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Source: Florida Entomologist, 104(1) : 51-53

Published By: Florida Entomological Society

URL: https://doi.org/10.1653/024.104.0108

Pests of Florida hops: preliminary observations

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The hop plant, *Humulus lupulus* L. (Cannabaceae), produces flowers, also referred to as cones, which are used to provide flavor and aroma to beer. Since 2016, hops has been studied at the University of Florida's Gulf Coast Research and Education Center in Wimauma, Florida, USA, as an alternative crop for Florida. In Florida, hops were not grown commercially before 2016, but it is estimated that hop production has expanded to nearly 16 ha in the state (Smith 2018). Hops typically is grown in temperate climates, and prior to 2016 there was little information available regarding the pest complex likely to affect hops in Florida. From 2016 through 2020, the Vegetable Entomology program at Gulf Coast Research and Education Center scouted hops research plots, submitted arthropods associated with hops for identification, and provided recommendations for chemical and biological control of pests including two-spotted spider mites, *Tetranychus urticae* (Koch) (Trombidiformes: Tetranychidae), on hops. The objectives of these efforts were to identify primary pests of Florida hops and beneficial arthropods associated with them, and to lay the foundation for a predator-based approach to managing two-spotted spider mites on hops. Scouting and pest management guidance also has been offered to a commercial hopyard in Brooksville, Florida, USA, since 2017.

The hopyard at Gulf Coast Research and Education Center consists of eight 72 m rows of hops with hills spaced 0.9 m apart within the row and 2 plants per hill (80 hills per row). The primary variety grown at Gulf Coast Research and Education Center is 'Cascade.' The space between rows is 4.6 m, resulting in 2,392 hills per ha. Plants are grown on 5.5 m trellises. Scouting consisted of visual examination of 5 randomly selected plants per row. Pest and beneficial arthropods were collected and brought to the Vegetable Entomology lab for curation and identification. Some specimens were submitted to the Division of Plant Industry, Gainesville, Florida, USA, for identification by specialists. A 10× hand lens was used during scouting to examine the underside of hops leaves for the presence of spider mites and mite predators. Insecticides and miticides were applied occasionally to the hops for management of caterpillars and spider mites during the 2016 to 2018 growing seasons. Insecticides were applied in 935 L of water per ha (100 gpa) using a Pak Blast Sprayer (Rears Manufacturing Company, Coburg, Oregon, USA) pulled by a John Deere 5310 tractor (John Deere, Moline, Illinois, USA). On 4 Jun 2018, water sensitive cards (TeeJet, Louisville, Kentucky, USA) were placed at 3 levels (1, 3, and 5 m above the ground) every 10 m per row prior to application of miticides at Gulf Coast Research and Education Center to evaluate the percentage of spray coverage. In total, 192 cards were deployed.

During the fall of 2019, releases of the predatory mite *Phytoseiulus persimilis* Athias-Henriot (Mesostigmata: Phytoseiidae) were evaluated for management of spider mites. About 5 *P. persimilis* were applied to the base and the upper canopy of each plant on 10 Sep, which was 69 d after bines were cut to initiate growth for the fall season. About 5 additional *P. persimilis* were applied to the base of each plant on 17 Sep. Spider mite sampling was expanded that season to include the upper canopy of the hops. Five leaves from 1.5 m above the ground and 5 leaves from 5 m above the ground were collected from 5 randomly selected plants per row. A Genie S40 Boom Lift (Terex Corporation, Redmond, Washington, USA) was used to scout and collect leaves from the upper canopy of the hops. Leaf samples were taken to the laboratory where motile (immature and adult) and egg stage spider mites were counted using a mite brushing machine (BioQuip, Rancho Dominguez, California, USA). The effect of stratum (1.5 m or 5 m above ground level), sample date, and the interaction of the 2 factors on number of spider mite eggs and motiles was assessed by analysis of variance (PROC GLIMMIX; SAS 2015). Data were log transformed prior to analysis.

