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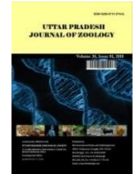

EFFECT OF TEMPERATURE ON THE LIFE HISTORY OF *Megacopta cribraria* (F.) (Hemiptera: Plataspidae) REARED ON *Lablab purpureus* (L). (Fabaceae: Lablab)

M. S. SHAMYASREE[1*] AND SACHIN P. JAMES[1]

[1]PG & Research Department of Zoology, Malabar Christian College (Affiliated to University of Calicut), Kerala 673001, India.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration between the authors. Author MSS managed the analyses, literature search and performed the study. Author SPJ designed the study, wrote the protocol, did the statistical analysis and wrote the final draft of the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

We evaluated the impact of five constant temperatures (15-35°C) on the development, survival, longevity and life table parameters of *Megacopta cribraria* (F.), on *Lablab purpureus* under laboratory conditions. The developmental time from egg to adult was negatively correlated with temperature. Temperatures between 20-30°C were ideal for development of *M. cribraria.* Eggs did not hatch at 15°C and the 3rd nymphal stage failed to molt to the next instar at 35°C. Female bugs exhibited highest fecundity and shortest development time at 30°C. Adult pre-oviposition period and total pre-oviposition period of females were highest at 20°C and decreased sharply at higher temperatures. Similarly, adult longevity was lowest at 30°C and highest at 20°C. The intrinsic rate of natural increase *rm* (0.09), finite rate of increase λ (1.09) and net reproduction rate R_0 (1.87) were greatest at 30°C. These results improve our understanding of the effects of temperature on development, reproduction and population dynamics of *M. cribraria,* which may be used to develop improved pest management strategies.

Keywords: *M. cribraria*; *Lablab purpureus*; intrinsic rate of increase; net reproduction rate.

1. INTRODUCTION

Megacopta cribraria (F.) (Hemiptera: Plataspidae), also known as the kudzu bug, is a potential pest of *Lablab purpureus* (L.) in India, especially in Madhya Pradesh and Karnataka [1]. *Megacopta cribraria* was described by Fabricius [2] in 1798 as *Cimex cribrarius* and since then several species have been placed in several genera, *Tetyra*, *Thyreocoris* and *Coptosoma*, before being placed in the genus

**Corresponding author: Email: shamyasreems@gmail.com;*

Megacopta Coptosoma xanthochlora [3] as a synonym. The adult bugs are small 3.5-6.0 mm in length, square in outline and dorsally convex giving them a rounded oblong shape. The dorsal side of the insect is covered in numerous dark punctations and is typically light brown to greenish yellow in colour. The scutellum is enlarged and width nearly 1.5 times length which covers the forewings and most of the abdomen. Female bugs are slightly larger than males possessing a pale venter around y-shaped terminal sternites and triangular genital segments while males have rounded, darker terminal sternites with a circular genital segment [4,5]. This pest is considered native to Asia and Indian subcontinent. It is also adventive in Australia, Georgia and USA. In the USA, *M. cribraria* was first reported in 2009 in Atlanta, Georgia on kudzu, *Pueraria montana* Merrill, an invasive weed [6]. The insects are voracious feeders on kudzu, but also feed on numerous agricultural crops, particularly soya bean (*Glycine max* (L.) Merrill) [7], lablab bean [8]. Pigeon pea (*Cajanus indicus* Spreng) [9], *Phaseolus* [10,11], broad beans (*Viciafaba* L.) [12], peach (*Amygdalus persica* Linn), plums (*prunus* spp.) and jujube (*Ziziphus jujube* Mill.) [13,14,15] are some additional hosts of the kudzu bug.

The primary reproductive hosts of this bug in Georgia include kudzu and soya bean [5]. In soya bean, both adults and nymphs feed on tender stems and leaves, causing purple spots on the latter. Heavy feeding can result in extensive defoliation [16]. Copious honeydew from the bug causes sooty mould growth that covers stems and leaves, reduces photosynthesis and ultimately results in yield loss [17]. The kudzu bug has caused serious damage and yield loss in soya bean crop along the central and southern China [13,14,15,18].

