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Orijinal araştırma (Original article)

The life table of the lucerne beetle, *Gonioctena fornicata* (Brüggem) (=*Phytodecta fornicatus* Brüggem) (Coleoptera, Chrysomelidae) on alfalfa under laboratory conditions[1]

Yonca Yaprakböceği, *Gonioctena fornicata* (Brügg.) (= *Phytodecta fornicatus* Brüggem) (Coleoptera, Chrysomelidae)'nın laboratuvar koşullarında yonca üstünde yaşam çizelgesi

Davut EFE[2] **Mehmet Salih ÖZGÖKÇE*[3]**

Summary

In this study, the life table of *Gonioctena fornicata* (Brügg.) was constructed at 25±1 ºC constant temperature, 60±5% relative humidity and 16:8 light:dark period in a climate cabinet. Life table parameters were calculated using the Euler-Lotka iteration method and their values were: Intrinsic rate of increase (r_m), 0.015; Net reproductive rate (R_o), 180.25 females/female; Mean generation time (T_o), 353.03 days; Gross reproductive rate (*GRR*), 287.93 females/female; Doubling time, (T_2) 47.11 days and Finite rate of increase (λ), 1.02 females/female. The fecundity rate was fitted in the Enkegaard equation and parameters were calculated as a = 0.886±0.055 ; b = 0.052±0.002. Mean development times for both sexes were: egg, 5.07, 2.85 days; larvae1, 2.83, 2.72 days; larvae2, 2.10, 2.36 days; larvae3, 2.15, 2.29 days; larvae4, 4.46, 4.29 days; pupae, 7.92, 7.69 days; total development time, 24.40, 24.32 days for females and males, respectively. Additionally, preoviposition, oviposition, postoviposition and generation times were 305.53, 32.73, 30.07 and 331.60 days, respectively. Life span of females was 366.07 days and it was 371.7 days for males. The best survivership curve was fitted to the Weibull distribution; its shape was defined as a Type I survivorship pattern and the calculated parameters were: b = 382.14±0.429 and c = 11.34±0.231.

Key words:*Gonioctenafornicata*, life table, Enkegaard equation, Weibull distribution, *Medicago sativa*, life curves

Özet

Bu çalışmada *Gonioctena fornicata* (Brügg.)'nın 25±1 ºC sabit sıcaklık, %60±5 orantılı nem ve 16:8 saat aydınlık periyodu koşullarında yaşam çizelgesi oluşturulmuştur. Yaşam çizelgesi parametreleri Euler-Lotka iterasyon yöntemine göre hesaplanmış ve buna göre Kalıtsal üreme yeteneği (r_m), 0.015; Net üreme gücü (R_o), 180.25 dişi/dişi; Ortalama döl süresi (T_o), 353.03 gün; Toplam üreme oranı (*GRR*), 287.93 dişi/dişi; Populasyonun ikiye katlanma süresi, (T_2) 47.11 gün; Artış oranı sınırı (λ), 1.02 dişi/dişi olarak hesaplanmıştır. Üreme oranı için en uygun eğri denklemi Enkegaard eşitliği ile sağlanmış ve parametreler, a = 0.886±0.055 ; b = 0.052±0.002 olarak bulunmuştur. Her iki eşey için ortalame gelişme süreleri dişi ve erkek eşeylere göre sırasıyla şöyle kaydedilmiştir: yumurta, 5.07, 2.85 gün; larva1, 2.83, 2.72 gün; larva2, 2.10, 2.36 gün; larva3, 2.15, 2.29 gün; larva4, 4.46, 4.29 gün; pupa, 7.92, 7.69 gün; toplam gelişme süreleri, 24.40, 24.32 gün. Buna ilaveten, preovipozisyon, ovipozisyon, postovipozisyon ve döl süresi sırasıyla 305.53, 32.73, 30.07 ve 331.60 gün olarak kaydedilmiştir. Ömür uzunluğu dişi için 366.07 ve erkek için 371.7 gün olarak kaydedilmiştir. Canlılık oranına göre en uygun hayat eğrisi Weibull dağılımı ile hesaplanmış ve *G. fornicata*'nın canlı kalma oranının Tip 1 hayat eğrisine uyduğu belirlenmiştir. Eşitlikte hesaplanan parametreler b = 382.14±0.429 ; c = 11.34±0.231 olarak kaydedilmiştir.

