leaf canopy has turned yellow, such trees need not be treated, as they do not recover. These trees have to be uprooted and the pest stages should be destroyed, and the timber can be used for other purposes including firewood.

d. Behavioural means

The volatiles emitting from the frass of the CSRB infested trees are found to attract female beetles for subsequent ovipostion in and around those infested trees. Though male as well as female sex pheromone activity exists in CSRB adults, attraction of egg laden females towards kairomone (plant volatile) is recorded as very strong. The research is underway to come out with a kairomone based trapping system for the beetles. If this becomes successful, CSRB can be managed effectively with non-chemical means.

3. SECONDARY INSECT PESTS OF CASHEW

Apart from TMB and CSRB, a few insect pests also infest cashew at specific period and cause damage at certain occasions. Some pests may not be problematic in certain regions but could be a problem in other regions. In general, management actions taken for managing TMB could manage these pests also, but separate spraying may be required during certain periods to prevent economic loss. The details of important secondary insect pests of cashew are given below.

3.1. Shoot tip caterpillars *Anarsia epotias* M. and *Hypotima* (*Chelaria*) *haligramma* M. (Lepidoptera: Gelechiidae).

Pest appearance:

Young caterpillars of *A. epotias* are pale yellowish green with black head and turn pinkish-brown later. The forewings of adults are dark grey. The hindwings are grey, and the base is thinly scaled. While, larvae of *H. haligramma* are tiny and yellowish to greenish brown in colour. The forewings of adult *H. haligramma* are yellowish-grey, and white speckled. The hindwings are grey, thinly scaled and subhyaline anteriorly.

Distribution:

Goa, Karnataka, Kerala, Tamil Nadu, Andhra Pradesh and Odisha.

Biology:

The egg, larval and pupal period of *H. haligramma* last for 3-4 days, 12-16 days and 7-10 days respectively, and the life cycle is completed within 25-29 days. Pupation takes place inside the bore holes on the shoots or inflorescences. *A. epotias* causes damage to shoot tips of cashew trees during active growth period. A female *A. epotias* moth lays upto 60 eggs singly or in groups of 10-20. The egg period lasts for 3-4 days. Pupation takes place in larval tunnels of the attacked shoot, in crevices of the branches, twigs or at the cut end of branches. Pupal period is 7-10 days and the total life cycle is completed within 27-29 days.

Seasonality:

September-December

Host range:

H. haligramma - Mango (*M. indica*); *A. epotias* - sapota (*M. zapota*)

Symptoms of damage:

The pest incidence is seen mostly during flushing stage. During active growth period, caterpillars of *A. epotias* at the early stage web together the tender leaves and feed within. Later on, they bore in to the terminal shoots and tunnel inside up to 2-3 cm. A gummy substance oozes out

Damage by shoot tip caterpillars

from the infected tips and finally the attacked shoots dry up. Larvae of *H. haligramma* also damage shoot tips by folding the fresh leaves and feed within and can tunnel upto 2 cm. The larvae may also damage inflorescences subsequently. Exudation of gummy web like substances mixed with faecal pellets from the injury site can be noticed. Later, the terminal shoots turn black and perish, which results in production of auxiliary shoots.

Management measures:

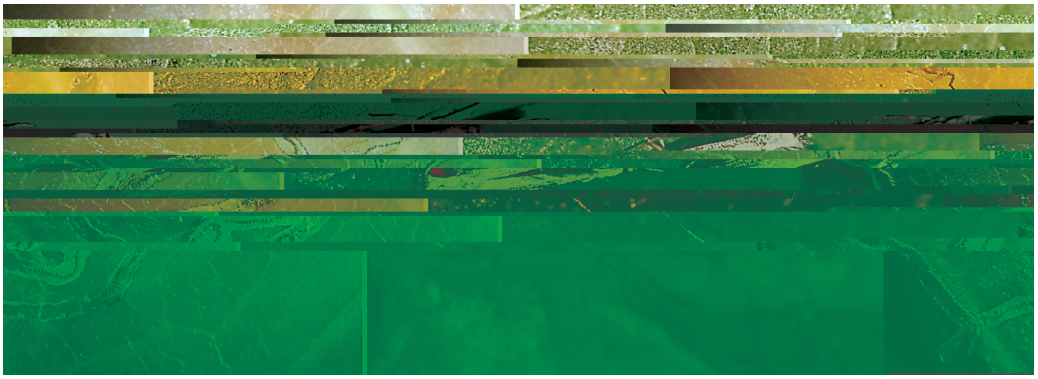
Spraying may not be required, since, natural enemies including parasitoids take care of this pest. Four larval parasitoids, *viz*., *Pristomerus* sp. (Ichneumonidae), *Apanteles* sp. (Braconidae), *Elasmus* sp. (Elasmidae) and *Sympiesis* sp., (Eulophidae) have been recorded on shoot tip caterpillar larvae causing parasitism up to 25 %. But, under severe incidence, spraying of either quinolphos (2 ml/lit) or phosalone (2 ml/lit) or phosphamidon (2 ml/lit) or monocrotophos (1.5 ml/lit)or lambda-cyhalothrin (0.6 ml/lit) or profenophos (1.5 ml/lit) will manage this pest effectively.

3.2. Leaf miner *Acrocercops syngramma* M. (Lepidoptera: Gracillariidae)

Pest appearance:

Eggs are tiny, transparent and glue like, laid on the upper side of tender leaves.

Dull white to reddish brown small caterpillars can be seen within the feeding mines. Pupation takes place in soil within silken cocoon. The adult is a tiny silvery grey moth with red eyes.



From left : Initial stage of leaf mines by leaf miner larvae and the adult moth

Distribution:

Leaf miner is one of the serious pests of cashew during post monsoon flushing period all over the country.

Biology:

Eggs are laid on upper side of tender leaves which hatch in 5-7 days. During the developmental period, larvae are dull white in colour. Full grown caterpillars measure about 5-7 mm in length, are reddish brown in colour. After full development, the larvae fall off to the soil, where they pupate and emerge as adult moths after 7-9 days.

Seasonality:

The incidence is most common in post monsoon flushes during August-December reaching the peak during October- November, but incidence can be seen upto April at low level.

Host range:

Mango (*M. indica*), jamun (*Syzygium cumini*)

Symptoms of damage:

The mining injury by caterpillars occurs both on tender leaves as well as shoots. Young plants are observed to be prone to attack by this pest. The caterpillars mine and feed below the epidermal layer of the tender leaves causing extensive

From left: Fresh leaf mines on tender leaves, crinkling, curling and drying of leaf miner infested leaves

leaf blisters, which later dry up resulting in distortion, browning and curling of the leaves. As the attacked leaf ages, holes develop due to drying out of the damaged portion. Generally 1-5 larvae are seen in a single leaf, but up to 45 larvae have been observed in single leaf during peak infestation at Puttur, Karnataka.

Management measures:

Two larval parasitoids *viz*., *Chelonus* sp. and *Sympiesis* sp. have been recorded on leaf miners in Kerala and Goa. Recently, three larval parasitoids namely, *Chyrsocharis* sp., *Aprostocetus* sp. and *Closterocerus* sp. (Eulophidae) are recorded in Puttur region of Karnataka. Spraying may not be required since these larval parasitoids manage this pest even up to 50 %. But under severe incidence in nursery and young plants, spraying is required. Spraying of quinolphos (1.5 ml/lit) or monocrotophos (1.5 ml/lit) or profenophos (1.5 ml/lit) or lambda-cyhalothrin (0.6 ml/lit) can effectively manage leaf miners.

3.3. Leaf thrips and flower thrips

Leaf thrips: *Selenothrips rubrocinctus* Giard (Thysanoptera: Thripidae), *Rhipiphorothrips cruentatus* Hood, *Retithrips syriacus* (Mayet).

Flower thrips: *Scirtothrips dorsalis* H. (Thripidae), *Rhynchothrips raoensis* G., (Phlaeothripidae), *Haplothrips ganglbaueri* (Schmutz) (Phlaeothripidae), *Thrips hawaiensis* (Morgan) (Thripidae), *H. ceylonicus* Schmutz (Thripidae) and *Frankliniella schultzei* (Trybom).

Pest appearance:

Thrips are minute worm like insects damage the crop by sucking the plant sap.

