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RESEARCH ARTICLE

Bionomics of *Opius bellus* (Hymenoptera: Braconidae), an endoparasitoid of *Anastrepha fraterculus* (Diptera: Tephritidae) in fruit-growing areas of Northwestern Argentina

Pablo Schliserman[a], Guido Alejandro Van Nieuwenhove[a], Laura Patricia Bezdjian[a], Patricia Albornoz-Medina[a], Lorena Inés Escobar[a], María Josefina Buonocore Biancheri[a], Javier Altamirano[a], Martín Aluja[b] and Sergio Marcelo Ovruski[a]*

[a]*Laboratorio de Investigaciones Ecoetológicas de Moscas de la Fruta y sus Enemigos Naturales (LIEMEN), División Control Biológico de Plagas, Planta Piloto de Procesos Industriales Microbiológicos y Biotecnología (PROIMI), CCT Tucumán, CONICET. Av. Belgrano y Pje. Caseros, (T4001MVB) San Miguel de Tucumán, Argentina;* [b]*Instituto de Ecología, A.C, Apartado Postal 63, C.P. 91000, Xalapa, Veracruz, México*

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Opius bellus is a neotropical larval-prepupal parasitoid known to attack the pestiferous fruit fly, *Anastrepha fraterculus*. Due to interest in the use of native parasitoids in forthcoming fruit fly biocontrol programmes in Argentina, *O. bellus* was colonised for the first time using laboratory-reared *A. fraterculus* larvae. A series of experiments were conducted to (1) best achieve an efficient parasitoid rearing by determining optimal larval host age, host:parasitoid ratio and host exposure time and (2) assess their potential as biological control agents by determining reproductive parameters. The most productive exposure regimen was: 7–9 d-old (early and middle third-instars) *A. fraterculus* larvae for 4 h at a 4:1 host: parasitoid ratio; this array of factors was sufficient to achieve the highest average adult emergence (48%) and an offspring sex ratio at equitable proportion. Increasing both host:parasitoid ratio further than 4:1 and the host exposure time beyond 4 h did not significantly enhance parasitoid female offspring yield. Females produced eggs for 29.5 ± 1.4 days. At 32 days of age, 50% of the females were still alive. The majority of the progeny were produced by females between 20 and 24 d-old. At 26°C, gross fecundity rate, net reproductive rate, intrinsic rate of increase and mean generation time were 20.7 ± 4.2 offspring/female, 9.6 ± 2.5 females/newborn females, 0.06 ± 0.01 females/female/day and 8.4 ± 0.2 days, respectively. The long lifespan and reproductive parameters suggest that this parasitoid species has suitable attributes for mass-rearing.

Keywords: fruit fly; parasitoid; Braconidae; rearing; demographic parameters; Argentina

Introduction

The native South American fruit fly, *Anastrepha fraterculus* (Wiedemann), and the exotic Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) are among the most important pests affecting commercial fruit production in Argentina (Guillén &

*Corresponding author. Emails: sovruski@proimi.org.ar; ovruskisergio@yahoo.com.ar

Sánchez, 2007). For example, in the citrus-growing areas of northern Argentina, approximately 143,000 tonnes of citrus is lost every year due to *A. fraterculus* and *C. capitata*. In addition, both tephritid species severely limit the export of fruit because of quarantine restrictions imposed by countries free of these pests (Guillén & Sánchez, 2007).

Interest in an integrated approach to control both pests in Argentina has resulted in attempts to apply biological control strategies. These programmes were based on the use of exotic egg, larval-pupal and/or pupal parasitoids that had first been established in Hawaii. Examples include *Fopius arisanus* Sonan, *Diachasmimorpha longicaudata* (Ashmead) (Braconidae), *Aceratoneuromyia indica* (Silvestri) (Eulophidae) and *Pachycrepoideus vindemiae* (Rondani) (Pteromalidae), which were introduced and released in the early 1960s (Ovruski, Aluja, Sivinski, & Wharton, 2000). Mass releases of the Indo-Pacific species *D. longicaudata*, a larval-prepupal endoparasitoid of several pestiferous fruit flies (Vargas et al., 2002), were recently performed on commercial fig crops in rural areas of San Juan (south-western Argentina) as part of an integrated *C. capitata* management programme on an area-wide basis (Ovruski & Schliserman, 2012). However, the integrated management of *A. fraterculus* in Argentina's northwestern citrus-growing areas might include the implementation of augmentative releases of native parasitoids (Aluja & Rull, 2009) as well as their conservation (Jonsson, Wratten, Landis, & Gurr, 2008).