Table 1 lists the arthropods identified from hops at Gulf Coast Research and Education Center and Brooksville and maintained in a reference collection. Spider mites are the only pest to establish each season on hops at Gulf Coast Research and Education Center. Testimonial evidence from Florida hops growers attending hops field d at Gulf Coast Research and Education Center confirm that spider mites are a recurrent pest of the crop in other parts of the state. Globally, spider mites are considered a primary pest of hops (Neve 1991). Research suggests high densities (up to 90 per leaf) of spider mites may be tolerated without impacting cone production or quality (Weihrauch 2005). Applications of miticides to control spider mites at Gulf Coast Research and Education Center with the Pak Blast sprayer did not result in consistent or long-term reduction in spider mite populations. Water sensitive cards deployed 4 Jun 2018 indicate a mean of 44% insecticide

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Table 1. Some arthropods associated with hops (*Humulus lupulus*) at Gulf Coast Research and Education Center, Wimauma, Florida, USA, and dates of collection of voucher specimens, 2016 to 2020.

Order	Family	Species	Collection date
Trombidiformes	Tetranychidae	*Tetranychus urticae* Koch	15 Jun 2016; 1 May 2018
Mesostigmata	Phytoseiidae	*Neoseiulus* sp.	10 Sep 2019
Hemiptera	Tingidae	*Corythuca gossypii* (Fabricius)	28 May 2019
	Aleyrodidae	*Bemisia tabaci* Gennadius	17 Sep 2019
Lepidoptera:	Lycaenidae	*Strymon melinus* Hübner	13 Aug 2019
	Noctuidae	*Pseudoplusia includens* (Walker)	6 Sep 2019
		Spodoptera albula (Walker)	24 Sep 2018; 19 Aug 2019
		Spodoptera latifascia (Walker)	24 Sep 2018; 17 Sep 2019
	Tortricidae	*Platynota* sp.	15 Aug 2016
Thysanoptera	Phlaeothripidae	*Haplothrips gowdeyi* (Franklin)	8 Apr 2020
	Thripidae	*Frankliniella bispinosa* (Morgan)	17 Jun 2016; 28 May 2019
		Scolothrips pallidus (Beach)	8 Apr 2020
		Thrips palmi Karny	17 Jun 2016

coverage at 1.5 m, 33% coverage at 3 m, and only 18% coverage 5 m above ground level.

Sample date and stratum had a significant effect on number of spider mite eggs (date: $F_{6,266}$ = 43.49; P < 0.0001; stratum: $F_{1,266}$ = 21.59; P < 0.0001) and motiles (date: $F_{6,266}$ = 12.15; P < 0.0001; stratum: $F_{1,266}$ = 26.58; P < 0.0001) during fall 2019. Motiles tended to be 7 to 10 times more abundant at 5 m than at 1.5 m (Fig. 1). Eggs also tended to be higher in the upper canopy than at ground level, but there was considerable variability in the egg samples, and the upper canopy was only statistically higher than the lower canopy on 10 Sep (Fig. 1). The interaction between sample date and stratum was significant both for eggs ($F_{6,266}$ = 2.78; P = 0.01) and motiles ($F_{6,266}$ = 2.18; P = 0.045). Numbers tended to be higher in the upper stratum, however, there were wk in which differences between the upper and lower canopy were not significant.

Prior to the release of approximately 5 *P. persimilis* in the upper and lower canopy of each plant on 10 Sep 2019, the mean number of motiles (± SEM) was 7.6 (± 2.6) at 1.5 m, and 69.1 (± 19.9) at 5 m (Fig. 1). The following wk (17 Sep), when an additional release of about 5 *P. persimilis* was made at ground level, the means were 4.6 (± 1.3) at 1.5 m, and 28.8 (± 7.9) at 5 m. Motile numbers peaked 24 Sep at 10.3 (± 5.2) and 85.1 (± 32.9) in the upper and lower stratum, respectively, after which spider mite numbers declined each wk until they were not detected on 15 Oct (Fig. 1). It was not feasible to leave part of the hop-