Adults of *S. rubrocinctus* are dark brown and about 1-2 mm long. Nymphs are pale yellowish and have a red band around the middle of their body. Eggs are laid singly into the lower epidermis and covered with black excrement of adults. Nymphs of *R. cruentatus* are white when they hatch, but pale red markings develop soon. The female thrips are 1.2 to 1.5 mm long, blackish-brown in colour, with yellow legs and antennal segments and the forewings are pale with yellowish veins. Male thrips are similar to females in structure but their pronotum and abdomen are yellow in colour. Whereas, *S. dorsalis* are pale / cream coloured and the length of their first, second instar larvae and pupae are 0.37-0.39, 0.68-0.71 and 0.78-0.80 mm, respectively. Adults are about 1.2 mm long with dark wings and dark spots forming incomplete stripes which appear dorsally on the abdomen.

Distribution:

Throughout cashew growing regions. Among the flower thrips, *S. dorsalis* and *R. raoensis* are prevalent in the East coast regions of India, whereas in West coast regions, *H. ceylonicus* and *F. schultzei* are prevalent.

Biology:

Eggs are tiny, laid inside leaf tissues. Egg period lasts between 3-7 days depending on the temperature. Nymphs are wingless, vermiform, while adults are winged. In *S. rubrocinctus*, nymphs hatch in 12 days, move freely carrying a drop of excrement at the anal end. The nymphal, pre-pupal and pupal period lasts for 10, 1 and 2-3 days, respectively. In *R. syriacus*, adult is 1.3-1.5 mm long, dark red and the wings are feather-like and pale brown in colour. The nymphs are initially hyaline, later turn in to yellowish orange, and then red; grow up to 1.5 mm.

Seasonality:

Leaf thrips: October - December, flower thrips: January - April

Host range:

Many agricultural and horticultural crops.

i. *S. rubrocinctus* – arecanut (*Areca catechu*), avocado (*P. americana*), guava (*P. guajava*), pear (*Pyrus* sp.), mango (*M. indica*), cocoa (*T. cacao*), rose (*Rosa* sp.), *Terminalia catapa.*

ii. *R. cruentatus* - Arecanut, cocoa (*T. cacao*), almond (*P. dulcis*), custard apple (*A. squamosa*), grapevine (*Vitis vinifera*), jamun (*S. cumini*), pomegranate (*P. granatum*), mango (*M. indica*), rose (*Rosa* sp.), castor (*Ricinus communis*), cardamom (*Elettaria cardamomum*), Jatropha (*Jatropha curcas*).

iii. *S. dorsalis* – Ber (*Ziziphus mauritiana*), sapota (*M. zapota*), miracle fruit (*Synsepalum dulcificum*), Canistel (*Pouteria campechiana*), tea (*Camellia sinensis*), straw berry (*Fragaria ananassa)*, citrus (*Citrus* sp.), chillies (*Capsicum annum*), grapevine (*V. vinifera*), cassava (*Manihot esculenta*), mango (*M. indica*), pomegranate (*P. granatum*), tamarind (*T. indica*), taro (*Colocasia esculenta*) and the common weed shrub in the cashew plantations of West coast *viz*., *Calycopteris floribunda*.

iv. *R. syriacus* - Custard apple (*A. squamosa*), grapevine (*V. vinifera*), pomegranate (*P. granatum*).

Symptoms of damage:

Three species of thrips mainly cause damage to tender cashew leaves. If they attack at nursery stage, even death of seedlings may occur. Among the thrips, *S. rubrocinctus* is very serious in nursery and young cashew plantations. In seedlings, initially it attacks lower leaves and cause premature leaf fall, stunting and

Top from left: *S. rubrocinctus* **nymphs (with red band) and adults (black and winged), its damage on cashew seedling showing leaf distortion and discolouration**
Bottom: *S. dorsalis* **and their damage on developing nuts**

finally drying of seedlings. In grown up plants, it damages young leaves, shoots, inflorescence and flowers and is more active during summer months. The adults and immature stages of thrips colonise the lower surface of leaves. As a result of

rasping and sucking activity, the leaves become pale brown and slightly crinkled with roughening of the upper surface. Their feeding cause leaf distortion and leaf drop. Honeydew excretory products from the thrips give rise to black sooty mould. In severe cases, there occurs shedding of leaves. Nymphs and adults of *Retithrips syriacus* (Mayet) colonize the lower surface of young leaves and suck the sap, as a result leaves become silvery white initially, later turn into pale brown and crinkle with roughening of upper surface. In severe cases, shedding of leaves occur.

Flower thrips attack buds, flowers, immature apples and nuts. Thrips infestation causes shedding of flowers, immature fruit drop, formation of scabby as well as, malformed apples and nuts. Up to 15-25 per cent fruit drop is noticed due to thrips damage.

Management measures:

There are several predators like various syrphids (*Paragus* sp.), coccinellids (*Pseudospidemerus circumflexa* Mots., *Menochilus sexmaculata, Coccinella transversalis, Scymnus* sp., *Illeis cincta*), lace wing bugs etc that take care of this pest. Spraying of monocrotophos (1.5 ml/lit) or lambda-cyhalothrin (0.6 ml/lit) or dimethoate (2 ml/lit) or quinolphos (2 ml/lit) or carbaryl (1 g/lit) is effective for managing thrips.

3.4. Leaf beetles and weevils: *Monolepta longitarsus* Jac., *Neculla pollinaria* Baly (Chrysomelidae: Coleoptera), *Deporaus marginatus* (Coleoptera: Attelabidae)

Several chrysomelid beetles attack cashew especially during post monsoon flushing period. Among them, *M. longitarsus* and *N. pollinaria* are important defoliators. While, *D. marginatus* occur occasionaly on tender shoots and nursery plants.

***Neculla pollinaria* adult**

Pest appearance:

Adult beetles of *M. longitarsus* are small, shiny red, also occur in four different colour morphs in elytra. While, adults of *N. pollinaria* are white or ash coloured, turn into black or grey upon aging. Since all other stages of these chrysomelid beetles remain inside the soil, only adult beetles are seen on cashew shoots. The adults of *D. marginatus* are small blackish weevils with red thorax.

Distribution:

East coast and West coast areas, especially Goa, Kerala, Karanataka and Odisha.

Biology:

Egg, grub and pupal stages of these beetle and weevils remain inside the soil and adults emerge after initial showers of South West monsoon. Egg, grub and pupal period are 3-4 days, 12 days and 7-9 days, respectively.

Seasonality:

During South- West monsoon (June-August)

Host range:

N. pollinaria - *Buchanania lanzan*, mango (*M. indica*); *M. longitarsus* – Cocoa (*T. cacao*), tapioca (*M. esculenta*), *Terminalia arjuna, T. paniculata* and *B. lanzan*.

Symptoms of damage:

Monolepta beetles appear abundantly especially on young trees and skeletonise the leaves which gradually dry up. Tender shoots are also attacked that finally dry off. When nursery seedlings are attacked, the entire seedlings dry up. In old trees, a group of 60-75 beetles are capable of causing complete drying of tender shoots in 2-3 days. It is also severe on current season limb pruned trees. While, adults of *N. pollinaria* also attack the post harvest flushes causing defoliation and drying up of the shoots. Scrapping of the bark of tender shoots by the beetles appears as linear depressions. *D. marginatus* weevils remain on the underside of the leaves and scrape the leaf surface making minute feeding holes which appear as 'windowpanes' on young leaves.

From left: A group of *Monolepta longitarsus* damaging a tender cashew shoot and a dried shoot upon beetle damage

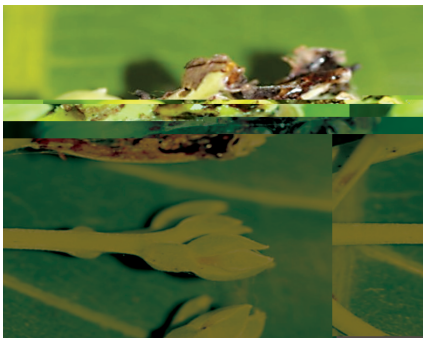
Management measures:

Spraying of any systemic or contact insecticide takes care of this beetle. Spraying of chlorpyriphos (1.5 ml/lit) or monocrotophos (1.5 ml/lit) or quinolphos (2 ml/lit) or lambda- cyhalothrin (0.6 ml/lit) could cause mortality of the beetles in a short period.

3.5 Leaf and blossom webber *Lamida* (*Macalla*) *moncusalis* Wlk. (Pyralidae: Lepidoptera)

Pest appearance:

Male moths are dark, fuscous and the females are green. Eggs are deposited ventrally on tender leaves and occasionally on tender shoots either singly or in groups of 5-6.



Damage on panicle

Distribution:

All cashew growing areas especially East coast tracts of India.

Biology:

The egg, larval, pre-pupal and adult stages last 4-7, 16-22, 9-15 and 3-6 days, respectively.

Damage on leaf

Seasonality:

Post monsoon flushing period (September - October) and flowering period (February- March).

