Interspecific Competition Between Two Parasitoids of the Mealybug, *Oracella acuta* (Lobdell) (Hemiptera: Pseudococcidae)[1]

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The pine-feeding mealybug, *Oracella acuta* (Lobdell), was accidentally introduced and established in Guangdong Province, China, in 1988 (Sun et al. 1996, J. For. 94: 27-32). It spread rapidly through the extensive plantations of exotic slash pine, *Pinus elliottii* Englem. var. *elliottii*, a species native to the U.S. Total volume growth loss has exceeded 33% in some cases, though tree mortality has not been reported (Ren et al. 2000, Natur. Enemies of Insects 22: 140-143). *Oracella acuta* is seldom a pest in the U.S. due to an effective natural enemy complex (Clarke et al. 1990, Environ. Entomol. 19: 99-103; Sun et al. 2002, J. Entomol. Sci. 37: 177-181). Outbreaks occur when natural enemy populations are drastically reduced, particularly by insecticide applications (Clarke et al. 1992, J. Econ. Entomol. 85: 1246-1252).

Sun et al. (2004, J. Entomol Sci 39: 11–22) conducted preliminary studies of the parasitoid complex of *O. acuta* in the U.S. to evaluate the potential for a classical biological control program against the mealybug in China. Two of the predominant parasitoids of *O. acuta* were *Allotropa* n. sp. (Platygastridae) and *Zarhopalus debarri* Sun (Encyrtidae). *Zarhopalus debarri* is a solitary endoparasitoid that primarily attacks adult females. Only one egg is deposited per *O. acuta* female. *Allotropa* n. sp. prefers adult females, but will attack second and third instar females. This species is gregarious and often lays multiple eggs in larger hosts. The complete life cycle of both species averages 26 days at 27°C, with the female adult stage averaging 6 days. The abundance of the two species may vary seasonally, annually, or by site. Studies on natural enemies and their host in their native country can provide insight into the nature of the interspecific relationships and help guide the selection of appropriate

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agents in an introduction program (Van Driesche and Bellows 1996, Biological Control, Chapman and Hall, NY). Luck and Podoler (1985, Ecology 56: 893-894) discussed the importance of interspecific competition as a dominant force in shaping host communities. To aid in the design and evaluation of a classical biological control program for *O. acuta* in China, we evaluated the interspecific competition between *Allotropa* n. sp. and *Z. debarri.*

In June 1997, parasitized *O. acuta* females (mummies) were collected from infestations in Georgia. The mummies were placed individually in gelatin capsules. Newly-emerged adult parasitoids were identified, sexed, and paired for mating. *Allotropa* n. sp. mated as soon as they were paired, but *Z. debarri* were held 2 days to insure mating. Both species were fed an artificial diet (Eliminade™, Entopath, Easton, PA), a proprietary diet for hymenopterous parasitoids.

In late June, entire seedlings or individual branches of larger loblolly pines infested with *O. acuta* were enclosed in cages made of fine mesh screen. Each cage contained approximately 120 wax cells constructed by *O. acuta* females. The infested pines were taken from a greenhouse culture of *O. acuta* that had been reared through several generations to prevent contamination with natural enemies. One of three treatments was randomly assigned to each cage: (1) one pair (a male and female) of *Allotropa* n. sp., N = 30 cages; (2) one pair (a male and female) of *Z. debarri,* N = 28 cages; and (3) one pair of *Allotropa* n. sp. and one pair of *Z. debarri,* N = 37 cages. For treatment 3, both species were released into the cage at the same time. The cages were maintained in a greenhouse in Athens, GA, under conditions of natural sunlight, a temperature of 27°C and a relative humidity of approximately 68%.

The caged branches or seedlings were cut 4 wks after the release date to collect the F_1 progeny. After vigorous shaking of the caged cuttings, the cages were removed. The resin cells were dissected, and all adult parasitoids and mummified *O. acuta* were collected, as were the dead parasitoids or mummies that were dislodged from the branches into the cages. The mummies were placed in individual gelatin capsules, and the developing parasitoids were reared to emergence. The number of each species of parasitoid in each cage was counted.

The mean number of F_1 adults produced by *Allotropa* n. sp. in treatment 1 and *Z. debarri* in treatment 2 were compared by a univariate *t* test (SAS Institute 1989, SAS/STAT user's guide, version 6, fourth edition, SAS Institute, Cary, NC). Approximate *t* tests were used to compare mean numbers of progeny for *Allotropa* n. sp. in treatments 1 and 3 and *Z. debarri* in treatment 2 and 3. A paired *t* test was used for mean separation of the number of progeny produced by competing females of the two species in treatment 3.

