ECONOMIC AND SOCIAL COMMISSION FOR ASIA AND THE PACIFIC

HANDBOOK ON PEST AND DISEASE CONTROL OF MULBERRY AND SILKWORM

UNITED NATIONS

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PREFACE

It is well known that the Asian and Pacific region has an age-old tradition of producing and using silk, besides being the supplier of the commodity to the whole world. Recently, the silk trade, both within and outside the region, has become complex and competitive. To cope with this situation, there is a need to increase production as well as to improve the quality of silk. However, one of the most serious problems faced by many countries of the region in such efforts is the incidence of pests and diseases of both mulberry and silkworms. Indeed, cocoon and raw silk production, and ultimately the quality of silk produced, depend heavily on the success of silkworm rearing, and pests and diseases are an important factor affecting the productivity of silkworms. Thus, an effective means of increasing the production of silk and improving its quality is the control of such pests and diseases. Even by conservative estimates, pest and disease incidence combined accounts for about 20-25 per cent of crop loss. Many kinds of pests and diseases of mulberry and silkworm, along with appropriate measures to control them, have been identified in the producing countries; however, the information has not been made available widely enough.

For these reasons, the Regional Consultative Group on Silk - an intergovernmental body established by ESCAP to promote multidisciplinary co-operative activities in silk - requested the ESCAP secretariat to compile an inventory of information on the principal pests and diseases which are seriously affecting the productivity of both mulberry and silkworms, as well as on the control measures currently being adopted, and to distribute that information to concerned countries. Supported by generous financial assistance from the Government of the Netherlands, ESCAP initiated a series of activities which culminate in the publication of the present handbook.

This handbook, prepared on behalf of ESCAP by a team of specialists led by Dr. K. Sengupta from the Central Sericultural Research and Training Institute of Mysore, India, contains a large amount of technical information on the various pests and diseases occurring in the region and their control, supported by abundant illustrative materials and is mainly meant as a comprehensive and valuable guide for both extension workers and silk farmers. Moreover, the technical information contained herein has been carefully compiled and is expected to be valid for many years to come. We therefore hope that this handbook will also become an authoriative reference book for scientists and personnel involved in research and development work in this field.

S.A.M.S. Kibria
Executive Secretary

"The team of specialists led by Dr. K. Sengupta from the Central Sericultural Research and Training Institute of Mysore, India, comprises Dr. Pradip Kumar, Mr. Murthuza Baig and Mr. Govindaiah".

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Mulberry and silkworm constitute the basic material for sericulture.

To obtain larger quantity of good quality mulberry leaf, not only high yielding mulberry varieties are to be evolved and grown under optimum agronomical conditions, they are required to be protected from diseases and pests.

Similarly, silkworm particularly the high yielding ones are susceptible to a number of diseases. In some of the tropical areas a pest on the silkworm is also a great menace. Consequently, to derive maximum benefit from silkworm rearing, one should very essentially take measures to protect them from the diseases and pests.

No exact estimates are available about the loss due to diseases and pests of mulberry and silkworm. This also varies from country to country, region to region and season to season, depending as well on the breeds/crosses used and preventive measures taken. However, rough estimates put the crop loss particularly in the tropical region due to diseases and pests of mulberry around 5 to 10 per cent and due to diseases and pests of silkworm as 20 to 25 per cent. Thus, an effective means to increase the sericultural productivity can be the control of the diseases and pests of the mulberry and the silkworm.

Many books are not available on the diseases and pests of mulberry and silkworm and almost none dealing with the practical aspects of their easy and accurate identification, prevention and control causing problems not only for the farmers, but also the field workers.

This illustrated handbook has been prepared to serve as a manual for the extension workers and farmers to help them in a quick identification and subsequent control of the diseases and pests of mulberry and silkworm. To help a quick identification, the symptoms of the disease and the pest attack have been illustrated and described in detail. This has been followed by a brief account of the life cycle of the causative organism and seasonal incidence which are very essential to be known to plan the appropriate preventive and control measures. The established preventive and control measures have also been described. While describing the diseases and pests orders of importance have been taken into consideration rather than any evolutionary sequence. Later, a chapter has been given on forms and formulations of the chemicals to serve as a guide for the preparation of usable dusts and solutions, where methods of use of the chemicals have also been given. Finally, a chapter has been given citing the common names of the chemicals, commercial names, chemical formulae, LD50 for mammals and mode of action to help the farmers in their easy procurement and safe use. It is hoped that the target group viz. the extension workers and farmers will find the handbook useful and beneficial.

Coming to the area coverage, illustrative material and information have been collected from almost all the sericultural countries right from Japan to Iran, covering in the process both the traditional countries like Bangladesh, China, India, Iran, Japan and Thailand as well as the newly coming-up non-traditional countries like Indonesia, Malaysia, the Philippines and Sri Lanka. It is in this way further hoped that this handbook brought out by the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) will be of use to a large number of countries.

PART I

DISEASES AND PESTS OF MULBERRY PLANT

CHAPTER 1

DISEASES OF MULBERRY AND THEIR CONTROL

Mulberry (*Morus* spp.) is affected by several diseases caused by fungi, bacteria, mycoplasma, viruses and nematodes. Among them about half a dozen diseases are economically important which affect the growth of mulberry and cause considerable damage to the plant and loss in leaf yield.

The incidence and loss due to these diseases vary with season, variety and cultivation practices. Biochemical studies have revealed that diseased leaves are poorer in proteins, moisture content and sugars. Feeding of diseased leaves has also been found to affect adversely the growth and development of the silkworm, cocoon yield and silk quality. It is thus very imperative to protect the mulberry plants from different diseases.

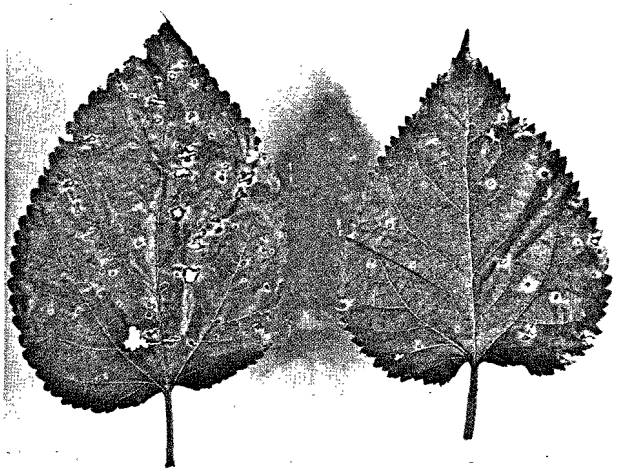


Figure. 1. Mulberry leaf affected by leaf spot showing irregular spots on the leaf

1.1. FUNGAL DISEASES

Among the pathogens affecting mulberry fungi are the predominent ones. About a dozen fungal diseases have been reported from mulberry of which 5-6 are economically important which are described here.

1.1.1. ***Leaf spot:*** Leaf spot disease is caused by *Cercospora moricola* (Cooke) Sacc. which belongs to the order Moniliales of class Deuteromycetes. In addition to this, there are a number of other pathogens which also cause leaf spot disease, like *Alternaria tenuissima, Drechslera yamadi, Fusarium solani, Phloeospora maculans, Myrothecium mori* and *Myrothecium roridum.*

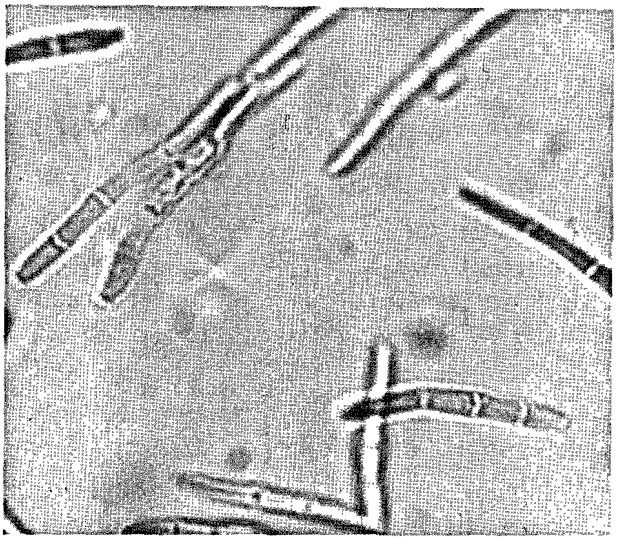


Figure. 2. Conidia of Cercospora moricola *causing leaf spot*

Symptoms: In the leaves affected by leaf spot, brownish irregular spot appear in the beginning and at later stages, these spots become enlarged, coalesced and lead to the formation of "shot holes". Severely affected leaves become yellowish and fall prematurely (Fig.1).

Disease cycle: The disease spreads primarily with rain droplets. The fungus produces a compact mass of interwoven cushion-like hypae, in which conidiophores are produced which in turn produce 3-7 celled conidia. Conidia are hyaline, tapering at one end and 70 x 3 μm in size (Fig.2). The conidia are capable of producing new hypae from any cell. It takes about 10-12 days after inoculation of conidia to produce a spot and another 3-4 days for the production of conidia (Fig.3).

The disease is very common in rainy and winter seasons (June to December) and it reduces the leaf yield by 10 to 30 per cent.

Control: This disease can be controlled by spraying the systemic fungicide Carbendazim. For one hectare of mulberry garden, about 500-625 grams of Carbendazim is to be dissolved in 500-625 litres of water and sprayed in cool hours. When the disease is very severe, another spray after 10 days from the first spray will be necessary. Leaves can be used for silkworm rearing after a safe period of 8 days.

Varietal resistance to the disease at least to some extent is known and it may thus be worthwhile

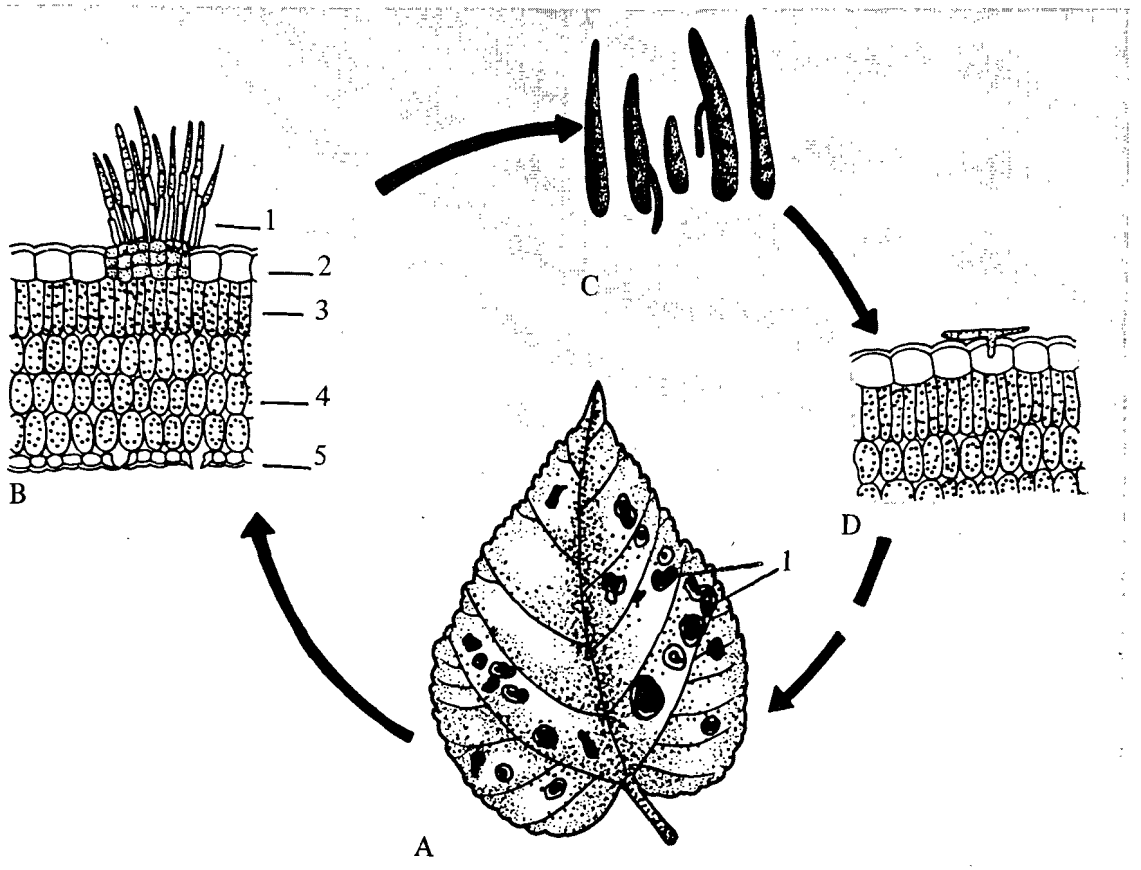


Figure. 3. *Disease cycle* of Cercspora moricola
A. Mulberry leaf affected by leaf spot
1. Brown spots
B. T.S. of infected leaf
1. Conidiophores with conidia
2. Upper epidermis
3. Palisade tissue
4. Spongy tissue
5. Lower epidermis
C. Conidia with germ tube/germinating conidia
D. Germinating conidia on the leaf surface

to screen the varieties available in a country against the leaf spot disease to isolate some resistant cultivars.

1.1.2. ***Powdery mildew***: Powdery mildew disease is caused by *Phyllactinia corylea* (Pers.) Karst. It belongs to the order Erysiphales of class Ascomycetes.

Symptoms: Initially white powdery patches appear on the lower surface of the leaves which cover the entire leaf surface at a later stage and turn black to brown in colour (Fig.4).

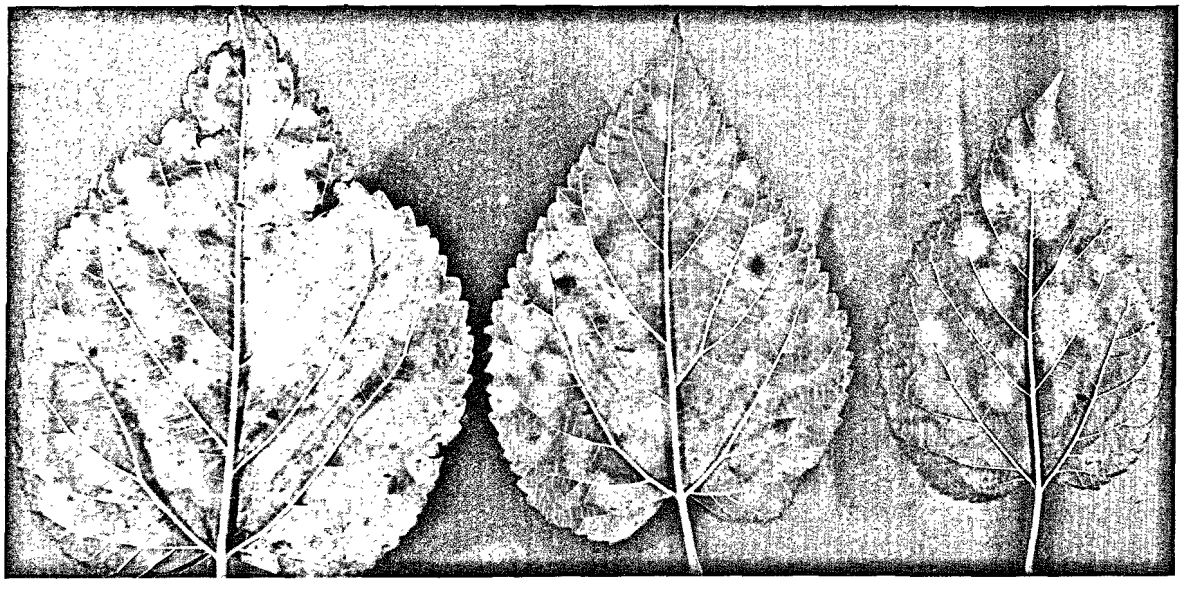


Figure. 4. *Mulberry leaf affected by powdery mildew showing the white powdery patches on the lower surface of the leaves*

Disease cycle: The pathogen *P. corylea* is an ectoparasite. It obtains nutrients by sending haustoria into the epidermal cells through the stomata. The fungus reproduces by both asexual and sexual methods.

Asexual reproduction takes place by means of conidia. Conidia are hyaline, unicellular and club shaped measuring 70 x 20 μm borne terminally on septate conidiophores (Fig.5). The liberated conidia disperse through wind current and spreads the disease. The mycelium is unbranched hyaline and forms a mycelial mat sticking to the leaf surface.

Sexual reproduction takes place by the formation of fruiting bodies called cleistothecia. Cleistothecia are covered with numerous colourless needle shaped appendages. Inside the cleistothecium 5 to 50 asci are present which on maturity are liberated during the favourable conditions by the splitting of the cleistothecia. Each ascus has two ascopores which on germination produce hyphae and spreads the disease through conidia (Fig.6).

The disease is more prevalent in hilly areas during the rainy and winter seasons and in the plains during the winter months.

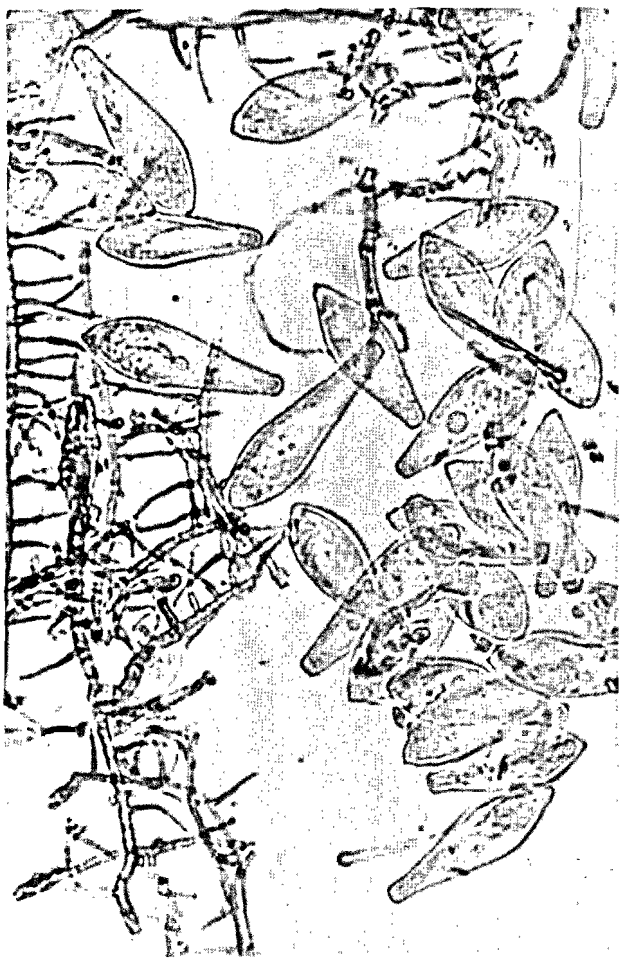


Figure. 5. *Conidia of* Phyllactinia corylea *causing powdery mildew*

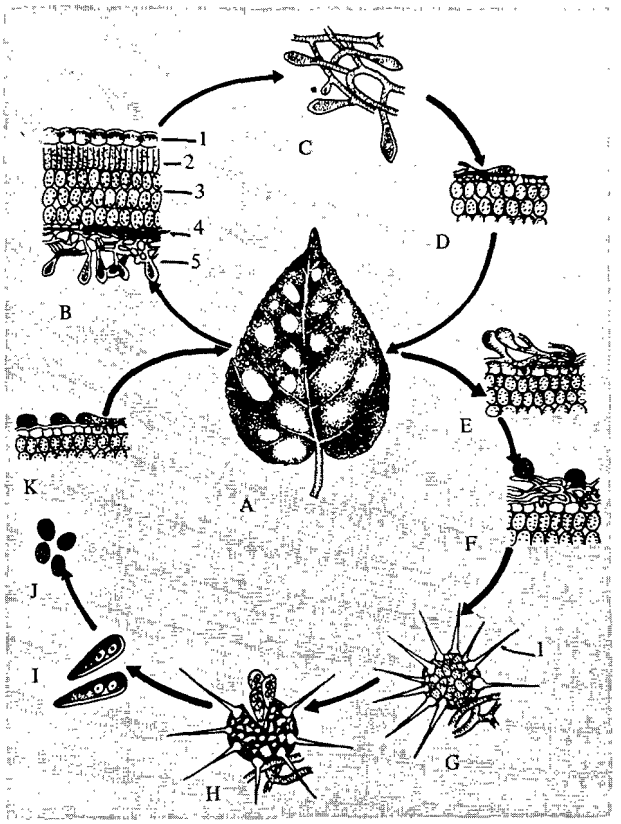


Figure. 6. *Disease cycle of* Phyllactinia corylea
A. Mulberry leaf affected by Powdery midew
B. T.S. of infected leaf
(1) Upper epidermis (2) Palisade tissue
(3) Spongy tissue (4) Lower epidermis
(5) Mycelia with conidia
C. Mycelia and Conidia
D. Germinating conidia
E. Ascogonium and Antheridium
F. Young cleistothecium
G. Matured cleistothecium
H. Liberation of Asci
I. Ascus
J. Ascospores
K. Germinating ascospore

Control: Spraying of Dianocap 0.2 per cent has been found to be very effective for the control of the disease. 400-500 ml. of Dinocap is to be mixed in 200-300 litres of water to spray one acre of mulberry garden. While spraying the lower surface of the leaves should be thoroughly drenched. Leaves can be used for rearing after 10 days of the spray.

Varietal resistance is known for the disease, Leaves having thicker cuticle and epidermis, less number of stomata and more of leaf hairs (trichomes) are less susceptible to the disease.

1.1.3. ***Rust:*** Leaf rust disease is caused by *Cerotelium fici* (cast.) Arth. It belongs to the order Uredinales of class Basidiomycetes. In India *Cerotelium fici* is the pathogen causing the disease affecting the leaf only, where as in China and Thailand *Aecidium mori* Barclay is the pathogen which affects leaves, petioles, tender buds and stem where it is

called the red rust. The red rust is reported to be a serious disease in Malaysia.

Symptoms: In case of leaf rust the pathogen produces numerous pin head sized circular to oval brownish to black eruptive lesions on the lower surface of leaves. As the disease becomes severe leaves become yellow and wither off prematurely (Fig.7).

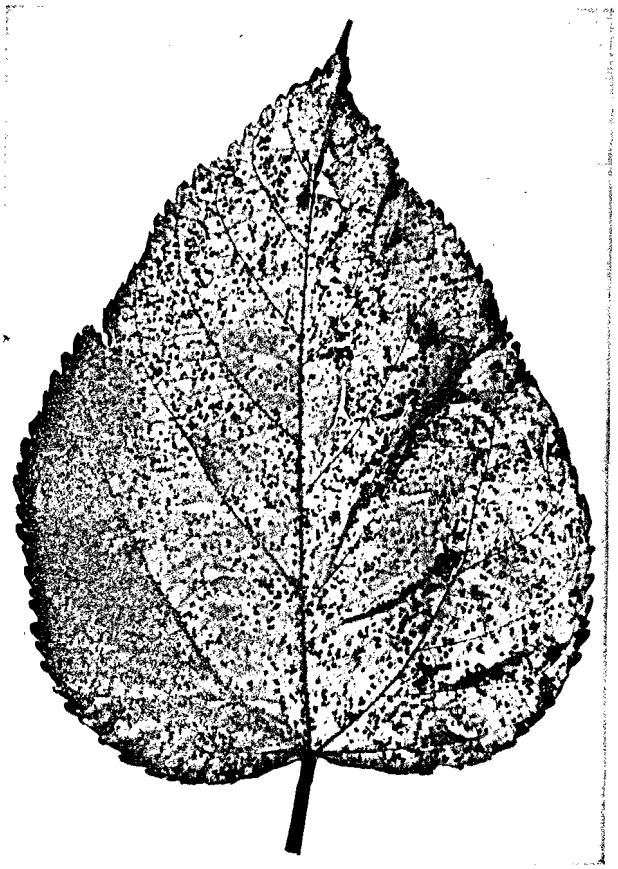


Figure. 7. Mulberry leaf affected by leaf rust showing the Pin head sized pustules

In case of red rust the affected buds become swollen and curls up in abnormal shape with many yellow spots on the bud. On both surfaces of the leaves neumerous small, round, shiny yellow coloured spots appear.

Disease cycle: The pathogen *Cerotelium fici* is an obligate microcyclic rust fungus. It exists primarily as mycelium, Uredium and Uredospore. Uredospores are oval to round and uninucleate produced singly on uredospores and Uredia (Fig.8). In favourable conditions (22-24°C with high humidity) Uredospores germinate and produce hyphae, which enter the leaf through stomata. The hypae grow intercellularly in the host tissue, sending haustoria into the host cells to draw the nutrients. Uredospores disperse through water droplets and wind currents and spreads the disease (Fig. 9).

Figure. 8. Uredospores of Cerotelium fici *causing leaf rust*

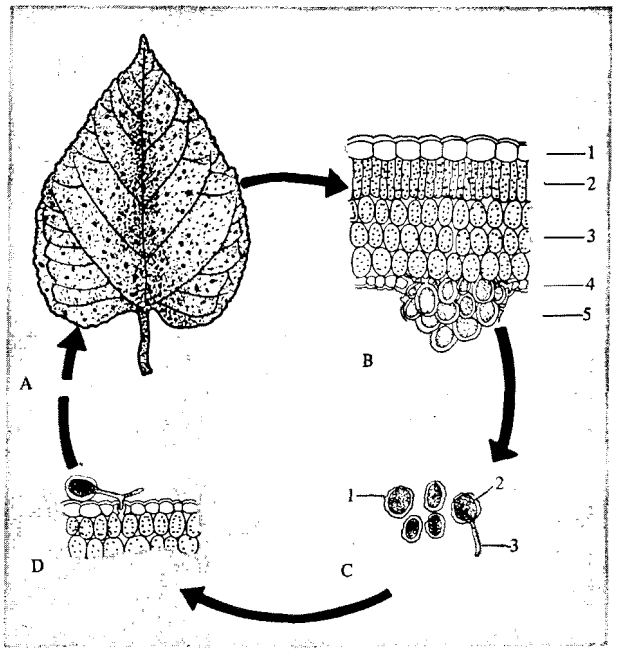


Figure. 9. *Disease cycle* of Cerotelium fici
A. Mulberry leaf infected by leaf rust
B. T.S. of infected leaf
(1) Upper epidermis
(2) Palisade tissue
(3) Spongy tissue
(4) Lower epidermis
(5) Uredospores
C. Liberated Uredospores
(1) Exine (2) Intine (3) Germ tube
D. Germinating Uredospore on the leaf surface

In case of *Aecidium mori* it produces ascospores instead of uredospores.

The disease is common during winter season and reduces the leaf yield by 5 to 10 per cent. The disease severity increases with the age of the leaf.

Control: Timely utilization of leaves without delaying the leaf harvest especially during winter months and wider spacing in plantation have been found to reduce the disease incidence. In addition spraying of fungicides like Dinocap and Carbendazim at 0.2 per cent concentration helps in controlling the disease. The leaves can be used for rearing after a safe period of 7 days.

Varietal difference in resistance to leaf rust disease is known, though no variety has been yet found to be completely resistant.

1.1.4. ***Root-rot:*** Two types of Root-rot diseases have been reported from India and Sri Lanka.

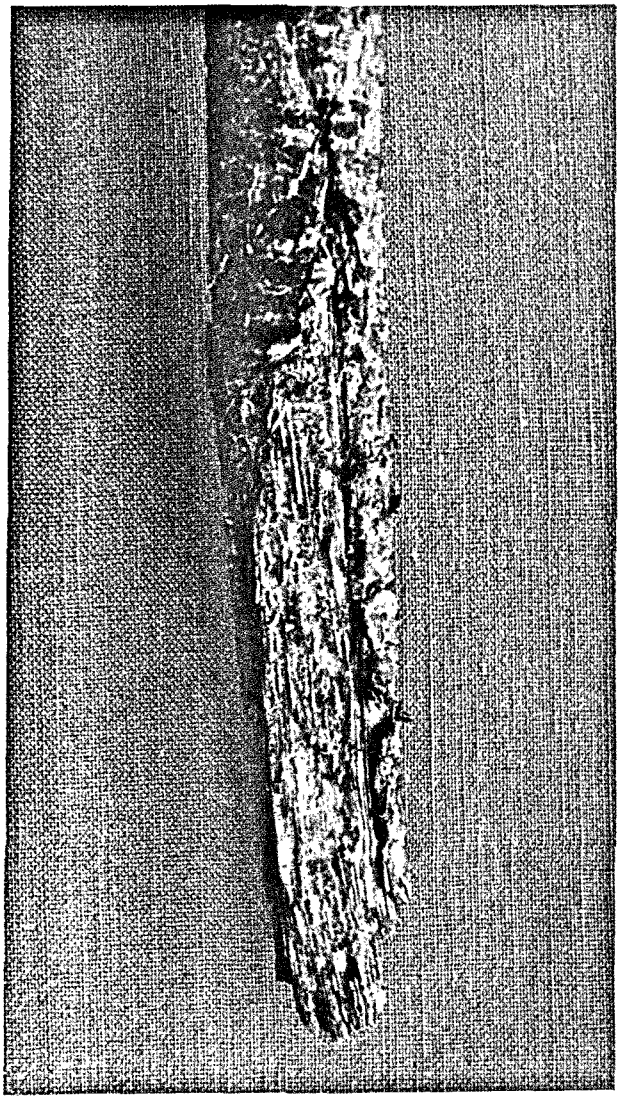


Figure. 10. Mulberry root affected by white root-rot caused by Rosellinia necatrix

They are white root-rot caused by *Rosellinia necatrix* Berlesse belonging to the order Sphaeriales of class Ascomycetes and the violet root-rot caused by *Helicobasidium mompa* N.Tanaka, belonging to order Tremellales of class Basidiomycetes. In Thailand these two diseases are considered to be the most serious diseases of mulberry.

Symptoms: In case of white root-rot, the diseased mulberry plants become weak, the leaf buds grow feebly, leaves wither off and the plant dies very soon. The stump region is covered with whitish gray mycelial mat (Fig.10).

In case of violet root-rot sudden withering off of leaves takes place followed by dying of the plant. The epidermal tissue of the larger and smaller roots are covered with violet coloured mycelial mat.

Disease cycle: The fungus *Rosellinia necatrix* reproduces by forming chlamydospores, sclerotia and rarely through conidia. In favourable conditions it reproduces sexually forming asci and ascospores in a closed fruiting body called perithecium. Eight ascospores are present in each asci. The hyphae emerging from different spores infect the primary roots and later spreads to the whole root system causing white root-rot. The sclerotia and sexual spores remain as resting spores in the soil, dried root and stump portions in adverse dry conditions and perpetuate the disease in favourable condition (Fig 11).

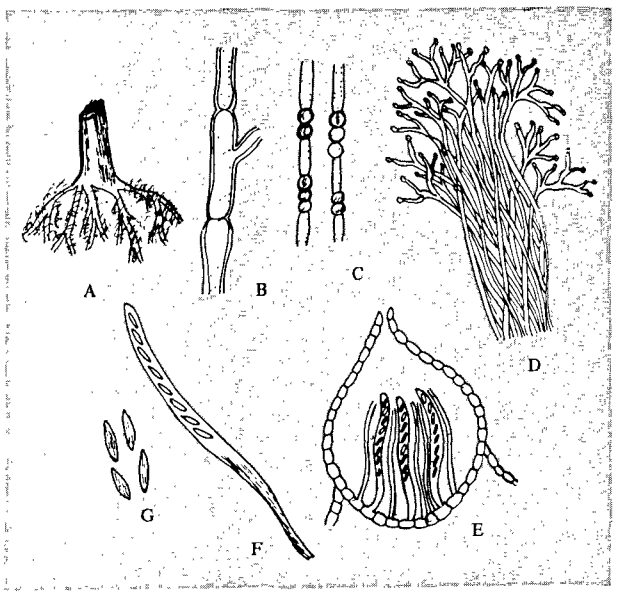


Figure. 11. Disease cycle of Rosellinia necatrix *causing white root-rot*
A. Mycelia on the root surface
B. Mycelium
C. Chlamydospores
D. Interoven mycelia with conidia
E. Perithecium
F. Enlarged ascus with ascospores
G. Ascospores

In case of *Helicobasidium mompa*, the hyphae are purplish, septate, terminating with fructification bodies called basidia. Each basidium bears four basidiospores at the top. Basidiospores rapidly germinate in wet soils and rain drops and the hyphae enter the new root system and spread the disease. To overcome long periods of adverse conditions mycelia from sclerotia or hardened mass of hyphae (rhizomorphs) in soil and root system and repeat the disease cycle in favourable conditions (Fig.12).

uniformly, mixing it properly with the soil @ 75.2 g/ 36 sq.ft. The latter method is effective in shallow cultivated soils. Care should be taken to see that the leaves are not collected from the plants coming in contact with these chemicals. In case of a plantation being severely affected, it may be worthwhile to uproot the whole plantation, sterilize the soil and raise a new plantation.

No varietal resistance to this disease is known.

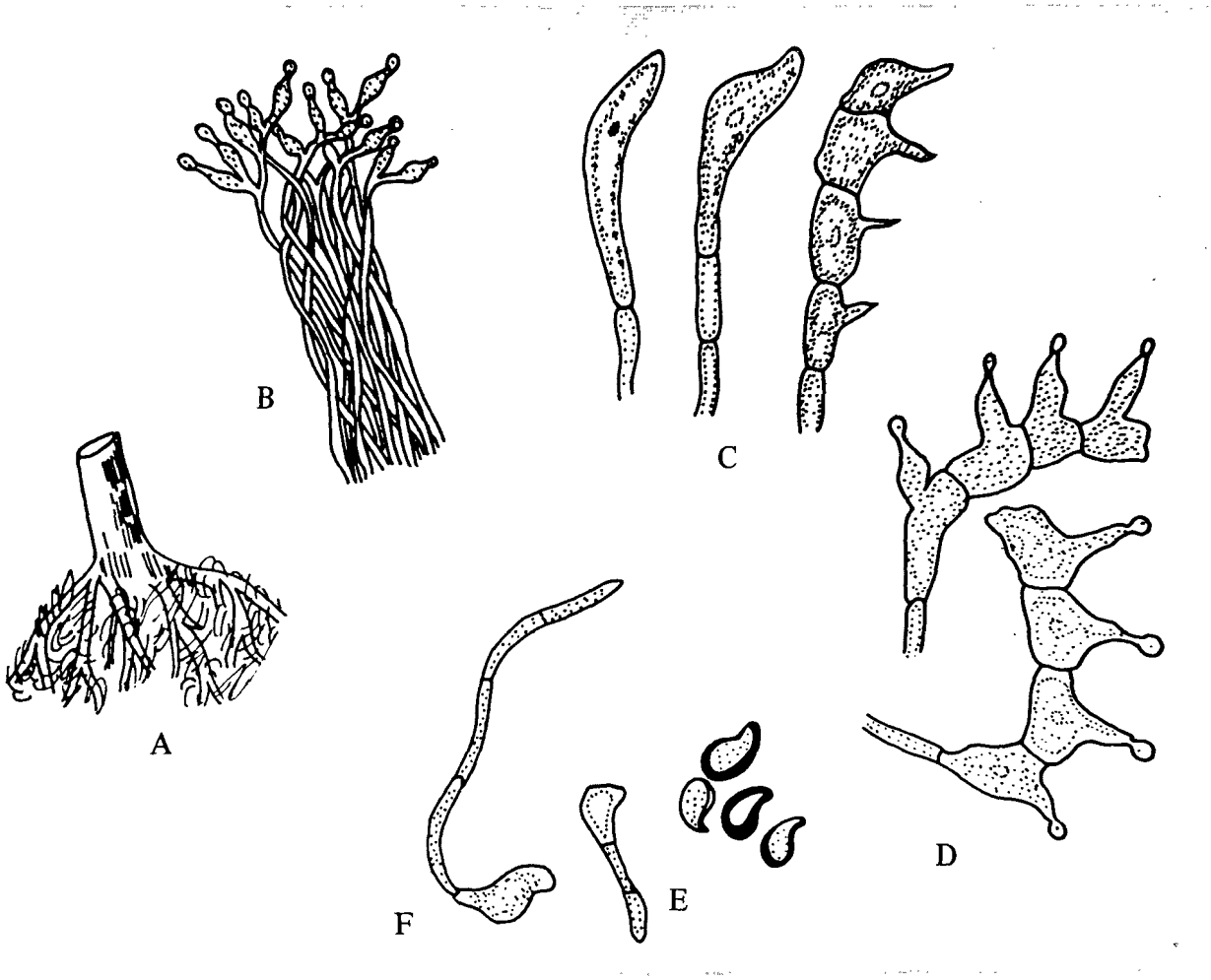


Figure. 12. Disease cycle of Helicobasidium mompa *causing violet root-rot*
A. Mycelia on the root surface
B. Interoven mycelium with basidia and basidiospores
C. Young basidia
D. Matured basidia with basidiospores
E. Basidiospores
F. Basidiospore germination

Control: As soon as the disease symptoms appear the infected plants should be uprooted and the remaining stumps and root portions collected and burnt. The soil around should be ploughed, levelled and disinfected with chloropicrin. For the application of chloropicrin small verticle holes 3-4 feet deep should be made and chloropicrin @ 1/2 kg. per 108 sq.ft. should be put in the holes and covered with soil. Calcium cynamide (lime nitrogen) may be applied

1.1.5. ***Twig blight:*** Twig blight disease is caused by *Fusarium pallidoroseum* (Cooke) sacc. It belongs to the order Moniliales of class Deuteromycetes. Different species of *Fusarium* like *F. lateritium*, *F. mori*, *F. oxysporum* and *F. roseum* have been reported from mulberry.

Symptoms: Leaves of the plants affected by the twig blight show marginal blackening/burning in the initial stage and complete burning and defoliation in the later stage (Fig.13). Affected stems (twigs) show black longitudinal lesions which later lead to the spliting and drying of the branches (Fig. 14). In case of bud blight caused by *Fusarium lateritium*, and *F. mori* the buds become rotten.

Figure. 13. Mulberry leaf affected by twig blight showing the marginal leaf burning

Disease cycle: The fungus is a facultative parasite remaining in the soil saprophytically for a long period. It produces both micro and macro conidia. The micro-conidia are small, elliptical or curved and unicellular. The macro-conidia are linear, curved, pointed at both the ends, thin-walled and septate.

Chlamydospores (resting spores), spherical and thick walled are often formed within the host tissue. All three types of asexual spores germinate in water to form germ tube and chlamydospores are said to be able to survive adverse climatic conditions and remain viable for a long period. The sexual method of reproduction is not known.

The disease is observed through out the year but more during the rainy and the post rainy seasons. The loss due to this disease is about 5-6 per cent.

Control: As the disease is both soil and airborne, the fungicides like Captafol or Mancozeb may be used both as foliar spray in lesser concentration (0.2 per cent) and soil drenching in higher concentration (0.5 per cent).

Varietal resistance is not known against the twig blight.

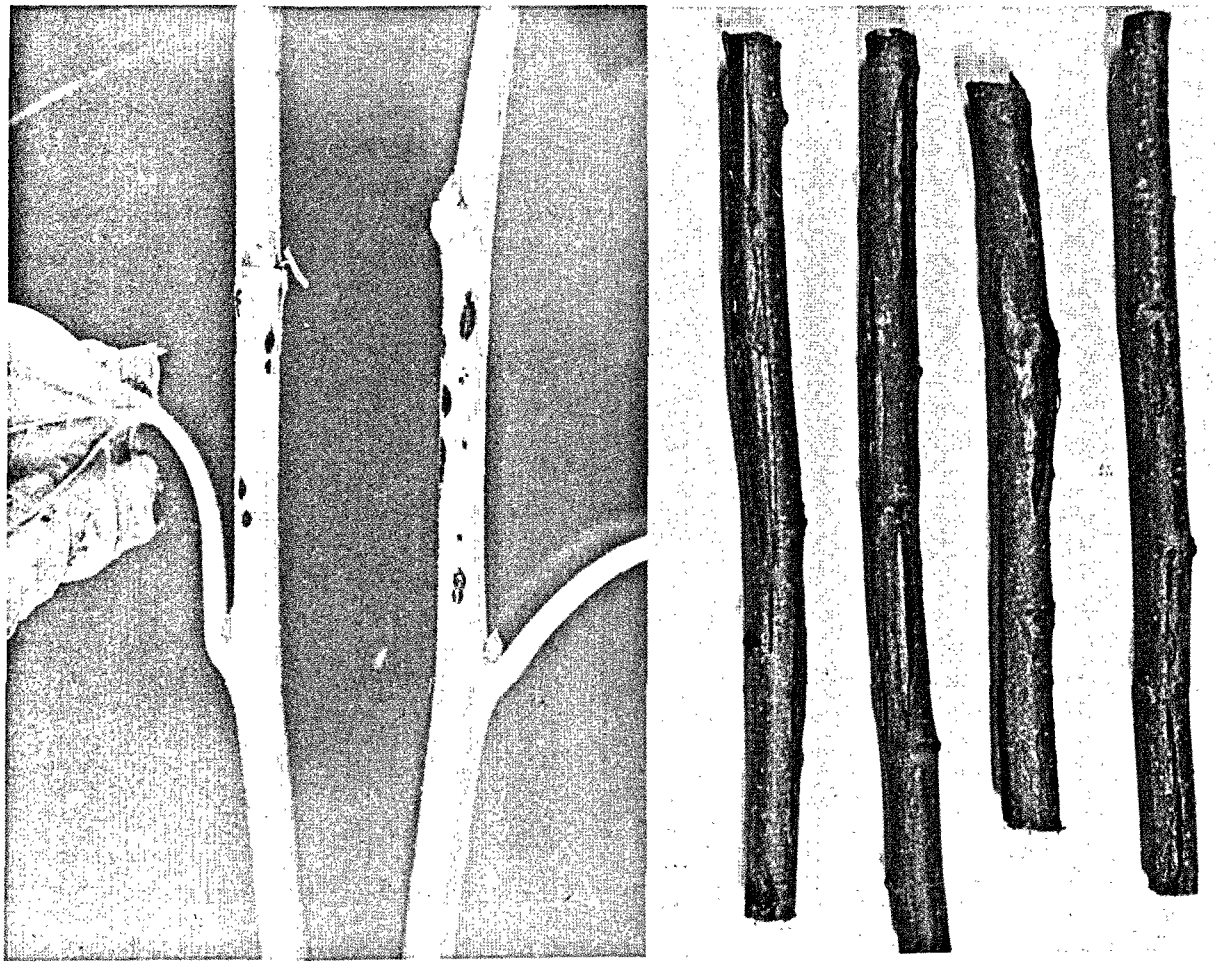


Figure. 14. Mulberry stem affected by twig blight showing the longitudinal lesions

1.1.6. ***Minor fungal diseases***: Besides the major diseases discussed, there are also some minor fungal diseases reported in mulberry. These are Stem Canker and Collar-rot. Stem Canker caused by *Botryodiplodia theobromae* pat. is common during rainy season. The symptoms of the disease are greenish black lesions on the stem surface later leading to the formation of carbonaceous structure (Fig.15). This disease affects the sprouting of the cuttings. For the control of the disease, the cuttings before plantation should be soaked in 0.1 per cent Bavistin solution for a period of 12 hours.

Figure. 15. Mulberry stems affected by stem canker showing the formation of carbonaceous structures

Collar-rot caused by *Phoma mororum* sacc. is also common during the rainy season. The symptoms are rotting of the stem near the ground level, resulting in the wilting of the plant (Fig. 16). The disease can be controlled by spraying 0.2 per cent Captafol.

1.2. BACTERIAL DISEASES

There are not very many bacterial diseases reported from mulberry. The only disease of economic importance is the bacterial blight.

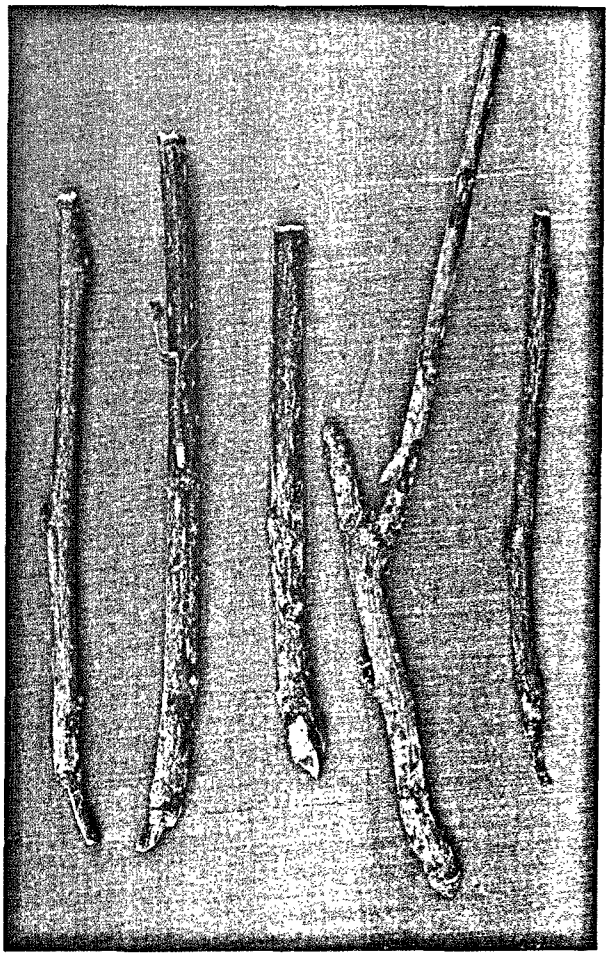


Figure. 16. Mulberry stems affected by collar-rot showing roting of stem

1.2.1. ***Bacterial blight***: Bacterial blight is caused by *Pseudomonas mori* Boyer and Lambert. It belongs to the order Pseudomonadales of class Schizomycetes.

