DISPERSAL AND MOVEMENT OF THE GLASSY-WINGED SHARPSHOOTER AND ASSOCIATED NATURAL ENEMIES IN A CONTINUOUS, DEFICIT-IRRIGATED AGRICULTURAL LANDSCAPE

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ABSTRACT

A combination of field and laboratory experiments in this study have been designed to advance our understanding of the operative host-plant factors utilized by adult glassy-winged sharpshooters (GWSS) and associated natural enemies as long-range cues to locate feeding and oviposition hosts in a complex agricultural landscape. Specifically, a second year of field studies have been conducted to determine the influence of continuous deficit irrigation regimes implemented in sweet orange cv. 'Valencia' oranges on the population dynamics of GWSS and other associated natural enemies. Dispersal and population dynamics of GWSS were monitored under continuous irrigation treatments receiving 60%, 80%, and 100% of evapo-transpiration (ET_c) rates. Similar to the results obtained in our 2005 season, citrus trees irrigated at 60% ET_c had warmer leaves, significantly higher xylem matric potential, and fewer adult and immature GWSS than experimental trees irrigated with 80% and 100% ET_c. Mean numbers of adult and nymphal GWSS collected from beat samples and observed in visual inspections were numerically higher in the 80% versus 100% ET_c treatments. In caged experiments using sweet orange cv. 'Washington navel' and avocado cv. 'Hass' maintained under different continuous deficit irrigation illustrated GWSS population shifts that occurred between plants. Adult GWSS showed a preference for contact with surplus-irrigated plants of both species compared with plants under continuous deficit irrigation, with a stronger response evident in the avocado trials. During preliminary nutrition trials with overwintered adults, GWSS that landed on plants showed a slight preference for settling on plants fertilized with ammonium versus nitrate averaging over 3 trials. An olfactometer system for studying the response of GWSS to host-plant volatiles has been built and the airflow dynamics adjusted to equally integrate odor fields from humidity or volatile sources. However, evaluation of the data (number of insects landing on the target) to date shows no conclusive differences among a variety of treatments, suggesting that GWSS may not use olfactory cues during host location, or that olfaction is used only in conjunction with visual cues. Identifying how the dispersing lifestages of GWSS locate and exploit specific host species will begin to provide the necessary information required to develop strategies for control of this highly mobile insect and the spread of *Xylella fastidiosa* into susceptible crops.

INTRODUCTION

The glassy-winged sharpshooter (GWSS) is a highly polyphagous and mobile insect utilizing numerous plant species as both feeding and oviposition hosts (Adlerz, et al. 1979, Daane et al. 2003, Groves et al. 2003). Recent research has documented that different host plant species are not equally utilized by all GWSS lifestages. Mizell and Andersen (2003) report that host plant xylem chemistry plays a key role in the regulation of GWSS feeding and oviposition over a wide range of host plant species. Similarly, Daane and Johnson (2003) concluded that ornamental landscape plant species greatly influence GWSS seasonal population biology. Specifically, ornamental species which favorably support adult GWSS oviposition and feeding do not equally support comparable nymphal populations. Although significant new information has become available regarding the sequence of hosts in which GWSS populations thrive, little is understood about the host-location strategies of GWSS, which are critical behavioral responses that assist the insect in locating suitable hosts. Successful insect-host associations depend upon an insect's ability to locate a suitable host(s) in a complex, heterogeneous landscape. Mechanisms of host location in many phytophagous insects are often mediated by long-range, semiochemical cues arising from their host plant(s), which vary by plant physiological conditions including nutrition (available nitrogen and carbohydrate), xylem water potential, and plant age or developmental stage (Finch 1986). Similarly, we have an incomplete understanding of host-selection cues utilized by the mymarid egg parasitoids of GWSS, which may involve the host (GWSS egg mass), the host plant, or a combination of both. Ongoing experiments in this study will increase our understanding of the operative host-plant factors utilized by adult GWSS and associated natural enemies as cues to locate feeding and oviposition hosts in a complex agricultural landscape. Identifying how the dispersing lifestages of GWSS locate and exploit specific host species will begin to provide the necessary information required to develop strategies for control of this highly mobile insect and further limit the spread of *Xylella fastidiosa (Xf)* movement into susceptible crops.

