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Life history traits of melon ladybeetle, *Epilachna chrysomelina* (Col.: Coccinellidae), on four host plant species

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Abstract

Melon ladybeetle, *Epilachna chrysomelina* (F.), is one of the key insect pests of cucurbit crops in Asia and North Africa. The development and reproduction of *E. chrysomelina* were studied on watermelon, snake cucumber, cucumber and melon under laboratory conditions. Mean total life cycle from egg to adult female was 21.3, 21.7, 26.0, and 21.3 days on the mentioned host plants respectively. Mean immature mortality was 70.12%, 77.00%, 76.99% and 79.89% on the same four host plants. The female of *E. chrysomelina* oviposited means of 212.90, 377.85, 168.00 and 194.00 eggs and had a mean longevity of 28.77, 48.00, 38.55 and 28.36 days on watermelon, snake cucumber, cucumber and melon respectively. The net reproductive rate was 34.85, 48.82, 22.33 and 17.39 and daily intrinsic rate of increase was 0.095, 0.103, 0.073 and 0.077 on the respective plants. Life table statistics showed that snake cucumber was the most suitable host plant for *E. chrysomelina*, followed by watermelon and melon, with cucumber least suitable.

Key words: *Epilachna chrysomelina*, cucurbitaceous plants, biology, life table parameters

چکیده

کفشدوزک خربزه، *Epilachna chrysomelina* (F.)، یکی از آفات کلیدی گیاهان جالیزی در آسیا و شمال آفریقا می‌باشد. طول دوره‌ی رشد، تولید مثل و پارامترهای جدول زندگی این کفشدوزک روی گیاهان هندوانه، خیار چنبر، خیار و خربزه در شرایط آزمایشگاهی (دمای ۳۰ درجه‌ی سیلسیوس، رطوبت نسبی ٦۰ درصد و طول دوره‌ی روشنایی به تاریکی ١٤ به ۱۰ ساعت) مطالعه شد. میانگین طول دوره‌ی زندگی از تخم تا مرحله‌ی بلوغ ماده روی هندوانه، خیار چنبر، خیار و خربزه به‌ترتیب برابر با ۲۱/۳، ۲۱/۷، ۲٦، ۲۱/۳ روز بود. میانگین مرگ و میر پیش از بلوغ روی چهار گیاه میزبان مذکور به‌ترتیب برابر با ۷۰/۱۲، ۷۷، ۷٦/۹۹، ۷۹/۸۹ درصد به دست آمد. میانگین تخم‌گذاری *E. chrysomelina* ماده روی هندوانه، خیار چنبر، خیار و خربزه به‌ترتیب برابر با ۲۱۲/۹۰، ۳۷۷/۸۵، ۱٦۸، ۱۹٤ عدد تخم بود. میانگین طول عمر کفشدوزک ماده روی چهار گیاه مذکور به‌ترتیب برابر با ۲۸/۷۷، ٤۸، ۳۸/۵۵ و ۲۸/۳٦ روز محاسبه شد. نرخ خالص تولید مثل (R_0) روی گیاهان مذکور به‌ترتیب برابر با ۳٤/۸۵، ٤۸/۸۲، ۲۲/۳۳ و ۱۷/۳۹ و نرخ ذاتی رشد (r_m) به‌ترتیب برابر با ۰/۰۹۵، ۰/۱۰۳، ۰/۰۷۳ و ۰/۰۷۷ بود. پارامترهای جدول زندگی نشان داد که مناسب‌ترین میزبان گیاهی از نظر رشد و تولید مثل کفشدوزک خربزه، خیار چنبر بود و بعد از آن به‌ترتیب هندوانه، خربزه و خیار قرار گرفتند.

واژگان کلیدی: *Epilachna chrysomelina*، کدوئیان، زیست‌شناسی، پارامترهای جدول زندگی

Introduction

The melon ladybeetle, *Epilachna chrysomelina* (F.) is an oligophagous, multivoltine coccinellid beetle, occurring in Near East (Tilavov, 1981, 1985), Middle East (Talhouk, 1969; Azzam, 2001; Modares Awal, 2001) and North Africa (Ali & El-Saeady, 1981, 1983). The larva and adult feed on either side of the leaf in a very characteristic manner, leaving either the upper or the lower epidermises only which results in a leaf with scraped tissue, that later

turns light brown. Damaged leaves die after a short time (Talhouk, 1969; Ali & El-Saeady, 1981).

