ASSESSING THE POST-WINTER THREAT OF GLASSY-WINGED SHARPSHOOTER POPULATIONS

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ABSTRACT

After glassy-winged sharpshooter (GWSS), *Homalodisca vitripennis*, arrived in California, it was believed that the insect would establish throughout much of the northern agricultural production areas. However, GWSS appears to be limited to discrete regions within the San Joaquin Valley where winter temperatures are mild and the temperature rarely drops below freezing. Prior research indicates that GWSS adults cannot feed at maximum daily temperatures below 50°F, thereby reducing its ability to survive cold winters. We plan to verify the impact of cool temperatures on GWSS adults by exposing them to a regime of seasonal temperatures (within temperature cabinets) that reflect some of the marginal areas where we expect GWSS to poorly survive California winters. The goal of the study would be to determine the ability of GWSS adults to survive winter conditions around the state by subjecting GWSS adults to low temperatures with daily temperatures below 10°C and nightly temperatures above 0°C. Using temperature records to calculate numbers of cooling degree days, we plan to construct maps to delineate areas where post-winter GWSS mortality should be substantial, thereby providing a tool to estimate the springtime GWSS threat to different regions. If successful, post-winter GWSS survival maps could be produced each spring (e.g., April) that would provide estimates of where GWSS populations should be absent or minimal because of winter conditions.

INTRODUCTION

The initial arrival of GWSS, *Homalodisca vitripennis*, into California's Orange and Ventura Counties was predicted to dramatically change Pierce's Disease (PD) epidemiology within infested areas (Varela et al. 2001). The insect soon spread into other southern California localities. PD devastated the wine grape industry in the Temecula Valley resulting in significant losses. First detected in Kern County in 1998, GWSS is now present in the San Joaquin Valley. However, the rapid population expansion first observed in southern California appears to be limited to discrete regions within the San Joaquin Valley coincident with citrus production areas where overwintering populations are highest and winter temperatures are relatively mild compared to locations elsewhere in the San Joaquin Valley. Additionally, persistent, localized GWSS populations are present within the urban areas of Fresno, Sacramento, and San Jose Counties where a range of perennial plant host types and slightly elevated daytime high and evening low temperatures might favor the survival and persistence of established populations.

Hoddle (2004) used the climate modeling program "CLIMEX" to estimate the potential worldwide distribution of GWSS. His reported estimates for California (when all localities received supplemental irrigation water) suggested that GWSS could establish reproducing populations along much of the California coast from San Diego north to the Eureka vicinity and within the Central Valley from Bakersfield north to the Redding vicinity. He did propose cold stress as a potential limitation to the establishment of GWSS in states north of California (i.e., Oregon, Washington). However, other observations and studies suggest that low winter temperatures may be the "bottleneck" that limits GWSS survival and distribution in the higher altitudes and northern regions of California. Pollard and Kaloostian (1961) observed that overwintering GWSS generally remained sessile at temperatures below 49°F (9.4°C) and that first flights occurred only after the ambient air temperature had reached or exceeded 52°F (~11.1°C). Russell Groves et al. (unpublished data from 2003) observed that seasonal patterns of GWSS capture on sticky traps within and among selected, perennial tree crops (e.g. navel, lemon, olive, avocado, sweet cherry, pomegranate, grape, peach, and plum) north of Porterville, CA, were surprisingly similar in the temperature requirements necessary for flights of adult insects. Specifically, regressions of logit-transformed, cumulative proportions of adults captured against estimated cumulative degree-day totals yielded peak correlation coefficients when a base flight temperature of 53°F (~11.1°C) was used in the development of the model. This value is very near to that estimated by

Pollard and Kaloostian (1961). CDFA-funded research showed that GWSS adults do not feed near or below 50°F (10.0°C), and that individuals will die if held below 50°F for long periods (e.g., 15 or more days) even in the presence of food and water (Johnson et al. 2006). Also of significant importance is the fact that the overwintering adult cohort is responsible for producing the offspring in the spring. Given this, if the daily maximum temperature infrequently surpasses the thermal activation threshold (50°F) necessary for GWSS ingestion, then GWSS survivorship may be curtailed by extended periods of cool temperatures in specific microclimatic regions of California. We have experimentally shown this phenomenon using programmable, temperature cabinets to simulate fluctuating diurnal temperature regimes based on January temperatures in the locations of Riverside (Riverside County.), Oakville (Napa County), and Buntingville (Lassen County), CA. In our study, the temperature for Riverside always exceeded 50°F (= 10°C), and about 20% of the test insects remained alive after 115 days; for Oakville it exceeded 50°F for 18 hours a day and only 10% of GWSS survived after 115 days; and for Buntingville the temperature never reached 50°F, and the entire test group died within 20 days (Youngsoo Son et al., unpublished data). We have applied the concept of cooling degree-days (CDD) to estimate the impact of cool temperatures on GWSS survival. The equation for CDD_{GWSS} may be expressed as:

$$\text{Daily } CDD_{GWSS} = \begin{bmatrix} |T_m - 50|, \text{if } T_m < 50\ ^{o}\text{F} \\ 0, otherwise \end{bmatrix}$$

where T_m = daily mean temperature in a given locality, $| T_m - 50 |$ = absolute value of difference between T_m and the feeding threshold of 50°F when the mean daily temperature is lower than 50°F. Daily CDD_{GWSS} equals zero if the daily mean temperature (T_m) is higher than 50°F. By summing the CDD_{GWSS} for each day over an extended period, one can estimate the cumulative CDD_{GWSS} over the specified time period for that locality. Using unpublished field data collected by Don Luvisi, Farm Advisor *Emeritus*, in 2001-2002, we plotted the relationship between cumulative CDD_{GWSS} and GWSS survival at various sites in the vicinity of Bakersfield (Kern County). Based on a curvilinear regression, GWSS survival dropped to 10% or less when about 230 CDD_{GWSS} are accumulated. Further studies are needed to better refine the relationship between cumulative CDD_{GWSS} and GWSS survival.

Because most of our previous CDFA-funded work on the impact of cool temperatures on GWSS feeding and survival was conducted using constant temperatures, it was necessary to validate our findings under actual fluctuating temperatures in the field. Prior efforts to field-validate the impact of cool winter temperatures on caged GWSS adults in the crop production areas of the San Joaquin Valley (e.g., east and west of Bakersfield, central Fresno and Merced Counties) and farther north (Napa and Sonoma Counties) were prevented. This was due to concerns of growers and regulatory officials about potential escapes of GWSS individuals that might threaten nearby crops via *Xylella fastidiosa* (*Xf*) spread or the establishment of new GWSS populations. Fortunately, we were permitted to establish one field test comparing GWSS adults caged in the urban area of Bakersfield versus caged GWSS in Riverside (UCR Citrus Experiment Station). The GWSS individuals died in a shorter amount of time at the cooler Bakersfield site than the Riverside site. However, only one field test of our hypothesis using fluctuating temperatures is inadequate. Therefore, we proposed to test the impacts of fluctuating temperatures on GWSS survival using programmable temperature cabinets as we have done for the study mentioned above. These additional studies would provide insights into the benefits of using cumulative CDD_{GWSS} to estimate GWSS survival. We also plan to analyze historical temperature data for various locations within the agricultural production areas of California to determine if winter conditions (e.g. November to March) would permit significant GWSS survival based on CDD_{GWSS} accumulation. The eventual product that we aim to produce from these efforts will be the production of GIS maps that estimate CDD_{GWSS} accumulation over the winter months (i.e., November to March) to provide estimates of the ability of local GWSS populations to be a substantial threat to local agriculture in the following growing season (i.e., a risk assessment). As resources for GWSS management dwindle, government agencies will be forced to make decisions on which regions should receive area-wide treatment to suppress GWSS populations. Our studies suggest that the presence of the GWSS threat may vary with the severity of local winter temperatures (i.e., reduced GWSS densities correlated with cold winters). An annual estimation of overwintering GWSS survival across agricultural regions will provide insights into where resources for GWSS suppression should be most effectively allocated.

OBJECTIVES

1. Verify impacts of winter temperatures on GWSS survival from selected California sites;
2. Quantify and compare variation in "cooling degree day" accumulation within and among selected California sites using historical temperature data; and
3. Construct Geographical Information Systems (GIS) maps that estimate GWSS survival during the winter period

RESULTS

Objective 1

Verify impacts of winter temperatures on GWSS survival from selected California sites

Dr. Hannah Nadel was hired in mid-September 2007 to replace Dr. Youngsoo Son, who started a position with CDFA in early summer 2007. Given the departure of Dr. Son, the study research site was moved from the CDFA Arvin Field Station in the San Joaquin Valley to the campus of the University of California at Riverside, where access to live GWSS would be easier and not a quarantine issue. Dr. Nadel has initiated activities to implement the experimental studies proposed under this objective. These studies will be conducted in temperature-controlled growth chambers on the UC Riverside campus. Studies will be conducted under laboratory conditions because using live GWSS in field-cage studies is prohibited outside of the GWSS-infested areas of California. Attempts to implement necessary field studies over the last two summers were impaired due to growers' concerns about potential escapes of field-caged GWSS individuals. Temperature cabinets are currently being procured for the studies. Cabinets will be programmed to run various fluctuating, diurnal temperature patterns that are representative of historical patterns from selected sites within California's agricultural regions. For ten CIMIS sites (e.g., Riverside, Santa Maria, Bakersfield, Porterville, Merced, Davis, Oakville, Chico, Gerber, and Glenburn), mean daily maximum and minimum temperatures will be calculated for the months of November, December, January, February, and March. Ten GWSS adults (five mated pairs) will be caged under a given temperature regime (e.g., Merced) for a five month period. In chronological order (November, December, January, February, and March), the temperature cabinets will be programmed to simulate the average maximum and minimum temperatures for the individual months (i.e., 30 days for November, 31 days for December, 31 days for January, etc.). GWSS adults are currently being field-collected for the laboratory studies. GWSS individuals will be provided with citrus and other host plants to feed upon. Numbers of live and dead individuals will be counted weekly until all insects die or the 5 month study period ends. Each temperature regime will be replicated 5 to 8 times. The cumulative CDD_{GWSS} will be calculated for each location regime (e.g., Merced) and percent survival compared among regimes using Repeated Measures ANOVA. The numbers of cumulative CDD_{GWSS} required to kill all GWSS individuals per cage will be compared across location regimes to determine if the value to kill all test insects remains fairly constant across different diurnal temperature patterns. Presently, we envision the actual laboratory experiments being started by 1 November 2007 as planned.

