Cold Tolerance and Distribution of *Myllocerus undecimpustulatus undatus* (Coleoptera: Curculionidae) (Sri Lankan Weevil) in Florida

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**ADDITIONAL INDEX WORDS.** species distribution models, repeated cold exposure, sustained cold exposure

*Myllocerus undecimpustulatus undatus* Marshall, the Sri Lankan weevil, is a serious plant pest with a wide range of hosts. It was first identified in the United States on Citrus sp. in Davie, Broward County, Florida, on 15 September 2000. This weevil has over 150 different host plant species including fruits, nuts, vegetables, and ornamentals. It has been detected in 26 counties in Florida through December 2012. Historical data from 2000–15 obtained from the Division of Plant Industry’s field agent submissions indicate the northward spread of the Sri Lankan weevil in North America. Cold tolerance data indicate adults are acclimated to lower temperatures until reaching 0 °C and –5 °C. A sustained and multiple exposure experiment that more closely resembles actual cold events in Florida and other potential areas tested insects gathered in summer and winter to determine increased cold hardiness. This may provide valuable information to assist Extension agents and pest management professionals in preparing control strategies.

Insects are more likely to be susceptible to climate modifications because their basic physiological functions are strongly influenced by environmental factors (Deutsch et al. 2007). The most significant factors in the environment influencing insect function are temperature and humidity (Singh et al. 2009). Specific strategies to overcome stressful environments include behavioral avoidance, migration, diapause, and adaptation (Bale and Hayward 2009). Adaptation of an organism to changing environmental conditions may happen in its lifetime, or through many generations as an evolutionary adaptation (Singh et al. 2009). The ability of an insect to develop at different temperatures is an important adaptation to survive in different climatic conditions, which is valuable in predicting insect outbreaks (Mizell and Nebeker 1978). Over time, insects that are subjected to cooler temperatures may evolve morphological, physiological, and behavioral adaptations (Lalouette et al. 2009). These adaptations may possibly enable them to move into other regions.

Insects have the potential to become invasive in regions where they were previously unknown, and where temperature can have a direct impact on the probability of establishment (Bale and Hayward 2009). Species distribution models (SDMs) utilize geographic information systems (GIS), along with computer software packages and climate databases, to predict a particular species distribution (Elith and Leathwick 2009, Franklin 2009, Stratman et al. 2014). These models allow us to project the geographic distribution of adventive species into other regions (Tognelli et al 2009). Ten beetles were selected from a region in southern South America along with six predictor variables extracted from WorldClim and Climate Research Unit databases and tested with eight of the most commonly used SDMs (Tognelli et al 2009). The differences of projections between SDMs were recognized and suggested that these models are simply a hypothesis of possible distributions of a species (Tognelli et al 2009).

Laboratory or field cold tolerant experiments may improve the projections of a SDM. A study with *Microtheca ochroloma* Štínl at cold temperatures of 5, 0, and –5 °C, found the egg stage was the most cold tolerant, and the first instar the least (Manrique et al 2012). This experiment acclimated individuals gradually to cooler temperatures from 15°C to the final temperature by 5 °C intervals each day. The times required to kill 50 (LT50) and 90% (LT90) of the population were estimated, models were developed, maps imported to ArcGis and isothermal lines created predicting areas favorable for *Microtheca ochroloma*. Stratman et al. (2014) predicted the potential distribution of the biological control agent, *Cricopus lebetis* Sublette, a tip miner of the invasive aquatic plant, *Hydrilla verticillata* (L. f.) Royle, utilizing predictions from cold tolerance data and ecological niche testing.

