Suitability of Different Host Plants for Oviposition and Development of *Homalodisca vitripennis* (Hemiptera: Cicadellidae) and Its Implication on Mass Rearing

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ABSTRACT The glassy-winged sharpshooter, *Homalodisca vitripennis* (Germar) (Hemiptera: Cicadellidae), is a major pest of grapevine (*Vitis vinifera* L.) in Texas and California. It is a known vector of Pierce’s disease and is considered the most significant insect pest threatening the grape industry in the United States. We evaluated the preference of four host plants for feeding and oviposition by *H. vitripennis* adult females. We also measured the suitability of nine host plants for the growth and development of eggs and nymphs under greenhouse and laboratory conditions, respectively. Embryonic survival exceeded 85% on all tested host plants, with the exception of sweet potato, *Ipomoea batatas* (L.) Lam. More than 80% of the nymphs successfully reached adulthood on sweet potato, black-eyed pea (*Vigna unguiculata* unguiculata (L.) Walp.), and eggplant (*Solanum melongena* L.). Developmental time of immature *H. vitripennis* nymphs was significantly affected by the plants on which they fed. The nymphs were more likely to die during the first instar on host plants such as Texas mountain laurel *Eucryphis japonica* (Thunb.), or citrange *Citrus sinensis* × *Poncirus trifoliata*. Host suitability (nutrients) and stem and leaf texture, which varied among host plant species selected, seem to both play a significant role in nymphal development. Adult females were able to feed on woody plants, but a preference for black-eyed pea and sweet potato was observed. In captivity and given the plant choices offered, they deposited more egg masses on hibiscus (*Hibiscus rosa-sinensis* L.) and black-eyed pea.

RESUME La cicadelle à ailes vitreuses, *Homalodisca vitripennis* (Germar) (Hemiptera: Cicadellidae), est un ravageur important de la vigne au Texas et en Californie. Cet insecte vecteur peut transmettre la bactérie qui cause la maladie de Pierce et il est considéré comme la menace la plus sérieuse à la production de raisins aux États Unis. Nous avons évalué la préférence de quatre plantes hôtes pour l’alimentation et l’oviposition des femelles de *H. vitripennis* et de neuf plantes hôtes pour la croissance et le développement des embryons et nymphes en conditions contrôlées au laboratoire et en serre. La survie embryonnaire et l’émergence des premiers stades nymphaux ont dépassé 85% sur toutes les plantes hôtes à l’exception de la patate douce. Plus de 80% des nymphes ont atteint le stade adulte sur la patate douce, le niébé et l’aubergine. Le type de plante hôte a significativement affecté la durée de développement des nymphes. La probabilité de mortalité des nymphes de la cicadelle à ailes vitreuses était plus élevée au premier stade de leur développement sur certaines plantes hôtes comme la laurier Texan ou l’orange amère. La convenance nutritive des plantes hôtes et la texture de leurs feuilles qui variaient entre les espèces testées ont pu jouer un rôle déterminant pour le succès de développement des nymphes. Les femelles adultes étaient capables de s’alimenter sur des plantes ligneuses mais ont préféré le niébé et la patate douce. En captivité, en fonction du choix des plantes offertes, les femelles ont déposé davantage d’œufs sur l’hibiscus et le niébé.

KEY WORDS Auchenorrhyncha, development, reproduction, life cycle, *Xylella fastidiosa*

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this grape decline. Incurable and eventually fatal, Pierce’s disease is the most studied disease of grape, and the most limiting factor of grape production in the United States. The spread of X. fastidiosa through a vineyard is difficult to control: the first foliar symptoms are easy to misidentify and usually are delayed until the end of the vegetative season. Therefore, the infected vines provide a source of inoculum for initiation of new infections until they are positively identified and removed. The economic importance of this insect vector is further increased by the fact that other strains of X. fastidiosa are pathogenic in a variety of agricultural and ornamental host plants, including stone fruit, almond, olive, alfalfa, and oleander in the United States; and citrus, coffee, and liquidambar in Central and South America (Purcell and Hopkins 2002, Pilkington et al. 2005). A broad range of plants harbor these bacterial strains. Those that are not susceptible often act as silent hosts.