The rate of population increase of insects can be expressed as the intrinsic daily rate of increase (r_m). The intrinsic rate of increase depends on fecundity, rate of development, and longevity. Population changes, on the other hand, are caused by many factors including parasitism, predation, food availability and disease. When these factors are excluded, it is possible to evaluate the effects of any selected variable such as various plant species on population growth (Southwood, 1978).

The coccinellid genus of *Epilachna* Dejean includes important plant feeding pests such as *E. chrysomelina* (tropics), *E. varivestis* Mulsant (USA) (Fan *et al*., 1992), *E. niponica* Lewis and *E. yasutomii* (Katakura) (southeast Asia) (Shirai & Morimoto, 1997, 1999). The current study is intended to deepen our understanding of the biology of some aspects of life history of *E. chrysomelina* in relation to its host plant species in the laboratory. The effects of four host plants on preadult developmental time, survival, longevity, preoviposition period and fecundity are studied. The data is used to construct vital rate (l_xm_x) curves and to provide estimates of population growth rates based on its host plants.

Materials and methods

Melon ladybeetle stock colony

The laboratory stock colony was established two months before starting the experiments and consisted of 30 adult *E. chrysomelina* collected from a cucumber field located on the campus of Shahid Chamran University, Ahvaz, Iran (31° 20' N, 48° 40' E), in June 2008. The adults and larvae were put in ventilated, plastic boxes (25 × 18 × 10 cm) lined with the moist paper towel and fed on snake cucumber leaves three times a week. The boxes were placed in a growth chamber at 25 ± 1°C, 50 ± 5 RH, and a photoperiod of 14: 10 (L: D) h.

The following four host plant species were used in the study: cucumber, *Cucumis sativus* L., cultivar Superdominus; snake cucumber, *C. melo* L., cultivar Flexuosus; Melon, *C. melo* L., cultivar Shahabadi; and watermelon, *C. vulgaris* L., cultivar Charleston grey. All experimental plants were grown from seeds in plastic pots (20 cm diameter) and housed in wooden-framed rearing cages (120 × 60 × 60 cm) covered with white nylon mesh of 210 µm aperture. The wooden cages were held in the laboratory condition at ≈ 20 ± 2 °C and 50 ± 5% RH. The photoperiod was 14: 10 (L: D), using fluorescent lamps.

Developmental time and mortality

The egg masses were removed from the plastic boxes every 24 hours and placed in a cylindrical plastic container (10 cm diameter × 5 cm height) lined with moistened filter papers. Later, each larva was put into separate cylindrical plastic containers supplied with young leaves of the above-listed plants to avoid possible larval competition. A 10-mm diameter circular hole was made in the lid and covered with organdy mesh to allow ventilation and prevent condensation. The containers were placed in growth chamber (30 ± 1°C, 60 ± 5% RH and 14: 10 L: D) and egg to adult developmental time and mortality of immature stages recorded on each plant species. The exuviae were counted to find the total successful moltings.

Longevity and fecundity

The longevity and daily fecundity of *E. chrysomelina* were studied by placing newly emerged (< 24 h) males and females (obtained from developmental experiment) in cylindrical plastic containers similar to those described above. Each pair was provided with young leaves of the respective host plant species. The dead or runaway males were replaced with the young males (age < 24 h old). At the onset of reproduction, females and males were transferred daily for feeding on fresh leaves while their longevity (mean total adult life span) and fecundity (mean daily and total number of eggs laid per female) on different host plant species were being recorded. All eggs were transferred to new cylindrical plastic containers until adult eclosion and the sex ratio was calculated.

Data analysis - Demographic parameters

Age-specific natality (m_x) and survivorship (l_x) schedules were constructed for the *E. chrysomelina* cohorts on each host plant, and life table statistics were calculated by following the methods of Birch (1948), Andrewartha & Birch (1954) and Southwood (1978).

