

## PSYLLID PESTS OF HORTICULTURAL AND FORAGE CROPS: TAXONOMY, BIOLOGY AND THEIR MANAGEMENT

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**ABSTRACT** – Psyllids are phloem feeding insects resembling minute cicadas belonging to series Sternorrhyncha of suborder Homoptera. These sternorhynchous homopterans are commonly known as jumping plant lice and lerp insects. The taxonomy of psyllids is based on the morphological characters like shape of the head, particularly genal cone and antennae, wing venation, metathoracic leg, modifications of genitalia and nymphal setae. Life cycle of psyllids involves an egg stage, five nymphal instars before becoming adult, all psyllids are dioecious and at emergence the sexes normally occur in a ratio of 1:1. Psyllids are economically important as pests of several crops and also as biocontrol agents of weeds. Pestiferous species includes Asian citrus psyllid, *Diaphorina citri* (Kuwayama); African citrus psyllid, *Trioza erytrae* (Del Guercio); Mango shoot gall psyllid, *Apsylla cistellata* (Buckton); Common pear psyllid, *Cacopsylla pyricola* (Foerster); Apple psyllid, *Cacopsylla mali* (Schmidberger); Subabul psyllid, *Heteropsylla cubana* (Crawford) and Potato psyllid, *Bactericera cockerelli* (Sulc.). They cause damage not only by direct feeding but also as vectors of deadly diseases like citrus greening and pear decline. Apart from pests, a few species of psyllids, *Arytinnis hakani* (Loginova) and *Arytainilla spartiophila* (Foerster) are exploited as biocontrol agents of weeds. The options available for management of psyllids includes constant monitoring of psyllid population; tending and caring of trees to encourage healthy growth, thus enabling them to be better able to withstand and recover from damaging attacks; use of indigenous and exotic predators, parasitoids and pathogens in limiting pest populations; selection of genetically resistant genotypes for plantings as well as the genetic manipulation of biological control agents to increase their efficacy against the target pest and use of pesticides. A brief account of economically important psyllid pests of horticultural and forage crops their taxonomy, biology and management is reviewed and presented in this paper.

**Key words** : Psyllids, biology, fruit/ horticultural crop, forage crop, taxonomy, management.

### INTRODUCTION

Psyllids or jumping plant-lice are small phloem-feeding insects, distributed worldwide from the Arctic Circle to the sub-antarctic islands of New Zealand with its greatest diversity in tropical and south temperate regions (Hollis, 2002). Together with the white flies, aphids and scale insects constitute the suborder Sternorrhyncha within the Hemiptera. Currently, 3850 species of psyllids in 238 recognized genera have been described worldwide (Li, 2011), which is probably less than half of the existing number of species. Bekker- Migdiscova (1973) suggested that psyllids are very old group which are already represented in the Permian by the extinct family Protopsyllidiidae.

Superfamily Psylloidea comprises six families viz., Psyllidae, Calophyidae, Phacopteronidae, Homotomidae, Carsidaridae and Triozidae. The family psyllidae of the sternorrhynchous homoptera comprises small sized phytophagous insects, characterized by two pairs of membranous wings held in stegopterous manner (roof-like over the body) with reduced venation, the forewings usually of a harder constituency than the hind wings.

Psyllids have ten segmented antennae, three ocelli widely placed on the vertex, thickened hind femora and uniformly dimerous tarsi terminating in two equal claws with associated pulvilli (Kandasamy, 1986).

Psyllids are free living and 15 per cent of known species are gall inducers. Adult psyllids resemble minute cicadas, ranging in length from 1-10 mm. The life cycle of psyllids usually consists of the egg stage, five nymphal instars and sexually reproducing adults. The ratio of males/ females is near to 1:1 (Hodkinson, 2009). Most psyllid species complete their larval development on one or a few closely related plant species. Adult psyllids are always winged and are easily dispersed by wind. Psyllids have large metacoxae, fused to the metathorax, containing strong muscles enabling them to jump, hence their names 'psylla' from Greek meaning 'flea', or 'jumping plant louse'.

#### Basic characters of Psyllids

- Adult psyllids resemble miniature cicadas, ranging in length from 1-10 mm.
- Both sexes possess two pairs of wings, forewings with harder constituency than hind wings.

- Beak is short and three segmented.
- Five nymphal instars, wingless, possessing fore wing and hind wing pads.
- Nymphs produce white waxy secretions.
- Male and female produces sex specific and species specific acoustic signals during mating.
- Economically important as pest, vector and biocontrol agents.

Psyllids have piercing and sucking type of mouth parts. While feeding, the mandibular and maxillary stylets are inserted into the host tissue, saliva is injected and then the liquid food is sucked. Before feeding, the insects probe more or less extensively. The probing involves injection of saliva, which is particularly relevant in species which transmit bacterial or viral pathogens. As with other Sternorrhyncha and many Fulgoromorpha, psyllids are specialized phloem-feeders and display several adaptations for coping with this unbalanced, nitrogen-poor diet. The anterior and posterior portions of the mid-gut form a loop which permits water to pass directly from the fore to the hind gut. The excess water with dissolved sugars is excreted as honeydew. Often copious production of waxy secretions is a result of the hydrocarbon-rich phloem sap. Psyllids possess bacterial endosymbionts which are situated in the mycetome, a specialized organ in the abdomen (Dalva Luiz de Queiroz *et al.*, 2011). Thao *et al.*, 2001, showed that psyllids and their primary prokaryotic endosymbionts co-speciated.

Most psyllids are well camouflaged on the substrate they live and remain generally unnoticed. As a result of these properties, they are predisposed to be accidentally transported by humans together with their host plants or accidentally dispersed by wind over large distances. Psyllids are attracted by yellow colour, a fact which is exploited in monitoring pests with yellow water or sticky traps (Dalva Luiz de Queiroz *et al.*, 2011).

Depending on the climatic conditions, psyllid species of temperate regions tend to be univoltine or bivoltine, while those of the tropics are often polyvoltine, with several overlapping generations per year (Burckhardt, 1994; Hollis, 2004; Santana *et al.*, 2010). Hodkinson (2009) analyzed the life history characteristics of 342 psyllid species from all over the world and concluded that environmental temperatures and water availability acting on the psyllids, directly or via the host plant, are the major determinants of psyllid life cycles. The phenology of psyllids is, therefore, well synchronized with that of their hosts. Psyllid populations are generally controlled by a range of predators and parasitoids (Hodkinson, 1974;

Hollis, 2004). Birds and small mammals are occasionally known to eat psyllids. In agricultural systems, anthocorids, syrphids, coccinellids and chrysopids are sometimes capable of controlling psyllid populations, but parasitoids such as encyrtids and eulophids {Eulophid parasite, *Tamarixia (Tetrasticus) radiata* (Waterston), encyrtid endoparasite, *Diaphorencyrtus aligarhensis* against Asian citrus psyllid} are usually more efficient. Psyllids are also affected by entomopathogenic fungi, with which they may be controlled (Dal Pogetto *et al.*, 2011).

Taxonomy (*taxis*: arrangement and *nomia*: method) is the science of identifying and naming species, and arranging them into a classification. Taxonomy includes nomenclature and classification. Taxonomic Characters used in classification of psyllids includes Head, Thorax, Antennae, Wing and wing venation, Legs, Abdomen, Genitalia, Nymphal setae (Kandasamy, 1986).