Host range:

Mango (*M. indica*), jamun (*S. cumini*), Indian marking nut tree (*Semecarpus anacardium*).

Symptoms of damage:

The caterpillars feed on the terminal leaves of new shoots and blossoms after webbing them. Presence of webbing on terminal portions, with clumped

appearance, and drying of webbed shoot/ inflorescences are noticed. Galleries of silken webs reinforced with plant scraps and castings, indicate the presence of caterpillars. It occurs sporadically and can cause damage between 25-60 per cent.

Management measures:

In East coast regions, leaf and blossom webber is parasitized by braconids (*Apanteles* spp.), elasmid (*Elasmus* sp., *Elasmus johnstonii* F.) and a tachinid fly (*Blepharella lateralis*) in Andhra Pradesh and Odisha and a maximum of 50 % parasitism has been reported. While in Kerala, *Apanteles* sp. and *Avga choaspis* (Nixon) (Braconidae) occur as parasitoid on leaf and blossom webber. The green lace wing, *Chrysoperla* sp. also predate on this pest. Spraying of monocrotophos (1.5 ml / lit) or lambda-cyhalothrin (0.6 ml / lit) can manage this pest.

3.6 Hairy caterpillars *Lymantria ampla* Wlk (Lymantridae), *Metanastria hyrtaca* Cram (Lasiocampidae), *Euproctis fraterna* Moore and *E. scintillans* Walker (Lymantridae)

Damage by hairy caterpillars: *Lymantria* sp., *Metanastria hyrtaca, Euproctis fraterna* and unidentified sp.

Pest appearance:

There are plenty of hairy caterpillars feed on cashew leaves as well as flowers. The caterpillars vary in size, colour and shape. Generally, their body is suffused with hairs. Larvae of *L. ampla* occur commonly during early flushing period. The larvae of *M. hyrtaca* stay in the trunk region during the day time and defoliate the trees during night. The caterpillars are active, dirty black and the body is suffused with black and yellow hairs arising from warts set in a ring around the middle of each segment. They pupate inside silken cocoons and are dark reddish- brown.

Other hairy caterpillars which occur sporadically include *Diacrisia obliqua* Walker (Arctiidae) and *Estigmene lactinea* Cramer (Lepidoptera: Arctiidae) which feed the tender foliage of cashew in some regions.

Distribution:

In most of the cashew growing regions, hairy caterpillars occur sporadically and defoliate the trees.

Biology:

Egg, larval, pupal and adult period of *M. hyrtaca* are 9, 33-35, 12 and 1-6 days, respectively. Eggs of *E. fraterna* are circular, flat and creamy-yellow in colour, laid in groups on the lower leaf surface. Fully grown larvae are stout, dark reddish-brown and about 3 cm and the body is thickly covered with whitish hairs with a pair of dark tufts on either side of the head and one on the anal segment. While full grown larvae of *E. scintillans* are stout, dark-brown with tuft of fine hairs. A pale yellow strip runs down the back and on the first abdominal segment a thick tuft of blackish hairs is seen. Larval period lasts for 30 days and pupation takes place within leaf folds. Pupal period lasts for 8-12 days. The light brown moths of *D. obliqua* lay 400-1200 spherical, pale yellow eggs in small clusters that hatch in about 8-10 days. Larva is black and yellow with long, black and white hairs, and several yellow bands are seen on the body. It pupates inside a loose silken cocoon after 4-5 weeks and adult emerges after 1-2 weeks. Eggs of *E. lactinea* are laid in batches on the leaves or in soil.

Seasonality:

Post monsoon flushing period (July - October) and flowering period (January-March).

Host range:

i. *M. hyrtaca* – wild badam (*T. catappa*), moringa (*M. oleifera*), sapota (*M. zapota*), jamun (*S. cumini*), guava (*P. guajava*), babul (*Acacia nilotica*), *S. robusta*, *Schima wallichii*, *Nyctanthes arbor-tristis*, *Mimusops elengi*, *Madhuca longifolia* etc.,

ii. *L. ampla* – apple (*M. domestica*), ban oak (*Quercus leucotrichophora*), cocoa (*T. cacao*), *Populus* spp., *Salix* spp., *Alnus nitida* and false acacia (*Robinia pseudacacia*), pear (*Pyrus* sp.), plum (*Prunus* sp.), cherry (*Prunus* sp.), mulberry (*Morus alba*), walnut (*Juglans regia*) and rose (*Rosa* sp.).

Symptoms of damage:

Early instars of *M. hyrtaca* are gregarious feeders of tender foliage and full grown caterpillars feed voraciously on mature leaves as well. During day time they congregate in large numbers on the ground under dry leaves near the base of the tree or in crevices of bark or lower parts of well shaded branches and feed voraciously on foliage only during night. Severe defoliation by *M. hyrtaca* results in bare branches. While other hairy caterpillars scrape the green tissues when young and start defoliating the leaves and inflorescence branches and also feed on the shell of the nut in the tender green stage as well as tender apples

Management measures:

Braconids such as *Aleiodes* spp., *Apanteles oblique*, the chalcid, *Brachymeria poithetrialis* and the tachinid flies such as *Blepharipa* sp., *Carcolia* sp., *Exorista* sp. and *Palexorista* sp. are the parasitoids recorded on *L. ampla*. While, *Perilampus microgastri* Ferr (Perilampidae) is a parasitoid recorded on *M. hyrtaca* Cram. Larvae of *E. scintillans* are parasitized by *Apenteles euproctisiphagus* (Braconidae). Spraying is required when severe defoliation and marked infestation on panicles is noticed. Insecticides including Monocrotophos (1.5 ml/lit) or lambda-cyhalothrin (0.6 ml/lit) can effectively manage this pest.

3.7. Apple and nut borers: *Thylacoptila paurosema* Meyrick, *Hyalospila leuconeurella* Ragonet, *Nephopteryx* sp. and *Anarsia epotias* Meyrick (Lepidoptera).

Cashew apples are also nutritious and are attracted by many insect pests during various developmental stages. Apart from the above mentioned common species, larvae of *Orthaga exvinacea, L. moncusalis* and *Euproctis* spp. also damage tender nuts and apples, however, they are considered to be external feeders.

Pest appearance:

Female moth of *H. leuconeurella* lays eggs in the grooves near the junction of nut and apple. Freshly laid eggs are whitish in colour, turn dark red before hatching. Caterpillars are reddish with light brown head. The adult moth of *Nephopteryx* sp. is medium sized with dark forewing and pale hind wings. Larvae of *T. paurosema* are dark pink in colour and occur commonly in West coast regions.

Distribution:

Throughout cashew growing regions. Pest incidence is high in Kerala, Karnataka, Tamil Nadu and Maharashtra.

Biology:

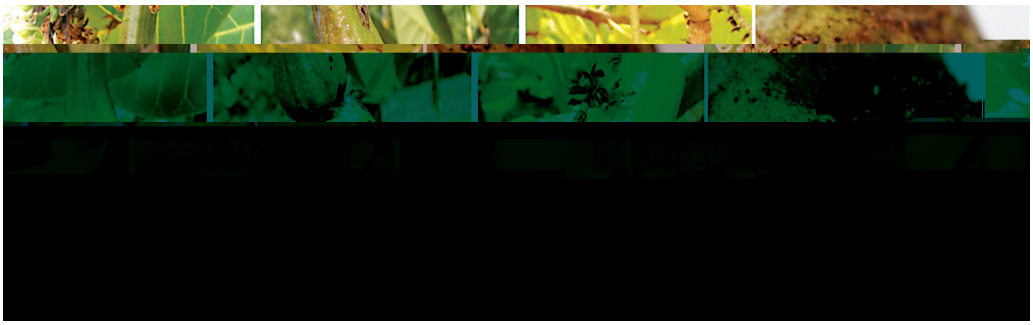
Eggs of *T. paurosema* are laid on the fruits and the incubation period is 3-5 days. The caterpillars are very active, dark pink measure 2-2.5 cm in length, and the larval period lasts for 15-20 days. The egg, larval and pupal period of *H. leuconeurella* lasts for 4-5, 12-17 and 9-12 days, respectively. The adult is dark-brown moth with a wing expanse of 16 mm. A female *A. epotias* moth lays 50-60 eggs singly or in groups of 10-20. The egg period lasts for 3-4 days. Pupation takes place in larval tunnels within the galleries in the apples. Pupal period is 7-10 days and the total life cycle is completed within 27-29 days. In *Nephopteryx* sp., larval period is 15-33 days. Full grown larvae are 2-2.5 cm in length, pink in colour having short setae. In one fruit, up to 5 larvae are found. Pupation takes place in earthern cocoon in soil and the pupal period lasts 8-10 days.

