



Observation of Potential Pests of Hops (*Humulus lupulus*) Grown in the Southeastern United States

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Humulus lupulus, commonly known as hops, is an herbaceous perennial crop cultivated from rhizomes for its strobiles which contain important compounds for the flavoring and aroma of food, tea, and beer. Interest in producing hops in areas outside of the Pacific Northwestern United States has been fueled by demand for locally produced products and growing craft beer market. Several arthropod pests threaten hop production in the Pacific Northwest; however, the pest or pest complexes that will impact hops grown in Florida are currently unknown. Without appropriate intervention, high density population of potential pests can result in total crop loss. Identification of potential pests provides important information that assists with establishing and integrating pest management controls. Sixty hop rhizomes consisting of four varieties ('Chinook', 'Columbus', 'Amalia', and 'Neo1') were transplanted into native deep sand soil (Tavares-Millhopper soil series) within a protected agricultural polyethylene covered, open-sided greenhouse located in Apopka, FL, and cultivated for a period of two years. Observation and identification of potential pests on hops produced in Southeastern United States included: spider mites (*Tetranychus urticae* and *Oligonychus ilicis*), whitefly (*Bemisia tabaci* and *Aleurodicus dugesii*), and aphid (*Aphis gossypii*). Results from this work are critical in aiding commercial hop producers in the Southeastern United States correctly identify potential pest of hops. Moreover, this observational report also serves as a foundational platform for production viability and development of future integrated pest management programs.

Hops (*Humulus lupulus*), along with barley, yeast, and water, are one of four main ingredients necessary for production of beer. Although beer production within several major countries has declined in the past several years, hop consumption and use has continued to increase as a result of shifts in consumer preferences and demand. Recent growth in the craft beer industry, coupled with high demand for locally produced horticultural products, has led to explosive interest in the cultivation of locally-produced hops (Tremblay and Tremblay, 2011). As a result of this demand, research programs have been developed to provide information necessary for successful commercial production of this unique specialty crop.

Introduction of hops into nontraditional areas exposes them to new pests or pest complexes and requires the development of an integrated pest management plan that accurately identifies the threat through effective monitoring and control methods. Identifying pests with the potential to inflict economic loss for this new crop is needed. Control options of these pests vary, making

positive identification for the commercial grower or the home garden vital to select effective management choices. Currently, there is little research on the potential pests of hops grown in the Southeastern United States. In this study, 60 hop rhizomes consisting of four varieties ('Chinook', 'Columbus', 'Amalia', and 'Neo1' obtained from RNV Enterprises in Yakima, Wash.) were transplanted into native deep sand soil (Tavares-Millhopper soil series) within a protected agricultural polyethylene covered, open-sided greenhouse located in Apopka, FL. The study was a randomized-incomplete block design with 15 replicates. Hops were cultivated for two years with weekly or bi-weekly scouting efforts. Arthropods associated with each variety were identified as potential pests of a commercial cultivation program. Potential important pests observed included spider mites (*Tetranychus urticae* and *Oligonychus ilicis*) (Fig. 1), whiteflies (*Bemisia tabaci* and *Aleurodicus dugesii*) (Fig. 2), aphids (*Aphis gossypii*) (Fig. 3), and Sri Lankan weevils (*Myllocerus undecimpustulatus undatus*) (Fig. 4). These pests were observed frequently feeding and infesting hops. Additional insects observed at lower frequency were lacebugs (*Corythucha* spp.) (Fig. 5A), leafroller moth larvae (*Platynota rostrana*) (Fig. 5B), armyworm *Spodoptera* spp., planthoppers (*Acanalonia servillei*) (Fig. 5D), and western flower thrips (*Frankliniella occidentalis*) (Fig. 5E). Although

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Fig. 1. (A) Two spotted spider mites (*Tetranychus urticae*), (B) southern red spider mite *Oligonychus ilicis* , and (C) speckling on top of leaf due to mite feeding underneath.

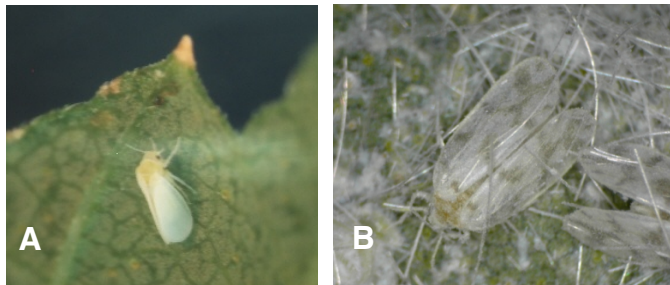


Fig. 2. (A) Silver leaf whitefly (*Bemisia tabaci*) and (B) giant whitefly (*Aleurodicus dugesii*).