#### Systematic position of family Psyllidae

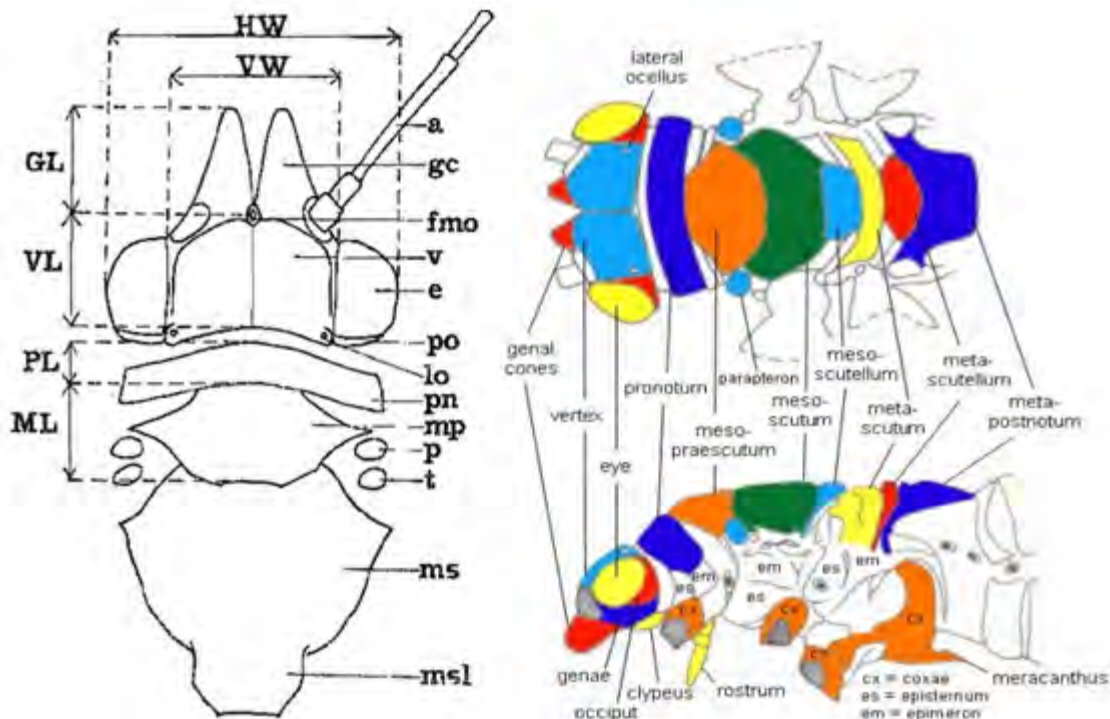
Kingdom	:	Animalia
Phylum	:	Arthropoda
Class	:	Insecta
Order	:	Hemiptera
Suborder	:	Homoptera
Series	:	Sternorrhyncha
Superfamily	:	Psylloidea
Family	:	Psyllidae

**Sub families:** Psyllinae, Triozinae, Pauropsyllinae, Ciriacreminae, Aphalarinae, Liviinae

**Genera:** *Acizzia*, *Apsylla*, *Cacopsylla*, *Diaphorina*, *Heteropsylla*, *Pachyopsylla*

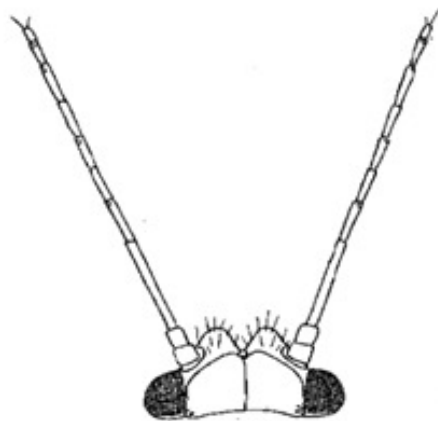
#### 1. Head and Thorax

**Head:** Globular or greatly elongated or horizontal or deflexed downwards or triangular. The prolongation of genae in the form of genal cones (Fig 1 and 2) and various shapes of vertex are the distinct features by which the family psyllidae could be distinguished from other homopteran families. The clypeus occupies an inferior position and is not visible from above unlike that of other families where it occupies a prominent anterior position. The large dorsal sclerite covering most of the head is the vertex which is divided by a prominent median suture and bears generally two foveal impressions, and two basal, posterior and lateral ocelli. Frons, the smallest sclerite of the head, is scarcely visible in some genera (*Trioza* and *Psylla*) and very prominent in others (*Paurocephala*, *Livia* and *Aphalara*). It always bears the anterior ocellus in the center, which is enveloped between the genal cone bases. The relatively large clypeus, which is cordate in

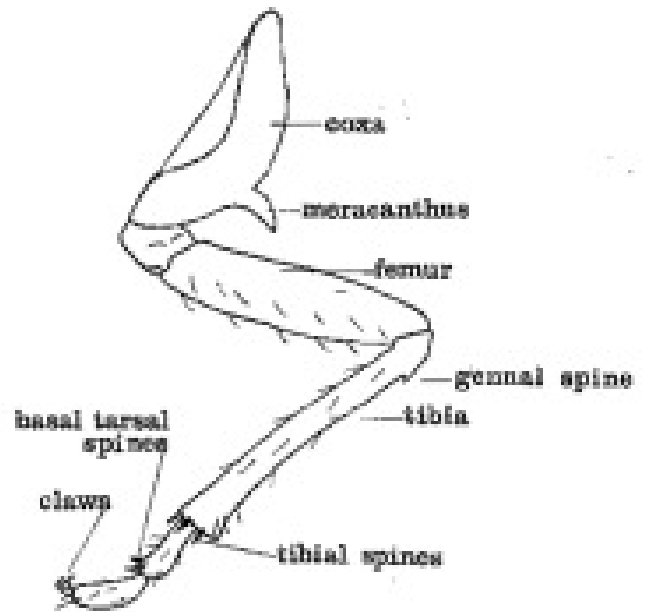


**Fig 1 and 2 : Psyllid Head and Thorax (Source : Hodkinson and White, 1979)**

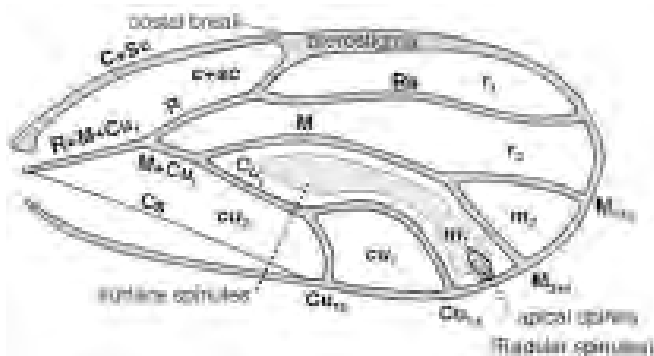
(a: antennae, gc: genal cone, fmo: frons bearing median ocellus, v: vertex, e: eye, po: post orbital ridge, lo: lateral ocellus, pn: pronotum, mp: mesothoracic praescutum, p: paryptera, t:tegula, ms: mesothoracic scutum, msl: mesothoracic scutellum, HW: head width, VW: vertex width, GL: genal cone length, VL: vertex length, PL: pronotum length, ML: mesothoracic praescutum length)



**Fig 3: Antennae of Psyllid (Source: Kandasamy, 1986)**



**Fig 5: Metathoracic leg of psyllid (Source: Kandasamy, 1986)**



**Fig 4 : Fore wing of psyllid (Source: Hodkinson and White, 1979)**

shape, usually covers the frons and is inferior in position. The rostrum consists of much reduced labrum and well developed labium which is sharply flexed between fore coxae and appears to rise between forelegs in the typical sternorrhynchous condition. The eyes are hemispherical and project laterally from the side of the head (Kandasamy, 1986).

**Thorax:** Generally large and strong, prothorax short when compared to meso and metathorax (Fig 1 and 2). The pronotum is of single sclerite and arched behind the head. Sometimes it extends only up to half the way towards the coxae (*Trioza* and *Psylla*), while in others it extends up to fore coxae (*Livia*). Mesothorax is the longest part consisting of prescutum (which is long as pronotum), scutum (large sclerite), and scutellum (small and hemispherical). Metathorax includes the scutum which articulates with the wing process of hind wings and scutellum is generally smaller. The post scutellum is larger than mesothorax and produced into prominent ridges. The parapytera are normally tubercular but in *Livia* they are developed into flat quadrate plates which fit into lateral angles of the mesothoracic praescutum and scutellum (Kandasamy, 1986; Hodkinson and White, 1979).

## 2. Antennae

Usually ten segmented, attached to the genae near the anterior margin of vertex, with well developed 4 or 5 sensoria at the apices. The first two basal segments are larger and less hirsute than the rest of the segments, while the third is always longest (Fig 3). The thickened terminal segment bears two thick setae of unequal length (Kandasamy, 1986).

## 3. Wing and wing venation

The general shape of wing is elongate-ovate to rhomboidal, four in number, anterior pair thicker than posterior and sometimes mottled; venation simple and shows striking differences. The venations of forewings, unlike the hind wings, are used as a specific character. Basal vein branches into three principle veins viz., radius, median and cubitus. It is usually divided into two “*Psyllinae* type” or into three “*Triozinae* type” (Fig 4). In the former, median and cubitus fuse forming a cubital petiole (leaving radius alone), a vein normally absent in *Triozinae* forms. The radius branches into a short  $R_1$  and a long radial sector which joins the coastal margin forming a narrow pterostigma. The median vein forks into  $M_{1-2}$  and  $M_{3-4}$ , the former joining near the apex or at the apex; the latter with the posterior margin, and the cell formed between these forks is the second marginal cell. The first marginal cell is formed by the forking cubitus ( $Cu_1$ ) into  $Cu_{1a}$  and  $Cu_{1b}$ . A short basal vein is present. Sometimes

cross veins may also occur connecting the above vein. Usually the hind wings show no remarkable specific variations.

