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Effect of temperature on life table parameters of *Diaphania indica* (Lep.: Pyralidae) under laboratory conditions

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Abstract

The cucumber moth, *Diaphania indica* (Saunders), is a tropical and sub-tropical pest on cucurbits and a key pest of greenhouse crops in Jiroft region of Iran. The effect of temperature on life table parameters of this pest was investigated in a growth chamber at four constant temperatures i.e. 20, 25, 30 and 35 ºC on *Cucumis sativus* L. The net reproductive rates (R_0) were found to be 68.19, 120.977, 64.05 and 21.23, respectively. The intrinsic rates of increase (r_m) were 0.0619, 0.1746, 0.1934 and 0.1491, and mean generation times (T) were 69.063, 27.45, 21.49 and 20.44, respectively. According to the results, for the intrinsic rate of increase (r_m), finite rate of increase (λ) and intrinsic birth rate (b), the optimum temperature was 30 ºC and the least suitable temperature was 20 ºC.
Key words: cotton caterpillar, cucumber moth, *Diaphania indica*, life table

چکیده

تأثیر دما روی پارامترهای جدول زندگی *Diaphania indica* (Lep.: Pyralidae) در شرایط آزمایشگاهی

ساره حسین‌زاده، حمزه ایزدی، پیمان نامور و محمد امین سمیع

پروانه برگ‌خوار کدوئیان، *Diaphania indica* (Saunders)، از آفات مهم گیاهان خانواده کدوئیان در مناطق استوایی و نیمه‌استوایی، و در ایران آفت کلیدی محصولات گلخانه‌ای در منطقه جیرفت است. در این تحقیق اثر دما بر پارامترهای ویژه جدول زندگی آفت در چهار دمای ۲۰، ۲۵، ۳۰، و ۳۵ درجه سلسیوس در اتاقک رشد و روی خیار، *Cucumis sativus* L.، مطالعه شد. پارامترهای نرخ خالص تولید مثل (R_0) در دماهای فوق به‌ترتیب ٦٨/١٩، ١٢٠/٩٧٧، ٦٤/٠٥، ٢١/٢٣، نرخ ذاتی افزایش جمعیت (r_m) به‌ترتیب ٠/٠٦١٩، ٠/١٧٤٦، ٠/١٩٣٤ و ٠/١٤٩١ و متوسط مدت زمان نسل (T) به‌ترتیب ٦٩/٠٦٣، ٢٧/٤٥، ٢١/٤٩ و ٢٠/٤٤ به‌دست آمد. براساس نتایج این تحقیق دمای ۳۰ درجه سلسیوس بهترین و دمای ۲۰ درجه سلسیوس نامناسب‌ترین دما برای نرخ ذاتی افزایش جمعیت (r_m)، نرخ متناهی افزایش جمعیت(λ) و نرخ ذاتی تولد (b) بودند.

واژگان کلیدی: شب‌پره پنبه، پروانه برگ‌خوار کدوئیان، *Diaphania indica*، جدول زندگی

Introduction

The cucumber moth, *Diaphania indica* (Saunders), also known as cotton caterpillar or pumpkin caterpillar, is a destructive pest on a wide range of crops. The larvae of *D. indica* attack leaves, flowers and fruit of their plant hosts. Preferred hosts for the larvae of this pest are: cucumber, *Cucumis sativus*, gourd, *Lagenaria siceraria*, watermelon, *Citrullus lanatus*, oriental melon, *Cucumis melo* var. *makuwa*., wax gourd, *Benincasa hispida*, melon, *Cucumis melo*, star cucumber, *Sicyos angulatus*, sponge cucumber, *Luffa cylindrica*, cotton, *Gossypium indicum*, bitter gourd, *Momordica charantia*, little gourd, *Coccinia indica*, and pointed gourd, *Trichosanthes dioica*, (Tripathi & Pandy, 1973; Pandy, 1977; Clavijo *et al*., 1995; Ravi *et al*., 1998; Capinera, 2001; Choi *et al*., 2003). This species is largely occur in tropical regions such as South America, Pakistan and India (Capinera, 2001), as well as Japan, Southeast Asia, Pacific islands, Australia and Africa (Peter & David, 1991).

Little data are available on demographic parameters of *D. indica* in the literatures. Changes in population of this pest on pumpkin, *Coccinia grandis*, was studied in India (Peter & Daivid, 1991) and Kinjo & Arakaki (2002) investigated the effects of different temperatures on the development and reproduction rates of the pest on *C. sativus*.

