

Life Table and Demographic Parameters of the Metallic Blue Ladybeetle, *Curinus coeruleus* Mulsant, Fed with the Asian Citrus Psyllid, *Diaphorina citri* Kuwayama

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ABSTRACT

Life table parameters were calculated for the blue metallic ladybeetle, *Curinus coeruleus* Mulsant, fed with the Asian citrus psyllid, *Diaphorina citri* Kuwayama, at temperatures of 26 - 28°C and 75 - 85% RH and natural photoperiod in the insectary of Faculty of Agriculture, Universiti Putra Malaysia. The development of immature stages took 19.1±0.3 days; mated adult females lived for 34.2 ± 4.7 (range 24-39) days and produced a mean of 80.3 ± 13.6 progeny female⁻¹ during oviposition period of 21.3 ± 1.4 days, with a sex ratio of 1:1.8 (♂:♀). The net reproductive rate (R_0) was 59.1 and the capacity for increase (r_c) was 0.113. The finite rate of increase (λ) was 1.29 female⁻¹ day⁻¹ while the intrinsic rate of natural increase (r_m) was 0.116 female⁻¹ day⁻¹. Each female contributed 60.2 individuals to the population in a mean generation time (T) of 35.3 days.

Keywords: *Curinus coeruleus*, *Diaphorina citri*, life table, intrinsic rate of increase, progeny

INTRODUCTION

The metallic blue ladybeetle, *Curinus coeruleus* Mulsant (Coleoptera: Coccinellidae), originating from Mexico is an important generalist predator of many insect pests. It has been recorded feeding on the spiralling whitefly *Aleurodicus dispersus* (Waterhouse and Norris, 1989; Villacarlos and Robin, 1992; Ramani *et al.*, 2002), mealybugs and green scale (*Coccus viridis* (Green)), (Wagiman *et al.*, 1990 in Showler, 1995). It also attacks psyllid, particularly the *Leucaena* psyllid, *Heteropsylla cubana* Crawford (Funasaki, 1988 in N.F.T.A., 1990; Michaud, 2001) and the Asian citrus psyllid, *Diaphorina citri* (Michaud, 2002).

Curinus coeruleus was introduced to Hawaii in the 1920s to control mealybugs and scale insects infesting coconuts. It was also introduced in Florida in the 1950s (N.F.T.A., 1990; Showler, 1995). Beginning mid-80s to early-90s, it was introduced into Indonesia, the Philippines, Thailand, India, Myanmar, Vietnam, Guam, Papua New Guinea, Nepal and Reunion Island

for controlling the *Leucaena* psyllid. It has proven successful in the control of the *Leucaena* psyllids, besides being a biological control agent for the Asian citrus psyllid, *Diaphorina citri* (Homoptera: Psyllidae) (Michaud *et al.*, 2002). *Diaphorina citri* is a serious pest of citrus trees and is a vector of the citrus greening disease, the most serious and devastating of all the diseases affecting citrus (Ko, 1996; Hoy and Nguyen, 1998).

So far, research on *C. coeruleus* has emphasized its ability to suppress the *Leucaena* psyllid and its distribution after released. Except for information on its potential to suppress *D. citri*, little is known of its biology, particularly on its population growth. Essential information on its developmental rate, age-specific fecundity, and survival in relation to its host *D. citri* is unavailable. These data are made available in a life table that can be used to examine the demographic structure of a population.

The objectives of this study were to gather life history information on *C. coeruleus* fed on *D.*

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citri for demographic analysis, and to measure the intrinsic rate of natural increase in order to elucidate the stable age-distribution of *C. coeruleus* fed on *D. citri*.

MATERIALS AND METHODS

Predator and Prey Source

The prey *Diaphorina citri* and the predator *C. coeruleus* were obtained from glasshouse and laboratory cultures, respectively. *Diaphorina citri* was cultured on orange jusmin plants, *Murraya paniculata* (L.) Jack (Fam. Rutaceae) while *C. coeruleus* was reared on a mixed population of psyllid nymphs comprising *D. citri*, *H. cubana* and an identified legume psyllid. The ambient environmental conditions were 28-34°C, 60-75% RH and a natural photoperiod in the greenhouse for rearing *D. citri*, and 26-28°C, 75-85% RH and a natural photoperiod in the laboratory for rearing the predator.

