Title of Report

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Title of Project

Insecticide Resistance in the Glassy-winged Sharpshooter: Using Historical Use Patterns to Inform Future Management Strategies

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Reporting Period

The results reported here are from work conducted July 2017 through June 2019

Introduction

Chemical management of Glassy-winged sharpshooter (GWSS) populations within citrus orchards and vineyards continues to be an integral part of managing the spread of Pierce's disease (PD) to grapes. The timing and location of insecticide applications is informed by the CDFA PD-GWSS Area-wide Management Program. Initiated in 2001, this program dramatically reduced and maintained low numbers of GWSS within Kern County fields through 2008, and PD incidence in grapes remained low during this time. However, in 2009, annual numbers of GWSS began to increase, leading to extremely high densities in 2012, alarming the industry and leading experts to hypothesize that insecticide resistance had developed in Kern County GWSS populations. Despite continued insecticide usage, high densities of GWSS from 2012-2015 existed. At the same time, surveys of PD-infected vines indicated an increase in disease incidence in the General Beale area of Kern County (Haviland 2015).

The research reported herein was initiated in July 2016. It was an extension of a pilot study that was conducted in 2014 and 2015 with support from the Consolidated Central Valley Table Grape Pest and Disease Control District and the CDFA Pierce's Disease Control Program. In the 2015 study, we evaluated the effectiveness of 8 compounds in 4 insecticide classes: Neonicotinoids (Imidacloprid, Thiamethoxam and Acetamiprid), Butenolide (Flupyradifuron), Pyrethroids (Bifenthrin and Fenpropathrin), and Organophosphates (Chlopyrifos and Dimethoate) in both systemic uptake and foliar bioassays. These studies showed that GWSS collected in 2015 were much less susceptible to the insecticides than they were in 2001 and 2002 (Prabhaker et al. 2006), when the Area-wide GWSS Management Program was initiated. For some insecticides, the studies showed LC_{50} values to be much higher in 2015, an indication of resistance in the populations (Perring et al. 2015). These results were similar to those obtained by Redak et al. (2015) in the same geographic region. In the same study, we documented variation in the relative toxicities at different times and locations throughout the 2015 season. In particular, there was a 79-fold increase in the LC_{50} value for imidacloprid from the first bioassay of the season to the last, and there were differences in susceptibility of sharpshooters collected from different fields and geographic areas. This study suggested that toxicity was related to factors in the local context.

The purpose of this project was to determine if GWSS has become less susceptible to various insecticides over the last 15 years and if resistance development contributed to the recent resurgence of GWSS in Kern Co. Additionally, we aimed to determine how patterns of GWSS resurgence (areas and timing) were related to historical insecticide applications. Increasing our understanding of the factors contributing to reduced resistance, both seasonal and over the years, may help growers in their selection of GWSS management materials and application timing in their particular fields.

Objectives

1. Conduct laboratory bioassays on field-collected *H. vitripennis* from Kern County to document the levels of resistance at the beginning of the 2016 and 2017 field seasons, and to document changes in susceptibility as each season progresses.
2. Document differences in insecticide susceptibility in GWSS collected from organic vs. non-organic vineyards (grapes) and/or orchards (citrus) and from different locations in Kern County.
3. Obtain and organize historic GWSS densities and treatment records (locations, chemicals used, and timing of applications) into a Geographic Information System for use in statistical analyses.
4. Determine the relationship between insecticide susceptibility of different GWSS populations and treatment history in the same geographic location and use relationships to inform future insecticide management strategies.

Activities and Accomplishments

Objective 1. Conduct laboratory bioassays on field-collected H. vitripennis from Kern County to document the levels of resistance at the beginning of the 2016 and 2017 field seasons, and to document changes in susceptibility as each season progresses.

Objective 2. Document differences in insecticide susceptibility in GWSS collected from organic vs. non-organic vineyards (grapes) and/or orchards (citrus) and from different locations in Kern County.

In 2016, we evaluated two pyrethroids (Bifenthrin and Fenpropathrin) and 3 neonicotinoids (Imidacloprid, Thiamethoxam, and Acetamiprid) on 2 dates from table grapes and 1 date from citrus. These studies showed susceptibility levels similar to those in 2015 for all 5 chemicals (Perring et al. 2016), demonstrating that resistance levels in 2015 and 2016 were higher than in 2001 and 2002. In addition, research showed declining susceptibility to the systemic neonicotinoids imidacloprid and thiamethoxam over the course of the season, revealing a trend shown in the 2015 bioassays and similar to Redak et al. (2016).