Symptoms: Numerous irregular water soaked patches appear on the lower surface of leaves. In severe condition leaves become curled, rotten and turn brownish black in colour (Fig 17). The black

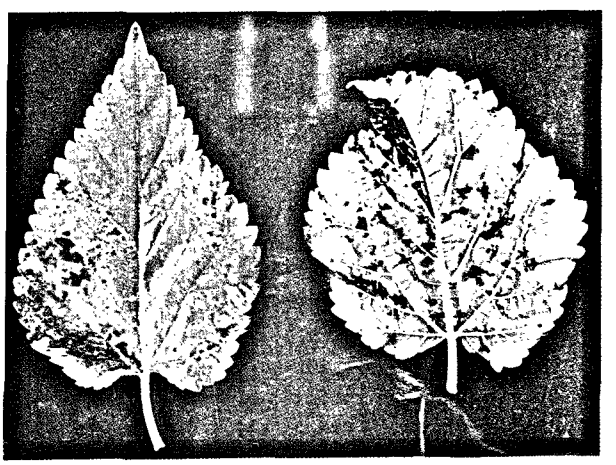


Figure. 17. Mulberry leaves affected by Bacterial blight showing the water soaked patches on the lower surface of the leaf and yellowing

longitudinal lesions are also seen on the bark of the young shoots.

Disease cycle: Soil is the primary source of infection. The secondary infection of the disease takes place through irrigation, cultivation activities, mechanical injuries and biological agents. The bacterium is rod shaped measuring 0.9 to 1.4 μm x 1.8 to 4.5 μm. It is gram negative and encapsulated with no endospore. Colonies on nutrient agar are white, circular, smooth, flat and translucent. The thermal death point is 52°C. The disease is favoured by high relative humidity (following rains) and an atmospheric temperature around 23-32°C. It multiplies by binary fission. Under favourable condition it infects the new plants.

This disease commonly occurs during rainy season. The loss due to the disease is 5-10 per cent.

Control: The diseased plants should be uprooted and burnt and the contaminated soil should be exposed for sun drying. Agricultural antibiotics like streptomycin or streptocyclin can be used as foliar spray at 0.1 per cent concentration. In addition, fungicides like Captafol or Moncozeb at 0.2 per cent concentration may be used for an effective control of the disease.

No varietal resistance is known against the disease.

1.3. MYCOPLASMA DISEASES

Mycoplasma diseases was first reported from Japan. Currently, it is also being reported from Korea, Thailand and China. It was reported as early as in 1818 from Japan as "dwarf after pruning disease" and confirmed as a mycoplasma disease during 1964.

1.3.1. ***Dwarf diseases:*** The disease is caused by Mycoplasma like organism (MLO) belonging to the order Mycoplasmatales of class Mollicutes. The disease is very serious in China, Japan and Sri Lanka. Other countries have not reported it to be a serious disease.

Symptoms: The characteristic symptoms are chlorosis and stunted plant growth, Leaves turn yellow, crinkles and curls outwards (Fig 18). Internodes become shortend, the diseased shoots give the appearance of witches broom. The disease is transmitted by insect vector and grafting.

Disease cycle: The mycoplasma are transmitted by leaf hopper vector and by grafting. The primary source of inoculum are the affected plants.

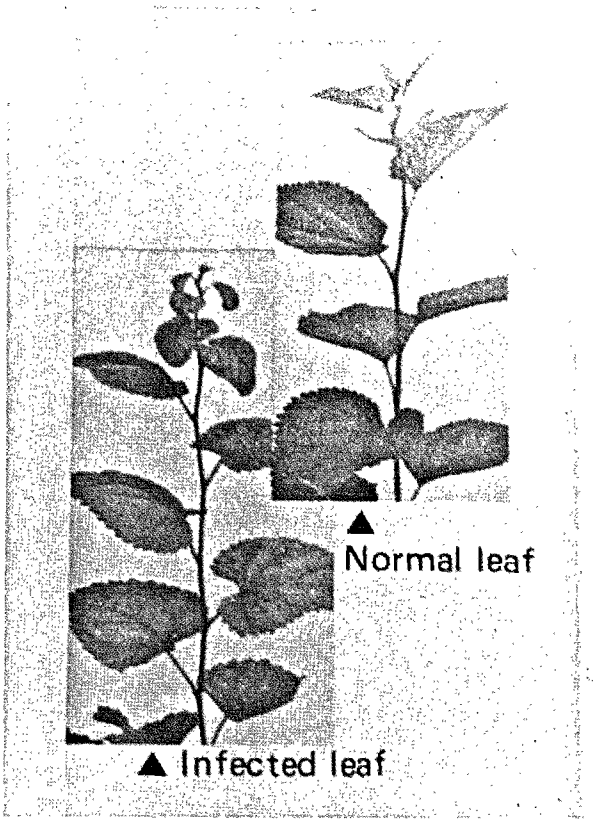


Figure. 18. Mulberry twig affected by mycoplasma like organism showing yellowing of leaves and stunted growth

The shortest aquisition feeding period for the vector insect is three hours. The pathogen proliferates in phloem sieve tubes and moves through the plant in the phloem tissue. It leads to phloem necrosis in the root system and in later stages it progresses to branches. The leaf hoppers feeding on the diseased leaves become infected and eventually transmit the disease to healthy plants. With incubation period of 13 days at 28°C or 55 days at 18°C, the insect has the ability to transmit the disease. The prevalance of the disease depends on amount of vectors available in the field. The disease becomes severe with warmer condition and occurs generally in summer season.

Control: Digging out of the diseased plants and their burning. For the control of the insect vector malathion emulsifiable concentrate diluted with water 1:1000 or DDVP (Diochlorovos) 0.1 per cent may be sprayed. Safe period for the use of leaves after treatment is 7 days.

Varietal resistance for mycoplasma disease is known in some varieties of temperate countries.

1.4. VIRAL DISEASES

There are only a few viral diseases reported from mulberry viz. Mosaic disease, Yellow net vein and mulberry ring spot. Though occurring in many

countries they have not been reported to be serious ones.

1.4.1. ***Mosaic diseases:*** It is caused by mosaic virus and reported from almost all the countries. The intensity of the disease and the loss in crop yield vary considerably depending upon the variety and climatic conditions.

Symptom: The symptoms of the disease are inward curling of leaves particularly leaf margin and tip with chlorotic lesions on the leaf surface (Fig.19).

Figure. 19. Mulberry twig affected by mosaic disease showing the curling of leaves and chlorotic lesions on the leaf surface

Disease cycle: The disease spreads primarily through the infected plants. The transmission of the disease takes place by insect vectors and by grafting. Once the virus is inside the susceptible host tissues, it becomes systemic. The incubation period varies from 7-25 days. Depending upon the climatic and host pathogen relationship, the symptoms of the disease may be expressed or masked. The disease is found more common during rainy season.

Control: Uprooting and burning of diseased plants and elimination of insect vectors by spraying insecticides help in the control of the disease.

1.5. NEMATODE DISEASES

Nematode diseases are distributed world wide and found mostly in tropical and subtropical countries. They have wide range of host plants and cause economic damage to many crops including mulberry. There are different nematode species reported from mulberry viz., *Meloidogyne, Xiphinema, Pratylenchus* etc. Due to perennial nature of mulberry and no crop rotation more attention is required for the control of this disease.

1.5.1. ***Root-knot nematode:*** Root-knot nematode disease is caused by *Meloidogyne incognita* (Kofoid and White) Chitwood belonging to the super family Heteroderoidea order Tylenchida of class Secernentia of phyllum Nematoda.

Symptoms: The affected plants show stunted growth, marginal necrosis and yellowing of leaves. The underground symptoms include the formation of characteristic knots or galls on the roots (Figs.20 and 21a). Nematode damage the Xylem and Phloem tissues resulting in the disruption of water and food conduction.

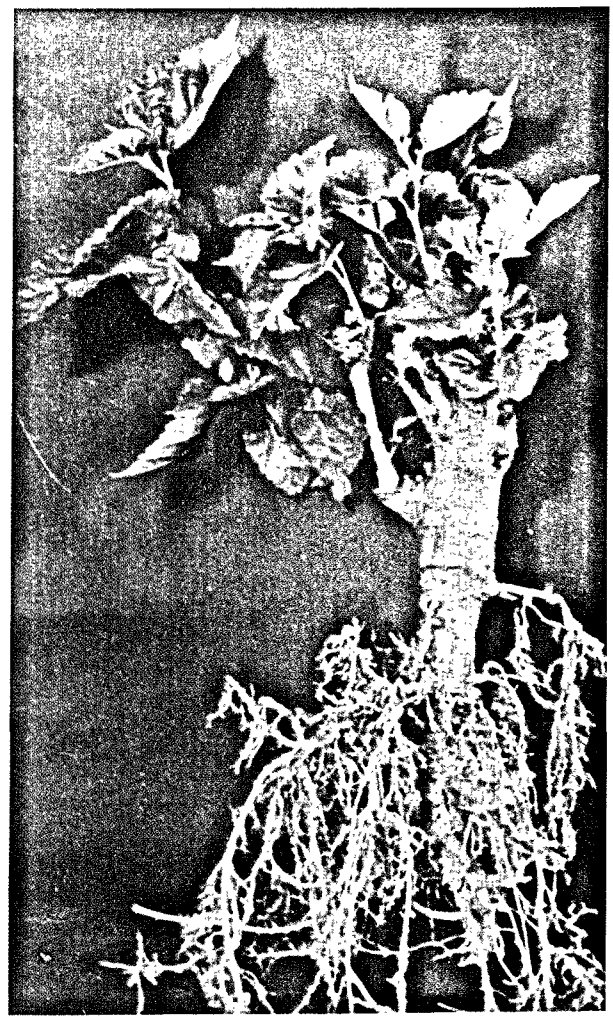


Figure. 20. Mulberry affected by root-knot nematode

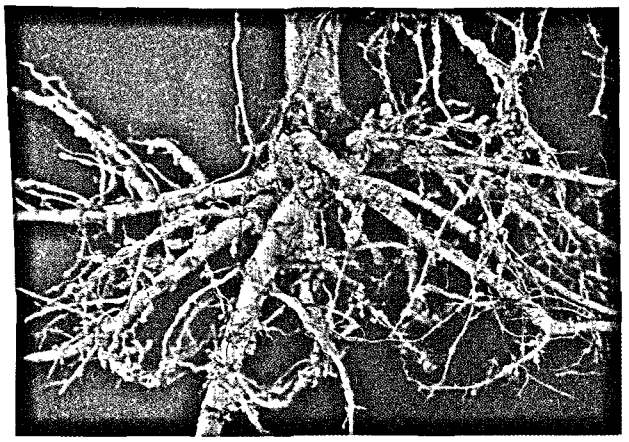


Figure. 21a. Root system showing the formation of galls/knots

Disease/life cycle: There are three stages in the life-cycle of the nematode viz., egg, larva and adult. The second stage female larvae enter the root through the hole made by the stylet and harbour in the sub-epidermal layer (Fig 21b). After entry it starts feeding on the parenchymatous cells. Due to the stimulus induced by the nematode, cells undergo repeated division and enlargement. As a result cancerous knots/galls appear on the roots. Female larvae undergo four moults in the roots and develop into a mature oval/spherical egg laying female. Each female lays 200-322 ellipsoid eggs covered with gelatinous substance (Fig.22). In favourable conditions eggs hatch and larvae are liberated into the soil. The nematode takes about 30-40 days to complete the life cycle and it can repeat the life cycle 2-3 times in its life span (Fig.23). Temperature from 15-30°C and soil moisture from 40-60 per cent are more favourable for its growth. In water stagnant and completely dry soils the intensity of nematodes is very less.

Figure. 21b. Second stage female larva entering the root

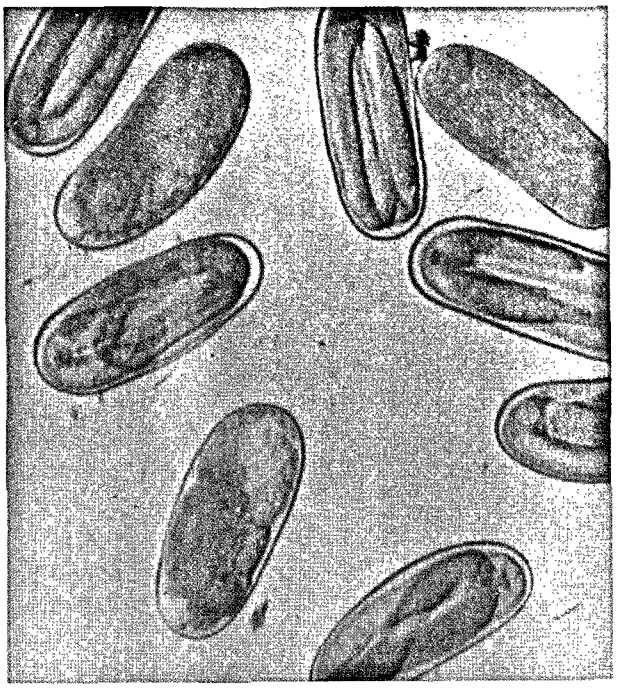


Figure. 22. Eggs of Meloidogyne incognita *causing root-knot disease in mulberry*

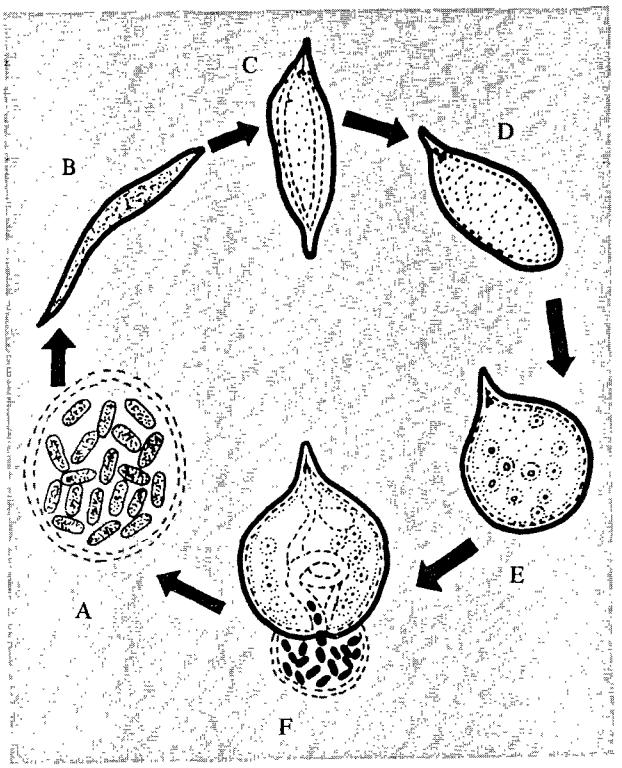


Figure. 23. Disease cycle of Meloidogyne incognita
A. Eggs within gelatinous matrix
B. Second stage infective larva
C. Larva with hemispherical posterior and terrainated spike
D. Female completed moults
E. Typical female
F. Mature egg laying female

The disease is very common in sandy soil under irrigated condition. The disease reduces the leaf yield in advanced stages by 10-12 per cent.

Control: As mulberry is a perennial crop and the disease is soil born in nature, integrated disease control is more important. The disease can be controlled by deep digging or ploughing of infested garden during summer, which exposes the nematode eggs and larvae to direct sunlight. Due to high soil temperature the nematode larvae and eggs are destroyed. Oil cakes like Neem in addition to the improvement of plant growth controls the disease. Application of Neem (*Azadirachta indica*) oil cake at the rate of one tonne per hectare per year in four equal split doses has been found to be effective. Application of nematacides like Aldicarb or Carbofuran at the rate of 30 kgs per hectare per year in four equal split doses along with fertilizer is also recommended. After application of these nematicides, they should be mixed in the soil by digging or ploughing followed by irrigation. The leaves can be used for silkworm rearing after 45-50 days from the nematicide application.

Varietal resistance against the root knot nematode disease is not yet known.

1.6. DEFICIENCY DISEASES:

Like any other crops, besides the various diseases caused by micro-organisms, mulberry also suffers due to the deficiency of available minerals in the soil.

1.6.1. ***Mineral deficiency in mulberry:*** Deficiency symptoms occur in mulberry mainly due to the non-availability of minerals, like nitrogen, phosphorous, potash, calcium, sulphur, zinc and magnesium. Disorders caused by the mineral dificiencies can be overcome by the application of suitable fertilizers/chemicals to the soil.

Nitrogen deficiency: Slow and weak growth of plant with less branching/vigour. Young leaves show chlorosis (Fig.24). Stem is slender and yellowish green with stunted root growth. Application of nitrogenous fertilizers like urea, ammonium nitrate and calcium nitrate at appropriate doses is recommended for correction.

Potassium deficiency: Marginal scorching of leaves in younger stage and later become coarse, non-jucy and necrotic (Fig.25). Stem and root systems become weaker. Application of potassium fertilizer at appropriate dose is recommended for correction.

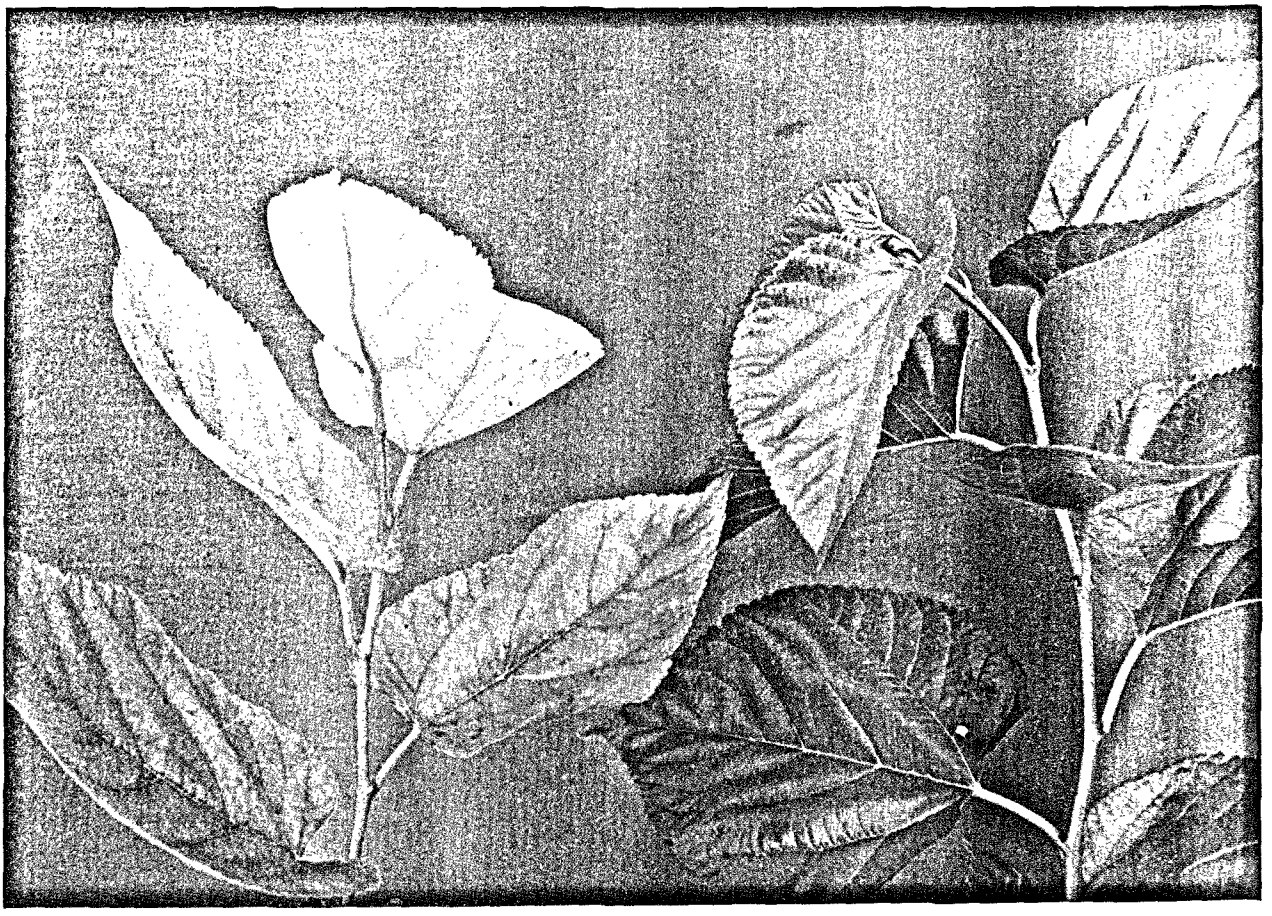


Figure. 24. Yellowing of mulberry leaf due to deficiency of nitrogen

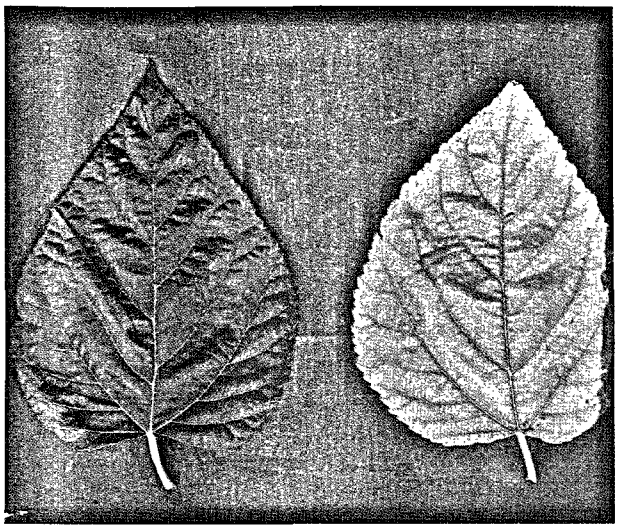


Figure. 25. Marginal scorching & yellowing of mulberry leaf due to deficiency of potassium

Phosphorus deficiency: Intra-veinal chlorosis of older leaves. The chlorosis spreads throughout the leaf followed by marginal necrosis and defoliation. Stem slender, without fresh growth and stunted growth of roots. Through application of phosphatic fertilizer the deficiency can be controlled (Fig.26).

Calcium deficiency: Defoliation of young leaves with necrosis along the veins. The stems become woody and short with yellowish tips. Roots become stubby and dry. Application of calcium nitrate at appropriate dose is recommended for correction.

Sulphur deficiency: Slight chlorosis of leaves, lack of plant growth. Application of gypsum or ammonium sulphate at appropriate dose is recommended for correction.

Zinc deficiency: Young leaves show interveinal and yellowish spots on leaves. Zinc sulphate should be applied at appropriate dose for the correction of the deficiency.

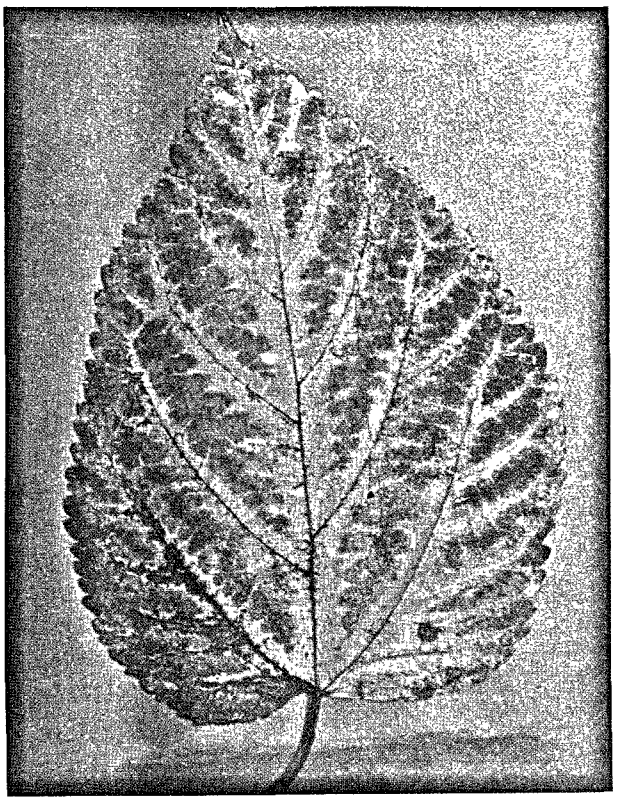


Figure. 26. Intra-veinal chlorosis of mulberry leaf due to deficiency of phosphorus

CHAPTER 2

PESTS OF MULBERRY AND THEIR CONTROL

Mulberry, like most of the economic plantations and field crops, is also subject to the attack of a vast pest complex belonging to a large number of insect orders and acarids. Though the frequent leaf picking and pruning of the shoot restrict the attack of pests, many of them still find enough time and place on mulberry for feeding and breeding on it.

The major insect orders known to be the pest of mulberry (in order of largest number of species attacking the mulberry) are:

(a) Lepidoptera
(b) Hemiptera
(c) Coleoptera
(d) Thysanoptera
(e) Orthoptera
(f) Isoptera

besides the Acarids.

In the following pages are given the details of the species known as pests of mulberry along with their life cycle, type of damage, symptoms and period of occurrence which are very essential to be known to identify the pest, assess the damage and plan an effective control. Control measures, individual and integrated, based on the above are suggested. A chapter on the forms and formulations indicating the forms in which they are available, how the solutions are to be prepared and the precautions to be taken before and after the application is also given (Chapter 5). In annex-I are given a list of commonly used pesticides including insecticides, acaricides and fungicides with their common names, commerical names, chemical names, and formulae, L D 50 for mammals and mode of action.

A number of other pests including a mollusc, *Pila globusa* have also been reported from mulberry causing occasional damage. But their occurrence being rare and localised, they have not been dealt in this handbook. Their control may be taken up following the guidelines given for the control of other pests or through reference to a specialist.

2.1. LEPIDOPTERA

The order Lepidoptera consists of small to large sized moths and butterflies. They are of great economic importance to mulberry cultivators as a very large number of species of this order in their caterpillar stage feed on mulberry leaves or cause damage to other parts of mulberry plants.

2.1.1. *Bihar hairy caterpillar, Spilosoma obliqua* Walker

(= *Diacrisia obliqua*) (Family : Arctidae)

Presence has been reported in India and Philippines

(a) ***Life Cycle:*** Adults (Fig. 1a) are light brown with brick red abdomen, peppered with dark row of spots laterally and dorsally. 1000-2000 eggs are laid in batches on the lower surface of the leaf (Fig. 1b). Eggs hatch in 5-7 days. Caterpillars moult six times. Fully grown caterpillar measures 4.5 to 5 cm. Anterior and posterior regions are black in colour and the rest of the body is reddish brown (Fig. 1d). The pupa is dark brown in colour and measures about 2 cm in length. Pupal period lasts for 12-14 days. The life cycle is completed in about 48 days.

(b) ***Type of damage and symptoms:*** Gregarious young caterpillars (Fig. 1c) feed upon the chlorophill layer of the leaf exposing the veins. Late instar caterpillars are voracious eater of mulberry leaves. The affected leaves look dead and dried and easily fall off. Clear branches without leaves can also be noticed after a severe attack.

(c) ***Period of occurrence:*** Incidence is frequent from August to February.

(d) ***Management/Control:***

(i) Installation of light traps to attract adults.
(ii) Collection and destruction of egg masses and gregarious young instars caterpillar.
(iii) Deep ploughing and flood irrigation for exposing and killing the pupae. and
(iv) Spraying of 0.2 per cent Dimethoate (safe period - 13 days) or DDVP (safe period - 17 days) on mulberry plants to kill the caterpillars.

2.1.2. *Cutworm, Spodoptera litura* (F.)

(= *Prodenia litura*) (Family : Noctuidae)

Presence has been reported in India

(a) ***Life Cycle:*** Adult moth (Fig. 2a) is stout. Forewings dark with wavy white markings. Hind-

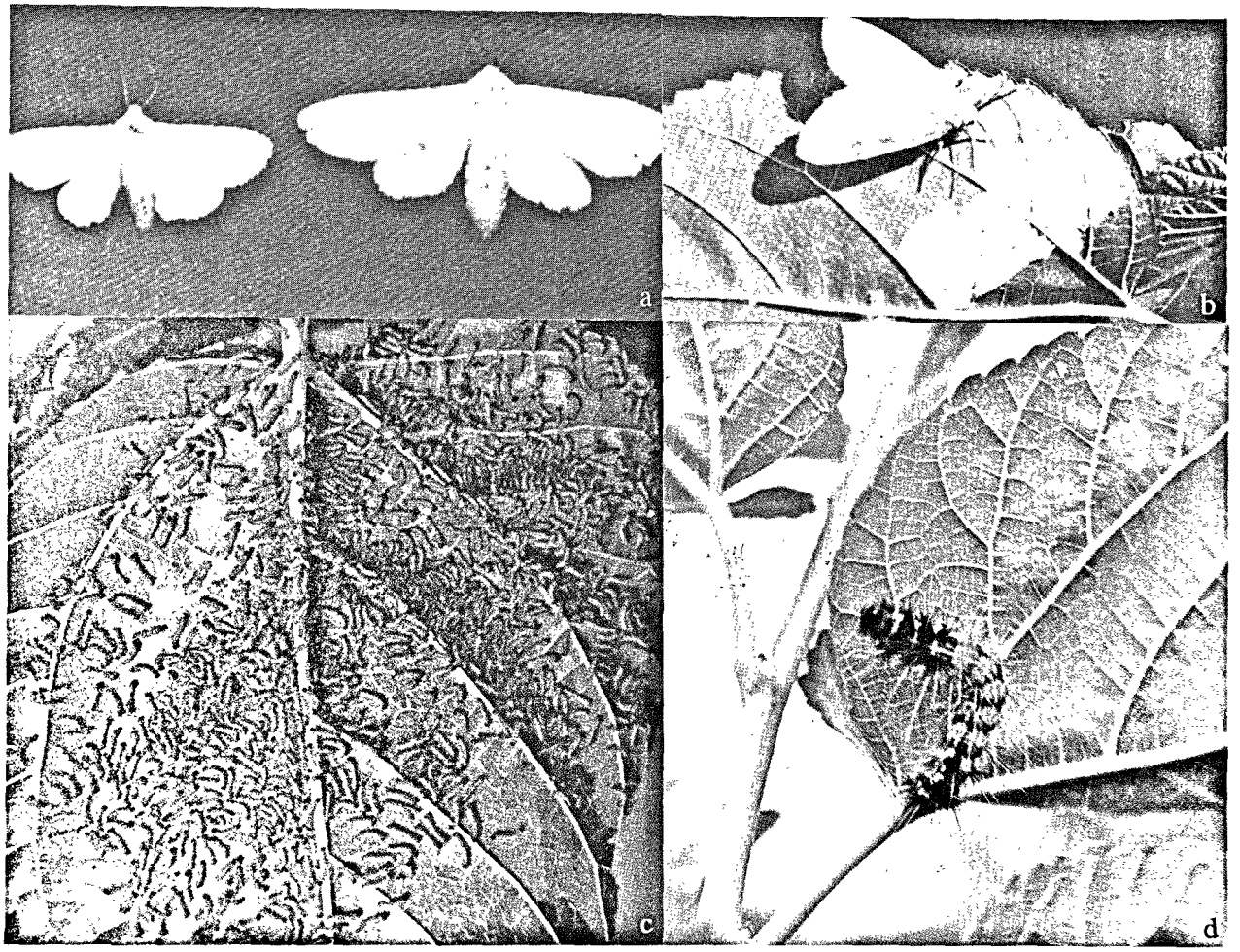


Figure. 1. Bihar hairy caterpillar
a) Adults
b) Eggs and adult female on mulberry leaf
c) Young gregarious caterpillars
d) Late age caterpillar

wings white with margins having a brown colour. Eggs are laid in clusters of 200-300 underneath the leaves covered with brown hairs. The incubation period is 4-5 days. The full grown caterpillar (Fig. 2b) larva is stout, cylindrical and pale greenish brown in colour with dark markings. They have transverse and longitudinal gray and yellow bands. The caterpillar is nocturnal in habit, measures 35-40 mm in length and pupates in the soil (Fig. 2c,d). the larval period lasts for 2-3 weeks. Adult emerges from pupa in about two weeks. Life cycle occupies 30-40 days.

(b) *Type of damage and symptoms:* The caterpillars attack the shoot of young plants and cut them. The cut portion of the shoot dries up and falls down. They also feed upon the leaves. Newly sprouted mulberry garden or the garden having young plants are found without branches having dried leaves.

(c) *Period of occurrence:* Mostly during August to February.

(d) *Management:*

(i) Deep ploughing of the mulberry garden exposes the different stages of pest which can be picked up and killed.

(ii) Deep digging around the mulberry plants after pruning and dusting of BHC 5-10 per cent kills the caterpillars. Safe period - 45 days.

(iii) Spraying of 0.025 per cent parathion on mulberry plants also kills the caterpillars. Safe period - 8 days.

2.1.3. ***Moringa hairy caterpillar, Eupterote mollifera* W.** (Family : Eupterotidae)

Presence has been reported in India

(a) *Life Cycle:* Male moth (Fig. 3a) are smaller in size and light yellow in colour. Females are larger and dark brown in colour. Freshly laid eggs are sulphur-yellow in colour and later changes to brownish yellow. Eggs laid in closely attached mass around the tender twigs or on the petiole of leaves (Fig. 3b) which hatch in 9-13 days. Larval stage has generally four moults and it takes about 68 days to pass through the five instars. Final stage caterpillars are dark in colour with thick growth of the hairy tufts

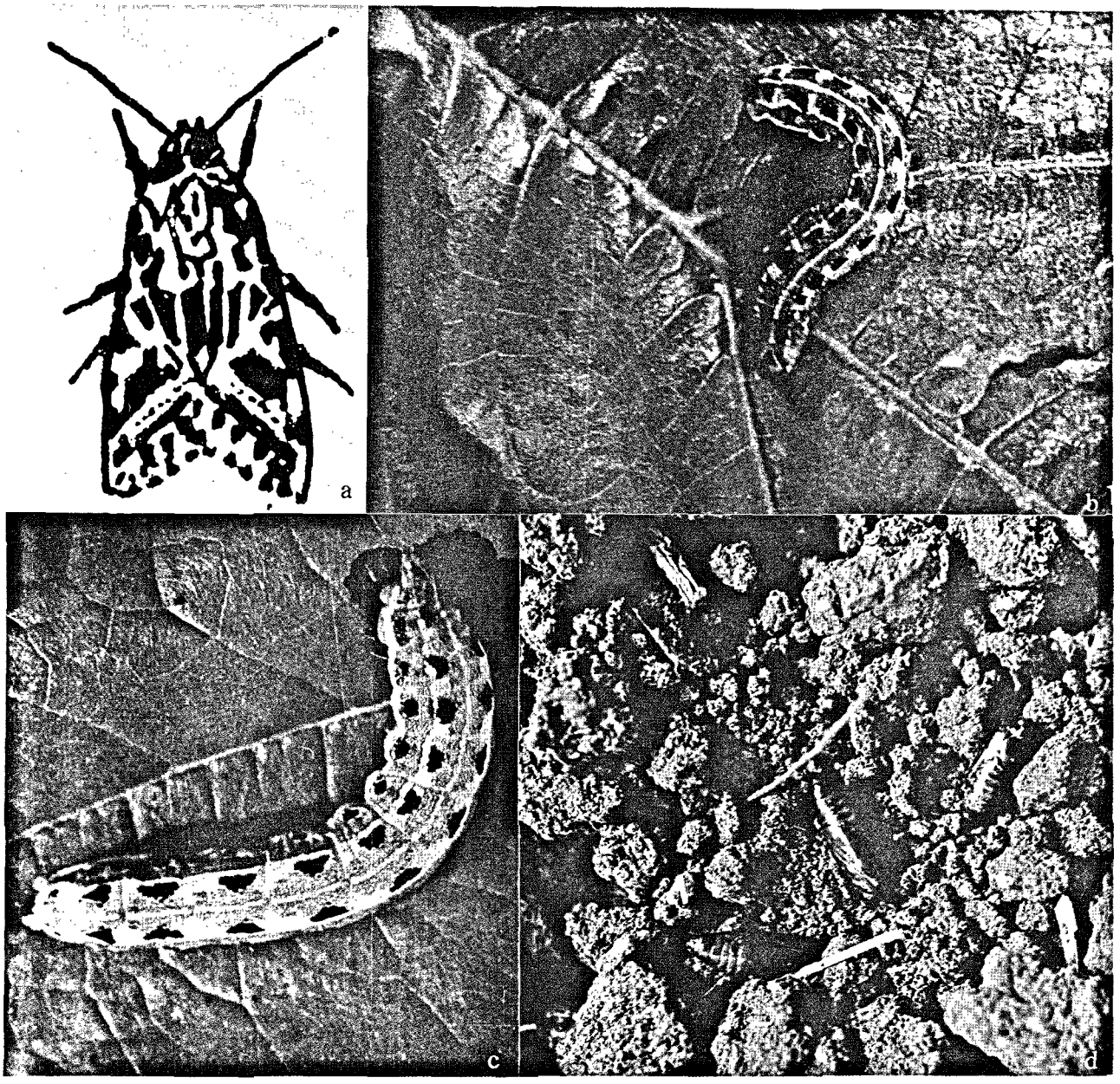


Figure. 2. Cutworm
a) Adult
b) Young caterpillar feeding on mulberry leaf
c) Late age caterpillar
d) Pupae in the soil

and each measures 48-50 mm in length (Fig. 3c). Pupation takes place in a soft thin cocoon, up of silk secreted along the hairs of the caterpillars. Pupa is dark brown in colour and measures 18-20 mm in length. Pupal stage lasts 35-60 days.

(b) ***Type of damage and symptoms:*** Caterpillars feed on mulberry leaves (Fig. 3c) leading to a reduction in the leaf yield. Branches of mulberry without leaves are noticed in the garden.

(c) ***Period of occurrence:*** Mostly during August to February.

(d) ***Management:*** As suggested against Bihar hairy caterpillar.

2.1.4. ***Tussock caterpillar, Euproctis fraterna*** (Moore) (Family : Lymantriidae)

Presence has been reported in India

(a) ***Life Cycle:*** Moths (Fig. 4a) are yellow in colour. Two dark spot are present on the apical angle and two larger ones on the cubital angle of the forewings of the female and an additional dark one near the costal margin in the forewing of the male. About 100-120 pale yellow coloured eggs are laid in masses on the underside of mulberry leaves by each adult female which are covered with yellow hairs (Fig. 4b). Eggs hatch in about 15-18 days. The hatched caterpillars are yellow in colour with dark tufts of hairs on the second and third ab-

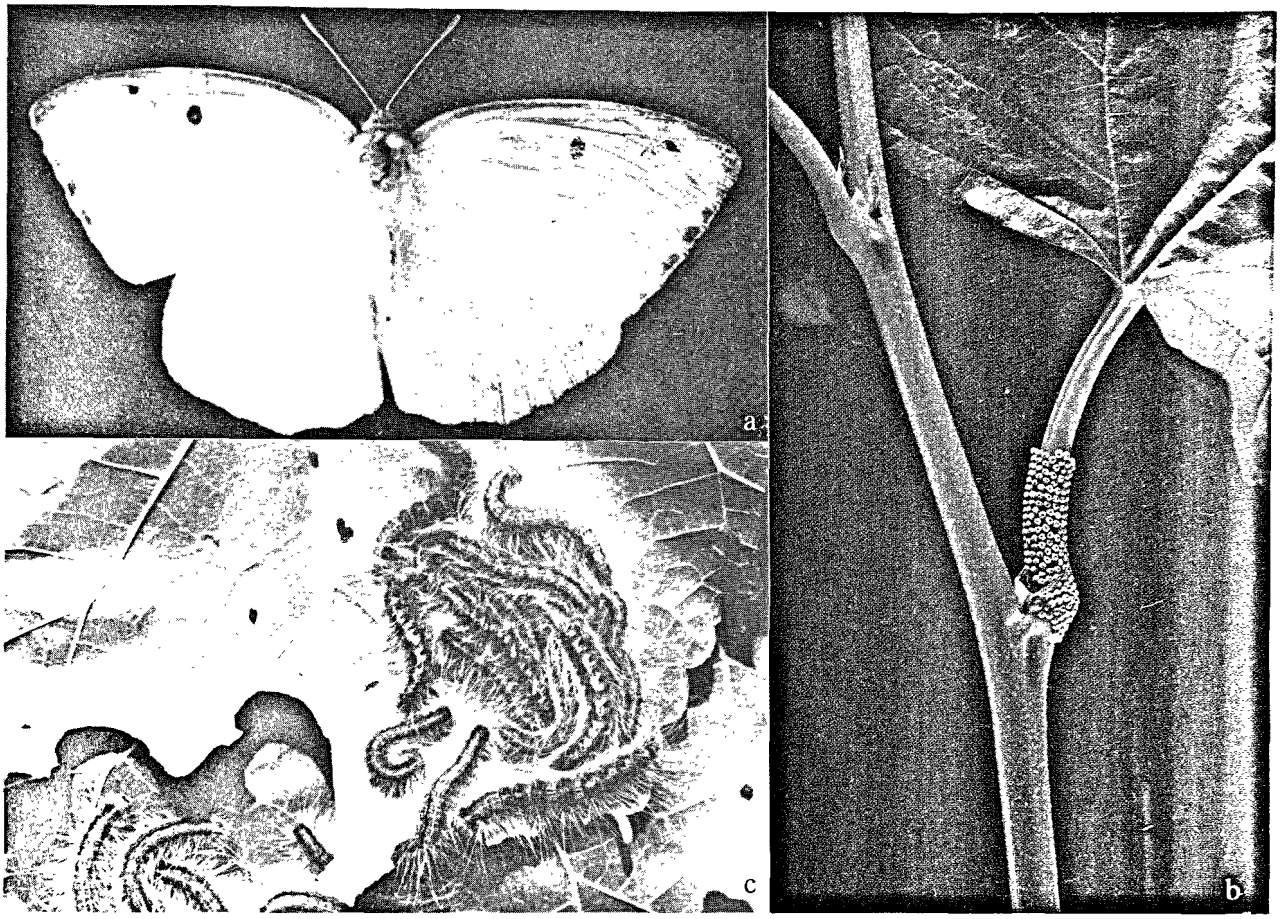


Figure. 3. Moringa hairy caterpillar
a) Adult
b) Eggs on the mulberry branch
c) Caterpillars

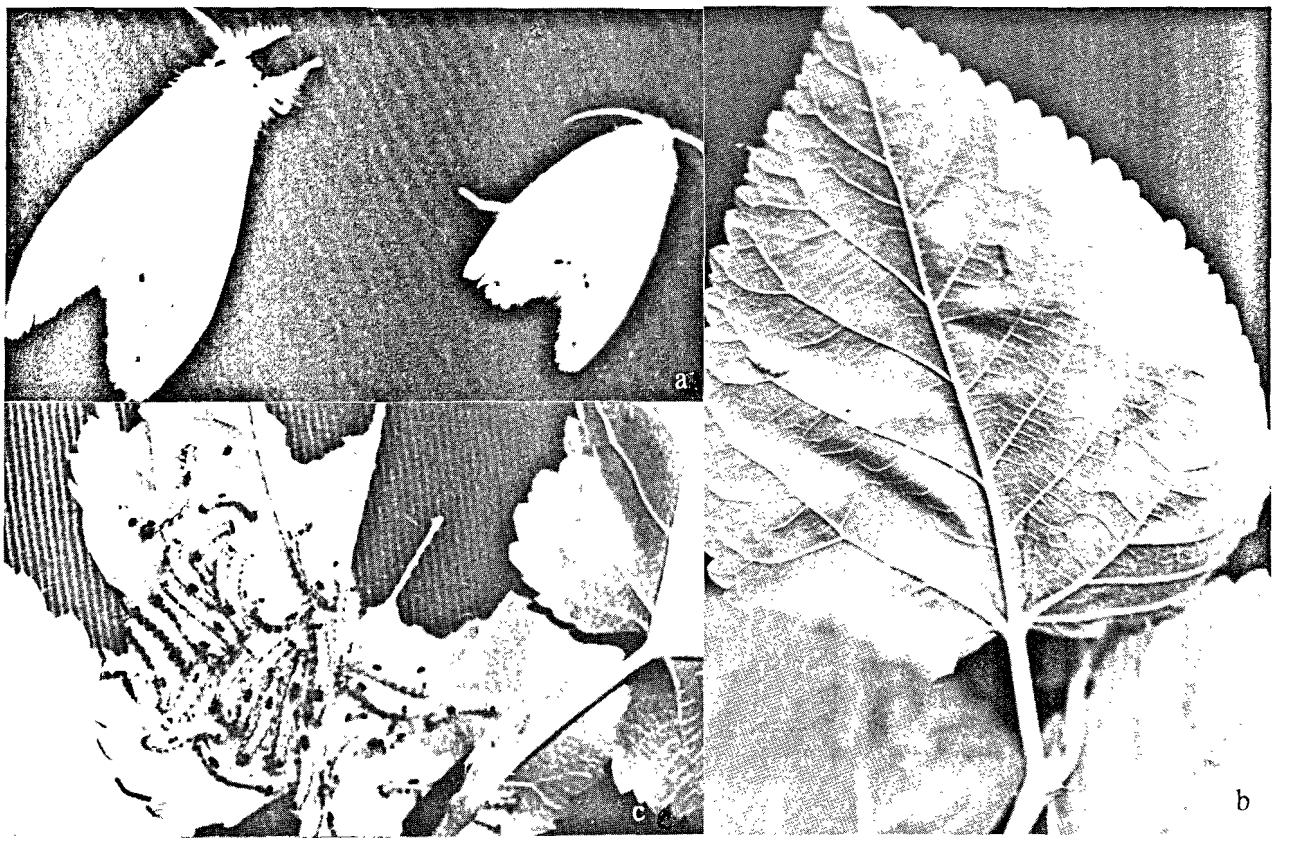


Figure. 4. Tussock caterpillar
a) Adult moths
b) Egg mass on the ventral side of the leaf
c) Tussock caterpillars

dominal segments. They feed on mulberry leaves gregariously. The final instar caterpillars are dark brown in colour and measure 20-25 mm in length (Fig. 4c). Larval duration is 60 days with four moults. Pupa is dirty brown in colour. Pupal stage lasts for about 13-15 days.