Life Table Construction

In order to construct the age-specific survival/mortality life table, a cohort comprising 100 eggs of *C. coeruleus* was placed in 10 batches, 10 eggs each in a 25 cm Petri dishes. The eggs were placed on white filter paper in one row to facilitate observations. Upon hatching, the larvae were provisioned daily with fresh psyllid nymphs of mixed instars in groups of four in separate Petri dishes to avoid cannibalism. Developmental time of larval stages until adult emergence was measured as days within each stadium. Determination of instars was affirmed by the presence of exuviae. Observations on age-specific survival and mortality of eggs, larvae, pupae and adults were made daily.

Age-specific Survival and Fertility Table

To determine the age-specific fertility, an index (sex ratio) was required to compute the number of female progeny female⁻¹ in the life table. Fifty newly hatched larvae were reared individually each in a 12 cm Petri dish until adult emergence. Upon adult emergence, 15 pairs of male and female were separately confined within a mating-oviposition container. Since males of many ladybird species are consistently smaller (Dixon, 2000) and lighter (Otteenheim *et al.*, 1992) than females, beetles of similar body length (0.4-0.5 cm for males and >0.5-0.6 cm for females) were selected for the study to avoid high variability in

egg production. Eggs deposited by each female were recorded daily and observed for hatching. Newly hatched larvae were individually transferred into plastic containers (15 x 12 x 10 cm) that were covered with fine mesh nylon screen for aeration. Individuals were sexed at adult emergence in order to get an index for fecundity. Observations were recorded on such parameters as development period, oviposition and reproductive periods, fertility and longevity until death.

To construct age-specific survival and fertility table of female predators, 40 pairs of adult males and females that had mated (6-7 days after emergence) were maintained separately in plastic containers (15 x 12 x 10 cm) for egg laying. The number of eggs laid and the proportion of live females were recorded daily until all had died. Standard life table parameters were calculated from daily records of mortality and fecundity of the cohort using the procedure adopted from Carey (Vegas *et al.*, 2002).

RESULTS

Age-specific Survival/Mortality Life Table

The duration of immature stages from egg to adult is shown in Table 1. The egg mortality had contributed to the drop in the survivorship (l_x) of *C. coeruleus* by the 6th day. The decrease in l_x was further recorded between day 7 and 14 due to the larval mortality (8%). Thereafter, the l_x remained stable until day 48, beyond which the survivorship sharply descended after day 54 due to the death of adults until the last individual on day 77. In general, the percentage of survival from egg to adult (88%) was relatively high.

Age-specific Survival and Fertility Table

At an ambient environment of 26-28°C, 75-85% RH and natural photoperiod, the development of immature stages of *C. coeruleus* fed *D. citri* nymphs from egg hatching to adult emergence took 19.1 ± 0.3 days. Adult females lived for 34.2 ± 4.7 days (range between 24-39 days), produced a mean of 80.3 ± 13.6 progeny female⁻¹ during an oviposition period of 21.3 ± 1.4 days. That progeny consisted of 38.5 males and 51.8 females, hence the sex ratio was 1 male: 1.8 females. This sex ratio was used to compute population parameters as shown in Table 2.

The female *C. coeruleus* began laying eggs around day seven of post-emergence of the adult

TABLE 1
Life table for computing life expectancy of *C. coerules*
feeding on *D. citri* nymphs

