Foraging behavior of Aphidius colemani (Hymenoptera: Aphidiidae) on three aphid species [Aphis gossypii, Aphis craccivora and Rhopalosiphum maidis] (Homoptera: Aphiidae)

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ABSTRACT

The acceptance and suitability of three aphid species [Aphis gossypii Glover, Aphis craccivora and Rhopalosiphum maidis (Fitch)] (Homoptera: Aphiidae) for the parasitoid Aphidius colemani Viereck (Hymenoptera: Aphidiidae) were studied and evaluated. Parasitoid female parasitized fewer R. maidis than the other two aphid species. Also, fewer offspring successfully completed development in R. maidis than in the other two host species, suggesting that R. maidis is a poor quality host for the mentioned parasitoid. No significant differences in sex ratios of emerging parasitoid adults between A. colemani reared on the three aphid species. Ovipositing A. colemani encountered R. maidis at a slower rate, also, parasitoid offspring died at a higher rate in R. maidis compared to A. gossypii. The results showed that oviposition behavior and offspring performance were correlated. The results of this research can be used for establishing integrated pest management (IPM) strategies against aphid species.

Keywords: development time, Aphid parasitoids, Aphis gossypii, sex ratios.

INTRODUCTION

Studies of host range can provide insight into the tradeoffs associated with specialization and into speciation via host-race formation (Futuyma & Moreno, 1988; Thompson & Pellmyr, 1991). Individuals with a broad host range have an advantage over those with a narrow host range because they can switch host species when one host becomes difficult to find. However, many species are highly specific in their use of hosts; thus the challenge is to explain why the host ranges of such species are not broader. Most theories concerning specialization in host use assume there are trade-offs between host range and host use efficiency (Via & Lande, 1985; Lynch & Gabriel, 1987). Specialists are often more efficient at host location or better able to cope with host defenses than generalists, but specialization may come at the cost of being poorly adapted to other host species. Because of such trade-offs, specialist parasites whose development is intimately tied to host physiology are more likely to have highly restricted host ranges.

Studies of host range and host use efficiency are also important for applied pest management. The success and safety of biological control introductions depend on an ability to predict post-introduction host use. Many pest populations are ephemeral; populations of natural enemies that can switch successfully to alternative host species may persist better and provide control when pest populations resurge (e.g., DeBach & Rosen, 1991; Pike et al., 1999). On the other hand, knowledge of the behavioral and physiological bases of host use will help in assessing the potential for deleterious impacts on non-target species, an increasingly contentious issue in biological control (Simberloff & Stiling, 1996; Hopper, 2000).

Experimental studies of the trade-offs associated with the use of different host species, especially those focusing on trade-offs within a parasite species, are rare (Futuyma & Moreno, 1988) and this is particularly true for parasitic wasps (Godfray, 1994). Compared to many predators, parasitic wasps (parasitoids) have narrow host ranges, presumably because parasitoid development is often intimately associated with the physiology and immune responses of their hosts. This is thought to be especially true of parasitoids that allow their hosts to continue development (koinobionts) and develop internally (endoparasitoids) (Askew & Shaw, 1986; Strand, 1986). Yet, even among koinobiotic endoparasitoids, host range varies widely. Several species of aphelinid and braconid parasitoids, including Aphidius colemani Viereck (Hymenoptera: Braconidae), are known to attack as many as 60 species from several aphid genera (Stary, 1975, 1983; Kalina & Stary, 1976; Hopper et al., 1998; Takada, 1998). However, some extremely polyphagous species appear to be composed of distinct host races that rarely switch between host species in the field (Nemec & Stary, 1983; Stary, 1983; Cameron et al., 1984; Tardieux &
Rabbing, 1986, 1990; Powell & Wright, 1988; Messing & Rabasse, 1995; Atanassova et al., 1998; Takada & Tada, 2000). While much is known about the relationship between host use and offspring fitness within a host species (Godfray, 1994), less is known about the relationship between host use patterns and offspring performance across host species in the present work and the behavioral and developmental behavior of the parasitoid wasp, A. colemani, when exposed to three host aphid species.

MATERIALS AND METHODS
Rearing of aphids:

Rearing of Aphis gossypii Glover.

The cotton aphids were obtained from okra plants in the Farm of Agriculture Faculty, Al-Azhar University. The cotton aphid was colonized on cucumber at 25 ± 1°C, 65 ± 5% R. H. and a photoperiod of 12L: 12D hours. Seedlings of cucumber were grown to the 4–5 leaf stage in a mixture of sand (33%), clay (33%) and compost (33%) in 25 cm pots.

Rearing of Aphis craccivora Koch.

