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Biology and parasitism rates of *Pteromalus* nr. *myopitae* (Hymenoptera: Pteromalidae), a newly discovered parasitoid of olive fruit fly *Bactrocera oleae* (Diptera: Tephritidae) in coastal California

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ABSTRACT

An undescribed wasp, *Pteromalus* nr. *myopitae* (Hymenoptera: Pteromalidae) opportunistically parasitizes the olive fruit fly *Bactrocera oleae* (Rossi) (Diptera: Tephritidae), an introduced pest of olives in California. The native or typical host of *P.* nr. *myopitae* is unknown. We demonstrate that *P.* nr. *myopitae* is a solitary, ectoparasitic, idiobiont parasitoid of the third instar host inside fruit, and pupation occurs in the host tunnel. Reproduction of *P.* nr. *myopitae* on *B. oleae* in olives in the laboratory and in field cages generally failed. Host-feeding was not observed, and adults fed honey and water lived longer than those provided with water alone. Parasitism in non-commercial olives in the moderate coastal climate of San Luis Obispo occurred primarily from August to October, and was absent from a nearby location with more extreme climate and a low population of *B. oleae*. Greater parasitoid numbers were associated with greater host densities, and proportion of hosts parasitized was generally higher at lower host densities during 2 years of the study. The geographic range of the parasitoid extends along the coast from San Francisco Bay to Ensenada, Baja California, Mexico, and also inland in the Sacramento Valley, with one record in the San Joaquin Valley. The potential of the parasitoid as a biological control agent of *B. oleae* is probably low, however, the extent of its interference with other parasitoids being considered for release in California is unknown and warrants further study.

1. Introduction

The olive fruit fly, *Bactrocera oleae* (Rossi) (Diptera: Tephritidae), is an important introduced monophagous pest of olive (*Olea europaea* L.) that invaded California around 1998, and spread rapidly throughout the state and northern Mexico (Rice et al., 2003). Native to Africa, Asia, and the Mediterranean, this fruit-damaging tephritid is the first in the subfamily Dacinae to establish in California. High densities of *B. oleae* occur along the climatically moderate coastal region, while lower densities occur inland (Rice et al., 2003). Until *B. oleae*'s arrival, the California commercial olive industry mainly battled serious secondary pests such as olive scale, *Parlatoria oleae* (Colvee), and black scale, *Saisettia oleae* (Olivier), but these have been successfully controlled mainly through biological and cultural methods (Daane et al., 2005). Establishment of *B. oleae* requires mitigation because of a zero-tolerance policy for infested table fruit by processors (Vossen et al., 2005), and potential for reduced oil quality and quantity.

Olive production for canning and oil is concentrated in the San Joaquin and Sacramento Valleys in the interior of California (Barrio and Carman, 2005), while about 10% is produced on the coast. The olive is also a popular ornamental tree in urban and rural areas of California. Flowering and fruit set occur from mid to late spring, with harvest occurring in late summer and fall. Fruit become susceptible to *B. oleae* infestation about 2 months after bloom. The fly lays single eggs directly under the skin of the fruit, and larvae tunnel in the pulp until the mature third instar pupates in the tunnel or exits the fruit to pupate in soil. Before pupating, the third instar tunnels to the fruit surface and scrapes away pulp below the skin, leaving a transparent "window" through which it will exit as a larva or adult. The exit hole permits entry of spoilage organisms that can destroy fruit quality (Vossen et al., 2005).

An apparent lack of effective resident natural enemies spurred the formation of a new classical biological control program against this exotic pest (Hoelmer et al., 2004). Exploration yielded at least five braconid parasitoids from the African continent and associated islands in the Atlantic and Indian Oceans, and another, *Psyttalia ponerophaga* (Silvestri) from Pakistan (Hoelmer et al., 2004). Most were already known from previous surveys for *B. oleae* parasitoids

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carried out by Silvestri (1914) and Neuenschwander (1982). All are koinobiont larval–pupal parasitoids, except *Bracon celer* Szépligeti, which is an idiobiont parasitoid of the third instar (Neuenschwander, 1982; Sime et al., 2006). Permits have been issued for release of *Psyttalia lounsburyi* (Silvestri) and *Psyttalia concolor* (Szépligeti) after non-target impact assessments were conducted in quarantine at the University of California, Berkeley (Daane et al., 2008).

During surveys of *B. oleae* populations in California for extant natural enemies, a pteromalid (Hymenoptera: Pteromalidae) parasitoid was commonly reared from *B. oleae*-infested olives along coastal California (Pickett and Rodriguez, 2004). Hannes Baur (Natural History Museum, Bern, Switzerland) examined specimens and concluded that this species is similar or perhaps belongs to *Pteromalus myopitae* (Graham), which parasitizes *Myopites* species (Diptera: Tephritidae) infesting *Inula* (Asteraceae) flower heads in Europe (Jennings, 2005), and recommended that the species be referred to as *P.* nr. *myopitae* (Graham) until its identity is established. No records exist of *P. myopitae* attacking *B. oleae* in Europe or elsewhere.