(b) *Type of damage and symptoms:* Caterpillar feed on the mulberry leaves leading to a reduction in the leaf yield. Branches of mulberry plants are seen without leaves.

(c) *Period of occurrence:* Mostly during March to August.

(d) *Management:* As in Bihar hairy caterpillar.

2.1.5. ***Browntail moth, Euproctis similis xanthocampa Dyar*** (Family : Lymantriidae)

Presence has been reported in China

(a) *Life Cycle:* Adult (Fig. 5a) female lay eggs in heaps (irregular in shape) on mulberry leaf covered with brownish yellow hairs from the tail of female moth. The caterpillars injure the spring buds and the buds after summer or spring pruning. The caterpillars have plenty of venomous bristles on the body surface (Fig. 5b) which also exist on the surface of cocoons. These venomous setae of caterpillars are irritating to human being causing itching rashes and even death if too much of these setae are inhaled. Caterpillar transforms into pupa (Fig. 5c) pupate on the twig or in the crevice. It has 4 generations in a year.

(b) *Type of damage and symptoms:* Caterpillars cause injury to buds and devour mulberry leaves. Attack of this pest reduces leaf yield. Branches of mulberry without leaves or injured buds can be noticed in the garden.

(c) *Period of occurrence:* Mostly starts from spring season and continues up to autumn.

(d) *Management:*

(i) Installation of light trap to attract adults.
(ii) Collection and burning of leaves bearing eggs and caterpillars.
(iii) In case of severe attack spray 80 per cent DDVP emulsi-fiable concentrate diluted with 1000 times of water. Safe period - 3 days.

2.1.6. ***Wasp moth, Amata passalis*** Fb. (Family: Amatidae)

Presence has been reported in India

(a) *Life Cycle:* Adult males are elongated with narrow and slender abdomen whereas the females are stout and bulky. The thorax and the abdominal segments are brick red in colour. Wings are brownish black in colour. There are seven transparent spots on the forewing (Fig. 6a). Freshly laid eggs are white in colour but gradually changes to yellow and finally turns dark brown in colour a day before hatching. A single female lays about 500 eggs round shaped on the ventral side of mulberry leaves. Hatching takes place in 6-7 days. The newly hatched caterpillar is dull white in colour with thin brownish hairs all

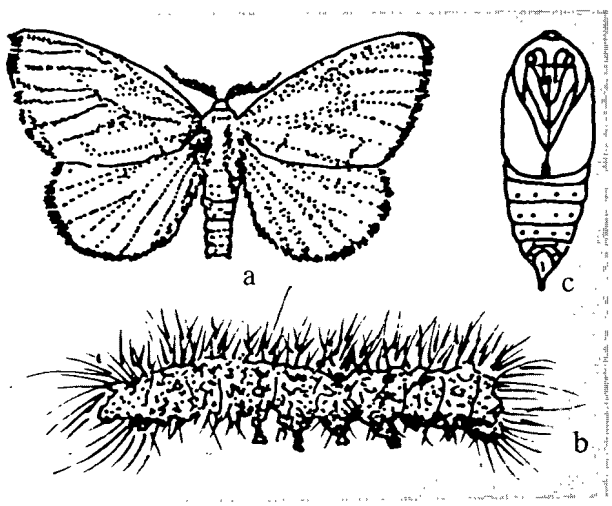


Figure. 5. Mulberry browntail moth
a) Male adult
b) Caterpillar
c) Pupa

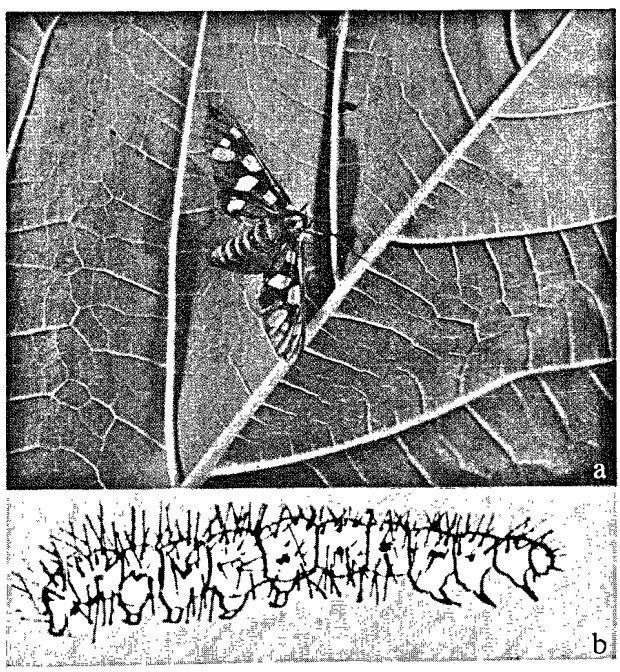


Figure. 6. Wasp moth
a) Adult moth
b) Caterpillar

over the body. The head capsule is shiny and the prothoracic segment is provided with a light brown shield. The caterpillars are active and scraps the chlorophyll layer of leaves. As the caterpillars grow, the body colour changes to brown. The full grown caterpillar measures 20-25 mm in length (Fig. 6b). When the caterpillar is disturbed, it emits a defensive fluid. The larval period lasts for about 32 days with 7 moults. The caterpillar pupates in the folds of leaves within a silken web. The pupa is pink in colour and measures 14-18 mm in length. The pupal duration is 10-12 days. The life cycle is completed in 48-51 days.

(b) ***Type of damage and symptom:*** Reduction in leaf yield. Branches without leaves are noticed in the garden.

(c) ***Period of occurrence:*** Mostly during February to August.

(d) ***Management:***

(i) Collection and destruction of egg masses and young gregarious caterpillars.
(ii) Application of 0.2 per cent DDVP on mulberry plants. Safe period - 17 days.

2.1.7. ***Ceryx godarti,*** Bdv. (Family: Amatidae)

Presence has been reported in India

(a) ***Life Cycle:*** Various stages of this pest generally resembles *A.passalis*. The forewing and hindwing of adult *C.godarti* have six and three clear areas lacking scales as compared to seven and four such spots respectively in *A.passalis*. About 130 to 235 eggs are laid by each female moth in batches. Eggs are deposited on the lower surface of the tender leaves. The eggs which are round in shape and pale yellow in colour, hatch in about five days. Young caterpillars are light brown in colour and bear hairs on all the segments. Caterpillars undergo four moults. Fully grown-up caterpillars measure about 22-25 mm in length. At this stage, caterpillars are almost black in colour and thickly covered with hairs. the larval stage lasts for about 30 days. The pupation takes place under the dry leaves and a thin cocoon is made out of its hairs and secreted silk. Pupae are dark copper brown in colour measuring 11-14 mm in length. Pupal stage occupies about 12-13 days.

(b) ***Type of damage and symptoms:*** As in *A. passalis*.

(c) ***Period of occurrence:*** As in *A.passalis*.

(d) ***Management:*** As in *A.passalis*.

2.1.8. ***Spanworm, Phthonandria atrilineata*** (Butler) (= *Hemerophilla atrilineata*) (Family : Geometridae)

Presence has been reported in Burma, China, Japan, Korea and Viet Nam

(a) ***Life Cycle:*** This insect has two generations per year in northern part of China and four generation per year in the middle part of China. Body of the adult (Fig. 7a) is dark brown in colour. The forewing is yellowish gray and has two black waves forming stripes on it. A big dark brown zone exists in the centre of the forewing, spreading from the wing base towards the outer margin. Outer margin of the forewing is wavy. Markings on the hindwing are similar to those of the forewing. It undergoes a complete metamorphosis and hibernates in caterpillar stage. The infant caterpillars are active in day time whereas in later stages move actively during night time. The caterpillar (Fig 7b) stays on the branch of mulberry tree by the abdominal legs, supporting the upper part of its body by the silk thread, spun from its mouth. Caterpillars are grayish brown and resemble the dead twig. Hibernated caterpillars moult 2 or 3 times, grow up fully and come down to the surface of the earth to transform into pupa (Fig. 7c).

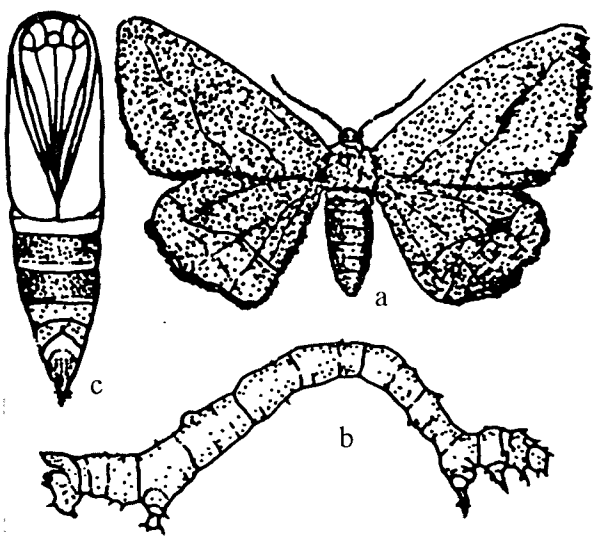


Figure. 7. Mulberry spanworm
a) Adult
b) Caterpillar
c) Pupa

(b) ***Type of damage and symptoms:*** Cryptic coloured caterpillars overwinter on the surface of shady side of the bark or in any crevice, begin feeding on mulberry winter buds which are just beginning to unfold after the dormant season is over. This is the critical period of damage by this

pest. They also feed voraciously on mulberry buds after summer pruning decreasing the summer-autumn leaf yield. Besides buds, they also feed on mulberry leaves.

(c) *Period of occurrence:* Summer, autumn and winter seasons.

(d) *Management:*

(i) Tying of the mulberry shoots together with a straw rope during autumn to enable the caterpillars to creep on the rope for overwintering and untying of the rope in next spring and burning of the rope together with the caterpillars on it.
(ii) In case the population is not so numerous as to warrant for the spraying of insecticide, collection and destruction of eggs and caterpillars are economical and
(iii) Spraying of 80 per cent DDVP emulsifiable concentrate diluted with 1000 times of water. Safe period - 3 days.

2.1.9. ***Mulberry pyralid, Margaronia pyloalis*** Walker (= *Glyphodes pyloalis*) (Family : Pyralli-dae)

Presence has been reported in Burma, Indonesia, Japan, Korea and Viet Nam

(a) *Life Cycle:* Adult (Fig. 8a) of this insect measures about 1 cm. in body length. Body is grayish white in colour. At the resting stage of the moth the wings are folded behind the body and the whole body takes a triangular shape the fore-wings are nearly triangular and grayish white, whereas the hindwings are semi-circular and white. Usually, 100-400 eggs are laid by a single mother moth, Eggs are deposited along the leaf-vein of the underside of leaves one by one. Eggs are soft, flat, spherical and semi-transparent measuring about 0.7 mm in diameter. Caterpillars hatch from these eggs in about 5-6 days. The newly hatched caterpillars swarm on the backside of mulberry leaves, covering themselves with fine thread-net, spun by them. They eat leaf-flesh, leaving upper cuticular layer. Thereby, leaves become transparent. At the 3rd stadium and thereafter caterpillars eat leaves, binding leaves with thread, therefore, sometimes mulberry leaves become transparent and sometimes become like not leaving leaf-veins. The full grown caterpillars (Fig. 8b) measures about 2 cm in body length. Caterpillars are light green at younger stages whereas the mature caterpillars are light pink or brown in colour. In about half-a-month they moult four times to become mature caterpillars and finally

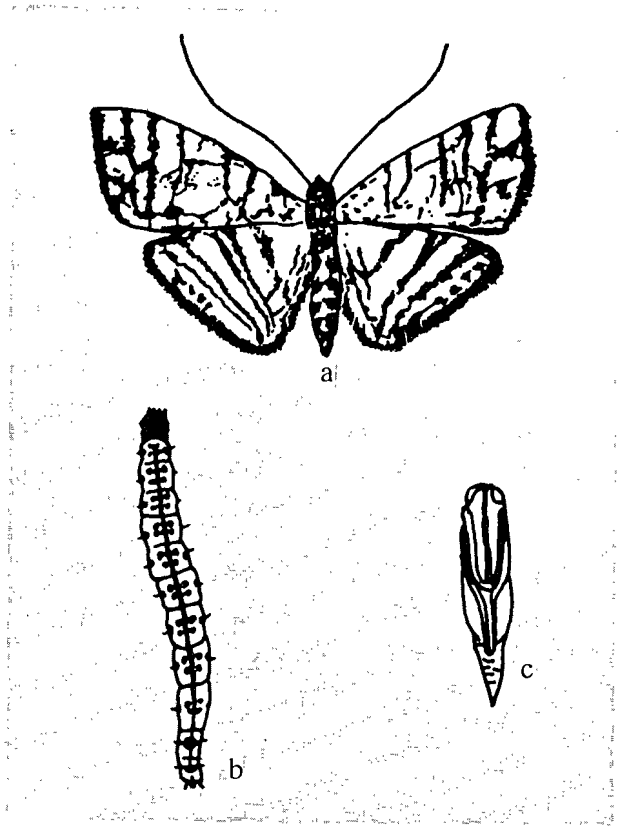


Figure. 8. Mulberry pyralid
a) Adult
b) Caterpillar
c) Pupa

turn into pupae (Fig. 8c). Pupae are brown in colour. The life cycle is completed in about a month's time.

(b) *Type of damage and symptoms:* Reduction in leaf yield and binded leaves with threads are noticed.

(c) *Period of occurrence:* Appears in sum - mer season and continues to cause damage upto autumn season.

(d) *Management:*

(i) Installation of light trap to attract the adults.
(ii) Collection and destruction of eggs and caterpillars.
(iii) Paper trashes or straw should be gathered near the mulberry stems, to enable the matured caterpillars to come down near the ground to hide into these trashes. Once the caterpillar have come down, the paper trashes or straw should be collected and caterpillars should be destroyed.
(iv) Spraying of infested mulberry plants with 0.2 per cent DDVP (Safe period - 17 days) or 0.1 per cent BHC (Safe period - 11 days) to kill the caterpillars.

2.1.10. ***Leaf-roller, Margaronia pulverulentalis*** (Hmps) (Family : Pyralidae)

Presence has been reported in Malaysia

(a) ***Life Cycle:*** Adults are grayish white in colour with black brown stripes on the forewings and each measures about 10 mm in body length. Adult female lays gelatinous eggs on the young leaves near the terminal buds. The caterpillars feed on leaves and produce spinning filaments when they grow which binds the leaf blades together. The caterpillars are greenish brown in colour with number of black brown spot regularly arranged on the side and back of the abdominal segments (Fig. 9a). Fully grown caterpillar measures about 20 mm in length. the mature caterpillar normally turns into pupa (Fig. 9b) in the grass.

(b) ***Type of damage and symptoms:*** Mulberry varieties which have multilobe leaves are relatively more prone to attack possibly due to larger surface area to bind the leaf blades together. Attack by this pest causes reduction in leaf yield. Rolled leaves of mulberry can be observed in the garden.

(c) ***Period of occurrence:*** Attack is usually noticed between the end of rainy season (February) to the end of dry season (September). However, severe damage generally takes place during dry season.

(d) ***Management:***

(i) Pruning of the infested branches followed by the destruction of the caterpillars.

(ii) Spraying of mulberry with 0.1 per cent BHC (Safe period - 11 days) or 0.2 per cent DDVP (Safe period - 17 days).

(iii) Biological control with the help of its natural enemies like *Apanteles* spp. and *Diadegma* spp.

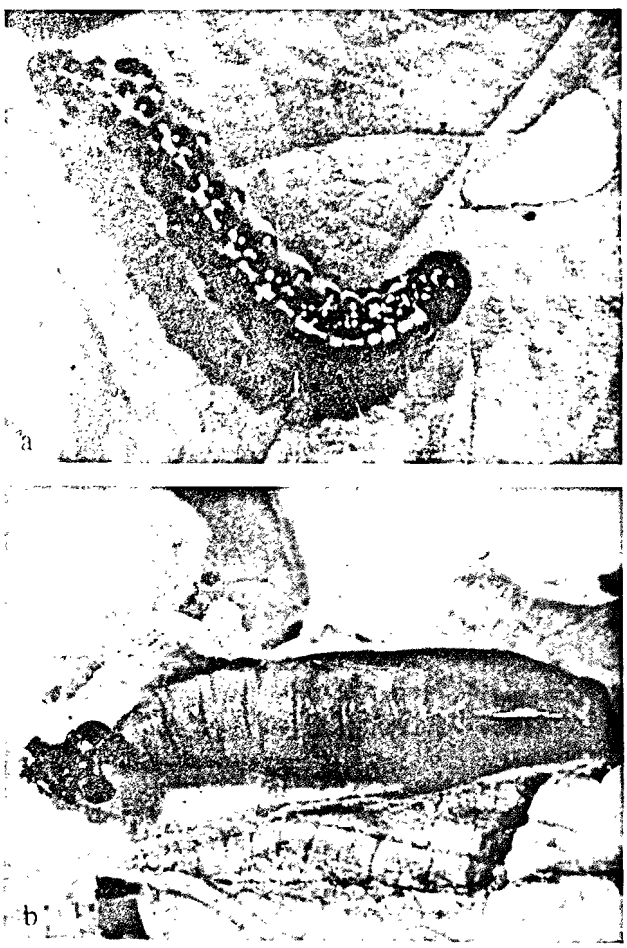


Figure. 9. Leaf-roller
a) Caterpillar
b) pupa

2.1.11. ***Leaf-tier, Diaphania pyloalis*** Walker (Family : Pyraustidae)

Presence has been reported in China

(a) ***Life Cycle:*** Adult (Fig. 10a) female deposits eggs by the side of leaf veins on the under surface of mulberry leaves. The caterpillar (Fig. 10b) devours the mesophyl and lower epidermis from undersurface of leaf, leaving only a transparent layer of upper epidermis which are often called "Attic windows". From 3rd stadium onwards the caterpillars generally tie or fold one to several blades of mulberry leaves with the silk secreted by them to form a hiding place for them to feed within. The caterpillars overwinter by hiding themselves in crevices during the end of autumn season. Pupae (Fig. 10c) are formed within the folded and tied leaves or in crevices which are generally protected by faint films of silk secreted by the mature caterpillars.

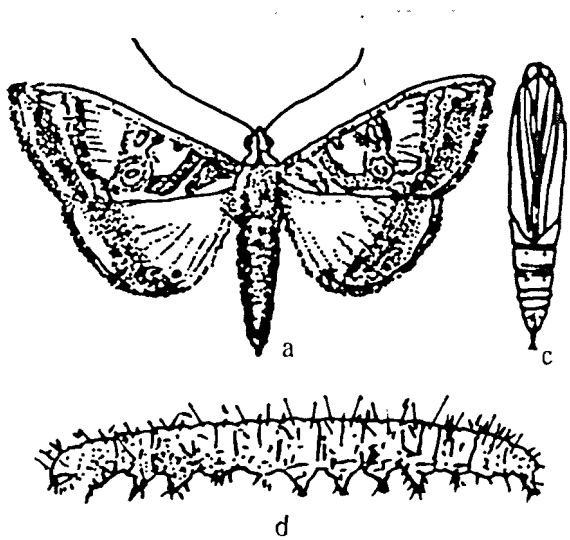


Figure. 10. Leaf-tier
a) Adult
b) Caterpillar
c) Pupa

(b) *Type of damage and symptoms:* Quantitative and qualitative loss of mulberry leaves. Tied or folded mulberry leaves are observed in the garden.

(c) *Period of occurrence:* Summer and autumn seasons.

(d) *Management:*

(i) Collection of tied or folded leaves with caterpillars within and their destruction.
(ii) Tying of straw on the mulberry trunks to entice the matured caterpillars to creep into them and their destruction.
(iii) Spraying of 80 per cent DDVP emulsifiable concentrate diluted with 1000 times of water. Safe period - 3 days.

2.1.12. *Clear-winged moth, Paradoxecia pieli* Liou (Family : Aegeriidae)

Presence has been reported in China

(a) *Life Cycle:* Eggs are laid on the undersurface of mulberry leaves by the side of leaf veins (Fig. 11b,c). After hatching, caterpillars tunnel (Fig. 11c) downward within the shoots. The faeces of caterpillars are expelled out of the shoots through small holes spaced at regular intervals of about 3 cm on the surface of shoots. The caterpillars pupate next summer. Before pupation, the mature caterpillar gnaw before hand an "emerging hole" about 2.5 mm above the last hole, leaving a flimsy layer of bark, untouched by the matured caterpillar to serve as a protection over the emerging hole. After this, the mature caterpillar retreate downward to the bottom of its tunnel to pupate there. Before emerging, the pupa (Fig. 11g) wriggles upward, with the aid of rings of dentate projections on some of the pupal segments, to the place where the emerging hole is located. The newly emerged adult (Fig. 11a) forces the flimsy bark away and emerges. Sometimes two caterpillars are found existing within the same shoot but their respective tunnels never coincide with each other though the space between these two tunnels is only like septum. The leaves growing on the attacked shoot become small sized, sometimes the shoots crack or wilt.

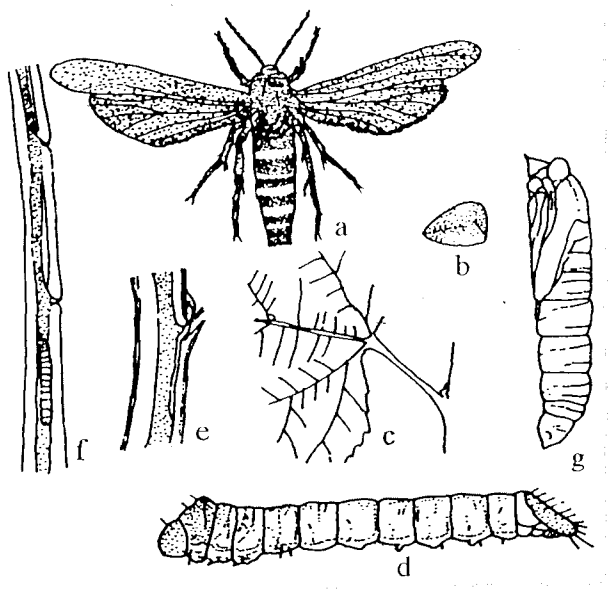


Figure. 11. Clear-winged moth
- *a) Adult*
- *b) Egg mass*
- *c) Egg laid near leaf vein on the lower surface of the leaf*
- *d) Caterpillar*
- *e) Caterpillar boring the tunnel*
- *f) Damaged mulberry shoot*
- *g) Pupa*

(b) *Type of damage and symptoms:* Reduction in leaf yield. Cracked or wilted shoots or shoots of mulberry having tunnel (Fig. 11f) are observed.

(c) *Period of occurrence:* Throughout the year.

(d) *Management:*

(i) Inspection of shoots of mulberry, against holes cracks and tunnels.
(ii) Application of permethrin emulsifiable concentrate diluted in water 1:500 and injection of this diluted emulsion into the tunnels. Safe period - 8 days.

2.1.13. *White caterpillar, Rondotia menciana* Moor (Family : Bombycidae)

Presence has been reported in China

(a) *Life Cycle:* Adult female (Fig. 12a) moth with black hairs on its ventral part of the abdomen lays hibernating eggs (Fig. 12c) while moth with yellow hairs on the ventral part of the abdomen lays non-hibernating eggs (Fig. 12b). Generally, it has three generations per year but uni-and bi-voltinisms are also observed. Eggs (Fig. 12d) are laid as egg piles on twigs or trunks or, in case of non-hibernating eggs, on leaves. The surface of the egg pile of hibernating eggs is smeared with black abdominal hairs of its mother moth. The surface of non-hibernating egg pile is bare. Caterpillars (Fig. 12e) of this insect chew holes through the mulberry leaves (Fig. 12g) from the undersurface. The hibernating eggs overwinter in egg piles stickin on the bark of mulberry.

(b) *Type of damage and symptom:* Leaf yield and the nutritional value of the leaves are reduced. Mulberry leaves with holes are observed.

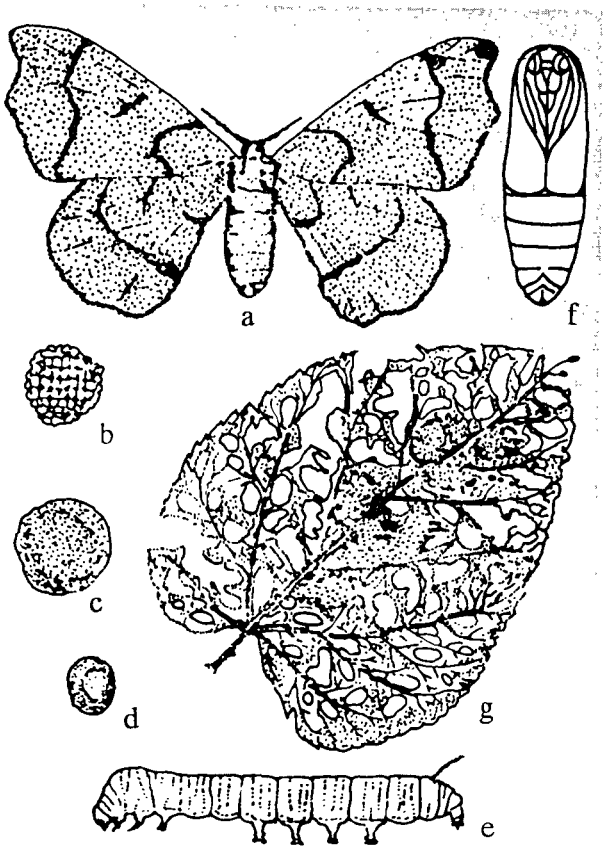


Figure. 12. White caterpillar
- *a) Female adult*
- *b) Non-hibernating egg pile*
- *c) Hibernating egg pile*
- *d) Egg*
- *e) Caterpillar*
- *f) Pupa*
- *g) Damaged mulberry leaf*

(c) *Period of occurrence:* Summer and autumn seasons.

(d) *Management:*

(i) Inspection of cuttings and grafts against egg-piles before transportation.
(ii) Scrapping of the hibernating egg piles from the bark and burning.
(iii) Piercing of the pupae within the cocoons to death.

2.1.14. *Wild silkworm, Bombyx mandarina* Leech (Family : Bombycidae)

Presence has been reported in China and India

(a) *Life Cycle:* Adult female (Fig. 13a) is larger than male (Fig. 13b). Hibernating eggs are laid on mulberry trunks or twigs while non-hibernating eggs are often laid on mulberry leaves. The newly tatched caterpillars generally congregate to the top of the twigs to feed on the tender leaves. Late age caterpillars (Fig. 13c) spread themselves in the garden and devour the mulberry leaves. They spin cocoons at the crotches of trees or within rolled leaves and turns into pupae (Fig. 13d) within them.

(b) *Type of damage and symptoms:* Attack of this pest brings about reduction in leaf yield. Mulberry shoots are observed without leaves.

(c) *Period of occurrence:* Throughout the year.

(d) *Management:*

(i) Collection and destruction of hibernating eggs and young caterpillars.

(ii) Spraying of mulberry with 80 per cent DDVP emulsifiable concentrate diluted with 1000 times of water. Safe period - 3 days.

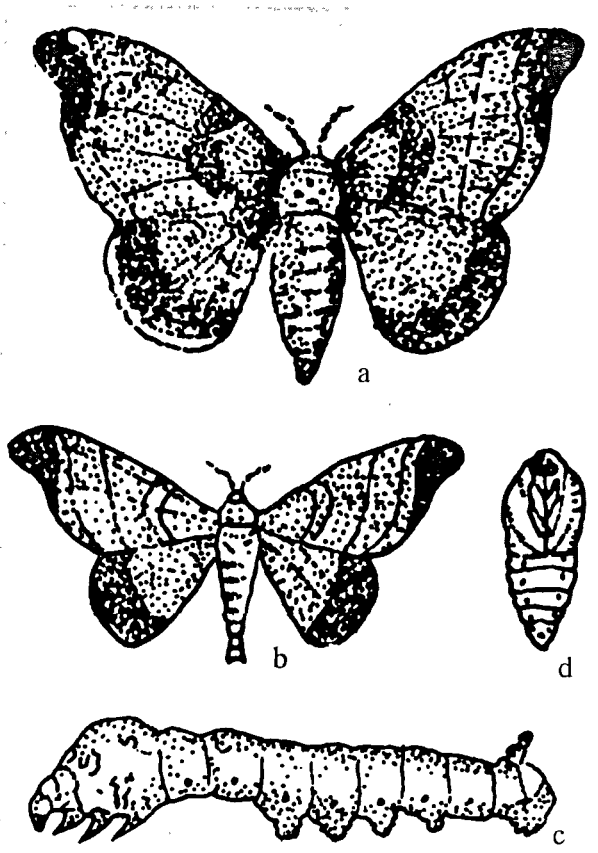


Figure. 13. Wild silkworm
- *a) Female adult*
- *b) male adult*
- *c) Caterpillar*
- *d) Pupa*

2.2. HEMIPTERA

This order consists of plant bugs and also referred to as a separate order Homoptera. Members of this order are sap feeders and some of them cause considerable damage to mulberry.

2.2.1. *Black scale insect, Saissetia* spp. (Family: Coccidae)

Presence has been reported in Bangladesh, India and Viet Nam. The Indian species has been identified as Saissetia nigra *(Nietm)*

(a) *Life Cycle:* Adult female of *S. nigra* lays 300-600 eggs which are minute, white and elongated. The colour of egg becomes reddish-brown with the advancement in age. The female shields the eggs and in about 6 days, they hatch. Within a few hours, the nymphs crawl and select the place of feeding on the stem. It secretes a fibrous waxy material which hardens to form the scale. The female moults three times while the male twice. In the process of moulting they lose the appendages. This make them sedentary in nature. Reproduction takes place parthenogenetically.

(b) *Type of damage and symptoms:* Black scale sucks the sap of the plants and affected shoots start dying from the distal end. The affected shoot is studded with thousands of dark brown or black scales (Fig. 14a,b). Yellowish or mottled appearance of the leaf blade can also be noticed.

(c) *Period of occurrence:* Mostly in summer months.

(d) *Management:*

(i) Diesel oil and soap emulsion (1:3 ratio) swabbing on the stem to dislodge the scale insects.
(ii) Scrapping with a blunt edge wooden plate to dislodge these insects.
(iii) Lime-sulphur swabbing on stem.
(iv) Spraying of 0.05 per cent malathion also controls this insect attack. Safe period - 10 days. In case of severe attack, the chemical control measure suggested against the mulberry scale insect in the following paragraphs should be followed.

2.2.2. *Mulberry scale insect, Pseudaulacapsis pentagona* (Torgioni, Tozzetti) (= *Sasakiaspis pentagona,* = *Diaspis pentagona*) (Family : Diaspididae):

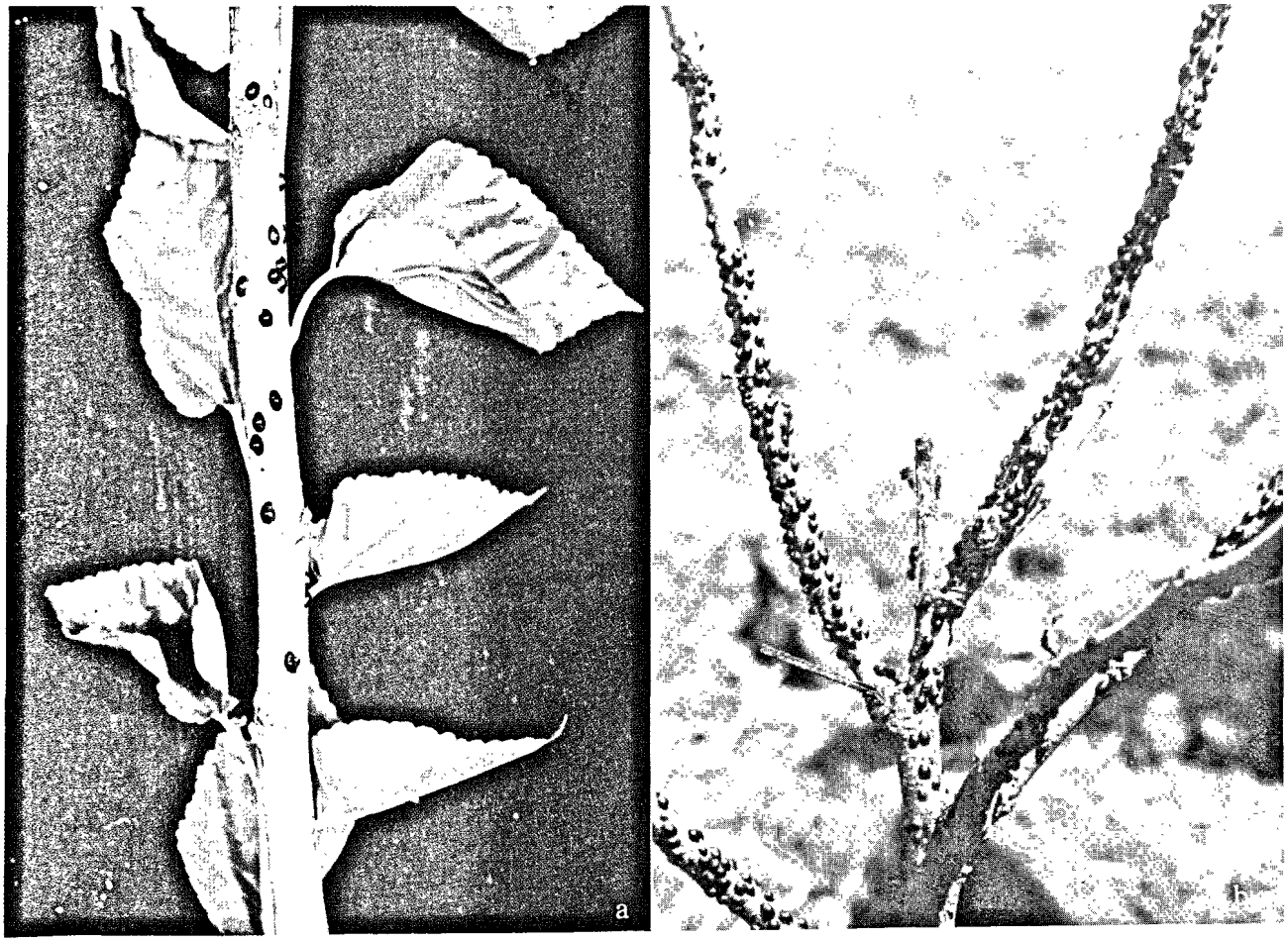


Figure. 14. Black scale insect
a) Initial stage of attack
b) Advanced stage of attack

Presence has been reported in Burma, China, Indonesia, Iran, Japan and Viet Nam

(a) *Life Cycle:* Male scales (Fig. 15a) are silver white, long and elliptical. Three projecting lines are observed on the dorsal side. Female scales (Fig. 15b,c,d) are round or seldom elliptical, flat and white or grayish brown, measuring about 2 mm in diameter. Females retain the shape throughout their lives. It has 3-5 generations per year and overwinters as female adults. On completion of hibernation, adult female deposits eggs under the scale. After laying eggs, females die. Eggs are short elliptical, measuring 0.25 mm in length. A female deposits about 40-200 eggs. In about 10 days, male nymphs hatch out from pale-reddish eggs. Hatched nymphs crawl and settle on different parts of mulberry. The female nymphs moult thrice. The male nymphs become pupae after second moult and then emerge as winged adults. The adult females need not mate always to produce young ones.

(b) *Type of damage and symptoms:* These insects are sap suckers. Mulberry trees frequently suffer badly from these scales which occur on the stem and usually succumb to their attack if the insects are not controlled in time. Infested mulberry yield scanty amount of leaves of inferior quality and the budding percentage of the infested trees is decreased. Branches of mulberry studded with scales are observed.

(c) *Period of occurrence:* Throughout the year except winter months.

(d) *Management:* Measures suggested for control of black scale insect should be practiced. However, in case of severe attack, a combination of following insecticides should be sprayed:

50 per cent Phosmet emulsifiable concentrate - 10 ml
50 per cent Malathion emulsifiable concentrate - 6 ml
80 per cent DDVP emulsifiable concentrate - 4 ml
Water - 10 litres

To prepare the combination of above insecticides, the steps mentioned below should be followed:

(i) Fill a knapsack sprayer with 10 litres of water, pour the stated amount of above mentioned insecticides into the tank. Stir to mix the added chemicals with the water in the tank.

(ii) Pour warm water into a bowl containing 62 g of detergent powder. Stir to mix thoroughly detergent powder with warm water.

(iii) Pour the mixture prepared by following the steps mentioned against (ii) into (i) or vice-versa.

(iv) As soon as the liquids in the tank are fully mixed, undertake spraying without delay.

This mixture should be sprayed twice at the interval of seven days depending upon the programme. Safe period - 10 days.

Biological control of this insect pest by using a parasitoid, *Prospaltella berlesie* has been reported to be highly successful.

2.2.3. ***Soft scale insect, Pulvinaria maxima*** Gr. (Family : Coccidae)

Presence has been reported in India and Thailand

(a) *Life Cycle:* The adult scales are shield-shape, oval, rater convex and about 2-3 mm in body length. As with other scale insects the first instar nymph (Crawler) is the active discursive phase responsible for starting new infestation. Eggs are laid beneath the body of the mature female in a conspicuous egg-sac, whereupon the female dies.

(b) *Type of damage and symptoms:* Young shoots and young leaves are infested with this scale

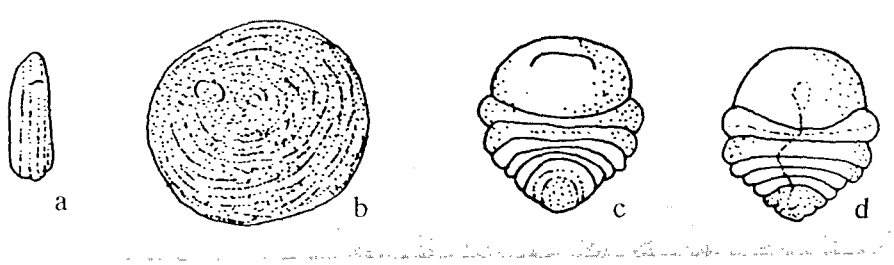


Figure. 15. Mulberry scale insect
a) Male scale
b) Female scale
c) Dorsal view of female adult
d) Ventral view of female adult

(Fig. 16). Affected leaves gradually wilt and the honey dew secreted by the insect cause sooty mould formation on the lower leaves. The leathery brown females and the small white males puparia are also seen on the stem or leaves of the infested plant. This pest is usually attended by ants for the honey dew secreted.

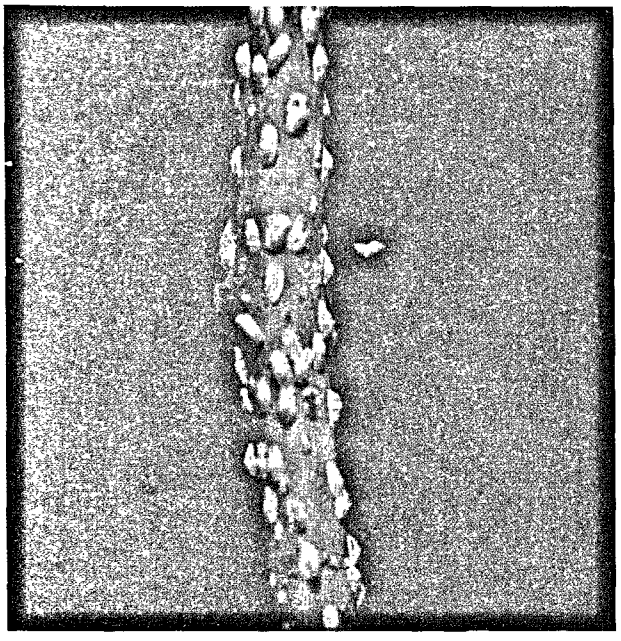


Figure. 16. Mulberry branch attacked by soft scale insect

(c) *Period of occurrence:* Throughout the year, maximum in summer months.

(d) *Management:* The best remedy is to promptly prune all the first infested shoots and burn them. As regards the chemical control, measures suggested against black scale insect should be followed. However, in case of severe attack, the insecticidal combination suggested against mulberry scale insect should be undertaken.

2.2.4. ***Red scale insect, Aonidiella aurantii*** (Maskell) (Family : Coccidae)

Presence has been reported in India and Viet Nam

(a) *Life Cycle:* The young red scale insects are born at the average rate of 2-3 a day for a period of about 2 months during warmer months. The first instar crawlers have well developed legs and antennae and move about for an hour or so before settling, when they begin to cover themselves with a white waxy covering. The female moults twice at 10-20 days interval, loses its legs and antennae and incorporates its cast skin into the waxy covering, which becomes circular, depressed and reddish in colour. The female rotates while forming the scale covering, so that the waxy threads secreted from the pygidium are added uniformly to the periphery of the armer. The female reaches maturity in 2.5 to 3.5 months and lives for several months longer while reproducing. The male scale becomes elongated after the first moult; the 3rd instar is a "pre-pupal" stage, and the 4th instar a "pupal" stage. The winged adult emerges in about 1-2 months, fertilises the female and dies.

(b) *Type of damage and symptoms:* It attacks the twigs, branches and stems, causing loss of vitality. The maximum damage done by this insect is during the first 1.5 years of planting. It rarely attacks the older plants. It sucks the plant sap. In case of severe attack on young plant, the leaves become yellow and finally the whole plant dries up and dies. The plant shoots, when heavily attacked are covered with reddish brown scales with dark patches of sooty mould which grows on honey dew secreted by this insect.

(c) *Period of occurrence:* Mostly during warmer months.

(d) *Management:* Same as in black scale. In case of severe attack, chemical control measure suggested against mulberry scale insect should be followed.

2.2.5. ***Mealy bug, Maconellicoccus* spp.** (Family: Pseudococcidae)

Presence has been reported in Bangladesh, India and Indonesia. Indian and Indonesian species of the mealy bug have been identified as* Maconellicoccus hirsutus *(Green)

(a) *Life Cycle:* Each adult female (Fig. 17b) deposits from 350-500 eggs in a loose cottony terminal ovisac during a week's time. Eggs are elongated in shape and orange in colour. Hatching takes place in about 5-10 days, depending upon the climatic conditions. The crawlers (Fig. 17a) are also orange in colour. Nymphs are covered with mealy substances (Fig. 18a). The females have three while males have four nymphal instars, which are passed in about 25 and 26 days respectively. Adults (Fig. 17b,c) reproduce parthenogenetically. They mate but do not feed and die in 2-3 days.

