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Anagyrus pseudococci Girault (Insecta: Hymenoptera: Encyrtidae)[1]

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Introduction

Anagyrus pseudococci is a well known encyrtid parasitoid capable of developing on a variety of mealybug species (*Planococcus* spp. and *Pseudococcus* spp., Hemiptera: Sternorrhyncha: Pseudococcidae). This wasp is used for biological control programs and is the most common commercial parasitoid reared for mealybug control (Triapitsyn et al. 2007; Mahfoudhi and Dhouibi 2009). It is a solitary, internal parasitoid and lays one egg per host, with the larva developing inside the host's body.

Synonymy

Girault (1915) originally described it as *Epidinocarsis pseudococci*.

Distribution

Anagyrus pseudococci is found naturally in China, Cyprus, Egypt, Italy, Israel, Pakistan, Saudi Arabia, and the former USSR (Noyes and Hayat 1994). It has been introduced into Argentina, Brazil, South Africa, and the United States (Noyes and Hayat 1994). It was first introduced into California from Brazil in 1934 for biological control of the citrus mealybug (*Planococcus citri* (Risso)) (Noyes and Hayat 1994; Triapitsyn et al. 2007). It was imported again into California in 1953 from South America (Frank and McCoy 1994). It is now widely established in California and used for biological control against the invasive vine mealybug (*Planococcus ficus* (Signoret)) (Daane et al. 2004a; Gutierrez et al. 2008).

Its documented distribution appears to correlate with wine-growing areas. Documented localities include Argentina, where it was introduced with grape seedlings from Italy (Trjapitzin and Trjapitzin 1999), Uzbekistan for the control of *Planococcus citri* (Noyes and Hayat 1994), South Africa for control of *Planococcus citri* on citrus (Noyes and Hayat 1994), and Turkey (Güleç et al. 2007). Use as a biocontrol agent in greenhouses is more recent, with successes noted in greenhouses in Texas and Europe (Noyes and Hayat 1994).

Description

Eggs: The eggs are yellow-white and 0.24 × 0.15 mm (Rosen and Rössler 1966). The egg is stalked with a heavy rib running down the side and through the stalk; this appearance is referred to as encyrtiform type and is common in the Encyrtidae (Rosen and Rössler 1966). The egg stalk will protrude through the mealybug exoskeleton and is visible from the outside.

A black scar forms on the host one day after the female wasp oviposits (Rosen and Rössler 1966, Avidov et al.

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1967). Ovipositor insertion is typically on the dorsal side near the margin (Daane et al. 2004a).

Larvae: The larvae are white and undergo five instars (Rosen and Rössler 1966).

The first and second instars are transparent to pale white and have light brown, sclerotized mouthparts (Daane et al. 2004a). These instars remain attached to the host integument by the egg stalk (Daane et al. 2004a). Third and fourth instars (hymenoptiform in shape) are white with well-developed mandibles. The egg stalk connection is broken by the fourth instar (Daane et al. 2004a). The fifth instar occupies the majority of the mummified host's body (Daane et al. 2004a) and has 13 segments (Rosen and Rössler 1966). A dark brown fecal mass at the anterior part of the host is visible at the end of the final larval stage (Rosen and Rössler 1966).

Pupae: Pupae face the posterior end of the mummified hosts. They measure 1.4-2.1 mm (females) and 1.1-1.4 mm (males). Female pupae resemble the orange-brown color of the adult female, and male pupae are black like the adult male (Rosen and Rössler 1966).

Adults: The adults display sexual dimorphism (Figures 1 and 2).

Figure 1. Female *Anagyrus pseudococci* and exit hole in a mealybug host.
Credits: Kent M. Daane, University of California

Females (Figure 1) are typically 1.5-2.0 mm, with the smallest recorded at 0.75 mm (Rosen and Rössler 1966). The females are dull orange to brownish with a yellow, triangular head that is not dorsoventrally flattened (Girault 1915, Rosen and Rössler 1966, Noyes and Hayat 1994). The lower portion of the face has dark brown markings (Noyes and Hayat 1994). The antennae are distinctively black and white banded; the first funicular segment has the basal half black and the distal portion white (Rosen and Rössler 1966; Triapitsyn et al. 2007). The sixth funicular segment is slightly longer than wide (Girault 1915). The compound eyes are grayish brown, and the simple eyes (ocelli) are pink (Rosen and Rössler 1966). Legs are white to yellowish, with blackish coxae and femora on the distal surfaces (Rosen and Rössler 1966; Noyes and Hayat 1994). The wings are hyaline with brownish veins (Girault 1915). The ovipositor is short and only slightly exserted (Noyes and Hayat 1994).