The objective of the present study is to improve our knowledge about the effects of temperature on the life table parameters of the cotton caterpillar. Our better understanding of the biology of *D. Indica* in the region will help us to develop a viable population prediction system against the pest.

Materials and methods

Rearing of cucumber moth

Larvae of cucumber moth were collected from

cucumbers grown in greenhouses located in Jiroft, Iran, in November 2010. They were reared on cucumber leaves (Tunca variety) at 25 ± 1 ºC, 65 ± 5% RH and 16: 8 L: D until pupation. Pupae were sexed and kept in separate plastic Petri dishes until the emergence of adults and then, one-day old pairs were confined to plastic containers (8 × 10 cm) for mating. Each container had been supplied with a piece of cucumber leaf as an oviposition substrate and diluted honey (1:10) solution-soaked cotton for feeding. Fresh eggs laid on the cucumber leaf were counted and transferred into plastic Petri dishes.

Life table parameters

To determine the life table parameters, 60 newly laid (one-day old) eggs were placed in separate Petri dishes and kept at four different constant temperatures (20, 25, 30 and 35 °C), 65 ± 5% RH and a photoperiod of 16: 8 L: D until eclosion. Newly hatched larvae were individually reared in plastic Petri dishes on a piece of fresh cucumber leaf. The bottom of each Petri dish was lined with a slightly moistened filter paper to prevent desiccation until pupation. Pupae were sexed and kept in separate plastic Petri dishes. Developmental stages were examined daily using a stereomicroscope. The Petri dishes and cucumber leaves were replaced at 24-48 hours intervals. Later, seventeen one-day old females and males were randomly selected and left to mate. Each mated female was transferred into a plastic container (8 cm dia. × 10 cm ht.) with a 3 cm diameter opening on the top covered with nylon mesh to facilitate its ventilation. During the reproduction period, a cotton wool, which was soaked with 10% honey-water solution, was placed in container for their feeding. Females were transferred daily into new plastic containers with of fresh leaves and honey solution. For the males, honey solution was added daily to the cotton. Plastic container and cotton were changed at 48-72 hours intervals. The number of eggs laid by each female was recorded daily until the last female died.

The essential factors for the quantitative analysis of population (demographic) were the age of females in days (x), the number of females alive at age x (l_x), the mean number of eggs laid per alive female per day (m_x) and life expectation at age x (e_x).

Stable population parameters

The parameters of stable population in this study were intrinsic rate of increase (r_m), finite rate of increase (λ), intrinsic birth rate (b), intrinsic death rate (d), gross reproduction rate, net reproductive rate (R_0), mean generation time (T) and doubling time (DT).

Data analysis

Standard demographic parameters were obtained from daily records of mortality, fecundity and fertility of female individuals of *D. indica* according to Carey (1993). Data were initially tested for normality (Kolmogorov-Smirnov test) and homoscedasticity (Levene's test) before subjecting them to ANOVA. A non-parametric test (Mann-Whitney U and Kruskal-Wallis test) was used to test for differences in the non-normal data. The statistical differences in demographic parameters were tested using jackknife procedure to estimate the variance for demographic parameters (Meyer *et al*., 1986; Maia *et al*., 2000).

Statistical analysis

The normality and homogeneity of data were analyzed using Minitab 14.0 software and differences between means determined by the least significant difference test (Duncan's multiple range test) with the P-value set at 0.05 (SPSS 16.0). Excel software was used for drawing the curves.

Results and discussion

Survival parameters

The survival rate (l_x) of *D. indica* in different temperatures is shown in fig. 1. The mortality at 35 °C and 20 °C started on 2nd and 12th day, respectively. The highest survival ability (83 days) and the lowest

survival ability (26 days) occurred at 20 °C and 35 °C, respectively.

Age specific mortality rate (q_x) and mortality rate (d_x) are shown in figs. 2 and 3, respectively. The peak of q_x at the temperatures of 20 °C, 25 °C, 30 °C and 35 °C were recorded on 80th (0.42), 30th (0.28), 26th (0.5) and 24th (0.44) days, respectively. The peak of d_x at temperatures of 20 °C, 25 °C, 30 °C and 35 °C were recorded on 73rd (0.172), 30th (0.174), 21st (0.121) and 22nd (0.27) days, respectively. Adult deaths for q_x, at temperatures of 20 °C, 25 °C, 30 °C and 35 °C were on 81st (0.25), 36th (0.2), 30th (0.5) and 24th (0.44) days, respectively, while for d_x, were on 83rd (0), 36th (0.043), 36th (0) and 25th (0.15) days, respectively. Results of q_x showed that the mortality rate increases slowly with increase in age.

