SPATIAL POPULATION DYNAMICS AND OVERWINTERING BIOLOGY OF THE GLASSY-WINGED SHARPSHOOTER IN CALIFORNIA'S SAN JOAQUIN VALLEY.

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ABSTRACT

The purpose of this project is to define specific environmental constraints that influence glassy-winged sharpshooter (GWSS) population dynamics and overwintering success. The production of xylem excreta was used as a measure of GWSS feeding rates. GWSS individuals held at 8.3 to 31.1°C exhibited a positive linear relationship between xylem excreta per adult and temperature. A low temperature feeding threshold was estimated to be 13.3°C. A Logan Type I model described the relationship between temperature and daily excreta production (mg). The percentage of adults that produced xylem excreta was significantly different among tested temperatures ($P < 0.0001$), but not between sexes. From 24.6–35.1°C, all adults produced xylem excreta, but the percentage of adults producing excreta declined as temperature decreased. At temperatures ≤ 13.3°C, only 1 of 41 adults tested produced xylem excreta. Using percent data from 8.3–24.6°C, a linear increase in the percentage of adults that produced xylem excreta was observed and provided a lower threshold temperature of 10.0°C, where no xylem excreta were produced. Results from these experiments will be coupled with climatological data to help to spatially define where GWSS can be expected to persist in the agricultural landscape and identify where continued management efforts can be directed to limit introductions into currently non-infested areas.

INTRODUCTION

Climate appears to play a significant role in the geographic distribution of diseases caused by *Xylella fastidiosa* (*Xf*) in California and throughout the southeastern U.S. (Purcell 1997). Similarly, populations of glassy-winged sharpshooter (GWSS), *Homalodisca vitripennis*, in the southeastern US appear to be constrained by climatic factors that limit the pest's establishment and persistence (Hoddle 2004). Presently, limited information exists on the overwintering biology and ecology of GWSS in the San Joaquin Valley of California. Our results from Year 1 of this project indicated that survival and feeding activity of GWSS adults were significantly influenced by temperature and exposure duration. In particular, low temperatures caused rapid mortality. Access to host plants for feeding was a critical factor for survival at high temperatures (≥ 20°C). In Year 2, models were developed to approximate the influences of temperature on GWSS survival with changes in exposure duration. Additional studies focused on the impacts of temperature on GWSS feeding rates with the aim of determining the thresholds below which feeding stops and to further determine the critical duration of time spent in this non-feeding state, which may result in increased mortality. The results below and future experiments will advance our ability to define the specific environmental constraints that influence GWSS population dynamics and overwintering success by increasing our present understanding of the overwintering requirements of GWSS with a focus on critical environmental and host species factors that may limit population distribution in the Central Valley of California.

OBJECTIVES

1. Identify the critical environmental constraints that influence the spatial population dynamics and overwintering success of GWSS in California's Central Valley.
2. Characterize the impact of host plant species succession on the overwintering survivorship of GWSS populations that constrain the insect's ability to become established and persist throughout the San Joaquin Valley.

RESULTS

Objective 1:

(1) Effects of temperature on the survival of GWSS adults

Based on laboratory data collected in Year 1, the time to 50% mortality (LT_{50}) of GWSS adults was estimated at each tested constant temperature (-1.0, 4.0, 8.3, 18.8, 24.6 and 40.1 °C ± 1°C) and feeding regime [water only (WO), host plant only (HPO), no plant or water (NPW)] using the methods of Kim and Lee (2003). The model estimated that the longest time to 50% mortality at the optimum survival temperature (for each feeding regime) occurred at 12.2 days (9.6°C), 11.4 days

(6.7°C), and 74.9 days (21.1°C) under the regimes of WO, NPW, and HPO, respectively (Figure 1.). Regardless of feeding regime, the skewed bell-shaped curve of temperature-dependent model indicated that GWSS survival was more seriously impaired by exposure to temperatures below the optimum temperature than temperatures above the optimum temperature.

An ongoing experiment was designed to determine the effect of fluctuating diurnal temperatures on adult GWSS survival during the winter season. Temperature-controlled incubators were set to simulate the hourly temperature cycles in three geographically distinct locations in California: Riverside (Riverside County; daily maximum ca. 16°C), Oakville (Napa County; daily maximum ca. 13°C), and Buntingville (Lassen County; daily maximum ca. 9°C) during the month of January. To date, under the simulated winter regime of Buntingville, GWSS adults experienced 100% mortality within 2 weeks, 50% mortality was observed at 5 days, and no xylem excreta production was observed. In contrast, at the end of the first month under the simulated regimes of Riverside and Oakville, 70.0 and 66.7%, respectively, of the GWSS individuals have survived with xylem excreta production observed in both treatments. These initial findings imply that short-term exposure to temperatures above the feeding threshold could provide adequate feeding time to permit GWSS survival in contrast to areas where the temperatures remain below or close to the feeding threshold. These studies will continue until all insects die or greater than 50% mortality is recorded.

