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Parasitoids for Biological Control of Brown Citrus Aphid: Recent Observations

Y. Q. Tang, R. K. Yokomi, and L. G. Brown

ABSTRACT. Some parasitoids and predators of the brown citrus aphid, *Toxoptera citricida*, are reviewed. There are many predators associated with the brown citrus aphid but they are typically polyphagous and may not be good candidates for specific augmentation or release programs. Parasitoids of the brown citrus aphid are more host-specific and offer good potential as biological control agents. Therefore, a search for parasitoids of brown citrus aphid was initiated. During four surveys of Asia conducted in 1991, 1992 and 1995, eight parasitic wasp species were found attacking brown citrus aphid. Two species, *Aphelinus spiraecolae* from China and *Lysiphlebia japonica* from Japan, were imported to Florida for study. In the laboratory, *A. spiraecolae* preferred the spirea aphid, *Aphis spiraecola*, and in October 1995, a permit was obtained for field release in Florida against spirea aphid. *Lysiphlebia japonica* was released against the brown citrus aphid in spring, 1996 in south Florida. The impact of these two nonindigenous parasitoids on brown citrus aphid populations will be monitored along with their effect on other aphids.

Index words. *Aphelinus spiraecolae*, citrus aphids, *Lysiphlebia japonica*, vector management.

Citrus tristeza virus (CTV) is an aphid-borne, semipersistently transmitted closterovirus. Control of CTV is a challenge because of the diversity of viral strains, citrus cultivars, horticultural practices, and vector species and abundance. In a recent review, Garnsey et al. (14) indicated that the choice of control strategies depends on the incidence and strain of CTV present in the region. Vector control largely has been ignored because it has been assumed that reduction of vector populations will not appreciably reduce virus spread, especially with nonpersistent viruses. However, CTV is phloem-limited and is transmitted only by vectors that colonize citrus. For this reason, its epidemiology more closely resembles that of persistently transmitted viruses than that of nonpersistently transmitted viruses. Vector control has been shown to have a major impact on limiting spread of the luteovirus, barley yellow dwarf virus (15) and, thus, could also be expected to impact spread of CTV. Although one aphid can infect a citrus tree, reduction of aphid populations reduces the probability of that occurring. Insecticides may be useful in restricting virus spread if the major vector species colonizes the crop and the objective is to minimize secondary spread. Biological control has an additional benefit in that vector populations can be reduced in their reservoirs outside of the treated fields.

Since the late 1980s, the brown citrus aphid, *Toxoptera citricida* (Kirkaldy), has been spreading through Central America and the Caribbean Islands (2, 20, 49) and is now established in Florida (16). Because of the aphid's importance as a CTV vector (3, 49), research has begun on various aspects of the aphid including biological control to develop improved control strategies for CTV (14, 48). Biological control is a sensible approach because it is environmentally friendly and can be readily incorporated into the pest management program with other citrus pests. Several studies have reported that the brown citrus aphid in the New World does not have effective natural enemies (24, 25, 47). Since the aphid is thought to be

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native to Asia (37), the rapid spread of the brown citrus aphid in New World may be due, in part, to the absence of the aphid's co-evolved natural enemies.

More than 60 species of the predators have been observed to feed on the brown citrus aphid (1, 4, 5, 9, 21, 26, 44). These predators include species from the following groups: coccinellids (Coleoptera); syrphids and chamaemyiids (Diptera); lacewings (Neuroptera); and pirate bugs (Hemiptera). Predators sometimes exert significant mortality on citrus aphid populations but they are polyphagous and are generally unpredictable as biological control agents for low aphid populations (21, 44) unless inundative measures are used (7). In general, it is suggested that predators are less suitable than parasitoids as individual species for classical biological control since all cases of successful biological control of aphids have been achieved with hymenopterous parasitoids (7). Hence, we have been investigating the potential of several nonindigenous wasp parasitoids as natural enemies of the brown citrus aphid. In this paper, we first review the parasitoids that were recorded to attack the brown citrus aphid from the literature and discuss their potential for biological control of the brown citrus aphid, then we present a progress report on our research on this subject.

REVIEW OF PARASITOIDS OF THE BROWN CITRUS APHID

Although aphid parasitism has been reported by gall midges (Diptera) (43), nearly all primary parasitoids of brown citrus aphid belong to Aphelinidae and Aphidiidae (Hymenoptera). A review of general biology of Aphelinidae and Aphidiidae is given by Stáry (31). In our search of the literature, we found nine species of parasitoids that attack brown citrus aphid (Table 1).

Aphelinus gossypii Timberlake parasitizes both the brown citrus aphid and the black citrus aphid, *Toxoptera aurantii* (Boyer de Fonscolombe) (5). *Aphelinus spiraecolae* Evans & Schauff was collected from the spirea aphid, *Aphis spiraecola* Patch in southern China and described as a new species (13, 48). *A. spiraecolae* has been observed to attack brown citrus aphid in field surveys in Fujian Province of China (Y. B. Tang, pers. comm.).