Life expectancy (e_x) in the first day for temperatures of 20 °C, 25 °C, 30 °C and 35 °C, was 68.53, 28.19, 19.70 and 19.15 days, respectively (fig. 4).

Reproductive parameters

Reproductive parameters are shown in table 1. The amount of gross hatch rate parameter for all treatments is identical (= 1) and the values for other parameters remain the same two by two. Kinjo & Arakaki (2002) found that 100% hatchability for the eggs occurred at 20 °C -35 ºC. Studies by Shine *et al*. (2002) on the biological property of the cotton caterpillar revealed that the hatching rates on cucumber and melon were 87.2% and 72.8%, respectively.

The highest level of eggs per female per day and highest number of fertilized eggs per female per day were observed at 25 °C. The highest level of net fecundity and fertility rates as well as gross fertility and fecundity rates were recorded at 25 °C. The highest level of mean age hatch, mean age gross fecundity and fertility, in addition to mean age net fecundity and fertility occurred at 20 °C.

Stable population parameters

There was significant difference at 5% level between the following variables at different constant temperatures: gross reproduction rate (df = 3, 54; F = 769.237; $P < 0.01$), net reproduction rate (df = 3, 54; F = 1.003; $P < 0.01$), intrinsic rate of increase (df = 3, 54; F = 1.762; $P < 0.00$), finite rate of increase (df = 3, 54; F = 1.792; $P < 0.01$), intrinsic birth rate (df = 3, 54; F = 3.775; $P < 0.01$), intrinsic death rate (df = 3, 54; F = 4.130; $P < 0.01$), doubling time (df = 3, 54; F = 509.873; $P < 0.01$) and mean generation time (df = 3, 54; F = 488.08; $P < 0.01$).

As shown in table 2, the effect of temperature on gross reproduction and net reproductive rates at 25 °C was the highest (157.437 and 120.977) and at 35 °C was the lowest (24.47 and 21.23), respectively. The maximum doubling time (*DT*) at 20 °C was recorded 11.32 and the minimum *DT* (3.58) occurred at 30 °C.

The highest levels of intrinsic rate of increase (r_m), finite rate of increase (λ) and intrinsic birth rate (b) occurred at 30 °C (0.193, 1.213 and 0.195, respectively) and the lowest levels were recorded at 20 °C (0.0619, 1.063 and 0.0624, respectively). Intrinsic death rate (d) was at the highest level (0.0049) at 35 °C and at the lowest level (0.0005) at 20 °C. Maximum mean generation time (T) was 69.063 at 20 °C and the minimum level (20.44) was recorded at 35 °C.

The results suggest that the survival rate decreases as temperature increases and reaches to the lowest level at 35 °C. The maximum age specific mortality rate and mortality rate is also inversely proportional with the increase in temperature. The life expectancy was proportional with the increase in temperature.

Kinjo & Arakaki (2002) investigated life table parameters of *D. indica* in the temperature ranged from 15 °C to 35 °C and found the maximum survival rate for *D. indica* at 25 °C. In this temperature, the survival rate for females within eight days after their emergence was 100% that gradually decreased in a period of 29 days. Survival rate for males was higher than females but reduced after 33 days. The values of R_0, r_m and T in Kinjo & Arakaki (2002) were 383.5, 0.2 and 29.5 days, respectively. In the present study, the hatching rate for