In 2017, we conducted bioassays on GWSS collected in citrus on 24 July, 8 August, 29 August, 12 September, and 9 October. All collections were made in citrus orchards because we observed consistently higher GWSS counts in citrus than in grapes that year. Collections were made from four sites in Kern Co. throughout the season. Two treated and two non-treated (organic) sites were chosen from two different zones of the Kern Co. Area Wide Trapping map. The 2017 spray records were placed into our GIS, and sites were selected based on two primary criteria: 1) proximity to recent imidacloprid-treated regions; and 2) GWSS population densities. Treated areas were considered those in which imidacloprid was applied in the 2017 growing season within 0.75 miles of the collection site. Organic sites were defined as those in which imidacloprid had not been applied within at least one mile of the collection site. The four sites were spread out through Kern County with the treated 1 (T1) and organic 1 (O1) sites located in the Edison region in Zone 3 and the treated 2 (T2) and organic 2 (O2) sites occurring along Highway 65 in Zone 1 (Figure 1). The CDFA GWSS trap counts were used to determine the sites from which to collect GWSS on each collection date. Totals of 750, 600, 100, 420, and 510 GWSS were collected on each aforementioned date, respectively.

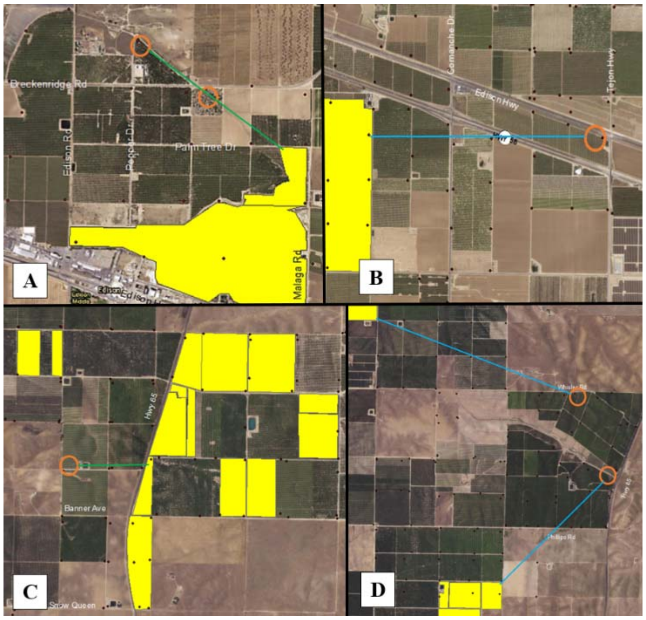
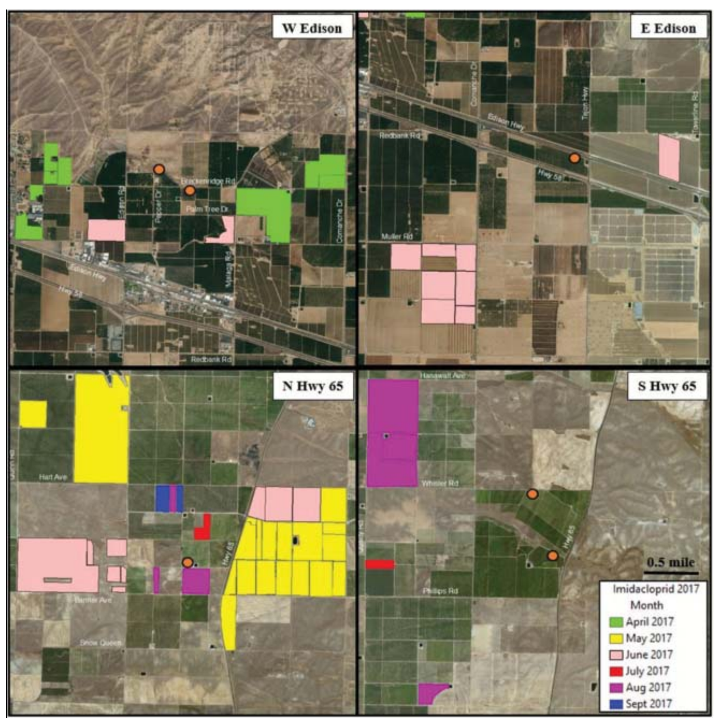


Figure 1. Four Kern County locations chosen for *H. vitripennis* collection and imidacloprid bioassays. (A) Treated Site 1 (T1), (B) Organic Site 1 (O1), (C) Treated Site 2 (T2), and (D) Organic Site (O2). Citrus or grapes treated with imidacloprid in 2017 are represented by the yellow areas. Orange circles indicate collection sites. Green lines represent distances between collection sites and treated areas that are less than 0.75 miles. Blue lines represent distances between collection sites and treated areas of 1 mile or more.