Knowledge of the basic biology and ecology of native *Anastrepha* parasitoids is critical during the selection of a candidate for augmentative release programmes in particular environmental conditions and with unique host-densities (Sivinski, Piñero, & Aluja, 2000). Among the factors important to the selection of biological control agents are interactions within local parasitoid guilds (Sivinski, Aluja, & López, 1997), the type of host fruit attacked by the pest (Sivinski, Vulinec, & Aluja, 2001), the ability of the parasitoid to respond to varying densities of the host fly (García-Medel, Sivinski, Díaz-Fleischer, Ramirez-Romero, & Aluja, 2007), the parasitoid demographic parameters and the feasibility of mass-rearing (Aluja et al. 2009). The use of native parasitoids in a biological control programme provides substantial benefits by avoiding costly trips abroad in search of exotic species, importation and quarantine protocols, and potential non-target effects on local fauna (Gates et al., 2002).

Opius bellus Gahan is a wide-spread neotropical parasitoid. It is a solitary larval-prepupal endoparasitic koinobiont (Ovruski et al., 2000), that has one of the shortest ovipositors of any native *Anastrepha* opiine parasitoids (Aguiar-Menezes & Menezes, 2001; Ovruski, Schliserman, & Aluja, 2004). It attacks 13 species of *Anastrepha* and *C. capitata* and has been recovered in 26 host plant species from Mexico (Hernández-Ortiz, González, Escalante-Tio, & Manrique-Saide, 2006), Panama (Medianero, Korytkowski, Campo, & de León, 2006), Trinidad (Wharton & Marsh, 1978), Venezuela (Katiyar, Camacho, Geraud, & Matheus, 1995), Brazil (Aguiar-Menezes & Menezes, 2001; Uchôa-Fernandez et al., 2003; De Jesús et al., 2008), Bolivia (Ovruski et al., 2009) and Argentina (Ovruski & Schliserman, 2012). However, '*O. bellus*' probably represents a group of cryptic species that are very difficult to distinguish morphologically. Future genetic analyses and/or crossing experiments will be needed to establish differences (Wharton, 1997; Canal & Zucchi, 2000).

Since many vegetative environments are rapidly disappearing in the highly endangered subtropical forest of Northwestern Argentina, there is an urgent need to find and preserve native parasitoid species associated with *A. fraterculus*. Consequently, Argentinean populations of *O. bellus* were colonised in the laboratory for the first time. The aim of the current study was to describe the demographic parameters of *O. bellus* and identify optimal host-exposure regimens for rearing. Laboratory assays were conducted using a wild *O. bellus* strain colonised on *A. fraterculus* to determine: (1) the best host larval age, (2) the best ratio of host larvae to female parasitoids, (3) the best exposure time to achieve the greatest parasitoid yield with the highest female-biased progeny ratio, (4) daily survival and fecundity of females, (5) daily parasitism and adult emergence rates and (6) reproductive parameters. These findings ultimately reflect on the suitability of *O. bellus* for augmentative release.

Materials and methods

Source of insects and laboratory colonisation procedures

The laboratory colony of *O. bellus* was started in the insectary of the PROIMI, Biological Control Division, Tucumán, Argentina, between March and April 2006 with insects obtained from ripe guavas collected within wild vegetation patches in Horco Molle, Tucumán. This parental colony was initiated by holding 38 female and 45 male *O. bellus* that emerged from approximately 5,000 puparia of wild *A. fraterculus* in cubical plexiglass cages (30 cm), covered with organdy cloth on two opposite sides, provided with water and honey every other day. The colony was kept in a room at 25 ± 1°C, 75 ± 5% relative humidity (RH) and a 12:12-h (L:D) photoperiod. A separate room, maintained at 26 ± 1°C, 65 ± 10% RH and a 12:12-h (L:D) photoperiod, was used to rear *A. fraterculus*.

The initial step in the colonisation process was to simulate a naturally infested fruit. Roughly 500 third-instar *A. fraterculus* larvae (8–11 d-old) were removed from an artificial diet and placed naked (without a diet) inside either a hollow uninfested 'feral' guava or a commercially grown peach fruit. The procedure for filling fruit with larvae was as described by Aluja et al. 2009. Inoculated fruits were then individually placed within the plexiglass rearing cage, and exposed to the parental generation of *O. bellus* for 24 h. Infested fruits were exposed daily to parasitoids over their entire adult lifespan. After the exposure period, each infested fruit was placed in a plastic container (500 ml) with sterilised vermiculite on the bottom as a pupation substrate and covered with a piece of organdy cloth on the top. Pupae obtained from individual fruit were sifted from the pupation medium and kept in plastic cups, with new sterilised moist vermiculite until all of the flies and parasitoids emerged.

