Glassy-winged Sharpshooter Transmission of *Xylella fastidiosa* to Plants

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Xylella fastidiosa is a xylem-limited bacterium that causes disease in many plants such as grape, almond, citrus, and coffee (Hopkins and Purcell 2002). Insect dissemination of *X. fastidiosa* is only possible by xylem-feeding vectors belonging to the subfamily Cicadellinae (Hemiptera, Cicadellidae; sharpshooter leafhoppers) and the family Cercopidae (Hemiptera; spittlebugs) (Redak et al. 2004). Several insects within these groups are vectors of *X. fastidiosa*; however, their transmission efficiency is variable and dependent on many factors (Purcell 1989).

The best studied vector of *X. fastidiosa* in relation to pathogen transmission is *Graphocephala atropunctata* Signoret (blue-green sharpshooter), which is the main vector of the bacterium in coastal California areas. However, in recent years another sharpshooter has been the focus of much interest. *Homalodisca vitripennis* Germar (glassy-winged sharpshooter) has been a known vector of this bacterium to plants in southeastern areas of the United States (Turner and Pollard 1959). Since its introduction into California in 1989, the economic importance of this species has increased considerably (Purcell and Feil 2001). It now threatens to transmit *X. fastidiosa* to many crops in California, including grape, almond, and ornamentals such as oleander (Hopkins and Purcell 2002). This insect has also been recently introduced into tropical islands in the Pacific, notably French Polynesia, where it is abundant and widespread (J. Grandgirard, personal communication), and the island of Oahu in Hawaii.

On rare occasions the glassy-winged sharpshooter may have a direct impact on plants (Andersen et al. 2003), but in general these insects are economically important because they transmit *X. fastidiosa*. Understanding *X. fastidiosa* transmission parameters will help determine the potential threat of this pest and develop effective integrated pest management practices to control the dissemination of this bacterium. Here I discuss the basic characteristics of *H. vitripennis* transmission of *X. fastidiosa* to plants, focusing on work conducted on grapevines. Potential implications of this vector-pathogen system to tropical island ecosystems in the Pacific are also addressed.

Transmission characteristics. Although the underlying mechanisms of *X. fastidiosa* transmission are not yet fully understood, experiments under controlled conditions have provided some information on how the pathogen is transmitted to plants. *Graphocephala atropunctata* transmits *X. fastidiosa* in a persistent manner (Severin 1949) with a short, or absent, latent period (Purcell and Finlay 1979). The pathogen multiplies in the foregut of vectors (Hill and Purcell 1995) and is apparently limited to this area of the gut; nymphs lose infectivity after molting (Purcell and Finlay 1979) when the cuticular lining of the foregut is shed. There is no evidence for transovarial transmission of the bacterium (Freitag 1951). These transmission characteristics are unique when compared to other insect-borne plant pathogenic bacteria and viruses.

Recent research with *H. vitripennis* addressed similar questions related to the transmission biology of *X. fastidiosa* to grapevines by this species. Nymphs and adults of *H. vitripennis*

transmit *X. fastidiosa*, however, transstadial transmission was not observed (Almeida and Purcell 2003a). As shown for *G. atropunctata*, acquisition and inoculation of the bacterium can occur within one hour of plant access, but efficiency increases over time. The lack of a detectable latent period suggests that bacterial multiplication on the foregut of vectors is not essential for pathogen transmission. Little association between *X. fastidiosa* detection (by culture) in the vector's head and its transmission to plants by the same individuals suggest that attachment sites on the foregut required for inoculation are so small as to be often undetectable, and can be saturated quickly after acquisition (Almeida and Purcell 2003a).

Homalodisca vitripennis is an inefficient vector of *X. fastidiosa* to grapevines when compared to *G. atropunctata* (Almeida and Purcell 2003a). Currently there are no data suggesting reasons for these observed differences. However, tissue feeding preferences may be associated with pathogen acquisition efficiency. *Graphocephala atropunctata* prefers to feed on leaves and young tissue, while *H. vitripennis* can be found on those tissues but also on mature woody parts of the plant (Hopkins and Purcell 2002). *Xylella fastidiosa* is unevenly distributed within symptomatic plants, a characteristic that may affect acquisition efficiency if certain species prefer to feed on tissues with lower bacterial concentrations. Acquisition efficiency was higher from plants with higher bacterial loads, indicating a direct correlation between bacterial concentrations and vector transmission efficiency (Hill and Purcell 1997).

