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Suitability of Different Mealybug Species (Hemiptera: Pseudococcidae) as Hosts for the Newly Identified Parasitoid *Allotropa suasaardi* Sarkar & Polaszek (Hymenoptera: Platygasteridae)

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ABSTRACT

The parasitoid *Allotropa suasaardi* Sarkar & Polaszek (Hymenoptera: Platygasteridae) was recently described from a series of specimens reared from *Phenacoccus manihoti* Matile-Ferrero on cassava (*Manihot esculenta* Crantz) in a field in Kanchanaburi province, Thailand. It is currently being evaluated as a biological control agent of the cassava mealybug complex. In order to understand host/parasitoid ecological interactions and optimize the mass-production system of this parasitoid, nine mealybug species (*P. manihoti*, *Pseudococcus jackbeardsleyi* Gimpel & Miller, *Ferrissia virgata* (Cockerell), *Phenacoccus madeirensis* Green, *Planococcus citri* (Risso), *Dysmicoccus neobrevipes* Beardsley, *Coccidohystrix insolita* (Green), *Rastrococcus spinosus* (Robinson) and *Paracoccus marginatus* Williams & Granara de Willink) widespread in Thailand, were tested to determine their potential as alternative hosts for the parasitoid. A set of tests was conducted in the laboratory on susceptibility, preference and suitability. Successful parasitization and the development of progeny were obtained with four mealybug species, *D. neobrevipes*, *P. manihoti*, *P. madeirensis* and *P. jackbeardsleyi*; the other mealybug species were not utilized by the parasitoid. *A. suasaardi* accepted multiple species for development, with the ranking of species preference, from the most to the least being *D. neobrevipes*, *P. manihoti*, *P. madeirensis* and *P. jackbeardsleyi*. The mean developmental time was shorter and a higher number of progeny were produced in *D. neobrevipes* mealybug species followed by *P. manihoti*. The results presented in this study show some of the range of hosts available for *A. suasaardi* Sarkar & Polaszek in Thailand.

Keywords: mealybugs, parasitoid, *Allotropa suasaardi* Sarkar & Polaszek, host species selection

INTRODUCTION

Mealybugs (Hemiptera: Pseudococcidae) are small, soft-bodied plant sap-sucking insects that constitute the second largest family of scale insects (Hemiptera: Coccoidea), with more than 2,000 described species and circa 290 genera (Downie and Gullan, 2004; Ben-Dov, 2006). Mealybugs are severe agricultural pests with 158 species of mealybugs being recognized as pests worldwide (Miller *et al.*, 2002). These species most frequently originate from the Palearctic region (29%),

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followed by the Nearctic (17%), Neotropical (16%), Oriental (15%), Afrotropical (12%) and Australasian (11%) regions. Approximately 22% of mealybug pests are polyphagous, 20% occur on grasses (for example, sugar cane), 16% on citrus and tropical fruits, and 6% on coffee (Miller *et al.*, 2002). A taxonomic study of the mealybugs (Hemiptera, Sternorrhyncha, Coccoidea, Pseudococcidae and Putoidae) from southern Asia, over an area comprising 17 countries (Bangladesh, Bhutan, Brunei, Burma, Cambodia, India, Indonesia, Laos, Malaysia, Maldives, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand and Vietnam) observed and reviewed 354 species in 62 genera, of which 147 species and 6 genera are new to science with 15 new combinations of species and 19 species placed in synonymy (Williams, 2004).

Recently, crop production has been severely threatened by increasing difficulties in controlling these pests. Mealybugs are difficult to control once they have had time to establish themselves and while chemical control is still the most common control tactic used, the cryptic behavior of mealybugs, their typical waxy body cover and clumped spatial distribution pattern render the use of many insecticides ineffective (Franco *et al*., 2009). Repeated insecticide use, especially of broad-spectrum chemicals, also adversely impacts the mealybugs' natural enemies and insecticide resistance has caused the use of some chemicals to be unsustainable (Franco *et al*., 2009). Furthermore, many of these products are increasingly unacceptable because of their human toxicity and low selectivity; some are no longer available and others are targeted for reduction under national programs and regulations for sustainable use of pesticides, in light of their risk or hazard assessments (Franco *et al*., 2004; Charles *et al*., 2006; Walton *et al*., 2006).