Eger et al. [4] provided information on the host plants, biology and distribution pattern of *M. cribraria.* Zhang et al. [5] studied the biology of *M. cribraria* on different host plants and demonstrated that soya beans were preferred hosts compared to other legumes. The kudzu bug successfully developed on caged potted soybeans in a greenhouse study [19].

Huffaker [20] reported that temperature plays a major role in the longevity, fecundity and development of insects. Life tables were used as a powerful tool to monitor the influence of various biotic and abiotic factors on the growth, survival, reproduction and intrinsic rate of increase of insect populations. In the present study, the role of different constant temperatures on the life history of *M. cribraria* was studied. The results obtained from the study would be useful for predicting the phenology and population dynamics of this insect and developing effective control measures against this nuisance pest.

2. MATERIALS AND METHODS

2.1 Insect, Host Plant and Mass Culturing

Eggs, nymphs and adults of *M. cribraria* were collected from a *L. purpureus* (L.) field (Malaparamba, Lat. 11.292975, Long-75.803572) in Kozhikode district, Kerala, India. Field-collected individuals were transferred to plastic jars (25 by 27.5 cm) for mass culturing in the lab. The top of the jars was covered with muslin cloth to avoid the escape of bugs and to prevent the contamination of system from external medium. Each jar was provided with a fresh lablab stem with leaves (tender shoot with 4 to 5 leaves) wrapped at the cut end with watery cotton and kept inside a small plastic jar (5 by 1 cm) filled with 10% sugar solution. The lablab stem was replaced daily. Stem (tender shoot) laden with *M. cribraria* eggs were scrutinized, kept in separate Petri dishes and maintained until first instar nymphs emerged. These nymphs were transferred to fresh tender shoots of lablab enclosed in plastic jars. The laboratory colonies were maintained at room temperature (28±2°C) and 80±5% RH with a 14:10 L:D photoperiod. Third generation nymphs were used for life table experiments.

2.2 Developmental Time and Survivorship

Newly laid eggs were collected from mass culture and transferred into dishes (8-cm-diameter). These dishes were then placed into an environmental chamber with different cabins that could be set at five different constant temperatures simultaneously (15, 20, 25, 30 and 35°C). Each chamber was maintained at constant relative humidity of 83±3% and a photoperiod of 14L:10D. Two replicates were conducted for each temperature. We recorded the total number of eggs that hatched at each temperature and the duration of development of each egg. First instar nymphs were individually collected and transferred into plastic jars using a thin paint brush and kept inside the same cabins in which they had been maintained as eggs. Fresh lablab shoots, wrapped with cotton, and soaked in 10% sucrose solution were provided as a food source. The nymphs were maintained in the cabin until death or completion of development to adults. The nymphs were checked daily for ecdysis, based on the presence of cast skin, and daily records kept on survival and duration of each nymphal stage.

2.3 Oviposition Period, Fecundity and Longevity

Upon emergence, adults were paired, placed in separate plastic jars (25 by 27.5 cm) which were then covered with muslin cloth and maintained in respective cabins at different constant temperatures as described above. Eggs were collected daily from each plastic jar and fecundity and survival were recorded daily until the death of all females. Adult pre oviposition period (APOP; the time period between adult female emergence and the onset of oviposition), total pre oviposition period (TPOP; the period counted from egg to first oviposition) oviposition period, daily fecundity, total fecundity and longevity of adults were recorded daily for each temperatures.

2.4 Life Table Parameters

Data on development, survival and reproduction of *M. cribraria* at different temperatures were used to calculate the net reproductive rate (Ro= ∑lx mx), mean generation time (T = ∑x lxmx/ Ro), finite rate of increase ($\lambda = e^{rm}$) and intrinsic rate of increase (rm = $\log_e$ Ro/T), where lx is age specific survival rate and mx is age specific fecundity. Life tables were prepared for each temperature according to Birch [21] and Atwal and Bains [22].

2.5 Data Analysis

One way analysis of variance (ANOVA) were performed using SPSS 16.0 software to compare developmental time, fecundity, longevity, pre oviposition period and oviposition period of *M. cribraria* at different constant temperatures Means were compared using Student-Newman-Keuls Test with a level of significance at 0.05.