OBJECTIVES

1. Evaluate host-plant factors utilized by adult GWSS and associated natural enemies as long-range cues to locate feeding and oviposition hosts in a complex agricultural landscape.
2. Monitor adult GWSS movement and host selection behavior, ovipositional preference, and nymphal population performance on host plants maintained under continuous irrigation deficits

Objective 1

Olfactometer

An olfactometer system for studying the response of GWSS to host-plant volatiles has been built and the airflow dynamics adjusted to equally integrate odor fields from humidity or volatile sources. Bioassays have been performed using spring adult GWSS collected from infested areas in Bakersfield and Fillmore, CA area. Behavioral responses of the adult insect replicates tested have been evaluated using the Noldus *Observer XT* software in an effort to measure the accuracy of taped recordings. Preliminary bioassays compare the level of GWSS responses to singly presented, humidified odor plumes. Preliminary tests demonstrate no differential response between the sexes; and to date, no sexual difference has been found in other leafhoppers orienting to plants or plant odors. However, evaluation of the data (number of insects landing on the target) to date shows no conclusive differences among a variety of treatments, suggesting that GWSS may not use olfactory cues during host location, or that olfaction is used only in conjunction with visual cues. To date, most trials were made with field-collected GWSS. Fifty trials of *Gonatocerus ashmeadi* behavior under a variety of choice treatments have been recorded in the Y-tube olfactometer, but analysis by the Noldus *Observer* is scheduled for fall and winter.

Objective 2

Laboratory Choice Bioassays

Field-collected GWSS adults were caged with a choice of two plants grown under two nutritional treatments, and with a choice of two plants grown under two water-deficit treatments. The nutritional study was conducted on citrus plants, while the water-deficit study was conducted separately on citrus and avocado to allow a comparison of the behavior of GWSS toward host plants with different water-deficit responses. During preliminary nutrition trials with overwintered adults, GWSS that landed on plants showed a slight preference for settling on plants fertilized with ammonium averaging over the 3 trials. However, means of 3 additional trials (12 replicates) conducted with summer adults did not show any apparent preference for either treatment. The mean number of GWSS egg masses deposited on the citrus under the two nutritional treatments were also similar (3.25 per NO_3 plant, 2.67 per NH_4 plant). Up to and during the water-deficit trials, the water-deprived avocado plants showed signs of stress, including loss of stem and leaf turgor and leaf excision, whereas the citrus plants showed no obvious signs of stress. The GWSS showed a preference for contact with surplus-irrigated plants of both species compared with plants under CDI and GDI, with a stronger response evident in the avocado trials. The recent results are consistent with preliminary data gathered previously from overwintered adults. However, although the number of egg masses deposited on plants was higher on surplus-irrigated avocado compared with CDI and GDI plants, GDI citrus had more egg masses than surplus-irrigated citrus. The latter represented a change from the preliminary data, where surplus-irrigated plants of both species had consistently higher numbers of egg masses. The preliminary trials were repeated because the overwintered GWSS suffered heavy mortality.

Laboratory no-choice bioassays

Preliminary results from 10 GWSS of each sex confined in sachets on citrus receiving supplemental fertilization (NH_4 versus NO_3) revealed no significant differences in excreta production between the treatments, suggesting no differential feeding rates on plants of either treatment. This agrees with results from choice tests. However, mortality was high in the sachets, so the test will be repeated with improved sachets. More excreta was produced on average on deficit-irrigated citrus and avocado than on surplus-irrigated plants, but the differences were not significant. Further replication is planned to confirm the observed trend, especially because it appears to conflict with results of choice tests. Secondary conclusions were drawn from the data, including that females produced significantly more excreta than males across all treatments, suggesting greater feeding rates by females. Furthermore, excreta production was significantly higher in the afternoon than in the morning, suggesting that feeding is a diurnal activity. Lastly, excreta production on avocado was <10% of the amount produced on citrus, suggesting that avocado is a less preferred host or that avocado branches are not suitable feeding sites.

CDI and GWSS Population Dynamics

Studies were conducted on the Citrus Experiment Station, UC Riverside, in Field 5 and the continuous deficit-irrigation schedules evaluated in this experiment included trees irrigated at 100, 80, and 60% *ETc* throughout the 2005-06 crop year.