The intrinsic rate of increase of *E. chrysomelina* was computed separately for each of four host plants by iteratively solving the Euler equation: $\sum e^{-r_m x} l_x m_x = 1$; where l_x is the proportion of individuals alive at time x of an original cohort and m_x is the mean number of female offspring produced per surviving female during the age interval x (1 day). Values of m_x were obtained by dividing the mean number of eggs laid per female per day by two, assuming that females were laying eggs at the same 1:1 sex ratio found for adults (see below). Life table statistics, such as the net reproductive rate ($R_0 = \sum l_x m_x$, number of female offspring

produced per female), the finite rate of increase ($\lambda = e^{r_m}$, number of times the population would multiply itself per unit of time), a discrete form of intrinsic rate of increase), mean generation time ($T = \ln R_0 / r_m$), and doubling time ($DT = \ln 2 / r_m$, number of days required for the population to double in numbers) were also calculated. Differences in r_m and other life table statistics were tested for significance by estimating variances through the Jackknife technique.

Developmental time, mortality, longevity (mean total adult life span) and fecundity (mean number of eggs laid) on each host plant species were compared, using ANOVA (SAS Institute, 1997). Means were compared by fisher's LSD method.

Voucher specimens of *E. chrysomelina* are deposited at the Department of Plant Protection, Faculty of Agriculture, Shahid Chamran University, Ahvaz, Iran.

Results

Developmental time

The results showed that the time required for *E. chrysomelina* to complete its life cycle, was influenced by the type of host plant on which the beetle was reared (table 1). Analysis of variance indicated significant differences in developmental duration for female ($F = 52.88$; $df = 3, 104$; $P = 0.0001$) and male ($F = 46.97$; $df = 3, 112$; $P = 0.0001$). The ladybeetle *E. chrysomelina* was reared on all host plants. Mean duration from egg to adult female ranged from 21.30 days on melon and watermelon to 26.00 days on cucumber. The required time for completing the preadult stage on melon, watermelon, and snake cucumber was 18% shorter than the time it required to complete the stage on cucumber. The developmental period of the longest duration was 31 days, recorded for individuals reared on cucumber.

The mortality of juvenile coccinellids ranged from 70.12% on watermelon to 79.89% on melon (table 2) and the highest mortality occurred at egg and first larval stages. An ANOVA indicated no significant host plant differences among mean mortality of *E. chrysomelina* ($F = 0.76$; $df = 3, 38$; $P = 0.05232$).

ANOVA indicated that the host plant species was a highly significant factor affecting the longevity of both females ($F = 14.12$; $df = 3, 83$; $P = 0.0001$) and males ($F = 16.29$; $df = 3, 84$; $P = 0.0001$) (table 3). The maximum longevity observed for an individual coccinellid was 77 days for one female and one male on snake cucumber. ANOVA indicated significant overall host plant effect on mean total fecundity ($F = 3.92$; $df = 3, 50$; $P = 0.0139$) and mean daily fecundity ($F = 6.25$; $df = 3, 50$; $P = 0.0004$) (table 3). Peak of total and daily egg

productions occurred on snake cucumber (table 3) where the maximum number of eggs produced by an individual female was 905.

The sex ratio varied from 47.44% (Female) on snake cucumber to 56.16% on watermelon (table 3). ANOVA indicated no significant differences in sex ratio among host plant species (F = 0.36; df = 3, 25; P = 0.7833).

Table 1. Mean ± SE developmental time (days) of *E. chrysomelina* on four host plant species.

Sex	Stage	Watermelone	Snake cucumber	Cucumber	Melone
Male	Egg	4.4 ± 0.10a	4.4 ± 0.10a	4.3 ± 0.10a	4.4 ± 0.10a
	L1	3.2 ± 0.10b	2.8 ± 0.20b	3.9 ± 0.10a	2.8 ± 0.10c
	L2	2.1 ± 0.07c	2.6 ± 0.10b	3.09 ± 0.10a	2.2 ± 0.10c
	L3	2.9 ± 0.07b	2.8 ± 0.10b	3.7 ± 0.20a	3.1 ± 0.20b
	L4	3.2 ± 0.15b	3.2 ± 0.10b	5.0 ± 0.20a	3.3 ± 0.12b
	Pupa	5.6 ± 0.10b	5.6 ± 0.10b	6.1 ± 0.10a	6.1 ± 0.10a
	Total	21.5 ± 0.26b	21.4 ± 029b	26.0 ± 0.35a	21.9 ± 0.20b
	n	44	28	21	23
Female	Egg	4.2 ± 0.10a	4.28 ± 0.13a	4.2 ± 0.10a	4.4 ± 0.10a
	L1	3.0 ± 0.10b	2.9 ± 0.10b	3.7 ± 0.20a	2.4 ± 0.10c
	L2	2.3 ± 0.10b	2.5 ± 0.08b	3.2 ± 0.10a	2.5 ± 0.20b
	L3	2.8 ± 0.10b	3.1 ± 0.10b	3.6 ± 0.20a	2.6 ± 0.20b
	L4	3.2 ± 0.20b	3.3 ± 0.10b	5.0 ± 0.20a	3.5 ± 0.10b
	Pupa	5.7 ± 0.10b	5.6 ± 0.10b	6.4 ± 0.10a	6.0 ± 0.08b
	Total	21.30 ± 0.26b	21.7 ± 0.25b	26.0 ± 0.40a	21.3 ± 0.26b
	n	35	32	21	19

