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Co-evolutionary Dynamics and Life Table Analysis of *Acerophagus papayae* in Response to Papaya Mealybug *Paracoccus marginatus*

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ABSTRACT

Background: The life cycle of the parasitoid *Acerophagus papayae* Noyes and Schauff is being documented in this work, which is essential for its successful application in integrated pest management initiatives.

Methods: Papaya mealybug *Paracoccus marginatus* Granara de Willink Williams, which were taken from different host plants, were used to assess the life cycle. The development of the parasitoid differed based on the mealybug's host plant, according to the results.

Result: The physiology and behavior of *P. marginatus* were altered by the host, which had an indirect effect on *A. papayae* performance. According to an investigation of age-specific life tables, the parasitoid's net reproductive rate (NRR) was lowest on tapioca (282.53), greatest on papaya (559.48 females/female) and lowest on cotton (498.28). These reproductive rates mirrored those of the mealybug across host plants. Development time was shorter and progeny output was higher on papaya and cotton, while the reverse was true for tapioca and hibiscus. The capacity for increase (rc) was highest in papaya (0.512) and lowest in tapioca (0.324). Similarly, the intrinsic rate of increase (rm) followed the same trend, with a maximum of 0.570/day in papaya and a minimum of 0.342/day in tapioca. These findings highlight how host plants influence the parasitoid's biology and offer valuable insights for enhancing mealybug control strategies.

Key words: *Acerophagus papayae*, Biological control, Host plant influence, Life cycle, *Paracoccus marginatus*.

INTRODUCTION

A useful ecological tool for recording stage-specific death and survival in a population is a life table. It describes the number of fatalities, survivors, mortality rates and life expectancy over a series of age intervals (Sethi *et al*., 2024). In entomology, where insects progress through distinct developmental stages with varying mortality rates, life tables provide critical insight into population dynamics. They help identify the stages with the highest mortality, enabling timely pest management strategies. Life tables are also instrumental in predicting the lifespan of beneficial insects, contributing to the design of effective biological control programs (Chen *et al*., 2025).

The Encyrtid parasitoid *Acerophagus papayae* Noyes and Schauff has been proven effective against papaya mealybug infestations. Studies have shown that the development and biological performance of *A. papayae* vary depending on the developmental stage of *Paracoccus marginatus* on different host plants. This close association underscores the influence of host plant-mediated changes on parasitoid efficiency. Since the host may develop defenses to ward off parasitism and a parasitoid's capacity to survive depends on the host's suitability, this interaction might be characterized as a co-evolutionary "arms race" (Dalton and Fuglie, 2022).

Parasitoids often encounter multiple host types within a habitat, not all equally suitable. Many species possess the ability to discriminate and selectively avoid hosts that offer lower fitness returns (Kruitwagen *et al*., 2022). Life fecundity tables are commonly used to quantify survival and reproductive parameters such as net reproductive rate and intrinsic rate of increase in insect populations (Pardeshi *et al*., 2011). The present study reports, for the first time, the complete life cycle of *A. papayae*, demonstrating that its development changes in accordance with the life cycle of its host, *P. marginatus*, on various host plants. Understanding these dynamics through life table analysis is crucial for identifying mortality patterns and determining key factors influencing parasitoid success in biological control programs (Seni and Chongtham, 2013).

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Materials and Methods

The study was carried out at the Entomology Laboratory, Department of Entomology at SRM College of Agricultural Sciences in Chengalpattu, Tamil Nadu, India, between 2024 and 2025.

Mass culturing of *Paracoccus marginatus*

In accordance with Serrano and Laponite (2002) methodology, mealybugs were raised using potato sprouts as an alternate food source. A camel hair brush was used to transfer papaya mealybugs which were gathered from papaya, tapioca, cotton, mulberry, brinjal and hibiscus at a rate of three to five ovisacs per potato onto potato sprouts. Within 25-30 days, mass multiplication of mealybugs was achieved. Their net reproductive rates on different host plants were also recorded and used for culturing *Acerophagus papayae*.