Aphidius colemani Viereck is of probable Indian origin (30), and is a common parasitoid of black citrus aphid and other Aphidinae (*Aphis, Macrosiphum, Myzus, Toxoptera,* and cereal aphids) in South Australia (5). However, parasitism of brown citrus aphid by *A. colemani* in the field was rare (5). *Aphidius matricariae* Haliday, a widespread and polyphagous parasitoid (22) was only occasionally recorded to attack brown citrus aphid (45).

Both *Lipolexis gracilis* and *L. scutellaris* are more or less host specific to the Aphidinae (22, 30) and are frequently recorded parasitizing citrus aphids including the brown citrus aphid in India, Hong Kong, Southern China, and Taiwan (8, 10, 12, 30, 34, 35, 36, 44).

Lysiphlebia japonica (Ashmead) has been reported to be the most important natural enemy of the brown citrus aphid in Japan (18, 19, 39). This parasitoid was found to be active throughout the season in Japan, maintaining aphid populations at low levels (18, 19). *L. japonica* is distributed throughout Hong Kong, India, Japan, South China, South Korea, and Taiwan (30). Although this parasitoid has been recorded from 13 aphid species in Japan (38), observations suggest that *L. japonica* is relatively specific to brown citrus aphid in citrus groves (19). Life table analysis of *L. japonica* on brown citrus aphid was conducted by Takanashi (39). *L. japonica* was recently imported from

TABLE 1
PARASITOIDS RECORDED TO ATTACK BROWN CITRUS APHID

Taxa and species	Country or region	References
Aphelinidae		
Aphelinus gossypii Timberlake	Southern China, Australia	5, 48, Y. B. Tang, pers. comm.
Aphelinus spiraecolae Evans & Schauff	Southern China	Y. B. Tang, pers. comm.
Aphidiidae		
Aphidius colemani Viereck (= *A. platensis* Brethes)	Argentina, Australia	5, 22, 23, 27, 29, 30
Aphidius matricariae Haliday	Peru	45
Lipolexis gracilis Forster	Southern China, Taiwan	8, 10, 44, Y. B. Tang pers. comm.
Lipolexis scutellaris Mackauer	Taiwan, India	8, 10, 12, 30, 34, 35
Lysiphlebia japonica (Ashmead) (= *Lysiphlebus japonicus* Ashmead)	Japan	18, 19, 25, 30, 38, 39
Lysiphlebus testaceipes (Cresson)	Peru, Puerto Rico, Venezuela	17, 33, 47, 48
Trioxys indicus Subba Rao & Sharma (= *Binodoxys indicus* Subba Rao & Sharma)	India	28, 34, 35

Japan to Florida for study and potential release as a natural enemy of the brown citrus aphid (R. Yokomi, unpublished data).

Lysiphlebus testaceipes (Cresson) is a polyphagous parasitoid with more than 30 recorded aphid hosts from many host plants in the Nearctic and Neotropical regions (22). *L. testaceipes* was recorded to attack the brown citrus aphid in Peru (17), Puerto Rico (47), and Venezuela (32, 48). *L. testaceipes* was reported to readily attack brown citrus aphid in the laboratory but only a small number managed to complete their development (6). However, we have observed native *L. testaceipes* attacking mixed aphid colonies which includes brown citrus aphid in south Florida in January 1996 and successfully reared adult parasitoids from mummies. Our surveys are continuing to determine if *L. testaceipes* can effectively parasitize brown citrus aphid.

Trioxys indicus was recorded to attack 24 aphid species including the brown citrus aphid (28, 34, 35) and has been found to be effective in controlling *Aphis craccivora* Koch and the melon aphid, *Aphis gossypii* Glover, in India (28). *Trioxys indicus* Subba Rao & Sharma (= *Binodoxys indicus*) was imported from India and released as a potential biological control agent for the melon aphid in Florida in 1969 and 1971, but no data exist which indicate if this parasitoid ever became established (11, 48).

RESEARCH ON BIOLOGICAL CONTROL OF BROWN CITRUS APHID

MATERIALS AND METHODS

Collection of parasitoids of brown citrus aphid. Foreign exploration for natural enemies of the brown citrus aphid was conducted in Asia. Several explorations were conducted: Malaysia and Taiwan in August 1991; southern China in July 1992; Fujian Province, P.R. China and Hong Kong in May 1995; and Japan in December 1995. Parasitized brown citrus aphid were collected in gelatin capsules and returned to the laboratory for emergence and identification. Specimens that emerged were sent for identification to the USDA, Agricultural Research Service, Systematic Entomology Laboratory, Beltsville, MD and M. Hayat, Aligarth Moslem University, Dept. of Zoology, Aligarth, India.