The biological control of mealybugs, which is widely recommended (Franco *et al*., 2009), has also been constrained by different factors. Moore (1988) reviewed the natural enemies used against mealybugs in biological control programs worldwide. He reported, more than 70 species of parasitoids have been introduced against mealybugs, and at least 16% of the introductions were considered to initiate substantial or complete control. He found that most of the introduced parasitoid species were encyrtids, but species of Aphelinidae and Platygasteridae were proved to be successful on several occasions. The genus *Allotropa* is in the subfamily Sceliotrachelinae of the family Platygastridae. The members of *Allotropa* are known as primary endoparasitoids of various mealybugs (Masner and Huggert, 1989; Vlug, 1995). *Allotropa* sp., a gregarious endoparasitoids of the cassava mealybug, *Phenacoccus manihoti* Matile-Ferrero, was found in Paraguay and Mato Grosso do Sul State of Brazil (Lohr *et al*., 1990). It is one of the most important native parasitoids of *Pseudococcus cryptus* Hempel in Japan as it can parasitize all the nymphal stages of the mealybug (Arai and Mishiro, 2004).

The introduction of a newly introduced natural enemy may have adverse effects on local mealybug biodiversity; extreme caution must therefore be taken to ensure that there is no negative impact on the local ecosystem. On the other hand, the impact of an insect parasitoid on target pest populations may be enhanced by the availability of alternative hosts in or around the crop, especially in periods of the target host shortage (Powell, 1986). It has been suggested that alternative hosts can help to improve synchrony between parasitoids and their pest hosts, improve parasitoid distribution and reduce intraspecific competition in the parasitoid population (Van den Bosch and Telford, 1964). The above facts are also important to knowing the newly identified native parasitoid *Allotropa suasaardi* Sarkar & Polaszek that is currently being evaluated as a biological control agent of the cassava mealybug complex and accordingly, this research emphasized that aspect. An understanding of host/parasitoid interactions is essential to determine if other co-

existing mealybug species could be used by *A. suasaardi* as alternative hosts. With this in mind, the present study was initiated and the objectives were to determine the susceptibility, preference and suitability of nine widespread mealybug species in Thailand to act as alternate hosts of the parasitoid.

MATERIALS AND METHODS

All experimental studies and rearing were carried out in the laboratory of National Biological Control Research Center, Kasetsart University, Kamphaeng Saen Campus, Nakhon Pathom, Thailand during 2011–2012.

Rearing of mealybug species

Nine mealybug species—namely, *P. manihoti* , *Pseudococcus jackbeardsleyi* Gimpel & Miller, *Ferrissia virgata* (Cockerell), *Phenacoccus madeirensis* Green, *Planococcus citri* (Risso), *Dysmicoccus neobrevipes* Beardsley, *Paracoccus marginatus* Williams & Granara de Willink, *Rastrococcus spinosus* (Robinson) and *Coccidohystrix insolita* (Green)—were collected from different crop fields (cassava, sugar apple, citrus, mango, papaya and eggplant) in different districts of Nakhon Pathom, Kanchanaburi, Ratcha Buri and Suphanburi provinces. After collection, eight mealybug species were reared on the fruit of ripe, medium-sized Thai pumpkins (*Cucurbita moschata* Duchesne) that were approximately 20 cm in diameter as a substitute for the stock culture. The pumpkins were selected with ridges, furrows and with small stalks which made the handling operation very easy. To prevent rotting, the pumpkins were treated with 0.1% Benlate and 5% formaldehyde solutions and left 1 to 2 hr under shade for drying (Krishnamoorthy and Singh, 1990). The pumpkins were kept on stands and arranged in a cabinet comprising five plywood shelves measuring 40 × 100 cm and placed 35 cm apart resulting in an overall height of 1.75 m. Each pumpkin was infested with 100 adult female mealybugs having well-formed ovisacs. Egg sacs and crawlers of different species of mealybug were dusted individually on the upper surface for settling and development. To avoid cross species contamination, separate cabinets were carefully maintained for each mealybug species and covered with a fine net. Monthly infestations ensured a continuous supply of different nymphal instars. Three weeks after infestation, the pumpkin had populations that consisted predominantly of second and third instar mealybugs. Adult females with ovisacs were available after 4-6 wk. The cultures were maintained in the dark at 27 ± 2 °C. *C. insolita* was reared on young eggplants, *Solanum melongena* L. seedlings and were individually infested with 100 adult mealybugs in a wooden rearing cage. Four weeks after initial infestation for each species, third instars and young adults were collected and used in the experiments.