Age (days), x	l_x	d_x	$100q_x$	L_x	T_x	e_x
1 Egg	100	0	0	100	5230.0	52.30
2	100	0	0	100	5130.0	51.30
3	100	0	0	100	5030.0	50.30
4	100	0	0	100	4930.0	49.30
5	100	4	4.0	98	4830.0	48.30
6 1 st instar	96	2	2.08	95	4732.0	49.29
7	94	1	1.06	93.5	4637.0	49.33
8	93	0	0	93	4543.5	48.85
9 2 nd instar	93	0	0	93	4450.5	47.85
10	93	0	0	93	4357.5	46.85
11	93	1	1.08	92.5	4264.5	45.85
12 3 rd instar	92	0	0	92	4172.0	45.35
13	92	0	0	92	4080.0	44.35
14	92	0	0	92	3988.0	43.35
15	92	2	2.17	91	3896.0	42.35
16 4 th instar	90	0	0	90	3805.0	42.28
17	90	0	0	90	3715.0	41.28
18	90	1	1.11	89.5	3625.0	40.28
19	89	0	0	89	3535.5	39.72
20 Pupa	89	0	0	89	3446.5	38.72
21	89	0	0	89	3357.5	37.72
22	89	0	0	89	3268.5	36.72
23	89	0	0	89	3179.5	35.72
24	89	1	1.12	88.5	3090.5	34.72
25 Adult	88	0	0	88	3002.0	34.11
26	88	0	0	88	2914.0	33.11
27	88	0	0	88	2826.0	32.11
28	88	0	0	88	2738.0	31.11
29	88	0	0	88	2650.0	30.11
30	88	0	0	88	2562.0	29.11
31	88	0	0	88	2474.0	28.11
32	88	0	0	88	2386.0	27.11
33	88	0	0	88	2298.0	26.11
34	88	0	0	88	2210.0	25.11
35	88	0	0	88	2122.0	24.11
36	88	0	0	88	2034.0	23.11
37	88	0	0	88	1946.0	22.11
38	88	0	0	88	1858.0	21.11
39	88	0	0	88	1770.0	20.11
40	88	0	0	88	1682.0	19.11
41	88	0	0	88	1594.0	18.11
42	88	0	0	88	1506.0	17.11
43	88	0	0	88	1418.0	16.11
44	88	0	0	88	1330.0	15.11
45	88	0	0	88	1242.0	14.11
46	88	0	0	88	1154.0	13.11
47	88	0	0	88	1066.0	12.11
48	88	4	4.55	86	978.0	11.11
49	84	4	4.76	82	892.0	10.62

TABLE 1 (continue)

50	80	5	6.25	77.5	810.0	110.13
51	75	2	2.67	74	732.5	9.77
52	73	0	0	73	658.5	9.02
53	73	7	9.59	69.5	585.5	8.02
54	66	0	0	66	516.0	6.82
55	66	4	6.06	64	450.0	6.82
56	62	14	22.58	55	386.0	6.23
57	48	13	27.08	41.5	331.0	6.90
58	35	3	8.57	33.5	289.5	8.27
59	32	8	25.0	28	256.0	8.00
60	24	0	0	24	228.0	9.50
61	24	0	0	24	204.0	8.50
62	24	0	0	24	180.0	7.50
63	24	4	16.67	22	156.0	6.50
64	20	0	0	20	134.0	6.70
65	20	0	0	20	114.0	5.70
66	20	4	20.0	18	94.0	4.70
67	16	2	12.5	15	76.0	4.75
68	14	0	0	14	61.0	4.36
69	14	2	14.29	13	47.0	3.36
70	12	2	16.67	11	34.0	2.83
71	10	1	10.0	9.5	23.0	2.30
72	9	5	55.56	6.5	13.5	1.50
73	4	2	50.0	3	7.0	1.75
74	2	0	0	2	4.0	2.00
75	2	1	50.0	1.5	2.0	1.00
76	1	1	100.0	0.5	0.5	0.50
77	0	0	0	0		

and kept going for up to 22 days (Table 2). The average total number of eggs laid day⁻¹ female⁻¹ ranged from a high of 10.05 on day eight of adult emergence to a low of 0.67 eggs female⁻¹ on day 22. The first female death was recorded on day 24 of adult life and increased gradually thereafter. However, the females could live for a maximum of up to 42 days after pupal emergence or 62 days of age. During the entire egg laying period, egg production female⁻¹ showed a variable or an undulating pattern (Fig. 2), thus indicating that the reproductive output of *C. coeruleus* demonstrated a tendency toward a sharp rise and reached the peak on the 8th day of the oviposition period. The decline in egg production (m_x) coincided with the aging and death of adult females. The survivorship curve of adult females was similar to that of all stages (Fig. 1), showing a Type 1 survivorship in which mortality was most heavy on the old individuals.