Mass culturing of *Acerophagus papayae*

Potato sprouts and infested host leaves bearing mealybugs were placed in 45 × 45 × 45 cm oviposition cages. Ten *A. papayae* adults were introduced for parasitism. After 10 days, mummified mealybugs were carefully removed with scissors and stored in containers. Emerged parasitoids were collected using an aspirator and evaluated for life history traits (Amarasekare, 2007). Life tables provide insights into the survival and mortality trends within a population (Ambethgar *et al*., 2025). The detail key statistics such as the number of individuals surviving, dying and the expected lifespan at various age intervals, based on age-specific mortality rates (Dublin and Lotka, 1937).

A life table offers comprehensive data regarding an organism's survival and mortality at various life phases. From birth to death, each parasitoid age is shown in the first column. The second column, represented by the symbol l_x, shows the number of insects who survive at each age, starting at birth and falling as parasitoid age because of mortality. The survival fraction (l_x), which is determined by dividing the number of survivors in the current stage by the number in the subsequent stage, is displayed in the third column. The death probability (m_x), which represents the chance of passing away during that stage, is provided in the fourth column for each age period.

The average number of female offspring per female and the total number of females produced are shown in the fifth and sixth columns, respectively. Life expectancy, which is found in column nine, is calculated using columns seven and eight. The average number of people living at each age is shown in this column, which can be seen as the total number of days spent in that stage of life. Column eight is calculated by summing the values in column seven from the bottom upward. Life expectancy is then derived by dividing column eight by the corresponding l_x values in column two. Columns ten r_m and eleven e^{-rmx} assist in calculating the column twelve $e^{-r_m}x\ l_x m_x$ (Maroufpoor and Moradi, 2022).

Construction of age and stage specific life table

By breaking down the life cycle into discrete developmental phases (*e.g*., eggs, larvae, pupae and adults) and evaluating survival, mortality and development time at each stage, insect life tables are created. Age-specific fertility is also documented for females. In accordance with established methodologies, key life table parameters were calculated, including survival fraction (Sx), survivorship (lx), survivorship curves, apparent mortality, mortality-survivor ratio, indispensable mortality, k-values, net reproductive rate, intrinsic and finite rates of increase, mean generation time and population doubling time (Kakde *et al*., 2014).

Results and Discussion

Acerophagus papayae life table data by age on *Paracoccus marginatus* for several host plants are shown in Table 1 to 7. According to the findings, adult parasitoids had the highest

Table 1: *Acerophagus papayae's* age-specific life table on *Paracoccus marginatus* from papaya.

x	n	l_x	m_x	$l_x m_x$	$x l_x m_x$	e^{-rc_x}	e^{-rc_x}. $l_x m_x$	$e^{-r}{}_{mx}$	r_m	e^{-rmx}	$e^{-r_m}x\ l_x m_x$
0	50	1	0								
1	48	0.960	0.000								
2	45	0.900	0.000	0.000	0.000	0.173	0.000			0.144	0.000
3	42	0.840	15.000	12.600	37.800	0.072	0.908	0.046	1.027	0.055	0.689
4	40	0.800	20.000	16.000	64.000	0.030	0.480	0.019	0.990	0.021	0.332
5	36	0.720	16.000	11.520	57.600	0.012	0.144	0.008	0.967	0.008	0.091
6	35	0.700	9.000	6.300	37.800	0.005	0.033	0.003	0.952	0.003	0.019
7	32	0.640	5.000	3.200	22.400	0.002	0.007	0.001	0.941	0.001	0.004
8	29	0.580	1.000	0.580	4.640	0.001	0.001	0.001	0.933	0.000	0.000
9	25	0.500	0.000	0.000	0.000	0.000	0.000			0.000	0.000
10	23	0.460	0.000	0.000	0.000	0.000	0.000			0.000	0.000
11	22	0.440	0.000	0.000	0.000	0.000	0.000			0.000	0.000
12	20	0.400	0.000	0.000	0.000	0.000	0.000			0.000	0.000
13	15	0.300	0.000	0.000	0.000	0.000	0.000			0.000	0.000
14	9	0.180	0.000	0.000	0.000	0.000	0.000			0.000	0.000
15	0	0.000	0.000	0.000	0.000	0.000	0.000			0.000	0.000
Total				50.20	224.24		1.57				1.14