In many species the membrane of the fore wing is covered in minute cuticular protruberances termed as spinules. The presence and distribution of spinules on the upper surface of the wing membrane is a valuable taxonomic character. In genera such as *Trioza* the spinules are of two types; the larger radular or apical spinules (Fig 4), which occur in distinct V-shaped clusters in the cells around the apical and anal margin of the wing and the smaller surface spinules which are distributed over the membrane and which may be present or absent. Other important forewing characters include shape, texture and pattern, relative length and shape of veins, relative shape and size of cells, the presence or absence of a coastal break and the point at which  $Cu_2$  meets the hind margin (Kandasamy, 1986; Hodkinson and White, 1979).

## 4. Leg (Metathoracic leg)

Among three pairs of legs, the pro and mesothoracic legs are simple and of little taxonomic significance. The metathoracic legs, however are highly modified for jumping and provide several useful characters. The hind leg is distinctly modified and the structure varies from species to species, each metacoxa is large and usually bears a characteristic posteriorly directed process called as meracanthus (Fig 5). The meracanthus is absent in *Rhinocola* and *Camaratoscena*, generally tibia is larger than femur; two short tarsal segment almost of equal lengthly present, of which the apical segment bears two claw-like spines with pulvillus. The number of basal tibial spurs, comb of apical spines and thick large black spines in the apex of tibia vary from species to species. The apex of basal tarsal segment also possesses spines in varying numbers. The metatibia often posses an outer basal genual spine or tubercule, but this is absent in genera *Psyllopsis*. The number of thick black saltatorial spines at the apex of the metatibia varies from three in certain species of *Trioza* species to maximum of ten in *Psyllopsis*. Similarly, the number of thick black saltatorial spines on the basal metatarsus varies from two in certain species of *Psylla* to one in *Arytaina* spp. and none in *Aphorma* and *Trioza* (Kandasamy, 1986; Hodkinson and White, 1979).

## 5. Abdomen

The abdominal segments in psyllids are comparatively fewer than in the typical generalized insect. Out of a total 11 segments, the abdomen shows only five segments. The first two are wanting, the third is reduced to a small sclerite; 4<sup>th</sup> to 8<sup>th</sup> are distinctly visible (Fig 6). In female, the 9<sup>th</sup>

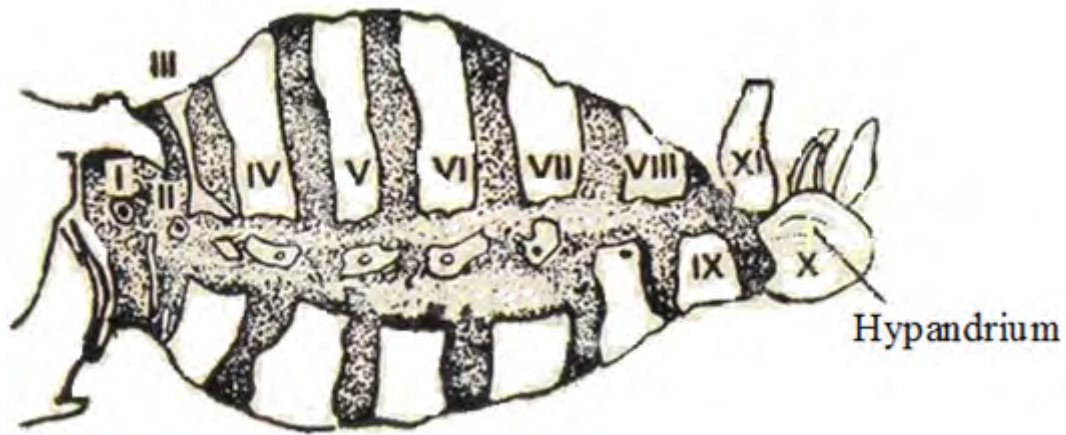


Fig 6: Abdomen of Psyllid (Source: Kandasamy, 1986)

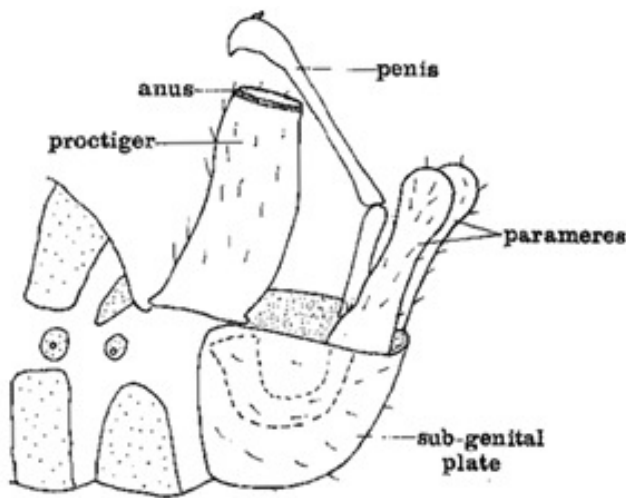


Fig 7: Male Genitalia of Psyllid (Source: Hodkinson and White, 1979)

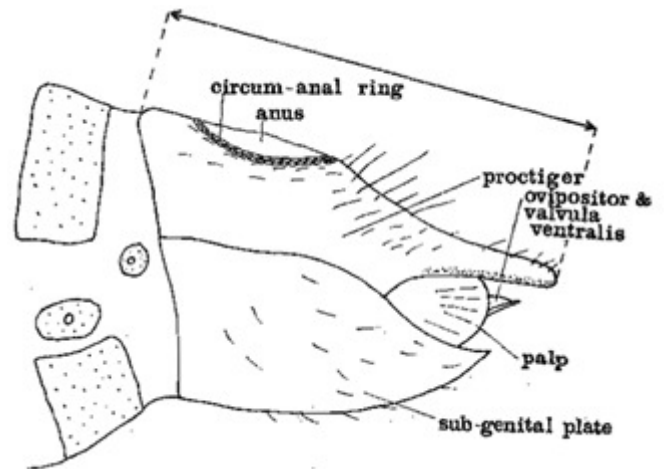


Fig 8: Female Genitalia of Psyllid (Source: Hodkinson and White, 1979)

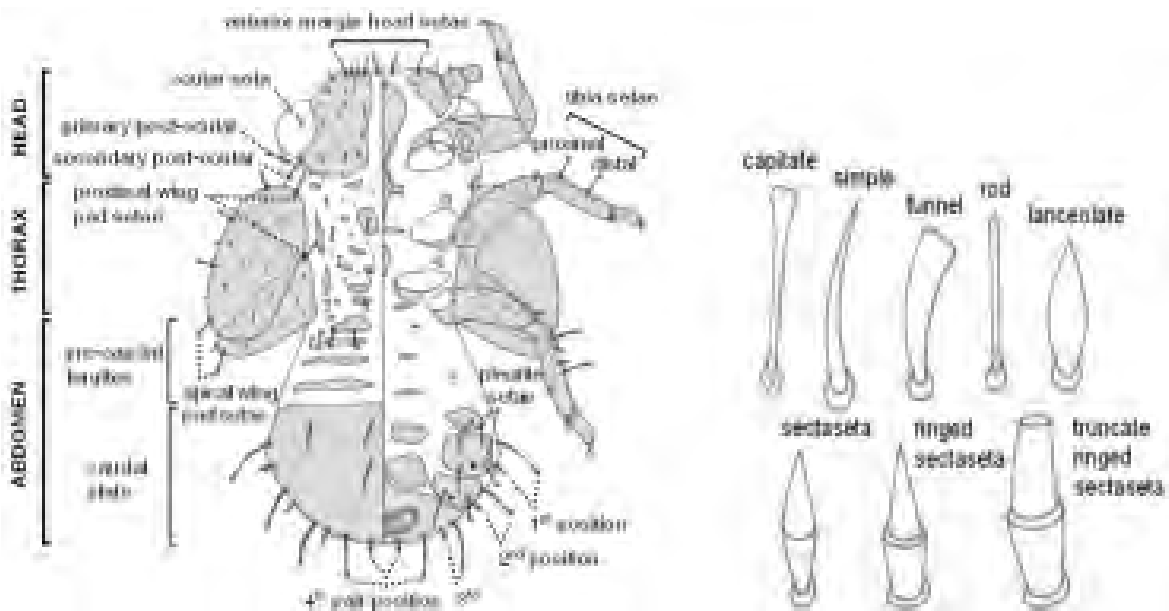


Fig 9: Nymph and Nymphal setae of Psyllid

and 10<sup>th</sup> are represented as ventral valve and ovipositor sheath of genitalia respectively while the 11<sup>th</sup> forms the dorsal valve. In male, the 9<sup>th</sup> segment is suppressed, the 10<sup>th</sup> is represented by hypandrium bearing a pair of forceps or parameres, and the 11<sup>th</sup> represents anal valve which bears the anal opening at its extremity (Kandasamy, 1986).