Cold tolerant studies are usually focused on the effects of a single cold exposure on insects under laboratory conditions. A rapid cold-hardening study subjected over-wintering pine needle gall midge larvae, *Thecodiplosis japonesis* Uch. et Inouye, to 4 °C for two hours, then back to 27 °C for 15, 30, or 60 minutes prior to transferring to –15°C for three hours (Yi-ping et al. 2000). A non-conditioned group was held at 27 °C for 15, 30, and 60 minutes prior to transferring to –15 °C for three hours (Yi-ping et al. 2000). The survival rate of conditioned larvae was
40.0% and unconditioned larvae 17.9%, suggesting that rapid cold-hardening is effective at increasing larval survival (Yi-ping et al. 2000). Marshall and Sinclair (2012) looked at repeated cold exposures (RCE) with *Drosophila melanogaster* Meigen crossing the chill-coma threshold at or below 10 °C in which all muscular movement ceases (MacMillan and Sinclair 2010). The control group was maintained at a relatively warm temperature, the RCE groups experienced repeated short cold exposures and the sustained cold exposure group was exposed once, for a long period (Marshall and Sinclair 2012). The authors found that RCE were perceived as advantageous to immediate survival, along with increasing cold hardiness when compared to insects experiencing a single, prolonged cold exposure (Marshall and Sinclair 2012). However, few studies have focused on the potential distribution of tropical adventive pest species found in different climates.

*Myllocerus undecimpustulatus undatus* Marshall (Coleoptera: Curculionidae) is a polyphagous broad-nosed weevil with a wide range of hosts (Neal 2013). *M. undecimpustulatus undatus*, a native of Sri Lanka, is a subspecies of the widely distributed *M. undecimpustulatus* (O’Brien et al. 2006). *M. undecimpustulatus undatus*, the Sri Lankan weevil, originated in Asia but has established populations in Florida. *M. undecimpustulatus undatus* was first identified in Florida in 2000. By 2015, the Florida Division of Plant Industry (DPI) identified the weevil as being present in 27 Florida counties and infesting over 150 different plant species (Fig. 1). Submissions from DPI field agents were identified by Michael Thomas, starting with the first identified occurrence in Sept. 2000 and continuing through Dec. 2012. Adults are folivores of ornamental plants, fruit trees, and vegetables, whereas the larvae injure roots (O’Brien et al. 2006). Arevalo and Stansly (2009) found heavy infestations of Sri Lankan weevil in citrus groves, and recent reports confirm damage to other economically important crops, such as avocado, peaches and lychee (R. Banack and M. Luciano, personal communication, Apr. 2015).

When adult weevils feed on leaves, they feed inward from the leaf margins (or edges), causing typical leaf notching. There are some instances where the leaf material is almost completely defoliated, when the weevil has fed along the leaf veins. The adults prefer new plant growth. Intense feeding by numerous weevils may cause plant decline or stunting. Young seedlings may not survive a large amount of feeding damage. With healthy plants, however, the feeding damage may be considered cosmetic if the plant recovers. Larvae feed on plant roots for approximately one to two months. This tropical insect is native to a climate where the coldest temperature is 22 °C.

A cold tolerance study was developed to define range expansion. Weevil locations were assigned geographical coordinates and entered into DIVA-GIS software and mapped. The model projected potential spread throughout the southern United States. A cold tolerant study with adult weevils, similar to the experimental design of Manrique et al. (2012), established that they could survive at −5 °C for five days. Another experiment was designed similar to Marshall and Sinclair (2012) implementing RCE that more closely resemble actual cold events in Florida and other potential areas. The RCE had minimal effect on mortality and feeding of adult weevils, whereas the weevils subjected to sustained cold exposure suffered a greater mortality rate and consumed less food. This sustained exposure not only affects

![Fig. 1. The spread of Sri Lankan weevils, *Myllocerus undecimpustulatus undatus* Marshall, in Florida based on Division of Plant Industry collections from 2000 to 2015. Credits: Anita Neal, UF/IFAS and diymap.net](image-url)
their feeding, but may have other negative impacts on fecundity and longevity.

*M. undecimpustulatus undatus* has the potential to make adaptations which will allow it to move into other areas with the southern United States. The most likely route would be through movement of potted plant material. This insect has shown the ability to survive for five days at –5 °C and has demonstrated though repeated cold exposures that it has the ability to adapt and survive.

**Literature Cited**