Both glassy-winged sharpshooter adults and nymphs are competent vectors of X. fastidiosa. The adults remain infectious throughout their lifetime, whereas the nymphs must reacquire the bacterium after each molt to remain infective (Purcell and Hopkins 1996). This insect species is known to feed on a wide range of plant species (Freitag 1951, Turner and Pollard 1959; Blua et al. 1999, Hoddle et al. 2003), which increases the chances of spreading the bacterium among plants growing in proximity to vineyards.

The present study examined the selection of different host plants by adult H. vitripennis females and the effect of host plants on the growth and development of the immatures. Unfortunately, most host plants used by this insect in its natural habitat are too large to be produced in pots and maintained in cages, many grow slowly, others are costly to produce. In a rearing program, plants that are easy and economical to produce and can maintain or even enhance the growth, development and reproduction of the insects in captivity are sought. The broad host plant range of H. vitripennis should be very helpful. Preliminary observations were conducted on forty plant species by the senior author, which gradually was narrowed to nine species based on acceptance by the insect and plant characteristics. These remaining plants were used to carry out more exhaustive observations with the intent to identify the best plant species useful for mass rearing of H. vitripennis in captivity. Here, we describe host selection by females placed in a choice-test situation, as well as the development of H. vitripennis eggs on the host plants where eggs were deposited. Nymphal survival and development to adulthood were studied in no-choice conditions on eight of these plant species.

Materials and Methods

Biological Materials. Insects used in these studies were from a stock colony produced and maintained at the U.S. Department of Agriculture’s Animal and Plant Health Inspection Service (USDA-APHIS), Moore Air Base, Edinburg, TX, by LL. A reliable H. vitripennis colony was established during 2001–2002 from individuals collected in Kern County, CA. Annual field trips to the same location allowed to replenish the colony and to ensure that insect vigor was maintained. Insects were reared under greenhouse conditions as follows: 1) spring–summer (April–September), 29 ± 5°C, 75 ± 14% RH, natural sunlight conditions; and 2) fall–winter (October–March), 29 ± 5°C, 49 ± 14% RH, photoperiod of 15:9 (L:D) h supplemented with artificial light (metal halide, 1,000 W, Sunlight Supply, Inc., Vancouver, WA) between 0530 and 0830 hours and 1730 and 2030 hours. Temperature and relative humidity were monitored using Hobo data loggers (Onset Computer Corporation, Bourne, MA).

Greenhouse tests were conducted in aluminum frame screened (0.40- by 0.45-mm mesh size, Econet M, Ludvig Svensson, Kinna, Sweden) cages (40 by 40 by 40 cm). The front of the cage constituted of a latched Lexan door which presented an opening closed by a cotton stockinette sleeve to allow insertion or collection of plants and insects. On the back of the cage were screw-type holes fitted for an automatic irrigation system with a tube connected to each plant. Plants were watered daily for 2 min by using a 1.9 liter/h emitter. Insects studied under laboratory conditions were maintained at 25 ± 0.5°C and 85 ± 5% RH under a photoperiod of 14:10 (L:D) h in an environmental growth chamber (Percival Scientific, Inc., Perry, IA). In the chamber, cages (21 by 21 by 45 cm) were used for tests were made of Plexiglas and screen. They comprised of two sections such that the insects were exposed to the plant stems and leaves only. This cage design prevented early instars from falling off the plant and into the soil and enabled us to accurately follow nymphal development.