Rearing of *A. suasaardi*

Pumpkins bearing mealybugs aged from 15 to 20 d were offered to adult *A. suasaardi* for parasitization in 40 × 40 × 40 cm transparent plastic rearing cages, each having two openings, closed up with black cloth. To ensure a continued source of parasitoid, 100 females of *A. suasaardi* were released onto newly mealybug-infested pumpkins every 15 d. As adult parasitoids emerged from the parasitized mealybug, they were collected within 24 hr of emergence and released into a plastic vial. Streaks of diluted honey were provided as food. To ensure mating and a full complement of eggs, the parasitoids were held in isolation for 48 hr. As no hosts were provided during the holding period, the parasitoids were inexperienced when used in the experiments. The rearing environment was maintained at 27 ± 2 °C and 60 ± 10% relative humidity under a 12:12 light:dark photoperiod. Light was provided by a white fluorescence tube light (Lamptan, Fl 18W Ex-D Tri-phosphor), fitted in the shelf 30 cm above the cages and the light:darkness cycle was maintained using

an electric timer switch. This procedure was continued during the experimentation period. Voucher specimens have been deposited in the Natural History Museum of London and hundreds of voucher specimens resulted from this study. In all experiments, third instars and early adult females were used of all nine mealybug species.

Host species susceptibility (no-choice experiments)

In no-choice experiments, 10 mealybugs at different stages from each species were collected and placed in separate Petri dishes (6 cm in diameter and 1.5 cm in depth). One mated female parasitoid was introduced into each dish. The parasitoid and the mealybugs were observed for 30 min to record the number of encounters and host probing with the ovipositor, the parasitoid was then removed. Twenty groups of each species were exposed to different individual *A. suasaardi* females in this manner. The number of encounters, ovipositor probes and hosts parasitized by each *A. suasaardi* were the criteria for determining host species susceptibility. One-way analysis of variance (ANOVA) was used to determine statistical variation of the number of encounters, ovipositor probes and hosts parasitized by each *A. suasaardi*. Means were separated using Duncan's multiple range test at $P = 0.05$.

Host species preference (paired choice experiments)

Before starting the preference tests, the most susceptible mealybug species was selected from the no-choice experiments. Five different instar mealybugs of that selected mealybug species were placed in a Petri dish (6 cm in diameter and 1.5 cm in depth), paired with five specimens of one of the other mealybug species and a single mated female parasitoid was introduced into each experimental arena. The parasitoid and the mealybugs were observed for 30 min to record the number of encounters and probes with the ovipositor for each mealybug species. The parasitoid was then removed. Twenty groups of each of the selected host combination were exposed to different individual *A. suasaardi* females in this manner. The numbers of mealybug successfully parasitized by each *A. suasaardi* were recorded and used as the criteria for determining the parasitoids' preference between the most susceptible mealybug species and the other mealybug species.

Host species suitability

Thirty individuals of each mealybug species (except *C. insolita*) were transferred onto a young cassava leaf (*M. esculenta*) and placed in a transparent plastic jar (6 cm long and 3.5 cm in diameter) and the top was then covered with a fine net. The mealybug species, *C. insolita* was transferred onto an eggplant leaf. Three adult female parasitoids were introduced into the jar for a period of 24 hr. Twenty groups of each species were exposed in this manner. The parasitized mealybugs were then placed separately onto a small plastic dish until adult emergence. The parasitized mealybugs were checked daily after 10 d and the emergence data were recorded. Parasitoid progeny were collected and sexed. The criteria used to determine host suitability were the average number of emerged parasitoids per replicate, the secondary sex ratio and the development time of the parasitoids. The number of emerged parasitoids and the development time of the parasitoids in each of the nine mealybug species were analyzed for differences among the host species using one-way ANOVA.