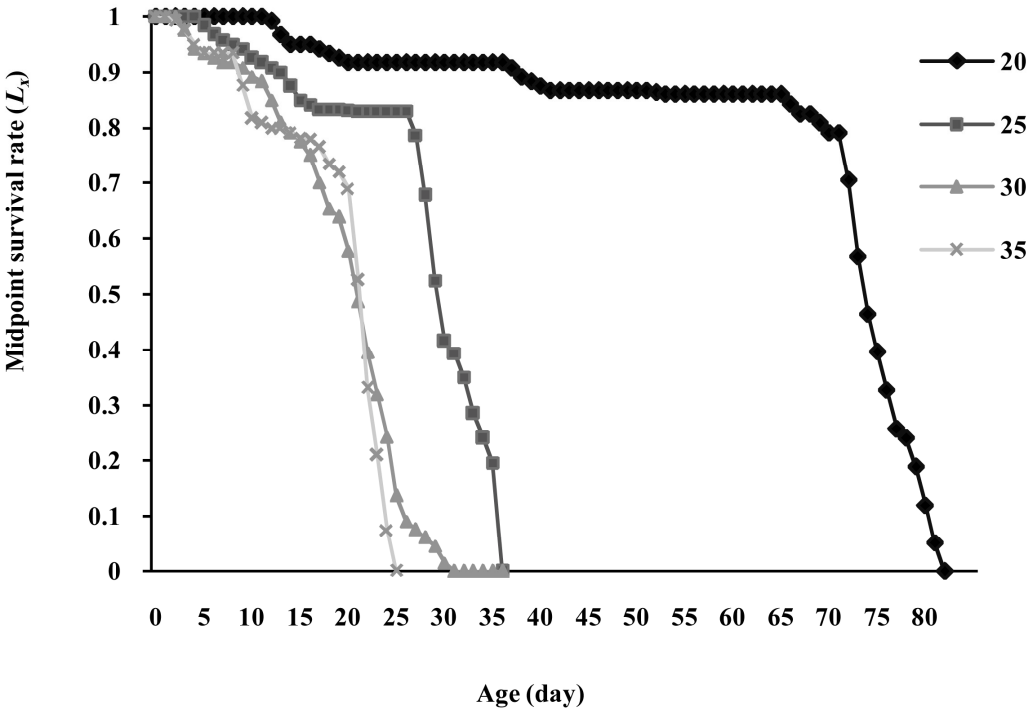

Fig. 1. Effect of temperature on survival rate (l_x) of *Diaphania indica* at four constant temperatures.

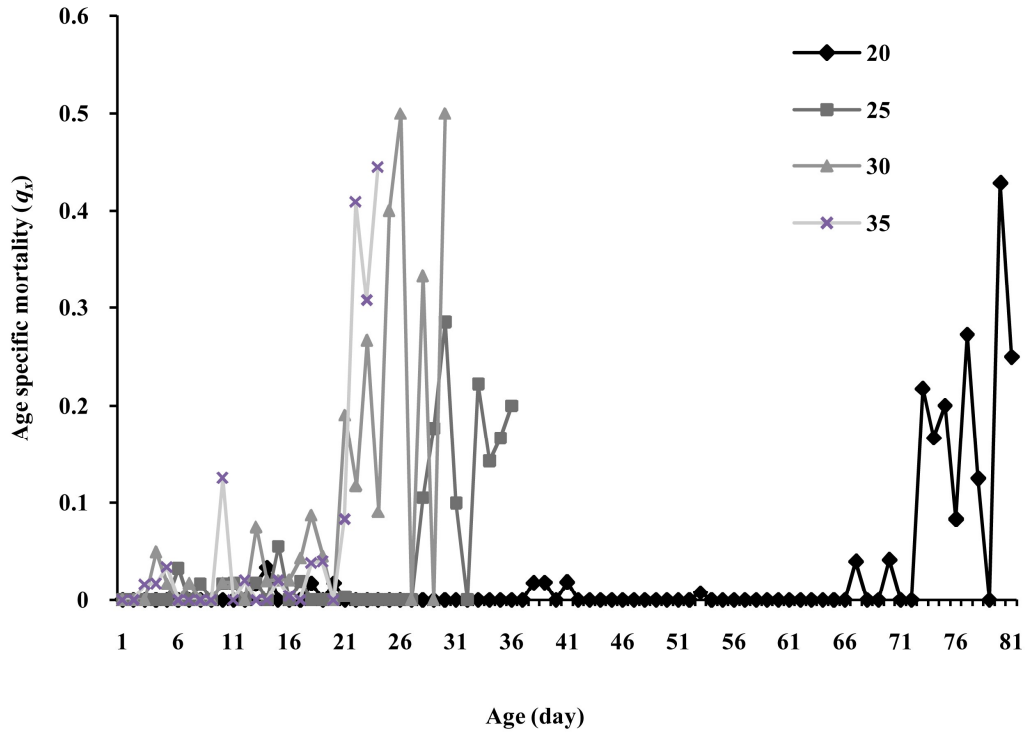

Fig. 2. Effect of temperature on age specific mortality rate (q_x) of *Diaphania indica* at four constant temperatures.