Seasonality:

During flowering and fruiting period (January-May), but severe during April-May.

Host range: i. *Nephopteryx* sp. - mango (*M. indica*), ii. *T. paurosema* - *Cassia fistula*.

Symptoms of damage:



Apple and nut borer damage on developing nuts

Larvae of *T. paurosema* attack tender apples and nuts. When apples are attacked, sometimes they are completely hollowed and drop prematurely. Larvae initially damage flowers by webbing the panicles and start feeding the unopened flower buds. Then, they bore inside the tender nuts and developing apples resulting in shriveling and premature fall. In the developed green nuts and apples, larvae tunnel near the junction of apple and nut, and the bore holes are plugged with frass and excreta. Damaged fruits can be easily located as they have frass hanging externally at fruit and nut joint.

While, caterpillars of *H. leuconeurella* bore through the apple from one end to the other and remain inside the apple till the fruit drops. Attacked apples generally fall down from the trees. Nuts when attacked become severely deformed. The larva of *A. epotias* binds dry inflorescences to the side of the apples or nuts hanging adjacently and nibbles them continuously. The infestation is manifested by the presence of dry inflorescences touching cashew fruits. In the progressive stages of injury, the caterpillars even make galleries inside the nut. While, the larvae of *Nephopteryx* sp. scrape the epidermis of tender nuts and apples. The young larvae move to the point of attachment of nut and apple, scrap the epidermis and bore into apples and tender nuts. The entry hole is minute and plugged with the excreta. The infestation spoils the apples and nuts. The larvae also damage the kernel. The fruits shrivel and drop prematurely, while, the nuts do not develop and dry up.

***T. flavorbitalis*, a parasitoid of ANB**

Management measures:

Removal and destruction of infested inflorescences as well as infested apples and nuts having larvae can be followed to prevent spread of the pest. Three larval parasitoids *viz*., *Panerotoma* sp., (Braconidae), *Trathala flavorbitalis* (Ichneumonidae) and one unidentified tiny dipteran fly occur on apple and nut borer larvae and a maximum of 46.2 to 50 % parasitism has been recorded under field conditions. Spraying of carbaryl (1 ml/lit) or lambda cyhalothirn (0.6 ml/lit) or quinolphos (2 ml/lit) or dichlorvos (1 ml/lit) is found effective for apple and nut borers.

3.8. Mealybugs *Planococcus citrii* Risso, *Planococcus lilacinus* Cockrell and *Ferrisia virgata* Cockrell, *Planococcoides robustus* Ezzat and Meconnel.

Mealybugs are potential pests in case of cashew.

***Ferrisia virgata* on cashew shoot**

Pest appearance:

F. virgata are small plumpy, soft insects, body is covered with number of white waxy filaments all over, with two pronounced long

waxy processes at the posterior end. A pair of dark submedian stripes is also present. Nymphs of *P. citri* are pale yellow without waxy coating. Adult females are slightly elongate, ovate, 5-7 mm long but covered with white mealy wax including the appendages.

***Distribution*:**

Karnataka, Kerala, Tamil Nadu, but severe in Konkan region and Goa.

Biology:

Egg masses of *F. virgata* remain under the females till the young ones hatch out. A female lays 100-300 eggs in 3-4 weeks. Eggs hatch in 3-4 hours and the nymphs develop as adults in about 26-47 days. Adults live for 14-21 days.

***F. virgata* on inflorescence**

Seasonality: December- April

***Host range*:**

i. *P. lilacinus* – Citrus (*Citrus* sp.), cocoa (*T. cacao*), coffee (*Coffea arabica*), custard apple (*Annona squamosa*), fig (*Ficus carica*), guava (*P. guajava*), pomegranate (*P. granatum*), sapota (*M. zapota*), tamarind (*T. indica*)

ii. *P. citri* – Coffee (*C. arabica*), crotons, ficus (*Ficus* sp.), fig (*F. carica*), ageratum (*Ageratum* sp.), citrus (*Citrus* sp.), erythrina (*Erythrina* sp.), pineapple (*Ananas comosus*), sapota (*M. zapota*), tea (*C. sinensis*);

iii. *F. virgata* – Apple (*M. domestica*), banana (*Musa* spp.), citrus (*Citrus* sp.), crotons, custard apple (*A. squamosa*), grapevine (*V. vinifera*), guava (*P. guajava*), jatropa (*J. curcas*), jack (*A. heterophyllus*).

Symptoms of damage:

Mealybug colonies develop on young vegetative shoots, leaves, inflorescence ,and tender nuts and fruits. Damaged flowers wither and dry, while the fruits shrivel, under develop or sometimes dry up. Due to honey dew secretion by mealy bugs, sooty mould develops on the affected portions.

Management measures:

Removal and destruction of mealy bug infested plant parts help to minimize their infestation and spread. *Apanteles* sp. has been reported as a parasitoid on *F. virgata*, besides *Blepyrus insularis* Cameron. In Kerala, up to 35 % parasitism

has been reported in *F. virgata* to be caused by *Aenasius advena* Campere (Encyrtidae). In Karnataka also, *A. advena* could cause upto 50 % parasitism in *F. virgata*. If essential, spraying of profenophos (2 ml/lit) or chlorpyriphos (2ml/lit) or dimethoate (2 ml/lit) or thiamethoxam (0.6 g/lit) or imidacloprid (0.6 ml/lit) may be followed to manage mealy bugs in combination with fish oil Rosin soap at 20 g/lit .

4. INSECT PESTS OF MINOR IMPORTANCE IN CASHEW

There are several minor insect pests of cashew that occur occasionally in a scattered manner at very low incidence and very rarely cause economic damage. Some of these pests occur seasonally and sporadically, and are of regional importance. In general, natural enemies take care of these pests and hence, rarely management actions are required.

***O. exvinacea* shoot damage**

4.1. Defoliating caterpillars:

Bombotelia jacosatrix Guenee (Noctuidae: Lepidoptera), *Orthaga exvinacea* Hampson (Pyralidae: Lepidoptera) and *Euthalia aconthea* Moore (Nymphalidae) are the common defoliators in cashew. Besides, the larvae of *Spodoptera litura* F., *Helicoverpa armigera* Hubner (Noctuidae: Lepidoptera) and bag worm, *Dappula tertia* Templeton (Psychidae: Lepidoptera) also defoliate cashew in certain pockets of India. In few cashew pockets in Karnataka and Kerala, the caterpillars of Tassar silk moth (*Antherea mylita* Linnaeus) and *Circula trifenestrata* Helfer (Saturniidae: Lepidoptera) respectively, are sometimes noticed on cashew that defoliate voraciously.

Pest appearance:

Larvae of *B. jacosatrix* are greenish, stout, striped with reddish-brown spots. Adult is a medium sized stout moth, black coloured with white specks throughout. Whereas, caterpillars of *O. exvinacea* are slender, pale-green with dark bands, remain inside the webs and move vibrantly upon disturbance. Eggs of *E. aconthea* are laid singly on leaves, greenish in colour and beautifully articulated. The larvae are spiny caterpillars, green in colour, lie along the midribs. Moth is big sized, bluish black in colour with white patches.

An egg of *E. aconthea*

Distribution:

Andhra Pradesh, Karnataka, Kerala, Tamil Nadu, Odisha, Goa

Biology:

Eggs of *B. jacosatrix* are laid in rows on leaf margins of tender leaves; they hatch in 3-5 days. Larval period lasts for 11-18 days. Body segments have tubercles and have sparsely distributed pale-whitish hairs all over the body. Pupation takes place in a silken cocoon inside the leaf folds and adult emerges in 9-15 days. Eggs of *O. exvinacea* are yellowish green that hatch in 4-5 days. Caterpillars complete its development within 28-33 days. Pupation takes place inside the webs in silken cocoon. The pupa is reddish-brown and pupal period lasts for 11-14 days. While, the egg and larval period of *E. aconthea* last 5-6 and 17-23 days, respectively.

Seasonality:

Post monsoon period (August- October)

Host range:

B. jacosatrix – Mango (*M. indica*), jack (*A. heterophyllus*) and *Terminalia belarica*; *O. exvinacea* – mango (*M. indica*)

Symptoms of damage:

B. jacosatrix is a leaf eating caterpillar that feeds on the tender leaves from the margins. Early instars are gregarious and during the later stages they feed on the entire leaf, leaving behind only the midribs. Caterpillars of *O. exvinacea* mostly attack young cashew plants, web together tender shoots and leaves, live within the webs and feed on the leaves. Several caterpillars are found in a single webbed-up cluster of leaves. Presence of silken webs reinforced with pieces of plant parts on terminal portions and blossoms as well as dried up appearance are the symptoms of its infestation. In Kerala, stout reddish brown caterpillar of the wild silk moth, *C. trifenestrata* occurs during September-October and causes severe defoliation. They feed voraciously for more than a month and pupate in golden yellow hairy silken cocoons which are found in masses inside group of leaves during November.