lifespan on papaya 14 days while tapioca and hibiscus had the shortest (7 days). In papaya, reproduction began on the 3rd day and continued until the 7th day, producing a total of 15 females per female. A similar reproductive pattern was noted on cotton, potato sprouts and brinjal. Females lived 10 days on brinjal and 11 days on cotton, potato

Table 2: *Acerophagus papayae's* age-specific life table on cotton-derived *Paracoccus marginatus.*

x	n	l_x	m_x	l_xm_x	xl_xm_x	$e\text{-}^{rc}{}_x$	$e\text{-}^{rc}{}_x.\ l_xm_x$	$e^{-r}{}_{mx}$	r_m	e^{-rmx}	$e^{-r}{}_m x\ l_xm_x$
0	50	1	0								
1	45	0.9	0								
2	40	0.8	0	0.00	0.00	0.257	0.000			0.220	0.000
3	40	0.8	5	4.00	12.00	0.130	0.520	0.089	0.808	0.103	0.412
4	36	0.72	8	5.76	23.04	0.066	0.379	0.045	0.776	0.048	0.278
5	30	0.6	15	9.00	45.00	0.033	0.300	0.023	0.757	0.023	0.203
6	30	0.6	22	13.20	79.20	0.017	0.223	0.012	0.744	0.011	0.140
7	22	0.44	10	4.40	30.80	0.009	0.038	0.006	0.735	0.005	0.022
8	17	0.34	5	1.70	13.60	0.004	0.007	0.003	0.728	0.002	0.004
9	11	0.22	0	0.00	0.00	0.002	0.000			0.001	0.000
10	7	0.14	0	0.00	0.00	0.001	0.000			0.001	0.000
11	3	0.06	0	0.00	0.00	0.001	0.000			0.000	0.000
12	0	0	0	0.00	0.00	0.000	0.000			0.000	0.000
Total				38.06	203.64		1.47				1.06

Table 3: *Acerophagus papayae's* age-specific life table on *Paracoccus marginatus* from tapioca.

x	n	l_x	m_x	l_xm_x	xl_xm_x	$e\text{-}^{rc}{}_x$	$e\text{-}^{rc}{}_x.\ l_xm_x$	$e^{-r}{}_{mx}$	r_m	e^{-rmx}	$e^{-r}{}_m x\ l_xm_x$
0	50	1	0								
1	32	0.64	0								
2	26	0.52	0	0.00	0.00	0.330	0.000			0.318	0.000
3	20	0.4	0	0.00	0.00	0.190	0.000			0.179	0.000
4	20	0.4	15	6.00	24.00	0.109	0.653	0.099	0.579	0.101	0.607
5	14	0.28	20	5.60	28.00	0.063	0.350	0.057	0.574	0.057	0.319
6	8	0.16	15	2.40	14.40	0.036	0.086	0.033	0.571	0.032	0.077
7	2	0.04	15	0.60	4.20	0.021	0.012	0.019	0.568	0.018	0.011
8	2	0.04	0	0.00	0.00	0.012	0.000			0.010	0.000
9	1	0.02	0	0.00	0.00	0.007	0.000			0.006	0.000
10	0	0	0	0.00	0.00	0.004	0.000			0.003	0.000
Total				14.60	70.60		1.10				1.01

Table 4: *Acerophagus papayae's* age-specific life table on *Paracoccus marginatus* from mulberries.