Means in a row followed by the same letter were not significantly different (α = 0.05, LSD).

Table 2. Percent mortality (mean ± SE) of *E. chrysomelina*, from egg to adult emergence, on four host plant species.

Stage	Host plant species			
	Watermelon	Snake cucumber	Cucumber	Melon
Egg	44.11 ± 6.13a	42.74 ± 5.84a	41.59 ± 6.50a	37.64 ± 6.29a
Range (n)	4.54-70.59 (13)	4.76-66.67 (13)	20.83-66.67 (7)	14.81-65 (8)
L1	13.01 ± 4.24a	10.49 ± 2.10a	16.38 ± 6.09a	12.7 ± 5.27a
Range (n)	0-45.71 (13)	0-25 (13)	0-35.71 (7)	0-36.17 (8)
L2	1.21 ± 0.83a	6.84 ± 2.53a	8.61 ± 6.12a	4.72 ± 3.59a
Range (n)	0-9.09 (13)	0-33.34 (13)	0-42.81 (7)	0-29.41 (8)
L3	0.89 ± 0.89b	4.12 ± 1.84b	1.85 ± 1.30b	19.10 ± 7.63a
Range (n)	0-11.53 (13)	0-22.23 (13)	0-8.82 (7)	0-7.69 (8)
L4	5.24 ± 1.80a	5.09 ± 2.14a	5.03 ± 2.81a	2.44 ± 1.17a
Range (n)	0-18.18 (13)	0-16.67 (13)	0-16.67 (7)	0-7.69 (8)
Pupa	5.65 ± 2.23a	6.66 ± 2.73a	3.97 ± 1.73a	3.29 ± 1.49a
Range (n)	0-27.27 (13)	0-28.57 (13)	0-12.5 (7)	0-10 (8)
Total	70.12 ± 4.50a	77.00 ± 3.02a	76.99 ± 6.94a	79.89 ± 3.03a
Range (n)	50-88.89 (13)	61.90-91.67 (13)	38.46-92.86 (7)	69.23-95 (8)

Means in a row followed by the same letter were not significantly different (α = 0.05, LSD).

Table 3. Longevity (in days) and fecundity of *E. chrysomelina* on four host plant species.

Parameters	Host plant species			
	Watermelon	Snake cucumber	Cucumber	Melon
Preoviposition period	11.50 ± 0.98b	10.35 ± 1.13b	18.85 ± 0.78a	13.70 ± 2.36b
Range (n)	9-18 (10)	5-21 (20)	13-24 (13)	5-28 (10)
Oviposition period	14.90 ± 2.75b	22.55 ± 3.01a	9.77 ± 1.26b	15.9 ± 3.39ab
Range (n)	7-31 (10)	3-45 (20)	5-20 (13)	3-32 (10)
Postoviposition period	5.90 ± 1.18	2.60 ± 0.60	8.30 ± 1.77	2.41 ± 0.76b
Range (n)	2-15 (10)	0-11 (20)	3-27 (13)	0-7 (10)
Longevity:				
Female	28.77 ± 1.36c	48.0 ± 3.61a	38.55 ± 2.53b	28.36 ± 3.08c
Range (n)	17-48 (30)	15-77 (22)	17-66 (20)	15-51 (14)
Male	29.16 ± 1.32c	52.64 ± 3.27a	42.25 ± 2.52b	39.45 ± 5.86b
Range (n)	18-49 (38)	24-77 (22)	28-62 (16)	15-61 (11)
Fecundity:				
Daily	6.21 ± 0.80a	8.51 ± 1.00a	3.05 ± 0.76b	6.41 ± 1.1a
Range (n)	0-21 (10)	0-31.78 (20)	0-22.38 (13)	0-40 (10)
Total	212.90 ± 42.62b	377.85 ± 60.06a	168.00 ± 18.15b	194.00 ± 54.38b
Range (n)	76-474 (10)	44-905 (20)	97-313 (13)	35-585 (10)
Sex ratio (female %)	56.16 ± 6.61a	47.44 ± 5.03a	52.38 ± 2.38a	49.33 ± 5.54a
Range (n)	38-75 (6)	25-70 (9)	50-57.14 (3)	25-80 (10)

