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Life cycle of the parasitoid *Acerophagus papayae* Noyes and Schauff on papaya mealybug *Paracoccus marginatus* Williams and Granara de Willink *vis-a-vis* local adaptation with co-evolutionary "Arms Race"

R Nisha and JS Kennedy

Abstract
The life cycle of the parasitoid *Acerophagus papayae* Noyes and Schauff was studied for first time, as it is very important for integrated pest management programme. The life cycle was studied on Papaya mealybug *Paracoccus marginatus* Williams and Granara de Willink from different host plants. The host plants induced changes in the behavior and physiology of mealybug that indirectly influenced the efficiency of parasitoids. While observing the age specific life table of the parasitoid, the net reproductive rate NRR of *A. papayae* was observed to be higher in papaya (559.48 females/female) and lower in tapioca (282.53 females/female). The net reproductive rate (NRR) of *A. papayae* was changed in accordance with NRR of *P. marginatus* Williams and Granara de Willink on different host plants. Intrinsic rate of increase (r_m) was maximum in papaya (0.570 increase per day) and minimum in tapioca (0.342/day). The host induced life cycle of parasitoid *A. papayae* and the information gathered from this study will be important in the management of this host papaya mealybug *P. marginatus*.

Keywords: Life cycle, life table, parasitoid, *Acerophagus papayae*, Papaya mealybug *Paracoccus marginatus*, local adaptation, co-evolutionary "arms race"

1. Introduction

A life table is a kind of book-keeping system that ecologists often used to keep track of stage specific mortality in the population they study [3]. A life describes for successive age intervals, the number of deaths, the survivors, the rate of mortality and the expectation of further life [25]. Life table provides an important tool in understanding the changes in population of insect pests during different developmental stages throughout their life cycle. Life expectancy of beneficial insects can be calculated and used for biological control program by predicting natural things in particular instar within which the maximum mortality of the pests is obtained and plan for managing pests in time. The Encyrtid parasitoid, *Acerophagus papaya* Noyes and Schauff effectively controlled papaya mealy bugs (Myrick *et al*., 2014) and the development and biology of this parasitoid was varied accordingly to the development of papaya mealybug on different host plants [38]. It is an especially useful approach in entomology, where developmental stages are discrete and mortality rates may vary widely from one life stage to another [14]. It is very useful to analyse the mortality of insect population, to determine key factors responsible for the highest mortality within population. Life table is an important analytical technique in studying distribution, determination of age and mortality of an organism and individuals can be calculated [25].

The intimate reaction between a parasitoid species and its host species may result in specific adaptations towards each other. Survival of the parasitoid depends on the suitability of the host, while survival of the host is warranted by developing unsuitability for parasitization. Such an adaptive interaction between insect parasitoids and their larval host can be characterized as "arms race". A parasitoid searching a patch for hosts is likely to encounter several host types that will not all represent the same profitability to the parasitoid. Many parasitoids are able to distinguish between various host types and reject the less suitable ones [54]. Hence, the present study was conducted to study the life cycle of parasitoid *Acerophagus papayae* and it reported for first time in the current study.

2. Materials and methods
The research work was carried out during the year 2013- 2014 in the Insectary of Department of Agricultural Entomology, Tamil Nadu Agricultural University, Coimbatore and Tamil Nadu, India.

2.1 Collection and mass culturing of *Paracoccus marginatus*
Potato sprouts was used as an alternate food source for rearing mealybugs. Mass culturing of potato sprouts (Fig. 1) was done in line with the reference of [45]. Papaya mealybugs collected from different host plants like papaya, tapioca, cotton, mulberry, brinjal and hibiscus were released on potato sprouts (Fig. 2) using camel hair brush at the rate of 3 to 5 ovisacs per potato and mealybugs *en masse* were obtained within 25 to 30 days of release. The net reproductive rate of PMB on different host plants was observed in this experiment. They were used for mass culturing of *A. papayae*. Mass culturing was also carried out in above said host plants and used for further experiments [3].

2.1.1 Mass culturing of parasitoid *Acerophagus papayae*
The sprouted potatoes and infested host leaves from the above experiment colonized with mealybugs were transferred to oviposition cages of 45 x 45 x 45 cm. Ten *A. papayae* adults were allowed inside the cage for parasitisation. After 10 days of release, the sprouts and leaves along with the mummified mealybugs were removed from the potatoes using a fine scissor and collected separately in the plastic containers. The emerged parasitoids were collected by an aspirator and observed for life history traits [2].