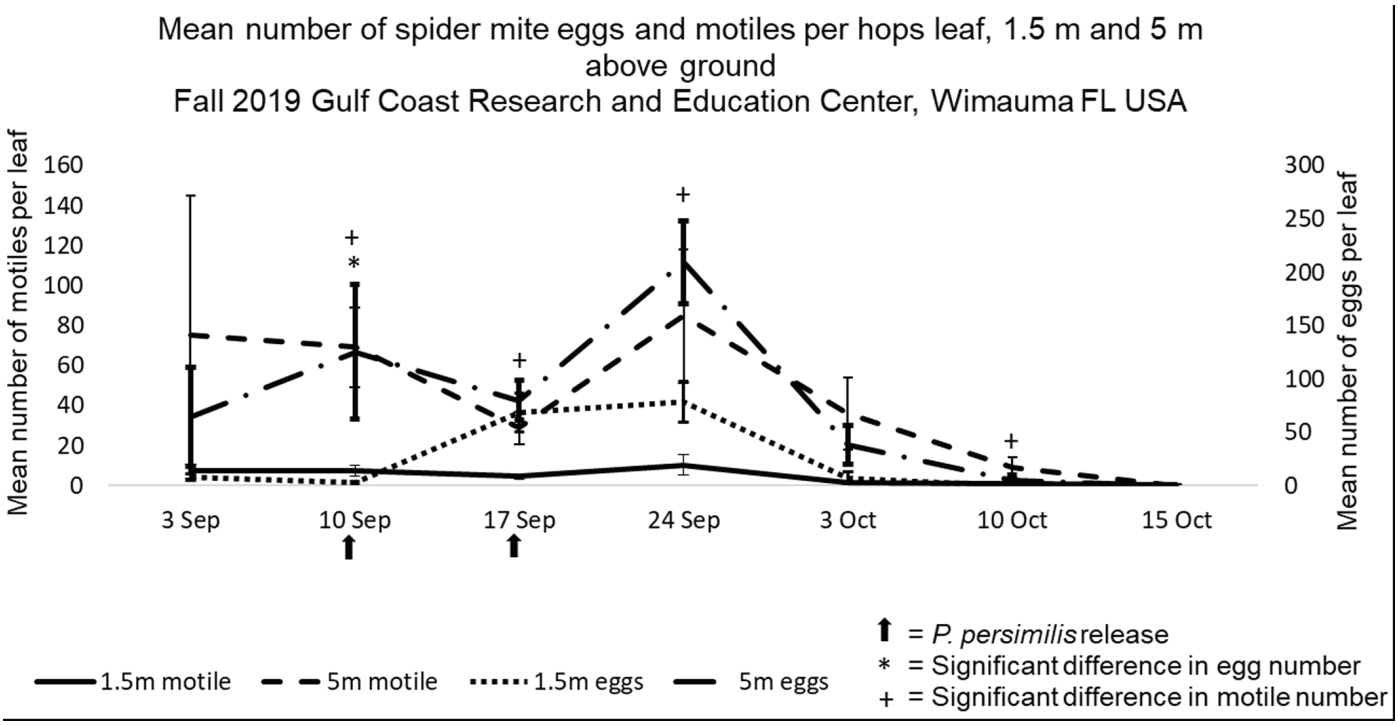

Fig. 1. Mean number (± SEM) of spider mite eggs and motiles collected from 1.5 and 5 m above the ground from hops (cv. 'Cascade'), fall 2019, Gulf Coast Research and Education Center, Wimauma, Florida, USA. About 10 *P. persimilis* per plant were released 10 Sep (5 at 1.5 m and 5 at 5 m) and about 5 *P. persimilis* per plant were released in the lower canopy 17 Sep. An asterisk (*) indicates that numbers of spider mite eggs at 1.5 and 5 m were statistically different using Tukey's mean separation test (p < 0.05); a cross (+) indicates that numbers of spider mite motiles at 1.5 and 5 m were statistically different.

yard untreated; therefore, no data are available showing how spider mite populations would have behaved in the absence of *P. persimilis* releases. However, *P. persimilis* was observed consistently on leaves with spider mites, and we are confident that the releases contributed to the decline of spider mite populations. In addition, naturally occurring spider mite predators were observed, including *Stethorus* sp. (Coleoptera: Coccinelidae), *Neoseiulus* sp. (Mesostigmata: Phytoseiidae), *Orius* sp. (Hemiptera: Anthocoridae), and trash bugs (Neuroptera: Chrysopidae).