Unless otherwise noted, plants were grown in 3.8-liter plastic pots (15 cm in diameter, National Growers Inc., Lakeville, MN) filled with Sunshine Mix #1 growing media (SunGro Horticulture, Bellevue, WA) supplemented with Osmocote 14–14–14 controlled release fertilizer (Scotts-Sierra Horticultural Products Company, Marysville, OH). Black-eyed peas, Vigna unguiiculata (L.) Walp. ‘GS3505 CA blackeye’ (Leguminosae) (BWI Companies, Inc., Texarkana, TX). Unless otherwise mentioned, black-eyed peas were planted at five seeds per pot, and this constituted one plant unit. Peas were grown under greenhouse conditions for a total of 7–8 d (15–20 cm) before being used for tests. Citrange, Citrus sinensis × Poneirus trifoliata ‘Carrizo’ (Rutaceae) (Reed Brothers Citrus, Dundee, FL), is often used as root stock for other commercial varieties and was grown from seed using one seed per pot. Eggplant, Solanum melongena L. ‘Black beauty’ (Solanaceae) and broad bean, Vicia faba L. ‘Con amore’ (Leguminosae) (Champion Seed Company, Brea, CA), also were produced from seed by using one seed per pot. Hibiscus, Hibiscus rosa-sinensis L. ‘Brilliant red’ (Malvaceae) (Lambert Plant Farms, Inc., Edinburg, TX), and sweet potato, Ipomoea batatas (L.) Lam. ‘Diane’ (Convolvulaceae) (Canisso
Produce Company, Livingston, CA), were grown from cuttings and used at a size varying between 20 and 30 cm. Texas mountain laurel, Sophora secundiflora (Ort.) (Leguminosae), was produced from seeds collected from plants growing locally. Chrysanthemum, Chrysanthemum morifolium Ramat. ‘White diamond’ (Compositae), was donated by Yoder Brothers, Inc. (Barberton, OH). Euonymus japonica’ Grandifolia’ Thunb. (Celastraceae) (Monrovia, Azusa, CA), was produced as 15–20-cm-tall liners in 5-cm-diameter plastic “rose pot” (Farrand Ent., Chino, CA) and used when rooted, 6–8 wk after cuttings were planted.

Throughout these experiments, all egg masses were collected and placed individually in petri dishes (55 mm in diameter) lined with filter paper moistened with reverse osmosis water to prevent excessive leaf desiccation during incubation. Eggs were incubated in an environmental growth chamber as described above. Embryonic development was monitored daily (1500 hours), and the number of nymphs emerged per egg mass was recorded through time. Ten days after the last egg hatched, egg masses were dissected under stereomicroscope (12–16X) to determine embryonic mortality and calculate the total number of eggs per egg mass.

**Egg Mass Size and Embryonic Development on Different Host Plants.** Mated and reproductively active *H. vitripennis* females (most presenting brochosomes) were assigned in groups of 30 individuals to cages with five plants of: 1) black-eyed pea, 2) hibiscus, 3) eggplant, 4) citrange, 5) chrysanthemum, 6) mountain laurel, 7) sweet potato, and 8) *E. japonica*. For 5 d, the plants were checked daily for egg masses. All egg masses produced on each host plant were collected up to a total of 30 masses. They were individually placed in petri dishes lined with moistened filter paper and incubated as described above. Developmental time was noted for nymph emerging in the experimental arena. Subsequently, egg masses were dissected to assess any embryonic mortality on different host plants. The percentage of eggs that successfully developed into nymphs and embryonic developmental time were subjected to one-way analysis of variance (ANOVA) to test for host plant effect. When significant *F* values were obtained, treatment means were compared using the Student–Newman–Keuls (SNK) test (*P* < 0.05). Percentages were arcsine-transformed before analysis to achieve normality assumption, but means of untransformed data were presented. A simple correlation analysis was performed to assess the relationship between egg mass size and mean developmental time of the eggs in the masses.