Reproductive and population parameters are summarised in Table 3. The intrinsic rate of natural increase (r_m) was 0.116 female⁻¹ day⁻¹ and a daily finite rate of increase (λ) was 1.122

females female⁻¹ day⁻¹. With a mean generation time T of 35.33 days, theoretically each female would contribute 60.24 individuals. When a stable-age distribution is reached, each development stage (egg, larva, pupa and adult stages) would contribute 46.0, 43.8, 4.6 and 5.6% respectively to the population. This proportion would be considered advantageous to prey suppression since around 50% of the population comprised the nymph-preying stages, ie. larvae and adults.

DISCUSSION

Life table construction termed demography by Stilling (1992) contains such vital statistics as the probability of an individual of a certain age dying, or conversely, the average number of offspring produced by a female of a given age (Poole, 1974). The demographic parameters like the intrinsic rate, mean generation time, and population doubling time are useful indices of population growth of an insect under a given set of growing conditions (Tsai, 1998). No demography comparison study on *C. coeruleus*

TABLE 2
Life- and age-specific fecundity table of *C. coeruleus*
(1-19 days immature stages and 20-26 days preoviposition period)

Pivotal age (days) x	Proportion of surviving females l_x	No. of female progeny/female m_x	$l_x m_x$	$x l_x m_x$
27	1	1.08	1.08	29.16
28	1	1.08	1.08	30.24
29	1	1.70	1.70	49.30
30	1	1.86	1.86	55.80
31	1	1.72	1.72	53.32
32	1	4.63	4.63	148.16
33	1	4.46	4.46	147.18
34	1	6.46	6.46	219.64
35	1	5.17	5.17	180.95
36	1	3.66	3.66	131.76
37	1	4.10	4.10	151.70
38	1	3.23	3.23	122.74
39	1	2.70	2.70	105.30
40	1	2.80	2.80	112.00
41	1	3.02	3.02	123.82
42	1	2.91	2.91	122.22
43	1	2.26	2.26	97.18
44	0.950	2.59	2.46	108.26
45	0.900	1.51	1.36	61.16
46	0.850	1.11	0.94	43.40
47	0.825	1.40	1.16	54.29
48	0.750	0.43	0.32	15.48
49	0.750	0	0	0
50	0.700	0	0	0
51	0.550	0	0	0
52	0.400	0	0	0
53	0.350	0	0	0
54	0.350	0	0	0
55	0.225	0	0	0
56	0.150	0	0	0
57	0.050	0	0	0
58	0.050	0	0	0
59	0.025	0	0	0
60	0.025	0	0	0
61	0.025	0	0	0
62	0	0	0	0
Σ	24.93	59.88	59.08	2163.05

has been reported. This study noted the mean incubation period of *C. coeruleus* when fed with *D. citri* was 5 days with a viability of 96%. The high egg viability indicated that the adult female and male predators had successfully mated and the eggs produced were fertile. Several laboratory studies revealed that virgin females would lay eggs, but far fewer than mated females (Dixon, 2000). The nymphs underwent three moults with the total nymphal development period of

14 days, which was similar to the period of most predaceous ladybird beetles (Olsen, 2004). The average female longevity was 34.2 days.