3. RESULTS

3.1 Effect of Temperature on Developmental and Survivorship

Duration of egg development and different nymphal stages of *M. cribraria* differed significantly among the five different constant temperature (Table 1). Eggs maintained at 15°C failed to hatch, hence further use of this temperature in our study was discontinued. The developmental times of different immature stages of *M. cribraria* decreased significantly with increases in temperature (egg: $F_{3,36}$ =684.419; P<0.05. 1st instar: $F_{3,36}$ =655.304; P<0.05. 2nd instar: $F_{3,36}$ =615.145; P<0.05. 3rd instar: $F_{3,36}$ =2.192; P<0.05. 4th instar: $F_{3,36}$ = 1.573; P<0.05. 5th instar: $F_{3,36}$ =3.152; P<0.05). At 35°C 2nd instar failed to reach third instar. The shortest developmental time was at 30°C (32.40±0.49 d) and the longest was at 20°C (84.90±0.34d) ($F_{3,36}$ =7.138; P<0.05). Survival of eggs and each instar was highest at 30°C, with significant reductions at 20°C and 35°C ($F_{3,16}$ =34.307; P<0.05) (1st to 2nd instar: $F_{3,16}$ =270.597; P<0.05; 2nd to 3rd instar: $F_{3,16}$ =191.917; P<0.05;3rd to 4thinstar: $F_{3,16}$ =333.495; P<0.05; 4th to5thinstar: $F_{3,16}$ =329.996; P<0.05) (Table 2).

3.2 Effect of Temperature on Pre Oviposition Period, Oviposition Period, Fecundity and Longevity

Temperature significantly affected pre oviposition period, oviposition period, fecundity and longevity of *M. cribraria.* As temperatures increased from 20°C to 30°C, there were significant reductions in adult pre-oviposition period ($F_{2,27}$ =4.260; P<0.05) and total pre-oviposition period ($F_{2,27}$ =7.700; P<0.05). Females reared at 25°C had the longest oviposition period ($F_{2,27}$ = 2.216; P<0.05) but fecundity was greatest at 30°C ($F_{2,27}$ =1.421; P<0.05) (Table 3). Adult longevity differed significantly among different constant temperatures (male: $F_{2,27}$ =294.478; P<0.05, female: $F_{2,27}$ =916.630; P<0.05) (Table 4). In contrast to all other parameters, both sexes had shortest life span at 30°C and longest at 20°C (male: $F_{2,27}$ =1.311; P<0.05, female: $F_{2,27}$ =3.509; P<0.05).

3.3 Life Table Analysis

M. cribraria population attained a maximum net reproductive rate (149.29 female/ Generation) at 30°C temperature. The total fecundity was also maximal at this temperature. The suitable range for *M. cribraria* reproduction was observed between 20–30°C. Intrinsic rate of increase (rm) and finite rate of increase (λ) were maximum at 30°C with values of 0.09 and 1.09 respectively. Values estimated for 'T' indicated that the mean length of generations decreased with increase in temperatures from 142.70 days at 20°C temperature to 55.62 days at 30°C. Shortest doubling time was observed at 30°C (7.70 days) (Table 5).

Table 1. Mean duration (± SE) of immature stages (days) of *M. cribraria* at different temperatures in the laboratory

Temperature	Incubation period (d)	1st instar period (d)	2nd instar period (d)	3rd instar period (d)	4th instar period (d)	5th instar period (d)	Total developmental time (d)
20°C	12.30±0.15a	12.50 ± 0.17a	11.50±0.17a	15.50±0.17a	13.60±0.16a	19.50±0.17a	84.90±0.35a
25°C	7.50±0.17b	7.30±0.15b	8.20±0.13b	9.30±0.15b	8.50±0.17b	11.40±0.16b	52.20±0.36b
30°C	4.20±0.13c	4.50±0.17c	4.30±0.15c	5.40±0.16c	5.50±0.17c	8.50±0.17c	32.40±0.49c
35°C	3.40±0.16d	3.30±0.15d	3.30±0.15d	0.00	0.00	0.00	0.00

Within columns, different letters indicate significant difference at P<0.05 level by Student-Newman-Keuls test