(2) Effects of temperature on the feeding of GWSS adults

Laboratory experiments were continued on the effects of temperature on xylem excreta production by GWSS adults using the Parafilm sachet method (Pathak et al. 1982), which assumes a positive correlation between feeding activity and xylem excreta production (Paguia et al. 1980, Padgham and Woodhead 1988). GWSS adults were individually confined inside a Parafilm sachet (7.5 x 6.5 cm) that was attached to the main stem of a host plant ('Frost Eureka' lemon plant) and sealed after enclosing the insect. Plants were transferred to environmental chambers (10 L: 14 D hours) at six constant temperatures: 8.9, 13.3, 18.8, 21.7, 24.6, 31.1, 35.1, and 40.8°C ± 1°C. After 48 hours feeding, GWSS xylem excreta production (mg) was determined by weighing sachets on an electronic balance before and after removal of excreta. One insect per host plant was considered a replicate, and each treatment had ten to twelve replicates per sex. Treatment effects were determined using ANOVA (P = 0.05) and treatment means separated using the Student-Newman-Keuls (SNK) test. Data presented herein are mean values (± SEM) unless otherwise noted.

Forty out of the 194 GWSS individuals tested did not survive the 2-day feeding period in the Parafilm sachets. Six adults that produced xylem excreta in the sachet died from drowning (1, 1, 1, and 2 adults at 21.7, 24.6, 31.7, and 35.1°C, respectively). Response variables from the drowned adults were not included in the data analysis. No adults survived at 40.8°C, whereas survival was higher than 80% within the range of 8.3–35.1°C (Table 1). There was no difference in the survival rates of males and females ($\chi^2 = 0.48$; $df = 1$; $P > 0.05$), but temperature was a significant factor influencing survival ($\chi^2 = 119.02$; $df = 7$; $P < 0.0001$). Xylem excreta production by GWSS individuals that survived the 2-day trial was highly dependent upon temperature ($F = 38.53$; $df = 5, 129$; $P < 0.001$), but there was no significant difference in xylem excreta between males and females ($F = 0.1933$; $df = 1, 129$; $P > 0.05$) (Table 1). Therefore, data from males and females were pooled for regression analysis. The highest xylem excreta production was 4,963.0 ± 1,317.5 mg per adult at 31.1°C, while no xylem excreta was observed at 8.3°C. Intriguingly, there was high variation in the excreta production among individuals held at 35.1°C (e.g., the lowest and highest excretion amounts for an individual ranged from 7.2 and 25,241.7 mg, respectively). Hourly excreta production (Table 1) was influenced by temperature ($F = 25.80$; $df = 6, 153$; $P < 0.001$).

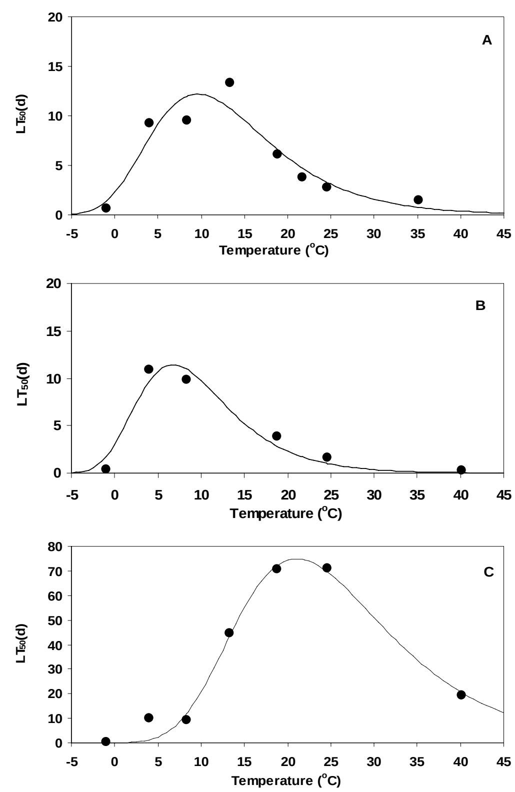

Figure 1. Effects of temperature on time to 50% mortality (LT_{50}) at constant temperatures under different feeding conditions: (A) water only; (B) no water or host plant; and (C) host plant.

Data from individuals (males and females pooled) held at 8.3 to 31.1°C indicated a positive linear increase in xylem excreta per adult as temperature increased (Y = 102.74– 2350.5, $R^2 = 0.7314$; $df = 1, 5$; $F = 10.89$; $P < 0.05$). A low temperature feeding threshold was estimated to be 13.3°C. A Logan Type I model (Logan et al., 1976) was used to describe the relationship between temperature and daily excreta production (mg) ($R^2 = 0.987$; $F = 75.14$; $df = 3, 6$; $P < 0.01$) (Figure 2). Xylem excreta production increased gradually up to 21.7°C and then sharply increased to the temperature of maximum production (2,833 mg) at 33.0°C. Feeding activity in terms of xylem excreta production abruptly declined between the temperature of maximum production and the upper threshold of production (36.4°C).