(b) *Type of damage and symptoms:* The leaf yield is tremendously reduced and are depleted in nutritive values. The affected apical shoot show retarded growth and flattening of apical shoot (Fig. 18a,b). Thickening of the affected leaves is also observed (Fig. 18a). The leaves are wrinkled and dark green in colour (Fig. 18b).

(c) *Period of occurrence:* Mostly in summer months.

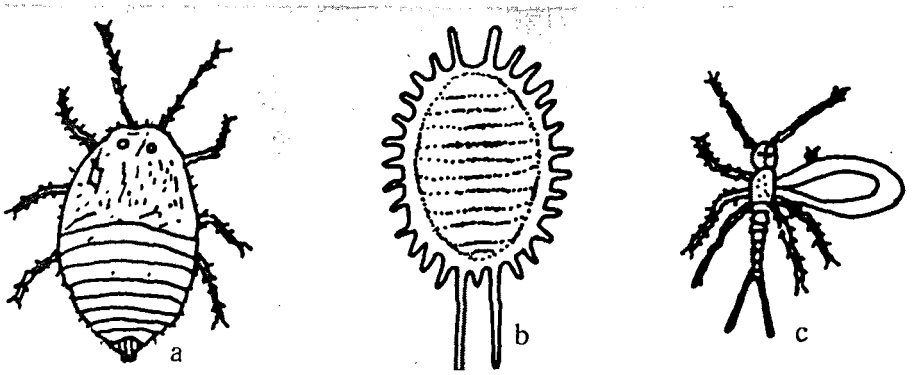


Figure. 17. Mealy bug
a) Nymph
b) Female adult
c) Male adult

Figure. 18.
a) & b) Characteristic symptoms of the Tukra disease

(d) ***Management:***

(i) Removal of the affected shoot and burning.

(ii) Spraying of 0.01 per cent parathion. Safe period - 13 days.

(iii) Soil application of phorate at the rate of 4 kg per ha after pruning. Safe period - 45 days from the first application and 15 days from the last application. It should be applied in 3 equal split doses at the interval of 10 days, the first application should be undertaken immediately after pruning.

(iv) Successful biological control of mealy bug can be achieved by employing predator like *Cryptolaemus montrouzieri* (Muls.) (Coccinellidae).

2.2.6. ***Mulberry mealy bug, Drosicha contrahens*** Walker (Family : Monophlebidae):

Presence has been reported in China. Thailand species has not been identified

(a) ***Life Cycle:*** This insect has one generation in a year. It overwinters as egg (Fig. 19d) in its egg case (Fig. 19c) which is made up of layers of eggs stuffed with white waxy materials secreted by the egg-laying female. The egg hatches early next spring. The nymphs force their way through the soil layer and crawl up to the surface of the ground. In some

extreme cases its huge population may "flood" the ground to the depth of about 2.5 cm and the nymphs may crawl up on any object they encounter. On mulberry plantation, they flock around the wither buds to suck the sap with their piercing and sucking mouth parts thereby reducing plant vigour. The body fluid of this insect has a peculiar stinking smell. The female adults (Fig. 19a) and their nymphs (Fig. 19e) of successive stages are similar in appearance, differing only in sizes; but, the male ones, though their first two stages are similar in appearance to that of females, turn into pre-pupae (Fig. 19f) after second moult, enwrapped in cottony waxy secretions in which transformation into winged adults (Fig. 19b) take place after pupal (Fig. 19g) stage i.e., after another moult. During the period of gestation, female adults fall to the ground and oviposit in soil.

(b) ***Type of damage and symptoms:*** Only the nymphs are destructive as they suck plant sap causing the tender shoots to dry up. Leaf yield is reduced. Dried twigs of mulberry are observed in the garden.

(c) ***Period of occurrence:*** Throughout the year except winter months.

(d) ***Management:***

(i) Destruction of egg mass by digging the soil upto a depth of 15 cm near the base of the mulberry plant/tree.
(ii) Removal and burning of dried twigs.
(iii) Using of sticky bands around the base of the plant/tree to prevent crawling up of nymphs.
(iv) Spraying of 0.1 per cent methyl parathion to kill nymphs. Safe period - 13 days.

2.2.7. ***Jassid, Empoasca*** spp. (Family: Cicadellidae)

Presence has been reported in Bangladesh and India
The Indian species has been identified as *Empoasca flavescens* F.

(a) ***Life Cycle:*** Adults (Fig. 20) are pale green in colour. They measure 2.5 - 4.0 mm in body length. Adult and nymphs move sideways. Eggs pale yellow in colour and elongated in shape are laid on the lower surface of the leaves below the epidermis. They hatch in 4-9 days and moult four times. Nymphs are pale green in colour. Pupation takes place on the leaf itself.

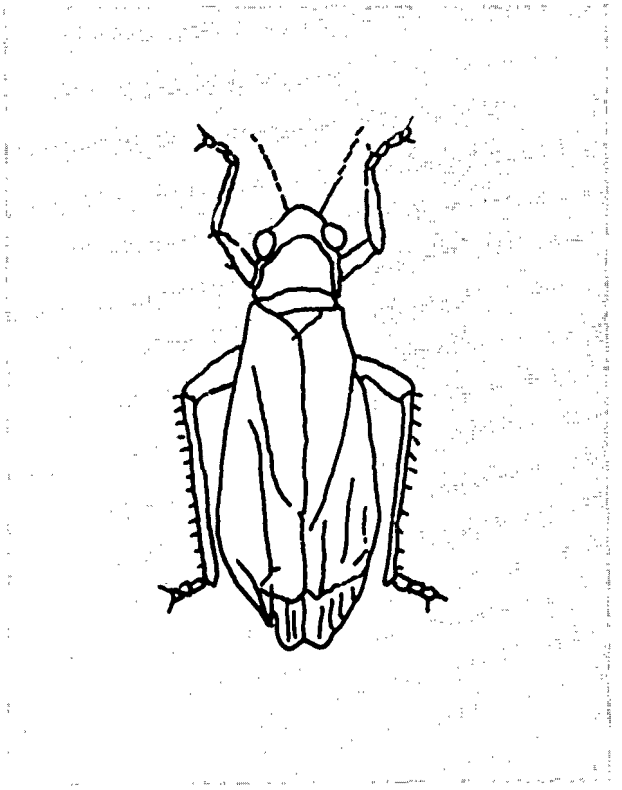


Figure. 20. Adult Jassid

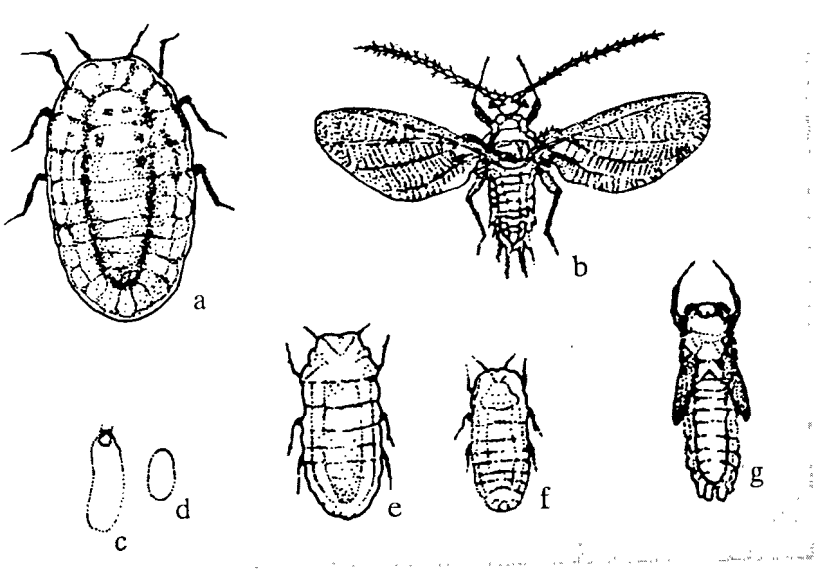


Figure. 19. Mulberry mealy bug
a) Female adult
b) Male adult
c) Egg case
d) Egg
e) Second instar Nymph
f) Male pre-pupa
g) Male pupa

(b) *Type of damage and symptoms:* The adults and nymphs attack the mulberry leaves from lower side of the margins of the veins. Affected the nutritive value gets depleted. While feeding this insect introduces the toxic virus which results in scrotched appearance of the leaves. This characteristic symptom, brown in colour appears at the tip followed by such patches along the margin of veins. It starts from the periphery and extends towards the midrib of the leaf. This is know as the hopper burn (Fig.21). In the final stage of attack the leaf becomes cup shaped and withers off.

Figure. 21. Characteristic symptom of hopper burn.

(c) *Period of occurrence:* Mostly in summer months.

(d) *Management:*

(i) Setting up of light traps for attracting and trapping adults.
(ii) Spraying of 0.1 per cent dimethoate or 0.05 per cent DDVP. Safe period - 11 days.

2.3. COLEOPTERA

Members of this order are commonly called as beetles and weevils. This is the largest order in the animal kingdom and exhibits great diversity of form and habits. Some members of this order act as pests of mulberry.

2.3.1. *Stem girdler beetle, Sthenias grisator* F. (Family : Cerambycidae)

Presence has been reported in India

(a) *Life Cycle:* Adult (Fig. 22f) insect is a stout built longicorn beetle with strongly developed mount parts. Female deposits eggs (Fig. 22b) underneath the bark of the girdled branch at night. The incubation period is about 8 days. The grub tunnels into the wilting branches and feeds. Grubs (Fig. 22c,d) turn into pre-pupa and pupa (Fig. 22e) inside the tunnel. The whole life cycle lasts for 7 to 8 months.

(b) *Type of damage and symptoms:* This beetle has a peculiar habit of ringing the stems, the bark and wood are neatly cut around the main stem or branch leaving a clear girdle (Fig. 22a). The portion above the girdle gradually wilts and dies. Girdled branches of the plant or wilting plants are observed in the garden (Fig. 23).

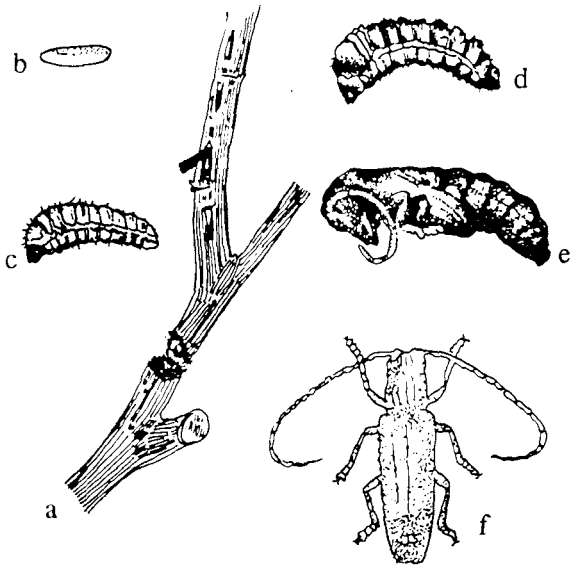


Figure. 22. Stem girdler
a) Affected stem
b) Egg
c) & d) Grubs
e) Pupa
f) Adult

(c) *Period of occurrence:* Throughout the year.

(d) *Management:*

(i) Cutting and burning of the branches and stems showing the symptom of beetle attack.
(ii) Swabbing of the base of main stem or branches with 0.1 per cent BHC solution (Safe period - 11 days) or 0.1 per cent malathion emulsion (Safe period - 13 days).

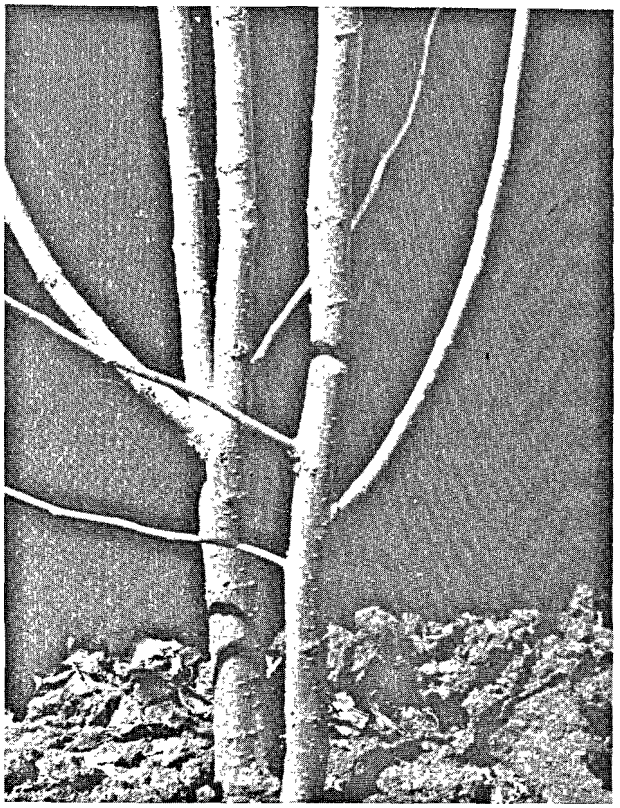


Figure. 23. Girdled branch of mulberry

2.3.2. ***Stem borer, Apriona*** spp. (Family : Cerambycidae)

Presence has been reported in Bangladesh, China, Japan, Malaysia and Viet Nam. The species reported from Viet Nam is *Apriona germarii* Hope.

(a) ***Life Cycle:*** The adults (Fig. 24a) are large, dark gray beetles, about 4 to 6 cm in body length, with conspicuous dark (blackish) tubercles at the base of the elytra. Males are smaller and have longer antennae than the females. They feed a little and eat the bark of the tree in patches. Adults are seen mating on the tree trunk a few days after emergence. Eggs are laid on the trunk or branches usually in crevices of the bark. The eggs hatch in about 7-10 days and the grubs start burrowing under the bark in the sap wood. The length of the grub life varies from 1 to 2 years depending upon the climatic conditions. Grubs tunnel along the branches and in the tree trunk just under the bark and sometimes into the heart wood (Fig. 24a,b,c). Pupation takes place at the end of the tunnel which is blocked by a mass of chewed wood fragments.

(c) ***Type of damage and symptoms:*** Twigs are easily broken by winds because the twig tissues are partially destroyed by the adult beetle during the egg laying process. Severely attacked plants/trees (Fig. 24d) may die. Frass expulsion holes are made at intervals along the main gallery, so frass can be seen externally and these provide conspicuous symptom of attack.

(d) ***Period of occurrence:*** Throughout the year.

(e) ***Management:***

(i) Cutting and burning of heavily infested branches. Piercing of the grubs to death by a flexible wire probed into lowest hole to know the location of the vertical tunnel and use of a chisel to drill a small hole leading to the vertical tunnel, followed by the use of a long wire with a hook at its tip to pierce all the way down the tunnel. This process helps to pierce the grubs in the tunnel to death and also helps to pull up the dead grubs by the hook.

(ii) Spraying of the trunks and branches with 0.01 per cent aldrin has been proved to be of some value and

(iii) Injection of a mixture of 0.01 per cent aldrin and kerosene 1 : 1 into the frass holes to kill the boring larvae.

After any chemical treatment has been applied the old frass under the infested tree should be removed so that any new frass to be expelled will be immediately obvious and the chemical treatment can be repeated. A marker die (Methylene blue), may be added to the aldrin solution to indicate the extent of the solution penetration within the larval tunnel system. Safe period - 11 days.

2.3.3. ***Mulberry weevil, Baris deplanata*** Roelofs (Family : Curculionidae)

Presence has been reported in China, Japan and Korea

(a) ***Life Cycle:*** The adult (Fig. 25a) weevil is lacquer black in colour. Rostrum is long, big and curves somewhat towards inside. The sheath has several longitudinal grooves and a knob on it. The hindwing is membraneous and semi-transparent. This monophagous insect has only one generation in a year and undergoes a complete metamorphosis. The adults hibernate in the holes of xylem tissue of mulberry which are carved out by the matured grubs under the bark. With the coming of warm spring when the atmospheric average temperature rises upto about 15°C, the overwintered adults emerge and come out of the holes. The weevil eats young buds or young leaves. In this process, mulberry trees are seriously injured. On the other hand, the adult females start depositing eggs in the holes made by them 10 days after mating. Usually, 100-200 eggs are laid by a single female. The life span of an adult is variable from 30 days to 100 days. During this pe-

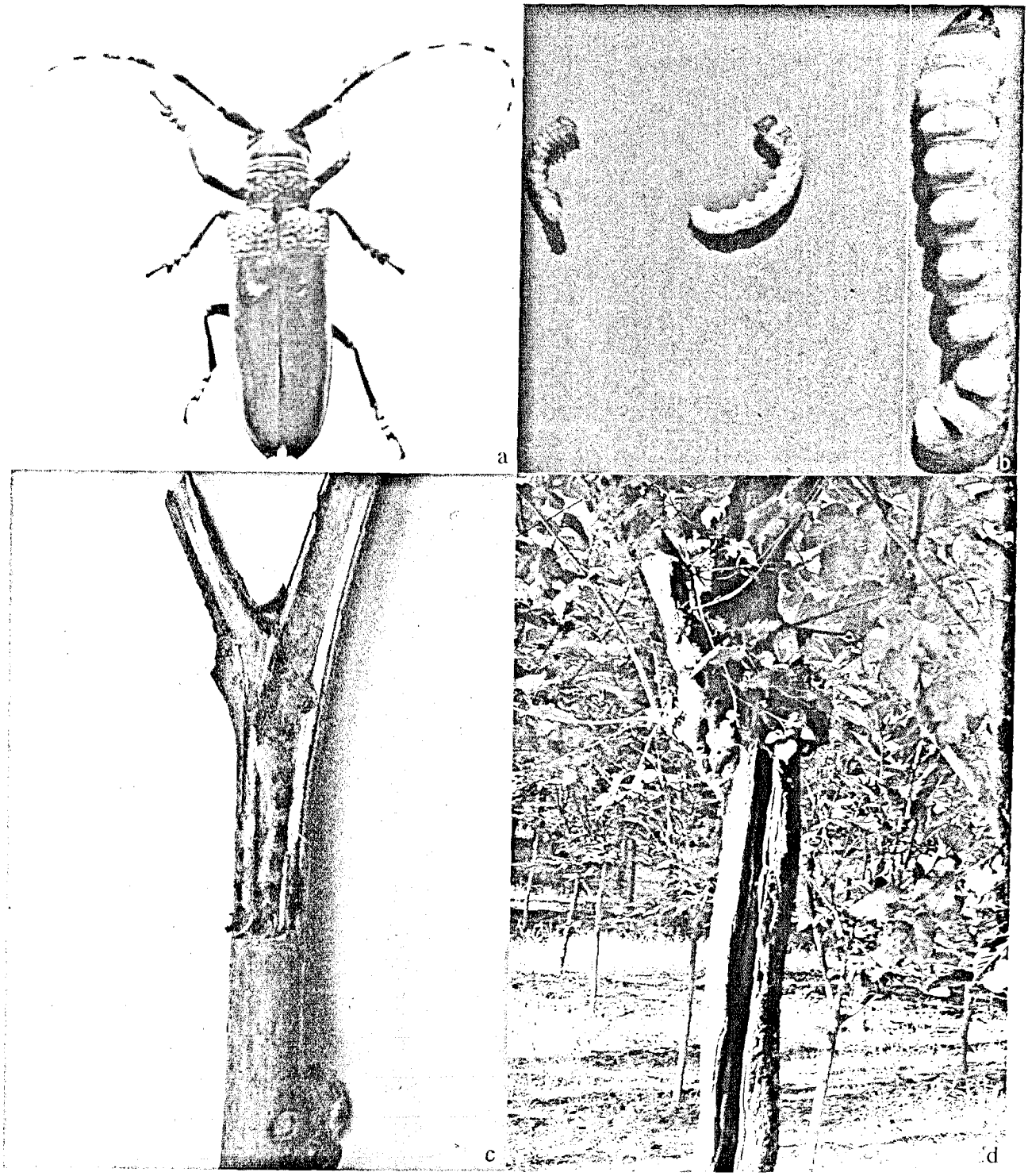


Figure. 24. Stem borer
a) Adult
b) Grubs
c) Grub in the tunnel
d) Damaged mulberry tree

riod, the female adults lay eggs in holes one by one. Accordingly, hatching of eggs and progress of grubs become very irregular. Grubs which hatch from eggs in about two weeks after egg laying, bite the cortex and xylem of branch and make a tunnel into the branch. Grubs (Fig. 25b) are light yellow and cylindrical, usually curve their bodies in an arch-form. In about two months, grubs turn into pupae (Fig. 25c). Adults emerged in tunnel stay there and hibernate.

(b) ***Type of damage and symptoms:*** The habit of the overwintered adult weevil is to feed on the mulberry buds just after pruning irrespective of the season. This causes reduction in the leaf yield and the injured mulberry trees cannot be grown as an ideal type. Damaged mulberry shoots (Fig. 25d) are observed.

(c) ***Period of occurrence:*** Throughout the year.

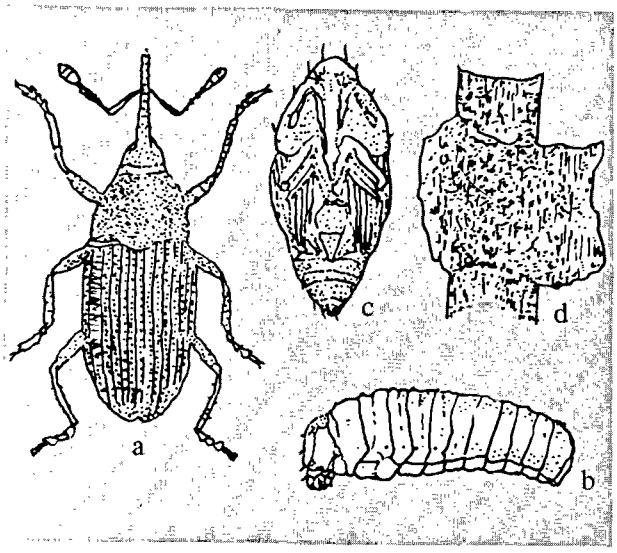


Figure. 25. Mulberry weevil
a) Adult
b) Grub
c) Pupa
d) Damaged mulberry shoot

(d) ***Management:***

(i) Cutting and burning of wilted and dead branches during winter.
(ii) Collection and destruction of adult weevils during summer and spring season.
(iii) Avoidance of planting mulberry as a hedge.
(iv) Spraying of pyrethroids or permethrin diluted to 1:300 after pruning before the buds begin to unfold. Safe period - 10 days.

2.3.4. ***Weevils, Myllocerus*** spp. (Family: Curculionidae):

Presence has been reported in Bangladesh and India. Four species reported from India are *Myllocerus subfasciatus* G. *Myllocerus viridanus* M., *Myllocerus discolor* Boheman (Fig. 26) and *Myllocerus postfasciatus* M.

(a) ***Life Cycle:*** Adults are gray and black coloured measuring 0.5-1.5 cm in length. The head is more or less prolonged into a snout which varies considerably in size, shape and length. Eggs are laid in superficial layers of the soil. A single female lays 150-350 eggs over a period of 20-90 days. The grubs hatch out from the egg in 4-8 days. The grubs pass through four instars in a period of about 40-75 days and pupate inside the soil. They normally complete 3-5 generations in a year.

(b) ***Type of damage and symptoms:*** Both adult and grubs cause injury to mulberry. The adults feed on the leaves and buds whereas grubs feed on the underground parts of the mulberry. In case of severe attack the plants wilt and dry up. Irregular serrated margins on foliage are observed from the feeding by the adults.

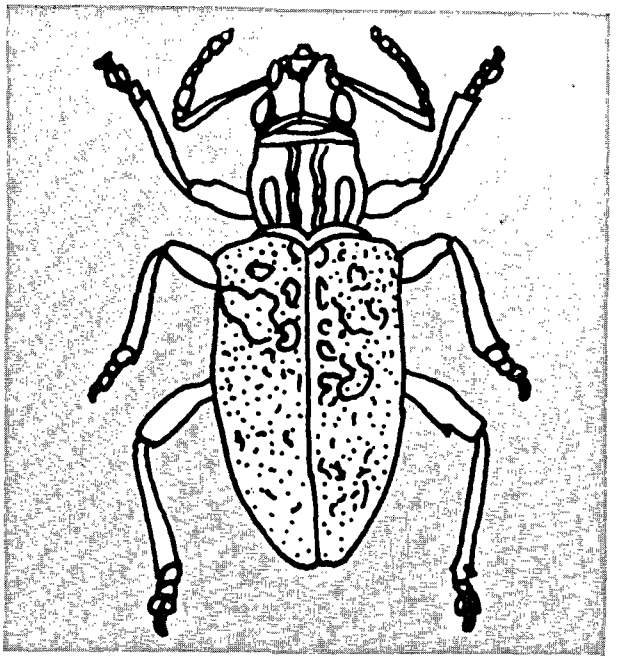


Figure. 26. Adult weevil, Myllocerus discolor

(c) ***Period of occurrence:*** Throughout the year, maximum damage from July to October.

(d) ***Management:***

(i) Digging of the soil upto a depth of 7-8 cm and destruction of the eggs, grubs and pupae.
(ii) Spraying of 0.01 per cent quinalphos (Safe period - 7 days) or 0.02 per cent methyl parathion (Safe period - 10 days) or malathion (Safe period -8 days).

2.4. ORTHOPTERA

Important members of this order are grasshoppers, locusts and crickets. Two species of this order are known to cause damage to mulberry which is occasionally serious in restricted areas.

2.4.1. ***Grasshopper, Neorthacris acuticeps nilgriensis*** Uvarov (Family : Acrididae)

Presence has been reported in India and Malaysia. *Cyrtacanthacris ranacea* (Fig. 27) has also been reported from India as a pest of mulberry. *Neorthacris acuticeps nilgriensis* is a polyphagous pest popularly known as wingless grasshopper or short horned grasshopper. This species causes considerable damage to mulberry in southern parts of India. The second one is of minor importance.

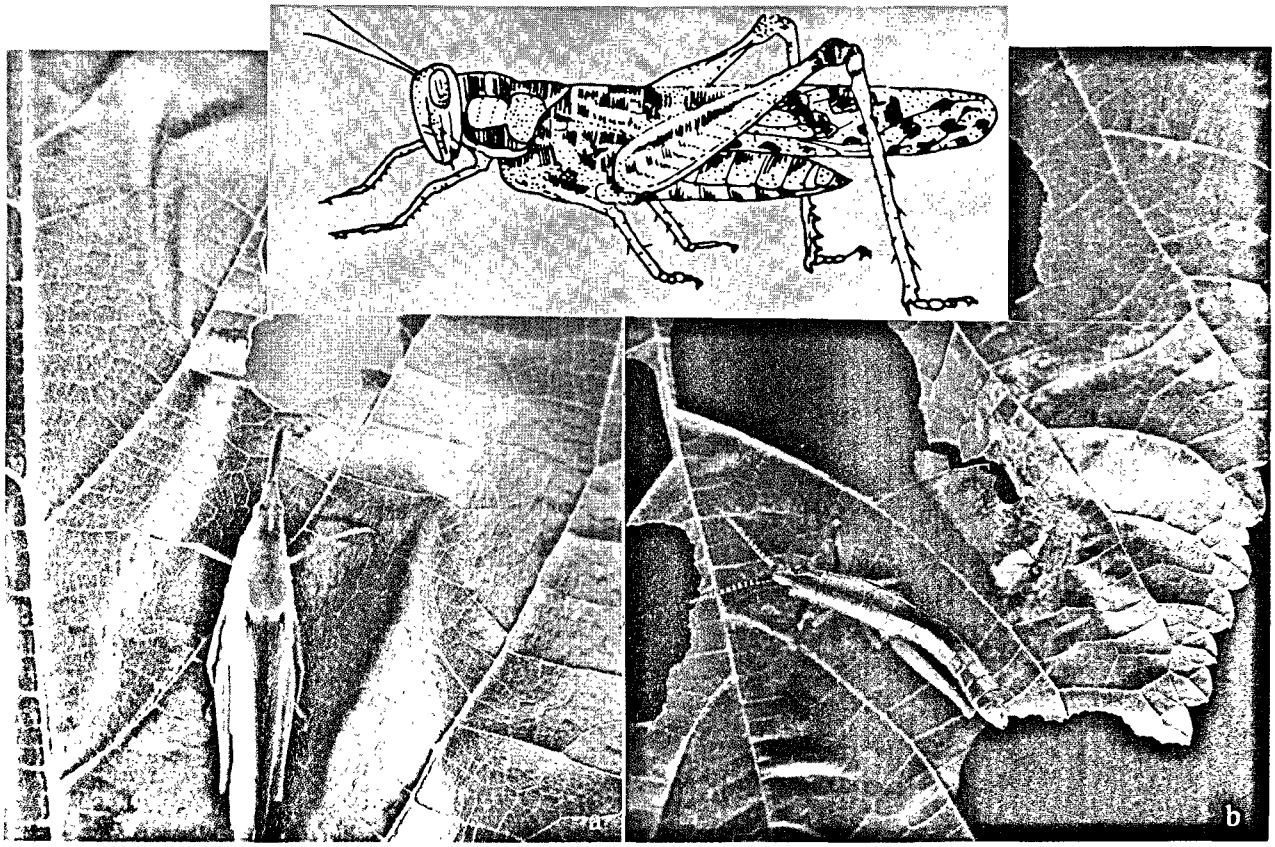


Figure. 27. Adult Cyrtacanthacris ranacea

Figure. 28. Wingless grasshopper
a) Adult
b) Nymph

(a) ***Life Cycle:*** Adults of short horned grasshopper are green in colour (Fig. 28a). The female lays on an average 6 to 8 egg pods each having 11-18 eggs. The egg pods are deposited in the loose soil at a depth of 2-3 cm. Eggs hatch in about 28-31 days. Nymph undergoes six moults before it reaches the adult stage. Early instar nymphs are light brown in colour (Fig. 28b) whereas late instar nymphs are green in colour. It completes its life cycle in 5-6 months.

(b) ***Type of damage and symptoms:*** Nymphs and adults of this pest voraciously feed upon the mulberry leaves and leaf yield is reduced considerably. Branches of plants without leaves are observed in the mulberry garden.

(c) ***Period of occurrence:*** More frequent in July-August.

(d) ***Management:***

(i) Exposure of egg masses by deep ploughing for destruction by natural enemies like bird etc.
(ii) Spraying of 0.5 per cent BHC. Safe period - 10 days.

2.4.2. ***Cricket, Brachytrupes portentosus echlenetein (Re)*** (Family : Gryllidae)

Presence has been reported in Viet Nam

(a) ***Life Cycle:*** Adult (Fig. 29a) is a large, brown insect with a heavy square head, long thin antennae and powerful hindlegs. The body excluding appendages is about 5 cm long. Female lays about 300 eggs over a period of 3-4 months. The eggs are elongate, oval, about 3-4 mm long when first laid white and later becoming brown and expanding to about 5-6 mm. They hatch after about one month. Newly hatched nymphs leave the burrow (Fig. 29b) of the mother cricket and construct on their own which is gradually enlarged during the nymphal period. The full grown nymph is brown in colour and about 4-5 cm long. There are four nymphal instars. The total nymphal period is about eight months.

(b) ***Type of damage and symptoms:*** Damages young shoots and buds. Seedlings are particularly vulnerable. It has also been observed that both the nymphs and adults collect seedlings, leaves and other soft part of the plant both dead and alive and drag them into their burrow where they are stored and

a

b

Figure. 29. Cricket
a) Adults
b) Burrow on the ground formed by cricket

finally eaten. Fresh sappy material is often left on the surface for a day or two, to wilt before being taken into the burrow. Generally attacks mulberry grown on such soils where burrows are easy to be excavated. Young mulberry plantation with damage on various soft parts are noticed in the garden. Even burrows (Fig. 29b) are observed on the ground.

(c) ***Period of occurrence:*** Throughout the year.

(d) ***Management:***

(i) Bran baiting by mixing the bran with BHC dust or aldrin WP.
(ii) The moist crumbly mixture should be broadcasted on weed free soil between the crop rows in the evening as the pest is nocturnal.

2.5. THYSANOPTERA

This order consists of insect species commonly known as Thrips. Most of the members are plant feeders. Some species act as vectors of viral diseases of plants. Some members of this order occasionally cause serious damage to mulberry especially during summer months.

2.5.1. ***Thrips, Pseudodendrothrips*** spp. (Family : Thripiidae)

Pseudodendrothrips spp. has been reported from Bangladesh whereas *Pseudodendrothrips mori* Niwa has been reported from India, Japan, Sri Lanka and Viet Nam. In addition to this, other species of thrips reported from India and Sri Lanka are *Haplothrips coloratus* (Trybom), *Taeniothrips glycines* (Okamoto),

Taeniothrips melanicornis (Shumsher) and *Taeniothrips claratris* (Shumsher) (Fig. 31). The most commonly found species of thrips in India is *P. mori.*

(a) ***Life Cycle:*** Adult males of *P. mori* is brownish yellow whereas female is dark brown in colour. Females are larger than males. On an average an adult (Fig. 30e) measures 0.9 mm in body length. 30-50 bean shaped yellow coloured eggs are laid by a single adult female of *P.mori* on the ventral side of the leaf. Nymphs hatch from these eggs in 6-8 days. The nymphs (Fig. 30a,b) are pale yellow coloured. They moult four times in 15-18 days. Adults are with fringed wings.

Adults of *H.coloratus* are black coloured stout, tubiliferan thrips measuring about 1.90-2.00 mm in total length. 8-12 eggs are deposited in a cluster on the lower side of the tender leaves. The egg is oblong in shape and reddish-yellow in colour. Incubation period ranges between 6-9 days. Nymphs are saffron coloured with light pinkish-yellow colour on the inter segmental regions of the abdomen.

Adults of *T. glyciens* are light yellow coloured and are found in farely good numbers on the mulberry leaves affected with powdery mildew. These insects feed over the fungal spores of the mildew. The adults measure 1.11 to 1.21 mm in total body length.

Adults of *T. melanicornis* are brownish yellow in colour. Females are longer than males. The size of the adult female is about 1.12 to 1.20 mm in total length.

(b) ***Type of damage and symptoms:*** Thrips affect the leaves of the mulberry shoot. They injure the epidermal tissue. Early maturity, depletion of moisture, reduction in crude protein and total sugars are met with the affected leaves. Leaves become unsuitable for healthy silkworm rearing. Affected leaves show streaks (Fig. 32) in the early stage of attack whereas blotches are observed at the advance stage of attack which become yellowish-brown on maturity.

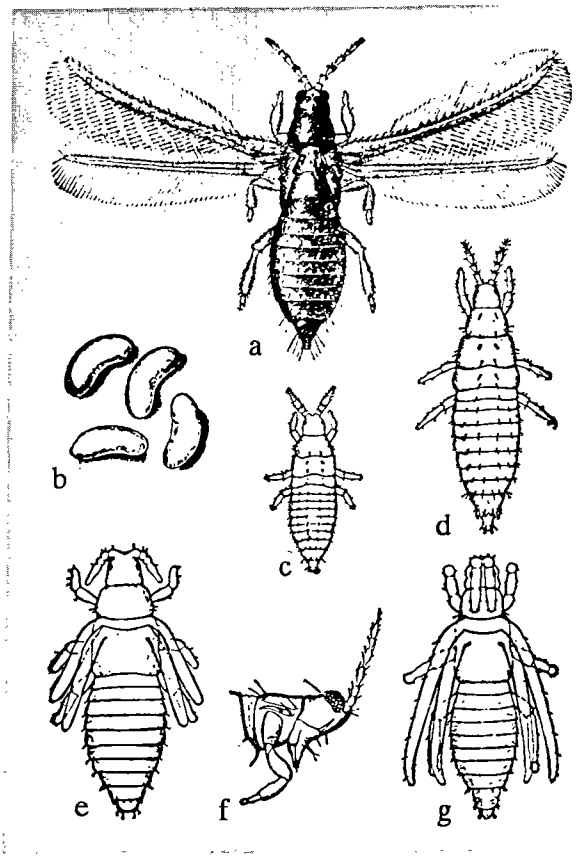


Figure. 31. Taeniothrips *spp*
a) Adult
b) Eggs
c), d), e) & f) First, second, third and Final instar Nymphs
g) Lateral view of adult head

(c) ***Period of occurrence:*** Throughout the year. Very high in summer months.

(d) ***Management:***

(i) Sprinkler irrigation disperses the nymphs and adults.

(ii) Spraying of 0.02 per cent DDVP twice at weekly intervals to kill the nymphal and adult stages. Safe period - 7 days.

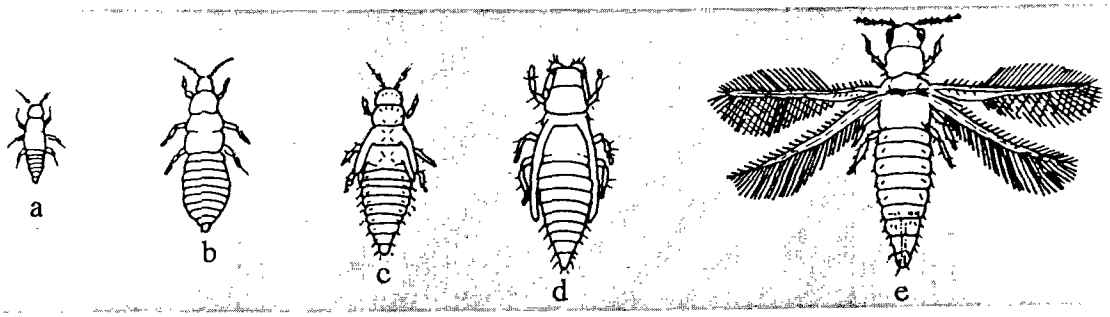


Figure. 30. Pseudodendrothrips mori
a) & b) Nymphs
c) Pre-pupa
d) Pupa
e) Female adult

Figure. 32. Symptoms of early stage of thrips attack on mul berry

2.6. ISOPTERA

Members of this order are commonly called as termites, sometimes quite eroneously called "White Ants". They are social insects and some of them are known to cause minor damage to mulberry.

2.6.1. *Termites*

Presence has been reported in India and Malaysia

(a) ***Life Cycle:*** Since several species of termites are associated with mulberry and many of them have not been identified, typical life cycle of termite is described. Wings are present only in the sexually mature males and females (Fig. 33c). During the swarming season wings of these sexually mature members are broken of following a shorter flight. The individuals separate in pairs and a cell is excavated in the soil or wood where repeated matings take place. The eggs are normally deposited singly. Mature queen lays several thousand eggs. Incubation period varies from 24-90 days. Duration of development and number of nymphal instars vary greatly with the cast (Fig. 33a,b) and usual environmental factors. Workers of colony cause the main damage.

(b) ***Type of damage and symptoms:*** Termite attack is found in all types of soil but more frequent in the sandy and red loamy soil. They feed upon the roots and bark of young and old plants. Attack of termite results in mortality of the plant. Drying plants are observed in the garden.

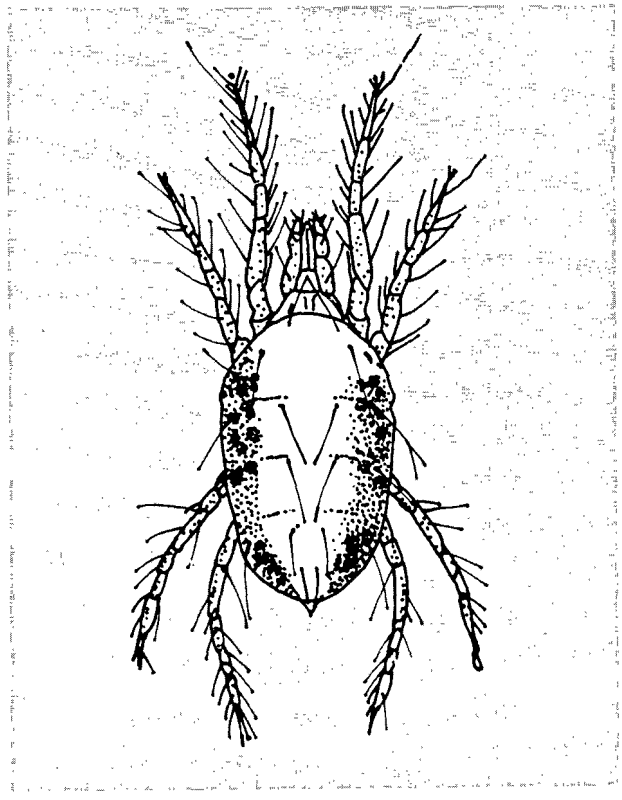


Figure. 34. Female adult mite, Tetranychus telarius

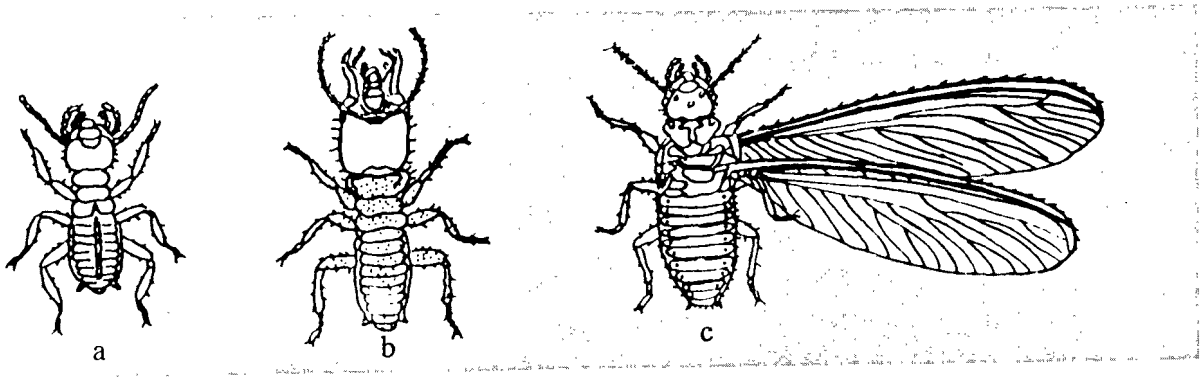


Figure. 33. Termite
a) Worker b) Soldier c) Winged adult

(c) *Period of occurrence:* Usually from October onwards and continues till the onset of monsoon.

(d) *Management:*

(i) Location and destruction of termite colonies by removing queen termite.
(ii) Treatment of mounds with phorate at the rate of 50 g per mound or 50 ml of chlordane.
(iii) Swabbing or drenching of established plants at the base with 1 per cent chlordane. Safe period - 25 days.

2.7. ACARINA

This order belongs to class Arachnida. Members of this order are commonly called as mites and are characterised by having four pairs of legs in the adult stage. Some acarids act as pests of mulberry.

2.7.1. ***Mites, Tetranychus*** spp (Family : Tetranychidae)

Tetranychus equitorius MsGr (= *Tetranychus neocaledonicus* Andre) and *Tetranychus telarius* L. are reported from India and Sri Lanka. Another species *Tetranychus ludeni* Zacher has also been reported from India. However, the most commonly occurring species *T. ludeni* and *T. equitorius* are described.

(a) ***Life cycle:*** Adult male of *T. ludeni* has a narrow body with distinctly pointed abdomen when compared to the female and measures about 345 μ in length. The female measures about 440 μ in length and is bright red in colour which subsequently changes to carmine with advancement in age. Adult female lays about 75 eggs. The eggs are laid on the lower surface of the leaves and on the webs. Eggs are spherical in shape. The first few eggs are brown in colour and finally the colour of eggs become translucent white. The incubation period is 4-5 days. The newly emerged larva is spherical in outline and creamy white in colour with 2 prominent red spots on the sides of dorsal, propodosomal region. Generally measures 176.5 μ in length. After crawling around for sometime settles for feeding. Initially the larva is greenish-yellow and subsequently turns dark green in colour. The mature larva enters a stage of quiescence by anchoring itself to the leaf surface and assumes a characteristic pose. The larval period occupies about two days. Later, they moult into protonymph, deutonymph and finally to adults. The total time taken for development from egg to adult emergence is about 10 days.

Newly emerged adults of *T. equitorius* are light pinkish in colour and later attains reddish colour with pale-yellowish legs. The adult female measures about 570 μ in length while males average body length is about 370 μ. Female lays 45-140 eggs. The eggs are laid on the ventral side of the leaves as well as among webs. The eggs are smooth, spherical and translucent which gradually turn into light brown in colour and measure about 133 μ in diameter. Incubation period is about 5 days. The newly emerged larvae are light amber in colour which changes to light greenish with dark lateral specks after they start feeding and ultimately to dark greenish, when they feed for sometime. The larva measures about 183 μ in body length. The grown up larvae enter quiescent stage by attaching itself to the leaf surface. The larval period occupies about 2 days. The initial protonymph is amber in colour and measures about 225 μ in length. This stage lasts for about two days. Before moulting in to deutonymph it passes through quiescent stage. Newly moulted duetonymph is amber colour which soon changes into light green followed by blackish-green. Males are smaller, elongated and each measures about 290 μ in length while the females are broad more or less ovoid and measures about 360 μ in length. The duetonymphal period also occupies about two days. The fully grown duetonympth after a brief period of quiescence, moults into adult. The total duration to complete life cycle is about 10 days.