Bioassays conducted on organic versus treated sites throughout the 2017 season demonstrated different levels of resistance as the season progressed. Initially we grouped the data and analyzed them according to the 'organic' versus 'treated' site designations as reported in Perring et al. (2017). We reanalyzed each site individually to determine if susceptibility reduction over the season was related to the distance of the collection sites from field applications of imidacloprid. The previously named 'organic' sites included the E Edison (O1) and S Hwy 65 (O2) locations, and the 'treated' sites included the W Edison (T1) and N Hwy 65 (T2) locations (Figure 1). We created a new map of our 4 sites which included the timing of nearby imidacloprid applications (all formulations) applied to surrounding perennial hosts (grape, grapefruit, lemon, orange, pistachio, tangelo, and tangerine; listed in CDFA Plant Quarantine Manual, Section 454; http://pi.cdfa.ca.gov/pqm/manual/pdf/454.pdf) from January 1 through October 9, 2017 (Figure 2).

Figure 2. Locations of GWSS collections in 2017. Orange dots represent the exact collection sites. The upper left quadrant is site W Edison; upper right is E Edison; lower left is N Hwy 65; and lower right is S Hwy 65. Each quadrant contains the approximately 3 mi^2 region surrounding each site. The legend indicates the months in which imidacloprid applications were made to fields near the collection sites (from Andreason et al. 2018).



Each GWSS collection site had a unique situation of proximate imidacloprid applications and treatment timings. The two 'treated' sites, W Edison and N Hwy 65, had applications early in the growing season (April and May, respectively) whereas the previous 'organic' sites, E Edison and S Hwy 65, had the earliest applications in June and July, respectively. There also were more frequent applications within a 1.5 mi radius around the W Edison and N Hwy 65 collection sites as well as applications closer to these sites. Collections from citrus orchards and subsequent bioassays began in July and were repeated at each site in August (Table 1). Resulting LC_{50} values were similar to those determined at the beginning of the 2015 and 2016 tests, indicating that the reduced susceptibility levels at the end of the previous year do not continue into the next year and that LC_{50} values revert back to previous years' early season levels. The LC_{50} values also were not significantly different among sites nor were they different from July to August. Unfortunately, E and W Edison could not be tested into the late season because GWSS numbers were significantly lower in September. N and S Hwy 65 collections were assayed in mid-September, but only S Hwy 65 could be tested in October. Analyzing these sites individually, we found that the susceptibility of the GWSS collected at the N and S Hwy 65 sites decreased significantly from July to September and July to October, respectively (Table 1). At N Hwy 65, where imidacloprid was applied early and often, susceptibility dropped 29-fold. At S Hwy 65, with applications later and less frequent, susceptibility decreased 11-fold. These results suggest that seasonal reductions in susceptibility to imidacloprid occur and that differential proximity to field applications likely contributes to the degree of reduction.

Table 1. Toxicities of imidacloprid to GWSS determined in uptake bioassays in multiple locations in Kern County, California, USA in 2017.

Year	Date	Location	*n*	LC_{50} µg/ml (95% FL)	Slope ± SE	χ^2 (df)
2017	July 24	E Edison	270	4.01 (0.63-11.31)	1.26 ± 0.23	3.15 (3)
		W Edison	140	*0.38 (0.02-12.49)	0.88 ± 0.13	9.12 (3)
		S Hwy 65	150	0.80 (0.13-2.07)	1.29 ± 0.36	2.46 (3)
		N Hwy 65	150	1.79 (0.54-3.98)	1.50 ± 0.37	1.73 (3)
	August 8	E Edison	238	1.27 (0.26-4.73)	0.95 ± 0.12	4.71 (3)
		W Edison	50	*1.12 (0.03-22.72)	0.90 ± 0.20	3.57 (3)
		S Hwy 65	237	0.56 (0.09-2.09)	1.11 ± 0.15	5.48 (3)
		N Hwy 65	59	*0.13 (0.08-0.18)	1.37 ± 0.58	0.09 (3)
	September 12	S Hwy 65	150	*8.99 (1.00-47.78^{+})	1.15 ± 0.25	6.48 (3)
		N Hwy 65	150	51.53 (21.33-204.99)	1.02 ± 0.27	2.50 (3)
	October 9	S Hwy 65	504	8.71 (2.93-27.28)	0.89 ± 0.09	5.62 (3)

* LC_{50} determined by probit analysis using PoloSuite because of high variability in dose responses.
$^{+}$ 90% FL reported in place of indeterminable 95% FL.