Once the parasitoids had reproduced for two generations using the artificially infested fruit method, the second step in the *O. bellus* colonisation process was to adapt adult females to a non-natural parasitisation substrate. For that, an artificial oviposition unit consisting of a plastic ring (9.8 cm, 1 cm) covered with a 13-cm piece of organdy was built. On the cloth surface, ca. 500 *A. fraterculus* third-instar larvae were placed mixed with either guava or peach pulp. Fruit pulp was used because the fruit aroma attracts parasitoid females to the artificial oviposition devices (Eitam, Holler, Sivinski, & Aluja, 2003). The cloth, containing the larvae and fruit pulp, was then covered tightly with another 13-cm piece of organdy attached to the first ring by

another plastic ring (10 cm, 1 cm) by pressing the cloth against the smaller ring. After this, several slices of either guava or peach epicarp (ca. 1 mm in thickness) were placed on top of the organdy cover (Aluja et al. 2009). The artificial oviposition unit was then elevated by placing it onto an inverted plastic device (3 cm diameter, 4 cm height) to place it closer to the centre of the parasitoid rearing cage. After 24 h of exposure to parasitoids, host larvae were removed from the fruit pulp and transferred to plastic cups with sterilised and moistened vermiculite as a pupation substrate. Adult flies and parasitoids were allowed to emerge inside these cups. Emerged parasitoids were then transferred to a new Plexiglas rearing cage.

The rearing technique described above was used for three parasitoid generations, and a variant of this method was employed during the third step of the *O. bellus* colonisation procedure. The artificial parasitisation unit was the same as described above, except that for this set-up the host larvae were exposed without fruit pulp, although either guava or peach skin layers were still held on top of the organdy cloth cover. After the *O. bellus* colony had gone through six generations of lab rearing, the fruit skin pieces were also eliminated from the top of oviposition unit. During this fourth step of the *O. bellus* colonisation process, the oviposition unit was filled with ca. 500 *A. fraterculus* third-instar larvae and artificial diet (brewer yeast, wheat germ, sugar, agar and water). The oviposition unit was exposed to 100 parasitoid females for 8 h inside a rearing cage. When the *O. bellus* colony reached 13 generations, the host larvae exposure time was changed to 6 h. All of the *O. bellus* colonisation phases and experiments described below were performed under similar previously described environmental conditions.

Optimal host larval age for parasitisation

Five age ranges of *A. fraterculus* larvae were analysed to determine the optimal larval age to expose the host to parasitoids for oviposition: 1–3 d-old (first instars = L_1), 4–6 d-old (second instars = L_2), 7–8 d-old (early third-instars = L_{3E}), 9–10 d-old (middle third-instars = L_{3M}), and 11–12 d-old (late third-instars = L_{3L}). *Anastrepha fraterculus* larval instars were determined based on the size and shape of the cephalopharyngeal skeleton under a stereomicroscope, as described by Frias, Selivon, & Hernández-Ortiz (2008). For each age range, 75 laboratory-reared larvae, mixed with the diet on which they had been reared, were exposed to 15 mated *O. bellus* females for 24 h inside an oviposition unit placed on the floor of a cubical plexiglass cage (15 cm). Parasitoid females were 10 d-old, with no prior oviposition experience, and from a colony that was 14 generations old. Additional preliminary tests indicated that *O. bellus* females aged 10–12 d yielded the highest parasitoid emergence rate (Laura Patricia Bezdjian, unpub. data). After exposure to parasitoids, most of the larvae were transferred into plastic trays (100 ml) filled with a fresh diet medium. These trays were then placed inside a cubical plastic container (25 cm) with a 2-cm layer of vermiculite on the bottom and covered with organdy. Every seven days, puparia were sifted from the pupation medium and held in plastic cups (8 cm diameter, 5 cm height) with fresh, moist vermiculite until eclosion. The 11–12 d-old larvae were directly transferred to vermiculite inside plastic cups. The number of dead host larvae and the number of recovered puparia were recorded for all of the age ranges. At the time of eclosion, the number and sex of parasitoid progeny and the number of non-eclosed puparia were also recorded. Control tests

(host larvae not exposed to parasitoids) were conducted for each larval age range to determine the natural *A. fraterculus* mortality rate. Each test (including each control) was replicated 10 times. Prior to the beginning of each replicate, the quality of the *A. fraterculus* larvae was assessed. All the batches of host larvae with fly emergence percentages < 90% were discarded and were not used in the experiments.

