POPULATION DYNAMICS AND INTERACTIONS BETWEEN GLASSY-WINGED SHARPSHOOTER AND ITS HOST PLANTS IN RESPONSE TO CALIFORNIA PHENOLOGY

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ABSTRACT

We determined the relative phenology of host plant use by glassy-winged sharpshooter (GWSS), other leafhopper vectors, natural enemies, and *Xylella fastidiosa* (*Xf*) in ornamental, agricultural and California native host plants in key California locations in climatically different regions: Coastal (Piru, Ventura County), Inland (Redlands, San Bernardino County), and South (Pauma Valley, San Diego County). In this study, the only host plant used frequently in all life stages was cottonwood. On grape and crape myrtle, nymphs and eggs were frequently recorded, while photinia, cherry and sycamore frequently hosted egg masses but not the other life stages. This research will be used to develop a GWSS performance database on the host plant species that are identified as truly critical to GWSS survival.

INTRODUCTION

The focus of this research was to determine the relative phenology (the timing of biological events as influenced by the environment and intrinsic biological phenomena) of host plants use by GWSS, other leafhopper vectors, natural enemies, and *Xylella fastidiosa* (*Xf*) in ornamental, agricultural and California native host plants in key California locations in climatically different regions: Coastal (Piru, Ventura County), Inland (Redlands, San Bernardino County), and South (Pauma Valley, San Diego County). As year one of a three year study, we plan to replicate this years' observations (only if continued CDFA funding is reinstalled and received) using fresh host plants at the same locations. Full analyses of results will not be available until after all data is collected and analyzed. The findings of this one season are therefore presented as preliminary results but serve as the final report for the funded research project. This research will be used to develop a GWSS performance database on the host plant species that are identified as truly critical to GWSS survival, which is needed to fully support decision making, and to supplement what is observed in the field. Currently, no quantitative data is available on the relative suitability of single or multiple hosts most relevant in southern California's agriculture, landscape or native vegetation, to GWSS growth and development. This project will provide this baseline information, identify host plant limitations at different life stages and will ultimately identify key nutrients responsible for this phenomenon.

OBJECTIVES

1. Use 25 different host plant species in 4 replicates per location at 3 locations: Coastal (Piru, Ventura County), Inland (Redlands, San Bernardino County), and South (Pauma Valley, San Diego County) to determine: the age structure and utilization of GWSS on the host plants throughout the season; GWSS egg parasitization and mortality; GWSS fecundity and feeding rate on selected host plants; the presence of *Xf* in host plants; and the chemical composition of the host plant xylem fluids at tree times during the season.

RESULTS

From April onwards, the GWSS age structure and resident generalist predators on 25 different host plants were observed weekly. In four replications, 25 potted (5gal) host plants were used to test the preference of resident GWSS at 3 southern California locations within unsprayed citrus orchards. For each replication, 25 plant pots were placed in a completely randomized block design within the rows. Each block was enclosed in a square 1.5x1.5 m pen made with chicken wire. Plants were hand watered 2-3 times per week. The plant species were selected for their common ornamental or agricultural use or their status as orchard weeds or their occurrence in foothill and riparian environments in southern California (Table 1). Batch samples from each of the host plant species were tested for the presence of *Xf* on three occasions between April and July. With the exception of one *Hedera helix* batch sample in May, all batch samples tested negative. In follow-up tests of single *Hedera helix* plants, no individual plant tested positive for *Xf*.

Table 1. Mean number of egg masses, adults and nymphs recorded per GWSS host plant species in Piru, Redlands and Pauma Valley, California.