Further analysis of our bioassay results using a generalized linear mixed model (GLMM) corroborated the significance of the observed seasonal decreases. With all sites combined, there was a significant decrease from an average 50.5% mortality in July to 23.7% and 29.6% in September and October, respectively (Table 2). When the sites were analyzed separately, mortalities at S Hwy 65 significantly decreased from 61.3% to 29.6%, while mortalities at N Hwy 65 significantly decreased from 53.3% to 20.0%.

Table 2. Imidacloprid-induced mortality of GWSS collected in 2017 at different locations in Kern County, CA analyzed by a GLMM (from Andreason et al. 2018).

Year	Date	Combined Mortality (%)	S Hwy 65 Mortality (%)	N Hwy 65 Mortality (%)
2017	July 24	50.5 (147) a	61.3 (30) a	53.3 (30) a
	August 8	46.4 (120) b	47.5 (48) b	62.1 (12) a
	September 12	23.7 (60) c	27.3 (30) c	20.0 (30) b
	October 9	29.6 (101) c	29.6 (101) c	--------

Values within the same column followed by the same letter are not significantly different, Tukey's test ($P < 0.05$). The number of replicates (clip cages containing five insects) on each date are given in parentheses.

Comparing this study's results to the baseline susceptibility levels determined in 2001 and 2002 (Prabhaker et al. 2006), all data from the yearly bioassays conducted on imidacloprid, thiamethoxam, acetamiprid, bifenthrin, and fenpropathrin were used to calculate an overall LC_{50} value for each chemical (Table 3). We did not include data from some previously tested compounds (flupyradifurone, chlorpyrifos, and dimethoate) because of a lack of adequate bioassay replicates resulting from few GWSS in 2016, and because of high variation in the responses of the tests we were able to conduct. For each of the neonicotinoid and pyrethroid compounds, the annual LC_{50} values were not significantly different from 2015 to 2016.

For imidacloprid, the overall LC_{50} value of 2.91 µg/ml represented a 3.5-fold decrease in susceptibility compared to the average values from 2001 and 2002 (average $LC_{50} = 0.82$ µg/ml). However, with a 95% FL overlapping with one of the previous years (2001), this decrease was not significant. The thiamethoxam LC_{50} value determined in 2001/2002 could not be compared to the current value because the compound was previously tested as a foliar insecticide and we used a systemic bioassay in our studies. Thus, the present study establishes the baseline susceptibility level of GWSS to thiamethoxam applied systemically. For acetamiprid, the present overall LC_{50} of 1.78 µg/ml showed a 7-fold decrease in susceptibility from the previous assays (2001/2002 average $LC_{50} = 0.26$ µg/ml). With no overlap in 95% FL between the earlier and present bioassays, this was a significant decrease in susceptibility. GWSS susceptibility to bifenthrin significantly decreased as well. The current 2015/2016 overall LC_{50} was 0.67 µg/ml which is a 152-fold decrease from the 2001/2002/2003 average LC_{50} of 0.0044 µg/ml. The lack of overlapping 95% FLs indicate that these values are significantly different. Finally, for fenpropathrin, the 2015/2016 overall LC_{50} of 0.40 µg/ml was 9.5 times higher than the average 2001/2002 LC_{50} value of 0.042 µg/ml, but the overlap in 95% FLs indicates that this was not a significant increase. Overall, of the 5 compounds tested, acetamiprid and bifenthrin were determined to be significantly less toxic to GWSS, indicating that resistance to these compounds has likely developed over the last 15 years.

Table 3. Toxicities of various insecticides to GWSS collected from multiple locations in Kern County, Ca from 2015 through 2017 as determined by uptake and leaf dip bioassays. Average 2001, 2002, 2003 values calculated from Prabhaker et al. (2006).