Optimal exposure time and ratio of hosts to parasitoids

To determine the optimal proportion of *A. fraterculus* larvae per *O. bellus* female and optimal amount of time to expose host larvae to parasitoids for rearing, five host:parasitoid ratios were individually analysed: 2:1, 4:1, 6:1, 8:1 and 10:1. Five mated, 10 d-old *O. bellus* females that had prior oviposition experience, and from a colony that was 14 generations old were used for each host:parasitoid ratio treatment. Each oviposition unit was filled with 7–9 d-old host larvae plus fresh larval diet. Hosts at each density were exposed to parasitoid females in a separate cubical Plexiglas cages (20 cm) for 1, 2, 3, 4 and 5 h. After exposure to parasitoids, larvae were transferred into plastic trays and processed as described above. After 2 d, dead larvae were removed from trays and counted. Also, pupae were removed from the pupation medium on a daily basis.

Basic biological and demographic parameters

To determine the demographic parameters of *O. bellus*, four groups, with five pairs of newly emerged (<24 h old) adult parasitoids in each group, were placed individually in cubical plexiglass cages (20 cm) and provided daily with ca. A total of 100 laboratory-reared 7–9 d-old *A. fraterculus* larvae inside an oviposition unit placed on the floor of the cage. Water and honey were provided to the parasitoids every other day. After a 4-h exposure to parasitoid females, host larvae were removed and placed into plastic cups (8 cm diameter, 5 cm height) with sterilised vermiculite. Pupae were held in these cups for five weeks to allow for adult emergence. Emerged adult flies and parasitoids were taken out of each cup every day, counted and sexed. The remaining non-eclosed puparia were dissected to check for the presence of parasitoid cadavers. Wasp's mortality was recorded and the dead wasps were removed from each test cage on daily basis. The assay was continued until all of the parasitoids died. The basic biological parameters, such as the pre-oviposition and oviposition periods, adult lifespan, development time (from egg to adult), offspring sex ratios (measured as the female proportion), and daily parasitism and emergence rates, were determined for the *O. bellus* cohort. Furthermore, standard life table parameters (Carey, 1993) were determined from the daily records of mortality and birth (Vargas et al., 2002). The daily proportion of surviving parental females (l_x) and the daily female offspring produced per female (m_x) were estimated and illustrated. From the life table, the following demographic parameters were calculated according to formulae used by Carey (1993): gross fecundity rate, net fecundity rate, gross reproductive rate, net reproductive rate, intrinsic rate of increase, finite rate of increase and mean generation time.

Data analysis

Parasitism was estimated as the total number of emerged and non-emerged parasitoids divided by the total number of obtained pupae and multiplied by 100, whereas parasitoid emergence was calculated as the total number of emerged offspring divided by the total number of recovered pupae and multiplied by 100. Host mortality was estimated as the total number of dead larvae plus the total number of puparia that did not yield insects divided by the total number of exposed host larvae and multiplied by 100. The data regarding parasitoid emergence, parasitoid female offspring proportion (sex ratio) and host mortality were compared through univariate General Linear Models (GLM), with a significance threshold of $P = 0.05$ (Zar, 1999). Mean comparisons were analysed by Tukey's honesty significant difference (HSD) test at $P = 0.05$. Host mortality recorded from each host larval age trial was compared with its respective control through a *t*-test at $P = 0.05$. All of the proportional data were arcsine square root-transformed prior to analysis. Only the untransformed means (± SE) are presented in the text.

Results

A significant effect of host larval development stage on each response variable was found ($F_{(4,15)} = 42.843$, $P < 0.0001$ for parasitoid emergence; $F_{(4,15)} = 26.782$, $P < 0.0001$ for sex ratio; $F_{(4,15)} = 10.684$, $P < 0.0001$ for host mortality). Third-instar larvae were most parasitised and produced a higher percentage of emerged *O. bellus* and female offspring than those of the first and second instars (Figure 1). L_{3E} and

