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Insect vectors of virus diseases of sugarcane

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Abstract. Although 120 diseases of fungal, viral, mycoplasma and bacterial origin have been reported in sugarcane, insect vector associations have been established with virus/mycoplasma diseases only. Thirteen species of aphids have been identified to be vectors of mosaic and another bug, *Assamia moesta* Westw. is associated as a mechanical carrier. Three species of *Perkinsiella* transmit Fiji disease. The leaf hopper, *Cicadulina mbila* (Naude) transmits streak. The mycoplasma diseases, white leaf and grassy shoot are carried over by *Matsumaratettix sp.* and *A. moesta*, respectively. A mealybug has been reported to be a vector of spike disease. The future lines of approach for insect vector associations are also discussed.

Keywords. Insect vectors; virus diseases; sugarcane.

1. Introduction

Nearly 120 diseases of fungal, viral and bacterial origin have been reported in sugarcane in different parts of the world (Martin *et al* 1961). Due to readily available nutrients, large number of saprophytes as well as pathogens are present in this plant. Among these 11 diseases of viral and mycoplasma-like organisms have been reported to have vectorial association. However, definite proof of vectorial transmission is available in sugarcane mosaic, Fiji disease and streak disease.

Cumulatively diseases have been estimated to cause 10%–15% loss in sugarcane production (David and Alexander 1977).

2. Disease/vectorial association

Aphididae is the largest group of virus vectors in sugarcane transmitting sugarcane mosaic. Aphids have also been implicated as transmitting agents in grassy shoot disease (GSD) (Chona *et al* 1960). However, later work (Edison *et al* 1976) has proved GSD to be of mycoplasma origin and the role of aphids in transmitting GSD has to be viewed with caution. The species of leaf-hoppers (*Perkinsiella* spp.) are vectors of Fiji disease. Edison (1973) reported *Assamia moesta* Westw. transmitting GSD. *Cicadulina mbila* (Naude) is the vector of the streak disease of sugarcane. *Matsumaratettix hiroglyphicus* Mats. transmits white leaf disease of Taiwan.

Chlorotic streak which is not transmitted mechanically and is believed to be of virus origin is associated with a green leafhopper, *Draeculocephala portola* Ball. However, many attempts to transmit the disease elsewhere with the vector have not been successful. *Sphenorhina liturata ruforivulata* (Stal) is also associated with this disease. Spike disease reported by Sharma and Jha (1957) has been associated with mealybug,

Pseudococcus saccharifoli Green (Mohammed Ali 1962). However, there are no subsequent reports of the disease. The various disease transmitting vectors/ associations have been tabulated in tables 1 and 4.

Saladini (1971) observed that sugarcane mosaic (SCMV) strain isolates maintained for many years without aphid transmission, lost transmissibility by the aphid, *S. graminum*. The H strain of SCMV maintained in the green house in variety POJ 234 for successive years, was not subsequently transmitted by the vector, *D. ambrosiae*. These viruses probably mutated to form a non-aphid-transmissible and then the mutant became dominant (Koike 1979).

Table 1. Vector-virus association in sugarcane.