Means in a row followed by the same letter were not significantly different ($\alpha = 0.05$, LSD).

The calculated daily intrinsic rates of natural increase (r_m), ranged from 0.073 for coccinellid beetles reared on cucumber to a maximum peak rate of 0.103 on snake cucumber (table 4). The finite rate of increase (λ) ranged from 1.070 times per individual per day on cucumber to 1.108 times per individual per day on snake cucumber (table 4). The time required to double the population size, reached a minimum of only 6.72 days on snake cucumber.

Table 4. Life table parameters (mean ± SE) of *E. chrysomelina* on four host plant species.

Parameters	Host plant species			
	Watermelon	Snake cucumber	Cucumber	Melon
r_m	0.095ac	0.103a	0.073b	0.077bc
Range	0.086-0.105	0.092-0.115	0.068-0.088	0.057-0.100
R_0	34.85ac	48.82a	22.33bc	17.39bc
Range	19.19-50.53	32.55-65.09	16.95-27.72	6.40-28.84
λ	1.100ac	1.108a	1.070b	1.080ac
Range	1.090-1.110	1.096-1.120	1.070-1.084	1.058-1.105
T	37.180b	37.680b	42.050a	36.960b
Range	33.660-40.090	41.160-42.910	34.93-40.46	33.870-40.91
DT	7.260bc	6.720bc	9.380a	8.97ac
Range	6.510-7.970	5.940-7.430	8.520-10.170	5.930-11.350

Means in each row followed by the same letter were not significantly different at the 0.05 level when tested by LSD test.

Discussion

The previously reported developmental time of 28.7 days at 30°C for *E. chrysomelina* (Ali & El-Saeady 1981), which is higher than our records, can be related to disparities in host plant suitability or population differences between the ladybird beetles. In an experiment with *E. chrysomelina* feeding on a mixture of watermelon and cucumber leaves, Saeb (1995) found the mean preadult mortality of % 85 which is close to our results.

The current data on mean total fecundity falls within the previously recorded ranges of reproductive parameters for *E. chrysomelina*. Mean total fecundity of the ladybird beetle was reported to be 296 on a mixture of cucumber and watermelon leaves at 25°C (Saeb, 1995), 302.5 on melon at 26°C (Girai, 1971) and 219.7 on courgette (Al-Iraqi & Farag, 1986). Ali & El-Saeady (1981) reported the mean total fecundity of 121, 316, 232 and 132 eggs on cucumber, snake cucumber, squash and watermelon, respectively.

The species of host plant did not influence the sex ratio of *E. chrysomelina*, which corresponds with Ali & El-Saeady (1981) who emphasized the independency of sex ratio of melon ladybird from its host plant. The study on the development and reproduction of *E. chrysomelina* on cucumber, snake cucumber, squash, and watermelon by Ali & El-Saeady (1981) led to the same results as ours for the most and least suitable host plants, snake cucumber and cucumber respectively.

All life table statistics varied with host plant species (table 4). The natality and survivorship curves (fig. 1) reflected the highest GRR of *E. chrysomelina* on snake cucumber and the lowest on cucumber. The intrinsic rate of increase (r_m) is an instantaneous growth rate of a population under a given condition. Hence, the interpretation of this statistics could be better made by its discrete analog, the finite rate of increase (λ). The finite rate of increase is the capacity for population growth per time unit. Host plant species had a striking effect on finite rate of increase (table 4). However, *E. chrysomelina* was found to be viable to increase its population ($\lambda > 1$) on all host plant species (table 4). The highest rate of population increase occurred on snake cucumber, whereas cucumber yielded the lowest rate of population increase.