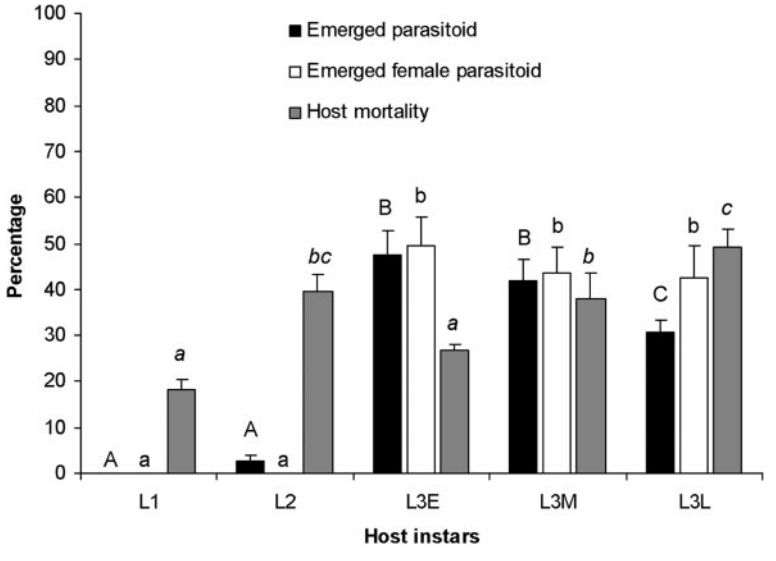

Figure 1. Influence of *A. fraterculus* instars on the percentages (mean ± SE) of emerged *O. bellus* adults, parasitoid female offspring (sex ratio), and host larval and pupal mortality recorded in optimal host larval-age tests. Bars followed by the same letter indicate no significant differences (Tukey HSD test, $P = 0.05$). Notations: L_1, first instars; L_2, second instars; L_{3E}, early third-instars; L_{3M}, middle third-instars; L_{3L}, late third-instars.

L_{3M} had the highest adult emergence values, while both larval instars and L_{3L} yielded statistically similar sex ratios (Figure 1). Among the third-instar larvae, the lowest host mortality percentage was recorded on L_{3E}, but was comparable to that recorded from L_1 (Figure 1). Host mortality recorded from L_1, L_2, L_{3E}, L_{3M} and L_{3L} was 2.5-, 3.9-, 4.9-, 4.2- and 7.1-fold significantly higher than mortality recorded from their respective controls ($t = 6.01$, $t = 9.42$, $t = 10.7$, $t = 5.83$, $t = 11.4$ for L_1, L_2, L_{3E}, L_{3M} and L_{3L} respectively; $df = 18$ and $P < 0.0001$ for all five host age classes)

Both exposure time and ratio of hosts to parasitoids and their interaction had a significant effect on parasitoid emergence and host mortality, but not on the sex ratio of parasitoid (Table 1). Parasitoid emergence significantly increased at 4:1, 6:1, 8:1 and 10:1 host:parasitoid ratios (Figure 2) and over the longer host larvae exposure times (4 and 5 h) (Figure 3). Percentage of parasitoid female offspring was significantly similar among all treatments and was generally male-biased. Only at 4:1 host:parasitoid ratio (Figure 2) and at 4 h exposure time (Figure 3), did *O. bellus* exhibit a relatively female-biased sex ratio (1.04:1 females/male). Host mortality was lower at a 2:1 host:parasitoid ratio (Figure 2) and over the shorter host exposure times (1–3 h) (Figure 3).

The pre-imaginal development times for male and female *O. bellus* were 20.1 ± 1.4 (mean ± standard error) and 21.6 ± 0.2 days at 25°C, respectively. A short pre-oviposition period (2.0 ± 0.6 days) was observed for mated females, which produced eggs for 29.5 ± 1.4 days on average. The mean female longevity was 30.3 ± 2.4 days, whereas the mean male longevity was 27.4 ± 1.4 days. At 32 days of age, 50% of the females were still alive, but at 60 d-old, less than 10% of the females remained alive (Figure 4). The daily production of female offspring per parental female increased until day 23 of the female reproductive life (2.3 ± 0.4 daughters per female) and decreased thereafter (Figure 4).

The lifetime production of offspring (males plus females) of an average parent female was 20.7 ± 4.2, and the mean sex ratio (proportion of females) of the progeny was 58.0 ± 0.3. The net fecundity rate was 16.1 ± 6.7 offspring per newborn female. The mean number of female offspring produced by a single female during her

Table 1. Summary of univariate GLMs on the effect of host exposure time, ratio of hosts to parasitoids, and interactions of these categorical factors on parasitoid emergence, parasitoid progeny sex ratio, and host mortality.

			Response variables					
			Parasitoid emergence		Parasitoid offspring sex ratio		Host mortality	
Source of variation	*df*	Error *df*	*F*	*P*	*F*	*P*	*F*	*P*
Host/parasitoid ratio (HPR)	4	100	9.92	< 0.0001[a]	0.38	= 0.8186	15.25	< 0.0001[a]
Host exposure time (HET)	4	100	91.54	< 0.0001[a]	0.96	= 0.4319	2.76	= 0.0319[a]
HPR × HET	16	100	2.10	= 0.0137[a]	0.63	= 0.8454	4.40	< 0.0001[a]

[a]Significant variables.