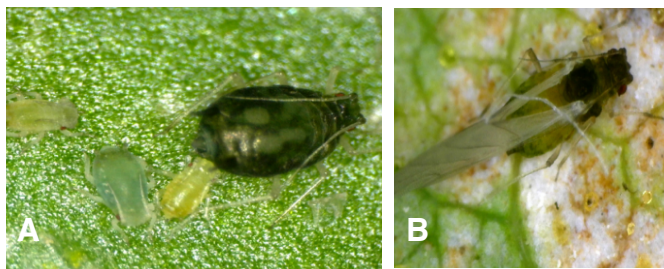


Fig. 3. Melon aphids *Aphis gossypii* (A) wingless and (B) winged forms.

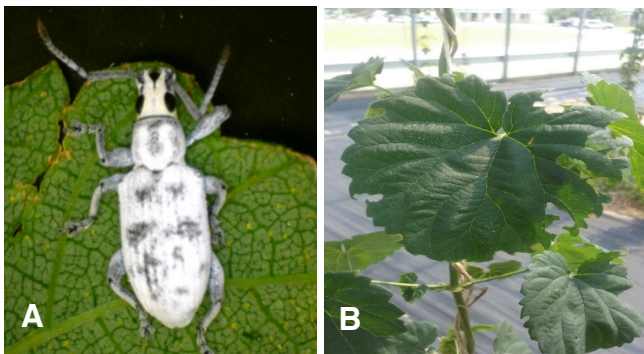


Fig. 4. (A) Sri Lankan weevil (*Myllocerus undecimpustulatus undatus* Marshall) and (B) feeding.

not directly feeding on the plant, adults of the hairy darkling beetle (*Epitragodes tomentosus*) (Fig. 5F) aggregated in hops in great quantities on occasion. Results from this work will aid in pest management programs and provide foundational information necessary for the development of future integrated pest management programs.

Spider Mites

DESCRIPTION. Spider mites (Fig. 1) are small and oval, with female mites about 0.5 mm long, while males are 3/4 the size. The two spotted spider mite (*Tetranychus urticae*) and the southern red spider mite (*Oligonychus ilicis*) spin fine strands of webbing on the host plant, providing protection from wind, rain, natural enemies, and contact pesticides. They are most problematic during warm and dry conditions and may overwinter in the leaf litter during dormancy (Gent et al., 2015).

DAMAGE TO HOPS. Spider mites feed by penetrating the plant tissue with their piercing-sucking stylet mouthparts, principally on the underside of the leaf, to remove plant sap, causing graying or yellowing of the leaves. Symptoms include necrotic spots on leaves, decreasing host plant's photosynthetic ability and nutrient availability. High populations lead to severe defoliation and plant death. Most commercial and economic harm results from spider mites feeding on hop strobiles, or cones, which may become discolored, desiccated and shatter (breaking up of the cone structure at or after harvest), inevitably diminishing value and yield of harvest. Even at low populations, reduction of alpha and beta acids, the primary bittering compounds in hops, can occur (Gent et al., 2015). The ability of spider mites to transmit plant disease due to their feeding habit is a concern, although no evidence of spider mites vectoring hop diseases has been documented. Two-spotted spider mites (*Tetranychus urticae*), considered to be one of the most economically important spider mites, infests over 200 species of plants and are found throughout the United States in greenhouses, surviving through winters. Southern red mites (*Oligonychus ilicis*) feed primarily on foliage of woody ornamental plants and are found throughout the eastern United States (Fasulo et al., 2000). Considered contaminants that lower cone quality, spider mite feeding damages both leaves and cones, consequentially lowering alpha-acid content in hop cones, which can lead to rejection by brewers (Gent et al., 2015).