RESULTS

Host species susceptibility (no-choice experiments)

In the no-choice tests, all nine mealybug species were encountered by *A. suasaardi*. Significantly higher *D. neobrevipes* and *P. manihoti* were encountered than the other mealybug species. Also, significantly more *P. madeirensis* and *P. jackbeardsleyi* were encountered than *P. citri*, *P.*

marginatus, *C. insolita* and *R. spinosus*. *F. virgata* received the lowest encounter rate by *A. suasaardi* (Table 1). The number of ovipositor probes of mealybugs was significantly different among the nine tested mealybug species. Ovipositor probing by *D. neobrevipes* was significantly superior to that of the other mealybug species except *P. manihoti*. The least number of ovipositor probes was with *P. citri* whereas *P. marginatus*, *R. spinosus*, *C. insolita* and *F. virgata* were not probed (Table 1). Significantly higher numbers of *D. neobrevipes* and *P. manihoti* were parasitized by *A. suasaardi*. The other two mealybug species, *P. madeirensis* and *P. jackbeardsleyi*, were also parasitized successfully but at significantly lower levels than *D. neobrevipes* and *P. manihoti* (Table 1).

Host species preference (paired choice experiments)

Based on the results from the no-choice tests, the *D. neobrevipes* mealybug species was paired with other mealybug species in host species preference experiments. In the choice tests, *D. neobrevipes* was significantly preferred to all other mealybug species in relation to encountering, ovipositor probing and number of hosts parasitized (Table 2). When provided with *D. neobrevipes* and *P. manihoti*, ovipositor probing and number

Table 1 Mean ± SD number of mealybugs encountered, probed and parasitized by *Allotropa suasaardi* Sarkar & Polaszek in no-choice test for each species exposed to one female parasitoid for 30 min.

	Hosts encountered	Hosts probed	Hosts parasitized
Phenacoccus manihoti	21.90 ± 3.54^{a}	11.90 ± 2.44^{ab}	4.0 ± 1.70^{a}
Dysmicoccus neobrevipes	23.05 ± 3.10^{a}	12.50 ± 3.30^{a}	4.2 ± 1.97^{a}
Phenacoccus madeirensis	19.95 ± 2.58^{b}	11.15 ± 1.60^{bc}	3.2 ± 1.43^{b}
Pseudococcus jackbeardsleyi	17.21 ± 1.92^{c}	10.80 ± 1.53^{c}	3.1 ± 1.12^{b}
Planococcus citri	9.63 ± 2.25^{d}	1.65 ± 1.84^{d}	0.0^{c}
Paracoccus marginatus	8.60 ± 1.88^{de}	0.0^{e}	0.0^{c}
Coccidohystrix insolita	7.47 ± 1.76^{ef}	0.0^{e}	0.0^{c}
Rastrococcus spinosus	6.50 ± 2.04^{f}	0.0^{e}	0.0^{c}
Ferrissia virgata	2.45 ± 1.68^{g}	0.0^{e}	0.0^{c}

Values are means ± SD. Values in a column with different superscripts are significantly different at ($P < 0.05$).

Table 2 Mean ± SD number of mealybugs encountered, probed and parasitized by *Allotropa. suasaardi* Sarkar & Polaszek in paired-choice test for each species exposed to one female parasitoid for 30 min.

	Hosts encountered	Hosts probed	Hosts parasitized
Phenacoccus manihoti	15.80 ± 2.88^{a}	7.15 ± 1.14^{a}	3.40 ± 0.94^{a}
Dysmicoccus neobrevipes	16.75 ± 2.73^{a}	7.65 ± 1.50^{a}	3.95 ± 0.29^{a}
Phenacoccus madeirensis	7.25 ± 2.00^{b}	1.85 ± 1.09^{b}	0.74 ± 0.07^{b}
Pseudococcus jackbeardsleyi	6.75 ± 1.52^{b}	1.65 ± 1.27^{b}	0.62 ± 0.08^{b}
Planococcus citri	2.45 ± 1.05^{c}	0.0^{c}	0.0^{c}
Paracoccus marginatus	2.20 ± 1.67^{cd}	0.0^{c}	0.0^{c}
Coccidohystrix insolita	1.15 ± 1.09^{de}	0.0^{c}	0.0^{c}
Rastrococcus spinosus	1.10 ± 1.02^{de}	0.0^{c}	0.0^{c}
Ferrissia virgata	0.55 ± 0.69^{e}	0.0^{c}	0.0^{c}