Name of disease	Vector associated	Reference
Mosaic	*Acyrthosiphon pisum* (Harris)	Abbott and Charpentier (1963)
	Aphis gossypii (Glover)	Lawas and Fernandez (1949)
	Carolinaia cyperi Ainslie	Abbott and Charpentier (1963)
	Aphis nerii Fonscolombe	Tati and Vendenberg (1939)
	Dactynotus ambrosiae (Thomas)	Ingram and Summers (1936)
	Hysteroneura setariae (Thomas)	David *et al* (1972)
	Myzus persicae (Sulzer)	Anzalone and Pirone (1964)
	Amphorophora sonchi (Oestlund)	Abbott and Charpentier (1963)
	Rhopalosiphum maidis (Fitsh)	Brandis (1920) David *et al* (1972)
	Schizaphis graminum (Rondani)	Ingram and Summers (1938)
	Sipha flava (Forbis)	Abbott and Charpentier (1963)
	Melanaphis (*Longiunguis*) *sacchari* Zehnt.	
	M. indosacchari	David *et al* (1972)
	Assamia moesta Westw.	David *et al* (1972)
Fiji	*Perkinsiella saccharicida* Kirkaldy	Mungomery and Bell (1933)
	P. vastatrix (Breddin)	Ocfemia (1933)
	P. vitiensis (Kirkaldy)	Ayub *et al* (1967)
Streak	*Cicadulina mbila* (Naude)	Storey (1925)
White leaf disease	*Matsumarotettix* (*Epitettix*) *hiroglyphicus Matsumoto*	Matsumoto *et al* (1968)
	Associations	
Chlorotic streak	*Draeculacephala portola* Ball	Abbott and Ingram (1942)
	Sphenorhina liturata ruforivulata (Stal)	Franco (1956)
Grassy shoot	*Melanaphis* (*Longiunguis*) *sacchari* David	Chona *et al* (1960)
	M. indosacchari (Zehntner)	Chona *et al* (1960)
	R. maidis (Fitch)	Chona *et al* (1960)
	Assamia moesta Westw.	Edison (1973)
Spike	*Pseudococcus saccharifoli* (Green)	Mohammed Ali (1962)

Source: Pemberton and Charpentier (1969).

3. Bionomics and feeding habits of vectors

3.1 *Aphids and mosaic transmission*

The life history of aphid vectors in sugarcane has not been clearly worked out. Alexander and Rao (1977) observed high build up of alate aphid population during May–July with maximum in June (table 2). This synchronises with the onset of the south-west monsoon. The monsoon wind helps in the wide dispersal of the aphids.

David *et al* (1972) summarised the information on the activity of the different species of aphids at Coimbatore (table 3).

David *et al* (1972) reported the host range and preference of *H. setariae*. At Coimbatore, this aphid appears to be a potential vector of SCMV, infecting the crop immediately after germination, thus initiating secondary transmission of the disease in the field. Apart from sugarcane, this occurs in sorghum, maize, *Chloris barbata*,

Table 2. Aphid population during different months.

Date of observation	April	May	June	July	Aug.
5th	0	4	28	9	2
15th	2	7	10	1	0
25th	1	11	8	2	1

Table 3. Aphid vectors with the distinguishing features.

Vector	Distinguishing features	Period of occurrence
Rhopalosiphum maidis	Process (lst segment of antenna) and cornicle very short, green to dark or yellowish in colour. Generally within the spindle.	In shoot stage, generally during January to April
Melanaphis sacchari	Nymphs always yellow, adults yellow or purple when crowded. Head and spiracular plates pale, 6th antennal segment base to terminal portion 1:3 ratio, sorghum preferred host, generally found on senescent leaves	Generally found in canes after 6th month (May to December).
M. indosacchari	Always brown from nymph to adult. Head and spiracular plates brown, 6th antennal segment base to terminal portion 1:4 ratio, found only on sugarcane, 3rd to 5th leaf preferred	In young crop 3-5 months, May to October.
Hysteroneura setariae	Brown in colour, process very long, cornicles dark and slightly long, hind wing has only one oblique vein instead of the usual two, Cauda has two pairs of hairs	December to July.

Bothrichloa insculpta, Brachiaria sp. *Dinebra retroflexa, Cenchurus ciliaris, Panicum repens, Cyperus rotundus, Cynodon dactylon* and *Dichanthium annulatum.* Among these, it prefers *C. barbata* and *C. ciliaris* in which profuse multiplication takes place throughout the year. The aphid does not multiply well in sugarcane but the winged forms scatter to many plants and thus transmission of the disease is widespread. In transmission tests, 40% to 60% plants were infected through this species of aphid. *M. indosacchari* prefers sugarcane as a regular host and multiplies well during humid weather. It has a short life cycle, growth period being one week and adult life one week. Fecundity is about 10–30. *M. sacchari* prefers sorghum and maize. It chooses *Echinochloa colona*, generally growing around channels, as an alternate host.