Compound	**Year**	***n***	**LC_{50} µg/ml (95% FL)**	**Slope ± SE**	**χ^2 (df)**
Imidacloprid	2015	1,171	2.51 (0.98-5.29)	0.77 ± 0.06	53.68 (13)
	2016	575	3.43 (0.61-17.76)	0.74 ± 0.07	10.02 (3)
	2017	2,098	2.90 (1.05-6.45)	0.88 ± 0.05	11.59 (3)
	Overall	3,844	2.91 (1.93-4.21)	0.82 ± 0.04	47.27 (15)
	2001	312	1.27 (0.68-2.54)	1.1 ± 0.30	6.24 (4)
	2002	295	0.36 (0.09-0.51)	1.2 ± 0.35	4.76 (4)
Thiamethoxam	2015	775	0.74 (0.35-1.50)	0.93 ± 0.07	15.53 (6)
	2016	563	1.48 (0.35-4.94)	1.02 ± 0.08	11.33 (3)
	Overall	1,338	1.03 (0.54-1.87)	0.97 ± 0.05	20.67 (6)
Acetamiprid	2015	450	2.88 (1.06-8.13)	0.77 ± 0.07	4.41 (3)
	2016	450	0.94 (0.15-3.59)	0.59 ± 0.07	4.23 (3)
	Overall	900	1.78 (1.11-2.75)	0.67 ± 0.05	2.36 (3)
	2001	315	0.44 (0.18-0.56)	2.0 ± 0.14	4.85 (4)
	2002	320	0.08 (0.02-0.14)	1.4 ± 0.11	3.87 (3)
Bifenthrin	2015	746	0.54 (0.21-1.15)	0.74 ± 0.06	3.15 (3)
	2016	302	1.03 (0.29-3.72)	1.09 ± 0.11	6.73 (3)
	Overall	1,048	0.67 (0.30-1.29)	0.82 ± 0.06	4.00 (3)
	2001	312	0.0005 (0.0002-0.0038)	1.4 ± 0.24	3.76 (4)
	2002	320	0.0126 (0.0085-0.0347)	1.7 ± 0.32	2.88 (4)
	2003	285	0.0001 (0.00009-0.0004)	2.9 ± 0.27	2.64 (4)
Fenpropathrin	2015	735	0.33 (0.19-0.54)	0.60 ± 0.05	3.46 (4)
	2016	150	0.80 (0.32-1.70)	1.13 ± 0.20	1.13 (3)
	Overall	885	0.40 (0.19-0.77)	0.66 ± 0.05	4.45 (4)
	2001	306	0.064 (0.045-0.205)	1.2 ±0.21	5.82 (4)
	2002	215	0.020 (0.007-0.060)	1.1 ± 0.25	4.76 (4)

Objective 3. Obtain and organize historic GWSS densities and treatment records (locations, chemicals used, and timing of applications) into a Geographic Information System for use in statistical analyses.

To explore the relationships between historical pesticide applications and GWSS resurgence in different areas, we needed to work with 3 large data sets; the crop coverages, the pesticide use data, and the GWSS abundance data. For each of these data sets, we have obtained all the data that exists from 2001-2016 for CDFA Zones 1 (Hwy 65 Area, north of Bakersfield) and Zone 3 (General Beale/Edison Area east of Bakersfield).

Crop Coverage:
The foundation of the Geographic Information System (GIS) exists in the crop coverage data for each year. These data were obtained from the Kern County Department of Agriculture and Measurement Standards. Each field has a geographic location that has been placed on the map in the GIS, and also is identified by the Township, Range, Section (TRS) and Site ID. Using only the Site ID to define the parcel location proved inadequate because; 1) the Site ID is assigned to a land owner/lessor and the ownership could and did change over the years, and/or 2) multiple owners may use the same parcel notation (e.g., 1, 20, 13 or A, B, C). So we needed to keep track of the correct ID for that site as the years progressed. We used attribute layers for Townships and Sections provided by ESRI (Redlands, CA), a major source of GIS data and software for the international market, to determine where the parcel was located within the section. We needed to gather data from adjacent parcels that fell into another

section to insure that the parcel on which we wish to work is consistent through the 16 years of the analysis.

Pesticide Use Data:
We have obtained the application records for imidacloprid, thiamethoxam, acetamiprid, flupyradifurone, fenpropathrin, bifenthrin, chlorpyrifos and dimethoate from the Kern County Agricultural Commissioner Pesticide Use database from 2001-2016. These records include applications of every formulation of each compound to all reported hosts of GWSS, both annual and perennial, within Kern Co. zones 1 and 3. We received the records in Excel format and identified all formulations of the 8 materials because the pesticide use records contain trade names and we wanted to be sure to obtain all uses of each material for our analyses. The pesticide use database included Township, Range, and Section (TRS), allowing us to identify all applications of our eight compounds within a particular section. From this query, we could identify all applications to a particular parcel using the Site ID. At this point we identified each application and date of application for that parcel for each year. This was done for each parcel over the 16 years.