Objective 2
Quantify and compare variation in "cooling degree day" accumulation within and among selected California sites using historical temperature data

We are initiating activities on this objective. We have some of the necessary temperature data and will purchase additional data in the near future. Historical temperature data (last 10 years) will be used to quantify and compare variation in "cooling degree day" accumulation within and among selected California sites. For 20 CIMIS sites, the monthly accumulation of CDD_{GWSS} will be calculated for the individual months of November, December, January, February, and March for each winter season examined (e.g., winters of 1996-1997 through 2006-2007). We will statistically compare the sites and individual months to quantify the amount of variation in the accumulation of CDD_{GWSS} among sites and within sites. This exercise should provide insights into the amount of variation that occurs relative to probable survival of overwintering GWSS populations in various regions as a result of low temperatures. Based on our findings, it may be possible to reduce the number of regions in California that must be monitored for GWSS establishment. Certain northern or high altitude areas may consistently have temperatures so low that even annual temperature variation will not produce conditions under which significant numbers of GWSS individuals would survive the winter cold. Additionally, we should be able to compare our estimates of cumulative CDD_{GWSS} with historical CDFA records on GWSS sticky trap counts within specific areas. Dr. Mark Sisterson reports that CDFA will provide us access to their records on GWSS sticky trap counts within specific areas. We expect to find low numbers of GWSS trapped in those areas with high cumulative CDD_{GWSS} values.

Objective 3
Construct Geographical Information Systems (GIS) maps that estimate GWSS survival during the winter period

No progress to report at this time because data collection will not begin until November 2007. Using temperature data collected between the months of November 2007 to March 2008 by CIMIS and the Western Regional Climate Center (WRCC), we will estimate the accumulation of CDD_{GWWS} for about 340 temperature monitoring sites. We will then construct GIS maps of California that show: 1) the variation in cumulative CDD_{GWSS}; and 2) the estimated the risk of GWSS populations surviving the winter period. Spatial statistics techniques using ESRI ArcGIS® Geostatistical Analyst will be used to create interpolated surface maps using one of two analysis strategies: Inverse Distance Weighted or Krig surface generation. Risk will be expressed as a simple rating system such as: 0 = less than 0.1% possibility of the GWSS population surviving; 1 = possibility of between 0.1 and 1.0% of the GWSS population surviving; 2 = possibility of between 1.0 and 5.0% of the GWSS population surviving; and 4 = possibility of greater than 5% of the GWSS population surviving. For the time being, regions with ratings greater than 0 would probably require allocation of resources for GWSS suppression. However, standard GWSS monitoring should continue in all areas where GWSS populations are routinely found or might be expected to appear (e.g., areas along a transportation corridor, e.g., Hwy 65 in Tulare County). With an improved understanding of the climatological limits of GWSS overwintering survivorship, these risk estimates can 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.

CONCLUSIONS

This project has a high probability of success both in terms of generating significant new information regarding the impact of California winter temperatures on GWSS survival and also by providing a practical tool to use in the decision making process for GWSS management. Objectives outlined in this project address gaps in our present understanding that must be filled if we are to develop a comprehensive management plan to best manage GWSS over regional areas.

REFERENCES

Hoddle, M.S. 2004. The potential adventive geographic range of glassy-winged sharpshooter, *Homalodisca coagulata* and the grape pathogen *Xylella fastidiosa*: implications for California and other grape growing regions in the world. Crop Prot. 23:691-699.

Johnson, M., K. Daane, R. Groves, E. Backus, & Y. Son. 2006. Spatial population dynamics and overwintering biology of the glassy-winged sharpshooter, *Homalodisca coagulata*, in California's San Joaquin Valley, pp. 12-15. *In* M. A. Tariq, R. Medeiros, M. Mochel, and S. Veling [eds.], Proceedings, 2005 Pierce's Disease Research Symposium, San Diego, CA, Nov 27-29, 2006.

Pollard, H. N., and Kaloostian, G. H. 1961. Overwintering habits of *Homalodisca coagulata*, the principal natural vector of phony peach disease. Journal of Economic Entomology 54: 810-811.

Varela, L.G., R.J. Smith, and P.A. Phillips. 2001. Pierce's Disease. Univ. California. Agric. & Nat. Res. Publ 21600.

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