The developmental time from egg to adult was 25 days with the proportion of the total time spent in the egg, larval and pupal stages being 0.21, 0.58 and 0.21, respectively (Table 4). This is approximately similar to that recorded for other species of ladybirds (0.18, 0.62 and 0.23, respectively) (Dixon, 2000). Even though the

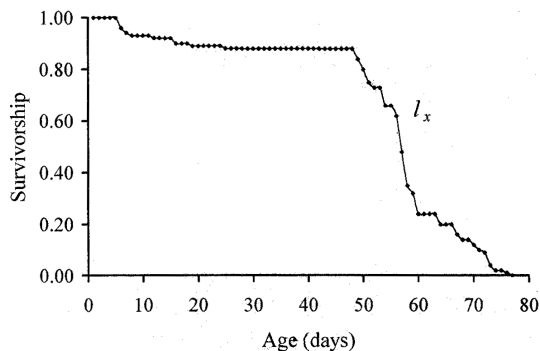


Fig. 1: Survivorship (L_x) curve of *C. coeruleus* fed with *D. citri* nymphs

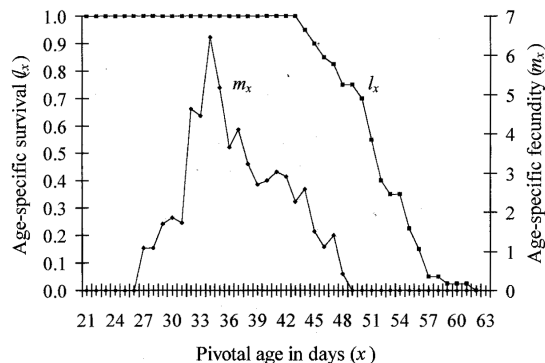


Fig. 2: Daily age-specific survival and fecundity of *C. coeruleus* fed with *D. citri* nymphs

developmental time is very dependent on both the temperature and food quality, the ratios of the time spent in each of the different stages do not differ. The developmental time is one of the life history parameters that can be used to measure the desirable characteristics of natural enemies (Olsen, 2004). When a predator develops slower than the prey, it is an ineffective biological agent (Hagen, 1974; Mills, 1982). According to Dixon (2000), if the developmental rate of a predator is similar or faster than that of its prey then the predator is potentially capable of dramatically reducing the abundance of its prey. In the current study, the developmental time for the four larval stages of *C. coeruleus* of 14 days (Table 7) was very comparable to that for the five nymphal stages of *D. citri* (13 days) (Tsai and Liu, 2000). The generation time and doubling time of *C. coeruleus* noted at 35.33 days and 5.97 days respectively, was relatively similar to those of *D. citri* (33.91 days and 4.28 days) (Tsai and Liu, 2000). Therefore, this predator should be considered as an important candidate of a biological control agent for the Asian citrus psyllid, *D. citri*.

Reproductive output of *C. coeruleus* was in general agreement with that of most insects; starts and reaches a maximum early in adult life and then declines with age. This situation had resulted in the sharp rise in fecundity and showed a right-angled triangular shape (Fig. 1). The decline in reproductive output in the triangular fecundity trend was mainly determined by the mortality (Stearn and Koella, 1986) besides due to the aging of adult females which is closely associated with a reduction in daily consumption of prey. Dixon (2000) pointed out that aging is

important in shaping the fecundity trend; the old adults are less efficient at converting biomass of prey into eggs than young adults. From Fig. 1, it was apparent that the female died at age of 62 days, while the maximum age could reach 77 days as presented in Table 3. This difference was presumably caused by the mated and unmated individuals whereby unmated individuals of both male and female live longer than mated individuals (Dixon, 2000).

The number of female predators produced in each generation greatly influenced the population size of the next generation. In this study, the proportion of females was higher than males. Of the total progeny (1205) produced by 15 females, 770 progenies were females, making the sex ratio of 1 male: 1.8 females (0.36 : 0.64). Similar sex ratios were reported by Otteenheim *et al.* (1992); from 53 ladybird families, 51 had sex ratios (proportion of females) around 0.6 or slightly above while the remaining had a very low sex ratio (<0.12). The higher proportion of female predators coupled with the high egg viability and the generation time that was comparable to that of its prey could be so beneficial in terms of mass rearing and releasing that in turn could contribute in suppressing the prey population.