### 6. Male Genitalia

The male genitalia are simple, consisting of subgenital plate (genital sternite), a proctiger (abdominal tergite containing anus), a single pair of paramere (paired structure attached to the male subgenital plate used during copulation to hold female terminalia) and a folding aedeagus or penis (Fig 7). The proctiger, which bears the anus apically, is usually unipartite, but in *Homotoma* it is bipartite. In genera such as *Psylla* the proctiger is a simple cylindrical tube but in certain genera it bears posteriorly directed lobes or processes. In *Psyllopsis* and certain *Trioza* the process takes the form of a simple lobe whereas in *Aphalara* the process is narrow and elongate.

The male subgenital plate is highly uniform in shape throughout the super family Psylloidea and is of little taxonomic significance. The size and shape of the male parameres, is the single most important specific character in the Psylloidea. The shape of the parameres is highly variable ranging from simple lamellate structure in the species such as *Psylla melanoneura* to complex structures in *Craspedolepta subpunctata* and *Psyllopsis* spp. The form of apical part of penis has limited taxonomic significance (Hodkinson and White, 1979).

### 7. Female Genitalia

The female genitalia consists of proctiger, subgenital plate, these valves enclose the palps, which in turn enclose the valvulae ventralis and ovipositor (Fig 8). The female proctiger bears the anus basally. The anus is circumscribed by the peri-anal ring, a ring of wax-secreting pores, the form of which is fairly constant in most genera, but has of great taxonomic significance in *Aphalara*. The general shape of female proctiger, subgenital plate is fairly uniform throughout Psylloidea (Hodkinson and White, 1979).

### 8. Nymph and Nymphal setae (Fig 9)

No efforts have been made on nymphal taxonomy; moreover nymphal taxonomy is extremely difficult. More convenient way is to breed nymphs to the adult stage for identification.

**Keys to subfamilies of Psyllidae** (Kandasamy, 1986)

1. Frons covered by genae; genae usually produced into conical processes; anterior ocellus embedded between vertex and genae (Fig 10).....2

1a. Frons not covered by genae; visible as a small sclerite; genal cones not produced into conical processes, front ocellus at extremity of frons..... Pauropsyllinae (Fig 11) (Ex. Mango shoot gall *Psylla*)

2. Fore wings with only usual two marginal cells formed by the bifurcation of media and cubitus, radial sector not branched and without any cross vein, head not cleft above (Fig 12).....3

2a. Fore wings with more than usual two marginal cells, the additional cells being formed by branching of radial sector and cross veins, head deeply cleft in front between antennae..... Ciriacreminae (Fig 13) (Ex. Fig Psyllid)

3. Basal tarsal segment of hind legs with two black claw-like apical spines at apex, the three veins from basal vein not diverging at the same point, but median and cubitus with a common cubital petiole, wings rarely angulate at apex..... Psyllinae (Fig 14) (Ex. Asian citrus psyllid)

3a. Basal tarsal segment of hind legs without apical spines at apex; radius, median and cubitus usually diverging at the same point, wings usually angulate at apex... Triozinae (Fig 15) (Ex. African citrus psyllid)

### Biology of Psyllids

**Eggs:** The eggs are generally brown to black in colour, 1 mm long and ovoid in shape, although colour, size, and shape can vary slightly between species. Each female lays between 45 and 700 eggs, either in clusters of approximately 10-150 eggs or in rows on leaf surfaces. Eggs are usually equipped with stalk, which upon insertion, anchors the eggs to the leaf surface. Following 10-20 days incubation period, the egg shells split along their length, thereby allowing first instar nymphs to emerge (Conservation and Environment 1992; CSIRO 1996; Phillips 1996). Incubation period depends upon on the atmospheric temperature and voltinism of insect, Asian citrus psyllid incubation period ranges from 3-4 days at 22 to 27°C, but it will take 9 days when temperature is less than 15°C.

**Nymph:** The newly hatched nymphs (or 'crawlers') cover the leaf surface in search of a stomata for insertion of their stylets and feed on plant sap, usually within 48 hours of hatching. Once settled, they commence construction of a shell (more commonly known as a 'lerp') from starchy material derived from the host plant. The lerp structure protects the psyllid insect from predation and desiccation during warm / hot weather. Nymphs usually pass through five instars before becoming adults (Table 1). This maturation process to adulthood occurs mostly within the confines of the original lerp. However, occasionally nymphs will move to another feeding site



Fig 10 : Key 1

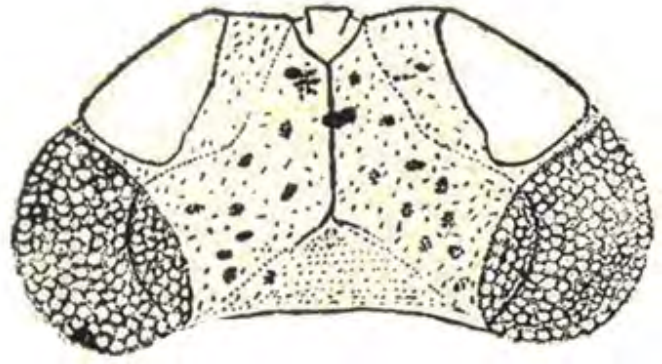


Fig 11 : Frons of Pauropsyllinae

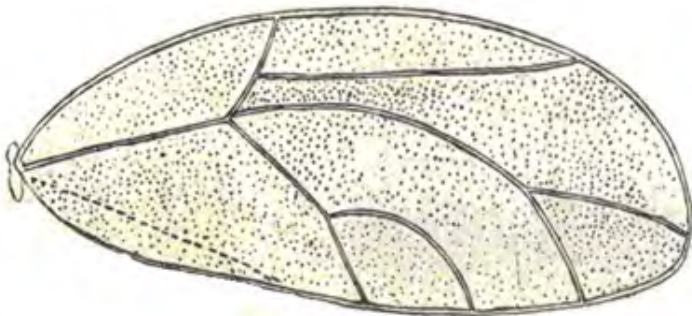


Fig 12 : Key 2

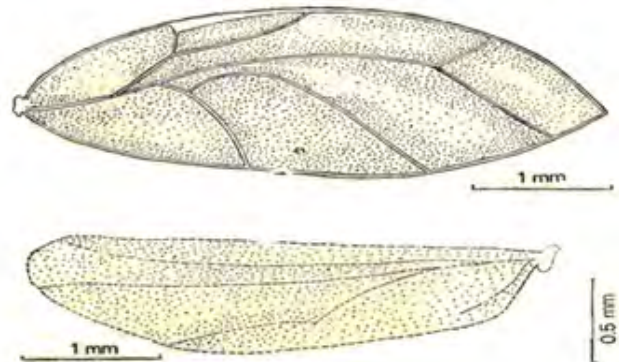


Fig 13 : Wing of Ciriacreminae

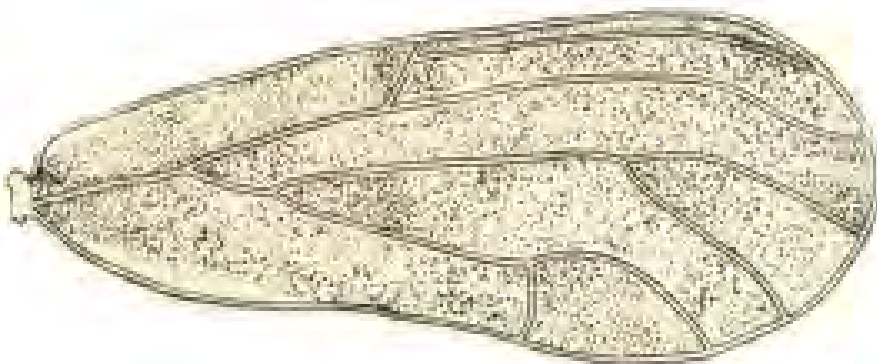


Fig 14 : Wing and leg of Psyllinae

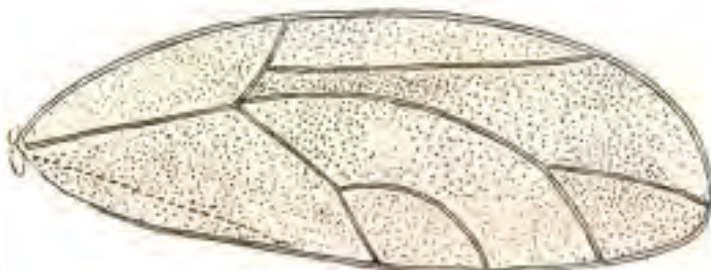


Fig 15 : Wing and leg of Triozinae

and construct a new lerp (Nick Collett, 2000).