**Nymphal Survival and Development on Different Host Plants.** To assess nymphal development, colony egg masses were collected and incubated until completion of embryonic development. Within 4 h of hatching, first instars (minimum *n* = 35) were introduced individually into cages containing one of each the following plants as food source: 1) black-eyed pea, 2) hibiscus, 3) eggplant, 4) broad bean, 5) citrange, 6) chrysanthemum, 7) Texas mountain laurel, and 8) sweet potato. In this assay, black-eyed peas were planted as one seed per pot. Fresh plants were provided weekly to maintain access to high quality food. Nymphs were maintained under the same environmental conditions as described above, only this time in a walk-in environmental chamber (EGC, Chagrin Falls, OH) where observations were made without disturbing the insects. Nymphal development was monitored twice daily (7000 and 1600 hours). Developmental time was recorded between each molt until adulthood. The stems and leaves were checked for the presence of nymphal exuviae, which was removed after each molt for each insect. It soon became evident that nymphal mortality was significant. To maintain adequate number of replicates for statistical purposes, newly emerged nymphs were introduced in a cage with the corresponding plant as replacement for dead ones and up to a maximum of five times. Instar-specific and total nymphal survival were compared using a log-likelihood ratio test (G-test, Zar 1999) to evaluate host plant effects. One-way ANOVA was used to determine the effect of host plant on the duration of nymphal development to adulthood. Treatment means were separated using the SNK test. The growth index, calculated as the ratio between the ultimate nymphal survival and the mean developmental time of nymphs, was determined for each host plant (Sétamou et al. 1999).

**Selection of Host Plants for Feeding and Oviposition by Mature *H. vitripennis* Females.** Naïve *H. vitripennis* females (<5 h old; *n* = 30) were individually assigned to a cage with five young males to allow mating. Adult females were provided eggplants throughout the preoviposition period. Upon the onset of oviposition, females were individually transferred to a new cage for choice tests by supplying simultaneously a single pot of the following host plants: 1) pea, 2) hibiscus, 3) *E. japonica*, and 4) sweet potato. Plants were inspected for egg masses once daily. Oviposition was recorded as the number of egg masses and total number of eggs per plant species. The total number of eggs per mass was obtained adding the number of nymphs emerged to the number of dead embryos, as described above. Each female was observed for a period of time that allowed the deposition of five egg masses (7.33 ± 0.96 d, on average). Observations on an individual stopped if no eggs were recovered for seven consecutive days after collection of the last egg mass. Plants used once for oviposition were renewed with a fresh plant. The feeding preference of adult females was determined by observing each individual once a day (1000 hours) for 5 d and recording the plant the individual was found feeding on at the time of observation. Feeding was assessed by observing abundant excretion of fluid from the anus. When searching for egg masses, all leaves of every plant were inspected and this disturbance interrupted the feeding behavior of the female. It often flew to land on the screen of the cage during this process. Thus, subsequent observations were considered as independent choices by the adult female. Data on adult *H. vitripennis* feeding and oviposition site selection were analyzed using log-likelihood ratio test, followed by a stepwise compar-
Developed faster on black-eyed pea, sweet potato, and eggplant (Fig. 1). The total duration of nymphal instars, except for insects reared on black-eyed pea, was significantly different between these latter host plant species. Embryonic development averaged 6.7 (hibiscus, chrysanthemum) to 7.9 d (Euonymus) depending on host plant species (F = 65.74; df = 7, 1859; P < 0.0001; Table 1). The longest egg development occurred in plants with the largest egg mass sizes. A positive and significant correlation was obtained between mean egg mass size and mean embryonic developmental time (r = 0.68, df = 7, P = 0.03).

Nymphal Survival and Development on Different Host Plants. Host plant species significantly affected nymphal survival (G = 271.56; df = 7, P < 0.0001). Survival was higher on sweet potato, black-eyed pea, and eggplant, with >80.0% of nymphs reaching adulthood. Nymphs that developed on Texas mountain laurel had the lowest survival rate (4.3%), whereas eggs laid on the remaining host plants emerged at a rate exceeding 85.0%. Embryonic survival was not significantly different between these latter host plant species. Embryonic development averaged 6.7 (hibiscus, chrysanthemum) to 7.9 d (Euonymus) depending on host plant species (F = 65.74; df = 7, 1859; P < 0.0001; Table 1). The longest egg development occurred in plants with the largest egg mass sizes. A positive and significant correlation was obtained between mean egg mass size and mean embryonic developmental time (r = 0.68, df = 7, P = 0.03).