Since the mortality of *C. coeruleus* females heavily affected the old individuals, the survivorship curve for the females showed a Type I as in Slobodkin (in Southwood, 1978) and Stilling (1992). Overall, the survivorship curve of all stages of this predator was that of Type I, this curve was different from standard curves described by Stilling (1992) where most invertebrates often exhibits Type III survivorship

TABLE 3
Reproductive and population parameters of *C. coeruleus* feeding on *D. citri* nymphs

No.	Parameters	Values
<i>Reproductive parameters:</i>		
1.	Gross reproductive rate $\sum m_x$	59.88
2.	Net reproductive rate $\sum l_x m_x$	59.08
3.	Average egg day ⁻¹ $\sum l_x m_x / \sum l_x$	2.37
4.	Mean age fecundity schedule $\sum x m_x / \sum m_x$	36.74
5.	Gross fecundity rate $\sum M_x$	93.15
6.	Net fecundity rate $\sum l_x M_x$	90.22
<i>Population parameters:</i>		
7.	Approximate generation time (T_c), $\sum x l_x m_x / \sum l_x m_x$	36.61
8.	Corrected generation time (T), $\ln R_0 / r_m$	35.33
9.	Innate capacity for increase (r_c), $\ln R_0 / T_c$	0.113
10.	Intrinsic rate of natural increase (r_m), $\sum e^{-r_m x} l_x m_x = 1$	0.116
11.	Finite rate of increase e^r	1.122
12.	Doubling time $\ln 2 / r$	5.97
13.	Intrinsic birth rate (b), $1 / \sum e^{-r_m x} l_x$	0.128
14.	Intrinsic death rate (d), $b - r_m$	0.012
15.	Stable age structure (from Table 4)	
	Eggs	46.01
	Larvae	43.79
	Pupae	4.56
	Adults	5.64

TABLE 4
Calculated stable-age distribution of *C. coeruleus* feeding on *D. citri* nymphs ($r_m = 0.116$)

Pivotal age (days), x	l_x	$e^{-r_m x}$	$e^{-r_m x} l_x$	% Distribution	
1	1.00	0.8910	0.8910	11.44	Eggs
2	1.00	0.7938	0.7938	10.19	46.01
3	1.00	0.7072	0.7072	9.08	
4	1.00	0.6301	0.6301	8.09	
5	1.00	0.5614	0.5614	7.21	
6	0.96	0.5002	0.4802	6.16	1 st instar
7	0.94	0.4456	0.4189	5.38	16.28
8	0.93	0.3971	0.3693	4.74	
9	0.93	0.3538	0.3290	4.22	2 nd instar
10	0.93	0.3152	0.2931	3.76	11.33
11	0.93	0.2808	0.2612	3.35	
12	0.92	0.2502	0.2302	2.95	3 rd instar
13	0.92	0.2229	0.2051	2.63	10.02
14	0.92	0.1986	0.1827	2.35	
15	0.92	0.1769	0.1628	2.09	
16	0.90	0.1577	0.1419	1.82	4 th instar
17	0.90	0.1405	0.1264	1.62	6.16
18	0.90	0.1251	0.1126	1.45	
19	0.89	0.1115	0.0992	1.27	
20	0.89	0.0993	0.0884	1.13	Pupae
21	0.89	0.0885	0.0788	1.01	4.56
22	0.89	0.0789	0.0702	0.90	

TABLE 4 (continue)