Values are means ± SD. Values in a column with different superscripts are significantly different at ($P < 0.05$).

of hosts parasitized were relatively similar between the hosts. Lower numbers (mean ± SD) of parasitization were obtained by *P. madeirensis* (0.74 ± 0.07) and *P. jackbeardsleyi* (0.62 ± 0.08) when provided with *D. neobrevipes* (3.95 ± 0.29). Although *P. marginatus*, *R. spinosus*, *C. insolita* and *F. virgata* were encountered during the two-choice tests, no mealybugs were probed or parasitized by *A. suasaardi* (Table 2). These mealybug species were not utilized by *A. suasaardi* female parasitoids and were not parasitized when exposed to *A. suasaardi* simultaneously with *D. neobrevipes*, *P. manihoti*, *P. madeirensis* and *P. jackbeardsleyi*. Based on the results of one–way ANOVA analyses, the ranking of preference for *A. suasaardi* from the most preferred to the least preferred was *D. neobrevipes*, *P. manihoti*, *P. madeirensis* and *P. jackbeardsleyi*.

Host species suitability

Among the nine mealybug species, successful parasitization and development of parasitoid progeny were observed in *D. neobrevipes*, *P. manihoti*, *P. madeirensis* and *P. jackbeardsleyi* mealybug species. Significantly higher numbers of progeny emerged in *P. manihoti and D. neobrevipes* compared to *P. madeirensis* and *P. jackbeardsleyi*. The average total number (mean ± SD) of progeny produced by *A. suasaardi* in *D. neobrevipes* was 16.1 ± 2.31, followed by *P. manihoti* (15.4 ± 2.83) out of the 30 hosts exposed to three female parasitoids. Significantly more female offspring were produced in *D. neobrevipes*. The numbers of male offspring produced from the four mealybug species were not significantly different (Figure 1). A female-biased sex ratio (2.1:1) was observed in *D. neobrevipes* but was slightly lower in *P. manihoti* (1.6:1). *P. madeirensis* and *P. jackbeardsleyi* also produced female-biased sex ratios but they were lower than for *D. neobrevipes* and *P. manihoti*. Both male and female *A. suasaardi* developing in *P. jackbeardsleyi* had significantly longer duration than those developing in *D. neobrevipes*, *P. manihoti* and *P. madeirensis* mealybug species. However, females in general had a longer developmental period ($P < 0.05$) than males. *A. suasaardi* developing in *D. neobrevipes* emerged within 21 d after parasitism which was followed by *P. manihoti* (22.5 d) and was 2–3 days shorter than those in *P. madeirensis*

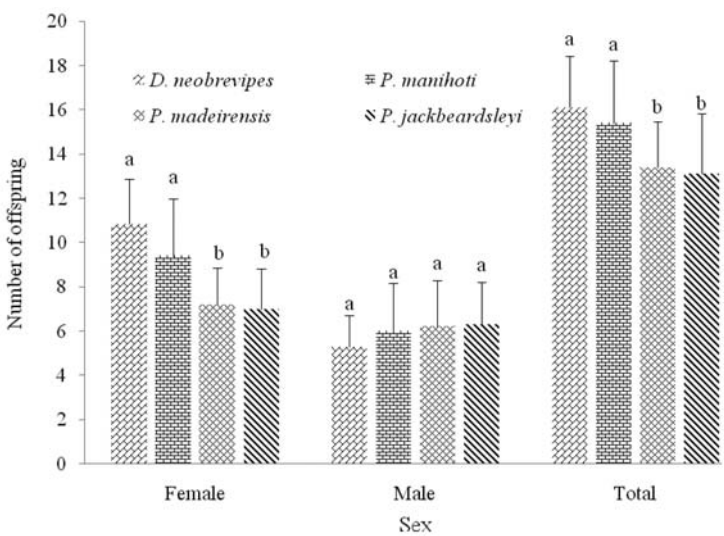

Figure 1 Number of female and male offspring (mean ± SD) produced by *Allotropa suasaardi* Sarkar & Polaszek in four mealybug species. Different letters on top of bars indicate a significant difference ($P < 0.05$).