(b) ***Type of damage and symptoms:*** Mites suck plant sap by penetrating the host plant tissue with sharp stylets inducing white specks at the place of feeding. With increase in the intensity of the feeding, the specks increase in number and thereby gradual increase in size and finally produce large patch. In severe case of infestation, the leaves lose their green healthy colour, sometime appears rusty in colour, gradually dry and fall - off resulting in the reduction in leaf yield.

(c) *Period of occurrence:* Throughout the year, maximum in summer months.

(d) *Management:*

(i) Sprinkler irrigation.
(ii) Spraying of Zolone 0.05 per cent and Thiodon 0.05 per cent. Safe period - 9 days.

2.8. INTEGRATED CONTROL OF MULBERRY PESTS

In the preceeding pages amongst other things like the description of the pests, their life cycle, extent of damage, periods of occurrence etc., their

control measures have been described in detail involving various methods like physical, chemical and biological. It may, however, be seen that none of them is perfect by itself, each one having its advantages and disadvantages. Further, one has to distinguish between a short term and a long term control and try always to achieve the latter instead of the former. In this connection, it may be worthwhile to see that instead of choosing one method, a combination of methods is chosen having an integrated approach. But before choosing a method or methods it is imperative to know precisely the advantages and disadvantages of each of them individually and collectively so that the most rational, economic and effective method/methods are chosen to the best advantage of the individual, the society and the environment. Advantages and disadvantages of different methods and possibility of their combining having an integrated approach are discussed below which may provide useful guidance in the matter.

2.8.1. *Physical control*

This covers the elimination of the pest by various physical means like mechanical, Phototropical and cultural.

(a) ***Mechanical:*** The mechanical elimination may be through hand and net collection of egg masses, larvae, pupae, scrapping of the bark etc. It is always advantageous to adopt this method when the insects are gregarious and are in an inactive stage. The other forms of mechanical destruction could be brought about through the cutting of the infested shoots and branches and their destruction, preferably by burning but that may be integrated with cultural control also involving the adjustment of pruning and destruction of the pests.

(b) ***Phototropical:*** Another method of physical control may be through light trapping taking advantage of the phototrophic nature of certain insects. This has been found to be particularly effective against the Lepidopteran pests forming one of the largest group of phytophagous insects.

(c) ***Cultural:*** Cultural control is brought about by turning up of the soil, flooding etc., which expose the pests to physical stress. During the process they are killed by exposure to sunlight, water and the predators. As already stated pruning of the plants and burning of the infested twigs may also lead to the control of certain foliar pests.

All the physical control methods have the advantage that they are pollution free and do not affect the environment but have the disadvantages of being limited in reach and labour intensive. For the physical control, one should have a thorough knowledge of the life history, bionomics as well as the habit and habitat of the pests.

2.8.2. *Chemical control*

Chemical control is done mostly through commercial pesticides. They are, no doubt, very quick in action but are be set with a number of disadvantages like pollution of the environment and danger to other than the target group of insects. They are mostly indiscriminate in action killing many useful insects thereby breaking the agro-eco-system. They may affect higher animals also. Use of chemicals for mulberry pest control may have special implications as the mulberry leaves are to be fed to the silkworm and any overdose or miscalculation regarding the safe period could play havoc with the cocoon crop.

2.8.3. *Use of resistant varieties*

Varietal resistance to pest infestation is known in almost all plants. Thus one way to avoid the pest infestation could be the selection of pest resistant varieties. Again one strain may not be resistant against all the pests. So, depending on the area and survey of the varieties, those particularly resistant to the pest prevalent in the area could be used/introduced.

The following criteria could be used in the screening of pest resistant mulberry varieties:

(a) Visual damage rating.

(b) Determination of the number of plants surviving infestation at regular intervals.

(c) Comparison of yield loss between the infested and the non-infested plants.

2.8.4. *Biological control*

Biological control may be of various types

(a) Use of hyperparasitoids to attack the primary parasitoid.

(b) Use of attractants and repellants including pheromones to trap and kill the insects.

(c) Use of hormones and other physiology imparing chemicals to upset the normal metabolism.

(d) Use of sterile male technique.

(e) Use of bacterial and fungal insecticides are ruled out as many of them are known to be toxic to the silkworm itself.

Biological control methods except the last one are no doubt safe but their extent of action are limited.

Finally, reviewing all the methods, it may be suggested that as much as possible physical including cultural control measures should be adopted. Biological control may also be resorted to when and where possible. Use of some pest resistant variety particularly resistant against the pest prevalent in the area may also be explored. When the above methods are not effective individually or collectively chemical or pesticidal control may be taken up but while doing so, the following should be kept in mind:

(1) Use pesticides only when the need is clearly established and it is inevitable.

(2) Where possible combine the use of pesticides with other non-chemical methods in an integrated pest management system.

(3) Select pesticides which have lower residual effect and are less toxic to other animals.

(4) Use minimum dose required for the management of the pest in question.

(5) Strict observance of the safe period.

PART II

DISEASES AND PESTS OF MULBERRY SILKWORM

CHAPTER 3

DISEASES OF MULBERRY SILKWORM AND THEIR CONTROL

Mulberry silkworm *Bombyx mori* is affected by a number of diseases caused by viruses, bacteria, fungi and protozoa. These diseases are known to occur in almost all the silkworm rearing areas of the world causing considerable damage to the silkworm cocoon crop. A number of measures have been suggested for the prevention and control of these diseases, but none of them has proved to be fool-proof with the result that one has always to be careful to eliminate the cause of primary infection as well as to prevent the cross infection. Care is also needed to be taken to see that they are not exposed to stress conditions like adverse temperature and humidity, bad ventilation and nutritional deficiency which may make them easily susceptible to various diseases.

3.1. VIRAL DISEASES

Viral diseases of silkworm pose a major problem to sericulture as they account for almost 70 per cent of the total loss due to diseases. Viral diseases of silkworm comprise of inclusion and non-inclusion types. The inclusion virus diseases form typical inclusion bodies. They are Nuclear polyhedrosis and Cytoplasmic polyhedrosis which can be more easily identified through ordinary microscopy. The non-inclusion type consists of Infectious flacherie and Densonucleosis which can be detected only through electron/fluorescent microscopy and serological tests.

3.1.1. *Nuclear Polyhedrosis*

It is one of the most serious virus diseases in tropical countries and occurs throughout the year. This disease is otherwise known as Grasserie, Jaundice, Milky disease, Fatty degeneration and Hanging disease.

Causes of the disease

This disease is caused by *Borrelina bombycis* virus belonging to the sub-group A of the family Baculoviridae. As the name implies, this virus multiplies and forms polyhedra (Fig. 1) in the nucleus of

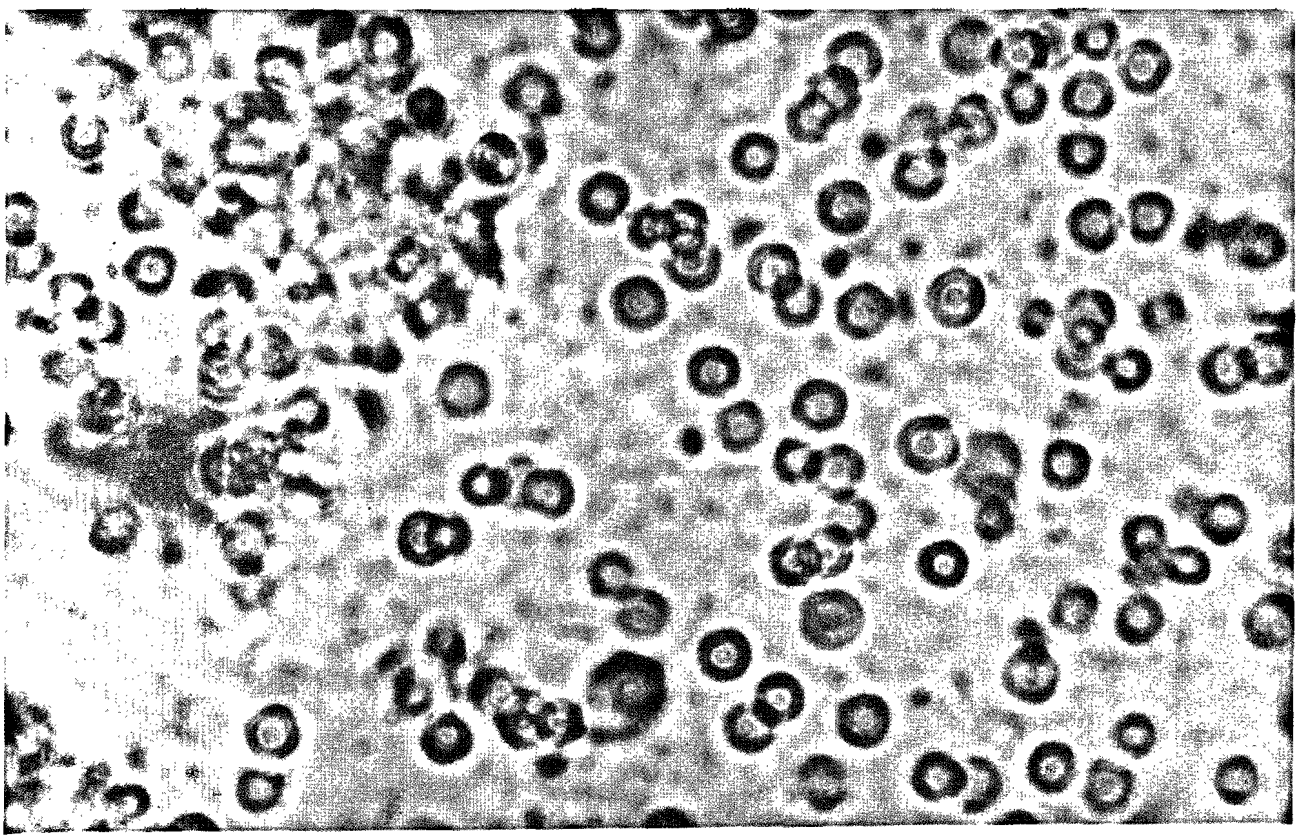


Figure. 1. Nuclear polyhedra

the tracheal epithelial cells, adipose tissue cells, dermal cells and blood cells. Occasionally the nucleus of the middle and posterior portion of silkgland cells are also affected. The viral particles are rod shaped and the size is around 330 x 80 nm. The size of the polyhedra varies from 3-6 μ. The shape is usually octadecahedral or hexahedral and sometimes tetragon or trigon.

Infection mostly takes place through feeding of polyhedra contaminated mulberry leaf, rarely through wounds. Heat, cold and chemical treatments have also been known to induce this disease. Factors influencing the outbreak of this disease are high temperature and humidity, their sudden fluctuations, bad ventilation in the rearing room, ineffective disinfection of rearing room and equipments and feeding of tender leaves during late instars. Inadequate larval spacing, starvation and excessive moisture in the rearing bed have also been known to contribute towards the outbreak and spread of the disease.

Symptoms: During early part of the disease no symptoms are noticed except the worms being slightly sluggish. Initially the skin shows oily and shining appearance (Fig. 2). As the disease advances the skin becomes thin and fragile and the body becomes milky white with intersegmental swellings (Fig. 3). The fragile skin is prone to rupture easily, liberating the liquified body contents containing innumerable number of polyhedra which become the source of secondary contamination. Another characteristic symptom of this disease is that the larvae become restless and crawl aimlessly

Figure. 2. Grasseri affected larvae (early stage)

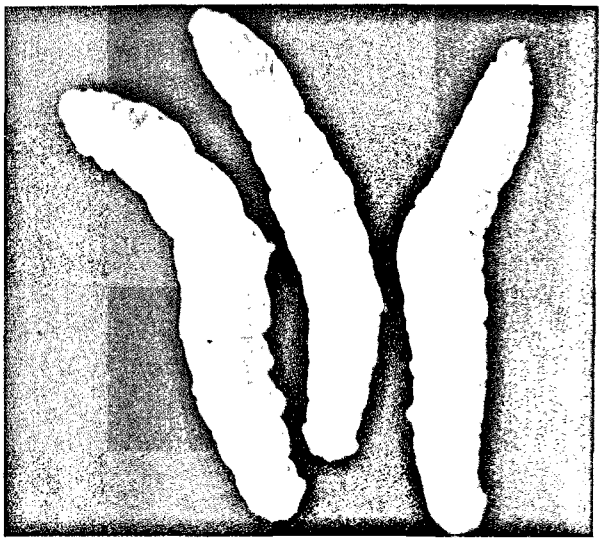


Figure. 3. Grasserie affected larvae (late stage)

along the ridges or rims of rearing trays, (Fig. 4) subsequently falling on the ground and dying. Death takes place after infection in about 4-5 days in the young larvae and 5-7 days in the grown-up larvae. Diseased larvae lose the clasping power of abdominal legs except the caudal legs by which it hangs with the head downwards (Fig. 5). If the infection is early the worms fail to spin the cocoons and die, whereas if the infection is late they are able to spin the cocoons but die inside producing melted cocoons.

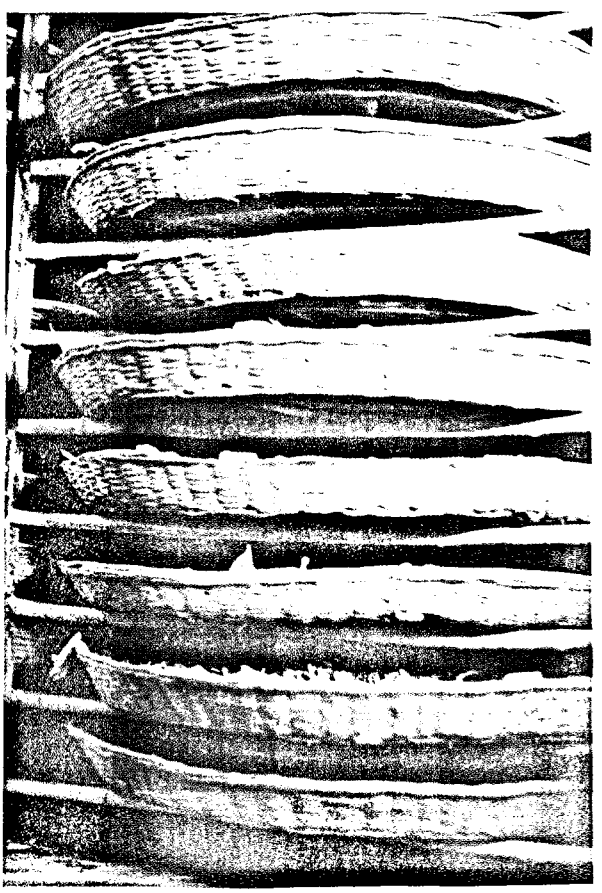


Figure. 4. Grasserie affected larvae crawling on the edges of trays

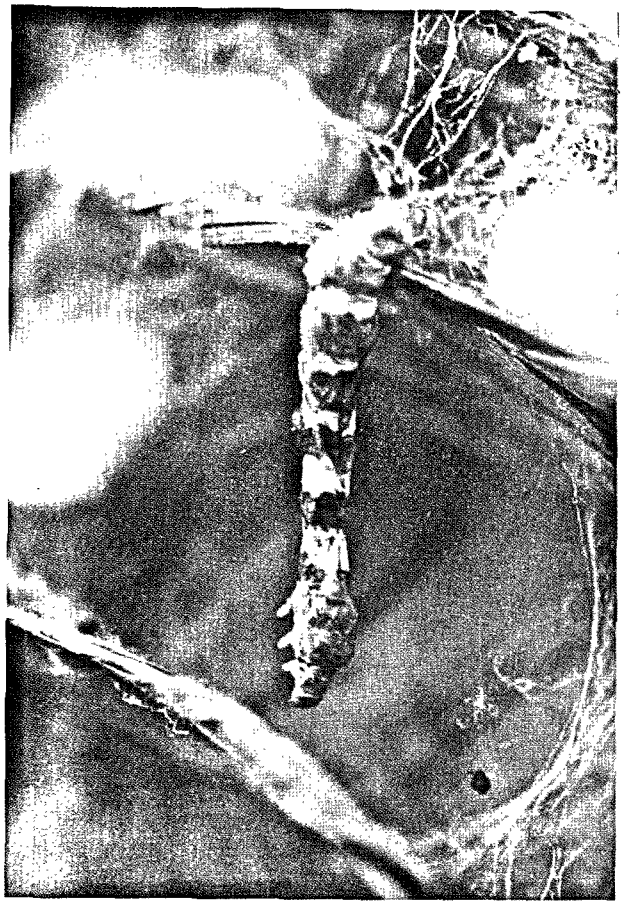


Figure. 5. Grasserie affected larva hanging with head downwards

Prevention and control: For effective prevention of this disease, the silkworm rearing rooms, mulberry storage rooms, mounting rooms, equipments and rearing premises should be thoroughly disinfected before brushing. The eggs should be essentially surface disinfected. Silkworms should be reared under strict hygienic conditions. During rearing the diseased and dead larvae form the major source of infection with the largest quantity of fresh polyhedra available. Hence, the diseased larvae should be removed carefully without breaking the skin and disposed suitably by putting them in lime vats or by burning. Depending upon the stage of silkworm, suitable temperature and humidity should be provided. During IV and V instars fresh air circulation should be ensured by providing cross ventilation. The silkworms should be fed with nutritively rich mulberry leaf and during later stages feeding of tender leaf should be avoided. Depending upon the stage of larvae, optimum spacing and required quantum of leaf should be given. Proper bed drying is necessary before each feed to avoid accumulation of moisture in the bed.

In addition to the above, use of certain bed disinfectants could also prevent secondary contamination and spread of the disease. Paraformaldehyde compounds are known to have anti-microbial properties and various formulations involving this chemical have been prepared like Papazol in Japan and Reshamkeet Oushadh in India. The latter is a bed disinfectant formulation containing 1 per cent captan (N-Trichloromythyl Thio-4-Cyclohexane 1,2-Dicarboxymide), 1 per cent paraformaldehyde (Trioxymethylene) 2 per cent Benzoic acid and 96 per cent slaked lime powder giving dual protection against grasserie and muscardine. It should be dusted on the larvae and bed with the help of a thin cloth at the rate of 2-3 grams/0.1 sqm. area during early instars and 4-5 grams.0.1 sqm. during IV and V instars. The dusting should be done (Fig. 6) preferably once after each moult, half an hour before resumption of feed. An additional dusting should be done on the 4th day of final instar after bed cleaning. The dusting should not be done when the larvae are under moult or preparing for moult. The quantity of Reshamkeet Oushadh required for 100 disease free layings (40,000 larvae) is between 3-3.5 kgs.

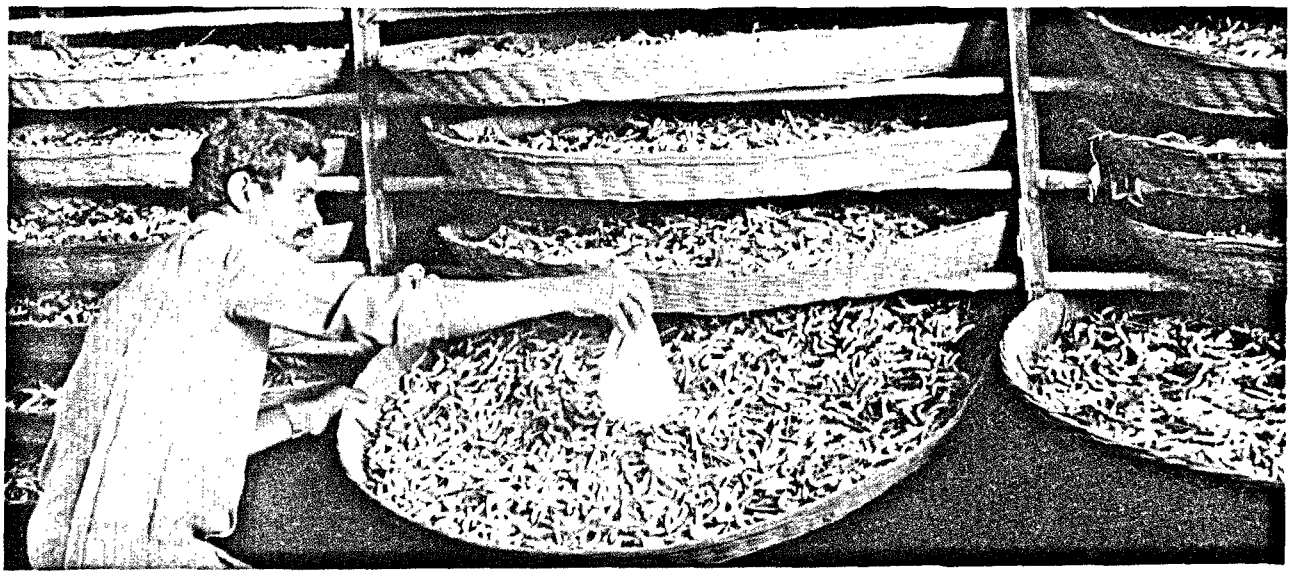


Figure. 6. Dusting of "Reshamkeet Oushadh"

3.1.2. *Cytoplasmic polyhedrosis*

Cytoplasmic polyhedrosis is one of the major viral diseases found during summer.

Causes of the disease

This disease is caused by *Smithia virus* belonging to the sub-group type I of the family Reoviridae. The virus is spherical 60-70 nm in size. It infects and forms polyhedra mainly in the cell cytoplasm of the midgut cylindrical cells. When the cylindrical cells are completely infected the virus switches its infection and forms polyhedra even in goblet and regenerative cells. The infection in the midgut starts from the posterior portion and slowly proceeds towards the anterior portion. The polyhedra varies greatly in size from 1-10μ. The shape is usually tetragonal or hexagonal but rarely trigon.

Infection usually takes place through the feeding of polyhedra contaminated mulberry leaf. Heat, cold and chemical treatment have also been found to induce this disease. The major factor influencing the outbreak of this disease is the inferior quality of mulberry leaf, high temperature and fluctuations in temperature and humidity. The major source of contamination and spread is the rearing bed itself as the virus with the polyhedra are excreted along with the faecal matter.

Symptoms: Generally cytoplasmic polyhedrosis virus infects larvae, but rarely pupae and adults. Affected larvae show symptoms of slow growth, stunted body, reduced mulberry consumption and dull white colour (Fig. 7). Individual sizes vary greatly and the worms show delayed moulting. If infection takes place in grown-up larvae, the thorax becomes transparent and the body atrophies. As the disease develops, the milky-white portion advances rostrally until the entire gut becomes chalky white giving the body of the worm a milky white colour (Fig. 8). At this stage larvae excrete soft whitish faecal matter containing numerous polyhedra. Occasionally the anal region is soiled with rectal protrusion. If the affected larvae are dissected the midgut is seen as whitish and opaque compared to the greenish and transparent midgut of the healthy larvae (Fig. 9).

Prevention and control: The cytoplasmic polyhedral virus, occluded in the polyhedra can persist for more than one year inside the rearing room, appliances and surroundings. Their resistance to formalin is greater than nuclear polyhedra. Hence the rearing room, appliances and surroundings should be thoroughly disinfected by using a 2 per cent formalin solution with 0.5 per cent freshly prepared slaked lime. The infected larvae, faecal matter and bed refuse should be completely destroyed either by burning or by decomposition in a manure pit. Care should be taken to rear silkworms under proper

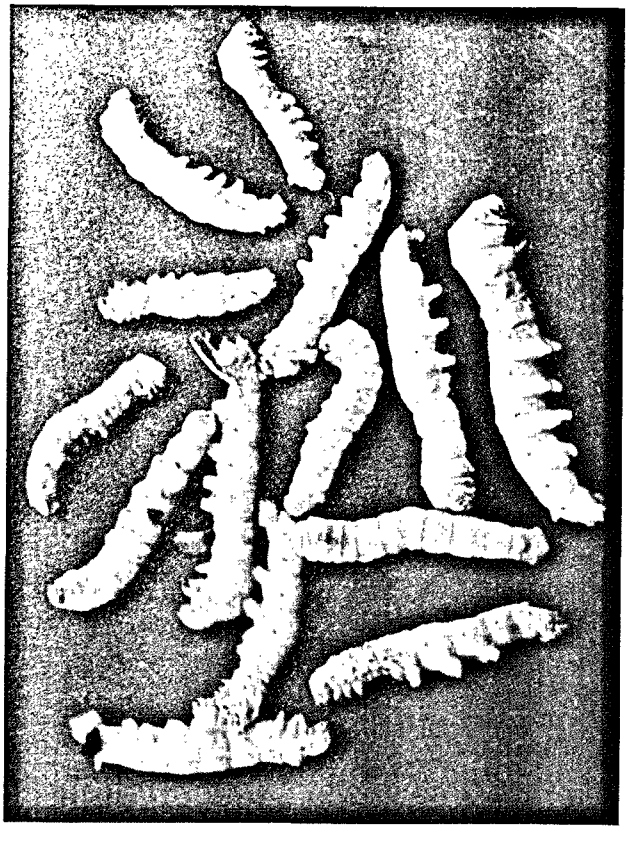


Figure. 7. Cytoplasmic polyhedrosis virus affected larvae (early stage)

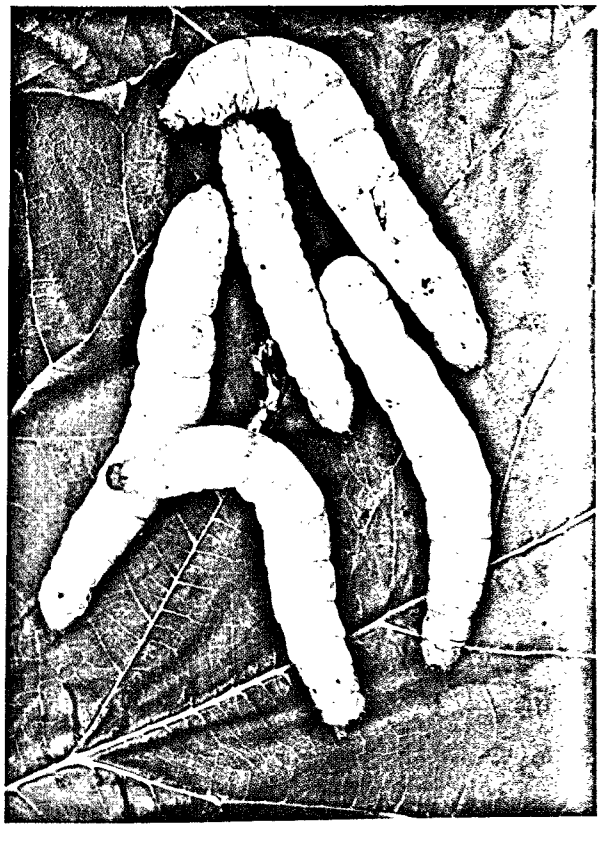


Figure. 8. Cytoplasmic polyhedroses virus affected larvae (late stage)

Figure. 9. Midgut of normal and cytoplasmic polyhedrosis virus and affected larvae

temperature, humidity and hygienic conditions. On appearance of the disease, trays, seat paper, nets and foam pads should be replaced with disinfected ones. Mulberry grown under shade, in phosphorous deficient, high acidic and alkaline soil conditions produce poor quality leaves. Feeding of such leaves has often been found to induce cytoplasmic polyhedrosis and hence should be avoided. Chemicals such as 1 per cent calcium hydroxide can be sprayed on the mulberry leaf and fed to larvae to reduce the occurrence of cytoplasmic polyhedrosis. Some interferon producing chemicals like Poly.I:c, 2', 5'-oligo (A) have been reported to inhibit the growth of cytoplasmic polyhedrosis virus (CPV) in the silkworms but they are yet to be introduced in the field for commercial use.

3.1.3. *Infectious flacherie*

It is a highly contageous and exceedingly disastrous disease found in all the silkworm rearing areas of the world.

Causes of the disease: This disease is caused by a non-occluded *Morator virus* belonging to the family Picornaviridae. The virus is globular and measures 24-28 nm. Infection usually takes place perorally. During the invasion of the midgut, the virus preferably infects the goblet cells. As the infection advances the virus is dispersed in the lumen of the digestive tract and excreted with the faeces. Unlike the cytoplasmic polyhedrosis the infection starts from the anterior region of the midgut and progresses toward the posterior region and never exhibits the chalky white appearance.

Symptoms: Symptoms are similar to bacterial flacherie, such as loss of appetite, transparent cephalothorax, shrinkage of the body, retarded growth and empty foregut (Figs. 10 and 11). This follows vomiting of gastric juice and diarrhoea. The midgut is empty with little mulberry leaf but full of yellowish brown fluid (Fig. 12). The diagnosis of this disease is not possible from external appearance nor through ordinary microscopy but can be detected by fluorescent antibody technique or by staining the infected cells with pyronine methyl green. Latex agglutination and other serological tests are also being used now for the detection of this disease.

Prevention and control: As the virus exhibits high virulence and may retain its pathogenicity in the body of the dead worms for 2-3 years, the rearing rooms, appliances and surroundings must be thoroughly disinfected by using 2 per cent formalin and 0.5 per cent calcium hydroxide or bleaching powder containing 1 per cent active chlorine in it. Silkworm rearing under optimum climatic and hygienic conditions and better feed management helps in the reduction in the incidence of the disease. As the disease spreads from the virus excreted along with the faeces, the diseased larvae with bed refuse

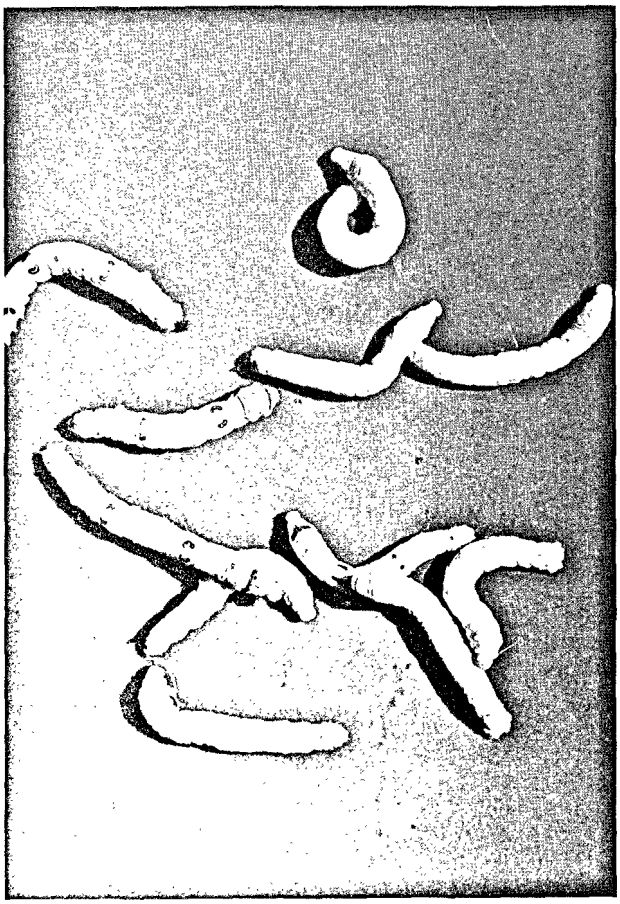


Figure. 10. Infectious flacherie virus affected larvae (early stage)

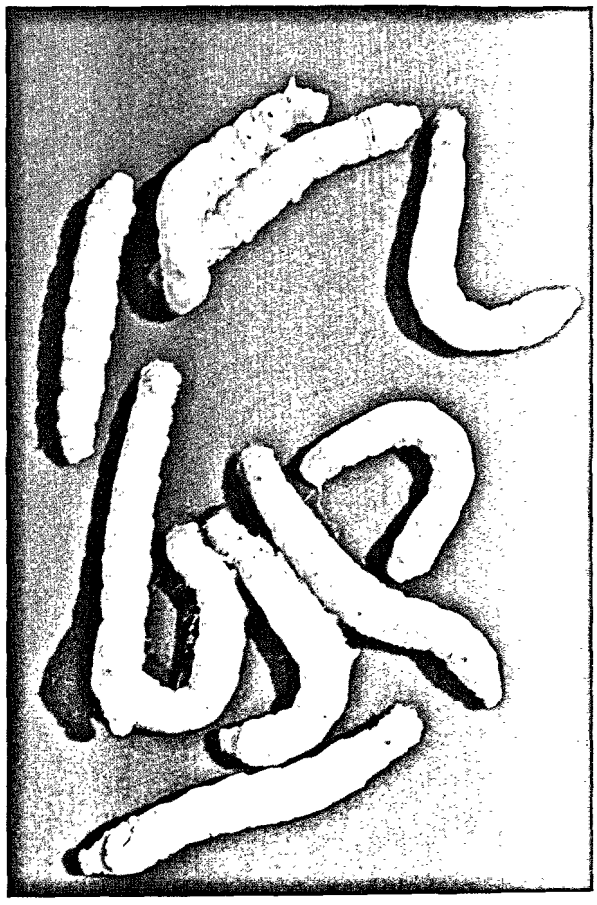


Figure. 11. Infectious flacherie virus affected larvae (late stage)

Figure 12. Midgut of normal and infectious flacherie virus affected larvae

should be burnt or put in a manure pit for thorough decomposition. Only corrective measure known for this disease is the testing of the chawki reared worms for an early detection of the disease through fluorescent antibody, agar gel diffusion, immunoelectrophoresis and seroagglutination and rejection of the infected batches.

3.1.4. *Densonucleosis*

This is a viral flacherie disease more recently reported from Japan (1973). Initially it was named as Ina-Flacheirevirus (Ina-F.V.) being found first in the suburbs of the Ina city in the Nagano prefecture. Following that several investigators studied it in detail and concluded in common that the virus was different from the earlier known IFV but quite close to the densonucleosis virus of the wax moth, *Gmellonella* and the new disease was named as *Bombyx* densonucleosis.

Causes of the disease: The disease is caused by a non-occluded virus belonging to the genus Densovirus of the family Parvoviridae. The virus particles are globular with a diameter of 20 nm. Infection usually take place orally. The major source of cross contamination is the virus excreted along with the faeces by the silkworm and the pyrallid moth frequenting the mulberry field which is also known to be a harbour of the disease.

Symptoms: Retardation of growth and shrinkage of body take place in the injected worms (Figs.13 & 14). Body flaccidity like flacherie infected worms is the other major symptom of the disease. On dissection, alimentary canal of the diseased larva appears pale yellow in colour without most of the content. This sign is quite similar to that in the case of IFV infection but one major difference observed from the histological study is that while the IFV invades the goblet cells of the midgut this virus multiplies in the nuclei of the columnar cells. This was also confirmed through the fluorescent antibody technique. When the silkworm larvae were per-orally infected with Bombyx densonucleosis virus (DNV) they usually died after seven days showing the flaccidity as the major symptom.

Prevention and control: Epizootiological investigations with DNV have shown it to be present in the rearing rooms and in the dusts on mulberry leaves from the field having pyrallid moths with this infection. The virus has been found to be highly thermolabile and when the larvae reared at 25-28°C were transferred to a temperature of 37°C the multiplication of the virus was greatly reduced. Susceptibility to DNV was also found to be genetically controlled with some varieties and crosses being non-susceptible to the disease. Effective methods of prevention and control of this disease may thus be the stoppage of cross-infection, early detection and rejection of the batches found to be infected

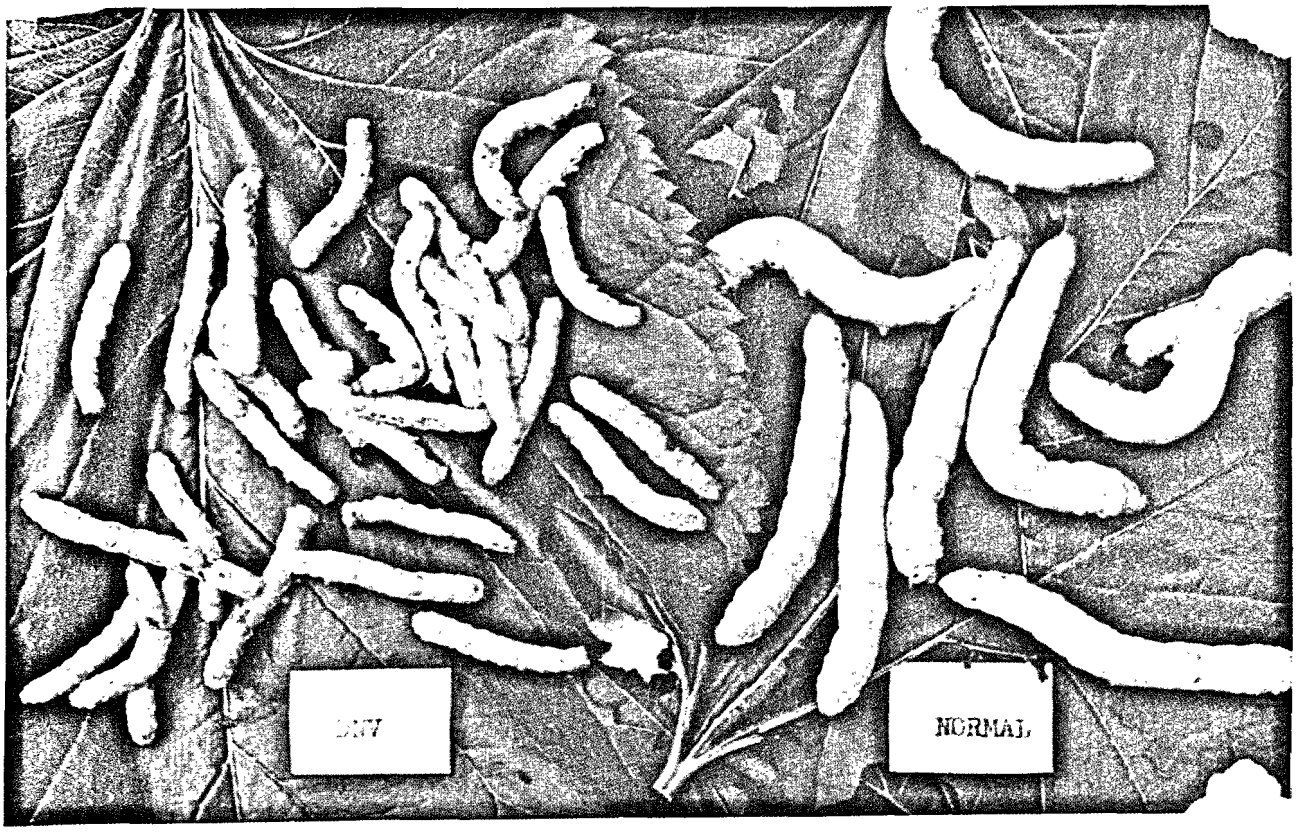


Figure. 13. Normal and Densonucleosis virus affected larvae

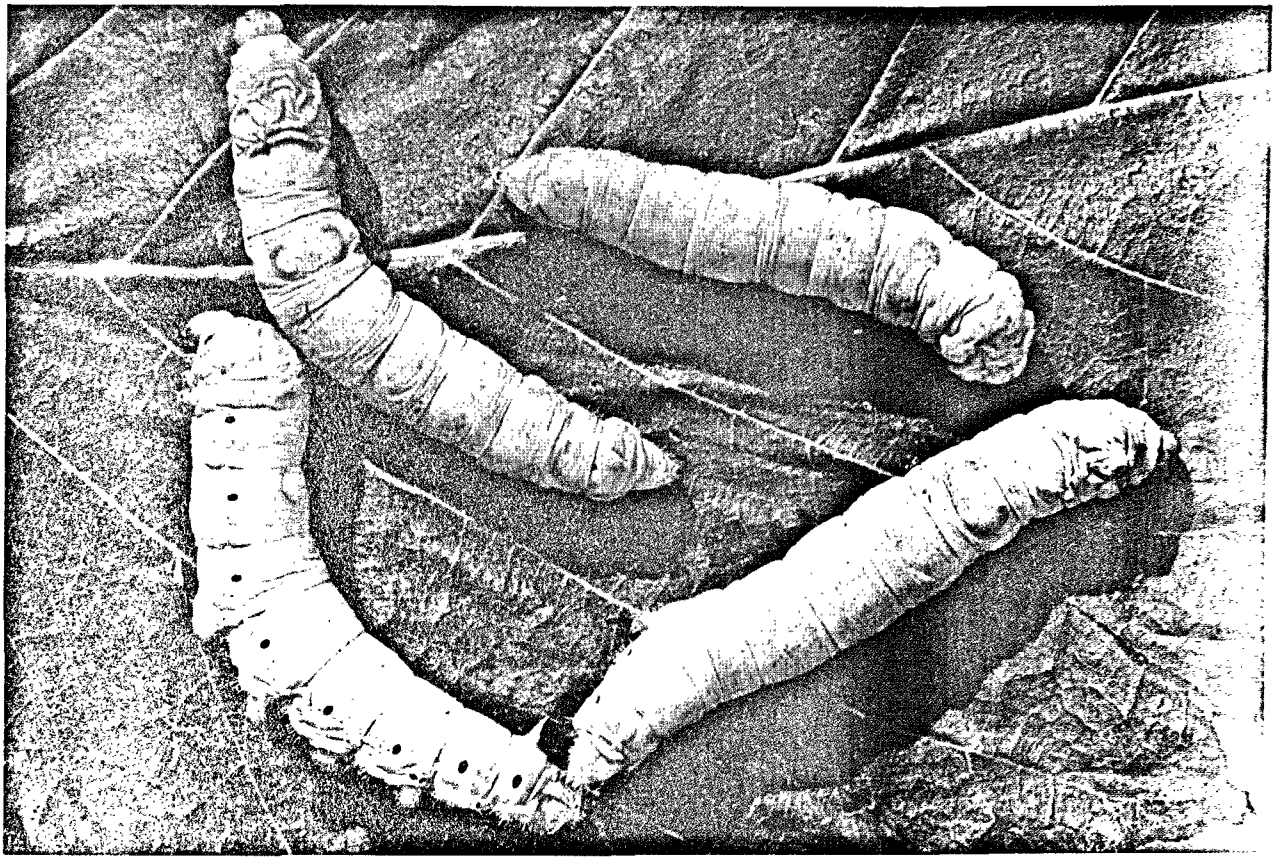


Figure. 14. Densonucleosis affected larvae (late stage)

with the virus through fluorescent antibody studies and rearing of the non-susceptible breeds/crosses.

3.1.5. ***Comparison of different virus diseases of silkworm***

In the preceding pages, the causes, symptoms, routes of infection, course of the disease etc. of different virus diseases of silkworm have been described individually. A summary comparison is given in table 1.

3.2. BACTERIAL DISEASES

Bacterial diseases affecting silkworm are collectively known as flacherie due to the flaccid nature of the diseased larvae. The incidence of flacherie is high during hot and humid seasons. In general, massive out-break of these diseases are uncommon but depending upon poor disinfection, accumulation of faeces in the rearing trays, feeding of mulberry leaves with contamination, improper handling and unsafe use of bacterial pesticides, large scale loss in crops sometimes occur. Bacterial diseases of silkworms are divided into three major types namely bacterial septicemia, bacterial diseases of the digestive tract and bacterial toxicosis.

3.2.1. ***Septicemia***

This is a condition where bacteria multiply enormously in the blood (haemolymph) of the larvae, pupae and moths. Septicemia during the larval stage leads to larval mortality whereas the infection in pupal and moth stages leads to a large number of melted cocoons affecting the egg production in the grainages.

Causes of the disease: This disease is caused by the multiplication of a large number of bacteria, bacilli, *streptococci* and *staphylococci* in the haemolymph. The route of infection is through injury or wounds and rarely perorally. Two major types of bacterial septicemia are generally observed, one is the black thorax septicemia caused by *Bacillus* sp. belonging to the family Bacillaceae of the order Eubacteriales size 1-1.5 x 3 microns, spores subterminal, gram-positive and the other is the red septicemia or serratia septicemia caused by the bacillus *Serratia marcescens* Bizio size 0.6-1.0 x 0.5 microns non-sporulating and gram negative. The former is more resistant to disinfectants than the latter except for lime emulsion.

Symptoms: They have some common symptoms like sluggish movement, decreased appetite, straightened body, swollen thorax, shrinkage of abdominal segments, vomiting and bead like faeces

Table 1. Comparison of the pathogens and symptoms of Nuclear Polyhedrosis Virus (NPV), Cytoplasmic Polyhedrosis Virus (CPV), Infectious Flacherie Virus (IFV) and Densonucleosss Virus (DNV).