Effect of irrigation deficit on citrus trees

Citrus trees irrigated with 60% *ETc* had warmer leaves than the trees irrigated with 100% and 80% *ETc* throughout the season. Although no difference in leaf temperature was evident between the 100% and 80% treatments, results suggested that citrus trees under the 80% deficit irrigation treatment had physiological changes at detectable levels. To support our observations, pressure chamber measurements also showed a difference in water potential between treatments. From mid-May to early June, mid-day leaf water potentials were not different among treatments. Perhaps the unusual 2005 rainy season contributed to an accumulation of soil water, which was exploited by deeper roots and resulted in undetectable differences in water potential among treatments using the pressure chamber. A clear pattern in water potential measurements was observed from early June to late July. Pressure chamber measurements steadily increased and were higher in the 80% and 60% *ETc* treatments than the 100% *ETc* treatment. However, after July 25th, we initiated pre-dawn sampling and observed that no difference existed between the 100% and 80% *ETc* treatments, but these differed from the 60% *ETc* treatment.

Effect of irrigation deficit on insect distribution

Beat net samples documented the presence of GWSS adults and beneficial insects. The numbers of GWSS collected were quite low, never exceeding one adult for every sample. The most common beneficial arthropods were spiders, adult lacewings, and lady beetles. GWSS population densities increased from early June to late July, followed by a decline that continued through early September.

Examining yellow trap counts, GWSS adults collected were slightly higher in the 100% and 80% *ETc* treatments compared to the 60% *ETc* treatment. Few GWSS were found on sticky traps from mid-April to late June. The yellow sticky traps showed a steady increase in insect activity from late June to a peak in late July, which was followed by a sharp decrease in the numbers of insects caught in all treatments. During the early and middle part of the peak, more GWSS were caught on traps located in the 100% and 80% *ETc* treatments than in the 60% *ETc* treatment. However, during the latter part of the peak, the number of GWSS caught on traps located in the 60% *ETc* treatment was higher than the numbers caught in the 100% and 80% Et_c treatments. During this period (mid-August), trap catches averaged two GWSS per trap per week.

Population density patterns found during our visual counts follow the patterns observed for both trap counts and beat samples. Visual counts show an increase in the number of GWSS per tree from late June to a peak in mid-July. Throughout the season, more GWSS adults were found on trees located in the 100% and 80% *ETc* treatments than in the 60% *ETc* treatment. The number of egg masses collected were quite low, never exceeding one mass for every observation. However, there seems to be two periods of egg deposition. One period corresponded to the smaller first GWSS generation (May) and another period corresponded to the second larger generation (July). In the second oviposition period, however, few fresh GWSS egg masses were found and more egg masses were observed on trees located in the 100% and 80% *ETc* treatments than in the 60% *ETc* treatment.

In summary, our measurements of plant condition suggested that there were no differences in leaf temperature and water potential between trees irrigated at 100% and 80% *ETc*. Trees irrigated with 60% *ETc* had warmer leaves, higher water potential, and consequently hosted a smaller number of GWSS than the well irrigated trees. Patterns of insect number throughout the season for trap catches, beat samples, and visual inspection were somewhat correlated, suggesting a solid estimate of population density. Interestingly, relatively more GWSS adults and egg masses were found on trees irrigated at 80% *ETc* than 100% *ETc* perhaps due to a less dilute concentration of available carbohydrate.

CONCLUSIONS

We believe that findings from this project have generated significant new information regarding the host selection behavior and movement patterns of GWSS in California. Combined results from lysimeter studies and field studies evaluating population dynamics illustrate that GWSS populations varied between plants maintained under varying, CDI treatments. Further, trees irrigated with 60% ET_c had warmer leaves, higher water potential, and also hosted fewer GWSS than the well irrigated trees. Patterns of adult GWSS capture throughout the 2005 sampling interval (July – August), estimated from a combination of yellow traps, beat samples, and visual inspections, suggest comparatively higher population densities of GWSS in CDI treatments 80 and 100% ET_c. Furthermore, higher counts of GWSS adults and egg masses were found on trees irrigated at 80% ET_c compared with the 100% ET_c treatment. A more complete understanding of the operative host-plant cues that influence GWSS population dynamics may result in the deployment of strategies to focus control efforts, enhance the efficacy of biological control, and effectively limit the spread of *Xf* induced diseases to susceptible crops.

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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