LIFE CYCLE. The spider mite life cycle is generally composed of the egg, the larva, two nymph stages, and the adult. Female spider mites can lay five or six eggs per day and up to several hundred eggs in a lifetime. Depending on climatic conditions, eggs hatch after approximately three days. When temperatures

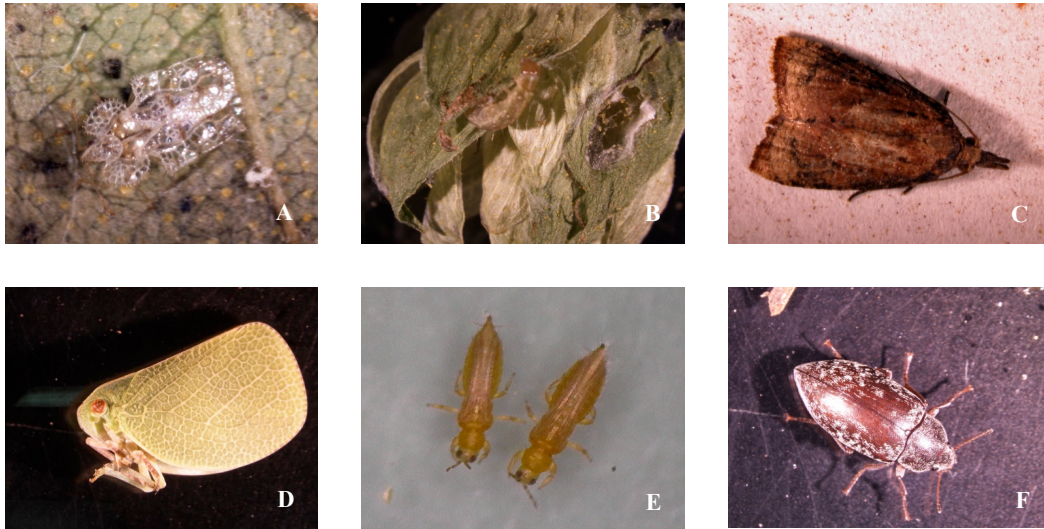


Fig. 5. (A) *Corythuca* Lacebug on underside of hop leaf in Fall 2014, (B) leafroller moth larvae (*Platynota rostrana*) feeding on hop cone in Fall 2014, (C) Adult leafroller moth, (D) Planthopper (*Acanalonia servillei*), (E) Western flower thrips (*Frankliniella occidentalis*), and (F) Adult hairy darkling beetle (*Epitragodes tomentosus*).

are high, spider mites develop from egg to adult in a little as five to seven days. High reproductive rates result in overlapping generations and high possibility of rapid outbreaks (Fasulo et al., 2000). Outbreaks of mites frequently occur during hot and dry summer months. As temperatures decrease in the fall, spider mites begin entering a physical dormancy known as diapause. Diapause allows spider mites to survive winter below the soil surface in freezing temperatures. As temperatures increase and environmental conditions improve in the successive spring, spider mites break dormancy to feed and lay eggs on the newly emerged young tender shoots of the hop plant (Gent et al., 2015).

Whitefly

DESCRIPTION. Whiteflies are related to aphids, scales, and mealybugs and resemble tiny white moths with yellowish bodies and four whitish wings (Fig. 2). Frequent pests of greenhouse-grown ornamental crops, whiteflies use their piercing-sucking mouthparts on undersides of leaves to ingest plant sap, resulting in yellowing leaf material that eventually dries and falls off the plant. Outside of protected cultivation, whitefly outbreaks generally occur during warm weather and when natural biological control is disrupted, such as through chemical pesticide applications. Once populations are high, management may be difficult (Flint et al., 1998).

DAMAGE. Feeding from underside of the leaves, the piercing-sucking stylet mouthparts of whiteflies cause tops of leaves to yellow and dry, decreasing host plant's photosynthetic ability and nutrient availability. Arguably, the most important threat from whitefly feeding is the insect's ability to transmit plant viruses. While *Bemisia* whiteflies vector several plant viruses (Polston et al., 2014), there is no current evidence that they vector disease in hops. Feeding produces a sticky excrement from whiteflies, commonly referred to as honeydew, which serves as a food source for ants and sooty mold fungus which can further restrict photosynthesis and reduce plant growth. Ants, in protecting their food source, also disrupt the efficiency of natural enemies.

The silverleaf whitefly (*Bemisia tabaci*) is mainly a pest of plants in tropical and warm temperate areas. It is found throughout the southern United States and can overwinter outdoors as

far north as South Carolina (Polston et al., 2014). The giant whitefly (*Aleurodicus dugesii*), native to Mexico, can be found in southwest and southeastern United States where it has become an important pest of ornamental plants (Hodges, 2004).

LIFE CYCLE. Eggs of whiteflies are laid on the underside of leaves. Female whiteflies can lay several hundred eggs in a lifetime. Crawlers hatch after 4–12 days and begin to feed after locating a place to feed, which may take several hours. Once a feeding location is found, the crawler becomes immobile by inserting its mouthpart into the host plant. After molting three times, an adult emerges. Influenced by temperature and humidity, development from egg to adult varies from four weeks to six months (Byrne and Bellows, 1991).