and *P. jackbeardsleyi*, respectively (Figure 2). The developmental period of male parasitoids varied significantly. Development of males in *D. neobrevipes* and *P. manihoti* took significantly less time (19.7 and 21 d, respectively) than in *P. madeirensis* and *P. jackbeardsleyi* (22.9 and 23.1 d, respectively).

DISCUSSION

The presence of alternative hosts is important to the success of a biological control program in that such presence allows the persistence of parasitoid populations over periods of scarcity of the primary hosts (DeBach and Bartlett, 1964). Host specificity of a biological control agent is one of the most important criteria in evaluating its potential uses and assessing its risks to nontarget organisms (Nechols *et al*., 1992; Van Lenteren *et al*., 2003; Louda *et al*., 2003; Briese, 2005; Sheppard *et al*., 2005). The host range, that is, the set of host species that are accepted and utilized for progeny development, of a parasitoid is therefore one of the first steps in the evaluation of the parasitoid (Van Driesche and Hoddle, 1997; Van Lenteren *et al*., 2003). The group of species that are utilized by the parasitoid in the field is the ecological host range (Onstad and McManus, 1996). The fundamental host range is the set of species that are accepted by the foraging parasitoid and can support development under laboratory conditions (Onstad and McManus, 1996). The fundamental host range differs from the previously used physiological host range in that the host acceptance behaviors, instead of simple physiological compatibility, are taken into account (Van Klinden, 2000). The selection of test species in fundamental host range studies should be based on the phylogenetic relationships between the target and the nontarget species (Van Klinden, 2000; Kuhlman and Mason, 2003; Sheppard *et al*., 2005). The current research presented a limited fundamental host range study of a newly identified mealybug parasitoid species, *A. suasaardi* based on laboratory testing.

Host range evaluation is usually the first, most tractable approach and often the only step in predicting risks of impacts on nontarget species. Usually the physiological/behavioral host range is measured in the laboratory and the ecological host range is measured in the field. An inherent assumption is that the host range in the area of origin is a reasonably good predictor of the host range in the area of introduction. If it can be shown

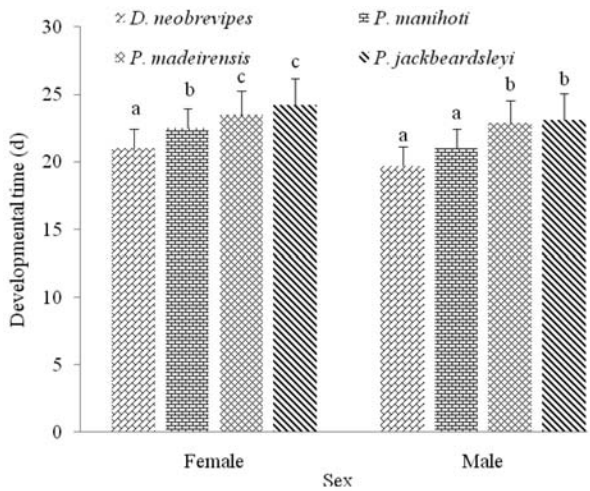

Figure 2 Developmental time (mean ± SD) of *Allotropa suasaardi* Sarkar & Polaszek in four mealybug species. Different letters on top of bars indicate a significant difference ($P < 0.05$).

that a candidate for introduction will not attack any nontarget species in the area of introduction, the risk of nontarget impacts is low (Hopper, 2001). *Allotropa citri* Muesebeck has been recorded as a parasitoid of *Maconellicoccus hirsutus* (Green) (Rao, 1967) and also on *P. cryptus*, a mealybug of citrus (Arai and Mishiro, 2004). *Allotropa oracellae* Masner, the primary endoparasitoids of *Oracella acuta* (Lobdel) has been recorded by Masner *et al.* (2004) and Buhl (2005) has recorded *Allotropa musae* Buhl from *Dysmicoccus grasii* (Lonardi) in banana (*Musa* sp.).