Fig 1: Mass culturing of papaya mealybug *Paracoccus marginatus*on potato sprouts

2.2 Description of life table statistics
Life table describes the mortality and survival patterns of a population. On the basis of mortality ratios for each age or age group, life tables provide information on parameters such as the number of survivors, the number of deaths and the life expectancy [16].

a) Papaya b) Cotton c) Tapioca d) Mulberry

e) Brinjal f) Hibiscus g) Potato sprouts

Fig 2: Host plants raised in pots for biology and life cycle studies of Papaya mealybug *Paracoccus marginatus* and *Acerophagus papayae*

Column one of the life table gives the age of life from birth to death. The second column shows the survivorship to each age of life, starting out at birth (age 0), and diminishing from age to age in accordance with the mortality. The figures in this column are generally denoted by the symbol l_x. The third column indicates the corresponding survival fraction (S_x) at each interval of life, being simply the fraction between l_x of the subsequent stage and l_x of the current stage. The fourth column gives the death rate in each day of life or to be more exact, the probability at a given age of dying in an interval, this being denoted by the symbol q_x.

The figures in the fifth and sixth column are the total number of females produced for total population and number of females produced per female, respectively. The seventh and eighth columns are auxiliary columns employed in computing the ninth column, which gives the expectation of life at each age. The ninth column gives the average number of insects living in each age of life. The figures in this column may also be interpreted as the number of days of life lived within a given age of life. Column eighth is obtained by cumulating the figures in column seventh beginning at the end. Lastly, column ninth, gives the expectation of life or the average after lifetime at each age class of life. It is obtained as the quotient of the figures in column eighth and the corresponding figures in column two, for this gives a total number of age class lived by survivors of a cohort after a given age, divided by the number of insects entering that age [16]. The 10th and 11th columns are auxiliary columns used in the calculation of the 12th column denoted as intrinsic rate of natural increase (r_m) [30, 17].

2.2.1 Construction of age and stage specific life table

The life tables for insect species were built by partitioning its life-cycle into distinct development stages (e.g., eggs, larvae, pupae and adults; eggs, nymphs and adults), and by evaluating the development time and survival or mortality for each individual stage. For females, the age-dependent total oviposition (fecundity/reproduction) was also determined.

The different life table parameters *viz*., Survivorship (l_x) [42], Survivorship curves [20], Fixation of survivorship curves [43], Survival fraction (S_x), Apparent mortality, Mortality survivor ratio (MSR), Indispensable mortality (IM), K-values [48], Net reproductive rate, Intrinsic rate of natural increase, Finite rate of increase (λ), Mean generation time (T), Doubling time of population (t) were calculated as per the earlier experiments [9, 12, 14, 25].

3. Results and Discussion

The data on the age specific life table of parasitoid *A. papayae* on mealybug from different host plants are exhibited in the tables 1to 7. The results revealed that the total life span of adult parasitoid was maximum and last for 14 days in papaya, while it was minimum in tapioca and hibiscus (9 days). In papaya, the production of offsprings

(15 females/female) started from the 3rd day and ceased on 7th day of life span with production of 1 female. The reproduction started from 3rd day in cotton, potato sprouts and brinjal also (Fig. 3).

The females had the adult longevity of 11 days on mealybug from cotton, potato sprouts and mulberry. And recorded life span of 10 days on mealybug from brinjal. Mulberry recorded 11 numbers of females on 4th day and 2 females on 8th day. In hibiscus and tapioca, the total oviposition days was lasted for 4 days only. They produced

(15 females/female) on the start of oviposition and ended with 15 females on 7th day.

Papaya, cotton and potato sprouts recorded higher production of offsprings with longest adult lifespan period and ovipostion days. Mulberry was marginally same as that of those crops. Whereas, tapioca, hibiscus and brinjal recorded lesser production of offsprings with shortest lifespan and oviposition days. The order of host plants for the efficient production of parasitoid was from “papaya> cotton> potato sprouts> mulberry> brinjal> hibiscus> tapioca” which was in accordance with the life span of papaya mealybug [40].