x	n	l_x	m_x	l_xm_x	xl_xm_x	$e\text{-}^{rc}{}_x$	$e\text{-}^{rc}{}_x.\ l_xm_x$	$e^{-r}{}_{mx}$	r_m	e^{-rmx}	$e^{-r}{}_m x\ l_xm_x$
0	50	1	0								
1	40	0.8	0								
2	40	0.8	0	0.00	0.00	0.278	0.000			0.262	0.000
3	36	0.72	0	0.00	0.00	0.146	0.000			0.134	0.000
4	30	0.6	11	6.60	26.40	0.077	0.508	0.065	0.682	0.069	0.453
5	30	0.6	20	12.00	60.00	0.041	0.487	0.034	0.673	0.035	0.422
6	24	0.48	15	7.20	43.20	0.021	0.154	0.018	0.668	0.018	0.130
7	18	0.36	6	2.16	15.12	0.011	0.024	0.010	0.664	0.009	0.020
8	12	0.24	2	0.48	3.84	0.006	0.003	0.005	0.661	0.005	0.002
9	9	0.18	0	0.00	0.00	0.003	0.000			0.002	0.000
10	6	0.12	0	0.00	0.00	0.002	0.000			0.001	0.000
11	2	0.04	0	0.00	0.00	0.001	0.000			0.001	0.000
12	0	0	0	0.00	0.00	0.000	0.000			0.000	0.000
Total				28.44	148.56		1.18				1.03

sprouts and mulberry. Eleven number of female insects were born on day four and two on day eight on mulberry. Ovulation in tapioca and hibiscus was limited to four days. Maximum reproduction and extended lifespan were recorded on papaya, cotton and potato sprouts, while lower reproductive output and shorter lifespan were observed on brinjal, hibiscus and tapioca. The efficiency ranking was: papaya > cotton > potato sprouts > mulberry > brinjal > hibiscus > tapioca, aligning with mealybug development patterns (Wan, 2024).

A successful insect pest biological control program depends on synchronizing the life cycle of the parasitoid with that of its host (Ramos *et al*., 2023). This study is the first to compare the life cycles of *Acerophagus papayae* across mealybugs from various host plants. Life table parameters such as reproductive rate, generation time and population growth were recorded (Table 8). Variations in parasitoid development were influenced by the host plant through its effects on mealybug physiology and behavior. Such plant-mediated effects on parasitoids have been supported by earlier studies (Ricciardi *et al*., 2021).

Assessing natural enemies' potential for biological control requires evaluating their intrinsic rate of increase (r_m), which not only indicates their capacity for reproduction but also directs the choice of field release strategy, whether it be inoculative, seasonal inoculative, or inundative (Santana *et al*., 2025). The capacity for increase (rc) in the current study varied from 0.324 in tapioca to 0.512 in papaya, with cotton (0.474) and potato sprouts (0.427) following closely behind. The intrinsic rate of rise showed a similar pattern, with tapioca displaying the lowest value (0.342/day) and papaya the highest value (0.570/day). Doubling time was longest in tapioca (2.028 days) and shortest in papaya (1.216 days). Comparable methods were applied by Mashhadi (2009) for evaluating *Trichogramma* hosts. Various factors influence r_m, including host and parasitoid species, size, host plant, temperature, kairomones, sex ratio, adult nutrition and environmental conditions (Lu *et al*., 2024).

The present investigation revealed that *Acerophagus papayae* exhibited shorter developmental time and higher progeny output on papaya and cotton, whereas the opposite

Table 5: *Acerophagus papayae's* age-specific life table on *Paracoccus marginatus* from brinjal.

x	n	l_x	m_x	l_xm_x	xl_xm_x	$e^{-rc}{}_x$	$e^{-rc}{}_x.\ l_xm_x$	$e^{-r}{}_{mx}$	r_m	e^{-rmx}	$e^{-r}{}_m x\ l_xm_x$
0	50	1	0								
1	40	0.8	0								
2	34	0.68	0	0.00	0.00	0.29	0.00			0.25	0.00
3	30	0.6	5	3.00	9.00	0.15	0.46	0.11	0.73	0.13	0.38
4	22	0.44	15	6.60	26.40	0.08	0.54	0.06	0.71	0.06	0.41
5	15	0.3	20	6.00	30.00	0.04	0.26	0.03	0.69	0.03	0.19
6	10	0.2	18	3.60	21.60	0.02	0.08	0.02	0.68	0.02	0.06
7	10	0.2	14	2.80	19.60	0.01	0.03	0.01	0.67	0.01	0.02
8	7	0.14	9	1.26	10.08	0.01	0.01	0.00	0.67	0.00	0.00
9	4	0.08	0	0.00	0.00	0.00	0.00			0.00	0.00
10	1	0.02	0	0.00	0.00	0.00	0.00			0.00	0.00
11	0	0	0	0.00	0.00	0.00	0.00			0.00	0.00
Total				23.26	116.68		1.38				1.06