Detailed information on the reproduction of these aphids, both parthenogenetically and sexually has to be gathered.

In north India, two species of aphids *R. maidis* and *Schizaphis graminum* have been reported to occur during the monsoon and spring seasons respectively (Chona and Rafay 1950; Seth and Chona 1961).

Bhargava *et al* (1971) have studied the activity of 7 species of aphids in different hosts in the vicinity of sugarcane in different seasons under north Indian conditions (table 4).

Rizvi and Bhargava (1973) further add that aphids such as *A. gossypii, L. pseudobrassicae, M. sacchari, M. persicae, R. maidis* and *R. rufiabdominalis* were present in and around sugarcane fields throughout the year in U.P. *M. sacchari* and *R. maidis* which generally occur in graminaceous hosts during monsoon period play a major role in mosaic spread, while others may cause only chance spread, due to their limitations of host plants or infrequency of occurrence.

Osborne (1970) reported that *R. maidis* was found especially in the early stages of colonisation of the plant, concealed within the leaf spindle.

Table 4. Aphids, their hosts and period of occurrence.

Aphid	Host	Period of occurrence
Aphis craccivora Koch	*Dolichos lablab, Vigna sinensis* and *Arachis hypogea*	October–April
Aphis gossypii Glov	Solanaceous, Cucurbitaceous and Malvaceous plants	April–May
Aphis nerri Boyde Fonsc.	*Calotropis procera, Nerium odorum*	January–April August-October
Lipaphis pseudo-brassieae (Davis)	Cruciferous plants	January–April
Longiunguis sacchari (Zehnt.)	*Sorghum vulgare, Zea mays* and *Saccharum officinarum*	May–November
L. indosacchari David	*S. officinarum* and occasionally on *Cynodon* sp. and *Cyperus rotundus*	July–November
Myzus persicae (Sulz)	*Cruciferous* and *Solanaceous* plants	November–Feb.
R. maidis	*Zea mays, Sorghum vulgare Eleusine* sp., *Cynodon* sp., *Setaria* sp., *Triticum vulgare, Hordeum vulgare, & S. officinarum*	June–November
R. rufi-abdominalis	*Triticum vulgare, H. vulgare*	January–March

Source: Bhargava *et al* (1971).

Under *in vitro* conditions around 27°C, using cut leaves of sugarcane maintained on 1% sucrose solution, *Melanaphis* spp. were cultured throughout the year (Ashok Verma 1982).

3.2 *Fiji disease transmission by leafhoppers*

Leafhoppers acting as vectors for Fiji and streak diseases, are persistent in transmitting the same. North and Baber (1935) concluded that the disease could be transmitted by *P. saccharicida* feeding on leaf spindles and leaf blades of varying age, up to maturity. Mungomery (1946) confirmed these findings.

P. saccharicida occurs in Java, Taiwan, South China Malay States and in Queensland and New South Wales in Australia but has been accidentally introduced into Hawaiian islands, Mauritius, Reunion, Madagascar, South Africa, Ecuador and Peru. Mating takes place at nights and oviposition also occurs during nights, and occasionally during the day. The female lives 1 to 2 months and lays up to 30 eggs, in the leaf midrib. Incubation extends to 14 days during warm weather but in cooler weather may be 35 to 40 days. There are 5 instars each lasting 4 to 9 days. The total duration of the life cycle is 48 to 56 days (Fennah 1969). The infective nymphs can transmit the disease in a 20 hr feeding period and can remain infective for at least 16 days (Mungomery 1946). He further reported a minimum incubation period of 29 days.

P. saccharicida also showed varietal preference. Variety 51-8194 caused premature mortality of the hoppers in Hawaii. Mortality was also high in variety 56-4848. While there is no correlation between Fiji disease and leafhopper resistance, it is suggested that high resistance to leafhopper of 51-8194 may play a role in its resistance to the disease (Chang 1975). Further studies conducted in Australia (Chang 1977) showed that virus carrying leafhoppers fed 24·6% of the time in phloem and 15·1% of the time in parenchyma, while virus free leafhoppers fed 7·3% of the time and 31% of the time respectively in these two tissues. This is significant in disease transmission, since the site of virus infection is in the phloem tissues and disease carrying leafhoppers found more time feeding on this tissue.