Plant	Plant name	Common name	Egg masses[1]	Adults[2]	Nymphs[3]
1	*Hibiscus* sp.	'Mrs. J. E. Hendrey' hibiscus	3.42 ± 1.064 abc	10.50 ± 4.265 a	3.42 ± 0.908 ab
2	*Lagerstroemia indica*	Crape Myrtle	9.58 ± 1.607 de	34.25 ± 20.350 a	17.92 ± 5.113 d
3	*Nerium oleander*	Oleander (white)	O	19.75 ± 8.294 a	10.17 ± 2.925 bc
4	*Gardenia jasminoides*	'Mystery' Gardenia	1.50 ± 0.832 ab	0.42 ± 0.193 a	2.17 ± 0.842 ab
5	*Citrus sp.*	Valencia Orange	2.42 ± 1.314 abc	13.15 ± 3.175 a	11.17 ± 3.164 c
6	*Photinia sp.*	Red Tip Photinia	6.67 ± 2.021 cd	2.08 ± 0.763 a	4.92 ± 1.681 abc
7	*Eucalyptus cinerea*	Silver Dollar Tree	0.50 ± 0.167 a	0.33 ± 0.188 a	0.50 ± 0.289 a
8	*Vitis vinifera*	Thompson Seedless Grape	11.17 ± 2.49 e	14.42 ± 3.019 a	29.75 ± 6.516 e
9	*Euonymus japonica*	Silver Queen	1.92 ± 0.654 ab	0.92 ± 0.358 a	0.25 ± 0.131 a
10	*Ligustrum japonicum*	'Texanum' Wax Leaf Privet	1.58 ± 0.617 ab	1.25 ± 0.494 a	3.25 ± 0.970 ab
11	*Agapanthus africanus*	Lily of the Nile	2.00 ± 0.834 ab	1.08 ± 0.336 a	0.42 ± 0.193 a
12	*Hedera helix*	English ivy	0.33 ± 0.243 a	1.08 ± 0.763 a	0.83 ± 0.297 a
13	*Sonchus oleraceus*	Sowthistle	O	O	0.08 ± 0.083 a
14	*Chenopodium berlandieri*	Lambsquarter	O	0.33 ± 0.188 a	0.33 ± 0.256 a
15	*Malva neglecta*	Cheeseweed	O	O	0.92 ± 0.288 a
16	*Senecio vulgaris*	Common Groundsel	O	O	O
17	*Rhus integrifolia**	Lemonade Berry	0.33 ± 0.263 a	0.58 ± 0.193 a	1.17 ± 0.767 a
18	*Heteromeles arbutifolia**	Toyon	2.00 ± 0.872 ab	0.33 ± 0.188 a	0.67 ± 0.497 a
19	*Baccharis pilularis**	Coyote Brush	1.25 ± 0.740 ab	0.92 ± 0.609 a	1.42 ± 0.434 a
20	*Lonicera subspicata**	Honeysuckle	0.08 ± 0.083 a	0.17 ± 0.112 a	0.08 ± 0.083 a
21	*Opuntia basilaris**	Beavertail Cactus	O	O	0.33 ± 0.333 a
22	*Oenothera speciosa*	Mexican Evening Primrose	0.33 ± 0.067 a	0.25 ± 0.131 a	1.42 ± 0.452 a
23	*Populus candicans*	Cottonwood	4.92 ± 1.493 bc	205.67 ± 96.643 b	54.25 ± 8.927 f
24	*Platanus occidentalis*	"Bloodgood" Sycamore	13.33 ± 3.404 e	12.75 ± 4.961 a	6.58 ± 1.694 abc
25	*Prunus subhirtella*	Akebone Ornamental Cherry	13.83 ± 4.606 e	17.08 ± 8.164 a	4.67 ± 1.689 abc

*: California native plant

O: life stage not recorded on host plant species

[1] Mean number of egg masses recorded on host plant species over all three locations (different letters indicate significant differences, Kruskal Wallis t=133.69, P<0.0001).

[2] Mean number of adults recorded on host plant species over all three locations (different letters indicate significant differences, Kruskal Wallis t=154.54, P<0.0001).

[3] Mean number of nymphs recorded on host plant species over all three locations (different letters indicate significant differences, Kruskal Wallis t=194.54, P<0.0001).