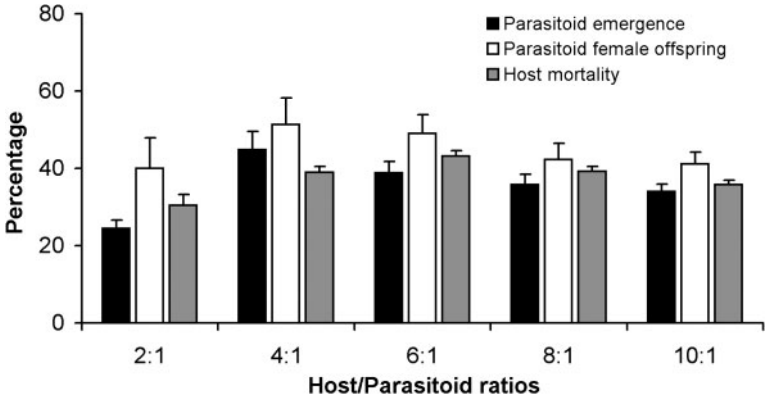

Figure 2. Mean (± SE) percentage of *O. bellus* emergence, sex ratio of parasitoid offspring (per cent females), and host mortality (percentage of dead host larvae plus non-eclosed host pupae) recorded from *A. fraterculus* at different host:parasitoid ratios. Bars followed by the same letter indicate no significant differences (Tukey HSD test, $P = 0.05$).

lifetime was 12.0 ± 2.9. The net reproductive rate was 9.6 ± 2.5 females per newborn female, and the mean generation time was 8.4 ± 0.2 days. The intrinsic rate of increase was 0.06 ± 0.01 female/female per day, and the increase in finite rate was 1.06 ± 0.01 per day.

Mean daily parasitism was lower than 1% when females were 0–3 d-old, but gradually increased until the females were 4–5 d-old, then ranged between 10 and 15% until the females were 22–23 d-old and decreased thereafter (Figure 5). The cumulative lifetime number of larvae parasitised per female was 27.9 ± 0.6, whereas

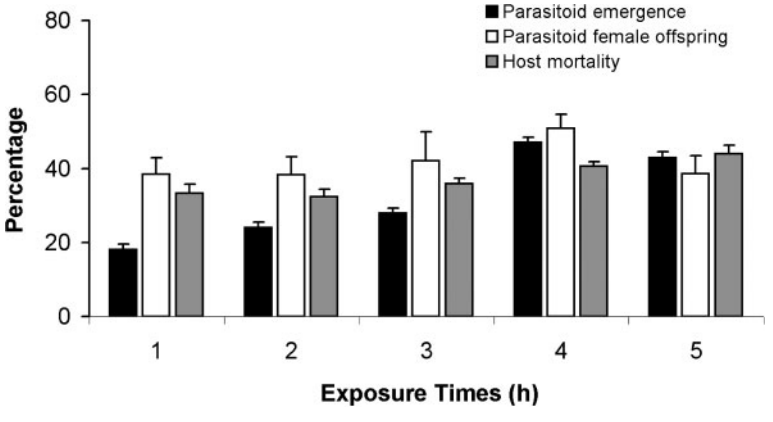

Figure 3. Mean (± SE) percentage of *O. bellus* emergence, sex ratio of parasitoid offspring (per cent females) and host mortality (percentage of dead host larvae plus non-eclosed host pupae) recorded from *A. fraterculus* at different host exposure times to parasitoid females. Bars followed by the same letter indicate no significant differences (Tukey HSD test, $P = 0.05$).

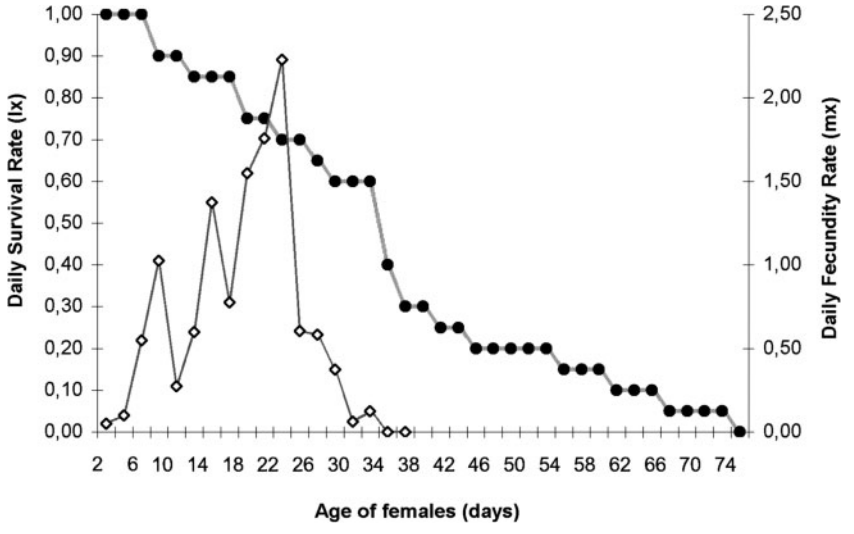

Figure 4. Daily survival (l_x) (black circle) and daily female offspring produced per female (m_x) (white circle) of *O. bellus* (14 generations old) reared on 7- to 9-d-old (early and middle third-instars) *A. fraterculus* larvae.

each day, 4.6 ± 0.1 larvae were parasitised by a female. Per cent offspring emergence was highest among the 20 and 24 d-old females and decreased for older females (Figure 5). The mean daily rate of emerged adults was 2.7 ± 1.1.