Leaf damage by *B. jacosatrix*

Similarly, *A. mylitta* occurs on cashew in Karnataka and parts of Kerala during July-October causing defoliation. Successful rearing of these silk worms on cashew has been established, showing the potential of sericulture in cashew.

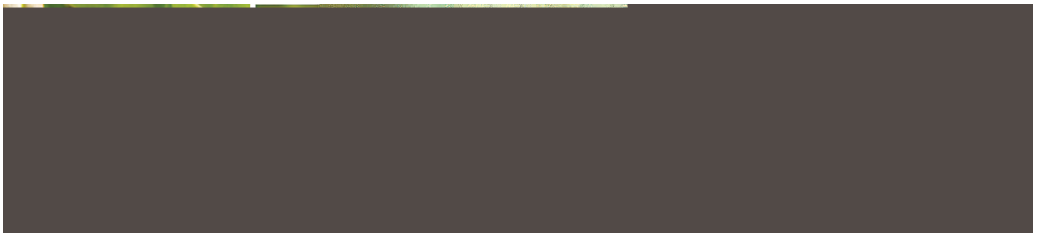
Management measures:

Larvae of *O. exvinacea* occur in a localized manner mostly on young cashew plants causing defoliation and drying of shoots which may require spraying at certain occasions. Spraying of monocrotophos (1.5 ml/lit) or lambda-cyhalothrin (0.6 ml/lit) can effectively manage this pest.

4.1.2. Loopers and semiloopers: *Oenospila flavifusata* Walker, *Thallasodes quadraria*, *Hyposidra talaca* (Walker) and *Pingasa ruginaria* Guenee (Geometridae: Lepidoptera)

Pest appearance:

Tiny reddish eggs of *O. flavifucata* are laid on the margins of tender leaves and hatch in about 5 days. Young caterpillars have reddish tinged body, thin, but become green in colour when grown. The larvae of *T. quadraria* are pinkish, slender and assume a characteristic pose oblique to the stem on the twigs and are mistaken for part of a twig or leaf petiole. Larva of *P. ruginaria* is green having white cross markings throughout the body. In adults, the patterns on both its forewings and hindwings would enable it to blend against the bark of a tree, especially one with lichen growth. Eggs of *H. talaca* are greenish blue in colour and oval in shape. First instar appears black or brownish black with transverse white stripes and turns brownish towards later stages. The wing colour of the male moth is brownish with minute black spots. Whereas, wing colour of female moth remain blackish brown, wings are pointed and designed with wavy lines of dark shades of grey and brown. Two distinct white spots are present at the apical region of the forewings of both male and female.



Larvae of different geometrid pests: *O. flavifusata*, *H. talaca* (early instar), *H. talaca* (late instar), *P. ruginaria*

Distribution:

In all cashew growing regions but at low level.

Biology:

Larval period of *O. flavifusata* lasts about 15 days and pupation takes place within leaf folds. Pupal stage last for 10 days. Eggs of *T. quadraria* are laid on the leaves which hatch in 3-5 days. Pupa is attached to the leaves and the pupal period lasts 6-8 days. Egg period of *H. talaca* is 6-7 days while, larval and pupal period lasts for 15-18 days and 7-10 days, respectively.

Seasonality:

These are common during the new flush period from August to November. While *H. talaca* occurs also during the flowering period.

Host range:

i *H. talaca*- Mango (*M. indica*), rose (*Rosa* sp.), tea (*C. sinensis*) etc.

ii. *P. ruginaria* – redgram (*C. cajan*), cocoa (*T. cacao*).

Symptoms of damage:

Though they are sporadic in occurrence they do cause considerable damage. All the loopers defoliate the tender leaves from the margins. The tender shoots damaged by *O. flavifusata* are left only with midribs. Besides leaves, the larvae of *P. ruginaria* damage inflorescences also.

Management measures:

Since these pests cause sporadic defoliation, spraying is generally not required against this pest. But if necessary, insecticides like monocrotophos (1.5 ml/lit) or profenophos (1.5 ml/lit) can be sprayed to manage the pest.

4.2. Bark eating caterpillar: *Indarbela tetraonis* Moore (Arbelidae: Lepidoptera)

Pest appearance:

Larva appears blackish, making tunnels in to the stem and branches.

Distribution:

All cashew growing regions especially in Kerala, Karnataka, Tamil Nadu and Odisha

Biology:

The eggs are laid under loose bark in clusters that hatch in 8-10 days. Larvae

are pale brown with dark head move along the branches concealed under the gallery. Larval period lasts even up to 10-11 months while, pupal period lasts 15-25 days. Adults are stout, pale brown moth with wavy grey markings on the wings.

Seasonality:

Throughout the year

Host range:

Ber (*Z. mauritiana*), *Casuarina equisetifolia*, citrus (*Citrus* sp.), falsa (*Grewia asiatica*), jack (*Artocarpus heterophyllus*), jamun (*S. cumini*), guava (*P. guajava*), litchi (*Litchi chinensis*), loquot (*Eriobotrya japonica*), mango (*M. indica*), mulberry (*M. alba*), rose (*Rosa* sp.), aonla (*Embelica officinalis*), *Peltophorum pterocarpum*, pomegranate (*P. granatum*), rain tree (*Samanea saman*), May flower (*Delonix regia*), badam (*T. catappa), Swietenia macrophylla, Macaranga peltata*, and silk cotton (*C. pentandra).*

Damage by bark eating caterpillar

Symptoms of damage:

The caterpillar makes a small residential hole on the wood normally where the branches fork and from there makes superficial galleries inside which it feeds on the tissues. The presence of winding galleries on the bark made of powdered bark, faecal pellets and the silk webbed together indicates this pest attack. Feeding damage on cambial tissues of small branches by this larva results in drying up of those branches.

Management measures:

To manage bark eating caterpillar, removal of galleries plastered on tree trunk or pouring of kerosene during early stage of infestation is suggested. In the chemical method, application of quinolphos (2 ml/lit) or dichlorvos (2 ml/lit) either by injection or by inserting a cotton swab soaked in the chemical is the most widely used method.

4.3. Aphids: *Toxoptera odinae* van der Goot and *Aphis gossypii* (Aphididae: Hemiptera)

Pest appearance:

Aphids are tiny (1-3 mm), soft, brownish in colour with prominent cornicles and found in groups.

Seasonality:

December – April and June

Host range:

T. odinae: *Citrus* sp., mango (*M. indica*), banana (*Musa* sp.), coffee (*C. arabica*), walnut (*Juglans regia*); *A. gossypii*- potato (*Solanum tuberosum*), cotton (*Gossypium* spp.), cabbage (*Brassica oleracea* var. *capitata*), cauliflower (*Brassica oleracea* var. *botrytis*), mustard (*Brassica juncea*).

Inflorescence infested by *T. odinae*

Biology:

Aphids reproduce mostly by parthenogenetic vivipary and also by sexual reproduction. Nymphs are tiny, complete four instars in a period of 9-16 days and become adults. A single female can produce around 35-50 young ones in a short period.

Symptoms of damage:

Though aphids are seen in huge numbers on leaves, shoots, inflorescence sand immature nuts, the feeding seldom results in damage.

Management measures:

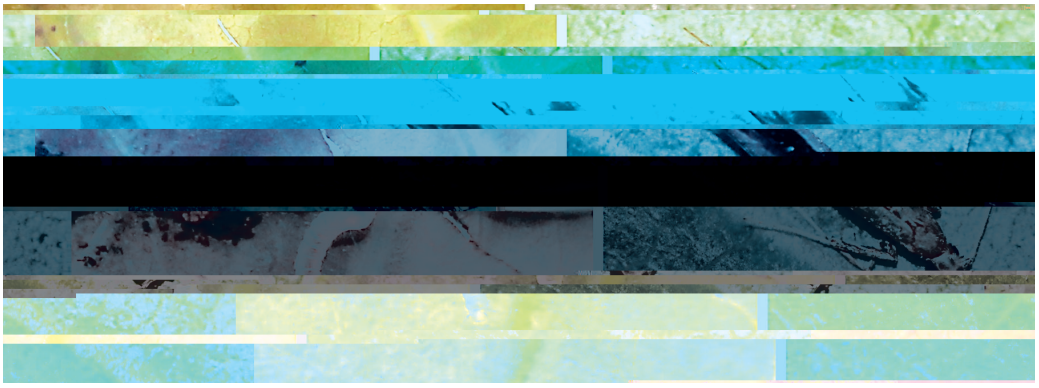
This is not a serious pest at present, but intense damage could cause drying of infested parts and sooty mould growth. Removal and destruction of aphid infested plant parts help to minimize their infestation and spread. There are several predators like syrphids (*Paragus* sp.,), coccinellids (*Pseudospidemerus circumflexa* Mots., *Cryptolaemus montrouzieri*, *Menochilus sexmaculata, Coccinella transversalis, Scymnus* sp., *Illeis cincta*), lace wing bugs, mantispid flies etc. take care of this pest. if necessary, spraying of dimethoate (2 ml/lit), phosphomidon (2 ml/lit), or methyl demeton (2 ml/lit) can be taken up.