Item/Disease	NPV	CPV	IFV	DNV
Virus	Shape Rod Shaped Size 330 x 80 nm	Globular 60 x 70 nm	Globular 24-38 nm	Globular 20 nm
Site of infection	Nucleus of trachéa, fat bodies, epidermis and haemolymph.	Cytoplasm of cylindrical cells of midgut.	Cytoplasm of goblet cells of midgut	Nucleus of cylindrical cells of midgut.
Polyhedra, if formed	Shape: Formed in nuclei Hexahedron	Formed in Cytoplasm irregular hexahedron/ tetragon	No polyhedra formed	No polyhedra formed
	Size: 3-6 μ	1-10 μ	–	–
Symptoms	Segments swollen, milky white body colour frantic movement defecation normal.	Empty headed, diarrhoea motionless faeces irregular shaped, milk-white stinge in advanced stages	Empty headed, diarrhoea, head and thorax upheld motionless, faeces irregular shaped, brownish fluid in the gut.	Empty headed, diarrhoea, head and thorax upheld motionless, faeces irregular shaped, brownish fluid in the gut.
Course of the disease	Subacute	Chronic	Chronic	Chronic
Pathological changes	Bodywall: Burst easily Haemolymph: Milky-white numerous poly-hedra Midgut: Normal	Burst uneasily Transparent. No polyhedra Milky-white in the posterior part, annular wrinkles formed.	Burst uneasily Transparent. No polyhedra Yellowish-green and transparent. No milky white tinge.	Do not burst Transparent. No polyhedra Yellowish-green
Source/ cause of infection	Corps of diseased worms contaminating environment and leaves. Peros or wound infection.	Faeces of diseased worms contaminating environment and leaves. Peros infection.	Faeces of diseased worms contaminating environment and leaves. Peros infection.	Faeces of diseased worms contaminating environment and leaves. Peros infection.
Diagnosis	Polyhedra in the haemolymph under microscopic examination.	Polyhedra in the posterior part of midgut under microscopic examination.	Biological and serological test	Biological and serological test.

Control: Common control measures suggested for all the above diseases are: (1) Disinfection of rearing room and utensils (2) Disinfection of worms, trays and discarding of sick worms. (3) Use of disease resistant varieties (4) Sound management, improving the rearing environment and feed stuff & (5) Early diagnosis and rejection of infected lots. Drug and high temperature therapy are done in research work but are not yet applied in production.

and loss of clasping power of legs. Further, the body becomes soft and discoloured and the body wall ruptures easily emiting foul smelling fluid.

Difference in the symptoms of two diseases are that, in case of the black thorax septicemia, the blackening starts from the thorax and extends to the dorsal vessel till the whole body blackens and rots (Figs. 15 and 16) whereas in the latter case the whole body softens taking a slightly reddish tinge (Fig. 17). Septicemias are generally acute diseases,

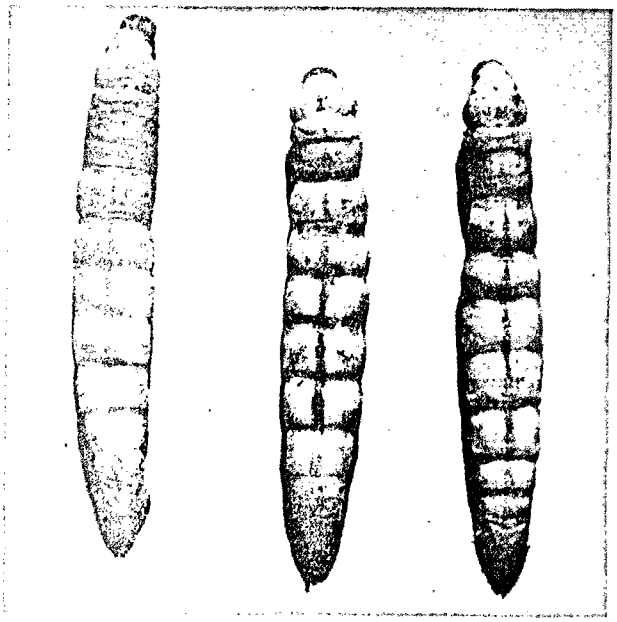


Figure. 15&16. Black thorax septicemia affected larvae (early and late stage of infection)

Figure. 17. Serratia Septicemia affected larvae

spreading quickly, the time elapsing from the time of infection to death at 28°C being about 10 hours. At higher temperature and under epidemic conditions they may die within 5-6 hours.

Prevention and control: High temperature and humidity conditions are most favourable to the propagation of the bacteria responsible for these diseases and so these diseases occur chiefly in the seasons having high temperature and humidity. They normally follow wound infection. The bacteria enters generally through the wound and multiplies in the haemolymph, disrupting the normal physiological functions, causing septicemia. The 5th instar larvae are more prone to injury and these diseases thus occur mostly in the later part of this stage. An effective means of control of these diseases can be the maintenance of hygienic condition so that these bacteria do not occur on the mulberry leaves, in the rearing room and rearing equipment. Care should be taken to avoid injury to the worms, overcrowding of trays and accumulation of faeces in the rearing bed.

3.2.2. *Bacterial disease of the digestive tract*

This disease is otherwise known as transparent head disease due to the bacterial multiplication in the digestive tract leading to the swelling and transparency of the head.

Causes of the disease: The causative agent of the disease is non-specific. However the common bacterium seen associated with this disease is a gram positive *Streptococcus* sp. belonging to the family Streptococceae. The bacteria are round 0.7-0.9 microns in size and are found joined by group of two or more to give a beaded appearance. Besides the *streptococcus* sp. some short bacilli and large bacilli have also been found to occur in the digestive tract eliciting the disease. Under poor nourishment and adverse environmental and rearing conditions, the physiological function of the digestive tract is disturbed. As a result, the bacteria devoured along with mulberry leaf multiply in large number and destroy the membraneous tissues.

Symptoms: General symptoms are poor appetite, sluggish movement, transparent head, stunted body size and retarded growth sometimes with oral and anal discharges (Fig. 18). The sick worms often hide under the mulberry leaves. In case of a late stage attack by the disease the worms remain in the spinning tray for a long period without spinning cocoons till they die.

Prevention and control: Feeding of proper type of nutritious leaf, maintenance of required temperature and humidity conditions, maintenance of hygienic condition in rearing beds and culling out of the diseased worms may prevent and reduce the disease occurrence to a considerable extent. Since this is an enteric disease, addition of chloramphenicol to the diet has been found to bring considerable improvement.

3.2.3. *Sotto*

This is otherwise known as bacterial toxicosis. This happens when the silkworms come in contact with the toxin producing bacilli.

Causes of the disease: This disease is caused by different strains of *Bacillus thuringiensis* belonging to family Bacillaceae of the order Eubacteriales. The sotto bacterium has a vegetative, cytocyst and spore form. The spore produces delta endotoxin. Infection is usually peroral but can also take place through wounds or injury. After entry into the silkworm body the toxic crystals are dissolved in the alkaline gut juice and are absorbed through the gastric wall affecting the nervous system, leading to spasm and paralysis.

Symptoms: Infected larvae lose appetite suddenly and show the symptoms of convulsions, lifting of head, spasm, tremors, paralysis, distress, sudden

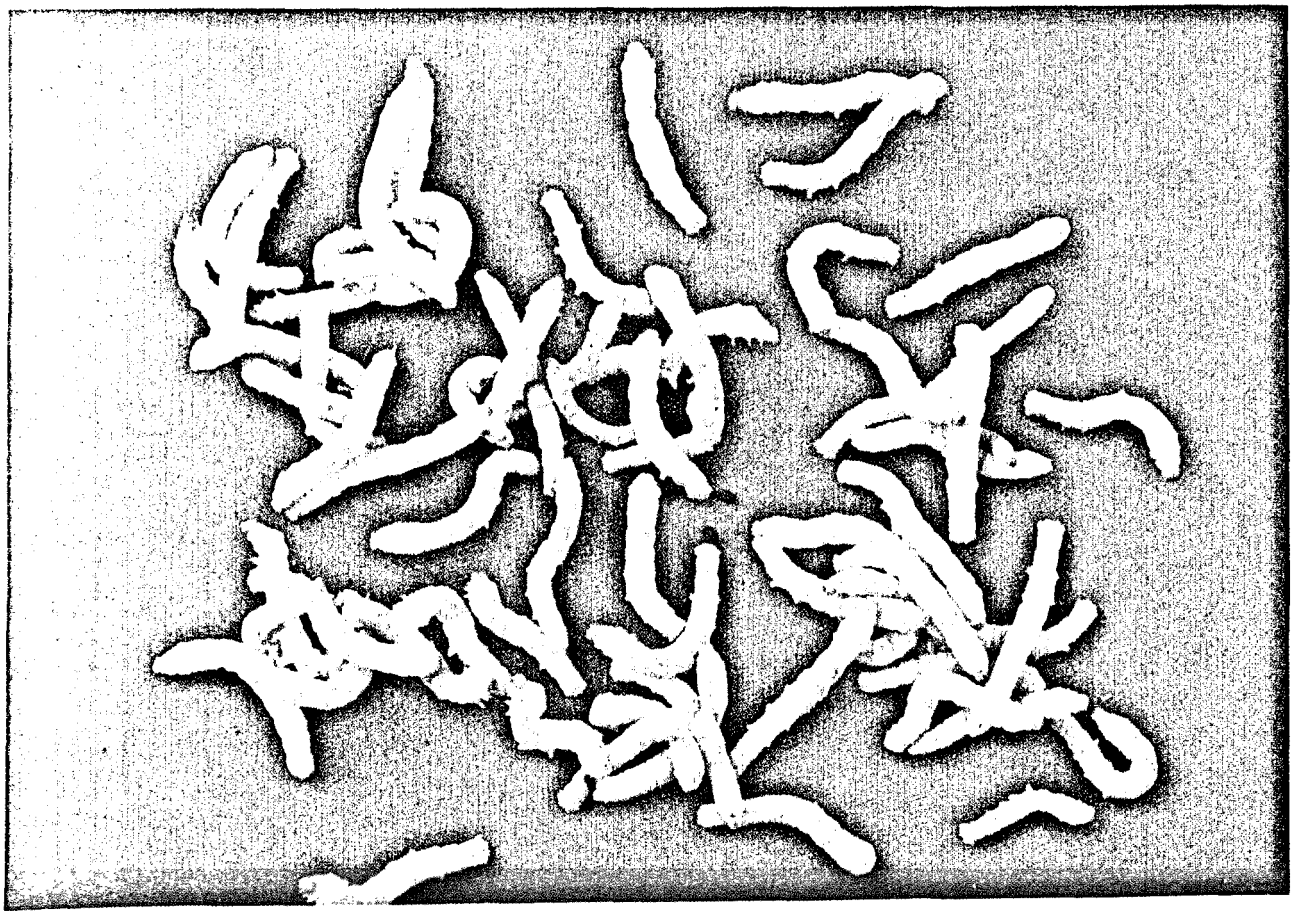


Figure. 18. Transparent head disease affected larvae

collapse and death. Shortly after death the corpse is out-streched, hard to touch and the head appears hook shaped (Fig. 19). The body turns gradually to brown, blackish brown and black and rot exuding foul smelling dark brown fluid.

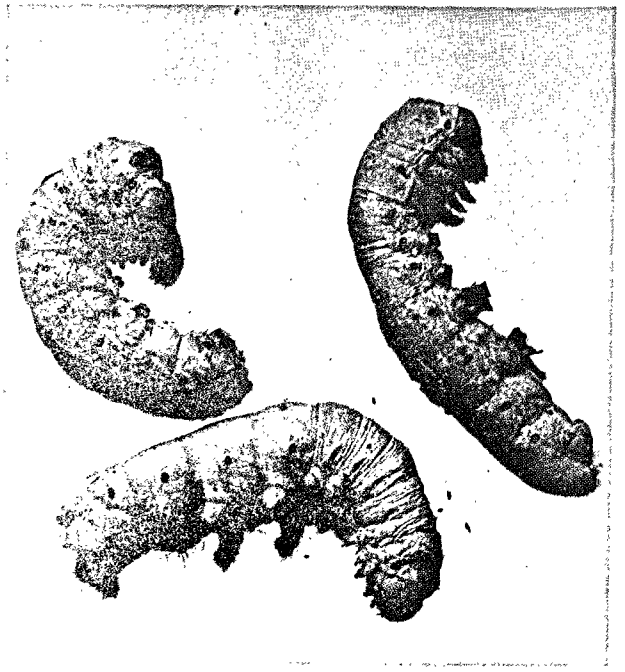


Figure. 19. Sotto disease affected larvae

Prevention and control: Besides conducting initial thorough disinfection of the rearing room and equipment to eliminate the bacteria, care should be taken to see that this bacteria does not get entry into the rearing room and rearing beds. Various strains of *Bacillus thuringiensis* are being produced now commercially as biological insecticides for the control of insect pests including mosquitoes. Their toxicity against silkworm should be assessed and strict care should be taken to see that the strains toxic to silkworm are not used in the silkworm growing areas.

3.3. FUNGAL DISEASES

Fungal diseases otherwise called mycosis, is caused in the silkworm by a few parasitic fungi. Two major kinds of such disease are Muscardine and Aspergillosis. Muscardine appears in various forms and depending upon the colour of spores which cover the body of the silkworm giving a characteristic colour, they have been named as white-muscardine, green-muscardine, yellow-muscardine, black-muscardine, red-muscardine etc. The more common muscardine diseases are, however, white and green-muscardine. In addition Aspergillosis is also found to occur. Since the silkworm attacked by a fungal disease in course of time turns hard and chalky, muscardine disease is also called Calcino.

3.3.1. *White muscardine*

It is the most common and widely prevalent fungal disease found in all sericultural countries. This disease occurs usually during rainy and winter seasons under moderate to low temperature and high humidity conditions.

Causes of the disease: This disease is caused by different species of *Beauveria* of which the most virulent is *Beauveria bassiana* (Balsamo) Vuillemin. This fungus belong to the family Moniliaceae, order Moniliales of class Fungi imperfecti. Infection is mainly by body contact, rarely through wounds and not by ingestion. Main sources of infection are the mummified larvae, infected seat paper, tray and dead wild lepidopterous larvae from the mulberry field. The disease is highly contageous as the conidia are air borne.

The developmental cycle of *Beauveria bassiana* consists of three dinstinct stages namely conidium, vegetative mycelium and aerial mycelium (Fig. 20).

The conidium is colourless, globular or rarely oval in shape and porcelain white when gathered in a mass. Under favourable conditions of temperature and humidity the conidium germinates within 8-10 hours of coming in contact with the body of silkworm. On germination the conidium not only sends out its germ tube but also secretes chitinase which facilitates the germ tube to penetrate the body wall for further multiplication. The germinating tube of the conidium after invading the blood of the larvae develops into vegetative hypae. At

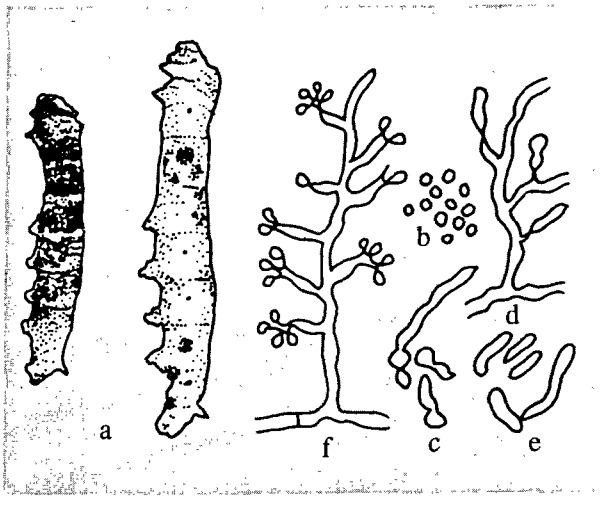


Figure. 20. Development cycle of Beauveria bassiana
(a) Affected larva
(b) Conidia
(c) Germination of conidia
(d) Formation of cylindrical spores
(e) Cylindrical spores
(f) A. Conidiophore with conidia

the tip of the hyphae round or oval shaped short hyphae develops. These often detach themselves and elongate to form vegetative hyphae.

The vegetative hyphae comes out of the skin to form aerial hyphae bearing innumerable conidiophores. These conidiophores give rise to small branches which bear one or two conidia.

Symptoms: At the early stage of infection symptoms are not distinct, but as the disease advances, moist specks appear on the skin. At this stage, larvae lose appetite and become inactive. The body of the larvae becomes limp, loses its skin elasticity, stops movement and finally they die. Before death, symptoms of diarrhoea and vomiting appear (Fig. 21). After death, the body is initially soft, but within 6-8 hours it becomes stiff and hard (Fig. 22). At this stage the body is pink in colour. This is due to the multiplication of *Serratia marcescens,* a secondary bacterium. One to two days later, wooly aerial hyphae grow out between intersegmental membrane. Subsequently the whole body is covered with white powdery conidia except the chitinous parts of the head. The larvae, unlike other diseases do not rot or decay but remain hard (Fig. 23) as the fungus secretes double oxalate - crystals of ammonium and magnesium.

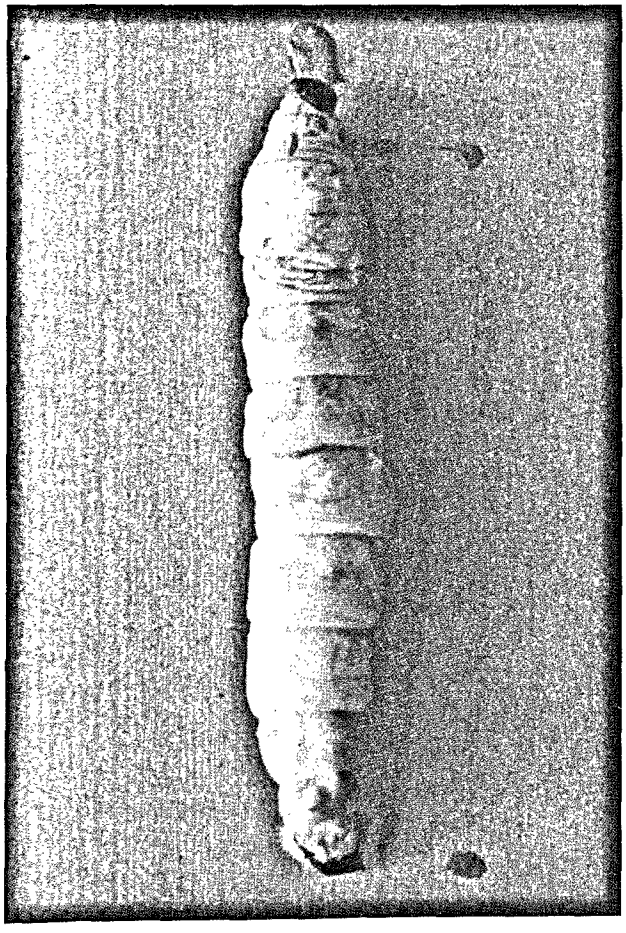


Figure. 21. Vomiting of a muscardine affcted larva

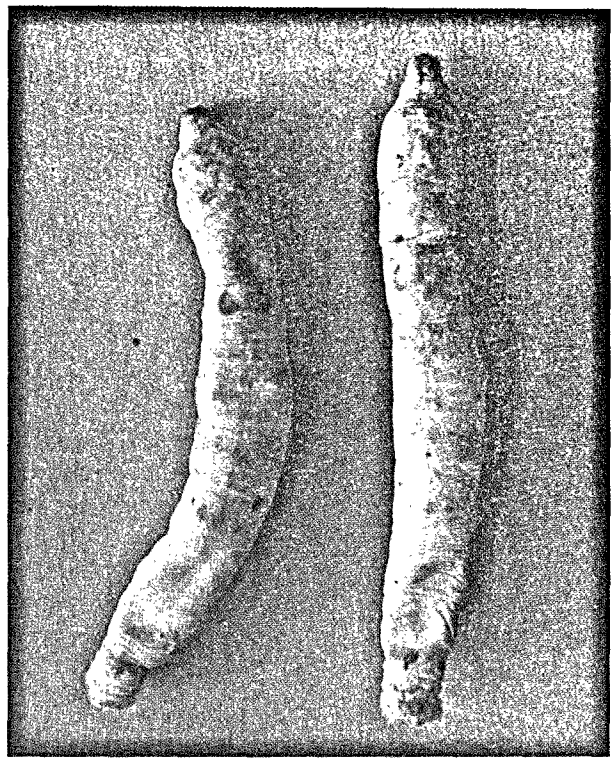


Figure. 22. Muscardine larvae becoming stiff and hard

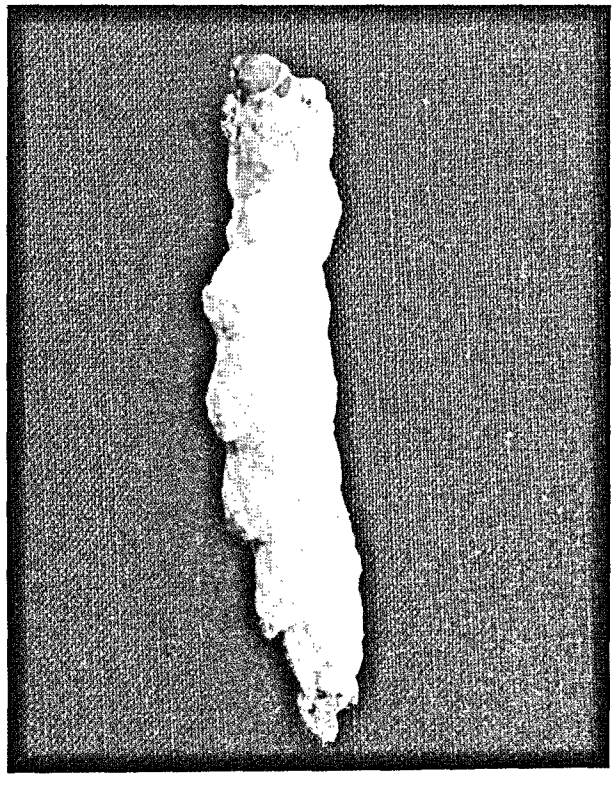


Figure. 23. Mummifed larva

In case of pupal infection the pupae slow down their reaction to outside stimuli. The thorax shrinks and abdomen is wrinkled. The aerial hyphae and conidia grow upto one third of its ordinary weight inside the cocoons. Such cocoons sound like dried cocoons when shaken. During moth stage the body is hardened and the wings fall of easily.

Prevention and control: Before the commencement of silkworm rearing, rooms, appliances and rearing surroundings must be thoroughly disinfected with 2 per cent formalin or 5 per cent bleaching powder solution. This disease can be kept under check by avoiding low temperature and high humidity during rearing as they are more ideal for fungal growth. The rearing bed should as much as possible be kept thin and dry in order to avoid the germination of conidia and spread of the fungus. If the disease is found during rearing, the trays, seat papers, cleaning nets, foam pads etc., must be disinfected and replaced. Diseased worms should be removed carefully before they get mummified and should be placed in lime jars or destroyed by burning or deep burying, with a disinfectant spray. Similarly the bed refuse along with the faeces should be disposed of properly. Mulberry pests in the garden should be controlled as they get easily infected with this pathogen, later becoming an important source for cross contamination to the silkworm.

In addition to the above, anti-muscardine powders can be fruitfully used to control the outbreak and spread of this disease. A few methods of application of the same are given below:

Application of formalin chaff:

In this method formalin solution of required concentration depending on the silkworm instar is mixed with burnt paddy husk and sprinkled on the larval body and bed (Fig. 24). The concentration of formalin required is 0.4 per cent during I and II instars, 0.5 per cent in III instar, 0.6 per cent in IV instar and 0.8 per cent during V instar. The paddy husk is charred or burnt either by burning or roasting in a pan without making ash. Depending on the instar of larvae, the required strength of formalin is mixed with the burnt paddy husk in the ratio of 1 : 10 by volume and mixed thoroughly. Then it is sprinkled evenly on the larvae and covered with a paraffin or double fold newspaper. After 1/2 an hour the paper cover is removed and feed is given. Formalin chaff application should not be done when larvae are preparing for moult or under moult. Application of formalin chaff can be done before brushing on the newly hatched larvae and after each moult 1/2 an hour before the resumption of feeding. The frequency of application of formalin chaff should be increased depending on the incidence of disease.

Application of Dithane M 45 (Zinc ion Manganese ethylene oxide bisdithio carbomate) or captan (N-Trichloromethyl Thio-4-Cyclohexane 1,2-Dicarboximide)

These are the two commonly available fungicides used for the control of muscardine. These fungicides are used at a concentration of 1 per cent during, I, II and III instars and 2 per cent during IV and V instars in combination with levigated China

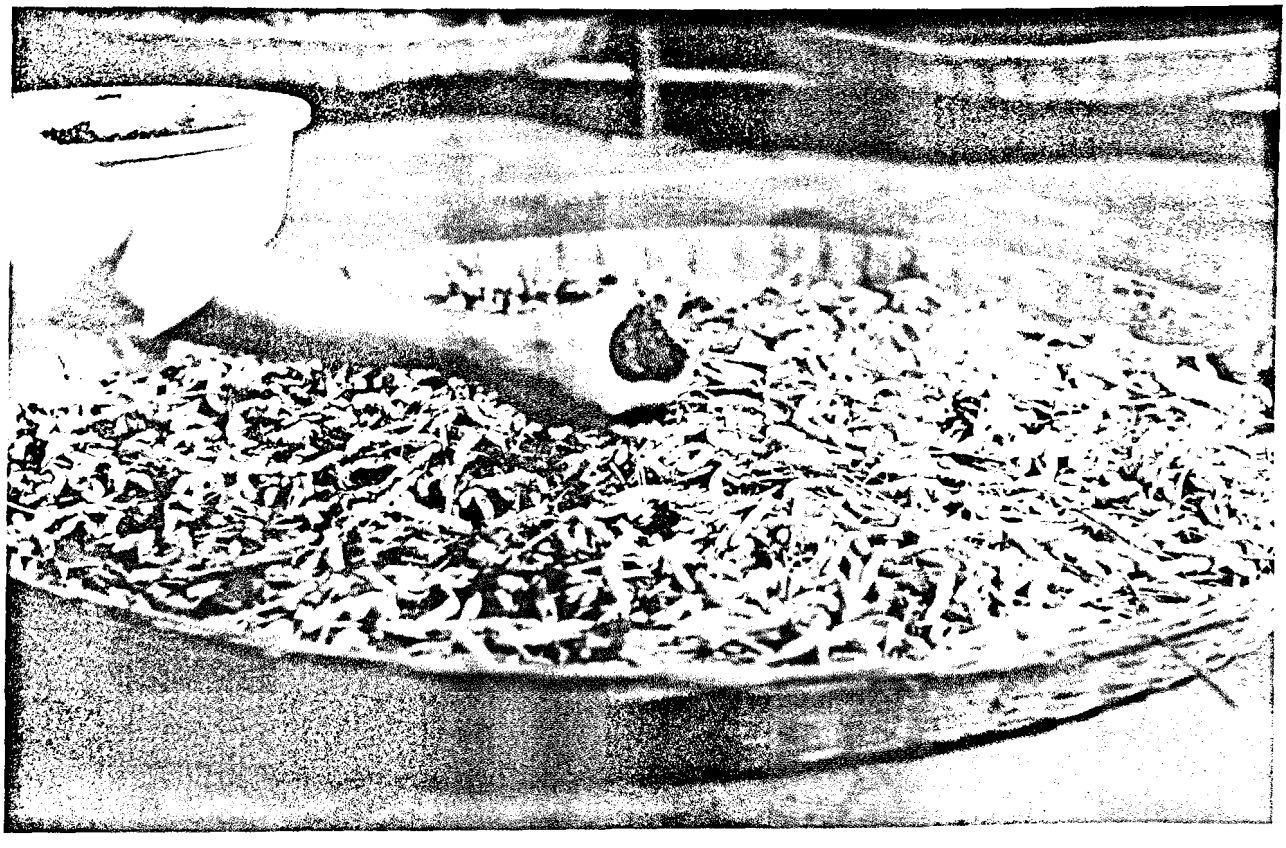


Figure. 24. Application of Formalin chaff

clay or Kaolin. The ingredients are thoroughly mixed and tied in a thin cloth and dusted on newly born larvae and after each moult 1/2 an hour before the resumption of feed. An additional dusting should be done on the 4th day of final instar after bed cleaning (Fig. 25). The quantity required is 2-3 grams per 0.1 sqm. area during I, II and III instars and 4-5 grams during IV and V instars. The dustings should not be done when the larvae are preparing for moult or are under moult. The dusting frequency should be increased if the intensity of infection is high.

Application of "Reshamkeet Oushadh"

It is a bed disinfectant formulation used to prevent both muscardine and grasserie. Its constitution, method of application and quantity required have already been indicated in the part covering the control of grasserie disease.

3.3.2. *Green muscardine*

This disease occurs during autumn, late autumn and winter season.

Causes of the disease: This disease is caused by *Nomuraea rileyi* Farlow, belonging to family Moniliaceae of class Fungi imperfecti. Infection takes place through skin by Conidia. They germinate in 15-20 hours in favourable conditions. The major source of cross contamination is the dead mummified larvae and infected wild lepidopterous insects from field.

The three growth stages of this pathogen are similar to white muscardine comprising the conidium, vegetative mycelium and aerial mycelium (Fig. 26).

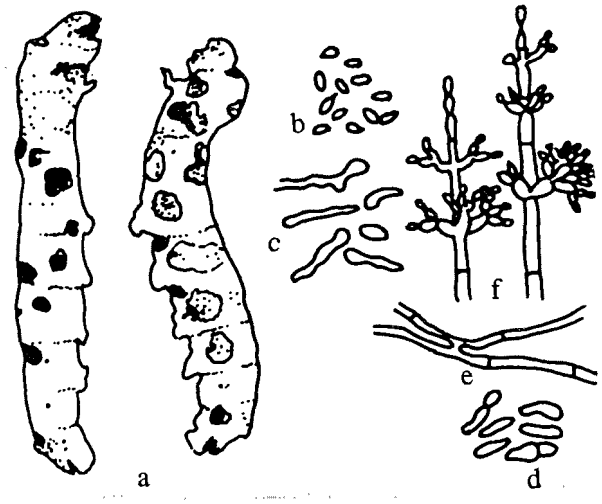


Figure. 26. Development cycle of Nomuraea rileyi
(a) Attacked larva
(b) Conidia
(c) Budding of conidia
(d) Hyphal bodies
(e) Anastomosis of mycelia
(f) Conidiophore bearing conidia

Figure. 25. Dusting of fungicide mixture

The conidium is oval in shape and slightly pointed at one end. It is light green and single celled. Germinates at 22-24°C in 20 hours.

The vegetative mycelelum has a germinating tube which elongates and gives rise to fine and filamentous mycelia with septae. They in turn produce large amount of colourless tubular or bean shaped hyphae. Vegetative mycelia become clustered with hyphae which in turn form conidiophores. These conidiophores are wheel shaped and unbranched. Conidiophores bear few or several gourd shaped sterigmata each of which carries at the tip a chain of conidia.

Symptoms: During early period of disease no noticeable symptoms are seen. As the disease progresses dark brown irregular lesions appear on the ventral, dorsal and lateral sides. These lesions sometimes gather into large spots with clear circumference. In a serious case the silkworm vomits fluid, has diarrhoea and dies. After death the corpse is soft initially and gradually hardens. Two to three days after death mycelia appear from the intersegmental membranes and spiracles. Gradually the whole body is covered with white mycelia. After 10-15 days these mycelia are covered with fresh green conidia (Fig. 27).

Figure. 27. Green muscardine mummifed larvae

Prevention and control: Prevention and control measures are similar to those recommended for the white muscardine.

3.3.3. ***Aspergillosis:***

This is a menace to young instar larvae particularly when high humidity is prevalent.

Causes of the disease: This is caused by different species of Aspergillus and Sterigmatocytis belonging to the family Moniliaceae of class Fungi imperfecti. About one dozen species are reported to infect silkworms of which *Aspergillus flavus* link and *Aspergillus oryzae* Wehmer are most common.

The growth stages of the pathogen consists of the conidium, vegetative hyphae and aerial hyphae (Fig. 28).

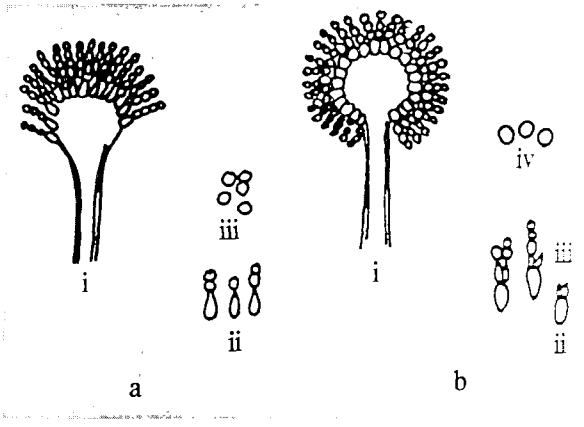


Figure. 28. Morphology of Aspergillus Sp.
(a) Aspergillus flavus *(b)* Aspergillus oryzae
i) Conidiophore *i) Conidiophore*
ii) Sterigma *ii) Phialidae*
iii) Conidia *iii) Sterigma*
iv) Conidia

The conidium is spherical, 3-7 μ in size. They are fairly resistant to environmental factors and formalin treatment. The favourable temperature for germination of conidia is 30-35°C. Conidia after germination invade the body of the silkworm and develop into vegetative hyphae without the formation of short hyphae and they grow only at the site of invasion. The conidiphore is thick and at the distal end expands into a globular or oval structure bearing one to two rows of radiating sterigmata on which conidia are formed.

Symptoms: This disease pathogen infects mainly first and second instar silkworms but it is not strong enough to affect grown up larvae. Infected larvae cease eating mulberry leaf, become lethargic, show body tension, lustrousness and then die. Just before death the head and thorax is extended outwards and vomiting occurs. One day after death aerial hyphae appear and later

conidia cover the body. The colour depends on the type of pathogen. The hardening of corpse in dead larvae is limited to the site of fungus penetration and other parts become black and rotten.

Prevention and control: They are basically similar to white muscardine. As the main source of pathogen is through mouldy objects, special care should be taken to bake/sundry the rearing trays and utensils. For disinfection purpose 4 per cent pentachlorophenol may be used instead of formalin.

3.4. PROTOZOAN DISEASES

Protozoa which are injurious to silkworm are the parasitic ones belonging to the class Microsporidia and genera *Nosema*, *Pleistophora* and *Thelohania*. Besides these, *Trypanosoma* and *Leptomonas* have also been reported to infect the silkworm *Bombyx mori* L. However, the major protozoan disease of the silkworm is the pebrine disease, so named due to the appearance of black peppery patches following infection.

3.4.1. *Pebrine*

Pebrine is a chronic and disastrous disease of the silkworm *Bombyx mori* L. It was this disease which was responsible for the sudden collapse of the silkworm industry of both France and Italy in 1965. Even though the fight against this disease in all the sericultural countries is going on since more than 100 years, the disease is not yet eliminated. However, it has been kept under check by following the techniques of strict mother moth examination for the supply of disease free silkworm eggs, in addition to disinfection and hygienic rearings. Though the disease is under reasonable control, it appears sporadically due to infected seed and persisting secondary contamination in the rearing house.

Causes of the disease: Pebrine is caused by Nosema bombycis Nageli belonging to family Nosematidae of order Microsporidia. The pathogen infects the host through feeding of contaminated mulberry leaf (peros) and also by rearing infected silkworm eggs (transovarial). In addition to *Nosema bombycis*, seven different microsporidians belonging to genera Nosema, Pleistophora and Thelohania have been reported to infect the silkworm. These microsporidians differ in their spore morphology, target tissue and virulence. They have been tentatively designated as M 11, M 12 and M 14 (Nosema sp.), M 24, M 25 and M 27 (Pleistophora sp.) and M 32 (Thelohania sp.). However, these microsporidians differ from *Nosema bombycis* in that they do not infect silkworm transovarially. So, they are harboured in wild lepidopterans and constantly introduced into silkworm rearing, leading to cross contamination.

Sources of infection are rather extensive. The main source is the rearing of transovarially and surface contaminated layings. Infection also results from diseased and dead larvae, faeces of larvae, moths, diseased egg shells, larval and pupal exuviae etc. In the rearing bed major source of infection is the faeces of diseased larvae, contaminated tray, seat paper and dust from infected rearing and leaf storage rooms. Sometimes infection takes place through contaminated mulberry leaf from field. The excreta and dead larvae of pebrine infected wild insects may also form a source of infection.

The life cycle of *Nosema bombycis* Nageli includes three stages namely, spore, planont and meront (Fig. 29).

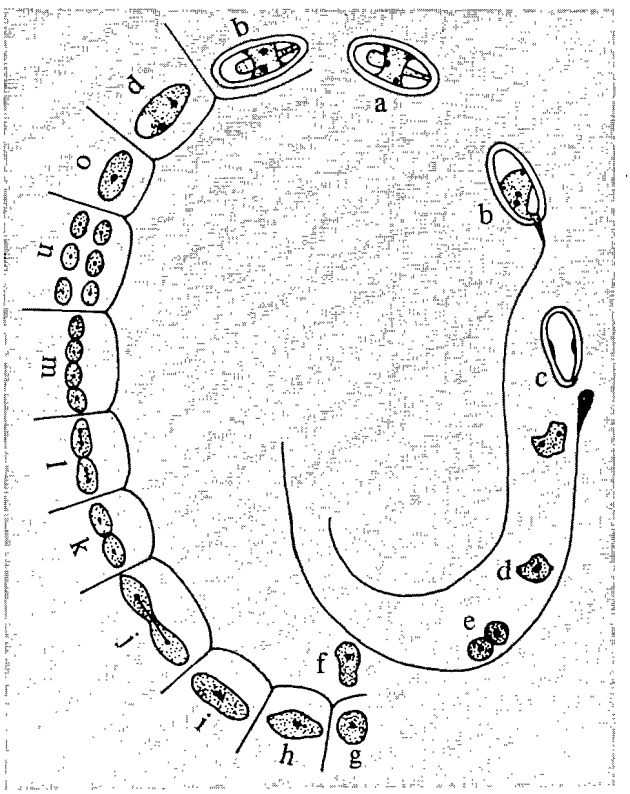


Figure. 29. Developmental cycle of Nosema bombycis
(a) Ripe spore with girdle of living substance with nuclei, two vacuoles and polar capsule
(b) Polar filament extruded; planont about to leave spore-case
(c) Planont with empty spore-case and polar filament immediately after leaving spore-case
(d) Planont with one nucleus
(e) Fusion of two planonts or division
(f) Planont about to enter gut-wall cell
(g) Meront in gut-wall cell
(h to k) Division of meront into two within gut-wall cell
(l to n) Further divisions of meront
(o) Meront ready to form spore
(p) First stage in spore formation-one main and three subsidiary nuclei and one vacuole formed
(q) Further stage in spore formation-thick spore-case secreted two vacuoles and polar capsule

The mature spore is oval or ovocylindrical (Fig. 30). It measures approximately 3 - 4 x 1.5 - 2.5 μ with three layered membrane: the inner, middle and outer. The sporoplasm is stretched in the form of girdle across the width of the spore and it contains a pair of nuclei. The spore has a polar capsule and polar filament. The polar filament is given out on treatment with a number of chemicals like H2O2 and Kcl. Spores are highly refractive and appears light blue under the microscope. The spore represents the dormant stage of the pathogen and can survive in the ordinary conditions of rearing house for more than a year. It retains its infectivity even after three years in the dried body of the female moth, in liquid medium for more than 3 weeks and in soil for more than 2 months. But the spore is susceptible to dessication and can not survive for more than 6 - 7 hours in direct sunlight (39 - 40°C). It is also weak against heat, chemicals and disinfectants.

Figure. 30. Pebrine spores

When live spores enter into the silkworm through mulberry leaf, they germinate in the gut due to high alkalinity and potassium ions. As a result the polar filament is extruded and the sporoplasm along with two nuclei creeps through it and injects into the midgut tissues. Subsequently the polar filament gets digested in the alimentary tract. The two nuclei of the sporoplasm unite to form a uninucleate planont. The planont measures 0.5 - 1.5 μ and is formed in 1 - 2 days. The planont is subglobular with a strong refractive nucleus without shell, performs amoeboid movement and reproduces by binary fission. The planont which intially infects the gut later passes through the gut wall and invades the various susceptible tissues.

Once the planont penetrates the host cell, it transforms into a sedentary form and becomes localized. This stage is known as meront. Meront is an intracellular stage and has a definite cell wall which absorbs nutrients from host cell. The meront is spherical or pear shaped and is formed in 2 - 3 days after infection. It reproduces by binary fission, multiple fission or by budding. When Cytoplasm of the host cell is exhausted, meronts are arranged in parallel rows.

The meront after massive proliferation fills up the host cells and when nutrients are depleted, sporulation takes place. From the germination of the spores to sporulation is the entire developmental cycle of the pebrine protozoan.

Symptoms: The symptoms of this disease can be observed in all the stages of silkworm viz., egg, larvae, pupa and adult. These symptoms form an important criteria for identifying the disease.

In the egg stage, poor egg number, lack of adequate adherence to the substratum, lack of egg uniformity, more of unfertilized and dead eggs, poor and irregular hatching are some of the symptoms. Some times infected eggs cannot hatch out and hatched larvae may also die.

Larvae show poor appetite, retarded growth and development leading to un-uniformity in size (Fig. 31). Larvae moult irregularly and show sluggishness. Transovarially infected larvae die before

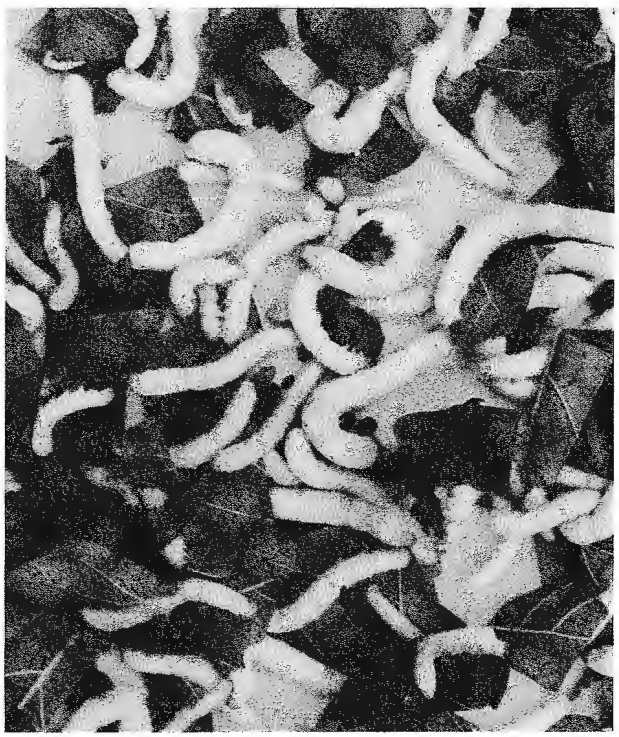


Figure. 31. Size variation in diseased larvae

third moult but those which are heavily infected die during first instar itself. The larval body shows wrinkled skin with rustic brown colour and in the moribund stage they do not rot but remain rubbery. The affected gut becomes opaque and the silkgland shows white pustules in different places along its length. Sometimes black irregular pepper like spots are noticed on larval skin (Fig. 32).

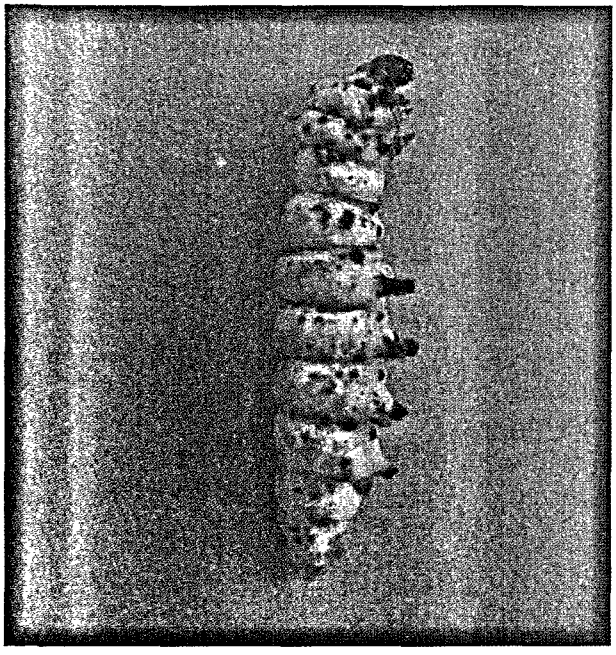


Figure. 32. Pepper like spots on the body affected by pebrine

The infected pupae are flabby and swollen with lusterless and softened abdomen. Sometimes irregular black spots are noticed near the rudiments of the wing and abdominal area. Highly infected pupae fail to metamorphose into adults.