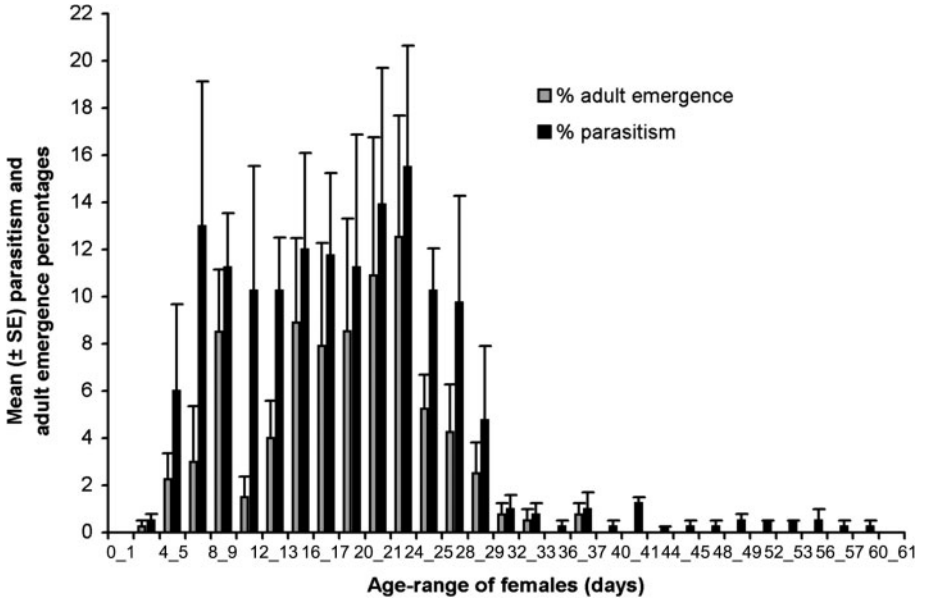

Figure 5. Mean (± SD) parasitism and emergence percentages of an age range of *O. bellus* females (14 generations old) reared on 7–9 d-old (early and middle third-instars) *A. fraterculus* larvae.

Discussion

Suitable host age and high host quality, as well as adequate handling procedures in fruit fly prepupal-larval parasitoid rearing are needed to achieve efficient adult production (Wong & Ramadan, 1992). Both host exposure time and ratio of host larvae to parasitoids, correlated with the parental female age (Ramadan, Wong, & Beardsley, 1989) are particularly useful for this purpose. Thus, both parasitoid emergence and progeny sex ratio significantly influence the success rate of the parasitoid rearing process (Aluja et al. 2009; Cancino, Ruiz, Sivinski, Gálvez, & Aluja, 2009). In this regard, 7–9 d-old (early and middle third-instars) *A. fraterculus* larvae at a low ratio (4:1) of host to parasitoid, were exposed to 10 d-old *O. bellus* females for a relatively long time (4 h); this array of factors was sufficient to achieve the highest average adult emergence (48%) and an offspring sex ratio at equitable proportion. Neither increasing host:parasitoid ratio over 4:1 nor exposing the host to a time beyond 4 h significantly enhanced overall parasitoid female offspring yield.

Overall, the biological parameter values estimated for *O. bellus* are within the general range of data recorded for other neotropical opiine fruit fly parasitoid species by Aluja et al. 2009 (Table 2). However, *O. bellus* exhibited various interesting

Table 2. Handling procedures for rearing four neotropical *Anastrepha* larval-prepupal opiine parasitoid species and summary of their biological parameters described by Aluja et al. 2009.