Figure 2. Male *Anagyrus pseudococci*. The body of the male is all black.
Credits: Kent M. Daane, University of California

Males (Figure 2) differ from the females in size, head structure, antennae, wings, and abdomen (Rosen and Rössler 1966). Adult males are smaller than the females (0.71-1.25 mm) and primarily black (Noyes and Hayat 1994). The lower part of the face is covered with conspicuous silvery setae arranged in lines (Noyes and Hayat 1994). White areas are found at the base of the antennae where the antennae join the head (the scape) and portions of the legs. The coxae are black like the body (Rosen and Rössler 1966), but the remainder of the legs is yellow (Noyes and Hayat 1994). The abdomen is shorter than the thorax (Rosen and Rössler 1966). The head is flatter than that of the female. The antenna is 9-segmented and filiform, with a triangular pedicel (Rosen and Rössler 1966). The compound eyes in the male are smaller than the female's eyes and reddish brown instead of gray. Pink ocelli are located in an obtuse triangle (Rosen and Rössler 1966).

Biology

Egg: Females lay one egg that will develop inside a host, making it a solitary endoparasitoid; if multiple eggs are laid per host, only one develops (Avidov et al. 1967, Chandler 1980). Oviposition is completed within 15-40 seconds. Female *Anagyrus pseudococci* oviposit between the wax filaments on the lateral margin of the host mealybug (Avidov et al. 1967). Oviposition may occur inside mealybug nymphs or adults, though larger hosts are preferred (Avidov et al. 1967).

Egg development takes 1-2 days at 28°C (Avidov et al. 1967). The optimal temperature for egg development is about 25°C, but development can occur between 14°C and 34°C. (Daane et al. 2004a, Güleç et al. 2007).

Larvae: The larvae are white and develop inside their hosts. Development includes 5 instars (Rosen and Rössler 1966). The parasitized mealybugs are still alive and mobile during the wasp's first and second instars but become immobilized by the time the wasp reaches the third instar (Avidov et al. 1967; Daane et al. 2004a). Development to the third instar and immobilization of the host occur by the fifth day at 28-32°C (Avidov et al. 1967, Güleç et al. 2007). The third instar lasts approximately one day. Development to the fifth instar takes 6-8 days at 32°C (Daane et al. 2004a) and 4-5 days at 28°C, with an additional day for prepupal development (Avidov et al. 1967). The host is completely mummified by the eighth day at 28°C (Avidov et al. 1967) and will appear yellow-brown (Rosen and Rössler 1966). The larvae overwinter inside mealybug hosts (Daane et al. 2006). Developmental time decreases as temperature increases until 34°C (Daane et al. 2004a). Development at 14°C took 79.3 ± 3.3 days, while development took only 10.5 ± 0.7 days at 34°C (Daane et al. 2004a). Development stops at 35°C, and death occurs at 40°C (Tingle and Copeland 1988). The lower threshold for development is 14°C. Although development may cease at slightly higher temperatures, *Anagyrus pseudococci* can survive brief periods of exposure to high or low temperatures (Daane et al. 2004a).

Pupae: Pupation occurs inside the mummified host and lasts approximately 4 days at 32°C (Daane et al. 2004a) or 4-6 days at 28°C (Avidov et al. 1967). At 32°C, pupae were found 8-11 days after oviposition (Daane et al. 2004a).

Adults: Adults emerge through an irregular exit hole that they chew in the posterior end of the mummified host mealybug (Figure 1) (Avidov et al. 1967). They begin emerging 12 days after oviposition (Daane et al. 2004a). *Anagyrus pseudococci* female developmental time ranges between 14 and 18 days, and male developmental time ranges between 12 and 27 days (Chandler 1980).