GWSS Abundance Data:
GWSS trap data have been collected by the CDFA GWSS Program and we obtained all trap counts from 2001-2016 for zones 1 and 3. We received these trap counts in GIS map format which shows the locations of each trap in the dataset. In the GIS we were able to determine which traps were located within one quarter mile of the parcel of interest. The number of traps per parcel varied depending on the shape of the parcel and the physical placement of traps. After identifying the traps by their unique ID, we were able to query the trap dataset by Trap ID, giving us access to Trap counts (adult GWSS) and the date of trap service, which are included in the trap data files. We have learned that not all traps were serviced with the same regularity (for example initially all traps were recorded weekly, but then it was changed to every 2 weeks on average; but this was not consistent across all trap sites. In addition, on some weeks the traps were not accessible, so there are "holes" in the dataset. For these dates, we needed to include a missing data point so that the count data could be aligned by date. Over the 16 years of the study, some traps were added and other traps were deleted. This requires us to query the traps annually to identify these changes. The trap data for each trap was transferred to another Excel file, organized horizontally by date, with a vertical listing of all traps within ¼ mile of the target field over the 16 years of trapping. The pesticide applications then could be added to the file on the appropriate date, allowing us to relate pesticide applications to the average number of GWSS present on traps surrounding the treated field.

Objective 4. Determine the relationship between insecticide susceptibility of different GWSS populations and treatment history in the same geographic location and use relationships to inform future insecticide management strategies.

We have been working to combine information from the crop coverage maps, the pesticide use data, and the GWSS abundance data in an attempt to shed light on the interaction between pesticide use and GWSS numbers. To illustrate the process, we present data from a citrus block in Area 1, just north of Bakersfield on State Highway 65. For this site we identified 9 GWSS traps within ¼ mile of the field and pulled all of the trap count data from 2001–2016. We learned that traps were not placed around this field until 2002 and from 2002-2007, only a few GWSS were caught over each year of trapping. In 2008, numbers began to increase so we analyzed the data from 2008 – 2016.

There are some interesting observations from our initial field site that could prove to be relevant to the increase in GWSS numbers from 2012 through 2016 in Kern County (Figure 3). From 2008 – 2010, the grower of this field used chlorpyrifos and imidacloprid in the orchard, with initial treatments in the field in April. In 2008, a late September treatment of imidacloprid may have provided winter-time protection as insects moved into citrus for oviposition. The combinations of these treatments likely contributed to the low numbers of GWSS through 2010. Acetamiprid was first used on the field in 2011, and the combination of this material with chlorpyrifos from April-June maintained relatively low GWSS numbers through the summer and fall months. However there was an increase in adult activity from August through November, and in the following spring there was a spike in GWSS abundance. Looking back, it may have been prudent for this grower to put on a fall 2011 insecticide application. Imidacloprid was applied in March, followed by another imidacloprid treatment in mid-June. This was followed by an increase in insect numbers through the fall, likely contributing to the large population from January through March in 2013. Interestingly, it was at this time that applications of imidacloprid were switched from early spring applications to summer applications. From 2013-2016, imidacloprid was applied in June, followed almost immediately by a spike in GWSS numbers. Given that it takes 6-8 weeks for trees to reach maximum dosage, and 6 weeks to see reductions in GWSS nymphs (Castle et al. 2005), it appears that the insecticide was applied too late to effectively reduce insects that grew into adults and populated the traps counted in this study. This late treatment also could result in sub-lethal doses of Imidacloprid in the trees to which the insects were exposed, leading to the levels of resistance documented in this project and by Redak et al. (2015, 2016). Populations of GWSS reached high densities in 2013 and 2014, followed by quick declines that may have been due to the imidacloprid reaching lethal titers in the trees and/or the applications of acetamiprid in August of both years. In late 2015 through 2016, the grower alternated thiamethoxam with acetamiprid which maintained low numbers through the winter and spring. Again, imidacloprid was applied in June which was followed by another GWSS spike; the field then was treated twice with thiamethoxam, bringing the insect numbers down.

While this analysis covers only one field, it is clear that combining long-term seasonal GWSS abundance data sets around a field with pesticide application to the field can offer insights into how we might better utilize the insecticide tools at our disposal. For example, during the early years, Imidacloprid was applied to this field in the spring, and this was changed to the summer during later years. The later application did not enable the insecticide to reach lethal titers within the trees and combined with other factors (like warmer winters and springs) this change in application timing may have contributed to the increases in GWSS abundance from 2012-2016. The timing change also could be partly responsible for increasing resistance levels in GWSS populations in the area; the field we selected for this study is in the same vicinity as the fields from which we collected GWSS in our resistance studies. Adding more field sites to our study will add robustness to the analysis, enabling us to validate whether the relationships we have presented here exist over the larger geographic areas of Kern County where GWSS remains a problem.