The percentage of adults that produced xylem excreta was significantly different among the tested temperatures ($\chi^2 = 131.58$; $df = 7$; $P < 0.0001$), but not between sexes ($\chi^2 = 1.69$; $df = 1$; $P > 0.05$). From 24.6–35.1°C, all adults produced xylem excreta, but the percentage of adults producing excreta declined as temperature decreased (Figure 3). At temperatures ≤ 13.3°C, only 1 of 41 adults tested produced xylem excreta during the 2-day period. Using percent data from 8.3–24.6°C, a positive linear increase in the percentage of adults that produced xylem excreta was observed ($Y = 6.3986x – 63.778$, R^2=0.9379; df =1, 5; $P < 0.01$) and provided a lower threshold temperature of 10.0°C, where no adult would produce xylem excreta. This lower threshold (10.0°C) is more conservative than the 13.3°C threshold obtained from the excreta amount model.

Table 1. Xylem excreta production by GWSS adults during 2-d feeding on 'Eureka' lemon tree at constant temperatures.

Temp. (°C)	N[1]	Mean ± SEM production (mg) of xylem excreta per surviving adult						
		n	Males	n	Females	n	Total	Excreta/h
8.3	23	11	0.0 ± 0.0c	10	0.0 ± 0.0e	21	0.0 ± 0.0e	0.0 ± 0.0d
13.3	22	10	0.0 ± 0.0c	10	47.8 ± 47.8de	20	23.9 ± 23.9e	0.5 ± 0.5d
18.8	23	11	105.6 ± 98.1c	12	340.7 ± 323.3cd	23	228.2 ± 173.1d	4.8 ± 3.6d
21.7	21	10	325.6 ± 140.9b	10	712.2 ± 310.0bc	20	518.9 ± 171.6c	10.8 ± 3.6c
24.6	25	12	1766.5 ± 987.6a	12	2302.0 ± 1027.6ab	24	2034.2 ± 699.2b	42.4 ± 14.6b
31.1	27	12	2993.9 ± 931.9a	12	6932.0 ± 2384.3a	24	4963.0 ± 1317.5a	103.4 ± 27.4a
35.1	25	10	4156.6 ± 1286.4a	12	4025.0 ± 2064.1ab	22	4084.8 ± 1240.9ab	85.1 ± 25.9a
40.8	24	0	—[3]	0	—	0	—	—

Means followed by same letter within each column not significantly different (Student-Newman-Keuls test, P<0.05).
[1] The number of tested adults (both males and females).
[2] Hourly xylem excreta production of adults (combined males and females).
[3] No data observed due to adult mortality.

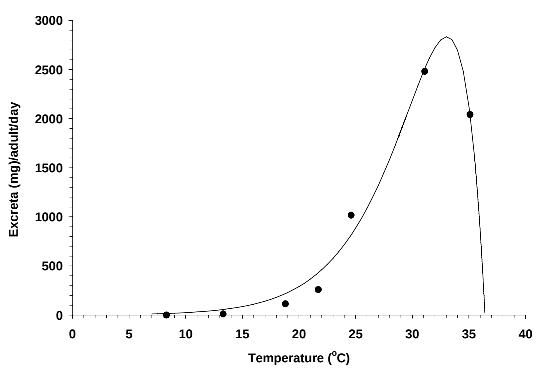

Figure 2. Relationship between temperature (°C) and daily mean xylem excreta (mg) production per GWSS adult on 'Eureka' lemon tree based on Logan et al. (1976) model.

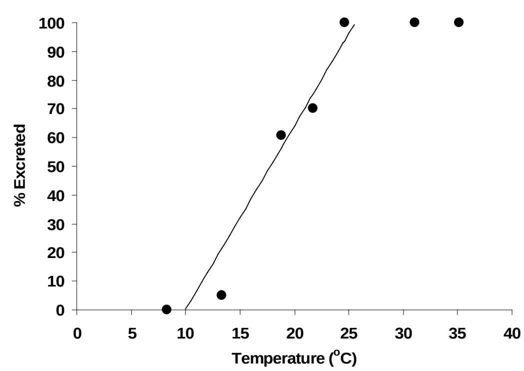

Figure 3. Linear relationship between temperature and percentage adults producing xylem excreta between temperatures 8.3–24.6°C.

