Available online at www.sciencedirect.com
SCIENCE DIRECT®
Biological Control 35 (2005) 93–103
Biological Control
www.elsevier.com/locate/ybcon

Biological characteristics of adult *Anagyrus ananatis* Gahan (Hymenoptera: Encyrtidae), a parasitoid of *Dysmicoccus brevipes* (Cockerell) (Hemiptera: Pseudococcidae)

Héctor González-Hernández [a], Raju R. Pandey [b], Marshall W. Johnson [c,*,1]

[a] *Instituto de Fitosanidad, Colegio de Postgraduados, Carretera México-Texcoco Km 35.5, Montecillo, Texcoco, Edo. de México 56230, Mexico*
[b] *Department of Plant and Environmental Protection Sciences, University of Hawaii at Manoa, Honolulu, HI 96822, USA*
[c] *Department of Entomology, University of California, Riverside, CA 92521, USA*

Received 18 August 2004; accepted 26 July 2005
Available online 12 September 2005

Abstract

The encyrtid *Anagyrus ananatis* Gahan preferred to parasitize adult females of pink pineapple mealybug (PPM), *Dysmicoccus brevipes* (Cockerell), compared to gray pineapple mealybug (GPM), *Dysmicoccus neobrevipes* Beardsley. When given a choice of PPM life stages, adult female PPM were preferred. Over its adult life, *A. ananatis* parasitized 27.7 (±2.5) mealybugs, with a range of 11–51 parasitized mealybugs. Development (eggs to adult) required 23.3 (±0.6) and 21.2 (±0.8) days for females and males, respectively, at 26 °C. Adult females had a mean longevity of 9.8 (±2.0) days, while males lived for a mean of 10.8 (±0.6) days at 26 °C when only provided a 50% honey–water solution. Adult longevity increased to greater than 26 days when pure honey and water were provided. Parasitoid adults allowed access to honey lived almost sixfold longer than those denied honey. Pure honey increased mean adult longevity almost 90 and 40% compared to water only or diluted honey concentrations, respectively. Starvation significantly reduced parasitoid survival and longevity with 52% of test individuals dying after being deprived honey and water for 48 h. *A. ananatis* only parasitized PPM during photophase. *A. ananatis* parasitized significantly more mealybug hosts as PPM densities increased from 1 to 10 individuals per experimental unit, but then plateaued at densities above 10 individuals.

Keywords: *Anagyrus ananatis*; *Dysmicoccus brevipes*; *Dysmicoccus neobrevipes*; Host preference; Biological control; Pineapple; Mealybugs; Rearing

1. Introduction

Mealybug wilt disease of pineapple (MWP) is the most important worldwide disease of pineapple, *Ananas comosus* (L.) Merr. (Bromeliales: Bromeliaceae) (Carter, 1963; Gunashinghe and German, 1986; Hu et al., 1996, 1997). Pink pineapple mealybug (PPM), *Dysmicoccus brevipes* (Cockerell), and gray pineapple mealybug (GPM), *Dysmicoccus neobrevipes* Beardsley (Hemiptera: Pseudococcidae), are the primary vectors of Pineapple Mealybug Wilt Associated Virus (PMWaV) (Sether et al., 1998). PPM is the most common mealybug in Hawaiian pineapple plantings (González-Hernández et al., 1999a), and the most widely distributed mealybug on pineapple worldwide (Williams and Watson, 1988). The presence of PMWaV in combination with PPM and/or GPM feeding leads to the expression of typical MWP symptoms and plant death, if mealybugs are not controlled (Carter, 1945b, 1963; German et al., 1992; Hu et al., 1996; Hughes and Samita, 1998). Introduction of biological control agents from South and Central

* Corresponding author. Fax: +1 559 646 6593.
E-mail address: mjohnson@uckac.edu (M.W. Johnson).
[1] Present address: UC Kearney Agricultural Center, 9240 S. Riverbend Ave., Parlier, CA 93648, USA.

1049-9644/$ - see front matter © 2005 Elsevier Inc. All rights reserved.
doi:10.1016/j.biocontrol.2005.07.014

America, where these mealybugs originated, provided partial control of the mealybugs on pineapple in Hawaii when ants were present (Beardsley, 1993; Collins, 1960; González-Hernández et al., 1999b). Surveys by González-Hernández et al. (1999a) found that *Anagyrus ananatis* Gahan (Hymenoptera: Encyrtidae) was the most common natural enemy of PPM in Hawaiian pineapple plantings, and it was present in all pineapple fields surveyed and parasitized ant-tended mealybugs.