The early nymphal stages are easily mistaken for aphids because of their small size, however psyllid nymphs produce white waxy secretions by which nymphs can be differentiated from aphids. These waxy secretions contain honey dew and found accumulating on the leaf surface, but in most cases they are blown off from the leaf surface by wind or consumed by the foraging ants (Michael and Philip, 2006).

**Adult:** Adult psyllids are generally small (<5 mm length), yellow coloured with black markings and equipped with two pairs of wings. They are strong fliers and jumpers (CSIRO 1996; Phillips, 1996).

### Climatic Requirements

The number of generations produced per year can vary depending on: (1) the species of psyllid, (2) the prevailing temperature and (3) the environmental conditions including the availability of leaves suitable for oviposition. However, the usual number is between three and five, with genera such as *Cardiaspina* usually producing three generations per year while *Glycaspis* can have up to five and possibly six. Growth and development of nymphal instars occurs throughout most of the year. During warm summer weather the generation turnover is approximately eight weeks from egg to adult compared with six months during cool winter weather (Conservation and Environment 1992; CSIRO 1996). The optimal temperature for growth and development appears to be around 25°C, but feeding and movement can still occur at below 10°C and at higher than 33°C. During warm winter spells, hibernating adults may resume feeding and breeding, thereby allowing additional generations to be produced (Nick Collett, 2000).

### Economic importance of psyllids

Psyllidae comprises the following pestiferous species which are economically important ones. They cause damage not only by direct feeding but also as vectors of deadly diseases like citrus greening and pear decline. Apart from pests, a few species of psyllids, *Arytinnis hakani* (Loginova) and *Arytainilla spartiophila* (Foerster) are exploited as biocontrol agents of weeds in some countries like Australia (Shivankar and Rao, 2010).

### Economically important Psyllid pests

1. Asian citrus psyllid, *Diaphorina citri* (Kuwayam)
2. African citrus psyllid, *Trioza erythrae* (Del Guercio)
3. Mango shoot gall psyllid, *Apsylla cistellata* (Buckton)
4. Common pear psyllid, *Cacopsylla* (*Psylla*)

*pyricola* (Foerster)

5. Apple psyllid, *Cacopsylla mali* (Schmidberger)
6. Apple pest, *Cacopsylla picta* (Foerster)
7. Fig psyllid, *Mycopsylla fici* (Tryon)
8. Subabul psyllid, *Heteropsylla cubana* (Crawford)
9. Potato psyllid, *Bactericera cockerelli* (Sulc.)
10. Blue gum psyllid, *Ctenarytaina eucalypti* (Maskell)
11. Olive psyllid, *Euphyllura olivina* (Costa)
12. Avocado psyllid, *Trioza perseae* (Tuthill)

### Psyllids as Biocontrol agents

#### 1. Broom Psyllid, *Arytainilla spartiophila* (Foerster)

Native to the Mediterranean region, this psyllid has been used in New Zealand from 1992 to control European broom (*Cytisus scoparius*), a pestilential invasive leguminous shrub.

#### 2. Melaleuca Psyllid, *Boreioglycaspis melaleucae* (Moore)

Used as a biocontrol for its host, *Melaleuca quiquenervia* (paper bark tree), which is native to Australia but a serious invasive weed tree in Florida.

#### 3. Mesquite Psyllid *Prosopidopsylla flava* (Burckhardt)

Introduced into Australia as a biocontrol for mesquite (*Prosopis* spp.) Fabaceae, which is native to North and South America and a rangeland weed in Australia). The psyllid did not reach the damaging infestation levels required for successful control.

#### 4. Mesquite Psyllid, *Heteropsylla texana* (Crawford)

Native to Texas (USA), this species was tested as a biocontrol in Australia for mesquite (*Prosopis* spp. Fabaceae, which is native to North and South America). Initially considered not specific enough to release, further tests in Australia have proposed it as a possible biocontrol agent.

### Psyllid pests of horticultural and forage crops

#### 1. Asian citrus psyllid, *Diaphorina citri*

It is a major pest of citrus and attacks new flush of all the seasons (Dorge *et al.*, 1968). It is also known to inject certain toxin while feeding on the flushes which causes die back. In addition to direct feeding damage to plants, it is also an efficient vector of the bacterium, *Candidatus Liberibacter asiaticus* which causes greening disease of citrus leading to slow death (Pluke *et al.*, 2008).



Fig 16: Life stages of Asian citrus psyllids



Fig 17: Direct damage caused Asian citrus psyllid

It may be the most serious pest of citrus in the world if any of the pathogens that cause citrus greening are present. If none of the pathogens are present, the psyllids usually are minor pests.

Asian citrus psyllid, *D. citri* ranges primarily in tropical and subtropical Asia and is reported from the following geographical areas: Afghanistan, Caribbean (Bahamas, the Cayman Islands, Jamaica, Dominican Republic, Cuba, Puerto Rico, plus interceptions from St.

Thomas and Belize), Central America (Guadaloupe), China, Hong Kong, India, Indonesia, Malaysia, Mauritius, Mexico, Myanmar, Nepal, Pakistan, Philippine Islands, Reunion Island, Ryukyu Islands, Saudi Arabia, Sri Lanka, South America (Argentina, Brazil, Venezuela), Taiwan, Thailand, the United States and some of its territories (Halbert and Nunez, 2004). In India it is a serious insect pest in Maharashtra, Punjab, Haryana, Himachal Pradesh, Coorg area of Karnataka and North eastern hilly region

(Dorge *et al.*, 1968; Bindra, 1969; Das *et al.*, 2007). It is known to infest host plants other than citrus like curry leaf (*Murraya koenigii* (Linn.)) and orange jasmine (*Murraya paniculata* (Linn.) Jack). Curry leaf is the most preferred host with high rate of fecundity and short duration of life cycle. The pest completes 9-10 or even up to 16 overlapping generations in a year (Hussain and Nath, 1927, Khan *et al.*, 1989). The favourable temperature range is 22-29°C and is not found 1300- 1500 m above mean sea level (Aubert *et al.*, 1986). It is most active on spring and after monsoon flushes but winter and temperature nearing 40°C is detrimental for their population build up. Moderate showers wash away the population. However following dry days witness rapid buildup of the pest (Shivankar and Rao, 2005). During winter heavy mortality of pest occurs *i.e.* about 53 per cent in July to 98 per cent in December; the eggs fail to hatch and 58 per cent of the hatched nymphs fail to develop into adults (Mangat, 1966). Heavy and prolonged flushing coupled with low temperature and high humidity favours psylla outbreak (Shivankar and Rao, 2005). Central India witnessed its severe outbreak during the years 1960-1962, 1998 -99, 2002- 2005 and 2006-07.

The Asian citrus psyllid causes damage to the crop primarily by transmission of the pathogen that causes greening, or “Huanglongbing”, which means “yellow dragon disease” in Chinese. As the fruit do not colour properly, leading to the name greening. Fruit from diseased trees have a bitter taste (Halbert and Manjunath, 2004).