Anahtar sözcükler:*Gonioctenafornicata*, yaşam çizelgesi, Enkegaard eşitliği, Weibull dağılımı, *Medicagosativa*, hayat eğrileri

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[2] Bingöl University, Agriculture Faculty, Department of Plant Protection, Bingöl

[3] Yüzüncü Yıl University, Agriculture Faculty, Department of Plant Protection, Van

* Sorumlu yazar (Corresponding author) e-mail: msozgokce@gmail.com
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Introduction

The Lucerne Beetle, *Gonioctena fornicata* damages alfalfa, trifolium and other Fabaceae species, and is listed as a quarantine pest in various countries. It has been reported from in Central and Southern Europe, the Middle East including Turkey, Eastern Europe, Ukraine and Moldova (Popova, 1966; Lustun&Panu, 1968; Apostolov, 1988).

Gonioctena fornicata was the first time recorded in Turkey in 1946 by Alkan (1946) (in Kovancı, 1982). Bodenheimer (1958) reported that it caused significant damage in Central Anatolia. Later studies showed the presence of this pest in Adana, İzmir, Aksaray, Ankara, Nevşehir, Konya, Yozgat, Erzurum, Erzincan, Bursa, Diyarbakır, Gaziantep, Artvin provinces, and caused significant damage on alfalfa (Kısmalı, 1973; Kovancı, 1982; Kasap, 1988; Yıldırım et al., 1996; Aslan et al., 2003; Coşkuncu&Gençer, 2006).

Although *G. fornicata* sometimes causes serious epidemics on alfalfa there is a limited literature on it. Since, it requires a very long period for laboratory studies. It has very long hibernation and aestivation periods close to alfalfa roots and has only one generation in a year. Lustun&Panu (1968) reported that this species was a very important alfalfa pest in Braşov area that fed on alfalfa from April to July. Bronshkik (1987) stated that both adults and larvae of *G. fornicata* eat the leaves, flowers, leaf buds, young shoots and leaf stalks of alfalfa. Coşkuncu&Gençer (2006) reported that *G. fornicata* was sometimes confused with *Coccinella septempuctata* L. (Col.: Coccinellidae) on alfalfa in the Bursa area. Ghavami et al. (1998) reported that *G. fornicata* old and new generations attacked alfalfa fields and caused heavy damage in Adana. The objective of this study was to determine the detailed life table parameters of *G*. *fornicata* under laboratory conditions.

Materials and Methods

The Lucerne beetle, *G. fornicata* and Alfalfa plants (*Medicago sativa* L.) (Elçi cultivar) were obtained from alfalfa production areas at the Faculty of Agriculture of Çukurova University Research and Application Area, Turkey. *G. fornicata* were collected from alfalfa field and then transferred to laboratory to start the experimental population. The individuals were placed in each transparent plastic rearing box (12 cm × 8 cm × 7 cm) with 0.5 cm of moist sponge-drying paper at the bottom and covered with densely woven nylon net, to provide sites for egg laying. Fresh, young alfalfa plants (approximately 10 cm long) with abundant leaves were placed in the rearing boxes and their roots were kept moist to maintain freshness.

Young females that had newly laid eggs were transferred to a new rearing box, thus providing an adequate number of eggs and hatching periods. Newly hatched first-stage larvae were transferred to rearing boxes with a fine, soft brush, to determine larval development and pupa stages. Then the larvae were numbered and larval exuvias were removed, the related stage was measured in hours and was converted into days for evaluation.

The rearing boxes in which larvae were kept were substituted every 2 days with new rearing boxes for fresh food continuity. After the pupa stage, newly emerged adults were transferred rearing cages containing fresh alfalfa plants in pots. Rearing boxes consisted of two components; the pots were 20 cm by 10 cm diameter. A jar (25 cm high, 8 cm diameter) was placed on top of the pot. Ventilation holes (10 cm long, 8 cm wide) were opened on both sides. The holes were covered with densely, woven nylon mesh. New adults with known codes were transferred individually to these cages with pots. Then the cages containing pots were kept in outside conditions. These nourished adults migrated onto plant roots firstly for estivation and then overwintering. The adults that completed the combined estivation and overwintering periods emerged from the soil and moved to plants in the following spring. They fed on alfalfa plants in the pots; plants were renewed as required. During observations, copulating males collected in the field and their elytra were marked to distinguish them from other experimental specimens,

and they were transferred to cages of other adult individuals. Individuals in rearing cages were constantly observed 2 hours intervals to determine the copulation pairs during the daytime.