Table 1. Characteristics of H. vitripennis egg masses deposited on different host plants under greenhouse conditions, percentage of survival, and mean developmental time of embryos reared at 25 ± 0.5°C

| Host plant          | N (egg mass) | Mean mass size (eggs ± SE) and range | N (viable eggs) | % survival | Mean developmental time (d ± SE) and range |
|---------------------|--------------|--------------------------------------|-----------------|------------|------------------------------------------|
| Black-eyed pea      | 30           | 12.7 ± 1.2 (2-24)ab                   | 354             | 92.9a      | 7.1 ± 0.1 (6-10)b                       |
| Hibiscus            | 30           | 11.2 ± 1.1 (2-24)b                    | 295             | 88.7a      | 6.7 ± 0.6 (6-9)c                       |
| Eggplant            | 30           | 8.3 ± 0.5 (2-16)c                     | 213             | 85.3a      | 6.9 ± 0.1 (6-9)bc                      |
| Euonymus            | 30           | 14.3 ± 1.2 (4-26)a                    | 417             | 97.0a      | 7.9 ± 0.1 (6-10)a                      |
| Citrange            | 30           | 6.9 ± 0.5 (1-23)c                     | 177             | 85.1a      | 6.8 ± 0.1 (6-8)c                      |
| Chrysanthemum       | 30           | 7.3 ± 0.9 (1-19)c                     | 195             | 89.4a      | 6.7 ± 0.1 (5-10)c                     |
| Mountain laurel     | 30           | 6.4 ± 0.5 (1-14)c                     | 166             | 86.0a      | 6.5 ± 0.1 (6-10)c                     |
| Sweet potato        | 30           | 5.9 ± 0.5 (2-14)c                     | 75              | 41.9b      | 7.9 ± 0.1 (6-8)b                      |

Means within a column followed by different letters are significantly different (P < 0.05; SNK test).

Results

Egg Mass Size and Embryonic Development on Different Host Plants. The mean number of eggs per mass laid by captive H. vitripennis females under greenhouse conditions varied with host plant (F = 12.49; df = 7, 232; P < 0.0001; Table 1). The number of eggs per mass was higher on Euonymus and black-eyed pea. Survival of H. vitripennis eggs differed significantly among plant species (F = 17.78; df = 7, 232; P < 0.0001; Table 1). Eggs deposited on sweet potato had the lowest emergence rate (41.9%), whereas eggs laid on the remaining host plants emerged at a rate exceeding 85.0%. Embryonic survival was not significantly different between these latter host plant species. embryonic development averaged 6.7 (hibiscus, chrysanthemum) to 7.9 d (Euonymus) depending on host plant species (F = 65.74; df = 7, 1859; P < 0.0001; Table 1). The longest egg development occurred in plants with the largest egg mass sizes. A positive and significant correlation was obtained between mean egg mass size and mean embryonic developmental time (r = 0.68, df = 7, P = 0.03).

Nymphal Survival and Development on Different Host Plants. Host plant species significantly affected nymphal survival (G = 271.56; df = 7, P < 0.0001). Survival was higher on sweet potato, black-eyed pea, and eggplant, with >80.0% of nymphs reaching adulthood. Nymphs that developed on Texas mountain laurel had the lowest survival rate, with only 4.3% reaching the adult stage (Fig. 1). Instar-specific survival of H. vitripennis nymphs also varied with host plants species (G = 38.7, P < 0.0001, for all five nymphal instars). For the host plants tested, mortality of the first instar was higher than mortality of later instars, except for insects reared on black-eyed pea, sweet potato, and eggplant (Fig. 1). The total duration of nymphal development also was significantly affected by host plant species (Table 2). Nymphs developed faster on black-eyed pea, sweet potato, eggplant, and broad bean compared with the remaining host plants. Nymphs feeding on potted citrange and Texas mountain laurel had the longest developmental times, whereas nymphal developmental times on hibiscus and chrysanthemum were intermediate. Similarly, instar-specific development of nymphs varied with host plant (Table 2). All five nymphal instars developed faster on black-eyed pea and sweet potato compared with other host plants. The growth index showed that H. vitripennis nymphs had the highest growth potential on potted black-eyed pea and sweet potato, and the lowest on Texas mountain laurel (Fig. 2). Four host plants, namely, eggplant, sweet potato, black-eyed pea and broad bean, allowed the production of adult males and females that were larger in size than the other plant species tested (Table 2).