Table 2. Mean percentage survival (± SE) of immature stages of *M. cribraria* at different temperatures

Temperature (°C)	Egg	1st to 2nd instar	2nd to 3rd instar	3rd to 4th instar	4th to5th instar
20	83.80±1.56a	68.40±1.75a	48.20±1.24a	33.80±1.59a	24.40±1.29a
25	87.60±1.03ab	71.80±0.86ab	52.60±2.22ab	36.80±0.66a	31.60±0.87b
30	92.40±2.20b	75.00±1.38b	57.40±1.81b	44.20±1.28b	37.40±0.93c
35	71.60±0.93c	30.60±0.81c	9.00±0.71c	0	0

Within columns, different letters indicate significant difference at P<0.05 level by Student-Newman-Keuls test

Table 3. Mean (±SE) adult pre-oviposition period (APOP), total pre-oviposition period (TPOP), oviposition period and fecundity of *M. cribraria*

Temperature (°C)	APOP (d)	TPOP (d)	Oviposition period (d)	Fecundity /female
20	48.80±0.25a	133.70±0.21a	3.20±0.44a	21.30±2.07a
25	19.30±0.37b	71.50±0.64b	29.80±0.20b	178.70±2.86b
30	8.30±0.34c	40.70±0.65c	23.60±0.16c	221.80±3.32c

Within columns, different letters indicate significant difference at P<0.05 level by Student-Newman-Keuls test

Table 4. Mean (±SE) adult lifespan and longevity of *M. cribraria*

Temperatue (°C)	Male adult longivity (d)	Female adult longivity (d)	Male entire life span (d)	Female entire life span (d)
20	61.10±1.30a	75.40±0.75a	146.0±1.52a	160.30±0.63a
25	49.70±0.919b	60.90±0.65b	101.90±1.05b	113.10±0.93b
30	27.40±0.67c	38.50±0.37c	59.80±0.89c	70.90±0.65c

Within columns, different letters indicate significant difference at P<0.05 level by Student-Newman-Keuls test

Table 5. Life table parameters of *M. cribraria* at different constant temperatures

Temperature (°C)	Net reproductive rate (R_O)	Intrinsic rate of increase (rm)	Mean generation time (T) (d)	Finite rate of increase (λ)	Weakly multiplication (Wm)	Doubling time (DT)
20	17.36029	0.02	142.7093	1.020201	1.150274	34.65736
25	122.8552	0.057	84.40362	1.058656	1.490334	12.16048
30	149.2979	0.09	55.62159	1.094174	1.877611	7.701635

4. DISCUSSION

Temperature is one of the most important ecological factors influencing physiology and behaviour of insects, affecting rate of growth, development, life time, survival, fecundity and other different biological aspects of insects [23]. Our results indicate that *M. cribraria* could sustain itself under constant temperatures between 20°C and 30°C and that 30°C was the most suitable temperature observed. A constant temperature of 15°C was lethal to *M. cribraria* with zero egg hatch. At 35°C, nymphs failed to reach the 4th instar. The shortest developmental time from egg to adult was at 30°C (approximately 33d). However, Shi et al. [24] reported the egg-to-adult mean development times of *M. cribraria* at different temperatures on soya bean were 114.81, 76.26, 44.54 and 38.54 days at 17, 21, 25 and 29°C, respectively.

Survival of immature *M. cribraria* varied significantly with temperature. Temperatures below 20°C and above 30°C were highly unfavourable for survival of all immature life stages. We observed highest survival percentage of egg and nymphs of *M. cribraria* when reared at 30°C in the laboratory, but it was 25°C when reared on soya bean [24].

The APOP, TPOP, oviposition period, fecundity and longevity of *M. cribraria* were highly temperature-dependent. APOP and TPOP were inversely proportional to temperature and this result is in conformity with earlier reports on *M. cribraria* reported by Shi et al. [24]. Thippeswamy and Rajagopal [1] reported that the pre ovipostion period of *M. cribraria* reared on *L. purpureus* variety *lignosus* L. at an average temperature of 28°C was 13-20 d. This observation noted was similar to the results obtained at constant temperatures of 25°C in this study. In contrary to this oviposition period of *M. cribraria* reared at 25°C and 30°C were significantly longer than that reported by Thippeswamy and Rajagopal [1].