During observations, male and females were identified and numbered as mated individuals. Every identified pair was kept in the same rearing cage until the end of the experiment. The numbers of eggs laid by females were recorded daily; the eggs were then removed together with the host leaf. Rearing cages were replaced with new cages weekly. The experiments continued until the death of the last individual.

Experiments were conducted in a climate room at 25±1°C, 65±5% relative humidity and 16:8 h light:dark period at 4000 lux. Rearing boxes and rearing cages were kept in the climate cabinet, except during the estivation and hibernation periods. Laboratory observations were done at 8 hours intervals.

Life table

The Age-specific life table parameters of *G. fornicata* were calculated at constant temperature, according to Euler-Lotka equation (Birch, 1948). All parameters were determined by using RmStat-3 (Özgökçe& Karaca, 2010).

The following parameters:

Age-specific survivor (l_x) and fecundity rate (m_x), (Birch, 1948),

Net reproductive rate, $R_0 = \sum l_x.m_x$ (Birch, 1948),

Intrinsic rate of increase (r_m), $\sum e^{(-r_m.x)}.l_x.m_x = 1$ (Birch, 1948),

Mean generation time, $T_0 = \frac{\ln.R_0}{r_m}$ (Birch, 1948),

Gross reproduction rate, $GRR = \sum m_x$ (Birch, 1948),

Finite rate of increase, $\lambda = e^{r_m}$ (Birch, 1948),

Doubling time, $T_2 = \frac{\ln 2}{r_m}$ (Kairo & Murphy, 1995)

Reproductive value, $V_x = \frac{\sum_{y=x} (e^{r_m.y}.l_y.m_y)}{l_x.e^{-r_m.x}}$ (Imura, 1987),

Life expectancy, $E_x = \frac{\sum_{y=x} \frac{l_y + l_{y+1}}{2}}{l_x}$ (Southwood, 1978; Carey, 1993),

Stable age distribution, $C_x = \frac{l_x.e^{-r_m.x}}{\sum_{x=0} (l_x.e^{-r_m.x})}$ (Birch, 1948),

The Weibull frequency distribution was used to describe the age-specific survival of all individuals (Pinder et al., 1978):

$$S_p(t) = e^{\left[-\left(\frac{t}{b}\right)^c\right]} \qquad t, b, c > 0$$ (Deevey, 1947)

where $S_p(t)$ represents the probability of surviving to a given age, b is the parameter that describes the scale, c is shape of the curve and t is time. The shape parameters c>1, c=1 and c<1 correspond to type I, II and III survivorship curves, respectively (Deevey, 1947; Pinder et al., 1978).

Statistical analyses were done by using following softwares; CurveExpert pro (ver. 1.6.7), SPSS (ver. 17), MS Excel (ver. 2003).

The Age-specific number of eggs laid by a female during the oviposition period was described by the Enkegaard equation:

$F(x) = a.x.e^{(-b.x)}$ (Enkegaard ,1993; Hansen et al., 1999)

where *F(x)* is the Daily age-specific fecundity rate (eggs/female/day), *x* is the female's age in days, *a* and *b* are constants. Day 1 is the first day of the oviposition period. Development times of males and females were determined by using the t-student test. Analayses were done with JMP (ver. 5), MS Excel (ver. 2003) and SPSS, (ver. 17) softwares.

Results and Discussion

After the egg stage, the total average development times of *G. fornicata* males and females were 24.32 and 24.40 days, respectively (Table 1). Newly emerged adults fed on plants for 2–9 days, then migrated into the soil for estivation and overwintering. Following the estivation period, the overwintered adults emerged after approximately 300 days, then they fed on the plants and mated. Following a preoviposition period of approximately 305 days, the insects produced their first eggs after approximately 331 days. The oviposition period lasted approximately 32.73 days, during which females laid an average of 12.72 (male + female) eggs per day (total of 490.47 male + female eggs). The sex ratio was 0.49 (F/(F+M)). This result is close to that of Coşkunsu and Gençer (2006).