### Identification and Biology

**Adults:** Adult psyllids are 3 to 4 mm in length with mottled wings held “roof-like” over the body (Fig 16) (Mead, 1977). When young, tender flush is present, adult psyllids are commonly found aggregated on this new flush where they feed and mate. After mating, the female psyllid must feed on young flush to produce mature eggs. Gravid females have an orange abdomen indicating that eggs are ready to be laid. Eggs are inserted into the leaf tissue inside the folds of the unexpanded leaves, on the edges of young leaves, or at the base of leaf buds which have just begun to form. When young flush is not available, psyllid adults can usually be found on the underside of leaves feeding in the area of the leaf mid vein.

The average lifespan of an adult female psyllid is 30 to 50 days when temperatures are between 20 to 30°C with the average life span increasing as temperatures become cooler (Liu and Tsai, 2000). For example, at 20°C, the average lifespan of a female psyllid is 50.6 days. However, during the winter months when temperatures are 13 to 16°C, the average longevity of adult psyllids increases to 88 days. Adult psyllids survive for long periods

on mature leaves until new flush is present. The ability to survive on mature leaves in the absence of new flush allows psyllid adults to over-winter and populations to build up quickly on the early spring flush (Michael and Philip, 2006).

**Eggs:** Eggs of the Asian citrus psyllid are almond shaped and measure about 0.3 mm long. When first laid, eggs are pale in color but gradually turn dark yellow to orange as they reach maturity and the psyllid nymphs are ready to emerge (Fig 16) (Mead, 1977). When laid, the stalked anterior (front) end of the egg is anchored into the plant tissue. Surveying for psyllid eggs is best accomplished using a hand lens to examine the feather leaf stage flush as it begins to expand, making certain to look between the leaf folds to inspect thoroughly the hidden areas where most eggs are deposited. The egg stage lasts an average of 3 to 4 days when temperatures are 24 to 30°C, but can last as long as 9 days when temperatures drop below 16°C for an extended period of time (Liu and Tsai, 2000).

**Nymphs:** Psyllid nymphs range in size from 0.3 mm long in the first instar to 1.6 mm long in fifth instars (Mead, 1977). The duration of the nymphal stage is about 12 to 14 days at 28°C. Nymphs are yellow with red eyes and visible wing pads in larger nymphs (Fig 16). Because of their small size, the early nymphal stages are easily mistaken for aphids. However, psyllid nymphs produce white waxy secretions which can be visible from a distance and thus provides an easy means of distinguishing them from aphids. These waxy secretions contain honeydew and may be found accumulating on the surfaces of leaves, but in most cases are either blown off the leaf surface by wind or consumed by foraging ants. Compared to adults, psyllid nymphs are relatively sessile and move only short distances on a branch when disturbed.

### Psyllid Feeding Damage

**Direct damage:** Psyllids, like other Homoptera, have piercing sucking mouthparts used for feeding on plants. Feeding by psyllid adults and nymphs causes newly forming leaves to twist and curl similar to feeding damage from the green aphid. Psyllid feeding also results in reduction of shoot length giving a witches’ broom effect (Fig 17). If heavy feeding occurs early on the developing flush, the new flush will fail to develop or abort. In addition to direct feeding damage, honeydew inside the white waxy secretions produced by the nymphs promotes the growth of sooty mold which can reduce effective leaf area for photosynthesis (Halbert and Manjunath, 2004).

**Indirect Damage:** The Asian citrus psyllid causes damage to the crop primarily by transmission of the



a. Chlorosis of citrus leaves due to greening and healthy leaves



b. Yellowing of citrus tree due to greening disease



c. Citrus greening damaged fruits



d. Small, lopsided fruit, dark seeds and rind that does not colored properly due to greening

Fig 18: Indirect damage caused by Asian citrus psyllids as a vector for Citrus greening disease



Fig 19: Modification of buds into galls due to mango shoot gall psyllid feeding.

Table 1: Distinguishing features of different instars (Hodkinson, 1974)

Instar	Antennal Segments	Wing Rudiments	Tarsus
I	3	None	None
II	4	None	None
III	5	Small	None
IV	7	Fairly large, slightly overlapping	None
V	9	Very large, widely overlapping	Present

pathogen that causes greening, or “huanglongbing”, which means “yellow dragon disease” in Chinese. Huanglongbing in English is termed as yellow shoot disease because of characteristic yellow shoots caused by the disease. In addition to yellow shoots, the disease also causes mottling, chlorosis resembling zinc deficiency, twig dieback and reduced fruit size and quality. Fruit do not color properly, leading to the name greening (Fig 18). Fruit from diseased trees have a bitter taste. Other names include citrus vein phloem degeneration and likubin, which means immediate withering disease (Halbert and Manjunath, 2004).

Citrus greening probably is the worst disease of citrus caused by a vectored pathogen. The dynamics, epidemiology, and molecular characteristics of the complex are poorly understood. *Trioza erytrae* (del Guercio) (Sternorrhyncha: Triozidae) in Africa and *Diaphorina citri* Kuwayama (Sternorrhyncha: Psyllidae) in Asia are the only known vectors of the two forms of the disease, namely African and Asian citrus greening, respectively.

Two species of fastidious phloem-limited bacteria (*Candidatus Liberibacter africanus* and *asiaticus*), are thought to be the causal organisms, but Koch’s postulates have not been fulfilled because the bacteria have not been cultured yet. (The term *Candidatus* is used for bacteria species that cannot be cultured. If *Candidatus* is used, the actual genus and species are not italicized.) The pathogens transmitted by the two psyllids are different, but both psyllid species will transmit either pathogen under experimental conditions (Lallemand *et al.*, 1986).

**Psyllid Transmission:** Psyllid transmission is the primary means of spread in the field. Acquisition time of 30 min for Asian psyllids (Roistacher, 1991) and 24 h for African psyllids (Buitendag and Von Broembsen, 1993) has been reported. Acquisition feeding period of 5-7 h was sufficient to transmit citrus greening pathogens, while feeding period of 1-3 h were not (Xu *et al.*, 1988). The pathogen probably multiplies in the vector (Aubert 1987; Moll and Martin 1973; Xu *et al.*, 1988), but this has not been demonstrated by molecular experiments. It is not known if psyllids can be infected simultaneously by both bacteria species (Garnier *et al.*, 1996), although both psyllid species transmit both pathogens experimentally (Lallemand *et al.* 1986). Adults and fourth and fifth instar Asian citrus psyllids are able to transmit the pathogen after a latent period as short as one day or as long as 25 days (Roistacher, 1991; Xu *et al.*, 1988). Fourth and fifth instars were able to retain the pathogen as adults, which were able to transmit the disease immediately after emergence (Xu *et al.*, 1988). First three instars were unable to transmit citrus greening (Xu *et al.*, 1988). A

latent period of 24 h has been reported for African greening (Buitendag and Von Broembsen, 1993). Transmission is thought to occur via salivary secretions (Aubert, 1987). Serial transfer experiments by Van Den Berg *et al.* (1992) suggest that young nymphs of *Trioza erytrae* can acquire the bacteria even though they do not transmit them.

*Candidatus Liberibacter* spp. potentially should be considered pathogens of the insect as well as the plant, if in fact they multiply in the psyllid vectors, as suggested by Xu *et al.* (1988) and Moll and Martin (1973). There are conflicting reports as whether *Candidatus Liberibacter* spp. are transmitted transovarially (Buitendag and Von Broembsen 1993; Roistacher 1991; Xu *et al.*, 1988). Xu *et al.* (1988) reported that there is no evidence for transovarial transmission, because *D. citri* nymphs collected immediately after hatching on diseased plants did not transmit citrus greening disease to indicator plants.

## 2. Mango shoot gall psylla, *Apsylla cistellata*

It is a serious pest of mango in northern India (Singh, 2000). Adults are brownish black in colour with membranous wings (Mathur, 1975). It is reported from Uttar Pradesh, Bihar and Terai regions of northern India. It has a single generation per year. Adult females lay eggs into the midrib of leaves in March-April. They prefer mature trees which are bearing to lay eggs and trees of less than five years old are not attacked. Eggs hatch after 200 days. Five nymphal instars are present and nymphal period is 140 days. Adults may live up to 30-72 h (Raman *et al.*, 2009; Singh, 2005). It causes the formation of shoot galls in place of buds. Galls are modified axillary and apical buds (Fig 19). Feeding effect of neonate nymphs which remain in egg case induces the modification of buds to galls. Second instar nymph migrates to the already formed gall (Shivankar and Rao, 2010). Loss depends on the number of eggs laid; 500 eggs in all leaves result in induction of 52 galls and reduce panicle emergence by 21 per cent. Heavily infested tree yielded only 5 kg fruits as against normal yield of 300 kg. Infested shoots have high auxin level and low phenolic contents (Singh, 2005; Kumar *et al.*, 2007).