The moth emergence is delayed and improper. They have clubbed wings with distorted antennae and do not mate properly. The scales from wings and abdominal area easily come off. In infected moths if the accessory glands are infected the moth may lay eggs with less gluey substance resulting in their detachment from the egg cards.

Prevention and control: The fundamental measure for the prevention and control of this disease is to produce healthy eggs, so as to avoid embryonic infection. This can be achieved by conducting systematic mother moth examination. The other methods are to conduct effective disinfection of rearing rooms, equipments and surroundings and maintenance of strict hygienic conditions during rearing. It is essential to surface disinfect the layings in 2 per cent formalin for 10 minutes before incubation. Such surface disinfection though practiced in grainages should be repeated again after release from cold storage as also by farmers. If the eggs are in advanced stage of embryonic development surface disinfection is done with 1 per cent formalin for 5 minutes. The room and equipments must be washed and disinfected before incubation.

Young silkworms should be reared under hygienic conditions. As a precaution test examination of unhatched blue eggs, dead eggs, hatched larvae and egg shells can be done and if pebrine is detected, such eggs should not be brushed and if brushed the larvae should be destroyed. Similarly predictive examination could be conducted by utilizing unequal larvae, late moulters, faecel matter and exuviae for the detection of pebrine spores. These tests may not only minimise the chances of rearing transovarially infected layings, but also check cross contamination and spread of the disease. Infected silkworms, faeces and mulberry field pests are important sources of infection and should be properly disposed of to prevent cross infection and spread of the disease.

During seed production in addition to mother moth examination, care should be taken to prevent contamination from other sources. The equipments used for one lot should not be used for the other till they have been thoroughly cleaned and disinfected. Eggs after surface disinfection should be dried and stored in a separate room away from egg production and examination room.

Besides, the above preventive/corrective measures, it has been reported that immersing of the silkworm eggs in hot water, high temperature treatment of the pupae, dipping of the eggs in hot hydrochloric acid minimise the incidence of pebrine. Chemotherapy of Nosema infection has been reported through a number of antimicrosporidian drugs like fumagillin, benomyl, bengard, bavistin, ethyl and methyl thiophanate and some of their analogues with positive results, but preventive methods have always been found to be better than the curative measures.

3.5. OTHER MISCELLANEOUS DISEASES

These are non-infectious diseases caused mainly due to poisoning by agricultural chemicals and factory exhaust gases. These poisonous substances gain entry into silkworms through feeding, body contact etc.

3.5.1. *Poisoning from agricultural chemicals*

Causative agents: The most important agricultural chemicals poisonous to silkworm are organophosphorus, organochlorine, organonitrogen and pesticides of plant origin. Among these both organophosphorus and organochlorine insecticides

can inflict acute poisoning. Organophosphorus compounds are known to inhibit chalorinesterases by poisoning the ganglion whereas organochlorine is an axonic poison affecting the sensory neurons. The other two agricultural chemicals like organonitrogen and insecticides of plant origin cause death but in mild cases they lead to the spinning of deformed or flimsy cocoons.

Symptoms: Symptoms due to poisoning by agricultural chemicals are similar. They include slight excitement, swinging of anterior half of the body, enlargement of thoracic region, erratic movement. These are followed by vomiting of the digestive juice, lying on the side, shortening of the body due to loss of digestive juice, muscle contraction, paralysis and finally death (Fig. 33).

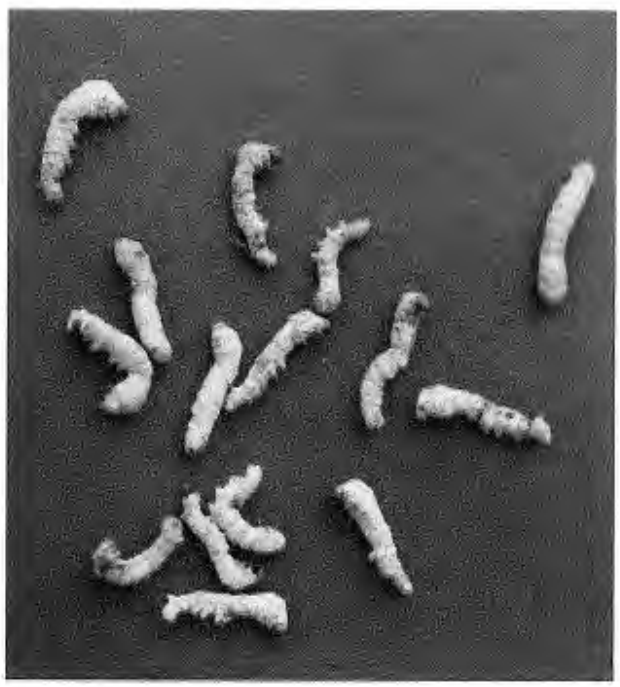


Figure. 33. Larvae affected by agricultural chemical poisoning

Prevention and control: The main preventive measure can be the avoidance of contamination of mulberry leaf by these insecticides. While spraying agricultural chemicals one should pay special attention to the direction of wind so as to avoid contamination to the mulberry leaf. If insecticides are sprayed on mulberry garden for the control of diseases and pests, safety periods should be followed for leaf harvest. During rearing if chemical poisoning occurs to silkworms, cross ventilation should be ensured for free circulation of fresh air. If needed, the worms may be dipped in cold water for a brief period and them reared in a cool well ventilated room with the supply of fresh mulberry leaves. All equipments and utensils that have come in contact with the insecticides should be thoroughly cleaned and washed with alkaline solution before re-use.

3.5.2. *Poisoning by factory exhaust gases*

Feeding silkworms with mulberry leaf contaminated from the factory exhaust gases like sulphur dioxide, hydrogen fluoride and chlorine also induces poisonous effect (Fig. 34).

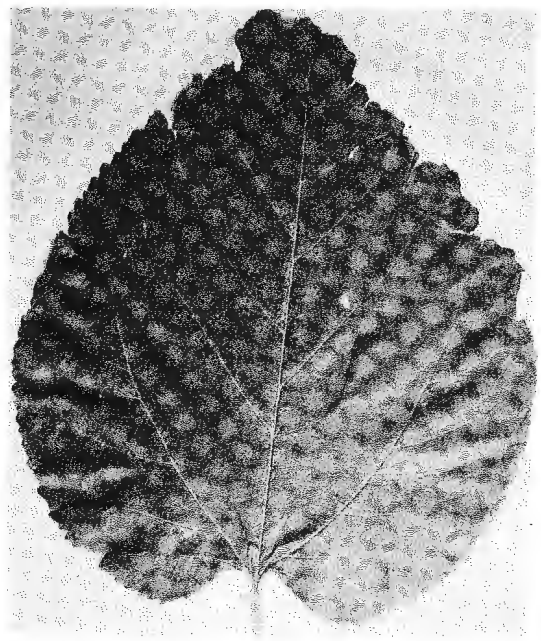


Figure. 34. Leaf polluted with hydrogen fluoride

Symptoms: The main symptoms are slow and uneven growth resulting in the disparity of the larval development. If young instar larvae are affected, the body atrophies, the thorax swells and the posterior part shrinks. In later instars larvae have band-like or ring-like dark brown lesions which are frequently found near the intersegmental membranes (Fig. 35). These lesions burst easily and release light yellow fluid.

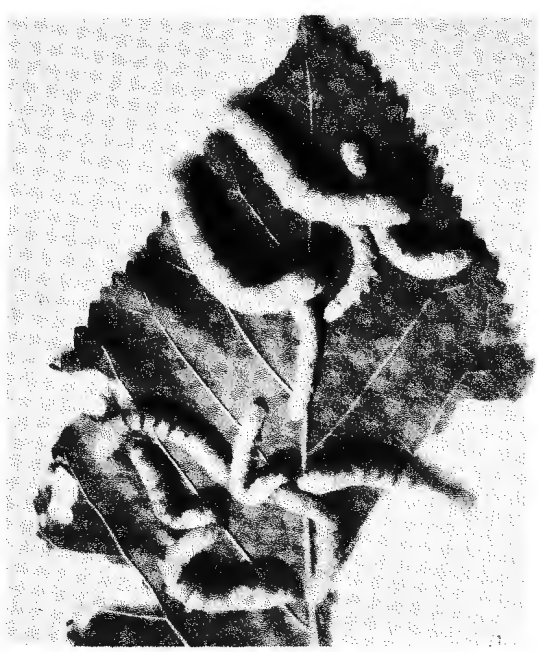


Figure. 35. Larvae affected by hydrogen fluoride poisoning

Prevention and control: The factories involved in the production and release of these gases should be located at least one km. away from the mulberry fields. If mulberry leaves are contaminated with these gases, they should be washed in calcium hydroxide to reduce the degree of damage to silkworms. If silkworms are found to be poisoned they should be supplemented with fresh good quality mulberry leaves, so that they may recover from the poisoning effect.

3.6. INTEGRATED CONTROL OF SILKWORM DISEASES

What have been described so long are the diseases in an individual manner with methods for their prevention and control. But it has to be understood that the protection is required not against any, but all the diseases. It has to be further understood that it is not only the presence of the pathogen that causes the disease, there are many other factors, biotic and abiotic which are directly and indirectly responsible for the initiation and spread of the diseases. So, to have a real control of the diseases and protection of the cocoon crop, one should rather adopt an integrated approach taking into consideration all the factors which lead to the initiation and spread of the diseases. Some of them are discussed below:

(i) Use of disease resistant varieties of silkworm

The prevention and control of silkworm diseases should start with the selection of disease resistant varieties. Different varieties and breeds of silkworm are known to have differential resistance against different diseases, temperature and humidity conditions as well as the condition of mulberry leaf. Depending upon these factors, while planning the rearing, the breeds/crosses to be reared should be properly selected which could go a long way in harvesting a successful crop.

(ii) The quarantine of the silkworm seed

The silkworm seed to be reared should be disease free. Firstly, for pebrine-freeness detection, mother moths should be thoroughly examined, followed by the surface disinfection of eggs to see that the eggs taken for rearing are disease free. As an additional step the unhatched larvae also could be tested for disease freeness.

(iii) Improvement of disinfection

Proper disinfection is one of the key factors determining the success of rearing. Besides the general disinfectants like formalin, there are a number of other disinfectants, known to be particularly effective against certain pathogens like lime against C.P.V., chlorine against bacteria. So, while choosing the disinfectants, the prevalence and likely incidence of a disease should be taken into consideration and depending on that the disinfection should be done either through a combination of chemicals or in succession with more than one disinfectant. The method and concentration to be used should also be properly taken care of.

(iv) Maintenance of hygienic condition during rearing

Besides the initial examination of eggs, their disinfection, disinfection of rearing rooms and equipments being carried out to remove the primary source of infection, adequate care should be taken to prevent secondary or cross infection during rearing. To achieve that, strict hygienic condition should be maintained during rearing in the rearing room and the rearing bed and, if necessary, bed disinfectants should be used.

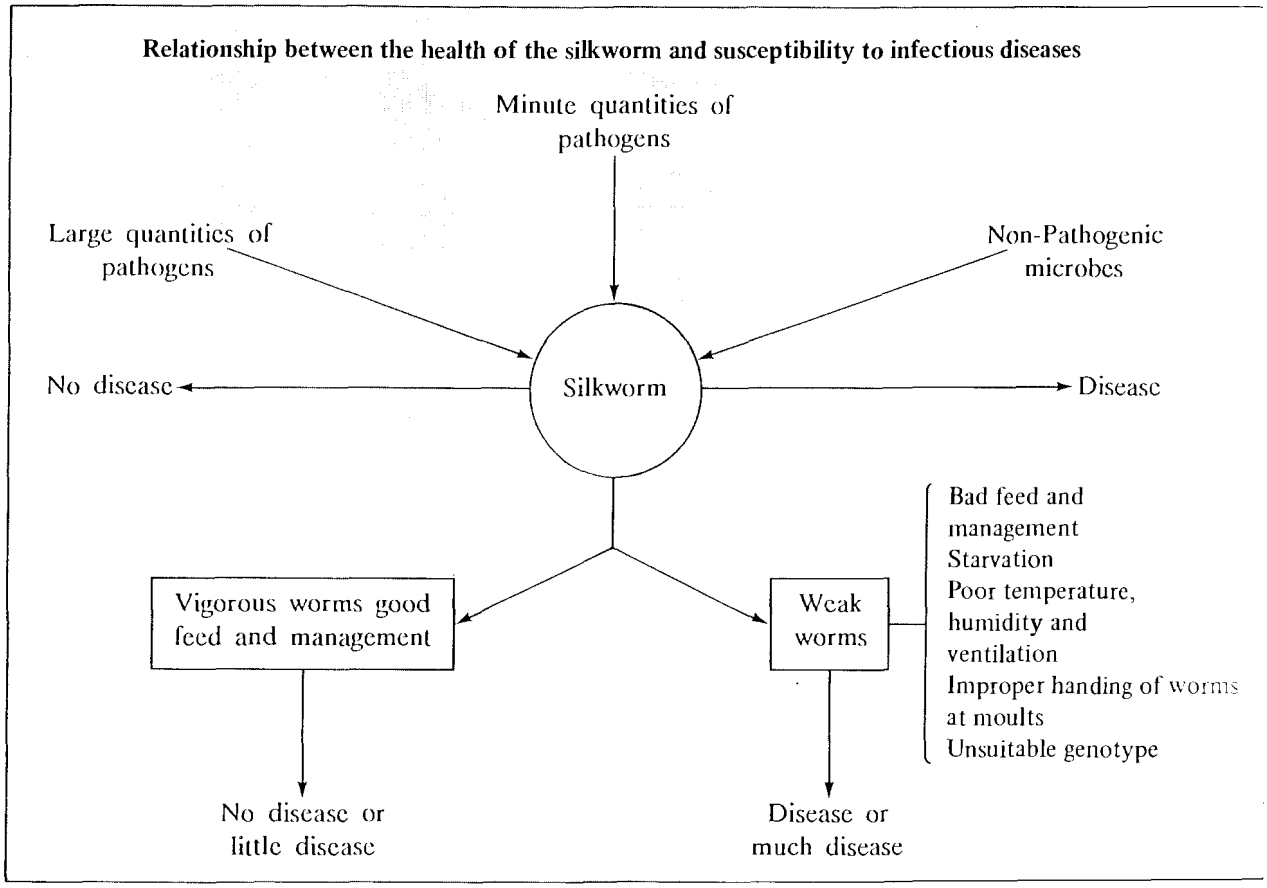
(v) Use of appropriate rearing room and equipment

Rearing room and equipment used have also bearings on disease incidence. A well ventilated house and a house where temperature and humidity can be controlled can always improve the health of the silkworm and reduce the incidence of diseases. Equipment used like proper type of stands, trays, seat paper and the bed-cleaning nets also help in the maintenance of hygienic condition and a consequent reduction and a consequent reduction in the incidence of diseases.

(vi) Improvement of rearing technique

Silkworm rearing is very much affected by the hygrothermic condition of the environment. Being a cold blooded animal it has little power to adjust against the fluctuations of temperature and humidity. Adverse climatic conditions thus affect the physiology of the worm very much and lower the resistance against the diseases. Such fluctuations of temperature are even known to induce certain viral diseases.

Feed is also a factor which affects the physiology and health of the silkworm very much. The feeding of insufficient unsuitable and non-nutritive leaves often leads to a high incidence of diseases as under certain infective conditions healthy silkworms can tolerate a certain amount of germ load, whereas the weak silkworms become easily susceptible even to a small germ load which is depicted in the next page:



Handling of worms at moult and spacing given in the rearing bed are also important factors determining the health of the worm and consequently the incidence and the spread of the diseases. The latter particularly acts in a number of ways restricting the food availability to the silkworm, changing the micro-climate in the bed as well as increasing the chance of cross-infection. These also need to be taken care of to check the incidence and spread of the disease.

(vii) Physical treatments

A number of physical treatments like treating with hot water at different stages have been known to kill certain pathogens and consequently control the disease. Where, necessary and possible, such methods should be used.

(viii) Chemical treatments

Similarly, certain chemicals have been known to be effective in the prevention and control of certain diseases. Those chemicals should also be used in a proper manner, at appropriate time and at appropriate doses to prevent and control those diseases.

(ix) Exploitation of immune response

Though it is a virgin field, information are coming out about the immune response in silkworm, humeral and other, particularly through the production of interferons as described elsewhere. An eye should be kept on such development also and their use.

CHAPTER 4

PESTS OF MULBERRY SILKWORM AND THEIR CONTROL

Besides being susceptible to different diseases, the silkworm, *Bombyx mori* L. is also attacked by a number of pests. Among the insect pests that attack silkworm, the most formidable one is a dipteran parasitoid, *Exorista sorbillans* Wiedemann, otherwise called the uzi fly.

4.1. MAJOR PEST

4.1.1. *Uzi fly, Exorista sorbillans Wiedemann (=Exorista bombycis = Tricholyga bombycis = Tricholyga sorbillans = Tachina sorbillans)*

This parasitoid is a member of the Tribe Exoristini under the sub-family Goniinae belonging to the family Tachinidae of the order Diptera.

Presence has been Reported in Bangladesh, China, Japan, India, South Korea, Thailand and Viet Nam

The incidence of this fly is very high in the tropical sericultural region, viz. Bangladesh, Southern part of China, India, Thailand and Viet Nam. The extent of damage ranges from 10-30 per cent.

(a) Life Cycle

Adults are blackish gray in colour (Fig. 1a). Male is longer in body length (about 12 mm) than female (about 10 mm). The head is triangular in shape. On the dorsal side of the thorax, there are four longitudinal black bands. The abdomen is conical. Of the abdominal segments, the first one is black and the rest grayish-yellow. Lifespan of adult flies varies with sex and season. Males survive for about 10-18 days. Females live 2-3 days longer than the males. Survival period is least during summer months.

Male can be distinguished from the female by the presence of external genitalia covered with brownish orange hairs on the ventral side of the abdominal tip (Fig. 1b). Lateral regions of the abdomen are covered with bristles more dense in male than in female and in the latter restricted mostly to last two segments (Fig. 1c). The width of the frons of the male fly is narrower than that of the female one. Longitudinal lines on the dorsum of the thorax of the male are more vivid than female. The pulvilli of male is larger than female.

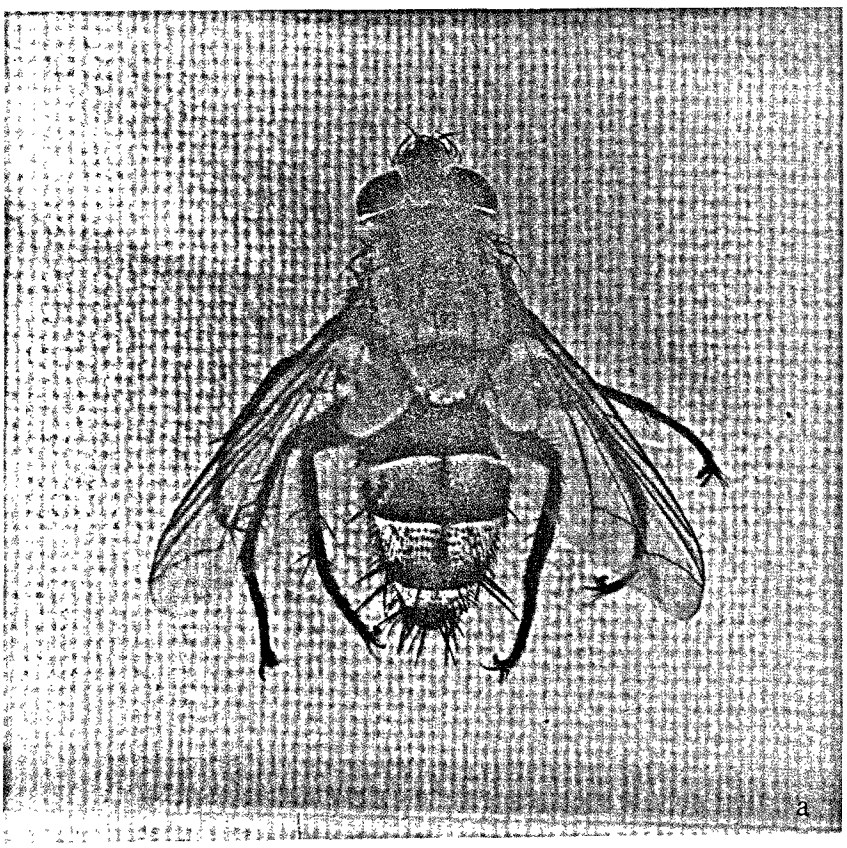


Figure. 1a Uzi fly: Adult dorsal view

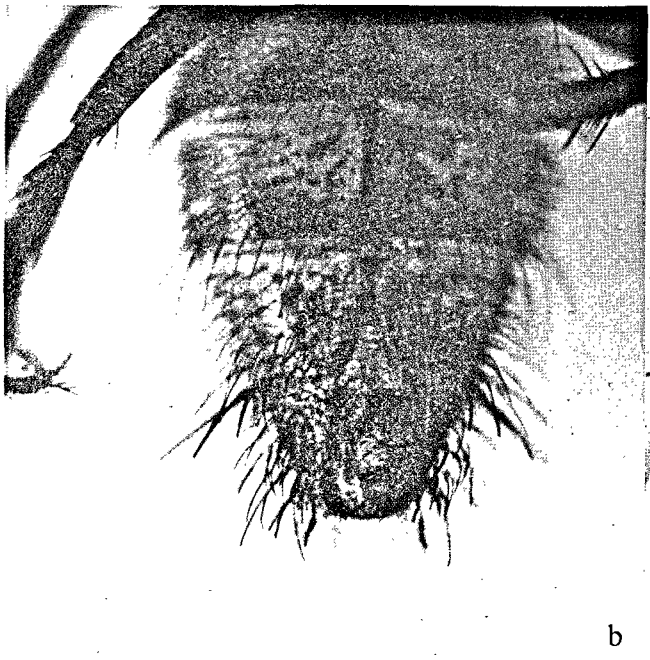


Figure. 1b Uzi fly: Ventral view of abdomen of male uzi fly

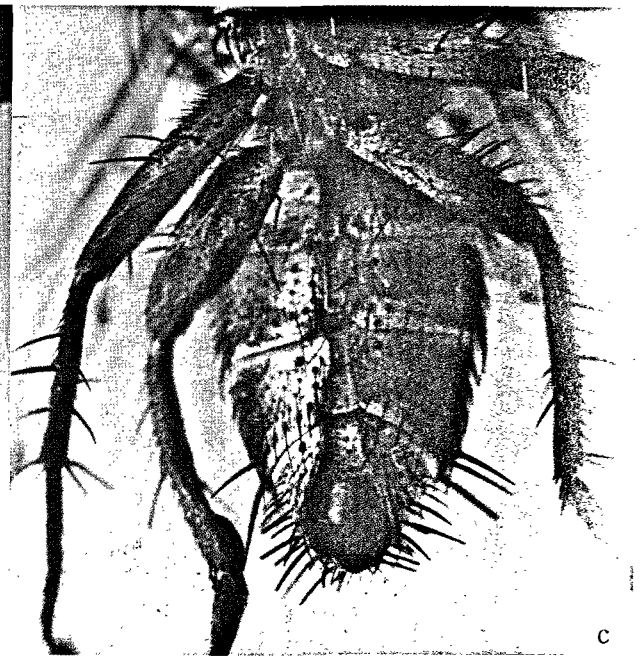


Figure. 1c Uzi fly: Ventral view of abdomen of female uzi fly

Adults exhibit a definite courtship behaviour. Males have no distinct orientation posture towards the females and they strike the resting and walking females. Mating strike by male is followed by agitated state of the female before the pair establishes the successful genital contact. Premating period is about 4-6 hours. The adults are polygamous. They mate 1-2 times and 3-7 times within 24 hours of the adult emergence and in the entire life respectively. Mating generally takes place during early morning or in the late evening. The duration of mating ranges between half an hour to two and half hours. A minimum of one hour mating is required for full fecundity and maximum hatchability. Mating is not a pre-requisite for egg deposition since virgin female also lays unfertilized eggs.

Oviposition in both the mated and unmated females start 44-45 h after their emergence. Female uzi fly approaches the host larvae and after repeated survey settles down on the body of the host (Fig. 2a). At the time of releasing the eggs, the female fly bends her abdomen in such a way that the tip of her abdomen touches the host integument. After releasing each of the egg the female fly withdraws its posture, walks over the host body and similar steps are followed before releasing every successive egg. Under normal condition, 1-2 eggs are laid per host larva (Fig. 2b). Flies oviposit practically anywhere on the body of the host larva. However, least number of eggs are laid on the ventral aspect of the body. This parassitoid prefers to lay eggs on late age host larvae which are also larger in size. The oviposition on young instars larvae depends on the age distribution of host larvae population and the relative area of the silkworm body.

A single mated female uzi fly lays about 300-1,000 eggs over a period of about 9-25 days depending upon the seasons. The fertilized eggs are laid throughout the life span of the female. Initially the number of eggs laid are few. Gradually, it increases to reach the peak between fourth and seventh day after adult eclosion. Subsequently, a gradual decline takes place with advancing age of the females. Eggs are macrotype and creamy white in colour. The egg (Fig. 2b) measures 0.45 - 0.56 mm in length and 0.25 - 0.30 mm in width. They are oblong in shape and hatch in about 2-5 days after oviposition depending upon the climatic condition. Once hatched, the maggot penetrates into the body of the silkworm.

The young maggot hatches out of the egg shell through the operculum which generally faces the silkworm body. The newly hatched maggot directly penetrates into the silkworm body. On penetration a sheath surrounding each maggot is formed by granulocytes and proliferating tissues at the site of the wound. The size of this sheath keeps the pace with the growth of the maggot, becoming thicker and black in colour, so as to discernible on the surface as black lesion or scar (Fig. 2c) sometimes bearing the attached egg shell.

Maggots pass through three instars. In the first two instars, they develop just below the skin of the host body and in the final instar they leave this site and move into the body cavity. Maggots of first and second instars are yellowish-white in colour and measure 0.7-1.5 mm and about 2.75 mm in length respectively while the third instar maggots are creamy-white in colour and measure 1.3-1.6 cm in length. Maggots have eleven body segments (Fig.

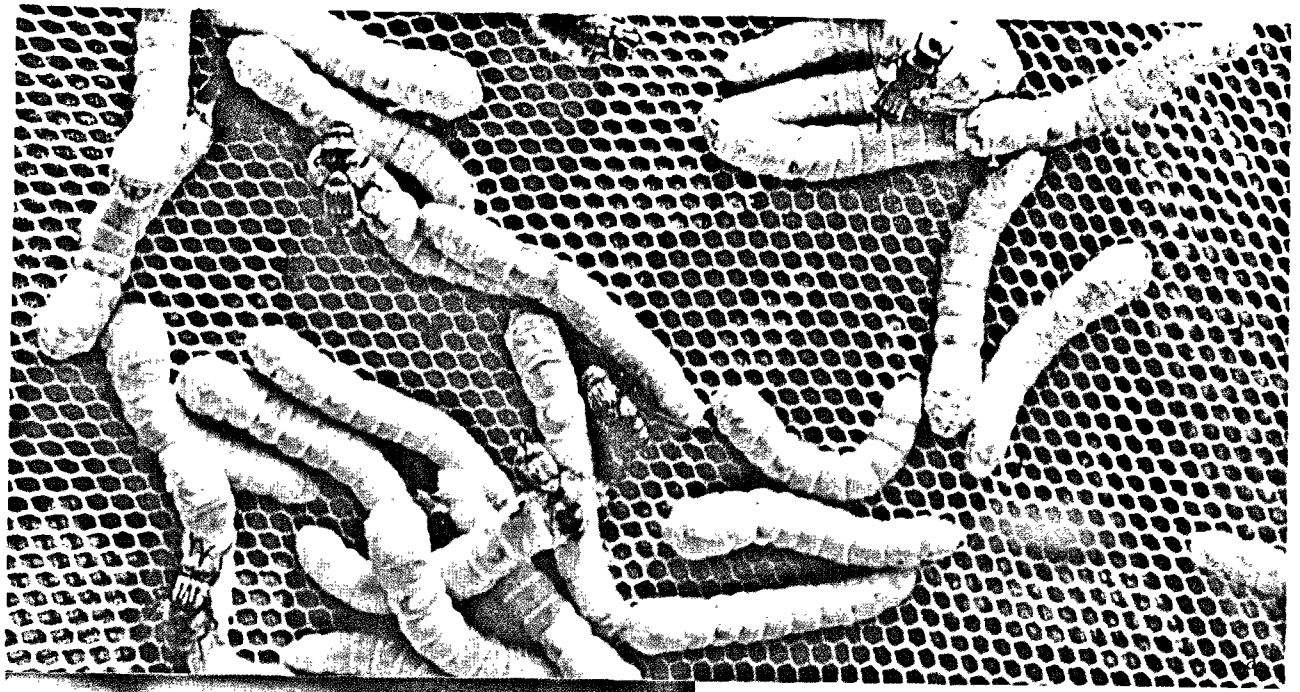
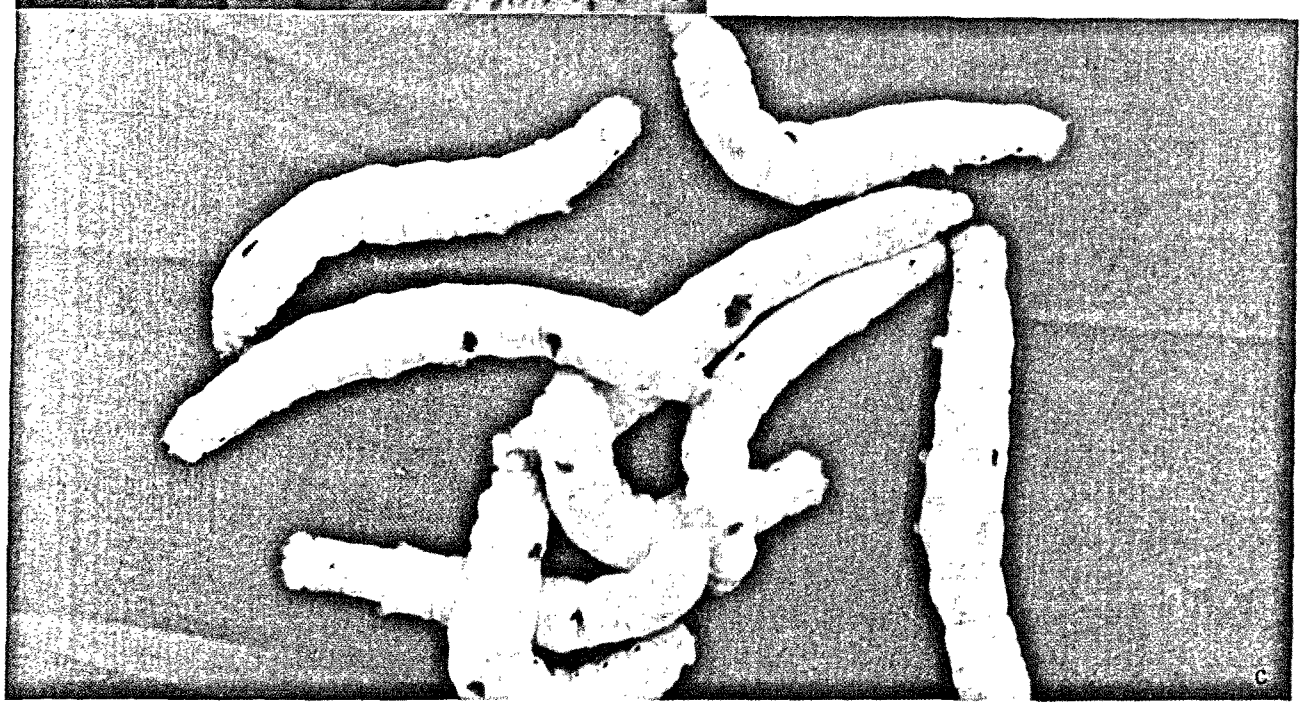


Figure. 2. Uzi fly
a) Adults depositing egg on silkworm body
b) An egg on host body
c) Silkworms bearing black uzi scars



3c). The mature maggots escape from the host body by piercing the integument (Fig.3a) by its pro-thoracic hooks in about 5-8 days depending upon season and number of maggots developing per host larva. They feed on various tissues of the silkworm body and the host larva dies by the time the maggots are mature to escape out from the host body.

The escaped mature maggots which are negatively phototropic and positively geotropic, pupate in about 10-20 h depending upon the season. Pupation takes place in the darker area in and around the silkworm rearing house like corners, crevices, silkworm rearing beds, cracks of the rearing stands or trays, below the antwells or in the superficial layer of the soil. Maggots just before pupation become motionless and the body shrinks. In certain areas where the temperature goes below 10°C, this fly mostly passes the winter season in the pupal form.

Pupae (Fig. 3d) are oblong in shape somewhat oval anteriorly and round posteriorly. They are light reddish brown to dark reddish brown in colour. Body segments are eleven in number and measuring 0.9-1.2 cm in length and 0.4-0.6 cm in lateral width. Adults emerge in about 10-12 days. The male adults always emerge out earlier than females.

(b) Type of damage and symptoms

The silkworm larvae infested upto early fifth instar die before they reach the spinning stage. If infestation takes place in the late fifth instar, the mature maggot comes out by piercing the cocoon (Fig. 3b) and thereby rendering the cocoons (Fig. 3e) unfit for mass reeling. Infested silkworms or pupae can be identified by the presence of black scar on the part of the skin where the maggot penetrates into the body of the host larvae (Fig. 2c). Sometimes, an egg shell is left behind in the centre of the black scar. At the initial stage of infestation minute creamy white oval eggs smaller than pinhead are observed on the skin of the larvae.

(c) Period of occurrence

The number of generations per year differs depending upon the climatic condition. In arctic region, there are four to five generations, in temperate regions six to seven generations and in tropical regions ten to fourteen generations. In tropical countries it generally occurs throughout the year.

(d) Prevention and control

For the prevention of uzi fly, sanitary and hygienic measures are of utmost importance. Care should be taken first to see that uzi fly maggots do not get access to the holes and crevices of the rearing room and the places around where from they normally come out and perpetuate the life cycle. Care should be taken to see that the early spinning cocoons, most of which are uzi infested are not mixed with normal cocoons and are stifled to kill the uzi maggots inside them. While taking the cocoons to the market it should be seen that uzi fly maggots do not come out and spill on the way and further. In the market it should be seen that uzi fly maggots are frequently sweeped and killed by putting them into hot water, formalin water or kerosine/insecticide mixed water. As far as seed cocoon transportation is concerned it should be seen that the uzi infested cocoons are not transported to uninfested areas and are disposed off at the nearest possible point.

For further prevention and control of uzi fly an integrated approach involving physical, chemical and biological control methods are suggested as follows:

(i) ***Physical:*** Creation of a physical barrier by providing wiremesh in the doors and windows of the rearing rooms or mosquito net curtains around the rearing stands. These methods have been found to be quite effective in preventing the uzi fly females from getting access to the silkworms and laying eggs on them reducing the crop loss to a considerable extent. Care should be taken to see that doors are not kept open and curtain covers are not disturbed. A physical barrier can also be created between the uzi fly and the silkworm by dusting levigated china clay on the body of the silkworm during mounting which prevents the oviposition by the fly. Doses recommended are 3-4 g per 100 spinning larvae and per sq.ft. area of the spinning tray.

(ii) ***Chemical:*** A commercial formulation uzicide containing 1 per cent of Benzoic acid has been developed in India which kills the eggs of uzi fly when applied (Fig. 4) within 48 h of egg laying. This treatment has to be repeated on alternate days. The dosage recommended is 7-8ml/sq.ft. area. A similar spray of 3 per cent phenol has been suggested by Bangladesh for killing the eggs of uzi fly.

Chemical control of uzi fly has also been found to be effective through the use (dusting) of diflubenzuron at 2.5 per cent, the diluent used being levigated china clay. Maggots/pupae collected from the cocoon market when treated with this material (covered with a dust layer 2.54 cm thick) give rise to sterile adults which mate but are not able to produce off spring. While treating, maggots/pupae should be spread in a single layer

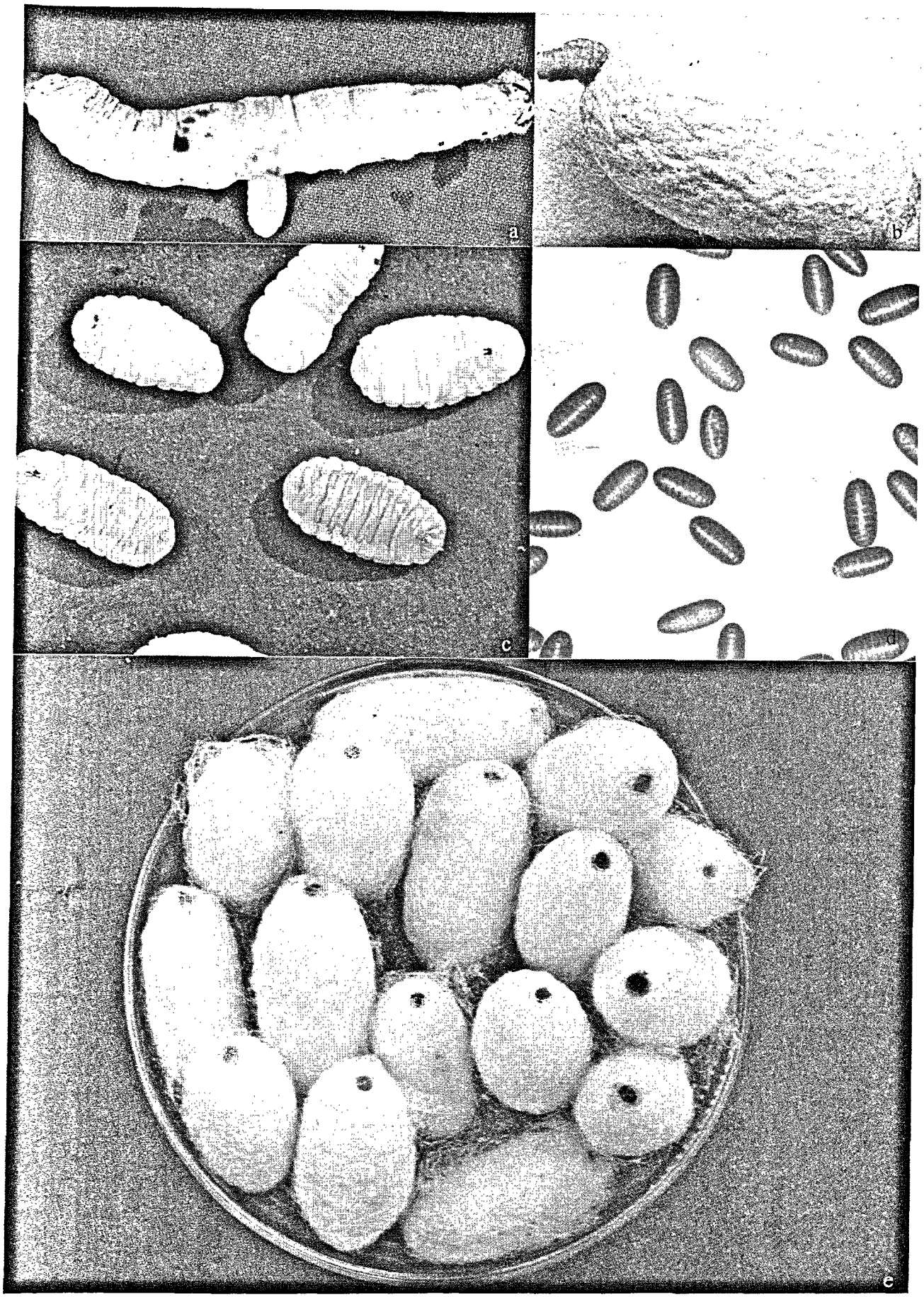


Figure. 3. Uzi fly

a) Maggot recovery from host body
b) Maggot emergence piercing cocoon
c) Maggots
d) Pupae
e) Uzi pierced silkworm cocoons

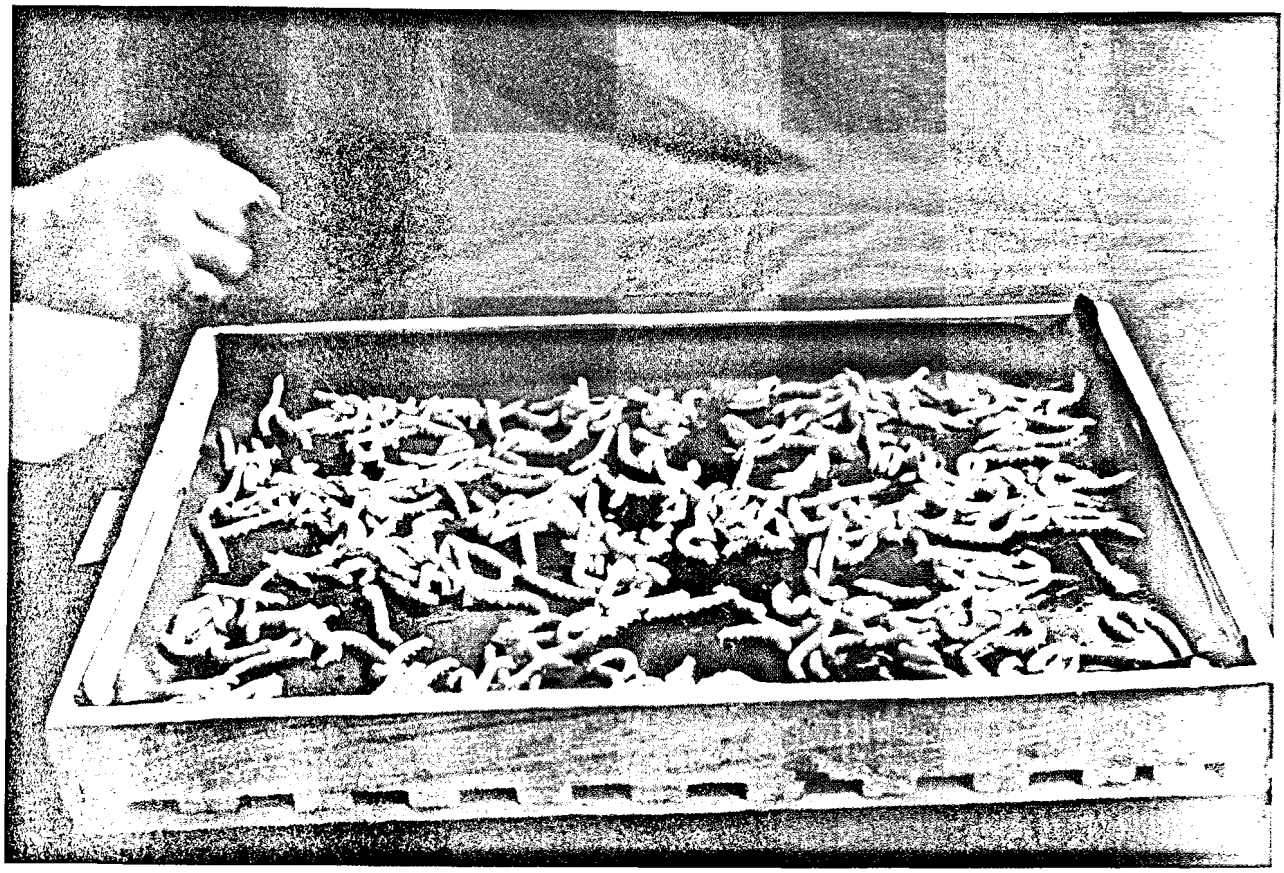


Figure. 4. Spraying of uzicide

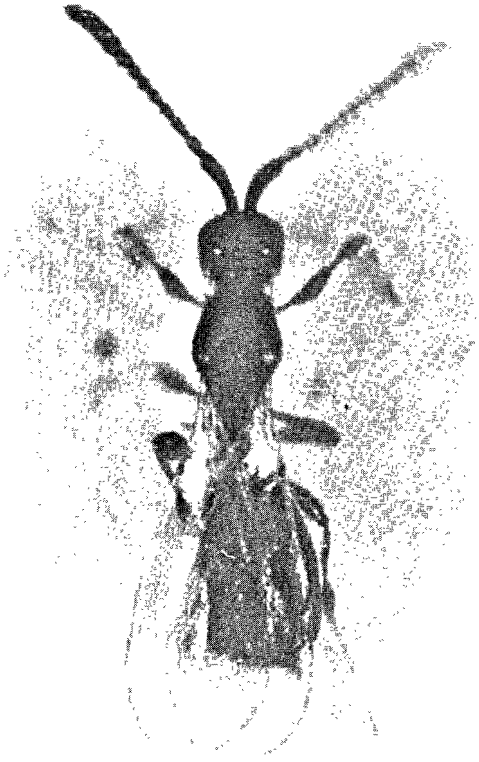
on a shallow tray with 200 maggots/pupae per sq.ft. Release programme of such flies which emerge from treated maggots/pupae could have a good impact on the reduction of the uzi fly population.