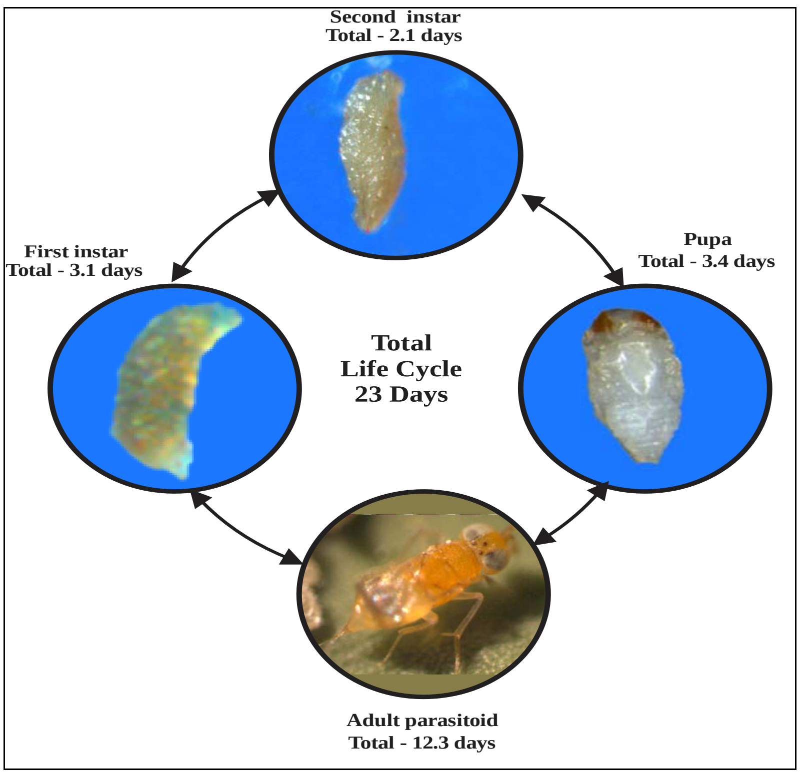

Fig 3: Biology of parasitoid *Acerophagus papayae* on *Paracoccus marginatus* from papaya

For successful biological control program of insect pests, the parasitoids life cycle should be synchronized with its host life cycle [55]. On this basis, comparative life cycles of the parasitoid, *A. papayae* was reported for first time in the current study on mealybugs from different host plants. The parameters of life table showing reproductive rate, increasing capacity in the population and time period of generation and doubling time were summarized here under and presented in the table 9.

The life cycle of parasitoid changed according to the life cycle of papaya mealybug from different host plants [40]. The host plants induced changes in the behavior and physiology of mealybug that indirectly influenced the efficiency of parasitoids. This was supported by many authors [41, 50, 10] in the parasitoid development studies. The difference in the total life cycle of the parasitoid might be due to the type of host plant of the pest [13].

In a preliminary evaluation of natural enemies, determining their intrinsic rate of increase (r_m) is important because not only it does directly represent their potential as biological control agent but also determines releasing method (i.e. inoculative, seasonal inoculative or inundative) in the field [51]. The capacity for increase (r_c) was minimum (0.324) in tapioca and maximum in papaya (0.512) followed by cotton (0.474) and potato sprouts (0.427). Intrinsic rate of increase (r_m) increased with the increase in the rate of capacity for increase in all the host plants by following same trend as that of r_c value. It was maximum in papaya (0.570 increase per day), while recording minimum in tapioca (0.342/day). Mealybug had the longest doubling time in tapioca (2.028 days) followed by hibiscus (1.696 days), while recorded shortest time in papaya (1.216 days). The same parameter was used to compare hosts of *Trichogramma* spp [23]. The intrinsic rate of natural increase is one of the most important factors to evaluate the efficiency of natural enemies in control of their host [28]. Different factors affect the r_m-value and constitutes of demographic parameters, such as host and parasitoid species [24], host and parasitoid size [47, 24], host plant and temperature [19], the number of male, Kairomone and adult feeding [24] and the experiment conditions.

It is reported in the present investigation, that parasitoid had lower developmental time but higher progeny development in papaya and cotton and *vice versa* in tapioca and hibiscus. It was confirmed with findings of [46], who reported that developmental period of female *T. chilonis* was significantly shorter and fecundity was significantly greater for the eggs of *C. cephalonica.*

A. papayae was found to be a gregarious endoparasitoid in the present study, by producing one to three numbers of parasitoid from the single second instar mealybug, which was in contrast with the [35], who reported *A. papayae* as a solitary endoparasitoid, but in confirmation with the report of [27], who found out that *T. bactrae*, on *C. cephalonica* produced up to two parasitoids emerged and there were almost equal chances of getting 1 or 2 parasitoids also. [33] reported that the female wasps of bethylid parasitoid *Laelius pedatus* produce large broods on larger host.