The cowpea aphid, A. craccivora was the second host species used for rearing of the parasitoid under investigation. Its individuals were firstly collected from faba bean plants in Farm of Agriculture Faculty, Al-Azhar University. Stock culture of the aphid species was reared under the laboratory conditions (23±2 ºC and 65±5%RH), on faba bean plants according to the following technique:-

Grains of faba bean were firstly soaked in water for 24-48 hours to accelerate germination.

Planting was made in plastic pots (22cm) filled with wet sawdust. A number of about 10 grains was distributed among the sawdust/pot.

As the germinated plants reached 2–3 cm, those were infested by 30-50 apterous adults of A. craccivora per pot.

Aphid nymphs were separated whenever needed for specific experiments on the investigated parasitoid.

Rearing of Rhopalosiphum maidis (Fitch):

The Corn leaf aphid R. maidis was the third host species used for rearing the parasitoid under investigation. Aphid’s individuals were firstly collected from maize plants in the Farm of Agriculture Faculty, Al-Azhar University. The following technique was used to rear this aphid:

Grains of maize were firstly soaked in water for 12-24 hours to accelerate germination.

Planting was made in plastic pots (30cm) filled with wet sawdust. A number of about 30-50 grains was distributed among the sawdust/pot.

As the germinated plants reached 2-3 cm, those were infested by (30-50) apterous adults of. R maidis per pot.

Nymphs were separated whenever needed for specific experiments on the investigated parasitoid.

The three aphid species were identified in plant protection institute.

Rearing the parasitoid:

The parasitoids were separately reared on A. gossypii in glass cages (30 × 60 × 35 cm). Colonies of parasitoid wasps were replenished with field- collected individuals during spring and autumn. The aphids and parasitoids were reared on cucumber in the laboratory for at least three generations before using in experiments.

Used patterns among three aphid species

To measure differences in use of the three aphid species by A. colemani, exposed females from each subculture to each of the three aphid species. This experiment was conducted 6–8 generations after the A. colemani population was subcultured on each aphid species. Mummified aphids containing A. colemani from each subculture were isolated. As female wasps emerged, they were allowed to mate with a single male from their own subculture for 24 h. One-day-old; mated females from each of the three subcultures were put individually into cages with a plant infested with approximately 100 aphids of each of the three species. Each combination was replicated 6–10 times. Cages were clear plastic cylinders, 10 cm diameter pots containing either cucumber infested with A. gossypii while, faba bean infested with A. craccivora and the maize infested with R. maidis. The exposed aphids were held in plant growth chambers under a photoperiod of L12:D12 and at 25 °C for 10 days (i.e., until mummies formed). The numbers of mummified aphids in each cage were counted, and after emergence, the adult wasp offspring were sexed and counted. Aphid age and size distribution at the time of parasitism was estimated from five additional cages for each of the three aphid species. The different ages of the three types of aphids were
separated to calculate the development period for each stage. Approximately 100 randomly selected aphids from each cage were categorized by nymphal stage. Different densities were made for the three aphid species; they were as follows (2, 5, 10, 25, 50 and 100). Antennal encounters and prickings have been calculated for each density separately for 8 hours per day. By directly observing whether an egg is laid at each encounter with a host, acceptance of the host was assessed by the Ovipositing female as well as progeny survival. Also, the relationship between oviposition and offspring survival among host species was measured, which is key to demonstrating adaptive host use. Host species influences offspring sex ratio was examined. Ovipositing females may allocate male and female differentially in different host species; alternatively, male and female may survive differently when developing in different host species. A female’s pattern of oviposition may depend primarily on the host species she encounters, or she may exhibit a higher acceptance rate of the same host species in which she developed (Godfray, 1994). Data were subjected to ANOVA by using Costat program (1988) and significant difference among the treatments was compared by Duncan’s (1955) multiple range test and L.S.D. test at probability level P=0.05 in all data obtained.

RESULTS

Table (1) shows the sex ratio of the parasitoid *Aphidius colemani* on three aphid species. There were no differences between the three aphid species were 1:1.2, 1:1.1and 1:1.2 on *A. gossypii*, *A. craccivora* and *R. maidis* respectively.

Data in table (2) show the number of antennal encounters by the parasitoid ovipositor with different host densities of three aphid species. It is clear that higher density of the host, led to higher antennal encounters process on the three aphid species. But the highest number of antennal encounters was recorded on *Aphis gossypii* followed by *Aphis craccivora* and the lowest number was on *Rhopalosiphum maidis*. They were 129.3±5.73, 102.9±7.48and 84.6±5.44 at density of 100 of tested aphids respectively.