## 3. Common Pear Psyllid *Cacopsylla pyricola*

Pear psylla (*Cacopsylla pyricola*), a western Europe native, is a very small sap feeding insect and is considered the most serious insect pest of pear in the United States. Serious infestations can stunt, defoliate, and even kill trees. Psylla feeding produces copious amounts of sticky honeydew that can cause fruit russetting. All commercial pear varieties are attacked, although smooth skinned pears are more injured than russeted varieties, and Asian and red pears are less prone to injury than European and green

pears.

Pear psylla is found throughout northern and central Utah and can have 3-4 generations per year. Primary control occurs during the dormant period when psylla adults begin laying eggs. This timing occurs about six weeks before bloom and when daytime temperatures exceed 8°C. A good monitoring program will indicate if and when summer controls are necessary (Diane Alston and Marion Murray, 2007).

### Life history

#### Summer form Adult – Damaging and Monitoring Stage

- Size and colour: 2.5 mm long and tan to light brown with clear wings; smaller than overwintering adult.
- Sucks sap from foliage and succulent tissues.
- Develops from egg to adult in about 1 month during the early season.
- There are 2-3 summer generations before winter generation develops in the fall.

### Egg

- Size, shape, and colour: minute, oval, and creamy white to yellow.
- Before buds open in spring, and through early fall, eggs are deposited in lines or rows on the terminals and fruit spurs; after buds open, eggs are deposited along mid-veins and petioles of developing leaves and on stems and sepals of blossoms.
- Hatch when foliage appears and continues throughout growing season.

#### Nymph – Damaging Stage

- Size and colour: early instars are about 1.6 mm long and light yellow; later instars are dark green to dark brown with wing pads and two conspicuous red eyes.
- Shape: cylindrical, but appear flattened.
- Usually found on the undersides of leaves.
- Pass through five instars, which are generally covered by a drop of honeydew.
- Moves little at first but later instars move easily.
- Feeds and develops on new growth and water sprouts.
- Produces honeydew.

#### Winter form Adult – Overwintering Stage

- Size and colour: 4 mm long; red brown to black; larger and darker than summer adults.
- Shape: resembles miniature cicada with wings held roof-like over the abdomen.
- Hides under bark, under litter on the orchard floor, or in sites outside the orchard

- Adults leave the pear trees in October-November for wintering sites and return about six weeks before bloom.
- Feed by sucking juice from the host tree.

Nymphs and adults suck sap primarily from the tender foliage of the new shoots and water sprouts. Feeding by nymphs produces a large amount of honeydew, which makes the tree sticky and promotes the growth of sooty mold (black fungus). The honeydew can run onto fruit causing dark russet blotches or streaks resulting in unmarketable fruit. Apart from secretion of honey dew, pear psyllid is also responsible for the transmission of phytoplasma resulting in pear decline disease.

**Pear Decline:** Pear psylla transmits a phytoplasma that causes “pear decline”. This disease has killed thousands of trees in the western U.S. and Canada. It prevents nutrients from moving down the tree and results in root starvation. Symptoms include stunted shoots, small or curled leaves, reduced fruit size, twig dieback, and premature leaf drop. Highly susceptible root stocks can die quickly. Pear rootstocks are available that are tolerant of the disease even with severe psylla feeding (Diane Alston and Marion Murray, 2007).

**Psylla Shock:** Psylla injects toxic saliva as they feed, and under heavy feeding, psylla shock can occur. Symptoms include stunted growth, wilting, defoliation, and fruit drop. Trees experiencing psylla shock are vulnerable to winter injury and may have reduced fruit set the following year.

## 4. Psyllids on Apple

### 4a. Apple psyllid, *Cacopsylla mali*

- Is an important pest of cultivated apples, *Malus* spp.
- Damage: Destruction of blossoms, an increase in the drop of buds and a decrease in the growth of leaves and vegetative shoots (stunting of shoots).
- 4-11 per cent reduction in fruit set.

### 4b. Apple pest, *Cacopsylla picta*

An apple pest, reported as a vector of apple proliferation phytoplasma in Germany.

## 5. Subabul psyllid: *Heteropsylla cubana*

Subabul, *Leucaena leucocephala* (Lam.) de Witt (Fabaceae), a native of Central America was introduced into India during 19<sup>th</sup> century to strengthen social forestry programme, but its real cultivation started only in 1972 (Krishnamurthy and Munegowda, 1982) as a fodder crop. It is considered to be an important new input for cattle feed, and fuel for use of the rural population where fuel wood is still preferred over modern substitutes (Singh,

2004).

Subabul psyllids, *H. cubana* is a major pest of *L. leucocephala*, a tree grown for fodder and fuel wood. It is a serious threat to the cultivation of subabul all over the tropics except the African continent. The *Leucaena* psyllid was described from Cuba by Crawford in 1914, it reached Sri Lanka in 1986 crossing the Pacific Ocean and was noticed in Chengalpattu district of Tamil Nadu, India during 1988 (Gopalan *et al.*, 1988). *Heteropsylla cubana* was recorded for the first time on subabul in and around Bangalore, and in other parts of Karnataka, during May-June 1988. In the areas surveyed incidence was 80-100 per cent on all varieties (Singh and Jalali, 1990). It devastated subabul plantations in Karnataka, Kerala, Tamil Nadu and Andhra Pradesh. It has since spread all over the country (Singh, 2004).

Adults are aphid-like, winged and light green to yellow in colour. Nymphs are similar to adults in appearance except they are smaller, wingless. Host plants other than subabul are *L. trichodes*, *L. pulverulenta*, *L. diversifolia*, *L. salvadorensis* and *Samanea saman* (Nair, 2001). Adults and nymphs attack tender shoots and desap the terminal leaves, buds and flowers of host plants. Repeated attacks cause wilting, defoliation, branch dieback or death of host trees. In severe cases, the plants could not recover (Napompeth, 1990). In Karnataka, it had created the fear of losing the subabul plantation due to the psyllid attack (Veeresh, 1990).

The developmental period of the *H. cubana* is short, the five nymphal instars taking just 10.4 days (Pratap Singh, 1988) and the fecundity is fairly high, 394 eggs (Nakahara *et al.*, 1987). *H. cubana* females laid about 400 eggs in the tender terminal shoots, completed life cycle in 10-11 days and had 8-10 overlapping generations in a year (Singh, 2004).

#### **Integrated Management of psyllid pests of fruit and forage crops**

The integrated management of the psyllids should start with monitoring, which should be continuous, with more attention being paid in peak periods. The monitoring of the psyllids can be done by installing sticky traps or by manual sampling. These should be run continuously and at regular intervals. Yellow sticky traps are the best way to monitor psyllids. Adult psyllids and psyllid parasites are attracted by the yellow colour and become stuck to the surface. The traps should be inspected once in a week and the number of adult psyllids and their parasites should be counted and recorded (Paine *et al.*, 2007).

Adult psyllids can also be monitored by shaking or beating plants over a collecting sheet to knock them onto

the collecting surface, where they can be easily seen and counted. The sample should be taken about once a week during the season of new plant growth, when adult psyllids are expected (Dreistadt and Dahlsten, 2007). Through monitoring, it is possible to determine the moment of population peak, the occurrence of natural enemies and other factors that affect the insect population (Dalva Luiz de Queiroz *et al.*, 2011).

In an Integrated Pest Management Programme, monitoring the pest's development is one of the main components, which uses different techniques to quantify the population and predict outbreaks of the pest. Apart from monitoring, other management tactics includes direct control, genetic control and biological control.

Direct control involves the use of pesticides or physical control measures, while biological control concerns the actions of indigenous predators such as birds, various insects, spiders, mites and fungi in limiting pest populations. Cultural control relates to the tending and caring of trees to encourage healthy growth, thus enabling them to be better able to withstand and recover from damaging attacks. Genetic control involves the selection of genetically resistant genotypes for use in plantings as well as the genetic manipulation of biological control agents to increase their efficacy against the target pest (Nick Collett, 2000).

An important aspect in psyllid management is not only to appreciate when to implement control measures, but more importantly, when not to apply them. Any decision to proceed with any of the above controls depends on a number of factors including: (1) the severity of attack, (2) the prevailing climatic conditions (e.g. drought) which may contribute to excessive loss of tree vigour/mortality, and (3) the purpose for which the trees are being grown.