Table 1. Mean development times and longevity of *Gonioctena fornicata* maleandfemales

Stages	Sex	N	Mean±SE	P*
Egg	Female	20	5.07±0.098	0.142
	Male	20	2.85±0.105	
Larvae 1	Female	20	2.83±0.192	0.632
	Male	20	2.72±0.112	
Larvae 2	Female	16	2.10±0.088	0.130
	Male	17	2.36±0.143	
Larvae 3	Female	16	2.15±0.114	0.445
	Male	16	2.29±0.140	
Larvae 4	Female	16	4.46±0.250	0.703
	Male	15	4.29±0.355	
Pupae	Female	16	7.92±0.324	0.673
	Male	15	7.69±0.415	
Total development times	Female	16	24.40±0.307	0.866
	Male	15	24.32±0.380	
Preoviposition		15	305.53±1.796	
Oviposition		15	32.73±5.186	
Postoviposition		15	30.07±5.959	
Generation time		15	331.60±1.712	
Life span	Female	15	366.07±7.298	0.576
	Male	15	371.70±6.758	
Daily eggs		15	12.72±1.244	
Total eggs		15	490.47±62.795	

* Within columns, means between sexes differ significantly (t-test, P< 0.05).

Lifetable parameters for the development, reproduction and survival ratios of *G. fornicata* are presented in Figures 1 and 2 and Table 2. In both genders, 25% of the population died in the pre-adult stage and the remaining adults survived the long preoviposition period (305.53 days). Females laid their first eggs on the 328^{th} day. After that date, the number of laid eggs increased rapidly during the first 8–9

days and peaked at the 15th day. The daily numbers of eggs then slowly decreased and the last egg was laid on the 451st day. This curve was identified via the Enkegaard equation, and the calculated parameters are presented in Figure 3.

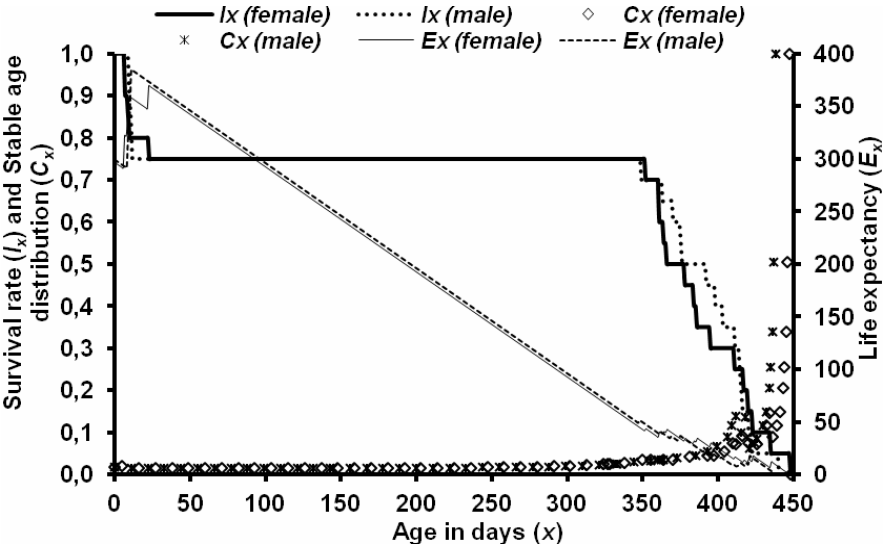

Figure 1. Survival rate (l_x), Stable age distribution (C_x) and Life expectancy (E_x) of *Gonioctena fornicata* of both genders.