Table 6: *Acerophagus papayae's* age-specific life table on *Paracoccus marginatus* from hibiscus.

x	n	l_x	m_x	l_xm_x	xl_xm_x	$e^{-rc}{}_x$	$e^{-rc}{}_x.\ l_xm_x$	$e^{-r}{}_{mx}$	r_m	e^{-rmx}	$e^{-r}{}_m x\ l_xm_x$
0	50	1	0								
1	35	0.7	0								
2	30	0.6	0	0.00	0.00	0.30	0.00			0.28	0.00
3	28	0.56	0	0.00	0.00	0.16	0.00			0.15	0.00
4	25	0.5	15	7.50	30.00	0.09	0.66	0.08	0.64	0.08	0.60
5	17	0.34	23	7.82	39.10	0.05	0.38	0.04	0.63	0.04	0.34
6	13	0.26	11	2.86	17.16	0.03	0.07	0.02	0.63	0.02	0.07
7	9	0.18	6	1.08	7.56	0.01	0.02	0.01	0.62	0.01	0.01
8	6	0.12	0	0.00	0.00	0.01	0.00			0.01	0.00
9	2	0.04	0	0.00	0.00	0.00	0.00			0.00	0.00
10	0	0	0	0.00	0.00	0.00	0.00			0.00	0.00
Total				19.26	93.82		1.13				1.02

was observed in tapioca and hibiscus. These findings align with Smitha *et al*. (2023), who reported significantly reduced development time and increased fecundity in female *Trichogramma chilonis* when reared on *Corcyra cephalonica* eggs. Interestingly, *A. papayae* was identified as a gregarious endoparasitoid, producing one to three individuals per second instar mealybug. This contrasts with Meyerdirk *et al*. (2004), who described it as a solitary species, but supports the observations of Krishnamoorthy (2012), who found *T. bactrae* produced up to two individuals per host with nearly equal chances of single or dual emergence. Similarly, Ode *et al*. (2022) noted that *Laelius pedatus* females produce larger broods on bigger hosts.

The sex ratio of *A. papayae* progeny, measured as the proportion of females, was significantly influenced by both parasitoid density and host plant type. Lower female emergence was consistently observed in host plants that supported fewer parasitoids, regardless of the plant species. Ensuring an adequate supply of hosts is essential to maintaining a higher proportion of females, which corroborates findings by Stefanache *et al*. (2023), who reported a male-biased sex ratio under host-limited conditions for *T. chilonis*.

Parasite survival curve on mealybugs from various host crops

The survivorship pattern of *Acerophagus papayae* followed a Type III curve, showing high early-stage mortality that declined over time. Mortality was highest in tapioca, with 50% loss by 2.1 days, while papaya showed the same by the 9th day (Fig 1). Non-derivative methods were used to smoothen the curves, with parameters (a and b) listed in Table 9.

The age-specific life table analysis of *Acerophagus papayae* in the present study revealed that the net reproductive rate (R_o) was highest on papaya (559.48 females/female), followed by cotton (498.28), while tapioca recorded the lowest value (282.53). The effectiveness of a parasitoid is strongly influenced by the net fecundity of both the host and the parasitoid itself (Varshney *et al*., 2022). The observed variation in NRR among host plants corresponded with differences in the reproductive potential of *Paracoccus marginatus* across those hosts (Table 10).