Cardenas *et al*. (1978) reported r_m values for *E. varivestis* on bean of 0.366 and 0.183 at 25°C and ambient temperature respectively. Shirai & Morimoto (1997) reported r_m values of 0.125 and 0.123 for *E. niponica* reared on thistle and potato respectively. The values of r_m of *E. yasutomii* feeding on *Caulophyllum thalictroides* L. and potato were found by Shirai & Morimoto (1999) to be 0.145 and 0.226 respectively. The values of r_m of *E. chrysomelina* in

the current study were lower than the values cited above. These differences are likely due to intra-specific variations or can stem from different experimental conditions such as, photoperiod, relative humidity, and host plant species.

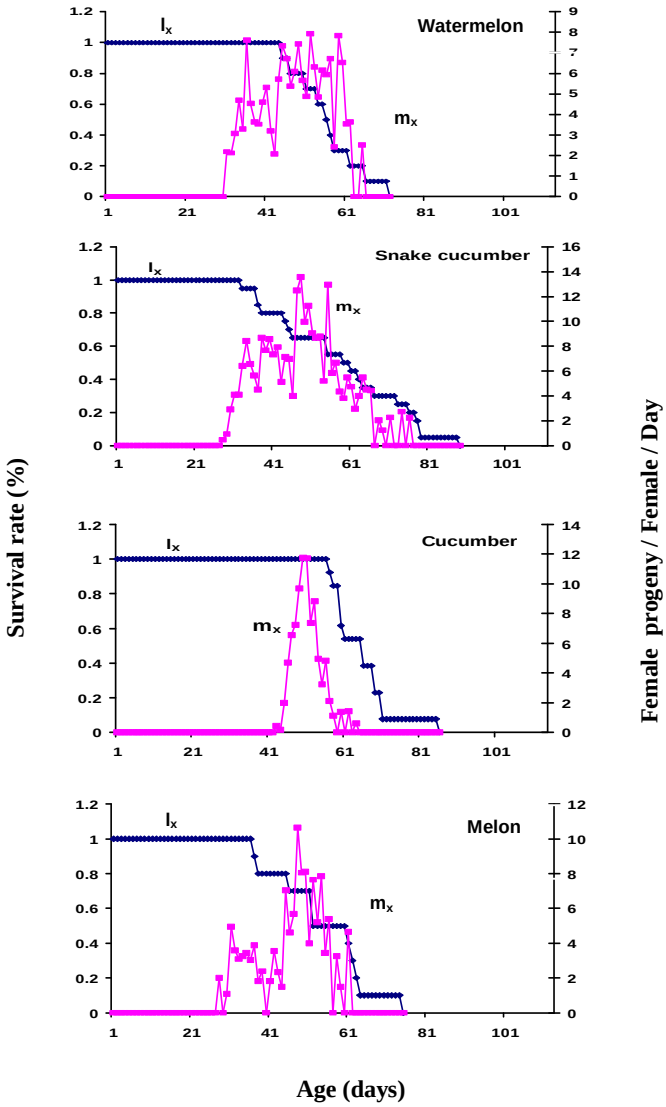

Figure 1. Survival rate (l_x) and daily proportion of female progeny per female (m_x) of *E. chrysomelina* feeding on watermelon, snake cucumber, cucumber and melon.

The results of this study suggest that the ovipositional strategy of female *E. chrysomelina* is to lay small numbers of eggs over a long period. MacArthur & Wilson (1967) characterized the species with a long life span and a relatively low fecundity, as k-selected species. Generally, k-species allocate more energy to efficiently use the environmental resources than to maximization of the reproductive rate (r-selected species). We believe that *E. chrysomelina* is a k-species and well-adapted to tropical environments (Landhall & Root, 1969). It is widely distributed throughout tropical habitats of Iran, Saudi Arabia, Lebanon, Turkey and Egypt (Talhouk, 1969; Girai, 1971; Ali & El-Saeady, 1981, 1983; Azzam, 2001; Modares Awal, 2001).

The results of this investigation indicated that snake cucumber was the most suitable host plant for development and reproduction of *E. chrysomelina*, while cucumber was its least favorite one. The susceptibility of the host plants should be taken into consideration for launching any pest management program in relation to the coccinellid pest *E. chrysomelina* in southwestern Iran.

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