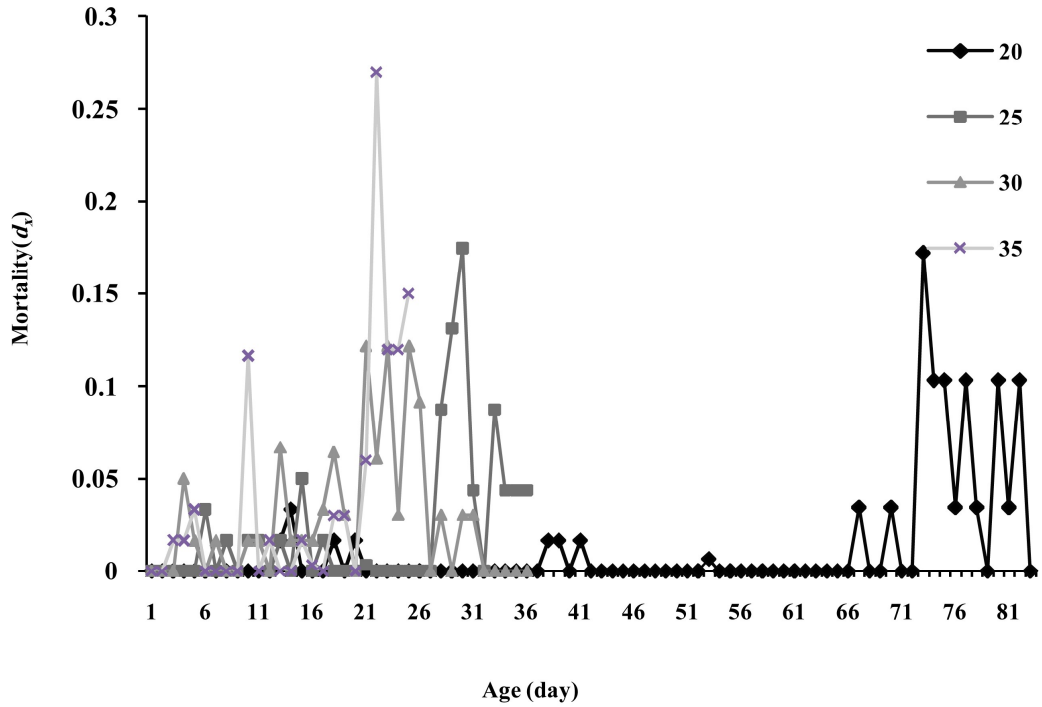

Fig. 3. Effect of temperature on mortality rate (d_x) of *Diaphania indica* at four constant temperatures.