4.4. Leaf folders and leaf rollers: *Hypatima haligramma* M. (Gelechiidae), *Caloptilia tiselaea* M. (Gracillaridae), *Dudua aprobola* M. (Tortricidae), *Sylepta derogatta* F. and *S. auranticollis* (Pyralidae).

Pest appearance:

Larva of *Hypatima haligramma* is yellowish green with black head and prothoracic shield and grows upto 7 mm long, pupates inside leaf roll, pupa is small and brown. Adult is a small, narrow shiny moth, with forewings having two whitish transverse bands. Larva of *C. tiselaea* is sluggish, light yellowish with creamy head, grows up to 7 mm and pupates inside a silken cocoon by making a small folding on lamina.

Adult is a tiny, narrow plume moth, dirty white in colour. Forewings are



From left: Larva and adult moth of *C. tiselaea*

narrow, elongate and smoky with greenish tinge. Hindwings are plumose and short. Tibial spurs are present in midlegs and absent in forelegs. Very active larva of *D. aprobola* looks dark green with black head and prothoracic shield, grows upto 1.5 cm long, pupates inside leaf roll while, adult is a tiny narrow grey moth. Wings are smoky green with ornamentation having black spot towards apical margin. A pair of spurs is present on both femoral and tibial ends of hind legs. While, larva of *S. derogatta* looks glistening green with dark brown head and prothorax, grows up to 2.5 cm and pupates inside the leaf roll. Adult is a small moth with light yellowish wings having brown wavy margins.

Distribution:

Throughout the country, but common in Kerala, Karnataka, Andhra Pradesh and Odisha.

Coleopteran minor pests: Top- Curculionid weevil, *Lypesthes indica* damaging a shoot, tortoise beetle (*Aspidiomorpha miliaris*)
Bottom - Cetonid beetle, chrysomelid leaf beetles, *Pagria* sp. and unidentified sp.

anthribid beetles also damage cashew in specific cashew growing regions during certain period.

The defoliating lepidopterans such as bag worms (*Clania* sp., *Dappula tertia*, *Eumeta* sp.), leaf cutting caterpillars, leaf feeding caterpillars (*Euproctis* spp., *Diacrisia obliqua*, *Sylepta* spp., *Dichocrocis punctiferalis*, *Argyroploce* tonsoria, *Latoia lepida*), midrib borer (*Palumbina glaucitis*) etc also occur in a scattered manner and feed on the leaves. While, orthopteran pests include grasshoppers (*Chrotogonus* sp., *Aularches miliaris*, *Conocephalus indicus*, *Holochlora* sp.) and katydids. Besides, termites (*Odontotermes* spp, *Microtermes* spp.,) form a series of narrow galaries on cashew trunks and branches. Some galleries lead to injured or cut forks of branches and hollows in stems of old trees, they also feed on bark.

Similarly, there are specific pests that attack the ripe cashew apples *viz*., fruit flies (*Drosophila melanogaster, Drosophila* sp., (Drosophilidae), *Dacus dorsalis*, *Bactrocera* spp., (Tephritidae) *Chrysomya megacephala* (Calliphoridae) and the beetles *viz*., *Carpophilus dimidiatus* (Nitidulidae). In due course, when the utilization of cashew apple gains importance, it will become important to manage fruit flies and apple beetles in cashew. The dried immature cashew apples and dried shoots are further attacked by a dark beetle known as *Araecerus fasciculatus.*

Lepidopteran minor pests: bag worm (*Clania* sp.), and unidentified defoliating as well as flower feeding caterpillars

Top: An acridid grasshopper and damage of termites on trunk
Bottom: *Carpophilus sp.*, and infestation of *Drosophila* flies on cashew apples

5. STORAGE PESTS OF CASHEW

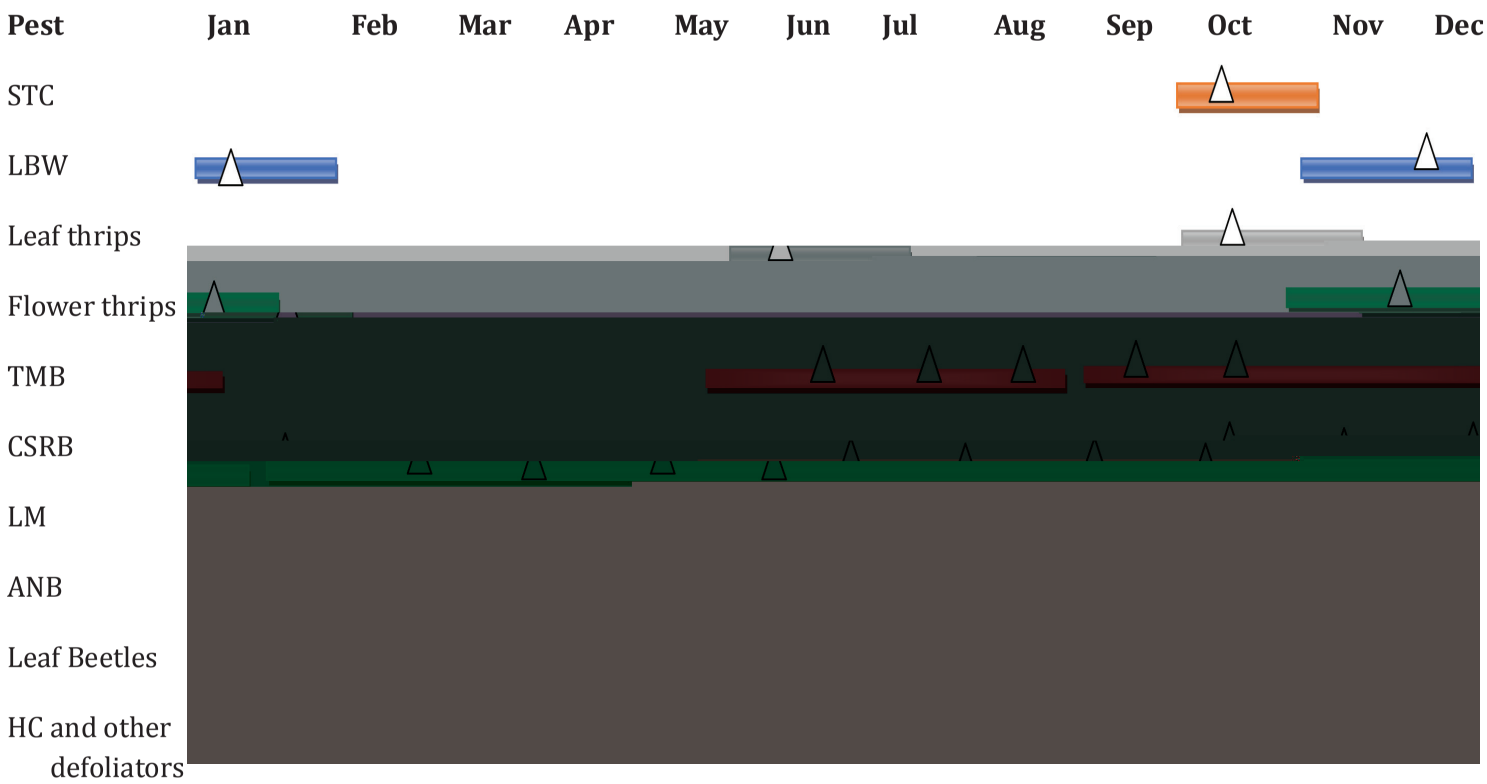
In general, the regular practice of sundrying of raw cashewnuts immediately after harvest kills most of the pest stages. Besides, raw cashewnuts are seldom stored more than two to three months and are rarely damaged by insects. But, processed cashew kernels are damaged by many insect pests during storage. Infestation by insects causes losses in terms of quality and quantity of cashew kernels and also changes the chemical composition affecting its nutritive value.