We observed a greater mean fecundity at 30°C (221.80 eggs) followed by 25°C (178.7) and 20°C

(21.30 eggs). However, Shi et al. [24] indicated that *M. cribraria* females had the fecundity of 49.00 eggs at 21°C, 69.67 eggs at 29°C and recorded 159.67 eggs at the optimal temperature of 25°C which was different from our results. In contrast to our results, Thippeswamy and Rajagopal [1] reported maximum fecundity at an average temperature of 20.5-22.35°C (102-274 eggs/female) during the month of December and January.

We found that the adult longevity and entire life span of both male and female varied with different constant temperatures. At higher constant temperatures the adult longevity and total longevity of both males and females decreased sharply and showed a closer agreement with the earlier reports of Thippeswamy and Rajagopal [1], Ruberson et al. [25] and Shi et al. [24] on *M. cribraria*.

Bellows et al. [26] explained that life table was an important tool to indicate growth, survival, reproduction and growth rate of an insect population. Data from our study indicated the intrinsic rate of increase (rm), net reproductive rate (Ro) and finite rate of increase (λ) increased with increasing temperatures between 20 and 30°C (Table 5). The longest and shortest mean generation time occurred at 20°C and 30°C respectively. The optimal temperature for population growth of *M. cribaria* was 30°C. In contrast to our study, Shi et al. [24] revealed that population trend index of *M. cribraria* was low at 21 and 29°C and the highest at 25°C, indicating the temperature of 25°C is optimal for the growth and establishment of *M. cribraria* on soybean. These differences in our findings from Shi et al. [24] might be due to the sensitivity of *M. cribraria* to different host plants, rearing conditions, and observation intervals.

5. CONCLUSION

Megacopta cribraria, the kudzu bug, is a potential pest of *Lablab purpureus* (L.) in India and has got a unique physical distribution in time and space because they are likely to interbreed and live together in the same habitat. *M. cribaria* population hold different ages and its size (density) is likely to change over time (growing or shrinking) according to the reproductive success of its members. Population of a pest is prejudiced by primary and secondary ecological events. Natality, mortality, immigration and emigration are the four primary ecological events and all other factors (biotic and abiotic) are secondary ecological events. A major secondary ecological events act as "population regulating factor" is temperature. Hence a study was conducted to find out the relationship of five different constant temperatures on the growth and development of *M. cribraria.* Under laboratory conditions it was concluded that all the tested temperature has impact on the development, survival, longevity, and life table parameters of the pest. Ideal optimum temperature for the maximum growth development was at 30°C and the developmental time from egg to adult was negatively correlated with temperature. Bugs exhibited highest fecundity and shortest development time in this temperature range. Even though highest value for the female pre-oviposition period and longevity at lower temperature (20°C) and highest fecundity, intrinsic rate of natural increase, finite rate of increase and net reproduction rate at 30°C. The results of the present study improved our understanding of the effects of temperature on development, reproduction and population dynamics of *M. cribraria* and the data can be used to predict pest out break model, developmental rates and population growth of this pest. This knowledge would also be very useful for developing an effective integrated pest management strategy against this noxious pest.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Thippeswamy C, Rajagopal BK. Comparative biology of *Coptosoma cribraria* Fabricius (Heteroptera: Plataspidae) on field bean, soya bean and red gram. Karnataka Journal of Agricultural Sciences. 2005;18(1):138-140.
2. Fabricius JC. Entomologia systematica emendata et auct, secundum classes, ordines, genera, species, adjectis synonymis, locis, observationibus. Supplementum. Proft et Storch, Copenhagan. 1798;2:572.
3. Walker F. Catalogue of the specimens of Hemiptera: Heteroptera in the collection of the British Museum. British Museum, London, Part 2. 1867;241-417.