Caution: Diflubenzuron should be handled with same care and caution exercised for agricultural pesticides.

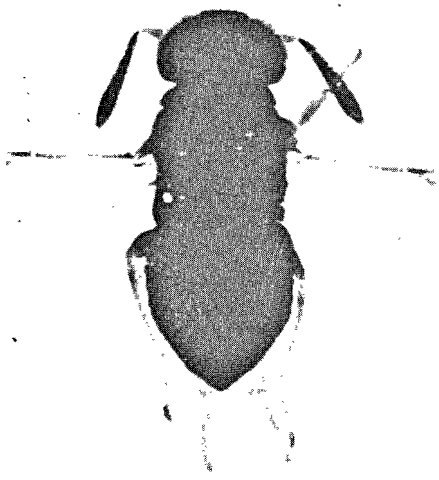
(iii) ***Biological control:*** Biological control has been used for the control of many insect pests either individually or as a part of integrated pest control programme. Control of uzi fly through biological means (hyperparasitoids), however, has a special relevance since the host itself is an insect and insecticidal measures cannot be taken against a pest associated with an insect host. A number of parasitoids parasiting on uzi fly pest of silkworm have been identified as follows:

Name	Family	Nature	Status
1. *Nesolynx thymus* Girault (Fig. 6c)	Eulophidc	Ecto-pupal parasitoid	Gregarious
2. *Trichopria* spp. (Fig. 6a)	Diapriidae	Endo-larval-pupal parasitoid	Gregarious
3. *Exoristobia philippinensis* (Ashmead) (Fig. 6b)	Encyrtidae	Endo-larval-pupal parasitoid	Gregarious
4. *Dirhinus himalayanus* (Westwood) (Fig. 5)	Chalcididae	Ecto-pupal parasitoid	Solitary
5. *Brachymeria lugubris* (Walker)	Chalcididae	Ecto-pupal parasitoid	Solitary
6. *Spilomicrus karnatakensis* (Sharma)	Diapriidae	Endo-larval pupal parasitoid	Gregarious
7. *Spalangia cameroni* (Perkins)	Pteromalidae	Ecto-pupal parasitoid	Solitary
8. *Pachycrepoideus vindimmae* (Rondani)	Pteromalidae	Ecto-pupal parasitoid	Gregarious

Figure. 5. Adult hyperparasitoid, Dirhinus himalayanus



a



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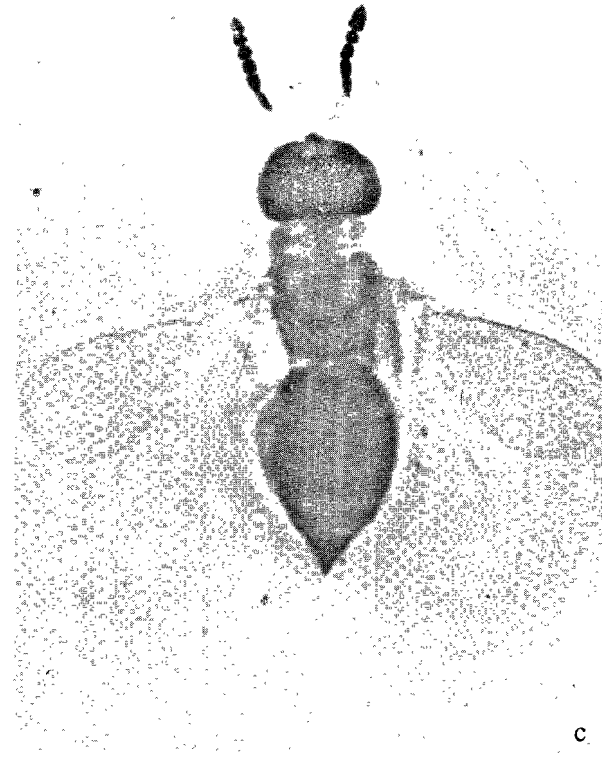

c

Figure. 6. Adult hyperparasitoids
a) Trichopria *spp.*
b) Exoristobia philippinensis
c) Nesolynx thymus

Studies carried out on them indicated that

(1) They can be cultured and multiplied with minimum efforts,

(2) They can search host even upto a distance of about 30 meters,

(3) Females oviposit the eggs inside the wall of the host puparium, which on hatching feed on the host tissue to develop into adults,

(4) Newly emerged adults cut a hole on the wall of the host puparium, come out and repeat the life cycle,

(5) Unfertilized females of the parasitoid reproduce parthenogenetically, and

(6) Developmental period varies from species to species and season to season, the average range being 13-33 days.

A systematic programme integrated with other measures is required to be taken up for the biological control of uzi fly.

4.2. MINOR PESTS

Mulberry silkworm is also attacked by several species of other insects like Coleopterans, *Alphitobius laevigatus* (Fab.), *Lyprops cuticollis* Facion, *Necrobie rufipes* (Degeer), *Tribolium castaeneum* (Hbst.) and many species of genera *Dermestes*; a dermapteran *Labia arachidis* (Yersin); tachinids, *Crossocosmia zebina* Walker and *Ctenophorocera pavida* Meigen and an acarid *Pediculoids ventricosus* (Newport). These pests are generally of minor economic importance in restricted localities. The important ones which cause occasional damage are described below.

4.2.1. Dermestid beetles

This group of insects belong to the family Dermestidae of the order coleoptera. They often attack pupae and adult silkworms in the grainages, and mostly cause extensive damage to the stored cocoons. Though a large number of species of dermestid beetle have been reported, description of the more important ones viz., *Dermestes ater*, *D. cadverinus*, *D. vulpinus*, *Anthrenus verbasci* and *A. pipinellae* Fab. are given below:

Presence has been reported in India and Japan. They may exist in other countries as well.

(a) Life Cycle

(i) Dermestes ater

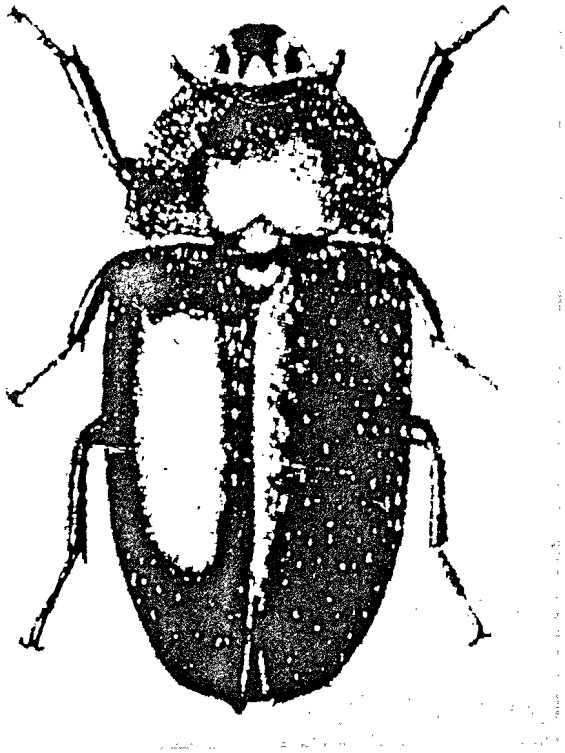

Figure. 7. Adult Dermertes ater

black. It measures about 7 mm in body length. Females start ovipositing in about 5 days after eclosion. The egg is milky white, elongate with an average measurement of 1.90 mm in length and 0.48 mm in width. Incubation period varies from 3-6 days. Newly hatched grub is white which gradually turns to brown in first instar itself. The colour of the grub turns to black from second instar onward. The first instar grub is about 2.4 mm in length. Morphologically the different instars are similar except in size. Grubs, in general, are spindle shaped and are covered with hairs of various length. The grub undergoes 4-6 moults in about 27-28 days. On an average, pupal period occupies about 7-8 days. Freshly emerged adult changes its colour from light yellow to dark brown.

(ii) D. cadverinus

Adults (Fig. 8c) of *D. cadverinus* are oval-elongate and dark brown in colour. It measures about 1 cm in body length. The female beetle deposits its eggs in the crevices. The elongate-oval egg is about 2 mm in length and milky-white in colour. Eggs hatch in about 7 days. The spindle shaped grubs are reddish brown in colour. They moult 5-7 times in about 1-2 months and attains a length of about 1.5 cm. Body of the grubs are covered with hairs (Fig. 8a). Although the insect generally passes the winter in the adult stage, since the time of metamorphosis varies, both the grub and pupal (Fig. 8b) stages may be encountered.

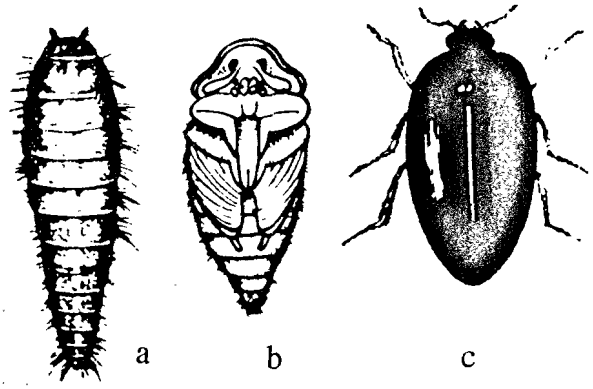

Figure. 8. Dermestes cadverinus
a) Grub
b) Pupa
c) Adult

(iii) D. vulpinus

Adults are shiny reddish brown to black in colour, subparallel in shape and clothed with hair. The males are slightly smaller than females, bear a pit and a brush of hair on the fourth sternite. The four short basal tarsal segments of fore- and midlegs lack the fine golden testaceous hair and also do not form distinct ventral pads. The adult female lays eggs in batches of two or three, some-

times single. The number of eggs laid ranges between 198 to 845. The creamy white egg is cylindrical and one end slightly broader. The incubation period ranges from 2-4 days. The full grown larvae are dark brown with a medium yellow stripes dorsally and is densely covered with hairs. They avoid light and moult 7-14 times. The larval period ranges from 25-60 days mainly depending upon the climatic conditions. It pupates in the last larval skin and the adult emerges in about 5-8 days. The number of generations in a year varies from 3-6.

(iv) Anthrenus verbasci

Adults of *A. verbasci* are convex, slightly elongated and round with yellow-white scales on the black colour of body. The female beetle lays about 20-100 oval shaped milky-white coloured eggs each measuring about 0.5 mm in length. Eggs are generally laid in wooden slits and crevices. Grubs hatch in about a month's time and moult 6-7 times and attain the size of 3-4 mm in length. They are grayish-brown in colour, swollen at the tail with an elongated tumbler shaped body. These beetles overwinter in grub stage and become pupae during summer months. In about a month's time the adults emerge from these pupae.

(v) A. pipinellae

A. pipinellae (Fig. 9) resembles *A. verbasci* but produces two generations in a year.

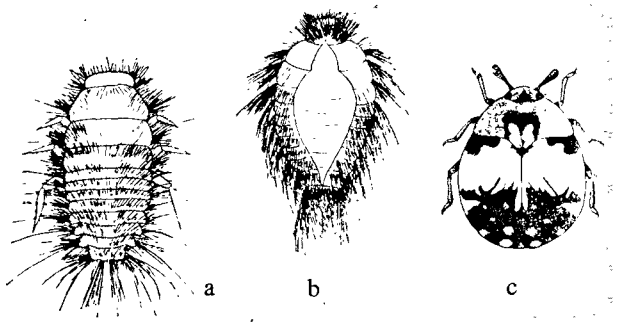

Figure. 9. Anthrenus pipinellae
a) Grub
b) Pupa
c) Adult

(b) Type of damage and symptoms

Grubs and adults of most of the species of Dermestid beetles are attracted by the smell of stifled and stored cocoons and the dried pupae inside. They bore into the cocoons and eat the dried pupae. They also damage pierced and melted cocoons which are stored within the grainage building for the longer duration. Sometimes they also attack adult silk moths, eggs and rarely the young silkworm larvae. Presence of cocoon pierced at several

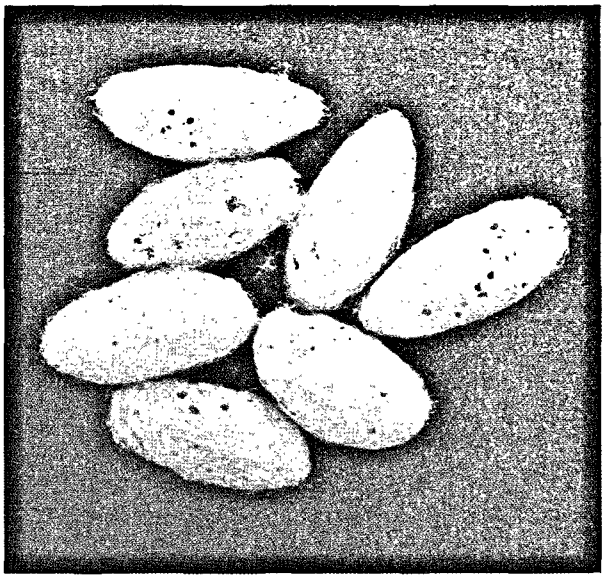

Figure. 10. Silkworm cocoons damaged by dermestid beetle

places (Fig. 10) in the cocoon storage rooms and also the presence of the egg laying silkworm adults in the grainages damaged mostly on the abdominal parts are indication of attacks by dermestid beetles.

(c) Period of occurrence

Throughout the year.

(d) Prevention and control

1. Storage of rejected cocoons and perished eggs for long period should be avoided.

2. The rearing house and cocoon storage rooms should be cleaned periodically.

3. Before and after emergence of silk moth the grainage premises should be cleaned.

4. Wooden article of the storage room and grainage should be dipped in 0.2 per cent malathion solution for 2-3 minutes. After 10 days the trays should be thoroughly washed in water and sun dried for 2-3 days before reusing.

5. Passing of hot air (50-60°C) into the storage rooms and maintaining low humidity like 30 per cent and below help to kill the beetles.

6. Fumigation of dried cocoon storage room with methyl bromide at 0.5 g per 3 m^2 for three days kills all the stages of beetle. Necessary precautions must be followed for using this chemical as fumigants. This treatment should be undertaken, if the

cocoon storage rooms are away from the grainage or rearing house.

4.2.2. *Silkworm tachinia fly, Crossocosmia zebina Walker (= Sturmia sericariae = Ugimyia sericariae = Crossocosmia sericariae = Blepharipa zebina = Blepharipa sericariae (Tachinidae).*

Reported from Japan.

(a) *Life Cycle:* The adult fly is grayish-black with pale ventral aspect. The male is longer (15 mm) than the female (12 mm). Both male and female flies have reddish-brown, semi-circular patterns or dots dorsally on either side of their abdomen. The red dots are more prominent in male fly. The pro- and meso-thorax have five longitudinal lines. In other aspects, the morphology is similar to *E.sorbillans*. A single female fly lays 3,000-5,000 oval shaped eggs which are black in colour and each measures about 0.2 mm in length. Unlike the uzi fly, which lays eggs directly on the body of the silkworm, this fly deposits eggs on the ventral side of the mulberry leaf along the vein. The eggs laid on the mulberry leaves remain viable for about a month. If the eggs are not ingested by the silkworm within about one month they perish. The egg ingested by the silkworm together with mulberry leaf hatch out in the gut through the action of the silkworm digestive juices. The young maggots bore their way through the wall of the digestive canal and penetrate into the 4th-7th ganglia of the nervous system and remain there for one to two weeks, later move and attach themselves to the spiracles of the host larva by their posterior end. These maggots breath through the host spiracles and feed upon the haemolymph and the body tissues of the host. The tissues of the silkworm around the spiracle dies and become black. The mature maggots which are pale-yellow, oblong and about 2 cm long come out of the silkworm/cocoon through the pupa mainly during morning hours and pupate into soil to a depth of 10 cm in about a day. The puparia hibernate in soil during cold season. The adults appear during mid-April and the emergence of the tachinia fly coincides with sprouting of mulberry in Japan. This has one generation in a year.

(b) *Type of damage and symptoms:* The silkworms which are parasitised in the 3rd and 4th instar die invariably either before or during mounting of the hosts but in case of infestation in 5th instar, the silkworms generally spin cocoon and transform into pupae. The hosts succumb later at the time of emergence of the mature maggots. In the early stages of infestation, the infested host larvae cannot be distinguished from healthy silkworm. As the time advances, the silkworm becomes inactive and loses appetite. In the advance stages of infestation dark irregular spots are observed around the spiracles of the host larva.

(c) *Period of occurrence:* May to September

(d) *Management:*

(i) Planting of mulberry away from pine plantation as it is reported that more eggs are laid on mulberry, if near pine plantation.

(ii) Dipping of the harvested mulberry leaves in hot water at 50°C for 5 minutes to kill the eggs.

(iii) Fumigation of the harvested mulberry leaves with naphtalene 5 g/1 000 cm^3 before feeding silkworm to kill the eggs.

(iv) Spraying of VCMP (2-Chloro-1-2,4,5-trichlorophenyl vinyldimethyl) on the ground to prevent the escape of this fly from cocoon storage room.

(v) Spraying of 0.05 per cent DDVP in the mulberry garden. Safe period - 11 days.

(vi) Sprinkling of a mixture of the natural enemy, a fungus, *Isaria fumoso-rosea* Wize and saw dust on places where maggots are likely to gather.

(vii) All the measures suggested to prevent infestation and pupation of the maggots of *E. sorbillans* in and around rearing house should also be followed.

4.2.3. *Hime uzi fly, Ctenophorocera pavida Meigen (Tachinidae)*

Presence has been reported in Japan

(a) *Life Cycle:* Adults are dark blue with metallic luster, measuring 7-9 mm in body length. An adult female lays about 1,000-2,000 eggs which are black in colour, oval in shape and each measures about 0.15 mm in length. Eggs are laid on the ventral side of the leaves. Eggs which are swallowed by the silkworm larva enter the alimentary canal and hatch. The maggots lodge temporarily in the silk gland and finally settle down with its caudal end fixed to the dorso-thorax region of the host larva. Mature maggot measures about 10 mm in length. In about 10 days these maggots escape from the host killing the host larva and pupate in

the soil. In 1-2 weeks adult flies emerge. It has 4-5 generations in a year. The first adult appears in the first half of May.

(b) *Type of damage and symptoms*: Damage caused is similar to *C.zebina*. On the skin of the affected part black scars about 1-2 mm in diameter are observed.

(c) *Period of occurrence:* From May to Onset of the Winter season.

(d) *Management:* As in *C. zebina.*

4.2.4. *Mite*

(i) *Straw itch mite, Pediculoides ventricosus (Newport) Targioni-Tozzetti (Family: Peduculoididae)*

Presence has been reported in China, India and Japan

(a) *Life Cycle:* The adult female is spindle shaped while the male is oval shaped. Head is triangular. The thorax-abdomen carry four pairs of legs each having small claws. This mite is an ovoviviparous. In the body of the female, the young acarids hatch out from the eggs and pass out in the form of adult like small acarid. Each adult female produces about 100-150 young ones. The newly born mite is about 0.2 mm in body length and light yellow in colour. The males are produced first and the females later. Each male after mating with some females dies in about a day. A mature female in which the eggs are fully developed, the posterior half of the body becomes extra-ordinarily large to assume a spherical shape (about 1 mm in dia). The fertilized female on getting a suitable host attaches itself with claws and suckers present on the legs. This mite passes through 17 generations in a year. Each generation time ranges between 7-18 days.

(b) *Type of damage and symptoms:* The larva, pupa and adult silkworm are attacked by this acarid. Mainly, the young age larval and pupal stages are attacked. The females lodge themselves on the soft skin between the segments of host larvae and pupae and obtain nutrition. Furthermore, their saliva contains a kind of toxin which ultimately kills the host.

After being infested, the silkworms almost stop feeding and become sluggish, the body turn purple brown and yellowish brown fluid is vomited. Defecation is difficult and beaded faeces are attached to the anus. The skin surface of the attacked host bears several rough and uneven black spots. Silkworms attacked during moult fail to pass the moult. The worms die in a day or two. Infested pupae develop lesions, the body is blacken and they fail to moult into adult. The suspected worm should be placed in a black box and gently knocked a few times. By doing so, this acarid can be seen in the box through a magnifying glass.

(c) *Period of occurrence:* Mostly from May to middle of September.

(d) *Management:*

(i) On discovery of the attack by this acarid, the rearing rooms and trays should be replaced.

(ii) The rearing appliances should be disinfected with steam.

(iii) Cotton, wheat straw or rice straw should not be kept to dry near the rearing rooms or rearing appliances.

(iv) Pre-rearing disinfection should be carried out with sulphur at the rate of 30 g sulphur to a cubic foot or spraying of the rearing room and appliances with a 1:500 solution of an acaricide.

PART III

FORMS, FORMULATIONS AND APPLICATIONS

CHAPTER 5

FORMS, FORMULATIONS AND APPLICATION OF PESTICIDES (INSECTICIDES, ACARICIDES AND FUNGICIDES)

To make best use of the available recommendations for pesticidal control of the diseases and pests of mulberry, it is essential to know the following:

1. Forms and formulations of pesticides.
2. Volume required per unit area (acre/ha).
3. Calculations for dilutions.
4. Proper execution of application.
5. Safe period of various pesticides.

5.1. FORMS AND FORMULATIONS

Pesticides are manufactured mostly in pure forms and are referred to as technical grade material. Chemical and physical characteristics of these material do not often make them readily usable. These pesticides are, therefore, required to be brought to the usable (formulated) form. The formulated forms of pesticides have better properties with respect to satisfactory storage and effective application including safety to the applicator and the environment. Their use is also often more economic. Formulations of pesticides are marketed in three forms viz. Solid, Liquid and Gaseous, each of them having again a number of variations which are described below:

(a) Solid formulations

(i) *Dusts (D):* The dust formulations are mixture of toxicants and inert diluent to form a dry, free flowing powder. The concentrations of toxicant mostly ranges from 0.1 to 50 per cent.

(ii) *Wettable powders (WP) or water dispersible powders (WDP):* These are essentially finely divided concentrated dusts containing a wetting agent i.e. surface active agent to facilitate the mixing of the powder with water to prepare the solution of a desirable strength before spraying. Water dispersible powder in addition contains a dispersing agent for uniform dispersion of the solute in the suspension.

Such powders usually contain 50 per cent to 75 per cent inert diluent and they sink rather quickly to the bottom of sprayer tanks. The tank, therefore, should be shaken repeatedly while spraying.

(iii) *Water soluble powder (SP):* It is a finely ground water soluble solid and contains nothing else to assist its solution in water. It is merely added to the proper amount of water in the spray tank where it dissolves immediately. Unlike WP or WDP, water soluble powders are true solutions and do not settle to the bottom.

(iv) *Granulars (G):* These formulations consist of inert material with the toxicants absorbed on to them. Granular formulations are classified as extruded (impregnated) and nonextruded (surface coated). The former readily disintegrates in water whereas the latter resist disintegration in water. Though both the types of granules differ in physical characters their inert diluent may consist of either the regular volatile material (RVM) or low volatile material (LVM).

(v) *Capsules, baits and pellets*: Capsules are the pesticide formulations which have essentially a very small mass of toxicant enveloped in a thick coating material from which the toxicant diffuse slowly. Baits are formulations which consists of small quantities of toxicants combined with food material attractive to the pests. As regards pellets, the toxicant is mixed with polyvinyl chloride and a plasticizer which release the toxicant over a period of time.

(b) Liquid formulations

These formulations are applied as sprays in the form of solutions, suspensions and emulsions.

(i) *Solutions*: They are homogenous mixture of two or more substances and usually are not soluble in water. However, most of them are soluble in organic solvents like xylene, carbon tetrachloride, kerosene etc.

(ii) *Suspensions:* They are also referred as Flowable or Sprayable suspensions (F or S). They consist of finely divided solid particles dispersed in a liquid medium by means of a wetting agent. Therefore, they mix well with water as a suspension and can be sprayed, but with the same tank-settling characteristics as mentioned in case of WP.

(iii) *Emulsions*: There are two types of emulsion, the first is the oil in water (O/W) type. In this, oil is dispersed in water. This is also referred as emulsifiable concentrate (EC). EC is the concentrated oil solution of the technical grade toxicant with enough emulsifier added to make the concentrate mix (emulsify) readily with water for spraying. The emulsifiers (they belong to a group of chemicals termed as surface active agents - SAA or surfactants) are generally a detergent-like material that makes possible the suspension of oil droplets in water to form an emulsion.

The second type is invert emulsion. This is a change from oil in water emulsion to water in oil (W/O). The invert emulsion is opaque in concentrated form resembling face cream. This type of emulsion is principally applied as herbicide. Spray of invert emulsion results in reduced drift and are applied in sensitive situation. Application of invert emulsions has not been widely accepted because of the need for specially designed equipment.

(iv) *Water miscible liquids*: They readily mix with water. They do not become milky when diluted in water. In these formulations the technical grade material may be water miscible initially or it may be alcohol miscible and formulated with an alcohol to become water miscible.

(v) *Concentrate insecticide liquids:* They are applied in a concentrate form without diluting in water at ultra low volume (ULV) rates. ULV formulations contain highest possible concentration of the toxicant which is sprayed by micronising to a droplet size of 70-120 u by means of spinning disc sprayer.

(c) Gaseous formulations

These include the formulation which may be available in liquid or solid state but act in gaseous or vapour state.

(i) *Aerosols:* These contain the toxicant dissolved in an inert liquid which is gaseous at ordinary temperatures but liquifiable under pressure. When the pressure is released the solution is discharged through a fine nozzle, the solvent evaporates and the toxicant is dispersed in a very finely divided state.

(ii) *Fumigants:* Pesticides in gaseous forms are known as fumigants and are most often formulated as liquids. These are generally useful in completely closed spaces.

5.2. VOLUME REQUIRED PER UNIT AREA

In a pesticide application programme, it is very essential to know the volume of spraying or dusting material required for an effective coverage of an area. Irrespective of the active ingredient required, if the volume of liquid to be sprayed is taken more, the pesticide will be wasted and the effective concentration will be less. On the other hand, if the volume of the liquid taken is less, it may not cover the entire field and the effective concentration may be more. Again the dispersal (coverage) of the liquid or the dust is dependant on the type of the sprayer or the duster used. In practice, selection of the volume of liquid of dust for liquid or dust for its application is left to users' discretion. However, the recent trend has been to bring about effective control of insect pest with considerable reduction in the volume of application material without the loss of efficiency. Reduction in the volume of application material helps in effective coverage of the target with minimum contamination of the environment. This can be done by using improved sprayer components and also by selecting optimum droplet size. Use of appropriate droplet, uniform in size and density according to the target is referred to as controlled droplet size application (CDA). Optimum droplet size ranges between 10-15 μm, 30-50 μm, 40-100 μm and 250-500 μm for the targets like flying insects, insects on foliage, foliage and soil respectively.

The volume of spray per unit area depends upon the output of the particular sprayer owned by the user, the spread and height of mulberry plants at the time of treatment and the number of plants per acre. Because of the influence of these variables on the volume of pesticide required, it is not possible to prescribe the actual volume needed by the sericulturist at the time of the insecticide application. It is, therefore, suggested to treat small number (ten or more) of mulberry plants selected randomly at the time of application and subsequently the total quantity required for treating the mulberry garden can be easily worked out with the help of the table given below:

Spacing	No. of plants/ha
30 x 30 cm	11 110
60 x 30 cm	5 555
60 x 60 cm	2 778
90 x 60 cm	18 518
90 x 90 cm	12 345

All the aspects described under application techniques should be strictly followed at the time of assessment of the volume of the application material.

5.3. CALCULATIONS FOR DILUTION

Commercial formulations of pesticides are generally marketed in concentrated forms, while for pest control very low percentages of the active ingredients are required. They are thus required to be diluted before use. With this also connected is the total volume of the pesticidal solution required to be prepared for a particular operation. Combining all of them a formula has been outlined and the same along with a worked out example are given below:

a = Percentage concentration of the pesticide to be used
b = Quantity of the solution/dust required
c = Percentage of active ingredient in the commercial pesticide
d = Quantity of the commercial formulation required to be used

$$d = \frac{a \times b}{c}$$

To cite an example:

If the dimethoate solution is to be used
= 0.2 per cent - (a)
Quantity of the solution required to be prepared
= 150 l - (b)
percentage of active ingredient in the commercial preparation
= 30 per cent EC - (c)

Then"d" or the quantity of the commercial pesticide required to be used will be

$$= \frac{0.2 \times 150}{30} = 1 \text{ (l/kg)}$$

or otherwise 1 l/kg of the commercial pesticide should be mixed with 149 1 l/kg of water. The same formula can also be used for diluting the dusting material in some inert medium like Kaolin.

For preparing solution from solids/wettable powders also the same formula can be used except that the volume of the parent material need not be subtracted from the prepared material to make up the total volume, as in case of a full solution whereby on addition of the parent material the total volume of the prepared material will not increase.

To cite an example

if Solution required to be prepared from any solid/wettable powder
= 0.05 per cent - (a)

Spraying material required from the solid/wettable powder
= 200 l -(b)

Concentration of the toxicant available
= 50 per cent -(c)

Quantity of solid/wettable powder required (d) will be

$$= \frac{0.5 \times 200}{50} = 2 \text{ kg}$$

5.4. APPLICATION TECHNIQUES

Effective spraying or dusting are technical jobs and must be planned prior to execution. This includes prevention of waste, uniform coverage of the target and avoiding hazards to the operator. Guidelines for effective and safe use of insecticides are presented below:

(A) Before application

1. Identify the pest followed by the observation on the symptoms.
2. Use pesticides only when incidence is high, otherwise adopt other suggested measures.
3. If more than one insecticide is recommended, select the least toxic to mammals (Refer Annex. 1).
4. Read the label on containers and literature supplied along with the insecticide (Refer list of the meaning of terminologies)
5. Ensure that all protective devices are available.
6. Ensure availability of first aid medicines in case of any symptoms of accidental poisoning.
7. Check application equipment for leaks and ensure its proper working.
8. Inform the owners of adjacent fields of your pesticide application programme.

9. Carry the commercial formulation of the pesticide to the field in its original container.

(B) While diluting

1. Wear appropriate protective devices to avoid contamination with skin.
2. Do not allow children near the diluting or mixing place. (Fig. 1)
3. Never work alone while handling pesticides.
4. Recheck the instructions on the label.
5. Avoid splashing while pouring liquid formulations.
6. Avoid solid formulation puffing up into the face.
7. Never eat, drink, smoke or chew while diluting or applying pesticides.
8. Don't draw the liquid into tubes by sucking with the mouth. Use graduated vessel to measure liquid.
9. Use glass rod stick for stirring the liquid.
10. Persons with sores or open wounds should never be allowed to carry out this work.

(C) During application

1. Avoid application during the hot hours of the day (Fig 1).
2. Apply dusts in early morning when the plants are wet with dews.
3. Start application of dust/liquid from the downward wind edge of the field and proceed upwind so that operators proceed into unapplied areas.
4. While covering the other side of the plant, if there is any chance of the sprayer/dust material enveloping the operator or getting blown into his face (Fig. 1), it is better to apply the pesticides on two occasions with opposing wind direction to cover both the sides of the plant.
5. Never apply pesticides, if the wind is blowing towards grazing livestock or regularly used pastures.
6. Don't blow clogged nozzles or hoses with your mouth. Use thin wire (Fig. 1).
7. For effective spraying and also to prevent waste of application material as far as possible run-off stage should be avoided.
8. Underleaf coverage should be ensured.

(D) After application

1. Never leave pesticide in application equipment. Clean equipments before keeping it.
2. Remove and clean protective devices used during application.
3. Destroy empty containers and cotaminated packing material by burying or burning them. If containers are burnt, do not stand in the smoke. In case of burying, metal containers should be made unserviceable by jamming.
4. Keep unused pesticides safely out of the reach of children and pet animals.
5. Any other specific precautions suggested by manufacturers should be scrupulously followed.
6. Wash hands or take bath after application.

(E) Safe period

Pesticides are widely used for the control of diseases and pests of several field crops. Improper method of their application results in undesirable drift residues to adjacent field crops. Accordingly mulberry garden have also been found contaminated due to use of pesticides in the nearby crops.

Since silkworms are highly sensitive to pesticides, harvest of mulberry leaves before the safe period should be completely avoided. In case, if this is not followed scrupulously and cotaminated leaves are harvested from the garden either located adjacent to field crops applied with pesticides or directly treated with pesticide, silkworm larvae develop toxic symptoms followed by the loss of the crop. These symptoms include:

(a) Vomiting of the digestive juice.
(b) Swinging of the anterior half of the body.
(c) Shortening of the body due to loss of the body fluid.

Figure. 1. Important precautionary measures for spraying of pesticides

(d) Muscle contraction
(e) Paralysis followed by death of the silkworm larvae.

Safe periods recommended to use mulberry leaves for silkworm feeding* after treatment by some of the commonly used pesticides

Name of pesticides**	Active ingredient (%)	Safe periods (days)
Monocrotophos (Nuvacron)	0.01 0.05	11 13
Demeton (Metasystox)	0.01 0.05	07 11
Aldrin (Aldrex)	0.01 0.05	11 13
Phosphomidon (Dimecron)	0.01 0.05	11 13
Dichlorovos (Nuvan)	0.01 0.05	07 11
Methyl parathion (Metacid)	0.01 0.05	07 13
Carbaryl (Sevimol)	0.05 0.10	09 11
Quinalphos (Ekalux)	0.05 0.10	07 13
Dimethoate (Roger)	0.05 0.10	07 11
Endosulfan (Thiodan)	0.05 0.10	09 17
Phosalone (Zolone)	0.05 0.10	09 11
BHC (BHC)	0.05 0.10	07 11
Chlordane (Termex)	0.05 0.10	11 13
Malathion (Cythion)	0.50 1.00	13 17

* Safe waiting periods have also been indicated with each pesticidal control measure suggested.

** Names in parentheses are the commercial/trade names of pesticides.

To avoid loss of silkworm crops (due to feeding of contaminated leaves) mulberry leaves should be harvested on or after the number of days shown against each pesticide in the table given below:

Meaning of the commonly used terminology on the containers of pesticides*

Toxicity	- How poisonous
Oral toxicity	- How poisonous it is to man or animals when it is swallowed
Dermal toxicity	- How poisonous it is when absorbed through skin
Inhalation toxicity	- How poisonous it is when inhaled
Acute toxicity	- How poisonous it is after a single exposure
Chronic toxicity	- How poisonous it is when a man or animal is exposed to small repeated doses
Lethal	- Deadly
LD 50	- Amount (Lethal dose) of toxicants of active ingredient that can kill 50% of the tested population through oral ingestion or dermal absorption. LD 50 is given as mg/kg of body weight.
LC 50	- Acute inhalation toxicity necessary to kill 50% of the test organism, LC 50 values are measured in mg/l .
Hazard	- The chance that it may harm the beneficial organism including man from the use of toxicant formulation. Hazard should not be confused with toxicity.
Residue	- Toxicant deposit remaining on the treated crops for sometime after the application.
Tolerance	- The maximum amount of residue which may safely remain on a harvested crop. It is measured in parts per million (PPM).

* Expanded forms of various abbreviations used on the labels of containers are given while describing different formulations of pesticides.

LIST OF COMMONLY USED PESTICIDES AND RELATED USEFUL INFORMATIONS

Common/Commercial* or Trade Names	Chemical Names/Molecular Formulae	Modes of Action/Acute** oral toxicity (Mammals-LD 50)
A. INSECTICIDES/ACARICIDES		
Aldrin (Octalene)	1, 2, 3, 4, 10, 10-hexachlorol-1, 4, 4a, 5, 8, 8a-hexahydroexo-1, 4-endo-5, 8-dimethanonapthaene (C_{12} H_8 Cl_6)	Contact, Stomach and respiratory action (67 mg/kg)
Aldicarb (Temik)	2-methyl-2-(methylthio) propionaldehyde 0-methylcarbamoyloxime. (C_7 H_{14} N_2 O_2 S)	Contact poison with systemic action (Absorbed through roots) (0.93 mg/kg)
BHC (HCH)	1, 2, 3, 4, 5, 6-Hexachloro cyclohexane (C_6 H_6 Cl_6)	Stomach contact and respiratory action. (88-125 mg/kg)
Carbaryl (Sevin, Murvin, Patrin)	1-Napthyl onethyl carbamate (C_{12} H_{11} NO_2)	Predominantly contact action (400-850 mg/kg)
Carbofuran (Furadan, Quraterr, Yaltox)	2, 3-dihydro-2, 2-dimethyl benzofluran-7-Y1 methyl carbamate (C_{12} H_{15} NO_3)	Stomach and contact action (8.2-14.1 mg/kg)
Chlordane (Octachlor Belt)	1, 2, 3, 4, 5, 6, 7, 8, 8-Octachloro-2, 3, 3a, 4, 7, 7a-hexahydro-4, 7-methanoindene (C_{10} H_6 Cl_8)	Stomach, contact and respiratory action (250 mg/kg)
Chlorfenvinfos (Birlane, Sapecron, Supuna)	2-Chloro-1-(2, 4 dichlorophenyl) Vinyl dithyl phosphate (C_{12} H_{14} Cl_3 O_4 P)	Contact and respiratory action (24-39 mg/kg)
Demeton (Systox, Systemox)	0, 0-diethyl 0-(2-(ethylthio) ethyl) Phosphorothiate, mixture with 0, 0-diethyl S-(2-(ethylthio)ethyl) Phosphorothioate (C_{18} H_{19} O_3 PS_2)	Systemic with contact and stomach action (6-12 mg/kg)
Dichlorvos (Nuvan, Vapona, Nogos)	2, 2-dichlorovinyl dimethyl phosphate (C_4 H_7 Cl_2 O_4 P)	Fumigant and penetrant action (50-80 mg/kg)
Dicrotophos (Bidrin, Carbicron, Ektafos)	Dimethyl (E)-2-dimethyl carbamyl-1-methylvinyl phosphate (C_8 H_{16} NO_5 P)	Contact and systemic action (22 mg/kg)
Dieldrin (Alvit, Octalox, Dieldrite)	(1R, 4S, 5S, 8R)-1, 2, 3, 4, 10, 10-hexachloro-1, 4, 4a, 5, 6, 7, 8, 8a-Octahydro-6, 7-epoxy-1, 4:5, 8 dimethanonapthalene (C_{12} H_8 Cl_6 O)	Persistent with contact and stomach (40-87 mg/kg)
Diflubenzuron (Dimilin)	1-(4-chlorophenyl)-3-(2, 6-difluorobenzoyl) urea (C_{14} H_9 Cl F_2 N_2 O_2)	Stomach and contact poison, interferes with chitin formation of caterpillars and larvae, prevents the egg hatching (4640 mg/kg)
Dimethoate (Rogor, Cygon, Dimetate)	Dimethyl S(N-Methyl carbomoylmethyl) Phosphorothiolothioate (C_5 H_{12} NO_3 PS_2)	Systemic insecticide and acaricide with stomach action (250 mg/kg)
Endosulfan (Thiodan, Beosit)	1, 4, 5, 6, 7, 7-hexachloro-8, 9, 10-trinorborn-5-en- 2, 3-ylenodimethyl sulphite (C_9 H_6 Cl_6 O_3 S)	Stomach and contact action (40-50 to 110 mg/kg)
Endrin (Endrex, Hexadrin)	1, 2, 3, 4, 10,10-hexachloro-1, 4, 4a, 5, 6, 7, 8, 8a-octahydro-6, 7-epoxy-1, 4:5, 8-dimethanonapthalene (C_{12} H_8 Cl_6 O)	Persistent insecticide contact and stomach action (5-45 mg/kg)
Malathion (Malathion, Cythion, Sumitox)	S-1, 2-bis (ethoxycarbonyl) ethyl 0, 0-dimethyl phosphorodithioate. (C_{10} H_{19} O_6 PS_2)	Predominantly contact action but also some stomach and respiratory action (1375-2800 mg/kg)
Parathion-Methyl (Folidol-M, Metacide)	0, 0-dimethyl 0-4 nitrophenyl phosphorothioate (C_8 H_{10} NO_5 PS)	Insecticide and acaricide with contact, stomach and respiratory action (12-42 mg/kg)

Common/Commercial* or Trade Names	Chemical Names/Molecular Formulae	Modes of Action/Acute** oral toxicity (Mammals-LD 50)
Demetion-S-Methyl (Metasystox, Duratox)	S-2-chylthioethyl 0, 0-dimethyl phosphorothioate ($C_6 H_{15} O_3 PS_2$)	Systemic insecticide and acaricide with contact and stomach action (40-60 mg/kg)
Monocrotophos (Monoeron, Nuvacron, Azodrin)	Dimethyl (E)-1-methyl-2-methylcarbamoylvinyl phosphate ($C_7 H_{14} NO_5 P$)	Systemic and contact action (21 mg/kg)
Parathion (Folidol, Thiophos)	0, 0-diethyl 0-4 nitrophenyl phosphorothioate ($C_{10} H_{14} NO_5 PS$)	Insecticide and acaricide with know systemic contact stomach and respiratory action (6-15 mg/kg)
Phorate (Thimet, Rampart)	0, 0-diethyl S-ethylthiomethyl phosphorodithioate ($C_7 H_{17} O_2 PS_3$)	Systemic and contact action (1.6-3.7 mg/kg)
Permethrin (Ambush, Ectiban, Perthrine, Kafil, Pounce, Permasect, Indothrin)	3-Phenoxybenzyl (IRS)-(1S, trans-3-(2, 2-dichlorovinyl)-2, 2-dimethyl-cyclopropanecarboxylate ($C_{21} H_{20} Cl_2 O_3$)	Stomach and contact action (4000 mg/kg)
Phosalone (Zolone, Rubitox, Azosene)	S-6-chloro-2, 3-dithydro-2 oxobenzoxazol-3-ylmethyl 0, 0-diethyl phosphorothioate ($C_{12} H_{15} Cl NO_4 PS_2$)	Systemic action insecticide and acaricide with wide spectrum. (135 mg/kg)
Phosphaomidon (Dimecron, Apamidon, Dixon)	2-chloro-2-dithylcarbamoyl-1-methylvinyl dimethyl phosphate ($C_{10} H_{19} Cl NO_5$)	Systemic insecticide and acaricide with stomach contact and respiratory action (17.92-30 mg/kg)
Pyrethrins (Pyrethrum)	Pyrethrin-1 (R = CH, R = CH:CH_2) ($C_{21} H_{18} O_3$)	Contact action (570-1500 mg/kg)
Phosmet (Imidan)	0, 0-dimethyl-S-Phthalimidomethyl Phosphorodithioate ($C_{12} H_4 NO_4 PS_2$)	Non-systemic acaricide and insecticide (113 mg/kg)
Quinalphos (Ekalux, Bayrusil)	0, 0-dimethyl 0-quinoxalin-2-ylphosphorothioate ($C_{12} H_{15} N_2 O_3 PS$)	Contact and stomach action (62-137 mg/kg)
B. FUNGICIDES		
Captafol (Difolaton, Haipen, Merpafol)	1, 2, 3, 6-tetrahydro-N-(1, 1, 2, 2-tetrachloroethylthio) Phthalimide ($C_{10} H_9 Cl_4 NO_2 S$)	Curative leaf fungicides (6200 mg/kg)
Captan (Orthocide, Pillarcap)	1, 2, 3, 6-tetrahydro-N-(Trichloromethylthio) Phthalimide ($C_9 H_8 Cl_3 NO_2 S$)	Curative leaf fungicides (9000-15000 mg/kg)
Carbendazim (Derosal, Bavistin)	Methyl benzemidazol-2-ylcarbamate ($C_9 H_9 N_3 O_2$)	Systemic leaf and soil fungicide (15000 mg/kg)
Dinocap (Karathane)	2(or 4)-Isooctyl-4, 6 (or 2, 6) -dinitrophenyl 2-butenoate ($C_{18} H_{24} N_2 O_6$)	Non-systemic acaricide and contact fungicide (980-1190 mg/kg)
Mancozeb (Dithane-ultra, Dithane M-45)	Zinc ion + manganese ethylene desdithiocarbomate (-SCS. $NHCH_2$ CH_2 NHCS.S.Mn-) x (ZN) Y	Protective leaf fungicide (5000 mg/kg)
Sulphur (Sulfex)	Sulfur (CA) Sx	Protective fungicide with secondary acaricide (Non-toxic to mammals)
Tridemorph (Calixin)	2, 6-dimethyl-4-tridecylmorpholine ($C_{19} H_{39} NO$)	Systemic fungicide (1900 mm^3/kg)

* Names in parentheses are the trade/commercial names of insecticides/acaricides/fungicides.

** Figures in parentheses are the acute oral toxicity (LD) values against mammals.