Around twenty species of beetles, five species of caterpillars and some psocids and mites are reported to infest cashew kernels during storage. Among these, *Cadra cautella* (Wlk.), *Corcyra cephalonica* (St.) (Pyralidae), *Tribolium castaneum* (Herb.) (Tenebrioniidae) and *Necrobia rufipes* (De C.) (Cleridae) damage directly the kernels. While other insects cause contamination of the cashew kernels by their excreta.

The biology of *T. castaneum*, *C. cephalonica* and *Oryzaephilus surinamensis* on cashew kernels have been studied. Egg, larval, pupal and adult period lasts for 4, 29.36, 10.04 and 28.6 days, respectively for *T. castaneum*. Egg, larval, pupal and adult period of *C. cephalonica* are 5, 29.59, 12.24 and 10.67 days respectively, while for *O. surinamensis*, they are 4, 19.7, 7.09 and 100 days, respectively. Grubs and adults of *Trogoderma granarium* infest the kernels damaging the entire soft portion. Infestation of *T. castaneum* reduces the levels of proteins, fat, carbohydrates and ash contents of cashew kernels. Upon pest damage, energy values of kernels drop down significantly and the moisture content increases. Hence, strict sanitation of the processing sheds and premises, keeping processed nuts in closed containers, undertaking peeling, grading and packing in quick succession are suggested as measures to control these pest infestations.

Cashew kernels damaged by beetles

6. CASHEW INSECT PEST CALENDER



△ Denotes peak infestation period.

STC- shoot tip caterpillar, LBW- leaf and blossom webber, TMB- tea mosquito bug, CSRB- Cashew stem and root borer, LM- leaf miner, ANB- apple and nut borer, HC- hairy caterpillars

7. CASHEW PEST MANAGEMENT : SOME CONSIDERATIONS

- A strong surveillance and proper monitoring of the pest situation has become imperative to rationalize management strategies and thus to avoid the need for blanket sprays of three rounds of insecticides.
- Phytosanitation and removal of CSRB infested branches as well as old dead trees from the cashew plantations help to minimize the spread of cashew stem and root borer.
- Removal of certain weeds in cashew plantations is required, since weeds especially *Terminalia paniculata, Chromolaena odorata, Calycopteryx floribunda* are not only competitors of cashew but also serve as host plants for many of the cashew pests.
- In young cashew plants, wherever possible, removal of different stages of pests like egg / egg laden leaves or shoots, caterpillars or grubs, pupa or cocoons from the infested plants gradually reduces the pest population.
- Under unsprayed conditions, an array of predators *viz*., spiders, ants, reduviids, coccinellids, neuropterans, hemipteran bugs and praying mantises take care of many of the cashew pests. But so far, very little progress could be made in biological control options.
- Red ants (*Oecophylla smaragdina*) are the potential biocontrol agents in cashew plantations that feed on bugs, caterpillars, hoppers, moths etc. Red ant colonized old cashew trees are generally free from pests and ant technology is under implementation in cashew plantations of Australia and Vietnam.
- Apart from predators, there are natural enemies that act as parasitoids on few cashew pests. Hence, indiscriminate spraying may be avoided as various cashew insect pests are parasitized by a number of parasitoids.
- Under situation that warrants spraying, tree to tree spraying is to be advocated, instead of whole plot spraying to avoid environment pollution. Trees harbouring ant nests especially red ants should be spared of spraying to allow them to take care of pests naturally. Ants besides controlling pests, may help to improve pollination also. Avoiding spraying on the non-target areas such as trunk, tree bases etc can help to protect some natural enemies.
- Natural as well as proprietary botanical insecticides are good biological

weapons that can be best integrated with chemicals. Neem oil (3-5%), Karanj (*Pongamia*) oil @ 2% and Fish Oil Rosin Soap and Neen seed kernel extract (NSKE) (5%) are some of the botanical preparations effective against many of the cashew foliage pests like leaf miners and leaf feeding caterpillars.

- While using botanicals, emulsifiers (soap water/ bar soap 0.5 % @ 5 g/lit or teepol (0.1 %) should be used in the spray fluid.
- Generally, the plant protection measures taken up against tea mosquito bug take care of the infestation of most of the foliage pests. Spraying is required, only under severe infestation.
- Rotation of insecticides between sprays is advised to prevent development of resistance to any particular pesticide.
- Spraying should be done before 9 am or after 4 pm in order to save non-target pollinators.
- The use of chemicals for short- term strategies and ease of operation led to chemical control playing a pivotal role. But, chemicals are to be used as a last line of defense.
- By integrating several options available for pest control, it is possible to realize increased yield and profit from our cashew plantations without impairing environment.

Preparation of spray solution and spraying of insecticides in cashew plantations

ANNEXURES

(i) Terminologies Related to pesticides, its formulations and hazard categorization.

a. Pesticides

❖ **Pests:** Organisms such as insects, rodents, nematodes, fungi, weeds, birds, bacteria, viruses, etc., which damage the crops and reduce yield. Pests are injurious to human health and/or farmers economic efforts.

❖ **Pesticides:** Chemicals or mixtures of chemicals that are used for killing, repelling, mitigating or reducing pest damage.

❖ **Insecticides:** Substances that prevent, inhibit, destroy, kill insects.

❖ **Fungicides:** Substances that prevent, destroy or inhibit the growth of fungi in crop plants.

❖ **Nematicides:** Chemicals that prevent, repel, inhibit or destroy nematodes.

❖ **Molluscicides:** Prevent, repel, inhibit or destroy members of the Phylum *Mollusca* such as snails.

❖ **Rodenticides:** Substances that prevent, inhibit, destroy, kill rodents.

❖ **Miticides/Acaricides:** Substances that prevent, inhibit, destroy, kill or mitigate mites

❖ **Herbicides:** Substances used for inhibiting growth of plants, plant parts, or to kill/destroy the plants / weeds.

❖ **Defoliants:** Substances that initiate leaves to fall.

❖ **Desiccants:** Substances that cause plant tissue to dry up.

b. Pesticidal Formulations

A formulation is developed to make the product safer, more effective and more convenient to use. A formulation is a mixture of chemicals (formulants) and made into the form in which a pesticide is sold for use.

A pesticide formulation contains:

❖ **Active ingredients (a.i.):** It is a part of a pesticide formulation which is the actual toxicant sometimes referred to as “technical grade” or “basic pesticide”.

❖ **Inert ingredients:** Other chemicals which have no pesticide action, but make the formulation suitable for use.

Inert ingredients include talc in a dust formulation or petroleum distillate in an emulsifiable concentrate formulation. Other inert ingredients may include solvents, wetting agents, extenders or emulsifiers. Although they have no pesticidal action, inert ingredients may be toxic to the applicator.

Pesticides are generally sold in three main types of formulations namely, solids, liquids and gases. But, many pesticides are applied as liquids and are diluted in water for use. Some products are ready to use and require no further mixing.

Abbreviations for formulations

Abb.	Formulation	Abb.	Formulation
A	Aerosol	S	Solution
B	Bait	SC	Sprayable Concentrate
D	Dust	SG	Soluble Granule
DF	Dry Flowable	SP	Soluble Powder
G	Gel	ULV	Ultra Low Volume
EC	Emulsifiable Concentrate	WSP	Water Soluble Powder
F	Flowable	WDG	Water Dispersible Granule
GR	Granular	WG	Wettable Granule
L	Liquid	WP	Wettable Powder
LO	Live Organism	WS	Water Soluble Concentrate
P/PS	Pellet	RTU	Ready To Use concentrate solution

*Some pesticides are formulated as Tracking powder, Paste, Liquid baits etc.

Type of formulation depends on several factors

- Chemistry of the active ingredient
- Toxicology of the active ingredient
- Effectiveness of the product against the pest
- Effect of the product on the plant, animal or surface
- Effect of the product on the environment
- Application procedure and equipment required
- The application rate

Hazard categorization of Pesticides

Every pesticide container carries certain information on its label. This information includes the trade name, technical name, composition, manufacturer's address, registered uses, date of packing, date of expiry, and toxicity label, and is mandatory under the Insecticide Act, 1968.

A toxicity label on a container conveys the toxicity hazard of the pesticide to mammals, mainly human beings, which is shown in a square set at an angle of 45`or a diamond, divided into two equal inverse triangles. The lower triangle is brightly coloured whereas, the upper contains warning words and signals. The warning words are always written outside the upper triangle, whereas, the signal words can be given either inside or outside the triangle.

