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Mealybugs as Vectors of Plant Viruses

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Mealybugs are small insects that can be significant pests in agriculture due to the direct and indirect damage they cause by feeding on plant sap, weakening the host plants and sometimes transmitting plant viruses. Mealybugs are not as well-known as other insect vectors of plant viruses, such as aphids or whiteflies, but they can still play a role in the spread of these pathogens. Mealybugs can transmit several plant viruses, and the specific viruses they transmit can vary depending on the mealybug species, the host plants involved, and the geographical location. Some of the plant viruses that can be transmitted by mealybugs include Grapevine leaf roll virus, Pineapple Mealybug Wilt-Associated Virus, African Cassava Mosaic Virus, Banana streak disease, etc.

Introduction

The vast majority of plant viruses are spread by vectors. Arthropods, nematodes, and fungi are responsible for 55% of all identified plant viruses, making them the most significant category of vectors. Arthropods, nematodes, and fungi are responsible for 76% of plant viral transmission. The characteristics of virus-vector interactions are used to categorise the modes of pathogen transmission; viruses that replicate within insects are transmitted in a propagative manner, while those that do not are transmitted nonpersistently, semi-persistently, or circulatively (persistently). The ability of a particular insect species to transmit a virus differs significantly amongst vector-borne plant viruses in terms of virus-vector specificity.

Mealybugs (Hemiptera: Pseudococcidae) are phloem feeders that use long, slender mouthparts to uptake plant fluids, which reduces the vigor of host plants. They can feed on all plant tissues, and severe infestations cause defoliation and, eventually, plant death. Some species inject plant toxins during feeding, causing twisted/stunted growth. The damage generated varies among taxa and is determined by their reproductive potential, temperature tolerance, preferred feeding locations, the existence of effective control strategies, and their ability to transmit viruses.

It is the indirect damage mealybugs can cause as pathogen vectors that makes their movement between crop plants potentially so destructive. With their piercing-sucking mouthparts capable of injecting viruses into specific plant tissues mealybugs have been shown to be the main vehicle for the dispersion of grapevine leafroll-associated virus GLRaV (Charles et al., 2009), pineapple mealybug wilt-associated virus PMWaV (Sether et al., 1998) and Piper yellow mottle virus (Lockhart et al., 1997). However, in terms of scale by far the most devastating impact of mealybugs to date has been their role in the spread of the Cacao swollen shoot virus (CSSV) among the West African cacao (Theobroma cacao) crop. At least 23 mealybug species transmit 10 viruses (Ekemen,2021) of banana, black pepper, citrus, cocoa, grapevine, pineapple, sugarcane and cherry.

Transmission

Females and nymphs are reported to transmit viruses. Crawlers are the principal dispersal life stage. The transmission is done in Semi-persistent manner. In Semi-persistent (foregut borne) transmission there is no latent period in vector Acquisition time varies from minutes-hours. Retention time varies from hours to a few days. Viral load cannot be recovered from haemolymph. It cannot be transmitted after injection into the hemocoel. Non trans-stadial and non-transovarial transmission. Transmission efficiency increases with acquisition feeding time Following are the viruses transmitted by mealybugs.

Ampelovirus (Fam: Closteroviridae) ssRNA: Pineapple mealybug wilt associated virus (PMWaV), Grapevine leaf roll-associated virus 3 (GLRaV-3) by Pink pineapple mealybug, *Dysmicoccus brevipes*, Citrus mealybug, *Planococcus citri*

Pineapple mealybug-wilt associated virus (PMWaV): Dieback / pineapple mealybug wilt**.** Carter, 1993 gave toxin hypothesis: phytotoxemiasis**.** PMWaV -1,-2 and -3 transmitted by genus *Dysmicoccus* (*D. brevipes* and *D. neobrevipes*)**,** PMWaV -4 and -5: unidentified vector (Dey *et al*., 2018)**.**

Grapevine leafroll-associated virus 3 (GLRaV-3): Grapevine leafroll disease (GLD), GLRaV-3 and GLRaV-5 are spread by Grape mealybug, *Pseudococcus maritimus*, longtailed mealybug, *Pseudococcus longispinus*, Citrophilus mealybug, *Pseudococcus calceolariae*, Citrus mealybug, *Planococcus citri*, Obscure mealybug, *Pseudococcus viburni*. They can acquire virus with 24 hours (is the shortest efficient period; 12 hours: 8.3% efficiency) and can transmit with upto 70% efficiency (Jones and Nita, 2020).

Rugose wood complex: different diseases, three of them associated with viral infection: Rupestris stem pitting - Rupestris stem pitting associated virus (RSPaV), Kober stem grooving - GVA, corky bark – GVB (*Planococcus ficus*). The viruses associated may also occur as mixed infections among themselves and with different grape leafroll associated viruses (ampelovirus). Propagation of infected plant material is the primary mechanism of spread.

Badnaviruses (Fam: Caulimoviridae) dsDNA: *Pseudococcus, Planococcus* and *Ferrisia*. Banana streak virus, Piper yellow mottle virus, Citrus yellow mosaic virus, Cocoa swollen shoot virus, Sugarcane mosaic virus and Dioscorea bacilliform virus

Banana streak disease: Sugarcane to banana are affected by this virus. *Planococcus citri, Pseudococcus* sp, pineapple mealybug (*Dysmicoccus brevipes*), pink sugarcane mealybug (*Saccharicoccus sacchari*) are known to transmit Banan streak disease. Banana streak Mysore virus have shown that the virus is seedborne but not mechanical or soil borne

There are two forms of transmission by mealybugs; **Episomal**- Normal particles plant sap ducts, Acquired and inoculated by mealybugs and **Endogenous**- DNA integrated in the banana genome (vertical transmission), Evolve into the episomal (horizontal transmission)

Piper yellow mottle virus (PVMY)- Cuttings and grafting are the means of inoculum. Citrus mealy bug (*Planococcus citri*) and black pepper lace bug (*Diconocoris distanti*), *Ferrisia virgata* in Kerala are reported to transmit the virus (Bhat, 2003).

Cacao Swollen Shoot Virus (CSSV)- Theobroma virus 1 or Cocoa mottle leaf virus. It is prevalent in West African countries (Togo, Ghana, Nigeria). *Planococcus citri, Pseudococcus longispinus and Ps. Viburni* are the vectors. At least 16 species of pseudococcids transmit CSSV between trees.

Cacao Mild Mosaic Virus transmitted by *Pseudococcus jackbeardsleyi*, *Maconellicoccus hirsutus*, *Pseudococcus comstocki* and *Ferrisia virgate*

Traditionally, studies aimed at the identification of vectors of plant pathogens focus on a few insect species and strains of a specific pathogen. These simple vector–pathogen combinations are desirable because the research focus is often on an important vector or pathogen. In addition, due to evolutionary constraints of such systems, one insect is often more commonly found associated with a specific disease and the most likely vector of its respective etiological agent. However, it is important to consider that extensive within-vector and -virus species variation in transmission efficiency has been documented for insect-borne plant viruses

Conclusion

A single mealybug species can vector **many viruses** like - *Planococcus citri*: 16 virus species. One virus may be transmitted by **many mealybug species** (CSSV): 16 mealybug species. **Dependency** of virus transmission by mealybugs is not completely understood. The **virus-encoded determinants** of the mealybug transmission are yet unknown. The question to be answered is that "What happens after **dormancy** of viruliferous mealybug?" In detail transmission by **scale** insects (Coccidae) is poorly understood.

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