Egan (1976) found that Fiji disease had become critical in Bundaberg district as a result of considerable infection of *P. saccharicida* in N. Co. 310, a susceptible variety to the leafhopper which was grown in southern and central Queensland, which was otherwise tolerant to Fiji disease. However, the leafhopper stages were uncommon from May to November after which population build up occurred, with the nymphal population reaching its peak in January and adults in February (Anon 1981).

P. vastatrix occurs in Malaysia, Indonesia, Philippines, Taiwan and Japan. It has a pre-ovipositional period of 2–25 days. Mating lasts for about an hour and egg laying is on the midrib of exposed leaves, during the cooler period of morning or evening. One to four eggs are laid per slit. The number of eggs laid in a leaf may reach 1800, but is usually much less. The incubation period is from 14–17 days. The nymphs prefer to feed on succulent leaves and soft leaf sheaths. There are five nymphal stages, each lasting 3 to 4 days and the total nymphal period is about 19 days with no difference among the 2 sexes. The total mean period of life cycle is 47 days, with a range of 32–66 days, being shortest during September–October and longer during January–February (Fennah 1969).

Ocfemia (1934) showed that adults of the leafhopper, *P. vastatrix* can transmit Fiji disease. He was successful in transmitting the disease through 2nd, 3rd, 4th and 5th

instar nymphs. Viruliferous adults have to feed for at least 24 hr in healthy plants to transmit the disease. Once viruliferous, *P. vastatrix* remained infective for life. Chang (1977) demonstrated that Fiji disease virus can be passed from viruliferous leafhopper through eggs to the nymphs. The latent period in the hopper is about 14 days.

P. vastatrix usually breeds in sugarcane but also attacks "Hilo grass" and *Paspalum conjugatum.* Both young and mature canes are attacked.

In Philippines the leafhopper breeds on sugarcane almost exclusively, while in Java it is reported from sorghum also and in Malaysia on corn. There are 5 generations in the open fields and 6 in shaded areas. Prevalence of higher temperature and lack of rains reduce the population much. Heavy rainfall and lower temperature favour build up of the population.

P. vitiensis has been recorded from Fiji and Samoa and has a similar life cycle to that of *P. saccharicida* (Fennah 1969).

3.3 *Streak disease transmission by leafhoppers*

The vector associated with streak disease, *C. mbila* breeds on sugarcane and maize and probably also on a number of wild grasses. The eggs are inserted in the leaf tissues and under favourable conditions they hatch in approximately 10 days and reach the adult winged stage in 23 days. The adults can survive for several months.

This leafhopper is known to transmit 3 strains of the virus, namely sugarcane streak, maize streak and the strain from *Coix lacrymi-fobi*, all of which infect sugarcane (Anon 1976). Progeny of maize streak infected parents emerges from the eggs free from the virus but can acquire the virus as nymphs or as adults by feeding on chlorotic tissue of maize streak virus infected leaf for as short a time as a minute or even for a few seconds. After a non-infective latent period of 24 to 48 hr following its first feeding on a virus source, the insect may become infective and continues so for the rest of its life. It can infect a healthy maize plant during a feeding of 1 hr time and occasionally in 10 min. (Storey and Thomson 1961). Only a part of the field population of *C. mbila* is able to transmit the disease. Some individuals, both males and females, are incapable of acting as vectors in the normal process of feeding (Storey 1932) and normal transmission of the disease is slow (Ricaud 1980).

3.4 *Grassy shoot disease transmission*

Grassy shoot disease (GSD) has been proved to belong to the "yellows" type of disease caused by a mycoplasma like organism and not due to a virus. However, there are reports of positive sap transmission of GSD by Chona *et al* (1960) and Singh (1968). Singh (1969) even reported transmission through juice, cane cutting knife and also production of local lesions on *Chenopodium amaranticolor* and *Nicotiana glutinosa.* But later work by Edison *et al* (1976) proved that such mechanical transmission is not possible.