Table 7: *Acerophagus papayae's* age-specific life table on *Paracoccus marginatus* from potato sprouts.

x	n	l_x	m_x	$l_x m_x$	$x l_x m_x$	e^{-rc_x}	$e^{-rc_x} \cdot l_x m_x$	$e^{-r_{mx}}$	r_m	e^{-rmx}	$e^{-r_m} x\ l_x m_x$
0	50	1	0								
1	45	0.9	0								
2	42	0.84	0	0.00	0.00	0.237	0.000			0.208	0.000
3	40	0.8	5	4.00	12.00	0.116	0.463	0.083	0.829	0.095	0.379
4	35	0.7	13	9.10	36.40	0.056	0.513	0.041	0.801	0.043	0.392
5	29	0.58	21	12.18	60.90	0.027	0.335	0.020	0.785	0.020	0.239
6	26	0.52	9	4.68	28.08	0.013	0.063	0.010	0.774	0.009	0.042
7	20	0.4	5	2.00	14.00	0.007	0.013	0.005	0.766	0.004	0.008
8	15	0.3	5	1.50	12.00	0.003	0.005	0.002	0.760	0.002	0.003
9	10	0.2	0	0.00	0.00	0.002	0.000			0.001	0.000
10	6	0.12	0	0.00	0.00	0.001	0.000			0.000	0.000
11	3	0.06	0	0.00	0.00	0.000	0.000			0.000	0.0002
12	0	0	0	0.00	0.00	0.000	0.000			0.000	0.000
Total				33.46	163.38		1.39				1.06

Table 8: *Paracoccus marginatus* life table criteria for several host plants.

Parameter	Papaya	Cotton	Tapioca	Mulberry	Brinjal	Hibiscus	Potato sprouts
Age of first oviposition (days)	3	3	4	4	3	4	3
Age of last oviposition (days)	8	8	7	8	8	7	8
Length of oviposition (days)	6	6	4	5	6	4	6
Net reproductive rate (R_0) (females/female)	50.20	38.06	14.60	28.44	23.26	19.26	33.46
Approx generation time (T_c) days	4.47	5.35	4.84	5.22	5.02	4.87	4.88
Capacity for increase (r_c)	0.88	0.68	0.55	0.64	0.63	0.61	0.72
Intrinsic rate of increase (r_m) per day	0.97	0.76	0.57	0.70	0.69	0.63	0.79
Mean generation time (T) (days)	4.04	4.80	4.68	5.00	4.54	4.70	4.47
Finite rate of increase (λ) per day	2.63	2.13	1.77	1.954	2.00	1.88	2.19
Doubling time (t) days	0.72	0.91	1.21	1.04	1.00	1.10	0.88

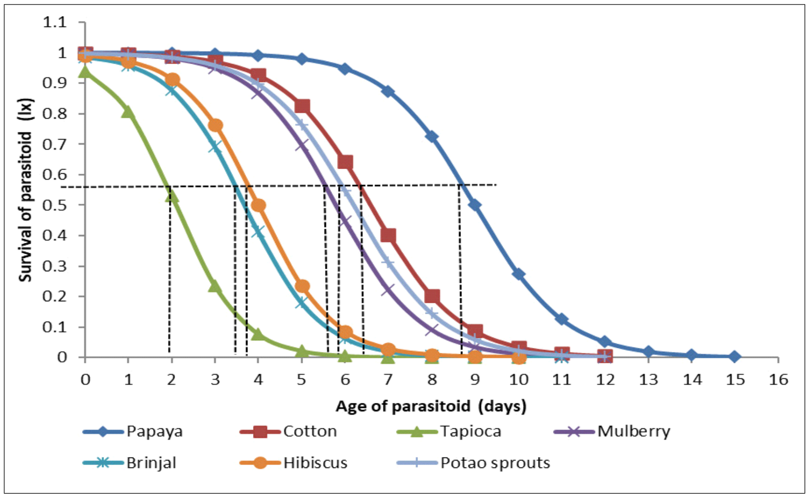

Fig 1: The *Acerophagus papayae* survival curve in relation to *Paracoccus marginatus* from several host plants.