When considering life stages at the different locations, more egg masses were found on the host plants in Pauma Valley between June 24 and August 19 compared to both Piru and Redlands in the same period (unequal variance: Kruskal Wallis: t=7.237, P=0.027) (Figure 1A). The numbers of eggs per egg mass were significantly higher in Pauma (ANOVA df=2, F=10.93, P<0.001), a larger proportion of the eggs were parasitized in Pauma (ANOVA df = 2, F = 10.67, P<0.001), with no difference in emergence of eggs masses (ANOVA df=2, F=3.04, P=0.05). The portion survival of eggs per egg mass is lowest in Pauma (ANOVA df=2, F=10.80, P<0.001) (Table 2). Of the parasitized egg masses recorded in Piru, all were *Gonatocerus* sp., but in Redlands 6% were parasitized by *Trichogramma* sp as were 4% of the egg masses from Redlands. The survival of *Trichogramma* parasitized egg masses was 0.595 ± 0.0544 significantly lower than the survival of *Gonathocerus* parasitized egg masses 0.764 ± 0.011 (unequal variance: Kruskal Wallis t=11.89, P=0.000563). No differences were found between the egg mass size and the fraction parasitized for *Trichogramma* or *Gonatocerus* (results not shown).

Table 2. The survival, fraction parasitized and fraction emerged parasitoids recorded in GWSS egg masses in Piru, Redlands and Pauma Valley, California.

	Location			ANOVA		
	Piru	Redlands	Pauma Valley	df	F	*P*
N	197	172	557			
#eggs/egg mass	11.56 ± 0.467 a	12.02 ± 0.499 a	13.81 ± 0.278 b	2	10.93	<0.001
Survival	0.847 ± 0.024 b	0.795 ± 0.025 b	0.725 ± 0.014 a	2	10.80	<0.001
Fraction parasitized	0.666 ± 0.029 b	0.676 ± 0.031 b	0.545 ± 0.020 a	2	10.67	<0.001
Fraction emerged parasitoids	0.804 ± 0.029 a	0.848 ± 0.031 a	0.762 ± 0.019 a	2	3.04	0.051

No egg masses were recorded on oleander, sowthistle, cheeseweed, lambsquarter, common groundsel or beavertail cactus. Over all sites, the mean number of egg masses recorded was largest on sycamore, cherry and grape, followed by crape myrtle and photinia (Table 1). The number of egg masses per host plant species differed significantly for crape myrtle, eucalyptus, grape, primrose and cottonwood, on which fewer egg masses were found in Piru and Redlands than in Pauma (results not shown). In Piru, most egg masses were recorded on sycamore and cherry, followed by grape. In Redlands, most egg masses were recorded on grape, followed by crape myrtle and photinia, which had more egg masses than sycamore and cherry. In Pauma, most egg masses were recorded on crape myrtle, grape, sycamore and cherry followed by photinia. Because of unequal variances, the Kruskal Wallis test was used for these analyses with P<0.0001 in all cases (results not shown).

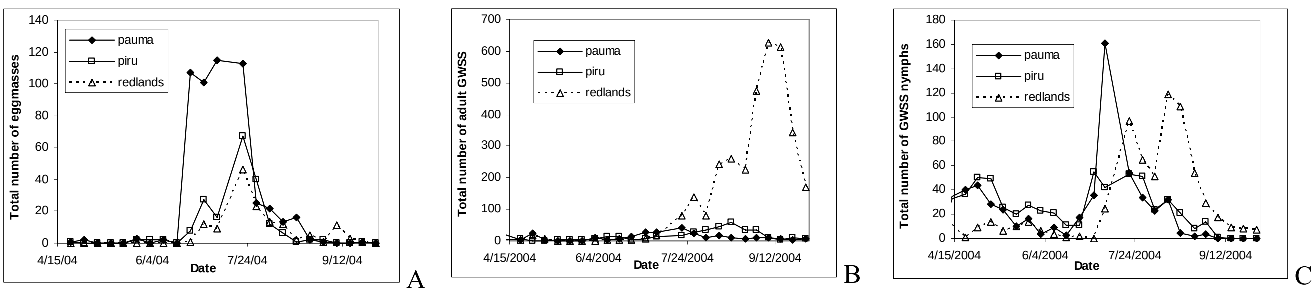

Figure 1. Total number of GWSS egg masses (A), adults (B) and nymphs (C) recorded between April and October 2004, on 100 host plants located in a citrus orchard in Piru, Redlands and Pauma Valley, CA.

