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Leafhopper and planthopper transmitted viruses of cereal crops

C B SULOCHANA
Centre of Advanced Study in Botany, University of Madras, Madras 600 005, India

Abstract. Leafhoppers in the family *Cicadellidae* and planthoppers in the family *Delphacidae* are known to be active vectors of about 25 viruses infecting cereal crops. These leafhopper and planthopper transmitted viruses are discussed in this paper.

Keywords. Leafhoppers; planthoppers; rhabdoviruses; reoviruses.

About half the ploughed land of the world is given to growing principal cereals and in most areas where cereals are grown, virus diseases are known. However, one is impressed by the localization of the cereal viruses. The general symptoms include various patterns of leaf-discoloration, deformation and stunting. In details, the symptoms and effects of virus diseases affecting cereals vary widely. Some virus diseases of cereals have been described under different names in different countries. In fact, the symptoms and host range overlap so much that a few can be identified by host reactions alone. The cereals being annuals and the viruses affecting them not being seed-borne, the disease incidence in any crop depends upon a rapid spread of the virus into the crop during a brief critical period each crop year. Some of these diseases are reported only on the host genus. Others are known to occur on or can infect experimentally other cereals and grasses. Their primary means of spread in the fields is by wind-borne, flying insects. The main environmental factors affecting the activity of the aerial vectors are air movements and temperature. Surprisingly, only a relatively small percentage of vectors feeding on a diseased plant usually become infective, but those which do remain so for a relatively long period.

Leafhoppers in the family *Cicadellidae* and planthoppers in the family *Delphacidae* are known to be active vectors of 25–30 viruses infecting cereal crops (Smith 1972; Peters 1981). These tiny insects have no wingless adult phase, and are, in general, more active than aphids. A certain percentage of natural populations, up to 25% in some cases, are viruliferous. The morphology of these viruses include isometric, bacilliform and flexuous thread-like particle types. Some well-known examples of diseases, size and morphology of the viruses and their vectors are listed in table 1. A few are now characterised as mycoplasma-like organisms with pleomorphic bodies, and one as *Spiroplasma*. The morphology of the causal agent is uncertain for a few diseases such as rice grassy stunt, oat-pseudo-rosette and rice hoya blanca; interestingly two types of particles have been associated with all of these diseases.

These causal agents share many similarities in relationships to their hosts and their respective vectors. None of these is transmissible to plants by leaf-rub methods; none is soil-borne or seed-borne. Furthermore no virus or mycoplasma infecting cereal crops is transmitted by both a leafhopper and a planthopper. These are in general persistent and/or propagative in the vectors. Semi-persistent relationship with their vectors are also known in rice tungro and maize chlorotic dwarf viruses. These resemble

Table 1. Viruses and other pathogens of cereals transmitted by leafhoppers and planthoppers.

Virus	Size in nm	Vector	Virus-vector relationship
I. Icosahedral		A. Leafhoppers	
Rice Orange leaf V	15	*Recilia dorsalis*	Persistent
Maize Streak V	20	*Cicadulina* spp.	"
Maize chlorotic dwarf V	26–31	*Graminella nigrifrons*	Semi-persistent
Oat blue dwarf V	28–30	*Macrosteles fascifrons*	Propagative
Rice tungro V	30–33	*Nephotettix* spp. *Recilia dorsalis*	Semi-persistent
Wheat Striate V (Eastern)	40	*Cicadulina mbila*	—
Rice dwarf V*	70	*Nephotettix* spp.	Propagative
Maize Wallaby ear V	85	*Cicadulina bimaculata, Nesoclutha pallida*	-do-
		B. Planthoppers	
Wheat streak V (African)	24	*Toya Catilina*	—
Rice Stripe V	25–35	*Laodelphax striatellus, Ribantodelphax albifascia & Unkandoes sapporonus*	Propagative
Maize rough dwarf V*	70	*L. striatellus, Javesella pellucida, & Sagotella vibix*	-do-
Oat sterile dwarf V	73	*J. pellucida, Dicranotropsis lamata & Cicadulina discolor*	-do-
Rice black streaked dwarf V	75–80	*L. striatellus, R. albifascia & U. sapporonus*	-do-
II. Rhabdovirus		A. Leafhoppers	
Rice transitory yellowing V	126 × 96 193 × 94	*Nephotettix* spp.	Persistent
Wheat striate mosaic V	200-250 × 75	*Endria inimca, & Elymana viriscens*	-do-
Wheat (Winter) mosaic V	—	*Psamonotettix striatus*	Propagative
		B. Planthoppers	
Maize mosaic V	242 × 48	*Perogrinus maidis*	-do-
Barley yellow striate mosaic V	330 × 60	*L. striatellus*	-do-
Oat pseudorosette V	500–600 × 40	*L. striatellus*	-do-
III. Particles of uncertain morphology			
Wheat striate mosaic V (Australian)		Leafhopper: *Nesoclutha obscura*	-do-
Wheat striate mosaic V (European)		Planthopper: *Javesella pellucida*	-do-
IV. Mycoplasma-like organisms			
Maize stunt disease		Leafhopper: *Dalbulus maidis*	-do-
Rice yellow dwarf disease		*Nephotettix* spp.	
Rice grassy stunt disease		Planthopper: *Nilaparvata lugens*	-do-