In the present study, sex ratio of the progeny was calculated as proportion of females in the progeny population. They showed significant effect of both the parasitoid density and host plants on the progeny sex ratio of the parasitoid *A. papayae.* It was observed that the host plants with low number of parasitoid production always decreases the production of female progeny in the population irrespective of host plants used. It showed that, to increase the proportion of female progeny in the population, sufficient number of hosts should be made available for the parasitoids. This is in accordance with findings of [15] who reported a limited supply of the hosts with increasing number of parasitoids *T. chilonis* always increases the male sex ratio in the population on different host plants.

Table 1: Age specific life table of *Acerophagus papayae* on *Paracoccus marginatus* from papaya

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	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

Table 2: Age specific life table of *Acerophagus papayae* on *Paracoccus marginatus* from cotton

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	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: Age specific life table of *Acerophagus papayae* on *Paracoccus marginatus* from tapioca

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	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: Age specific life table of *Acerophagus papayae* on *Paracoccus marginatus* from mulberry

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	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

Table 5: Age specific life table of *Acerophagus papayae* 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: Age specific life table of *Acerophagus papayae* 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

Table 7: Age specific life table of *Acerophagus papayae* on *Paracoccus marginatus* from potato sprouts

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}	$e^{-r}{}_mx\ l_xm_x$
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	0.000
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

3.1 Survivorship curve of parasitoid on mealybug from different host crops

The survival exhibited by *A. papayae* indicated that it belongs to type III survivorship curve. In general, survival decreased with increasing in days. The curve indicated that the mortality during early stage of the parasitoid was higher at higher in tapioca. Papaya recorded 50 per cent moratlity at 9th day and tapioca at 2.1 days itself (Fig. 4). Using doesn't use derivative method, survivorship curves of *A. papayae* on PMB from different host plants were smoothened. Parameters (a and b) of the smoothened curves of different host plants are given in the table 8.

Table 8: Response of survival of *Acerophagus papayae* on *Paracoccus marginatus* from different host plants

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

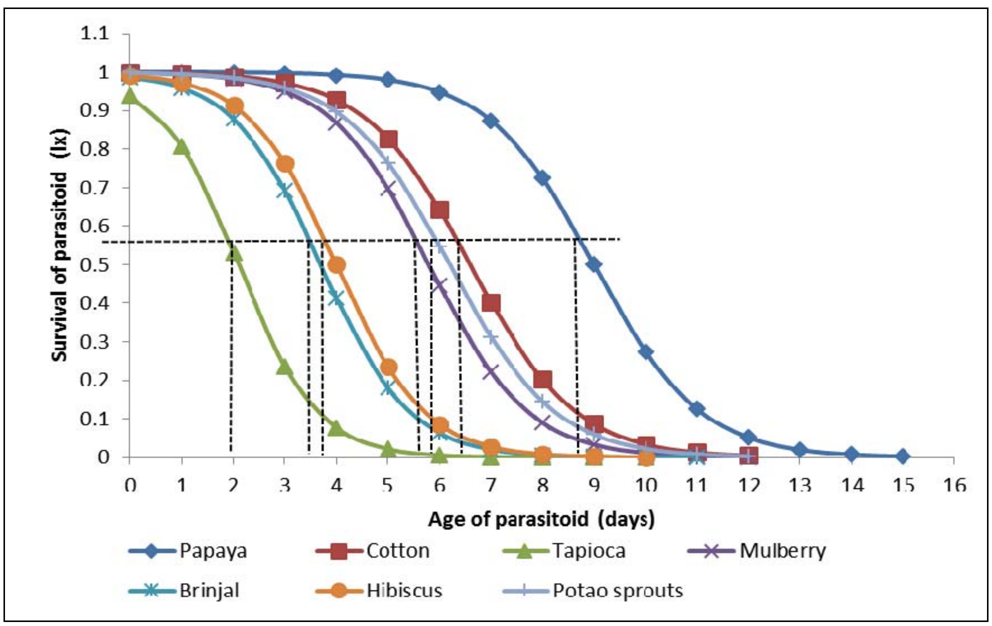

Fig 4: Survivorship curve of *Acerophagus papayae* on *Paracoccus marginatus* from different host plants