Selection of Host Plants for Feeding and Oviposition by Mature H. vitripennis Females. Female H. vitripennis presented a choice of four host plants for feeding and oviposition exhibited a strong preference for certain species (Table 3). The log-likelihood test indicated that feeding site selection by adult H. vitripennis females was strongly affected by host plant

Fig. 1. Instar-specific survivorship of H. vitripennis nymphs reared on different host plant species.
### Table 2. Mean nymphal development time and size of resulting adults reared on eight different host plants under laboratory conditions

| Host plant      | Developmental time (d) | Male | Female |
|-----------------|------------------------|------|--------|
|                 |                        | Mean (SE) | Mean (SE) |
|                 |                        | n     | n      |
| Black-eyed pea  | 1.53 ± 0.25b           | 4.39 ± 0.21b | 4.75 ± 0.20a |
| Hibiscus        | 5.11 ± 0.34a           | 5.24 ± 0.39b | 5.86 ± 0.37c |
| Broad bean      | 4.36 ± 0.31b           | 4.92 ± 0.28b | 5.34 ± 0.26a |
| Citrange        | 1.37 ± 0.18a           | 1.35 ± 0.18a | 1.45 ± 0.18a |
| Chrysanthemum   | 1.20 ± 0.17a           | 1.20 ± 0.18a | 1.20 ± 0.17a |
| Mountain laurel | 2.58 ± 0.26a           | 2.58 ± 0.26a | 2.58 ± 0.26a |
| Sweet potato    | 6.21 ± 0.50c           | 6.31 ± 0.50c | 6.44 ± 0.50c |

### Table 3. Host plant selection by adult *H. vitripennis* females for feeding and oviposition in a choice test

| Host plant      | % adult feeding on plant | % egg mass deposited on plant | Mean no. eggs per mass (± SE) | Total no. eggs |
|-----------------|--------------------------|------------------------------|-------------------------------|---------------|
| Black-eyed pea  | 68.4 ± 0.9a              | 49.1 ± 0.8a                  | 54.3 ± 1.8a (± SE)            | 504           |
| Hibiscus        | 12.7b                    | 48.0a                        | 13.4 ± 0.6a (± SE)            | 940           |
| Euonymus        | 0c                       | 18.9c                        | 10.5 ± 0.9a (± SE)            | 301           |
| Sweet potato    | 18.7b                    | 41.9d                        | 6.9 ± 1.72b (± SE)            | 48            |

Means within a column followed by different letters are significantly different (< 0.05, one-way ANOVA and SNK test).

