EENY 475

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an Asian citrus psyllid parasitoid *Tamarixia radiata* (Waterston) (Insecta: Hymenoptera: Eulophidae)[1]

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Introduction

Tamarixia radiata (Waterston) (Hymenoptera: Eulophidae) is an effective ectoparasitoid of the Asian citrus psyllid, *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae). *Diaphorina citri* is one of the most serious pests of citrus worldwide because it vectors the bacterial pathogen causing huanglongbing (HLB) disease in citrus. In addition, both nymphs and adults are obligate phloem feeders that cause chlorosis on infested leaves and excrete honeydew that promotes the growth of sooty mold. HLB affects plant phloem, causing yellow shoots, mottling, chlorosis, and twig die back which cause rapid tree decline and may ultimately cause tree death. Fruit on diseased trees do not color properly, and can be bitter tasting and misshapen as well as reduced in size (Capoor 1963, Halbert and Manjunath 2004, Bové 2006).

In the United States, *D. citri* was first discovered in Palm Beach County, Florida on orange jasmine, *Murraya paniculata* (L.) Jack. (Rutaceae) in 1998 (Halbert 1998). It is now a serious pest of citrus in Florida (Michaud 2002, Halbert and Manjunath 2004), and specimens have been found throughout the U.S., including Florida, Texas, Hawaii, Louisiana, Alabama, Georgia, Mississippi, South Carolina, and California (National Invasive Species Information Center).

Currently all possible vector and disease control methods are being employed to manage HLB in Florida including biological control with *Tamarixia radiata* (Waterston) (Hymenoptera: Eulophidae) and *Diaphorencyrtus aligarhensis* (Shafee, Alam and Agarwal) (Hymenoptera: Encyrtidae) (Hoy et al. 2006, Qureshi et al. 2009). *Tamarixia radiata* is presumed superior to *D. aligarhensis* based on previous reports of high psyllid parasitization rates and rapid establishment in new areas (Aubert 1987, Skelly and Hoy 2004). Release of *T. radiata* revived the citrus industry in Reunion Island after its introduction from India in 1978 (E´tienne et al. 2001) and the parasitoid caused substantial decline in *D. citri* populations in Guadeloupe Island within one year of release (Aubert and Quilici 1984, E´tienne et al. 2001).

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Distribution

Tamarixia radiata was discovered in the area of northwestern India (Punjab) which is now within present-day Pakistan (Waterston 1922). Because of the reported high parasitism efficiency and establishment rate of *T. radiata*, the parasitoid was imported into several countries, including the United States, to control *D. citri*.

Currently, the parasitoid is found in Brazil, China, Guadaloupe, Indonesia, Mauritius Mexico, Pakistan, Philippines, Nepal, Taiwan, Vietnam, Puerto Rico and the United States (Waterston 1922, Chien et al. 1991a, Hoy and Nguyen 2001, E´tienne et al. 2001, Halbert and Manjunath 2004, Pluke et al. 2008; León and Setamou 2010).

Description and Life Cycle

Adults: *Tamarixia radiata* adults are small black wasps (0.92 to 1.04 mm long) with widely separated eyes. The adult's head is slightly larger in width than length. The wings are hyaline with pale yellow veins. Sexual dimorphism is marked between the male and female adults. The male antennae are 1.5 times longer than those of females (Onagbola et al. 2009). Males are slightly smaller than females in total length and wing expanse. The female ovispositor is barely protruding (Waterson 1922).

Eggs: The adult female *T. radiata* lays one or occasionally two eggs beneath a *D. citri* nymph. Although more than one egg may sometimes be laid beneath a nymph, only one parasitoid larva usually reaches the adult stage and thus *T. radiata* is regarded as a solitary parasitoid. An adult female *T. radiata* can deposit up to 300 eggs (Hoy et al. 2006).

Larvae: The newly hatched parasitoid larvae feed on hemolymph from the site of attachment, eventually killing the hosts, *D. citri* nymphs. The first instar parasitoid larvae are about 0.28 mm long and 0.11 mm wide, while the fourth instar larvae are 1.14 mm long and 0.59 mm wide.

Visit this link to view a video of *T. radiata* larva, just prior to pupation, inside *D. citri* nymph http://entnemdept.ifas.ufl.edu/creatures/beneficial/wasps/tamarixia_radiata06.avi. (12 MB avi file courtesy of C. N. Rao, National Research Center for Citrus, Nagpur, India)

Figure 1. Adult *Tamarixia radiata* (Waterston), a parasitoid of the Asian citrus psyllid, *Diaphorina citri* Kuwayama. Photograph by: Angel Hoyte and Jamie D. Yates, University of Florida, Citrus Research and Education Center

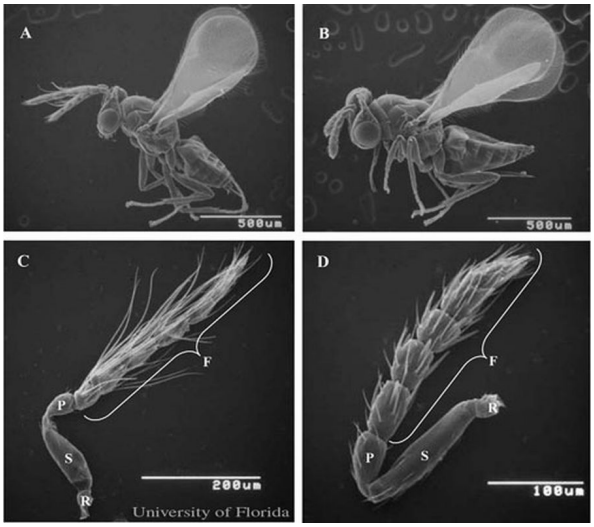

Figure 2. Scanning electron photomicrographs of adult male (A) and female (B) *Tamarixia radiata* (Waterston), and gross morphology of male (C) and female (D) antennae. The antenna of male or female *Tamarixia radiata* consists of a ball-like radicula (R), the long scapula-shaped scape (S), the barrel-shaped pedicel (P), and the long thread-like flagellum (F). Photograph by: Ebenezer Onagbola and Diann Achor, University of Florida, Citrus Research and Education Center