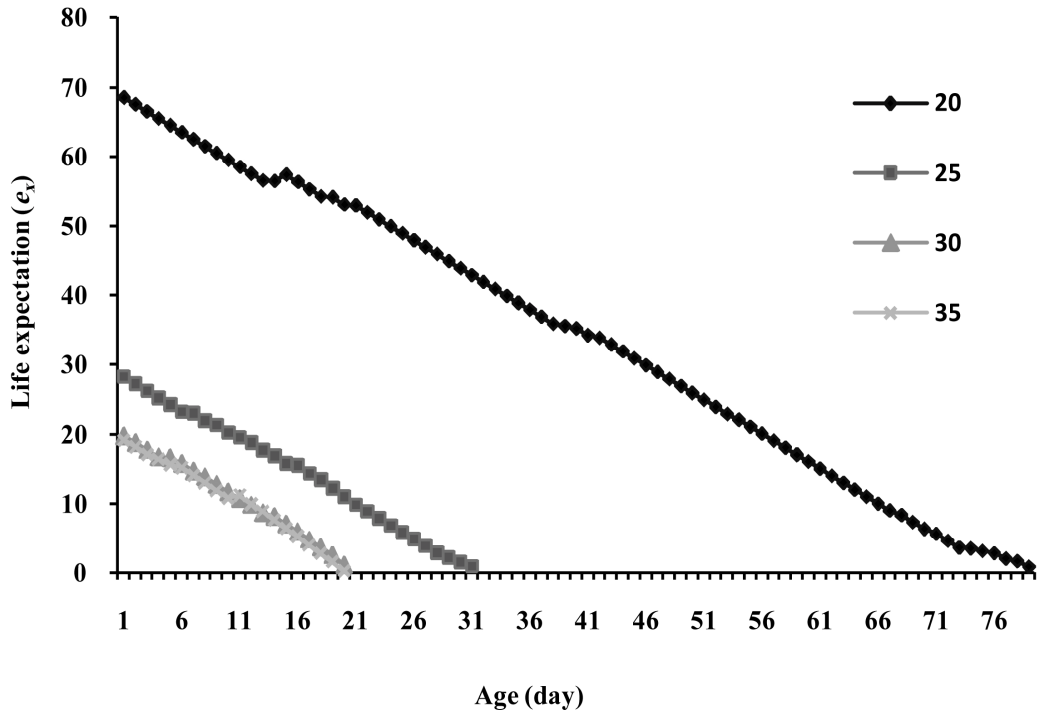

Fig. 4. Effect of temperature on life expectancy (e_x) of *Diaphania indica* at four constant temperatures

Table 1. Mean age specific reproduction parameters of *Diaphania indica* at four different temperatures.

Age specific reproduction parameters	Temperature (ºC)			
	20	25	30	35
Eggs / female / day	10.05	7.090	4.510	1.170
Fertile eggs / female/day	10.05	7.090	4.510	1.170
Mean age hatch	52.00	31.00	25.50	21.50
Mean age net fecundity	69.05	28.37	22.50	21.09
Mean age net fertility	69.05	28.37	22.50	21.09
Mean age gross fecundity	70.03	29.70	24.30	21.64
Mean age gross fertility	70.03	29.70	24.30	21.64
Net fertility rate	79.84	229.07	106.33	26.46
Net fecundity rate	79.84	229.07	106.33	26.46
Gross hatch rate	1.000	1.000	1.000	1.000
Gross fertility rate	92.50	306.95	222.39	35.67
Gross fecundity rate	92.50	306.95	222.39	35.67

Table 2. Mean (± SE) population growth parameters of *Diaphania indica* at four constant temperatures.

Life table parameters	Temperature (ºC)			
	20	25	30	35
Gross reproduction rate	72.31 ± 0.822 c	157.437 ± 2.536 a	123.897 ± 2.837 b	24.47 ± 0.754 d
Net reproduction rate	68.19 ± 0.827 b	120.977 ± 2.182 a	64.05 ± 1.077 c	21.23 ± 0.620 d
Intrinsic rate of increase	0.0619 ± 0.002 d	0.1746 ± 0.0009 b	0.1934 ± 0.0006 a	0.1491 ± 0.0016 c
Finite rate of increase	1.063 ± 0.0021 d	1.190 ± 0.001 b	1.213 ± 0.0007 a	1.160 ± 0.0018 c
Intrinsic birth rate	0.0624 ± 0.00018 d	0.1755 ± 0.00089 b	0.1959 ± 0.00061 a	0.1541 ± 0.00015 c
Death rate	0.0005 ± 0.0022 b	0.0008 ± 0.00001 b	0.0026 ± 0.00004 b	0.0049 ± 0.00016 a
Doubling time	11.32 ± 0.343 a	3.97 ± 0.0214 c	3.58 ± 0.0121 c	4.65 ± 0.055 b
Mean generation time	69.063 ± 2.274 a	27.45 ± 0.055 b	21.49 ± 0.042 c	20.44 ± 0.0231 c

Different letters in rows indicate significant difference at 5% level according to Duncan's multiple range test.

all temperatures was 100% but the highest survival rate was recorded at 20 °C and the values for R_0, r_m and T at 25 °C were 120.977, 0.174 and 27.45 days, respectively. Wang (1989) calculated the values of r_m at 28 °C and under natural day length for the second and third generations of *D. indica* 0.0792, 0.0487, respectively. Shine *et al*. (2002) studies on the impact of five hosts on the life table parameters of *D. indica* resulted in the highest survival rate for watermelon (76%) and the lowest for cucumber (50%). The value of T for melon was 47.2 days and R_0 and r_m for cucumber were 19.3 and 0.127, respectively. Differences in the present study with other studies could be attributed to geographical race of pest, rearing conditions, geographical temperature or method of calculating rm.

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