Data presented in table (3) show the numbers of pricking done by the parasitoid ovipositor with different densities on three aphid species. Although growing the number of pricking by increasing the aphid densities. The perfect recorded rate of pricking were $\gamma \pm 3.40$, $\gamma \pm 4.01$and $\gamma \pm 4.42$ on *A. gossypii*, *A. craccivora* and *R. maidis*, respectively.

Data in table (4) show the parasitized aphids by the parasitoid, *A. colemani* at different densities of *A. gossypii*, *A. craccivora* and *R. maidis*. Female of parasitoids parasitized fewer *R. maidis* than the other two aphid species on the six different densities. The percentage of parasitism increased with the increase in the density of the three aphid species. The highest number of parasitized aphid was at density of 100. It was 55±3.29, 50.1±1.66 and 38.6±2.45 on *A. gossypii*, *A. craccivora* and *R. maidis* respectively.

DISCUSSION

The results show that population of *A. colemani* is poorly adapted to *R. maidis* compared to the other two aphid species. Females exposed to *R. maidis* produced fewer mummies and adult offspring than females exposed to the other two species. The second experiment showed that the difference in use of *A. gossypii* and *R. maidis* resulted from how fast the ovipositing females encountered each host species, how fast each host species was handled, how readily each host species was accepted for oviposition. Taking these effects together in consideration, it is obvious that *A. colemani* females to produce about twice more offspring on *A. gossypii* than on *R. maidis* over a fixed period of time, and this difference was in the experiments. Differences in leaf shape or its chemical components may affect the aphid distribution on cucumber vs. maize; this may in turn influence the foraging activity of *A. colemani* females. In one population of *A. colemani*, females showed a foraging preference for the host plant on which they had emerged (Storeck et al., 2000). Host plant species may also influence the development of parasitoids in different aphid species. Differences in resistance to parasitism between *A. gossypii* and *R. maidis* might be determined by the different effects of host plant species on aphid.

Previous studies showed that *A. colemani* females encounter the parasitized and unparasitized *A. gossypii* with similar frequency (van Steenis & El-Khawass 1995). Age of parasitoids can affect their host searching and oviposition behavior (Völkli & Mackauer 1990; Asadi et al. 2012; Nikbin et al. 2014; Pasandideh et al. 2015). In the field, several foraging parasitoids may visit a host patch simultaneously (He & Wang 2014), which may cause competition and interference among parasitoids and reduce their per capita
host search and attack efficiency (Hassell & Varley 1969). Obtained findings appear to agree with those of Hassell & Varley (1969). However, reproductive fitness of A. colemani was actually the highest when the parasitoid density was between intermediate and high. This could be attributed to the significantly positive interactions between parasitoid and host densities. This property should encourage aggregation of parasitoids on host patches of high density, leading to the collapse of host patches (Hassell & May 1973; Kidd & Jervis 2005; Hanan et al. 2017) and preventing pest outbreaks from these patches. In two studies, there was a positive association between host acceptance by the Ovipositing female and larval survivorship. In a study of Asobara tabida, a parasitoid of drosophiles. van Alphen & Janssen (1982) showed that ovipositing females were more likely to reject a host species in which larval survival was low. In a series of host choice tests using Monoctonus paulensis, an aphid parasitoid, ovipositing females were most likely to accept aphid species with the greatest likelihood of producing adult offspring (Chau & Mackauer, 2001). All evidence proves that mass release of A. colemani can be a good option for effective control of aphids when the pest density is high. The sex ratio of A. colemani is usually female-biased (Saleh et al., 2014). However, this is affected by environmental factors. In a temperature range of 15 ~ 25 ºC, sex ratio is female-biased, whereas, at temperatures below 10 ºC or above 30 ºC, it is male-biased (Zamani et al. 2007). Body size of aphids is another factor affecting A. colemani sex allocation. For example, those attacking small aphids (first instar nymphs) produce offspring of a male-biased sex ratio and those parasitizing large aphids (third instar nymphs) have offspring of a female-biased sex ratio (Jarošik et al. 2003).

CONCLUSION

There are no differences in the sex ratio of the parasitoid when reared on three aphid species. The parasitoid can be reared on cotton or beans aphid successfully. The parasitoid can also be used in biological control to control most of species of aphids.

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**Table 1:** Sex ratio of the newly emerged parasitoid, *Aphidius colemani* parasitized on *A. gossypii*, *A. craccivora* and *R. maidis*.