Rearing handling procedures	Parasitoid species			
Biological parameters	*Doryctobracon areolatus*[a]	*Doryctobracon crawfordi*[b]	*Utetes anastrephae*[c]	*Opius hirtus*[a]
N° parasitoid females per experimental cage	30	30	40	40
Host exposure periods (h)	36	7–36	7–48	7–36
Exposed hosts per parasitoid female	1.8–8.3:1	1.8–19:1	1.4–6.4:1	1.4–6.4:1
Parasitoid emergence (%)	11–24	21–37	20–26	14–25
offspring sex ratio (female: male)	0.8–1.2:1	1.3–1.5:1	0.8–1.4:1	0.8–1.3:1
GFR (gross fecundity rate, offspring/parent female)	6.61 ± 1.75	29.15 ± 8.30	2.87 ± 0.40	6.27 ± 2.04
NFR (net fecundity rate, offspring/newborn female)	2.19 ± 0.41	10.68 ± 1.40	2.64 ± 0.34	2.14 ± 0.37
Ro (net reproductive rate, female offspring/newborn female)	1.39 ± 0.16	5.36 ± 0.66	1.34 ± 0.20	1.27 ± 0.13
r (intrinsic rate of increase, day)	0.03 ± 0.01	0.24 ± 0.04	0.07 ± 0.04	0.03 ± 0.01
λ (finite rate of increase, per day)	1.04 ± 0.01	1.27 ± 0.05	1.08 ± 0.04	1.03 ± 0.01
T (mean generation time, days)	8.65 ± 0.87	7.69 ± 1.44	3.08 ± 0.39	8.46 ± 0.68

The host, the rearing experimental conditions and the generation were: [a]*Anastrepha ludens*, T°: 25 ± 1°C, RH: 70 ± 5%, and F_{14}; [b]*A. ludens*, T°: 23 ± 2°C, RH: 70 ± 5% and F_{14}; [c]*A. ludens*, T°: 25 ± 1°C, RH: 70 ± 5% and F_9.

attributes. For example: (1) average parasitoid emergence rate was clearly 1.5- to 4-fold higher than values shown in Table 2; (2) female longevity was almost 3-fold higher than that of *Doryctobracon crawfordi* (Viereck), *D. areolatus* (Szépligeti), *Utetes anastrephae* (Viereck) and *Opius hirtus* (Fischer) (Braconidae, Opiinae) and (3) the net reproductive rate value was notably 2- to 7-fold higher than those recorded for all four native opiine species in Table 2, the intrinsic rate of increase value was 2-fold higher than that of *D. areolatus* and *O. hirtus*, and the mean generation time value was closer to those found for *D. crawfordi*, *D. areolatus* and *O. hirtus*, but it was about 3-fold higher than that recorded for *U. anastrephae*. In contrast, net reproductive rate, intrinsic rate of increase and mean generation time values recorded here for *O. bellus* were 2- to 5-fold lower than those described by Vargas et al. (2002) and Viscarret, La Rossa, Segura, Ovruski, and Cladera (2006) for the exotic opiine *D. longicaudata* reared on *Bactrocera dorsalis* (Hendel) and on *C. capitata*, respectively. However, ovipositing *O. bellus* females had a mean longevity comparable to that reported by Vargas et al. (2002), Viscarret et al. (2006), and González, Montoya, Pérez-Lachaud, Cancino, and Liedo (2007) for *D. longicaudata*. Rearing procedures and handling conditions, such as parasitoid female/cage density, host exposure period and host:parasitoid ratio, host species used for rearing (Cancino & Montoya, 2004) or a different adaptability to laboratory conditions for each parasitoid species (Eitam et al., 2003) could explain differences in parameter values. However, the three findings highlighted above for *O. bellus*, added to the relatively fast adaptation of this native parasitoid species to laboratory conditions, and are particularly important; they indicate that their rearing might increase at a greater rate thereby facilitating parasitoid production. Similar observations were also reported by Aluja et al. 2009 for *D. crawfordi*, whose mass-rearing has already taken place successfully in the fruit fly and parasitoid facility of the Medfly-Moscafrut programme in Metapa de Domínguez, Chiapas, Mexico (Cancino et al., 2009).

The results of the present study provide, for the first time, information on the performance of *O. bellus* reared on *A. fraterculus* larvae under laboratory conditions. These results may be used to develop a more efficient rearing method for this neotropical opine species for biological control purposes in Argentina; however, understanding all the factors that influence both offspring production and offspring sex ratio is critical for successful parasitoid rearing. Therefore, additional studies in the laboratory, focusing on factors that influence offspring sex ratios (Heimpel & Lundgren, 2000; Montoya, Cancino, Pérez-Lachaud, & Liedo, 2011), may be needed to achieve cost-effective production in the *O. bellus* rearing process. Nevertheless, the long lifespan and the reproductive parameter values estimated here suggest that this parasitoid species has suitable attributes for mass-rearing and augmentative releases. Finally, the biological information provided here can be used to pursue comparative studies of native parasitoid reproduction and its relationship to environment and host-range.

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