Research on management of hops pests at Gulf Coast Research and Education Center indicates that fogging insecticide application equipment commonly used in citrus, such as the Pak Blast sprayer, may provide insufficient coverage for effective spider mite management. Data collected in the fall of 2019 suggests that spider mite densities tend to be much higher in the upper canopy than the lower canopy, indicating that pest densities at ground level may not be representative of densities throughout the crop. Evaluations of releases of *P. persimilis* show great promise for management of spider mites in Florida hops. In the fall of 2019 and the spring of 2020, when *P. persimilis* was released for spider mite control and no insecticides were applied for any pest, other pests did not establish in substantial numbers. Cotton lace bug and caterpillars were problematic only in previous years when insecticides were applied. Caterpillar larvae and egg masses that were collected in 2019 and 2020 for identification frequently were parasitized by braconids or eulophids. Katydid (Orthoptera: Tettigoniidae) eggs collected from hops leaves 24 Oct 2019 produced the egg parasitoid *Anastus mirabilis* (Walsh & Riley) (Hymenoptera: Eupelmidae) but no katydids. *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae) nymphs were observed occasionally on hops leaves at low densities but usually were parasitized. Various thrips species were observed occasionally in low numbers on foliage and cones, usually associated with *Orius* sp. We speculate that the tall canopy of the hopyard, which provides full sun part of the d, but also shade and conserved moisture, creates a stable habitat for a variety of herbivorous, predatory, and parasitic arthropods, keeping pests (with the exception of spider mites) at low densities in the absence of insecticide applications.

Laurie Chambers assisted with this research, which was funded with support from the Florida Department of Agriculture and Consumer Services Specialty Crop Block Grant program. We are grateful to BioBee Biological Systems Ltd for donations of *P. persimilis*.

Summary

Surveys of arthropods associated with hops at the University of Florida's Gulf Coast Research and Education Center, Wimauma, Florida, USA, from 2016 to 2020 reveal that spider mites are the primary pest of the crop. Lepidoptera and lace bugs also were observed causing occasional damage to the crop. Whiteflies and thrips have been observed on the crop in low numbers. The tall (5.5 m) canopy of the hops trellis creates a challenge to applying insecticides with adequate coverage. Sampling data indicate that spider mite densities tend to be higher in the upper canopy than at ground level. Efforts to control spider mites with releases of the commercially available predator *Phytoseiulus persimilis* showed promise. Naturally occurring spider mite predators observed on hops at Gulf Coast Research and Education Center include *Stethorus* sp., *Neoseiulus* sp., *Orius* sp., and trash bugs.

Key Words: *Humulus lupulus*; spider mites; *Phytoseiulus persimilis*

Sumario

Los sondeos de artrópodos asociados con el lúpulo en el Centro de Educación e Investigación de la Costa del Golfo de la Universidad de Florida, Wimauma, Florida, EE. UU., desde el 2016 hasta el 2020, revelan que las arañas rojas son la plaga principal del cultivo. También, se observaron lepidópteros y chinches que causan daños ocasionales al cultivo. Se han observado pequeñas cantidades de moscas blancas y trips en el cultivo. El dosel alto (5,5 m) del enrejado del lúpulo crea un desafío para una aplicación de insecticidas con la cobertura adecuada. Los datos de muestreo indican que las densidades de arañas rojas tienden a ser más altas en el dosel superior que a nivel del suelo. Los esfuerzos para controlar las arañas rojas con la liberación del depredador comercial *Phytoseiulus persimilis* se mostraron prometedores. Los depredadores de las arañas rojas observados que ocurren naturalmente sobre el lúpulo en el Centro de Educación e Investigación de la Costa del Golfo incluyen *Stethorus* sp., *Neoseiulus* sp., *Orius* sp., y crisópidos.

Palabras Clave: *Humulus lupulus*; arañas rojas; *Phytoseiulus persimilis*

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