Whether *P.* nr. *myopitae* is indigenous or introduced to California is not known, despite a study conducted specifically to locate its native or alternative adopted host (Kapaun, 2007). However, it appears to be established, and therefore its biology and potential as a biological control agent against *B. oleae* merits study. We report herein the results of a study to describe the life history and seasonality of *P.* nr. *myopitae* and estimate parasitism rates on *B. oleae* on the central California coast from 2004 to 2006. Additionally, we report on a preliminary survey of the parasitoid's geographic range, and explore climatic and host-mediated constraints on its distribution.

2. Materials and methods

2.1. Study sites, climate, and experimental insects

Four study sites containing ornamental olive trees naturally infested with *B. oleae* were established to monitor fly and parasitoid dynamics (Table 1). Three of these sites were located in moderate coastal climates within San Luis Obispo (SLO), while the fourth site was established 30 km to the north in Templeton, which is at a slightly higher elevation, and has a climate more characteristic of the inland Central Valley, where the majority of commercial olives are produced. Sites were chosen where fruit were not harvested by owners, no insecticidal treatments were aimed at *B. oleae*, and where olive trees were not in close proximity to other types of fruit trees to reduce the chance of incidental drift from pesticide sprays. Within each site, a cluster of 2–6 mature landscape trees of a single varietal with heavy fruit set and easy access were chosen for monitoring. The SLO sites were surrounded by numerous other landscape olive trees, but the Templeton trees were isolated. The trees did not fit descriptions of commercial cultivars planted in California. Mature fruit measured in Oct. reached a max. of (length × width) 1.8 × 1.4 cm in Monterey Street, 1.9 × 1.6 cm in Laurel Lane, and 1.6 × 1.0 cm in Grand Avenue.

Daily max. and min. air temperatures for SLO were accessed from the California Irrigation Management Information System (CIMIS) for Nov. 2003 to Nov. 2006. Because CIMIS does not operate a climate station in Templeton, records for this site were accessed from a CIMIS station 8 km south in Atascadero. Spring (Feb. 1 to May 31) and summer (Jun. 1 to Sept. 30) data were statistically analyzed. Mean max. and min. temperatures at the two stations were compared by paired *t*-tests, while a comparison of 2004–2006 was done by ANOVA followed by Tukey's HSD to compare means. Temperature data were analyzed with JMP 8.0 (SAS, 2008).

During 2004–2006, adult *B. oleae* and parasitoids were reared from mass collections of approximately 200–300 infested olives from an ornamental tree of an unknown cultivar at the Laurel Lane study site. Experimental parasitoid populations were replenished from fruit that were collected every 2–3 wk throughout the summer and fall, as our attempts to establish a colony of the parasitoids failed. Fruit were held in 4 L nylon mesh bags (Trimaco, Durham, NC) under laboratory conditions at California Polytechnic State University, SLO (CPSU) (18–26 °C, 25–55% RH, and a combination of natural and fluorescent lighting under approximately 11:13 L:D). Emerged adult wasps and flies were extracted daily from the bags and isolated in 30 × 30 × 30 cm BugDorm–1® rearing cages (BioQuip Products, Inc., Rancho Dominguez, CA) with mesh and translucent polypropylene-sheet walls. Food for flies and parasitoids was supplied as equal volumes of honey, yeast extract (Fisher Biotech, Fairlawn, NJ), and water, streaked onto the walls of the cage, and replaced every few days as needed. Water was provided *ad libitum* in a glass vial with a cotton plug.

2.2. Parasitoid taxonomy

The pteromalid wasps that emerged from olives were compared to the extensive University of California, Riverside (UCR) tephritid parasitoid collection to determine if they had been previously found in California and if they could be associated with other host species. Additionally, pinned specimens (20 female and 2 male) were sent to H. Baur to confirm that they belong to the same species previously reared from California olives by Pickett and Rodriguez (2004).

2.3. Parasitoid biology

2.3.1. Host-stage preference and oviposition behavior

Fruit containing eggs or first through third instars of *B. oleae* were produced by controlled infestation. Uninfested Manzanillo olives were shipped overnight from the University of California Kearney Agricultural Center in Parlier, CA, (KAC) and refrigerated until use. Infested olives were produced by exposing 100 uninfested olives to 20 mated female *B. oleae* in a cage for approximately 48 h. Olives with 2–3 oviposition marks were selected for parasitoid oviposition studies. Host stages present in fruit were determined by random dissections of at least five infested olives per batch of 100.

Table 1
Location and description of study sites for weekly olive sampling. All study sites are in San Luis Obispo County, California.

Study Site	City	Coordinates	Elevation (m)	Description
Grand Avenue	San Luis Obispo	N 35° 17′49.57″ W 120° 39′12.09″	123	Dry residential landscape; six mature olive trees within 50 m
Monterey Street	San Luis Obispo	N 35° 17′19.89″ W 120° 39′06.49″	90	Irrigated commercial landscape; two mature olive trees within 100 m
Laurel Lane	San Luis Obispo	N 35° 16′01.13″ W 120° 38′22.86″	104	Dry residential landscape; four mature olive trees within 50 m
Duncan Road	Templeton	N 35° 33′21.88″ W 120° 42′43.02″	256	Dry commercial landscape; four mature olive trees within 50 m