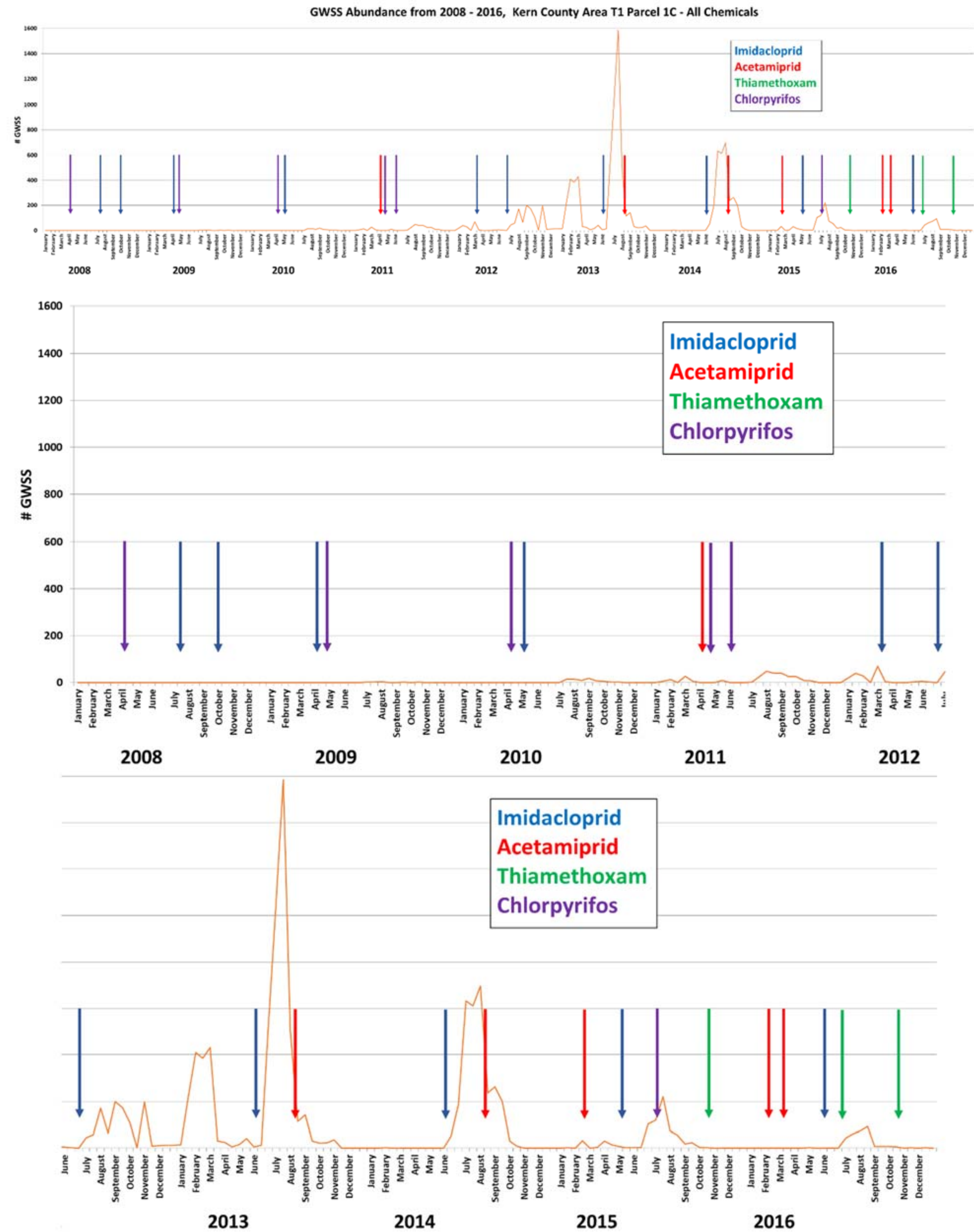


Figure 3. Average number of GWSS from 9 traps collected approximately every 2 weeks from 2008 – 2016 from Kern County Area T1, Parcel 1C, and the application times for imidacloprid, acetamiprid, thiamethoxam, and chlorpyrifos over the 8 years of the study. The top graph shows the complete time period of the study. The middle graph shows the data from 2008-2012 and the bottom graph shows the data from 2013-2016.

Publications and Presentations

Publications

Perring, T.M., N. Prabhaker, and S. Castle. 2015. Monitoring for insecticide resistance in the glassy-winged sharpshooter in California. Pp. 142-146 In. T. Esser and R, Randhawa (eds.) Research Progress Reports: Pierce's Disease and Other Designated Pests and Diseases of Winegrapes. December 2015. California Department of Food and Agriculture, Sacramento, CA.