When considering GWSS adults at the different locations, more were found on the host plants in Redlands between June 16 and October 1 compared to both Piru and Pauma in the same period (unequal variance: Kruskal Wallis: t=8.4481, *P*=0.0146) (Figure 1B). Adults were not recorded on sowthistle, cheeseweed, common groundsel or beavertail cactus. Over all sites, the mean number of adults recorded was largest on cotton wood (Table 1). In Redlands, more adults were found on hibiscus, oleander, Valencia orange, photinia, euonymus, ligustrum, cottonwood and cherry than in Piru or Pauma (results not shown). In Piru and in Redlands, more adults were recorded on cottonwood than on any other host plant species (t=59.75, *P*<0.00001 and t=72.05, *P*<0.00001 respectively). In Pauma, most adults were recorded on cotton wood, but these did not differ significantly from sycamore and grape (t=63.61, *P*<0.00001). Because of unequal variances the Kruskal Wallis test was used for these analyses (results not shown). The data on the immature GWSS were collected as small, medium and large GWSS nymphs. For the purpose of these preliminary analyses, the stages were added to present one number per host plant per observation at each location. The number of GWSS nymphs at the different locations changed through the season. From April though June, significantly fewer nymphs were recorded in Redlands when compared to Pauma and Piru in the same period (unequal variance: Kruskal Wallis: t=10.04, *P*=0.0066) (Figure 1C). From late July through October, significantly fewer nymphs were recorded in Piru, when compared to Redlands and Pauma in the same period (unequal variance: Kruskal Wallis: t=7.78, *P*=0.0204) (Figure 1B). No nymphs were recorded on common groundsel. Over all sites the mean number of nymphs recorded was largest on cotton wood, followed by significantly lower numbers on grape, crape myrtle, and Valencia orange (Table 1). No differences were found when comparing numbers of nymphs per host plant species between the locations (results not shown). In Piru, most nymphs were recorded on cottonwood, followed by grape and citrus (t=70.3, *P*<0.00001). In Redlands, most nymphs were also recorded from cottonwood, followed by grape and crape myrtle (t=72.49, *P*<0.00001). In Pauma Valley, most nymphs were found on cottonwood and grape, followed by crape myrtle and Valencia orange (t=68.92, *P*<0.00001). Because of unequal variances the Kruskal Wallis test was used for these analyses (results not shown).

On June 30, July 1-2, August 10-12, and September 28-30, xylem fluid samples were taken from all host plants except oleander, amaranthus, ivy, sowthistle, common groundsel, cheeseweed, lambsquarter, honey suckle, primrose and beavertail. These species were omitted because experience has shown that they do not comply with the technique used for xylem extraction, rendering the sampling impossible. With the use of a nitrogen gas pressure chamber, 150-600μl was collected per plant and frozen for storage. The xylem fluid from five host species (cottonwood, crape myrtle, cherry, grape, and sycamore) was chemically analyzed for amino acid content (four replications for each species per site per date). Species were selected based on GWSS utilization and consistency of xylem extraction (healthy hardwoods of each species were present at all sites). The five species varied greatly in amino acid composition with cottonwood consistently (8 of the 9 site/date combinations) having the highest titers of total amino acids. Amino acid profiles (ratios of individual amino acids) varied greatly with host species (mean values for each species are shown in Table 3). Concentrations of amino acids were also site and date dependent. When the chemical composition of each host species was analyzed separately as a factorial (3 locations x 3 sites for each of the five species), concentrations of individual amino acids were found to be greatly impacted by site and time of year. For the models analyzed (95 = 5 host species x 19 dependent variables (individual amino acids)) over 40% of the models showed significant effects ($P < 0.05$) of site and location. Date has significant effects ($P < 0.05$) in over 30% of these analyses, location was significant 26% and interactions (date*location) was significant in 17% of the models. We are currently entering all nutritional data (xylem chemistry) and insect data into an ongoing database to determine nutritional correlates to GWSS host utilization. This analysis is ongoing, but it is clear that our preliminary data is consistent with previous nutritional studies of GWSS. For example, cottonwood is consistently the host providing the highest overall concentrations of amino acids (Table 3) and is also the host most frequently utilized by GWSS in our plots. Cottonwood also has amide-rich (glutamine plus asparagine) profiles which have been previously shown to be correlated with GWSS abundances and feeding rates (Brodbeck et al. 1990, Andersen et al. 1992). We will continue to analyze this data to determine nutritional correlates to other aspects of GWSS life history.