Anagyrus pseudococci is arrhenotokous; females lay unfertilized eggs that develop into males or fertilized eggs that develop into females. Females do not need to mate to oviposit (Chandler 1980). Females begin to oviposit 48 hours after emergence and continue until their death. Adult females that lay fertilized eggs have a higher fecundity than females that lay unfertilized eggs (Avidov et al. 1967). The number of offspring and the proportion of female offspring increases with host size and age (Avidov et al. 1967).

Average lifespan for adults is 6.9 ±1.2 days to 8.2 ±1.3 days. The adults will feed on nectar. Adult mortality levels are not affected by humidity levels (Avidov et al. 1967).

Hosts

Recorded hosts include citrus mealybugs, *Pseudococcus citriculus* Green (Avidov et al. 1967) and *Planococcus citri* (Rosen and Rössler 1966, Noyes and Hayat 1994), the long-tailed mealybug, *Pseudococcus longispinus* (Targioni Tozzetti) (Rosen and Rössler 1966, Avidov et al. 1967), the Comstock mealybug, *Pseudococcus comstocki* (Kuwana), the pink hibiscus mealybug, *Maconellicoccus hirsutus* (Green), the cassava mealybug, *Phenacoccus herreni* Cox and Williams, the cryptic mealybug, *Pseudococcus cryptus* Hempel, and the pineapple mealybug, *Dysmicoccus brevipes* (Cockerell) (Noyes and Hayat 1994).

In laboratory studies, *Anagyrus pseudococci* were reared on *Pseudococcus longispinus*, *Pseudococcus calceolariae* (Maskell), *Planococcus ficus*, *Pseudococcus njalensis* Laing, *Dysmicoccus brevipes*, and *Pseudococcus affinis* (Maskell) (Noyes and Hayat 1994; Daane et al. 2004).

Larvae developing in third-instar citrus mealybugs show comparable development time to larvae developing in adult hosts (Chandler 1980; Güleç et al. 2007), but adult mealybugs provide the best host for potential fecundity and yield significantly more adult female wasps (Daane et al. 2004a).

Economic Importance

Anagyrus pseudococci is economically important as a biological control agent for agricultural and greenhouse pest mealybugs and to control the citrus mealybug in its native range of Italy and Israel (Noyes and Hayat 1994). It is a species that it is commonly used against the vine mealybug (Daane et al. 2006; Güleç et al. 2007; Gutierrez et al. 2008) and the citrus mealybug (Tingle and Copeland 1988; Gill et al. 2013). The vine mealybug is of economic importance because it infests wine grapes and uses a variety of weeds as alternate hosts (Gutierrez et al. 2008). Citrus mealybugs are primary pests on citrus, but their host range includes at least 27 different plant families, including economically important indoor ornamentals, vegetables, and fruits (Tingle and Copeland 1988; Gill et al. 2013).

Anagyrus pseudococci is the most effective parasitoid against the vine mealybug in California, but parasitism rates did not provide adequate pest population suppression (Daane et al. 2006, Gutierrez et al. 2008). Development is faster than other parasitoids used to control mealybugs at

all temperatures (Tingle and Copeland 1988). *Anagyrus pseudococci* was the most commonly reared parasitoid on field-collected vine mealybugs in California (Malakar-Kuenen et al. 2001).

Timing of releases is important in increasing the effectiveness of biological control programs using *Anagyrus pseudococci*. Users need to time releases to coincide with preferred temperatures for the best control (Daane et al. 2004a). Ants reduce the effectiveness of biological control against mealybugs, and growers will have to treat for ants to achieve the best results (Daane et al. 2004b; Gutierrez et al. 2008).

Commercial producers of *Anagyrus pseudococci* recommend its use in fruit tree orchards, vineyards, and protected culture in conjunction with the mealybug destroyer, *Cryptolaemus montrouzieri* Mulsant, for the most effective control (BioBee, Biological Systems Ltd). Wasps may be reared and distributed inside mummies, and they will emerge within 1-5 days after delivery. Application involves placing a bottle (Figure 3) containing the mummies in a dry spot of the crop and allowing the adults to emerge (Syngenta Bioline).

Figure 3. Commercial product of *Anagyrus pseudococci* produced by Syngenta Bioline.
Credits: Syngenta Bioline

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