#### **Cultural control**

- Excess nitrogen in leaves due to stress leads to an increase in insect populations, so balanced fertilization and irrigation in the dry season is recommended to avoid the concentration of nutrients in leaves (Garrison, 2001). Excessive use of nitrogenous fertilizers and irrigation should also be avoided. Sanitation, removal of weeds and destruction of ants which help in spreading of harmful sucking pests have been found useful in reduction of pest infestation (Balikai and Kotikal, 2011).
- Silicon is not considered an essential element for plants it is absorbed and is involved in the formation of structures of defenses such as trichomes and spines. Application of silicon for formation of defense structures such as trichomes, spines and leaf

toughness by forming polymers (crystals) that are immobilized in the leaf tissue (Camargo *et al.*, 2011).

- The application of industrial ashes rich in silicates has been recommended.
- Avoid summer pruning which encourages shoot growth.
- Infected twigs and trees should be removed as disease symptoms appear.
- Pulling out water suckers from scaffold twigs, from the centre of tree in order to remove tender foliage where psyllids feed and to gain better spray penetration.

### Plant resistance

- Tolerant or resistant plants been an economically viable alternative to curtail the insect population in large plantations. Prevention of planting susceptible species is the best way to avoid damage (Dreistadt and Dahlsten, 2007).
- Tolerant varieties for mango shoot gall psylla: Makaram, Chinnaswarnarekha, Mulgoa, Delhi, K.O.-11 (Shivankar and Rao, 2010).
- Sweet oranges, mandarins and tangelos are most susceptible, grapefruit and lemon are more resistant, and limes, *Poncirus trifoliata* and citranges are the most tolerant for citrus greening disease (Lee, 1996).
- Subabul genotype, *Leucaena leucocephala* K-636 has been identified as tolerant to psyllid bugs (Yelshetty *et al.*, 1998) and later released as variety Girija during 1995 for cultivation in Karnataka by the University of Agricultural Sciences, Dharwad.
- Subabul genotype, *Leucaena collensi* K-740 has been identified as resistant to psyllid bug (Yelshetty *et al.*, 1998) and later released as variety Chetan during 1997 for cultivation in Karnataka by the University of Agricultural Sciences, Dharwad.

### Biological control

#### Asian citrus psyllid

- **Parasitoids:** Eulophid parasite, *Tamarixia (Tetrasticus) radiata* (Waterston), encyrtid endoparasite, *Diaphorencyrtus aligarhensis* (Shafee, Alam and Agarwal), *Tamarixia radiata* (Waterston) apparently is more efficient at parasitizing *D. citri* than *D. aligarhensis* (Tang, 1989).
- **Fungal pathogens:** *Cladosporium sp. nr. oxysporum* and *Capnodium citri* Mont. (Aubert, 1987), *Hirsutella citrififormis* Speare will be common

during period when relative humidity is more than 90 per cent.

- **Predators:** *Mallada boninensis* (Okamoto) and *Cheilomenes sexmaculata* (Fabricius); histeryd beetle, *Saprinus chalcites* (Illiger); predaceous carabid, *Egapola crenulata*.
- In Saudi Arabia, spiders accounted for 33.6 per cent of total predators (Michaud, 2002).
- Biological control of the citrus greening pathogen using several strains of citrus tristeza virus (CTV) through cross protection (Van Vuuren *et al.*, 2000).

### Pear psylla (*Cacopsylla pyricola*)

- **Parasitoid wasps:** Endoparasites, *Trechmites psyllae* (Ruschka) and *Prionomitus mitratus* (Dalman) lay eggs inside the bodies of psylla nymphs where the wasp larvae consume the psylla host as they develop.
- **Predators:** Anthocorid bugs, predaceous plant bugs, Lacewing adults and larvae, Ladybird beetle adults and larvae, Spiders.
- Effectiveness of biological control increases in orchards where fewer codling moth treatments are applied.

### Subabul psyllid (*Heteropsylla cubana*)

- **Predators:** *Curinus coeruleus* Mulsant, *Olla v-nigrum*, *Cheilomenes sexmaculatus* (Fabricius) (Coleoptera: Coccinellidae), *Pantala flavescens* (Odonata: Libellulidae) (Rajagopal *et al.*, 1990)
- **Parasitoids:** *Psyllaephagus yaseeni* (Hymenoptera: Encyrtidae) and *Tamarixia leucaenae* (Hymenoptera: Eupelmidae) (FAOUN, 1998)

In 1988, the ladybeetle, *C. coeruleus* native of Mexico was introduced from Thailand for the biological suppression of *H. cubana*. In November 1988, *C. coeruleus* was successfully colonized on subabul around Bangalore. The predator established well in the field and in about four months after release 20-30 adults per tree was recorded. The grubs consumed 10,630 eggs and 3,500 nymphs during their life time. The predator has spread on its own to the area of more than 20 sq km in Bangalore district. In about two years after release the population of the psyllid was drastically reduced and the predator firmly established in the release sites. The beetles have since then been released in many other parts of Karnataka, Kerala, Andhra Pradesh, Tamil Nadu and Manipur where they have established and are providing efficient, cost effective and environmentally safe control of *H. cubana* on a sustainable basis (Singh, 2004). The

predator has since successfully established in Karnataka, Maharashtra, Andhra Pradesh and Tamil Nadu (Jalali and Singh, 1989). It has provided control of the psyllid at par with monocrotophos, a chemical that was recommended for the control of the psyllid before the introduction of the predator (Singh, 1995).

### Chemical control

Monitoring of the psyllids is done by installing sticky traps or by manual sampling. These should be run continuously and at regular intervals. Yellow sticky traps are the best way to monitor psyllids. The traps should be inspected once a week. Adult psyllids can also be monitored by shaking or beating plants over a collecting sheet to knock them onto the collecting surface, where they can be easily seen and counted. The sample should be taken about once in a week during the season of new plant growth, when adult psyllids are expected (Dreistadt and Dahlsten, 2007). Timing of pesticide is critical based on monitoring of psyllids. For phloem-sucking Sternorrhyncha, systemic pesticides are effective. Trunk applications have proven useful (Aubert, 1988). The best time to apply is just prior to spring flush.

### Asian Citrus Psyllid

- Populations are considered high when population reaches three nymphs and five adults per twig.
- Chemical control using dimethoate 30 EC @ 1.25 ml or imidacloprid 17.8 SL @ 0.3 ml or quinalphos 25 EC @ 1.0 ml or acephate 75 SP @ 1 g or thiometan @ 0.8 ml at bud burst stage. Second spray should follow after 10-15 days (Shivankar and Rao, 2010).
- Extracts of botanicals like *Vitex nigundo*, *Acorus calamus* can also be used

### Mango shoot gall Psylla

- Spraying of dimethoate 30 EC (0.03%) during 2<sup>nd</sup> fortnight of July followed by two more sprays at 10 days interval (Shivankar and Rao, 2010).
- Bark pasting using dimethoate.
- Bark injection using dimethoate 30 EC @ 0.3 ml a.i./cm circumference.
- Spraying 2, 4-D @ 150 mg/l for autocidal control of nymphs (Singh, 2005; Kumar *et al.*, 2007).

### Pear psylla

- Pre-bloom period: Endosulfan, lambda-cyhalothrin, lime sulfur, permethrin, pyriproxyfen, fenvalerate.
- Post bloom period: Carbaryl, clothianidin, thiacloprid, imidacloprid

Antibiotics injected into infected citrus greening affected trees provide temporary remission of symptoms (Buitendag and Von Broembsen, 1993). Injection with antibiotics is recommended as part of an integrated management program of citrus greening in India (Nariani, 1981). Tetracycline is used to treat budwood, the budwood is immersed in 1,000 µg/ml tetracycline hydrochloride for two hours or 500 µg/ml for three hours (Zhou, 1981). For pear decline, uprooting and destruction is recommended.

### Subabul Psyllid

Spraying of endosulfan (0.07 %) and phosalone; monocrotophos (0.04%); dimethoate (0.05%) and quinalphos afforded effective control for 2-3 weeks (Rajgopal *et al.*, 1990).

Apart from cultural, biological, chemical control, regulatory measures for the host material plays an essential part of managing psyllid transmitted diseases. RNAi technology is a novel method of psyllid management.

### Conclusion

Development of pest forecasting system by combining the available data on biology of psyllid pests and weather parameters and development of bio-intensive integrated pest management modules by exploring efficient natural enemies is a viable method for management of psyllids.

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