Perring, T.M., N. Prabhaker, S. Castle, D. Haviland, B. Stone-Smith. 2016. Monitoring for insecticide resistance in the glassy-winged sharpshooter *Homalodisca vitripennis* (Germar) (Hemiptera: Cicadellidae) in California. Pp. 221-229 In T. Esser (Ed.) Proceedings, 2016 Pierce's Disease Research Symposium. California Department of Food and Agriculture, Sacramento, CA.

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Perring, T.M., Prabhaker, N., Andreason, S., Castle, S., Haviland, D., Stone-Smith, B. 2017. Monitoring for insecticide resistance in the glassy-winged sharpshooter *Homalodisca vitripennis* (Germar) (Hemiptera: Cicadellidae) in California. Pp. 157-162 In T. Esser (Ed.) Research Progress Reports: Pierce's Disease and Other Designated Pests and Diseases of Winegrapes. December 2017. California Department of Food and Agriculture, Sacramento, CA.

Perring, T.M., Prabhaker, N., Andreason, S., Castle, S., Haviland, D., Stone-Smith, B. 2018. Insecticide resistance in the glassy-winged sharpshooter: Using historical use patterns to inform future management strategies. Pp. 153-160 In T. Esser (Ed.) Proceedings of the 2018 Pierce's Disease Research Symposium. California Department of Food and Agriculture, Sacramento, CA.

Presentations

Perring, T.M. 2016. Insecticide resistance in the GWSS: Using historical use patterns to inform future management strategies. 2016 Pierces Disease Research Symposium, San Diego, CA. December 2016

Andreason, S., Perring, T.M., Prabhaker, N., Castle, S., Ganjisaffar, F., Haviland, D., Stone-Smith, B. 2018. Insecticide resistance in glassy-winged sharpshooters in Kern County, California. Current Wine and Winegrape Research. Davis, CA. 21 February 2018.

Perring, T.M. 2018. Insecticide resistance in the GWSS: Using historical use patterns to inform future management strategies. 2018 Pierces Disease Research Symposium, San Diego, CA. December 2018

Research Relevance Statement

Previous work has shown that GWSS are less susceptible to insecticides commonly used in management programs than they were in 2001 and 2002. Of five compounds studied, we found significant reductions in GWSS susceptibility to acetamiprid and bifenthrin over the last 16 years. In addition, we have determined that susceptibility to imidacloprid decreases over each field season, and that differential proximity to fields where imidacloprid has been applied was a contributing factor to the degree of imidacloprid susceptibility. Having shown this relationship, we explored the relationship between seasonal abundance of GWSS and insecticide usage on a field-level scale. We have obtained and manipulated three very large data sets (the crop coverages of all crops in Kern County, the pesticide use data, and the GWSS abundance data) from 2001–2016. Completing our analysis of one citrus grove, we found that the timing of imidacloprid applications was changed from the spring (2008-2012) to the summer (2013-2016). The later applications were followed immediately by large increases in GWSS numbers, possibly caused by the lag time between imidacloprid application and reaching a lethal concentration of insecticide in the trees on which the insects feed. Furthermore, the later application may be exposing insects to sub-lethal dose of insecticide which could contribute to recent increases in resistance to Imidacloprid documented in this and other studies.

Layperson Summary

Insecticides are key to the management of Pierce's Disease, through their reducing impact on GWSS numbers. High insect numbers from 2012-2015, despite continued monitoring and treatment suggested a change in the susceptibility to commonly used products. Our studies in 2015, 2016, and 2017 showed varying levels of resistance to insecticides in Kern County populations of GWSS, with declining susceptibility as the season progressed. Fortunately, there was no further reduction in susceptibility from the initiation of our tests in 2015 to our final tests in 2017, but levels of susceptibility to two tested insecticides were still much lower than in 2001 when the area-wide GWSS program was initiated. We now are analyzing records of insecticide applications to specific citrus groves along with seasonal GWSS trap counts near the groves from 2001-2016. The first field we analyzed showed some interesting changes in the timing of imidacloprid application which could have contributed to higher GWSS numbers from 2012-2015 as well as increasing resistance.

Status of Funds

This was originally a two year project initiated in July 2016. In June of 2018, we were granted a no-cost extension to continue working on the last 2 objectives of this project. Funds have now been expended.

Summary and Status of Intellectual Property

Aside from the published papers and the presentations at various conferences, no intellectual property was produced as a result of this research project.

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