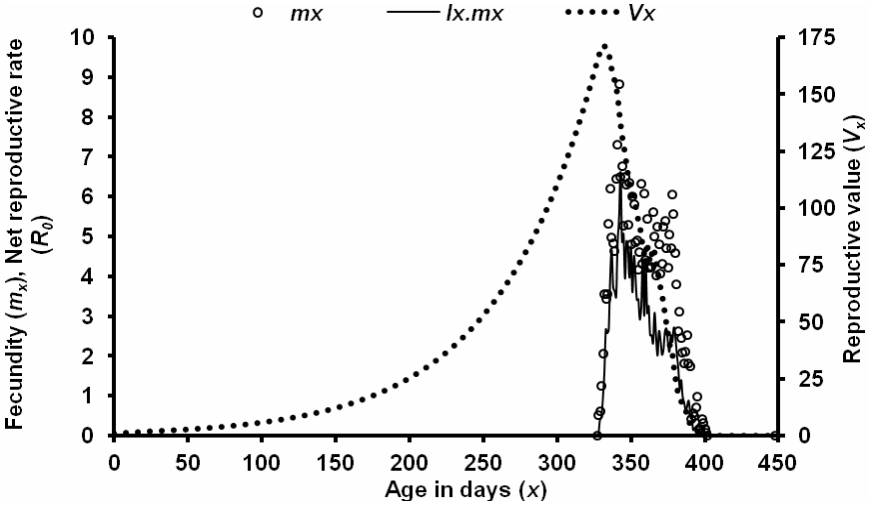

Figure 2. Fecundity (m_x), Net reproductive rate (R_0) and Reproductive value (V_x) of *Gonioctena fornicata*.

Table 2. The Life table parameters of *Gonioctena fornicata*

Parameters	
Intrinsic rate of increase,r_m	0.015
Net reproductive rate, R_o	180.25 females/female
Mean generation time, T_o	353.05 days
Gross reproduction rate, *GRR*	287.93 females/female
Doubling time,T_2	47.11 days
Finite rate of increase,λ	1.02 females/female
n	20

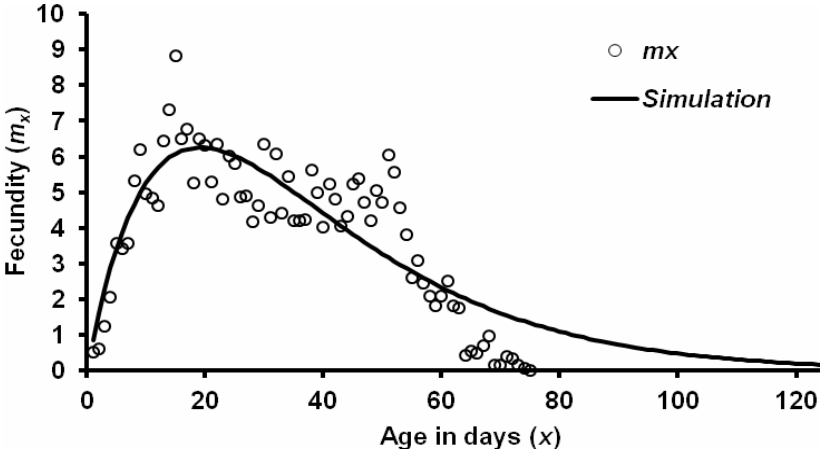

Figure 3. Age-specific fecundity (females/female/day) of *Gonioctena fornicata* as a function of female adult age (days) (Parameters: a = 0.886±0.055 ; b = 0.052±0.002; R^2 = 0.868).

The optimum curve equation for the model was obtained via non-linear regression and parameters were: a = 0.886±0.055; b = 0.052±0.002; correlation coefficient (R^2) = 0.868. The females laid eggs every day during the oviposition period. The mean generation time (T_0) calculated from the period during which 50% of eggs were laid, was 353.05 days (Table 2). In the first half of the oviposition period, the average number of eggs/day was 4.93 (females/female), compared with 3.18 (females/female) in the second half.

At the end of the oviposition period, the average total number of eggs/female *(GRR)* was 287.93 and net reproductive rate (R_0) was 180.25 (Table 2). This substantial difference resulted from the death of 25% of the population by the 323rd day, when reproduction started, in the pre-adult stage and sharp reduction of survival ratio during oviposition (Figure 1). The reproductive value (V_x) also showed a sharp increase, particularly between 250th and 300th days and peaked at the 332nd day, 5 days after the first egg laying. This value rapidly decreased in the following days, matching to increased death rates. After this period, 30% of the remaining population survived for approximately one month without laying eggs (Table 1, Figure 2).

The intrinsic rate of increase ($\boldsymbol{r_m}$), which was 0.015, was defined by Andrewartha and Birch (1954) as a parameter that exactly summarizes the physiological properties of a species. The theoretical population-doubling time ($\boldsymbol{T_2}$) was 47.11 days, while the increase rate limit was ($\boldsymbol{\lambda}$) 1.02 (Table 2). However, despite the calculation of various lifecycle parameters, the intrinsic rate of increase alone is the most important factor especially at the comparisions with eachother of different populations.