Objective 2

Due to concerns about maintaining live GWSS adult females in field cages in quarantined areas in the San Joaquin Valley, our studies were postponed until we could redesign the methods so that potential escape of GWSS individuals would pose minimal risk to the agricultural community. Methods were modified in the following manner: only GWSS males will be used that have been reared on *Xylella*-free host plants; replications have been reduced to 5 cages each at two test locations (Bakersfield and the Kern National Wildlife Refuge, Kern County); test plants will be double-caged with sticky traps and imidachloprid-treated plants in the outer cage; and the observation period will be reduced from 5 to 2 months. This study will be conducted in December 2006 and January 2007.

CONCLUSIONS

Findings from our studies clearly indicate that survival and feeding activity of GWSS adults are significantly influenced by temperature and exposure duration. In particular, low temperatures (< 10°C) caused rapid mortality. Availability of host plants was a critical factor for survival at high temperatures (≥ 20°C). This project has a high probability of success in terms of generating significant new information regarding the thermo-biology of GWSS in California. Models generated from these data will allow for the spatial estimation of GWSS overwintering success.

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WEB GEOGRAPHIC INFORMATION SYSTEMS FOR PIERCE'S DISEASE AND GLASSY-WINGED SHARPSHOOTER MAPPING IN CALIFORNIA

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ABSTRACT
The establishment of the non-native glassy-winged sharpshooter (GWSS) in California has seriously affected the epidemiology of Pierce's disease (PD) throughout the agricultural landscape. Geographic Information Systems (GIS) offers the opportunity to aid in the management of PD as well as in epidemiological research. We developed a web-based GIS site with spatial and temporal data relating to PD/GWSS based on feedback from a web-based survey emailed to 2005 PD research symposium participants. The survey focused on participants' interests in PD-related data, spatial analysis, and additional comments. The resulting webGIS displays various data layers of value to PD/GWSS researchers, including climatic variables and proximity analyses. Our survey results indicate an interest among PD/GWSS researchers in temporal analyses and some interest in data sharing. In addition, the data survey provides insight to PD researchers' attention to investigating PD patterns at a landscape scale and spatial modeling. However, there still exist some barriers preventing access to all statewide PD and GWSS data that will have to be overcome in order to develop and maintain a comprehensive statewide PD/GWSS webGIS system.

INTRODUCTION
Pierce's disease (PD), caused by the *Xylella fastidiosa* (*Xf*) bacterium, has been present in California for about 100 years. However, the introduction of the non-native glassy-winged sharpshooter (GWSS), *Homalodisca vitripennis*, in recent years has increased the ability for the bacterium to spread. GWSS and PD have the ability to invade areas outside of their natural range and pose serious threats to the health of agricultural crops such as alfalfa, almond, citrus, coffee, grape, peach, plum and oleander (Hoddle, 2004). In particular, the GWSS vector has contributed to above normal grapevine losses in Southern California and could influence grapevine losses in Northern California.

Past studies indicate a linkage between the local environment and PD incidence and spread. For instance, Hoddle (2004) indicated the improbability of GWSS colonizing areas north of California due to the climatic condition of cold stress. Fiel and Purcell (2001) found temperatures below 12 to 17º C and above 34 º C to negatively affect *XF* growth in vitro and in potted grapevines. Also, proximity to citrus crops or riparian habitats appears to influence PD incidence (Perring et al. 2001; Purcell and Saunders, 1999). The intersection of Geographical Systems (GIS) and the Internet has allowed the provision and visualization of geospatial data over the web possible. Web-based GIS (webGIS) provides insight into relationships between environmental variables at multiple scales to aid in natural resource management (Kearns et al., 2003). The ease of web-based access to spatial data is particularly advantageous for individuals to develop epidemiological hypotheses about distribution and spread at several scales – from vineyard to county to regional. This paper documents our progress in developing one for the PD/GWSS community.

OBJECTIVES
The goals for this project were twofold:
1. Provide researchers with a web-based tool to access spatial and temporal data relating to PD/GWSS in California at the landscape scale
2. Provide initial spatial analysis of known crop relationships to GWSS movements.

To achieve these goals, we developed a web-based GIS site and conducted a web-based survey to acquire user input about data needs relating to GWSS/PD research.

METHODS
WebGIS
We developed a webGIS site titled "Pierce's Disease & GWSS Mapping" utilizing ESRI's ArcIMS software (Figure 1). Determining which data to include in the webGIS was based on an initial evaluation of publicly available GIS data relevant to GWSS/PD. The GIS data were then downloaded from the web, processed, and integrated in the webGIS and finalized after survey responses were assessed. In addition to collecting data from the web, we developed and included a "Growing Degree-Days for 2005" and "Weather Stations" spatial data layers (Figure 2) based on a non-spatial degree-days model by UC Statewide Integrated Pest Management Program (http://axp.ipm.ucdavis.edu/WEATHER/ddretrieve.html).