Table 3. Mean uM concentrations of amino acids for five host species averaged over the collection locations and three sampling dates.

Amino Acid	Cottonwood	Crape Myrtle	Grape	Cherry	Sycamore
Aspartic Acid	54 ± 6	22 ± 5	35 ± 3	108 ± 18	32 ± 5
Glutamic Acid	75 ± 9	27 ± 4	30 ± 3	84 ± 14	47 ± 7
Asparagine	204 ± 77	5 ± 2	5 ± 1	93 ± 19	51 ± 24
Serine	34 ± 4	10 ± 1	17 ± 2	30 ± 6	26 ± 4
Glutamine	629 ± 143	33 ± 11	164 ± 49	45 ± 11	28 ± 6
Glycine	24 ± 3	6 ± 1	12 ± 2	17 ± 4	13 ± 2
Histidine	21 ± 4	2 ± 0.5	13 ± 3	8 ± 3	21 ± 4
Arginine	72 ± 13	22 ± 10	57 ± 15	188 ± 38	56 ± 20
Threonine	25 ± 7	4 ± 1	7 ± 1	15 ± 3	9 ± 1
Alanine	60 ± 7	20 ± 4	25 ± 3	32 ± 4	44 ± 6
Proline	19 ± 2	8 ± 1	17 ± 3	20 ± 3	16 ± 2
Valine	62 ± 17	10 ± 2	12 ± 2	12 ± 2	17 ± 2
Isoleucine	38 ± 11	9 ± 1	10 ± 1	10 ± 1	12 ± 1
Leucine	15 ± 2	7 ± 2	7 ± 1	5 ± 0.5	10 ± 1
Phenyalanine	6 ± 1	2 ± 1	2 ± 0.3	4 ± 1	4 ± 1
Lysine	4 ± 0.4	2 ± 0.2	2 ± 0.3	4 ± 1	5 ± 1
Total	1344 ± 213	189 ± 32	415 ± 62	673 ± 90	391 ± 58

CONCLUSIONS

The data thus far indicates that the most eggs, nymphs and adults are not necessarily recorded on the same plant species as has been reported before (Brodbeck et al. 1999). In this study the only host plant used frequently in all life stages is cottonwood. On grape and crape myrtle, nymphs and eggs are frequently recorded, while photinia, cherry and sycamore frequently hosted egg masses but not the other life stages. The suitability of the host plants for these GWSS life stages may be linked to the chemical composition of the xylem fluids (Andersen et al. 1992, Brodbeck et al. 1990, 1993, 1995, 1996, 1999). Sawthistle, common groundsel, lambsquarter, cheeseweed, primrose and beavertail did not host large GWSS numbers, if any. During 2005, the location influenced the size of GWSS egg masses (larger egg masses in the south), survival (lower in the south) and parasitism (lower in the south). The underlying factors may be related to temperature and humidity which have been recorded but have not been correlated to the findings yet. The major difference between the coastal and inland locations at similar latitude is the number of second generation adults, and all life stages from the second generation are responsible for most of the location differences. Aside from the egg masses, there are no obvious differences in the other life stages recorded in the coastal and southern location. The results of the xylem fluid analyses support our hypotheses that the phenology of host plants needs to be considered at each location, as this data clearly shows that the underlying host physiology varies with location as well as time of year.

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