Table 9: Life table parameters of *Paracoccus marginatus* on different 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

While observing the age specific life table of the parasitoid in the present study, it had been concluded that the net reproductive rate of *A. papayae* was observed to be higher in papaya (559.48 females/female) in this study, and followed by cotton with 498.28 females. Whereas in tapioca it had the least net reproductive rate of (282.53). The net fecundity rates of host and its parasitoid are the most important factors, to determine the effectiveness of the same parasitoid [7]. The net reproductive rate (NRR) of *A. papayae* was changed in accordance with NRR of *P. marginatus* on different host plants (Table 10). These are in agreement with findings of [6], who reported that net fecundity rate of *D. rapae* on *D. noxia* and *Myzus persicae* (Sulzer) was reported as 50.20 and 238.7, respectively, while [22] observed that the net fecundity rate of *D. rapae* was 40.82 on *B. brassicae*. Number factors such as temperature, photoperiod and size of the adult female influence the fecundity of parasitoids [19, 49, 31, 21, 53]. The fecundity and other components of the fitness of parasitoid progeny may also vary with host species, age of parasitoid females and parasitoid venom [29; 32, 56] studied the life history traits of both aphid *Diuraphis noxia* and its parasitoid, *Diaeretiella rapae* indicated that *D. rapae* is an adequate parasitoid for control of aphid. (22) reported that the net reproduction rate and generation time of *D. rapae* on *B. brassicae* are 10.5 and 11.29, respectively [36]. concluded life table parameters of the parasitoid *Campoletis sonorensis* varied significantly with different hosts species under laboratory conditions.

Table 10: Net reproductive rate of *Paracoccus marginatus* and *Acerophagus papayae* on different 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

An efficient parasitoid should have a potential maximum rate of population increase (r_m) equal to, or larger than, that of the host [52]. In the current study, the intrinsic rate of increase was in the range of in different host plants for mealybug and parasitoid. It was supported by [36], who reported that the intrinsic rate of natural increase for *C. sonorensis* (0.135 female/day) was similar to the rate obtained for *Trichoplusia ni*, when *T. ni* fed on soybean (0.132), higher when *T. ni* was fed on Cabbage (0.123) but lower when *T. ni* was fed on sunflower (0.187). Another supportive study of *T. brassicae* reported by [23], that intrinsic rate of natural increase and net replacement rate was significantly differ on pests from different crops respectively.

Differences in life-table and reproductive parameters of *A. papayae* are evident between those observed in this study and those reported by other authors in different pests. Such differences may be due to variations in experimental conditions, but in others (e.g.) [44], they are more likely due to intrinsic differences between the populations involved and the differences in biological attributes among conspecific populations of parasitoids [11, 18, 9, 26, 6].

The host induced life cycle of *P. marginatus* and its parasitoid *A. papayae* and the information gathered from this study will be important in the management of *P. marginatus*. From the above finings and discussion, further studies are needed in this regard to improve the efficiency of *A. papayae* in the crops of low preference level. In this regard, the attempt was made to evaluate the plant quality in the basis of secondary metabolites, antioxidants, nutrients and volatiles present in the different host plants. Keeping the biology of both mealybug and parasitoid in mind, local adaptability of *A. papayae* was investigated to evaluate the fitness trade-offs in a parasitoid-host system using the different host plants.

4. Conclusion

Construction of life tables is an important tool for understanding the population dynamics of an insect. It provide a way to tabulate birth and death of insects. It serves as a framework for organizing dates on mortality and natality. It generates simple summary statistics such as life expectancy and reproduction rate. With the help of life tables, we can calculate the life expectancy of beneficial insects and can be used for the biological control by predicting natural things in particular instar within which we get maximum mortality. From the present and earlier experiment, it was concluded that, the life cycle of parasitoid changed according to the life cycle of papaya mealybug from different host plants. The host plants induced changes in the behavior and physiology of mealybug that indirectly influenced the efficiency of parasitoids. From a pest management standpoint, it is very useful to know when (and why) a pest population suffers high mortality. It is applicable both for pest and beneficial insects. This is usually the time, when it is the most vulnerable and efficient. By knowing such stages from life table, we can make time based application of insecticide for the management of insect pests, to conserve the natural parasites and predators and to reduce the environmental pollution. On this basis, we can prepare a plan for the management of insect pest at particular time. Key factor analysis has proven to be a valuable aid in identifying the environmental factors most closely related to intergenerational population trend.

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