Table 9: *Acerophagus papayae's* response to *Paracoccus marginatus* from various host plants in terms of survival.

Host plants	'a' (50% mortality)	'b' (Intercept)	r^2 value
Papaya	9	1.031	0.970
Cotton	6.6	1.02	0.986
Tapioca	2.1	0.767	0.933
Mulberry	5.8	0.954	0.986
Brinjal	3.7	0.859	0.939
Hibiscus	4	0.849	0.841
Potato sprouts	6.2	1.016	0.994

Table 10: *Acerophagus papayae* and *Paracoccus marginatus's* net reproduction rates on various host plants.

Host	Net reproductive rate (R_0) (females/female)	
	P. marginatus	*A. papayae*
Papaya	559.48	50.20
Cotton	498.28	38.06
Tapioca	282.53	14.60
Mulberry	404.76	28.44
Brinjal	362.26	23.26
Hibiscus	295.96	19.26
Potato sprouts	462.91	33.46

These results align with findings by Bernal and Gonzalez (1997), who reported NRR values of *Diaeretiella rapae* on *Diuraphis noxia* and *Myzus persicae* as 50.20 and 238.7, respectively. Similarly, Hosseini-Gharalari *et al*. (2003) recorded an NRR of 40.82 for *D. rapae* on *Brevicoryne brassicae*. Several factors influence parasitoid fecundity, including environmental conditions (temperature, photoperiod), adult female size and host quality (Tabebordbar *et al*., 2022). Other determinants such as female age, host species and parasitoid venom also impact reproductive success (Zhang *et al*., 2022). Murillo *et al*. (2012) confirmed that life table parameters of *Campoletis sonorensis* significantly differed depending on the host. Collectively, these findings highlight the importance of host-specific interactions in parasitoid efficacy.

To effectively decrease pest populations, a parasitoid must have an internal rate of growth (r_m) that is at least as high as or higher than that of its host (Lin and Ives, 2003). The parasitoid *Acerophagus papayae* and its host *Paracoccus marginatus* showed varying r_m values in the current investigation. These findings are supported by Murillo *et al*. (2012), who reported similar r_m values for *Campoletis sonorensis* and its host *Trichoplusia ni* when reared on soybean (0.135 and 0.132, respectively), with fluctuations observed on cabbage and sunflower. Similarly, Nozad-Bonab *et al*. (2021) demonstrated significant differences in *Trichogramma brassicae* population growth parameters when associated with pests on various crops.

Variations in life table and reproductive traits of *A. papayae* observed in this study compared to previous reports may result from differences in experimental conditions, or more likely, from genetic and physiological variability among parasitoid populations (Chuai *et al*., 2022). The host-driven development of both mealybug and parasitoid in this investigation provides valuable insight for managing *P. marginatus*. Future research should explore how plant biochemical profiles such as secondary metabolites, nutrients and volatiles influence parasitoid fitness, while also considering the local adaptation and host-specific trade-offs of *A. papayae*.

CONCLUSION

Life tables are vital tools for understanding insect population dynamics. They systematically record birth and death rates, offering insights into life expectancy and reproductive potential. These tables help identify critical periods of mortality within an insect's life cycle, which is particularly useful for targeting pest control efforts. In the context of beneficial insects like parasitoids, life tables allow researchers to determine stages with the highest mortality and evaluate their effectiveness in biological control programs. The current and previous studies indicated that the life cycle of parasitoids varies in response to the development stages of the papaya mealybug on different host plants. These host plants influence the physiology and behavior of mealybugs, which in turn affects the performance of the parasitoids. Understanding when a pest is most susceptible enables the development of timely and efficient pest management strategies. This includes the optimal timing for insecticide application, minimizing harm to natural enemies like predators and parasitoids and reducing environmental impact. Additionally, key factor analysis helps identify the major environmental elements driving population changes, aiding in the planning of targeted pest control interventions.

Conflict of interest

We wish to confrim that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

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