In the current study, four mealybug species, *P. manihoti, D. neobrevipes, P. madeirensis* and *P. jackbeardsleyi*, were accepted by the parasitoid *A. suasaardi*, while the mealybug species, *P. citri* was probed but rejected by the parasitoid. A foraging *A. suasaardi* recognized potential hosts through antennal examination. Ovipositor probing provided further discrimination as most examined *P. marginatus, R. spinosus, C. insolita* and *F. virgata* were not accepted for ovipositor probing. Observations at the initial time of exposure indicated that parasitoids were nonresponsive to the presence of the mealybug species; *P. marginatus, R. spinosus, C. insolita* and *F. virgata*. The long, sticky, wax filaments projected from the body of *F. virgata* provided good protection. The antennae of the parasitoid species became entangled with the wax filaments, causing the parasitoids to retreat rapidly and immediately leave the arena or spend the rest of the observation period in grooming. The majority of the encountered mealybugs were subjected to antennal examination. The preference ranking of the four mealybug species, from the most to the least, was *D. neobrevipes, P. manihoti, P. madeirensis* and *P. jackbeardsleyi*. These four species were able to support the complete development of *A. suasaardi*. The parasitoid parasitized significantly more *D. neobrevipes* and produced more progeny from this than *P. manihoti, P. madeirensis* and *P. jackbeardsleyi*. Roltsch *et al*. (2007) reported that *Allotropa* sp. near *mecrida* parasitoids produced 17.5 first generation in each of the control replicates that contained 50 pink hibiscus mealybugs, *M. hirsutus* nymphs. Lohr (1991) found up to 12 *Allotropa* sp. adults emerged successfully from the mummy of the cassava mealybug, *P. manihoti*. Similar trends of progeny production by *A. suasaardi* were observed in the current study. *A. suasaardi* developed in *P. madeirensis* and *P. jackbeardsleyi* emerged later than in *D. neobrevipes* and *P. manihoti*. Mani and Krishnamoorthy (1989) reported that the *A. japonica* sp. n. parasitoid of *M. hirsutus* completed its life cycle in 25.5 d at 25.5 ºC. The developmental duration of *A. citri*, the parasitoid of *P. cryptus*, a mealybug of citrus, was 29.7 d at 27.5 °C (Arai and Mishiro, 2004). The developmental duration of *A. suasaardi* was slightly shorter than both of the above parasitoids at 27 ± 2 °C. A significant difference was observed in the developmental duration of male and female individuals. This was in agreement with Arai and Mishiro (2004) who found similar results in *P. cryptus* mealybug species. Lohr (1991) observed that male *Allotropa* sp. developed significantly faster than females above 20 ºC in the cassava mealybug, *P. manihoti*. The sex ratio of the current study was similar to that reported in a life history of *Allotropa* sp. by Lohr (1991) in the cassava mealybug, *P. manihoti*. The above results revealed that the parasitoid discriminated among different host species and selected the most suitable host for the development and survival of its progeny.

CONCLUSION

The parasitoid *A. suasaardi* is capable of parasitizing effectively in the *D. neobrevipes, P. manihoti, P. madeirensis* and *P. jackbeardsleyi* mealybug species represented in this study. Of the four mealybug species, *D. neobrevipes* and *P. manihoti* were the most suitable for progeny development. The above results indicate the host range of this native parasitoid in the ecosystems of Thailand. The parasitoid has a number of

alternative hosts, if populations of *P. madeirensis* and *P. jackbeardsleyi* are available during a period of low *D. neobrevipes* and *P. manihoti* abundance, this will allow the parasitoid to persist. From a mass production perspective, both the parasitoids *D. neobrevipes* and *P. manihoti* can be utilized but reliance should be on *D. neobrevipes* as hosts in order to achieve high parasitoid fitness in terms of a high survival rate, shorter developmental time and a more female-biased sex ratio. However, an ecological host range study is required to investigate the actual host range utilized by the parasitoid in the field.

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