The Weibull distribution was used to determine the curve that best describes the survival ratio of *G. fornicata*, and parameters were: b = 382.14±0.429, c = 11.34±0.231, R^2 0.876 for females; and b = 388.25±0.318, c = 14.51±0.568, R^2 = 0.796 for males (Figure 4). Accordingly, the parameter that explains the form of the curve for both genders is c > 1. With this value, survival curve fits the type 1 life curve. The advantages of the Weibull distribution as a survival curve include considerable flexibility of curve equation, ability to form statistical curves, and ability to draw significant ecological implications from model parameters (Hogg & Nordheim, 1983). Secondly, the model' parameters allow the determination of the forms of three types of basic survival curves, as defined by Pearl & Miner (1935) (Hogg & Nordheim, 1983). The c parameter is calculated from the curve equation and determines the form of the curve; If c> 1, the life curve of the population is then defined as a type 1 life curve, in which the death ratio increases as a function of age. For a type 2 life curve, c = 1 and the death ratio is constant, rather than age-dependent. For a type 3 life curve, c < 1, and death ratio decreases as a function of age (Pinder et al., 1978; Hogg and Nordheim, 1983).

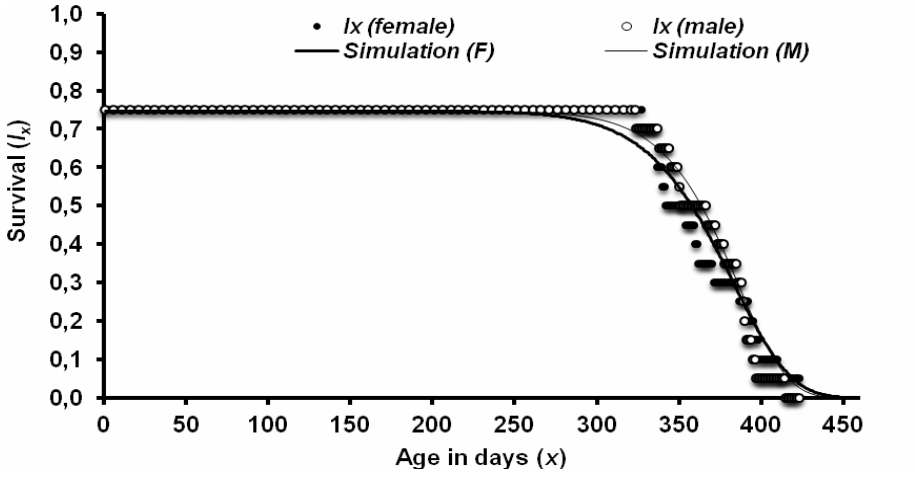

Figure 4. Survival probability of males and females of *Gonioctena fornicata* and lines of best fit by Weibull function (Parameters: Female, b = 382.14±0.429,c = 11.34±0.231, R^2 = 0.876; Male, b = 388.25±0.318,c = 14.51±0.568, R^2 = 0.796).

The age-dependent life expectancy (E_x) and stable age distribution (C_x) of *G. fornicata* were calculated for both genders and are presented in Figure 1. Both parameters were approximately the same for gender. Although the life expectancy rate affected negatively in the pre-adult stage with 25% death ratio, the relatively long survival period (approximately 330 days) of the adult stage caused life expectancy to increase to 370 days. Life expectancy in the adult period declined linearly until the first deaths were observed in 330th day. After that time, despite high death ratios, life expectancy showed a slight increase.

Stable age distribution remained almost constant during a significant part of the pre-adult and adult stages of the insect's life cycle. During the oviposition and post-oviposition periods the death ratio increased rapidly. In addition, the intrinsic rate of increase was inversely correlated with survival ratio.

In the current experiment, 75% of *G. fornicata* population survived to maturity. Coşkunsu and Gençer (2006) reported as 73.3% survival of the same species in their study at 21.5°C. Over the very long lifecycle of the beetle, the death ratio increased significantly within a short period of the final stage of life. As a result, parameter c was found to be much greater than 1. *G. fornicata* has a high epidemic potential due to high population ratio. Not surprisingly, this species is known to cause significant damage to alfalfa crops in some years. Culture methods appear to be the most adequate control measures for the lucerne beetle. Early harvesting in end of April, before the peak in larvae infestation occurred will most likely strongly reduce the population density of *G. fornicata.* An additional contact insecticide application just after harvesting may increase the control success of the lucerne beetle.

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