The big headed ant, *Pheidole megacephala* F., Argentine ant, *Linepithema humile* (Mayr), and fire ant, *Solenopsis geminata* (F.) (Hymenoptera: Formicidae), are commonly found in the Hawaiian pineapple agroecosystem, where they tend PPM and GPM for honeydew (Reimer, 1994; Reimer et al., 1990). These ants, especially *P. megacephala,* have been blamed for dispersing mealybugs and protecting them against their natural enemies while removing the excess honeydew produced by the mealybugs (Carter, 1932; González-Hernández et al., 1999a,b; Illingworth, 1931; Jahn and Beardsley, 1998). Elimination of tending ants from pineapple fields with the ant bait Amdro (hydramethylnon, American Cyanamid Corporation) has led to improved mealybug suppression by their natural enemies and reduced MWP development (Beardsley et al., 1982; Petty and Tutsin, 1993; Rai and Sinha, 1980; Reimer and Beardsley, 1990). However, approval for application of Amdro is annually granted on an 'emergency needs basis' (Section 18) (HDOA, 2001). Alternative pest management techniques are necessary if approval for Amdro is denied for commercial pineapple production. They are also needed for organic pineapple production where synthetic chemicals are not allowed. Developing integrated pest management techniques by maximizing biological control will help minimize dependencies on chemical pesticides.

Anagyrus ananatis is a solitary endoparasitoid of PPM, which successfully established in Hawaiian pineapple fields after its introduction from Brazil in 1935–1937 (Carter, 1945a, Funasaki et al., 1988, González-Hernández, 1995). Although De Santis (1964, 1979, 1980 as cited by Noyes and Hayat, 1994) reported rhodesgrass mealybug, *Antonina graminis* (Maskell), stripped mealybug, *Ferrisia virgata* (Cockerell), and citrus mealybug, *Planococcus citri* (Risso), as other hosts for *A. ananatis*, it has only been reared from PPM in Hawaii. Given the lack of biological information available and the potential of *A. ananatis* as a biological agent, studies were undertaken to determine various aspects (e.g., host stage and species preferences, adult longevity, sex ratio, parasitization capacity) of *A. ananatis* adult biology. This information will contribute towards a better understanding of the role of *A. ananatis* in mealybug control and the development of *A. ananatis* mass rearing and augmentation protocols.

2. Materials and methods

2.1. Origin of parasitoid and host colonies

Mealybugs and *A. ananatis* were initially collected from pineapple plantings in Kunia (N21°28′ W158°4′) on the island of Oahu, Hawaii. PPM and GPM individuals were collected and separately colonized on a mixture of butternut squash, *Cucurbita moshata*, and kobocha squash, *Cucurbita maxima* (Violales: Cucurbitaceae) as described by González-Hernández (1995). In Hawaii, PPM and GPM are uniparental and biparental species, respectively. Approximately 100 reproductively active females of each mealybug species were used to start colonies. Mummified mealybugs were isolated from field collections and held for parasitoid emergence. Emerged *A. ananatis* adults were reared in the laboratory on PPM infesting the two squash species or on PPM adults removed from the squash and held under the same laboratory conditions as used to rear PPM. Approximately 100 mated *A. ananatis* females were used to initiate the parasitoid colony. Mealybug and parasitoid colonies were reared for at least 1 year prior to use in experiments. Unless otherwise stated, mealybugs infesting newly grown Smooth Cayenne pineapple leaves (approximately 3 cm at the base and 15–20 cm in length and obtained from a 2-month old greenhouse planting) were exposed to parasitoids in all experiments. Leaves were initially infested with mealybugs 24 h before exposure to *A. ananatis*. Unless otherwise stated, all experiments were conducted under laboratory conditions of 26 ±2 °C, 52 ± 2% RH, and 14:10 (L:D) h photoperiod.

2.2. Host preference and suitability

Laboratory studies were conducted to determine host species preference and suitability (PPM versus GPM) and host stage preference (PPM only) for *A. ananatis*. Experiments were conducted under ambient laboratory conditions described above. Parasitoids were provided with 50% honey–water only before and during experiments.

2.2.1. Mealybug species preference

Choice and no-choice experiments were conducted to determine *A. ananatis* preference for PPM and GPM. Individual pineapple leaves were infested with five adult females of each species for the choice experiment. In the no-choice experiment, individual pineapple leaves were infested with either 10 adult PPM or GPM females. Infested pineapple leaves were individually kept inside a 5 L plastic container (20.3 cm high × 15.2 cm diam.) covered with a screened ventilated lid. One day after infesting leaves, one *A. ananatis* female and male (2- to 3-day old) were introduced into the container. Parasitoids were removed after 24 h, and the mealybugs were