*Reovirus

semipersistent aphid-borne viruses persisting only a few days in *Nephotettix impicticeps* and not being retained through moult (Ling 1966) and has no detectable latent period in its vector.

Extensive work with leafhoppers first showed that some plant viruses can and do multiply in invertebrate hosts as well (Black 1959; Maramorosch 1955; Fukushi 1965). These cereal infecting viruses are highly specific as regards their insect vectors, and do appear better adapted to insect hosts. These produce more disease in plant hosts than in insect hosts. It has been suggested that some of these could have originated as insect viruses and secondarily adapted to plants on which these insects feed (Andrewes 1967). Individuals within a vector species have specific genetic susceptibilities to different viruses which they transmit much the same way as plants have different specific genetic susceptibilities to virus infections. From the studies made so far, often only one vector species is involved in the transmission of any one of these cereal viruses. There are exceptions as in the case of the leafhopper *Laodelphax striatellus* which transmits four rhabdoviruses *viz* BYSMV, NCMV, WCSMV and WRSV (Peters 1981). A point of interest is that *Nephotettix* spp are the primary vectors for an isometric reovirus, a rhabdovirus and a MLO; likewise the planthopper *Nilaparvata lugens* is a vector of both an isometric virus and a MLO. It is not known whether different types of pathogens are carried in the insect simultaneously or whether specificity is at the level of the races.

Particularly interesting are the complex rhabdoviruses and reoviruses. The former group has single-stranded RNA of mol. wt. $3{\cdot}5$–$4{\cdot}6 \times 10^6$, complementary to MRNA. The bacilliform particle is enveloped with 10 nm spikes; inside is a helical nucleocapsid. The latter group has isometric nucleocapsid with an inner and outer shell (60–80 nm) and 10–12 segments of double-stranded RNA of mol. wt. 10–16×10^6. Both the types have transcriptase activity (Primrose and Dimmock 1980). Cereal viruses belonging to these two groups are not only propagative in their respective vectors but have been shown to pass on from viruliferous female parent to progeny for several generations. This is in sharp contrast to the response of the plant host. The plants of each generation have to acquire the virus afresh deposited by viruliferous insects while feeding, for there is no seed transmission. But it is in the plant host, that these viruses cause obvious disease symptoms, therefore recognised and identified; these studies have revealed astonishing involvement of the specific vectors. When the insects acquire the rhabdovirus from a diseased plant while feeding, the virions are enveloped with a membrane derived from the host plant. The plant hosts receive the virions with the enveloping membrane derived from the insect body. Thus there is a subtle difference in the composition of these rhabdoviruses in the two hosts—one an invertebrate and the other a higher plant—, with possibly no variation in the genome of the infecting virus. These are truly insect-plant viruses for the virus can be continually maintained in the insect line whereas there is no continuity of the virus from plant to plant or from generation to generation of plants. It could be that the plant is an essential alternate host serving an important role in the ecology and survival of these complex viruses in nature.

It is generally assumed that each virus must survive between crops in populations of its specific vectors or in weed, perennial or volunteer host plants. On the basis of transovarial transmission, and field observations, it has been suggested that these viruses over-winter in leafhoppers rather than in plants, while for large population build-up, summer or winter annual weeds are needed. The tiny insects are carried by wind for long distances in spring to breed in widely separated areas or may migrate in search of suitable hosts. The effects of virus infection on yields of grain are influenced by the virus, the extent and time of infection, the susceptibility of the crop, presence of other viruses and diseases, and the effects of cultural and environmental conditions. Although many of these diseases have been reported to occur over widespread areas, widespread devastating epidemics are not known. Considerable losses have occurred locally where there were abundant sources of susceptible plants on which the virus and vector could multiply; in addition, the crop in question was highly susceptible, and planted at such a time as to expose the young plants to heavy infestation of infective insects. As yet, there is no chemical treatment suitable for control of cereal infecting viruses. Approach to practical control appears to be the avoidance of build-up of vector populations and the need is to intensify research in this direction notwithstanding the fact that there are varieties of cereals with high degree of resistance to most of the known leafhopper and planthopper transmitted viruses.

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