Aphids

DESCRIPTION. Aphids are small soft-bodied insects, ranging from 1 to 2.5 mm that occur in wingless and winged forms during high population densities (Fig. 3). The melon aphid (*Aphis gossypii*), found in Southeastern and Southwestern United States, has a wide host range of approximately 60 plants in Florida and nearly 700 plants worldwide. Wingless forms of *A. gossypii* range in body color from whitish, pale green, light green, dark green, to yellow. Legs are pale with black tips. Black cornicles project from the abdomen of aphids and are used as protection from predators and parasitoids. The head and thorax of winged forms are black, while the body is commonly yellowish green with darker posterior parts. The wing veins of *A. gossypii* are brown in color (Capinera, 2004).

DAMAGE TO HOPS. Aphid adults and nymphs feed using a piercing-sucking mouthpart removing plant sap mainly from the underside of leaves, but can also be found at the growing tip of hop bines. Female aphids reproduce without mating, or parthenogenetically, as long as climatic conditions allow for feeding and growth. Heavy feeding from infestations causes yellowing of leaves, leaf curling, wilting, stunting and possible host plant death. Aphids secrete honeydew that can decrease the effectiveness of predatory insects and parasitoids by attracting ants, which protect the honeydew producing organisms. The honeydew also provides a food source for sooty mold, which

can decrease the plant's ability to photosynthesize. Having the ability to transmit viruses increases the importance of control of this pest. Although there is no evidence of the melon aphid (*A. gossypii*) vectoring diseases of hops, the hop aphid (*Phordon humuli*), potato aphid (*Macrosiphum euphorbiae*), and green peach aphid (*Myzus persicae*) have the ability to transmit known carlaviruses infecting hop plants (Gent et al., 2015). Therefore, emphasis should be placed on production practices which utilize certified clean plant material to avoid unwanted transmission from these pests.

LIFE CYCLE. The life cycle of aphids varies depending on environmental conditions. The melon aphid can complete development and reproduction in approximately seven days, therefore multiple generations can build quickly. When populations are high, aphids produce winged forms which disperse to new host plants (Capinera, 2004).

Sri Lankan weevil

DESCRIPTION. The Sri Lankan weevil (*Myloccerus undecimpustulatus undatus*) (Fig. 4), an exotic invasive species of weevil native to Sri Lanka, was discovered in Broward County, Florida during the fall of 2000. The Sri Lankan weevil is sometimes confused for a Florida native weevil known as the little leaf notcher (*Artipus floridanus* Horn). However, *M. undecimpustulatus undatus* has a yellow head, larger eyes, and longer antennae than *A. floridanus*, with spines on the hind legs (Neal, 2013). The Sri Lankan weevil is a serious pest of over 20 crops in India and Pakistan and had been documented to cause damage to over 100 species of ornamental and fruit trees. Both the adult and larval stage cause plant damage and are potential pests for hops production in the southern United States.

DAMAGE TO HOPS. The most noticeable damage to hops results from the leaf feeding activity of adult weevils which create notches on the leaf margins. Gent et al. (2015) states that weevil damage is not known to cause economic loss in the Pacific Northwest. However, damage to hops plants in our Florida study suggest that this new species of weevil has potential for economic loss in the southeastern United States. Although not evaluated in our study, perhaps of more concern, is the cryptic larval stages of the Sri Lankan weevil, which attack the roots of host plants. Larval feeding on roots can cause defoliation, plant decline, and eventually plant death (Mayer and Mannion, 2011).

LIFE CYCLE. Adult weevils typically emerge from overwintering and begin feeding within 24 hours and for about 30 days before they are able to lay eggs. Once the ability to oviposit is attained, over 300 eggs are laid during a several day period and deposited amongst organic matter just below the soil surface. The small creamy white cryptic larvae hatch from the eggs after about 3–5 days and begin to move down through the soil, feeding on host plant's roots for about one to two months. Larvae

overwinter then pupate to emerge in spring as adults near late April (Mayer and Mannion, 2011).

Conclusion

Since local environmental factors influence crop quality and commercial production success, it is critical to identify potential pests to newly introduced crops currently being evaluated for long-term commercial production. We identified several arthropods feeding on hops grown in Florida. Based on their occurrence in other regions, several of them, such as spider mites and whitefly, have the potential to become serious pests of commercial crops. Hops, a newly cultivated crop in the southeastern United States and Florida, requires insect pest identification to aid in control and develop future integrated pest management programs. Economic thresholds and action levels required for these pests in different hop varieties grown in the southeastern United States is being addressed in our ongoing research.

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