The etiological agent was reported to be transmitted by *L. indosacchari, L. sacchari* and *R. maidis* (Chona *et al* 1960). Later work of Edison (1973) proved the inability of the above to act as vectors of this disease. He reported another vector, *Assamia moesta.* This has an adult life of 5–7 days, an acquisition period of 12 hr inoculation feeding period of 1 hr, an apparent incubation period in the vector for 4 hr and an incubation period in the host for 18–34 days. An optimum of 15 viruliferous insects are required for

successful transmission of the disease. They gave an average percentage of transmission of 28·05. The etiological agent is non-persistent in the vector.

3.5 *White leaf disease transmission*

A similar disease, white leaf has been reported from Taiwan. The disease is transmitted by a leafhopper, *Matsumaratettix hiroglyphicus* Mats., with an incubation of 4–5 weeks in the vector and $2\frac{1}{2}$ to 3 months in the host plant (Matsumoto *et al* 1968). Young canes of 3–6 leaf stage take infection more easily. The vector remains infective until death, after feeding on diseased plants for one week (Lee and Chen 1972). Five adults were found sufficient for successful transmission. Chen (1973) reported minimum feeding time for acquisition and inoculation feeding as 3 hr 30 min, respectively. Of the adults examined 65·6% of the females and 45·8% of the males possessed infectivity.

4. Discussion

The review of the existing information on vectorial association with mosaic reveals that most of the reports are on mere transmission studies, with stray reports about the efficiency of the vectors. However, no attempt seems to have been made to study the details of biology, vector competency, existence of vector strains and their selectivity for mosaic strains, precise nature of acquisition, inoculation, retention, if any, and influence of ecological factors on vectors and in virus transmission. Efforts are also needed to study the population dynamics of each of the aphid species. According to Sylvester (1980), *L. sacchari*, *R. maidis* and *S. graminum* are semi-persistent with regard to Barley yellow dwarf virus. Even though sugarcane mosaic virus is not included in this category, the role of these three vectors to act as semipersistent vectors needs to be examined. Histopathological studies of the host virus and vector relationships using advanced techniques need also further study. This disease is universally present wherever sugarcane is grown and yet the attention in this direction is meagre.

Fiji disease is mostly confined to Australia and South East Asian countries. Even though some information on the biology, acquisition period, latent period and viruliferous nature of vectors have been gathered, these studies lack further thrust in these lines. Lot of information has to be gathered with regard to strains of these vectors and their ability to transmit the Fiji disease. Information is also lacking on the histopathological aspects involving the vector, virus and the host. The distribution of the virus in the host and the feeding habits needs further study. Similar information has also to be obtained with regard to the streak virus and its vector.

The mycoplasma-like organism associated with GSD and white leaf has not been easily cultured *in vitro*. Association of *Assamia moesta* with GSD has not been further proved, apart from the initial studies carried out by Edison in 1973. The inter relationships of these diseases and their vectors may be critically investigated.

5. Suggested lines of work

(i) Life cycle and feeding habits of different species of aphids involved in mosaic transmission, both under tropical and subtropical conditions need to be studied in

detail. (ii) Strains of vectors in relation to transmission of the different strains of mosaic need to be investigated. (iii) Detailed histopathological studies of the vector virus association have to be made. (iv) Population dynamics and seasonal variations of the vectors have to be worked out and correlated with the spread of the disease. Influence of ecological factors on vectors and transmission of disease may be investigated. (v) Survey of the different vectors involved in virus and mycoplasma transmission has to be carried out. (vi) Role of *Assamia moesta* and related insects in transmitting GSD has to be clearly studied. (vii) Different strains of leaf-hopper vectors and their efficiency in transmitting Fiji and streak viruses have to be studied further. (viii) Role of collateral hosts as reservoirs of the disease and the association of vectors may be studied in depth in respect to mosaic, grassy shoot, Fiji and streak diseases.

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