### Discussion

Glassy-winged sharpshooters exhibit a broad host range in their natural habitat in Texas. The first plants species (*G = 217.9, df = 3, P < 0.0001*). Females were observed feeding on black-eyed pea in 68.7% of cases, followed by sweet potato (18.7%) and hibiscus (12.7%). Given the plant combination they were exposed to and the timing of observations, females were never seen feeding on *Euonymus*. An oviposition substrate, hibiscus was the preferred plant with 48.0% of egg masses deposited on its leaves, followed by black-eyed pea (29.1%) and *Euonymus* (18.9%). The least preferred host for oviposition was sweet potato (*G = 80.50, df = 3, P < 0.0001*). The mean size of the egg masses also differed significantly between host plant species with hibiscus, black-eyed pea, and *Euonymus* harboring the highest number of eggs per mass, compared with sweet potato (*F = 3.85, df = 3, 144, P = 0.01; Table 3). Consequently, 52.4% of all the eggs obtained were deposited by the females on hibiscus, compared with only 2.7% on sweet potato (Table 3).
to be colonized in the spring are often ornamental trees and shrubs (I. L., unpublished data), including Texas mountain laurels (native) and *Euonymus* spp. common in urban plantings. The larger spring generation then moves to other suitable plants, including grape and *Hibiscus* spp. for the summer months. Fall hosts are a variety of evergreen plants on which they feed during overwintering. Field research in Texas has highlighted the seasonal shift between host plants (I. L., unpublished data) and is supported by Adlerz (1980) and Turner and Pollard (1959) in Florida and Georgia, respectively. Brodbeck et al. (1990, 1993) showed that the xylem composition of several plants used by *H. vitripennis* varies significantly among plant species, as well as in response to seasons and photoperiod for a given host plant. They reported that adult glassy-winged sharpshooter counts over time (natural distribution was correlated to feeding preference) were strongly influenced by high concentration of amino acids in the xylem. They concluded that rearing *H. vitripennis* through a complete life cycle would be difficult to achieve as it would require a variety of plant species at the proper phenological state. However, recent studies showed that *H. vitripennis* can successfully be reared on a single host plant (Sétamou and Jones 2005, Brodbeck et al. 2007, Virla et al. 2007). Plants produced under greenhouse conditions have to be suitable for pot production, multiply easily by seed or cutting, grow relatively quickly, be inexpensive and not easily harbor undesirable insect pests and plant diseases. The quality of some plants grown indoors can be maintained through time, whereas that of others stagnate or decline quickly when potted, caged (decreased lighting and ventilation) and fed upon by insects. The studies reported herein were conducted to determine if a compromise could be made to satisfy the needs of this insect in terms of growth, development and reproduction and the limitations imposed by a mass rearing program using live plants. Because wild *H. vitripennis* exhibit strong seasonal responses to plants and our knowledge of the dynamics of host plant use remains incomplete, rearing *H. vitripennis* year-round in captivity has been no easy task.

Through these experiments, we determined that adult *H. vitripennis* females preferred hibiscus, black-eyed pea, and *Euonymus* as oviposition hosts over other plants presented to them. Significantly larger egg masses were observed on preferred host plants and embryonic survival exceeded 55% on these plants. First-instar nymph emergence occurred in ~7 d at 25 ± 0.5°C. We observed significantly longer development times as the size of the egg mass increased, although more precision in the data could have been gained by evaluating emergence every 8 h instead of once daily. It was noticed that host plants found suitable by *H. vitripennis* females often have softer leaf and stem tissue that adult females can pierce easily for both stylet and ovipositor insertion. The leaf structure of these plants may allow female *H. vitripennis* to insert their eggs deeper under the epidermis compared with the more rigid leaves of less suitable host plants. It also may be that eggs from smaller size masses exhibit a more synchronized development and emergence because females required less time for their production, depositing mature eggs already stored in the ovarioles. Production of larger egg masses would require additional nutrients and time for the production of the individual eggs. A lag time between the production and deposition of the first and last eggs may occur because the eggs are relatively large (~2.1 mm; Hummel et al. 2006) in *H. vitripennis* and egg storage capacity was estimated to 16–20 mature eggs (Hummel et al. 2006).

When we confined first instar nymphs in a cage with a single host plant, survival and development were significantly affected by plant species. Plants with softer stems growing rapidly in pots such as sweet potato, black-eyed pea, and eggplant, were excellent hosts for nymphal survival in captivity. On slow-growing plants with rigid and less succulent stems such as Texas mountain laurel, chrysanthemum, citrange, and hibiscus, nymphal survival to adulthood did not exceed 32%. On these hosts, highest mortalities (36–74%) were observed during the development of the first instar. Development time of *H. vitripennis* nymphs to adulthood was also shorter on succulent, actively growing host plants suggesting that these plants were nutritionally more suitable. Similarly, the size of the resulting adults, expressed as the hind tibia length, was larger when reared on succulent host plants (Table 2). The growth index, calculated as the ratio between the ultimate nymphal survival and the mean developmental time of nymphs, indicated that *H. vitripennis* has a higher population growth potential on sweet potato, black-eyed pea, and eggplant relative to the other host plants tested. In addition, potted Texas mountain laurel was the least suitable host plant for population growth in captivity (Fig. 2). Brodbeck et al. (2007) reported that the concentration of essential amino acids in the xylem fluid of host plants that consistently support the development of *H. vitripennis* was positively correlated to immature development and adult performance.