Allotropa n. sp. produced about 15% more F_1 adults than *Z. debarri* when single females were enclosed separately on loblolly pines with limited numbers of hosts (Table 1), but this difference was not significant (univariate *t* test; $P = 0.2680$). When pairs of each species were caged together and forced to compete for *O. acuta* hosts, progeny production between the two species was significantly different (paired *t* test, $t = 12.14$; df = 26; $P = 0.0001$). More adult *Z. debarri* than *Allotropa* n. sp. emerged within a cage in only one instance (35:22). *Allotropa* n. sp. females competing with *Z. debarri* were able to maintain the same level of progeny production as isolated *Allotropa* n. sp. females (Approximate *t* test; $P = 0.3629$). In contrast, *Z. debarri* females competing with *Allotropa* n. sp. females produced about 80% fewer progeny than *Z. debarri* alone (Approximate *t* test; $P = 0.0001$) (Table 1).

The initial host-searching behavior of the adult parasitoids may explain the out-

Table 1. Mean number (±SEM) of F_1 progeny produced by single, mated females of *Allotropa* n. sp. and *Zarhopalus debarri* caged alone or together on loblolly pines infested by *Oracella acuta*.

Treatment	N	Mean ± SEM	Minimum	Maximum
Allotropa n. sp.	30	56.7 ± 3.5	28	89
Zarhopalus debarri	28	47.5 ± 5.0	11	107
Allotropa n. sp.		52.2 ± 3.4	21	94
+	37			
Zarhopalus debarri		8.8 ± 1.6	0	41

come in the competition study. Newly-emerged and mated *Allotropa* n. sp. were very active, constantly moving on the branches or in the vials while waving their antennae rapidly. When released into a cage with *O. acuta* infested pines, *Allotropa* n. sp. flew or walked quickly to locate hosts. In contrast, mated *Z. debarri* females rarely moved, often preening their wings with their legs. Both species prefer adult hosts, but *Allotropa* n. sp. may locate and parasitize the preferred hosts quicker than *Z. debarri*. The smaller, gregarious *Allotropa* n. sp. may produce multiple offspring in larger hosts, and when adults are scarce, *Allotropa* n. sp. can utilize earlier instars. These characteristics favor *Allotropa* n. sp. over *Z. debarri* when they must compete for limited hosts. Mass-rearing programs for each species should be designed to prevent contamination from competing parasitoids.

There was no evidence of multiple parasitism of *O. acuta*. Hyperparasitoids and one species of primary parasitoid occasionally emerged from gregariously parasitized hosts, but two or more species of primary parasitoids never emerged from a single host (Sun et al. 2004). *Allotropa* n. sp. and *Z. debarri* were never observed parasitizing hosts previously attacked hosts by either species, and this level of interaction requires further study.

In the U.S., abundance of these two species may be affected by host density, climatic conditions, competition, and/or the insecticide applications that often promote *O. acuta* outbreaks. Sun et al. (2004) determined by dissection 2 days after emergence that the mean number of eggs per female was 74 eggs for *Allotropa* n. sp. and 119 for *Z. debarri*. Perhaps when host populations are high, such as after insecticide applications, *Z. debarri* can recover more quickly due to higher fecundity. As host populations decline, *Allotropa* n. sp. may outcompete *Z. debarri* for the reasons previously described. Clarke et al. (1990) found *Allotropa* n. sp. to be the predominant parasitoid when *O. acuta* populations were low.

In China, host densities are high (Xu et al. 1992, Guangdong For. Sci. and Tech. 4: 22-24), and no insecticides are used. The establishment of the parasitoids may be dependent on how each species is adapted to the environmental conditions and effects of competition. Negative impacts of competition could be reduced by introducing each species into separate locations. Briggs (1993, Am. Natural. 141: 372-397) suggested that a parasitoid which attacks earlier stages of a host may prevent establishment of a parasitoid that attacks only later stages, and separate release sites would alleviate this concern. Field releases near the expanding edge of the infestation, where competitors are few (Pan et al. 2002, Chinese J. of Biol. Contr. 18: 36-38),

could reduce interference with or from native natural enemies. A suite of natural enemies initially may be required to significantly reduce *O. acuta* populations, which then could be maintained at low levels by one species. Based on this study and previous work, *Allotropa* n. sp. may be capable of reducing *O. acuta* populations alone, if it can tolerate or adapt to the conditions in China.

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