Parasitoid colonies. Parasitoid adults were caged with spirea aphid or the black citrus aphid, *Toxoptera aurantii* (Boyer de Fonscolombe), in the greenhouse or environmental chamber. The aphid host was *Viburnum odoratissimum* Awabuki and red tip photinia *Photinia* × *Fraserii* (ref.). Adult parasitoids were given a supplemental diet of honey and water (1:1 ratio).

Field surveys for parasitism rates. Dooryard and commercial citrus groves were surveyed for parasitoids attacking citrus aphids in Florida and Puerto Rico. Young citrus shoots were examined for aphids and their parasitoids. A representative sample from 30 to 300 aphids per site were collected and dissected in the laboratory to determine percent parasitism.

RESULTS AND DISCUSSION

Survey for native parasitoids of citrus aphids. The principal indigenous aphid parasitoid in Florida was *Lysiphlebus testaceipes* (Cresson) (Hymenoptera: Aphidiidae). It attacked the black citrus aphid and the melon aphid. The spirea aphid occasionally was parasitized by *L. testaceipes*, but the parasitoid died before emergence from the aphid mummy. Dissections of citrus aphids in autumn 1993 indicated that the parasitism by the aphidiids ranged from 2-5% in citrus groves except in one instance in Winter Garden when the parasitism rose to 33% (48). Occasionally, the melon aphid on hibiscus was found to be parasitized by *Aphelinus gossypii* (46), which was introduced from India to Florida in 1969 (11). A solitary endoparasitic gall midge, *Endaphis maculans* (Barnes) (Diptera: Cecidomyiidae), was found to attack the spirea aphid, the melon aphid, and the black citrus aphid in dooryard citrus, abandoned citrus, and ornamentals in central Florida but was absent in commercial citrus groves (43).

Surveys conducted in Puerto Rico for primary parasitoids of the brown citrus aphid in 1994 detected only *L. testaceipes* (47). Low parasitism rate (3.6%) and poor adult emergence from mummies (4%) indicated that the brown citrus aphid is not under biological control by the parasitoid in Puerto Rico and importation and release of the aphid's native natural enemies was suggested.

Foreign exploration for parasitoids. Eight parasitoids were collected from brown citrus aphid mixed with other citrus aphids: *Aphidius gifuensis* Ashmead; *Lipolexis gracilis*; *L. scutellaris; Lipolexis* sp.; *Lysiphlebia japonica*; *Aphelinus gossypii*; *A. spiraecolae*; and *Aphelinus* sp. *A. spiraecolae* from China and *L. japonica* from Japan were successfully imported and established at the U.S. Horticultural Research Laboratory, Orlando, FL for study and release as natural enemies of the brown citrus aphid.

Laboratory evaluation of parasitoids. *Aphelinus spiraecolae* showed a distinct preference for the spirea aphid although the melon aphid and the black citrus aphid were also acceptable (46). Longevity of *A. spiraecolae* was 17.8 d, fecundity was 138.2 eggs, and the female adult consumed 27.1 aphids per lifetime (41). Its narrow host range and high reproductive capacity, combined with thermal tolerance, good host discrimination, and preference for young life stages of the host aphid indicated that *A. spiraecolae* has potential as a natural enemy of the spirea aphid (40, 41, 42). Release of *A. spiraecolae* was made in central Florida in November 1995 and was followed by release in south Florida in January 1996.

Lysiphlebia japonica was imported to Florida in December 1995 and was reared on the spirea aphid and the black citrus *aphid. L. japonica* was released in South Florida as a natural enemy of the brown citrus aphid in spring, 1996. The follow up surveys will be made to evaluate impact of the nonindigenous parasitoids on the brown citrus aphid as well as nontarget aphids.

Integrated disease management. It is not clear what level of vector control is necessary to reduce rate of CTV spread. Biological controls directed at restricting build-up of citrus aphids may be feasible. Insecticidal control of vector populations may have use in specific situations such as in a citrus nursery or to protect budwood sources. There is no documented evidence that prolonged use of chemicals to control vector populations can offer long-term control of CTV. Some value may be derived by use of selective insecticides in combination with natural enemies. If aphid populations can be significantly reduced, spread of CTV may be mitigated. Pilot tests are underway in Puerto Rico to correlate the effect of vector suppression with rate of CTV spread (50). It is unlikely that the spread of CTV can be prevented solely by vector management. Rather, vector management is but one component of a regional disease management strategy which also includes: mild strain cross-protection; tolerant rootstocks; certification programs; selective use of insecticides; isolation or protection of nursery stock; feasible elimination of CTV reservoirs; and, eventually, citrus scions with genetical resistance to CTV (14).

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