<table>
<thead>
<tr>
<th>Sex</th>
<th><em>A. gossypii</em></th>
<th><em>A. craccivora</em></th>
<th><em>R. maidis</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>45</td>
<td>48</td>
<td>44</td>
</tr>
<tr>
<td>Female</td>
<td>55</td>
<td>52</td>
<td>56</td>
</tr>
<tr>
<td>ratio</td>
<td>1:1.2</td>
<td>1:1.1</td>
<td>1:1.2</td>
</tr>
</tbody>
</table>

**Table 2:** Mean numbers of antennal encounters by the parasitoid ovipositor with different densities of host; *Aphis gossypii*, *Aphis craccivora* and *Rhopalosiphum maidis*.

<table>
<thead>
<tr>
<th>Aphid spp</th>
<th>Aphid density</th>
<th><em>A. gossypii</em></th>
<th><em>A. craccivora</em></th>
<th><em>R. maidis</em></th>
<th>LSD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>A. gossypii</em></td>
<td>2.253</td>
<td>3.6±1.89a</td>
<td>5.4±2.36a</td>
<td>3.6±1.89a</td>
<td>3.457</td>
</tr>
<tr>
<td><em>A. craccivora</em></td>
<td>2.125</td>
<td>4.5±1.58b</td>
<td>8.4±3.09a</td>
<td>9±2a</td>
<td>3.092</td>
</tr>
<tr>
<td><em>R. maidis</em></td>
<td>2.079</td>
<td>7.5±2.12a</td>
<td>9±2.44a</td>
<td>9.3±2.21a</td>
<td>3.878</td>
</tr>
<tr>
<td></td>
<td>3.575</td>
<td>17.1±3.47c</td>
<td>26.1±3.47b</td>
<td>39.6±4.64a</td>
<td>5.397</td>
</tr>
<tr>
<td></td>
<td>4.937</td>
<td>37.8±6.03b</td>
<td>54±6.16a</td>
<td>55.5±3.53a</td>
<td>5.769</td>
</tr>
</tbody>
</table>

*Means followed by the same letter in each row are not significantly different.

**Table 3:** Mean numbers of pricking by the parasitoid ovipositor with different densities of host; *A. gossypii*, *A. craccivora* and *R. maidis*.

<table>
<thead>
<tr>
<th>Aphid spp</th>
<th>Aphid density</th>
<th><em>A. gossypii</em></th>
<th><em>A. craccivora</em></th>
<th><em>R. maidis</em></th>
<th>LSD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>A. gossypii</em></td>
<td>0.48</td>
<td>1.3±0.56a</td>
<td>1.3±0.48a</td>
<td>1.1±0.56a</td>
<td>0.48</td>
</tr>
<tr>
<td><em>A. craccivora</em></td>
<td>0.708</td>
<td>2±0.66b</td>
<td>2.5±0.70ab</td>
<td>2±0.66b</td>
<td>0.708</td>
</tr>
<tr>
<td><em>R. maidis</em></td>
<td>0.826</td>
<td>5.3±0.94c</td>
<td>6.9±0.73b</td>
<td>5.3±0.94c</td>
<td>0.826</td>
</tr>
<tr>
<td></td>
<td>1.34</td>
<td>13.1±1.91c</td>
<td>17.3±1.15b</td>
<td>13.1±1.91c</td>
<td>1.34</td>
</tr>
<tr>
<td></td>
<td>2.35</td>
<td>38.6±2.45c</td>
<td>50.1±1.66b</td>
<td>38.6±2.45c</td>
<td>2.35</td>
</tr>
</tbody>
</table>

*Means followed by the same letter in each row are not significantly different.
سلوك الرعي للمتطفل الحشري على ثلاثة أنواع من المثنىات من من (Hymenoptera: Aphidiidae)

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Aphidius colemani (Hymenoptera: Aphidiidae) (Homoptera: Aphididae)

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الملخص العربي

تم قياس قبول وملاءمة ثلاثة أنواع من حشرات المثنىات من (Aphidius colemani Viereck (Hymenoptera: Aphidiidae) وعدد من التجارب أن أنثى المتطفل تطفلت على عدد أقل من حشرة من الذرة مقارنة بالنوعين الآخرين وأكثر عدد من m. لم يظهر ذلك دالياً إحصائياً بين أنواع المثنىات الثلاثة في النسبة الجنسية للأفراد البالغة من المتطفل. وكان معدل البحث عن العائلات فائلاً في حشرة من الذرة مقارناً بالأنواع الأخرى وكذلك معدل النزول ووضع البيض أقل وبالمقابل نسبة تطفل أقل من النوعين الآخرين. وأظهرت النتائج ارتباط سلوك وضع البيض وأداء النسل الناجح. ويمكن استخدام نتائج هذا البحث لوضع استراتيجيات الإدارة المتكاملة لآفات (IPM) ضد أنواع المثنىات.

الكلمات الاسترشادية: متطفلات المثنىات، ذرة، النسبة الجنسية، مدة النمو.