Adult feeding preferences observed during early mornings in the greenhouse was similar from our observations on immature *H. vitripennis* survival and development in the laboratory. Black-eyed peas were used more often by adult females for nutrient acquisition, followed by sweet potato and hibiscus. *H. vitripennis* adults are able to pierce through the bark of shrub and tree stems. It is possible that the nymphs, particularly the smallest nymphs may encounter mechanical constraints that limit or prevent feeding on certain plants such as Texas mountain laurel and citrange, more so when potted plants show limited stem growth. When provided certain combinations of plants, some were never selected for feeding by the adults. These plants may be adequate under natural conditions at certain times of the year but are less suitable when grown in pots, as compared with other available plants. In a no-choice test, Brodbeck et al. (1995) did report 100% mortality of *H. vitripennis* adults feeding on *Euonymus* after 6 d. Sweet potato was an interesting plant to study. Highly palatable and
suitable for feeding of both nymphs and adults, it was less attractive for oviposition even if embryonic survival was high. We suggest that this observation is related to the fact that the leaves of this plant are thin (≈0.2 mm) which may render ovipositor insertion more difficult (plant tissue tears). This would be exemplified by the uncharacteristic shape of the egg masses observed on sweet potato (often bent, shallow insertion, torn tissue).

Given the project goals, the most suitable plants studied fell into two classes. Succulent and rapidly growing black-eyed pea, sweet potato, and eggplant were highly suitable as feeding hosts (Figs. 1 and 2). In addition to black-eyed pea, the slow growing woody plants such as hibiscus and Euonymus had more desirable characteristics as oviposition substrate. Sweet potato, hibiscus, and Euonymus are well adapted for year-round greenhouse production and are robust enough to withstand feeding by many insects at a time. Although it is possible to rear *H. vitripennis* using exclusively black-eyed pea (Sétanou and Jones 2005), this plant is somewhat more sensitive to low (germination rate compromised) and high (plant health compromised) temperatures such as the temperatures recorded in Texas. In addition, the black-eyed pea does not withstand high numbers of adults or nymphs and is prompt to wilting under insect pressure. Sweet potato and hibiscus are sensitive to whitelies, and black-eyed pea to thrips in greenhouse settings. Black-eyed pea and sweet potato are not a naturally occurring host plants in Texas. However, we found that they allowed satisfactory rearing of the different developmental stages of *H. vitripennis* under greenhouse conditions. We find useful to rear the nymphs on succulent plants and use a combination of succulent and woody hosts to rear the adults to promote reproduction. Because glassy-winged sharpshooters are polyphagous, it is possible that they acquire essential nutrients by exploiting a variety of hosts at any given time (Brodbeck et al. 1990). The continual shift in host plant selection may be critical to this species as a survival mechanism to counter host plant variations in xylem composition. Milanez et al. (2001) in Brazil reported similar alternative host selection behavior in two other cicadellids, *Dilobopterus costalimai* Young and *Oncometopia facialis* (Signoret), transmitting *X. fastidiosa* in citrus. In another study, Milanez et al. (2003) reported 40–62% mortality in adult males and females *D. costalimai* and *O. facialis* caged on potted sweet orange, *Citrus sinensis* (L.), for 96 h (no-choice test situation). Sweet orange is a common field host of these cicadellids. However, better survival rates and significantly more feeding were observed when providing these insects with plant species in the Asteraceae family. Data by Brodbeck et al. (1995) highlighted potential deficiencies in the use of single dietary sources by rapidly growing *H. vitripennis* immatures. In captivity, losses due to embryonic and nymphal mortality in *H. vitripennis* can be reduced using a combination of the most suitable host plants. Despite these efforts, it is difficult to reach over 90% survival under the best greenhouse conditions and all research experiments using immatures are affected by the difficulty to rear glassy-winged sharpshooters in homogenous culture.

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