23	0.89	0.0703	0.0625	0.80	
24	0.89	0.0626	0.0557	0.72	
25	0.88	0.0558	0.0491	0.63	Adult
26	0.88	0.0497	0.0437	0.56	5.64
27	0.88	0.0443	0.0390	0.50	
28	0.88	0.0394	0.0347	0.45	
29	0.88	0.0351	0.0309	0.40	
30	0.88	0.0313	0.0276	0.35	
31	0.88	0.0279	0.0245	0.32	
32	0.88	0.0249	0.0219	0.28	
33	0.88	0.0221	0.0195	0.25	
34	0.88	0.0197	0.0174	0.22	
35	0.88	0.0176	0.0155	0.20	
36	0.88	0.0157	0.0138	0.18	
37	0.88	0.0140	0.0123	0.16	
38	0.88	0.0124	0.0109	0.14	
39	0.88	0.0111	0.0097	0.13	
40	0.88	0.0099	0.0087	0.11	
41	0.88	0.0088	0.0077	0.10	
42	0.88	0.0078	0.0069	0.09	
43	0.88	0.0070	0.0061	0.08	
44	0.88	0.0062	0.0055	0.07	
45	0.88	0.0055	0.0049	0.06	
46	0.88	0.0049	0.0043	0.06	
47	0.88	0.0044	0.0039	0.05	
48	0.88	0.0039	0.0034	0.04	
49	0.84	0.0035	0.0029	0.04	
50	0.80	0.0031	0.0025	0.03	
51	0.75	0.0028	0.0021	0.03	
52	0.73	0.0025	0.0018	0.02	
53	0.73	0.0022	0.0016	0.02	
54	0.66	0.0020	0.0013	0.02	
55	0.66	0.0017	0.0012	0.01	
56	0.62	0.0016	0.0010	0.01	
57	0.48	0.0014	0.0007	0.01	
58	0.35	0.0012	0.0004	0.01	
59	0.32	0.0011	0.0004	0.0	
60	0.24	0.0010	0.0002	0.0	
61	0.24	0.0009	0.0002	0.0	
62	0.24	0.0008	0.0002	0.0	
63	0.24	0.0007	0.0002	0.0	
64	0.20	0.0006	0.0001	0.0	
65	0.20	0.0006	0.0001	0.0	
66	0.20	0.0005	0.0001	0.0	
67	0.16	0.0004	0.0001	0.0	
68	0.14	0.0004	0.0001	0.0	
69	0.14	0.0003	0.0	0.0	
70	0.12	0.0003	0.0	0.0	
71	0.10	0.0003	0.0	0.0	
72	0.09	0.0002	0.0	0.0	
73	0.04	0.0002	0.0	0.0	
74	0.02	0.0002	0.0	0.0	
75	0.02	0.0002	0.0	0.0	
76	0.01	0.0002	0.0	0.0	
77	0	0.0001	0.0	0.0	
			$\Sigma = 7.7907$		

curve in which a large fraction of the population is lost in the juvenile stages, whilst Type I curves are often observed in higher organisms, especially vertebrates. However, similar survivorship curve with this predator was also observed for other coccinellids such as *Scymnus hoffmani* and *Coelophora mulsanti* (Sallee and Chazeau, 1985 in Dixon, 2000). The Type I curve could be advantageous in the multiplication point of view as high survival rate of the immature and young female predator will contribute to the increasing rate of its population, which in turn could increase the predation rate and hence reduce the abundance of its prey.

The overall rate of increase of predator population will depend on the survival rate of each developmental stage as well as the fecundity of the adults (Hassell, 1976). Poor survival of the immature stages can markedly reduce the rate of increase of a predator population even if the fecundity and the number of progeny produced female is high. The intrinsic rate of increase of *C. coeruleus* was slightly lower than that of *D. citri*, ie. 0.12 (Table 3) compared to 0.16 (Tsai and Liu, 2000). This might be due to the lower fecundity rate of *C. coeruleus* (90) compared to that of *D. citri* (626) although the survival of *C. coeruleus* during immature stages was higher (90% : 75%) (Tsai and Liu, 2000). Even so, *C. coeruleus* with a slightly lower r_m than its prey might be able to effectively suppress the prey population if its other attributes such as voracity, developmental time and attack rate were good. The study conducted by Jansen and Sabelis (1992) suggested that predator mites having a lower r_m than their prey could nevertheless still effectively control the abundance of their prey if they have a high voracity.

CONCLUSIONS

Based on the demographic parameters exemplifying the biological characteristics, it appears that *C. coeruleus* is a potential predator candidate for biological control of *D. citri*. With high survival rates of the immature and young female (Type I survivorship), high egg viability and mean generation time comparable to its prey, *C. coeruleus* has the desirable attributes as an effective natural enemy, hence it would be beneficial in providing an ecological framework for a biological control programme against *D. citri* in the future.

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