Homalodisca vitripennis can also inoculate dormant grape and almond plants with *X. fastidiosa* (Almeida et al. 2005, Almeida and Purcell 2003b). Xylem sap within these plants is under positive pressure. This indicates that something other than involuntary detachment of bacterial cells from the foregut due to negative pressure in xylem tissue is responsible for inoculation of *X. fastidiosa* into dormant plants. Recent work has shown a good correlation between *X. fastidiosa* presence in the precibarium canal (as visualized by scanning electron microscopy) of *G. atropunctata* and its transmission to plants (unpublished data). Comparative studies of the morphology of the precibarium of vectors and non-vectors in different taxonomic groups could lead to new ideas on the basic transmission mechanisms.

Transmission of *X. fastidiosa* to two-year old wood and dormant grapevines allows *H. coagulata* to disseminate the bacterium during the winter when native California sharpshooters are in diapause (Purcell and Feil 2001). *Graphocephala atropunctata* and other vectors can transmit the pathogen to susceptible plants during the fall, however those inoculations do not survive because winter pruning removes infected material and/or bacteria die within dormant plants at low temperatures (Feil and Purcell 2003). *Homalodisca vitripennis* can inoculate woody tissue and dormant plants under experimental conditions, thus it is reasonable to postulate that this insect can also inoculate this bacterium into plants in the field. If that is the case, *H. vitripennis* can generate new infections during the fall and winter seasons, a period previously free of chronic *X. fastidiosa* infections in California grapes. This may cause secondary (vine-to-vine) spread of the pathogen and exponential growth of the disease. The recent epidemic in Temecula Valley, California, may have resulted from secondary disease spread. However, the large number of sharpshooters in that area at the time of the epidemic may have also contributed to disease spread; transmission efficiency is the outcome of many factors, including the number of vectors present on infected and susceptible plants (Purcell 1981).

***Homalodisca vitripennis* in the Pacific and the spread of *X. fastidiosa*.** *Homalodisca vitripennis* was first discovered in French Polynesia (Tahiti) in 1999. This insect is now present in many other islands of the archipelago, frequently in very large numbers causing a phenomenon known as "sharpshooter rain" (excrement drops). It was first found on the island of Oahu (Hawaii) in May 2004. So far *X. fastidiosa* has not been reported in either

location. Considering the intense traffic of agricultural commodities throughout the Pacific, it is unlikely that this insect will be limited to these islands. Environmental conditions throughout the region are appropriate for the establishment of both *H. vitripennis* and *X. fastidiosa* (Hoddle 2004). In Hawaii, large populations of *H. vitripennis* were found on several plants soon after its first sighting; however, within one year, populations have reduced dramatically. At the same time, parasitism of eggs by the adventive mymarid *Gonatocerus ashmeadi* was observed (R. Bautista, Hawaii Department of Agriculture, personal communication). It is currently unknown if *G. ashmeadi* is in fact controlling *H. vitripennis* populations or if there are other factors lowering sharpshooter numbers. Nevertheless, *H. vitripennis* populations in Hawaii throughout 2005 have been negligible.

The threat of *X. fastidiosa* spread by *H. coagulata* to island ecosystems is based on the establishment of a polyphagous sharpshooter vector. Native sharpshooters may have a limited host range or preferred habitat that would preclude them from being important vectors of *X. fastidiosa* (if the pathogen is introduced). However, *H. vitripennis* feeds on many different plants, achieves large populations and may colonize habitats previously free of sharpshooters or spittlebugs. *Xylella fastidiosa* also has a wide host range, thus it may be widely spread to crops and native plants in the presence of a polyphagous vector (Hopkins and Purcell 2002). Furthermore, even low vector populations can effectively disseminate *X. fastidiosa* and generate many new infections if the pathogen is present in plants visited by these insects. Thus, reducing vector populations may not result in dramatic slowing of disease spread.

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