There are four toxicity classes of pesticides:

Depiction				
Colour of the triangle	Bright Red	Bright Yellow	Bright Blue	Bright Green
Toxicity class	Extremely toxic	Highly toxic	Moderately toxic	Slightly toxic
Oral LD_{50} value (mg/kg)	< 50	51-500	501- 5000	>5000
Signal words (upper half)	Poison (in red)	Poison (in red)	Danger	Caution
Warning words (outside the diamond)	Keep out of reach of children.	Keep out of reach of children.	Keep out of reach of children.	-

The hazard ratings, or the toxicity classes, are based on the acute toxicity represented by LD_{50} (median lethal dose) values. The toxicity classification applies only to pesticides which are allowed to be sold in India. Some of the classified pesticides may be banned in some states of India, by the decision of the concerned

State Government. Some of the red label and yellow label pesticides were banned in the state of Kerala following Endosulfan poisoning. Regardless of the signal word on the pesticide product, it is important to remember that every product still has the potential to poison (*i.e.,* harmful at high doses). Special care should be taken to carefully follow all the directions on the label.

(ii) Preparation of Insecticide Solutions for spray

Recommended doses

Most insecticide recommendations are given in a.i. / ha. In this case, the volume of spray required per ha is determined by the type of equipment and its calibration. Recommendations are also given in a.i. (%) in the total volume of spray. Here, volume of the spray is always specified.

Calculations

a. When recommendations are based in a.i. (%)

For WP, EC, S:- Specifications required:

1. Spray volume as lit per ha.
2. Concentration desired as a.i. (%) in spray
3. Concentration of commercial product as a.i. (%)

Formula:

WP= a.i. (%) desired x spray volume/ a.i. (%) in commercial formulation

Eg. 1. To control TMB in a plot, if 2000 lit of 0.09 % carbaryl is to be prepared. How much Sevin 50 %, the commercial product of carbaryl is required?

Kg of Sevin required = 0.09 x 2000/50 = 3.6 kg

Eg. 2. If 2000 lit of 0.003 % Lambda cyhalothrin spray is to be prepared, how much commercial 5 % EC formulation of 'Karate' is required?

Litres of lambda cyhalothin required = 0.003 x 2000 / 5 = 1.2 lit

b. When recommendations are in kg a.i. per ha

Specifications required are,

Area to be sprayed, Concentration of a.i. in formulation, Recommended rate as kg a.i. per ha.

Formula:

Kg of WP/dust/granules = recommended rate x spray area (sq. m.) / a.i. (%) in formulation x 100

Eg. 1. If X insecticide 10G granule is to be used at the rate of 2 kg. a. i. per ha, then amount of X insecticide 10 G required for 1 ac is,

(1ac- 4000 m^2, 1 ha- 10000 m^2)

Then, Kg of X 10 G required = (2/10000 x 4000) / 10 x 100 = 8 kg.

Only the recommended dose should be applied.	Spraying against wind direction should not be done.
Safety wears like apron, hand gloves, face mask, goggles should be worn and the head need to be covered atleast with a cap.	Two or more pesticides should not be mixed together without proper information.
While spraying, entry of farm animals and workers in the field should be avoided to prevent exposure of pesticides.	EC formulations should not be used with battery operated ULV sprayers.
Detailed records of all pesticides used and the environmental conditions at the time of application can be kept for reference.	Must avoid eating, drinking, smoking or chewing while preparing solution.
In case of accidental exposure to pesticides, a doctor or nearby poison control center should be consulted immediately.	
After spraying	
The recommended 'waiting periods' should be followed before harvesting the produce.	Sources of water should not be contaminated while washing the sprayer.
Sprayer need to be washed with soap water and cleaned up so as to decontaminate.	
The clothes used while application must be washed using soap and the person can have a thorough bath.	
Disposal of pesticide containers	
The used pesticide containers may be crushed and buried deep into soil.	The remnant spray should not be drained in ponds or wells and also should not be poured down in the drain, sink or toilet.
The left over spray solution may be thrown in barren isolated area and the containers can be burnt with utmost care.	Empty pesticide containers must not be used for any other purpose especially domestic uses.

Care of Plant protection equipments

- Sprayer should be well maintained during the spraying season. Checking and preparation should commence well before the beginning of the season.
- Parts of the equipments that are likely to be needed should be kept in stock.
- It is important to clean both inside and outside of sprayer after each day's work, even if the same chemical is being used the next day. Sprayer should be lubricated regularly, especially all moving parts, before starting the work. Improper cleaning would leave the pesticides deposit in the feeder stem to completely or partially block the flow of the pesticide.
- Inspection of all parts of sprayer is required frequently. Worn out, broken and damaged parts should be replaced timely.
- If nozzle is worn out and delivers a 10 % overdose, chemical wastage in a couple of hours would cover the cost of a new one.
- In general, a detailed instruction book provided with each sprayer during its purchase gives simple advice and illustrated drawing of component and assemblies, which need to be followed.

(iv) First Aid and Antidotes for Insecticidal Poisoning

Insecticides are biologically active substances designed to kill insects by their toxic effects. They are not only toxic to insects but are poisons to all other kinds of animals including man. If they are not used carefully, they may cause acute and/or chronic adverse effects. Insecticidal poisoning may result from continuous contact; by adsorption through skin or by inhalation of the toxic vapour by the people who are handling pesticides either at manufacture level or at operation level. The insecticides sometimes accumulate through food chain, thus causing bio-magnification at different trophic levels and may result in poisoning.

Symptoms of insecticidal poisoning

Poisoning symptoms may appear immediately after exposure or may be delayed depending upon the insecticide, dose, length of exposure and the health condition of the individual. The common symptoms of insecticide poisoning are headache, nausea, convulsions, difficulty in respiration, paralysis, coma etc. But. specific symptoms do occur depending on the insecticide used.

First aid

Emergency treatment starts immediately after poisoning which should be continued till the patient is hospitalized. First the patient should be removed from the source of contamination. If breathing has stopped or becomes irregular, give mouth to mouth artificial respiration through a cloth. Keep the patient calm and comfortable. Collect the information about insecticide that had caused poisoning and immediately take the patient to the hospital.

Skin and eye contamination

Upon skin contamination, wash thoroughly in soap water followed by water and repeat it for 2 to 3 times. If eyes are exposed to pesticides, then keep eyelids open and wash eyes with gentle stream of water for 10 minutes. Repeat washing 2 to 3 times. Do not put any eye drop in the eye until doctor is consulted.

Inhaled poisons

If the insecticide has been inhaled, the patient should be moved to fresh air and his tight clothes should be loosened immediately. If breathing is irregular give artificial respiration. The patient should be prevented from chilling which can be done by wrapping him in a blanket.

Swallowed poisons

Vomiting should be induced immediately of poisoning which can be accomplished by administering one to two tablespoon of common salt in glass of warm water (200- 300 ml). When stomach is full, gentle stroking of the throat with a finger or blunt end of a spoon will induce vomiting. During vomiting, the head of the patient should be lowered with face downwards so that content of the stomach may not enter the lungs. Do not let the patient lie on the back. Such treatment should be repeated till the vomit fluid is clear. Vomiting should not be induced in case the patient is in coma, convulsions or in unconscious stage. In case of swallowed poisoning, gastric lavage using stomach tube may be given by the doctor. Intravenous fluid administration (glucose 5 %) or blood or plasma transfusion is given by the doctor in order to prevent the collapse of the patient.

Antidotes for insecticidal poisoning

Following are some of the antidotes for specific insecticidal poisoning practised under supervision. It is always advised to admit the victim in a hospital as early as possible for doctor's advice.

a. Organochlorine pesticides

Stomach should be evacuated following gastric lavage. Vomiting may be

induced. Universal antidote comprising of a mixture of 2 parts of activated charcoal, 1 part of magnesium oxide and 1 part of tannic acid should be given. Phenobarbital @ 0.7 g per day may be given to control convulsions. Pentabarbital @ 0.25 to 0.5 g per day may also be given. Calcium gluconate 10 per cent may be injected intravenously for controlling tremors. Artificial respiration may be required incase of respiration problem. Atropine may also be used for preventing bradycardia and to counteract the rise in blood pressure. Stimulants such as epinephrine should be avoided.

b. Organophosphate pesticides

On ingestion of OP insecticides rapid gastric lavage should be done. Artificial respiration may be given to the patient to overcome cyanosis before atropinisation. Atropine @ 2-4 mg should be given at 5-10 minutes interval for hours together. 2 gram of 2- pyridine-2-aldoxime-N- methyl iodide (2- PAM) by slow intravenous injection. In serious cases, both atropine and 2-PAM can be given.

c. Carbamate pesticides