Pupae: Pupation occurs within the mummified *D. citri* nymphs and new adults emerge through a hole on the thorax or head of the parasitized mummy.

Figure 3. Adult *Tamarixia radiata* (Waterston), an parasitoid of the Asian citrus psyllid (*Diaphorina citri* Kuwayama), prior to emergence from a mummified nymph. Black adult *T. radiata* head can be seen on upper right of *D. citri* nymph. Photograph by: Angel Hoyte and Jamie D. Yates, University of Florida, Citrus Research and Education Center

Figure 4. Adult parasitoid *Tamarixia radiata* (Waterston) (foreground), emerging from the mummified nymph of an Asian citrus psyllid (*Diaphorina citri* Kuwayama). Photograph by: Angel Hoyte, Jamie D. Yates, University of Florida, Citrus Research and Education Center

Visit this link to view a video of adult *T. radiata* emerging from mummified nymph of *D. citri* http://entnemdept.ifas.ufl.edu/creatures/beneficial/wasps/tamarixia_radiata07.wmv. (91 MB wmv file by Angel Hoyte and Jamie D. Yates, University of Florida)

Under experimental conditions (26±1°C, 70% RH), the total developmental period (egg to adult) for the wasps is completed in 11.4 days. The egg, larval, prepupal and pupal stages are completed in 1.9, 4.0, 0.6 and 4.9 days, respectively.

The average longevity of the female adult (23.6 days) is greater than that of the male (11.4 days). Males are capable of multiple matings. However, mating has no effect on longevity of adults (Chien et al. 1991b). The female to male sex ratio is 1.8 to 3.2, depending upon the origin of the colony and the rearing conditions (Chien 1995, Skelley and Hoy 2004, Hall 2008).

The adult *T. radiata* parasitoid emerges from the *D. citri* nymph's thorax, leaving a round emergence hole visible without magnification. *Tamarixia radiata* females parasitize all immature stages of *D. citri* and show a significant preference for 5th-instar nymphs (Chien et al. 1991b, Hoy et al. 2006).

Figure 5. Emergence holes of adult parasitoid *Tamarixia radiata* (Waterston), from mummified nymphs of the Asian citrus psyllid (*Diaphorina citri* Kuwayama). Photograph by: University of Florida

In addition to killing nymphs through parasitism, adult females feed on younger nymphs (Chein 1995, Skelley and Hoy 2004). Female *T. radiata* may obtain protein for egg development by feeding on hemolymph from psyllid nymphs, which is accessed through ovipositor-induced punctures (Hoy et al. 2006). A single *T. radiata* female is able to kill over 500 psyllids by a combination of host feeding and parasitism. Females also feed on honeydew excreted by psyllids (Hoy et al. 2006). *Tamarixia radiata* adults are strongly attracted to bright fluorescent lights (Skelley and Hoy 2004) and females primarily rely on olfactory cues for host location (Mann et al. 2010).

Hosts

Tamarixia radiata is not known to attack any other psyllid species than *D. citri* (Aubert and Quilici 1984).

Classical Biological Control of *D. citri* with *T. radiata* in Florida

Classical biological control of *D. citri* was initiated in Florida in 1999. Colonies of *T. radiata* and *D. aligarhensis* were imported from Taiwan and Vietnam, respectively (Hoy and Nguyen, 2001). In total, 12,000, 16,800, and 8,000, adults of a mixed colony from the two origins were released in Florida in 1999, 2000, and 2001, respectively (Skelley and Hoy 2004). The parasitoid dispersed quickly and established throughout the major citrus-growing regions of the State (Hoy and Nguyen 2001).

Currently, the parasitoid is also found in Texas and Puerto Rico where it was not released intentionally. While *T. radiata* has a short generation time and high reproductive rate in the laboratory, its effectiveness in suppressing psyllid populations under field conditions has been variable in Florida and other adjoining regions (Michaud, 2004, Pluke et al. 2008, Qureshi et al. 2009). Parasitism rates have averaged less than 20% during spring and summer, increasing to 39-56% in the fall as compared to 79 and 88% in Puerto Rico (Pluke et al. 2008). Parasitism rates in Florida are lower than observed in Reunion Island, Guadaloupe, and Puerto Rico.

No hyperparasitoid species attacking *T. radiata* have yet been observed in the United States (Hall 2008). However, 64-100% mortality of *T. radiata* has been reported from intraguild predation (killing and eating potential competitors) by coccinellid species in Florida (Michaud 2004, Qureshi et al. 2009). Coccinellids consume parasitized nymphs containing *T. radiata* larvae thus reducing populations of *T. radiata*. In addition, the more extreme climatic conditions of Florida and current intense use of insecticides to control *D. citri* populations are presumed to be responsible for low parasitoid populations in Florida.

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