4. Eger JE, Ames LM, Suiter DR, Jenkins TM, Rider DA, Halbert SE. Occurrence of old world bug *Megacopta cribaria* (Fabricius) (Heteroptera: Plataspidae) in Georgia: A serious home invader and potential legume pest. Insecta Mundi. 2010;21:1-11.
5. Zhang, James L. Hanula, Scott Horn. The biology and preliminary host range of *Megacopta cribraria* (Heteroptera: Plataspidae) and its impact on Kudzu growth. Environ. Entomol. 2012;41(1):40-50.
6. Suiter DR, Eger Jr. JE, Gardner WA, Kemerait RC, All JN, Roberts PM, Greene JK, Ames LM, Buntin GD, Jenkins TM, et al. Discovery and distribution of *Megacopta cribraria* (Hemiptera: Plataspidae) in Northeast Georgia. J. Integr. Pest Manage. 2010;1:1-4.
7. Zhang SM. Economic insect fauna of China. Heteroptera Plataspidae. Science Press, Beijing. 1985;31:34-35.
8. Schaeffer CW, Panizzi AR. Heteroptera of economic importance. Boca Raton, FL: CRC Press. The Old World Bug *Megacopta cribraria* Fabricius (Heteroptera: Plataspidae) in Georgia: A serious home invader and potential legume pest. Insecta Mundi. 2000;121:1-11.
9. Hoffmann WE. Notes on the bionomics of some oriental Pentatomidae (Hemiptera). Archivio Zoologico Italiano (Torino). 1932;16(3/4):1010-1027.
10. Hoffmann WE. Notes on Hemiptera and Homoptera at Canton, Kwangtung Province, Southern China 1924-1929. USDA Insect Pest Survey Bulletin. 1931;11(3):131-151.
11. Easton ER, Pun WW. Observation on some Hemiptera/ Heteroptera of Macau, Sourheast Asia. Proceedings of the Entomological Society of Washington. 1997;99(3):574-582.
12. Ishihara T. The developmental stages of some bugs injurious to the kidney bean (Hemiptera). Transactions of the Shikoku Entomological Society. 1950;1:17-31.
13. Wang Z, Wang H, Chen G, Zhu G, Tong C. Occurrence and control of *Megacopta cribraria* (Fabricius) (Heteroptera: Plataspidae) on soya bean. Plant Prot. 1996;22:7-9.
14. Wang HS, Zhang CS, Yu DP. A preliminary studies on occurrence and control technology of *Megacopta cribraria* (Fabricius). China Plant Prot. 2004;24:45.
15. Li YH, Pan ZS, Zhang JP, Li WS. Observation of biology and behavior of *Megacopta cribraria* (Fabricius). Plant Prot. Technol. Ext. 2001;21:11-12.
16. Srinivasaperumal S, Samuthiravelu P, Muthukrishman J. Host plant preference and life table of *Megacopta cribraria* (Fab) (Hemiptera: Plataspidae). Proc. Indian Natl. Sci. Acad. B. 1992;58:333-340.
17. Xing GC, Zhao TJ, Gai JY. Evaluation of soya bean germplasm in resistance of *Megacopta cribraria* (Fabricius). Acta Agron. Sin. 2006;32:491-496.
18. Wu MX, Xu KT. Preliminary studies on the pests of green soybean in Fuzhou suburb. Wuyi Sci. J. 2002;18:28-33.
19. Del Pozo-Valdivia AI, Reisig DD. First generation of *Megacopta cribraria* (Heteroptera: Plataspidae) can develop on soya beans. J. Econ. Entomol. 2013;106(2):533-535.
20. Huffaker CB. Temperature relations of *Anopheles*. Ann. Entomol. Soc. Am. 1944;37: 1-27.
21. Birch LC. The intrinsic rate of natural increase of an insect population. J. Anim. Ecol. 1948;17:15-26.
22. Atwal AS, Bains S. Applied animal ecology (Ludhiana: Kalyani Publishers), New Delhi; 1974.
23. Ratte HT. Temperature and insect development. In: Environmental Physiology and Biochemistry of Insects (Ed Hoffmann KH), Springer, Germany. 1985;33-66.
24. Shi Shu-Sen, Juan Cui, Lian-Sheng Zang. Development, survival and reproduction of *Megacopta cribraria* (Heteroptera: Plataspidae) at different constant temperatures. J. Econ. Entomol. 2014;107(6):2061-2066.
25. Ruberson JR, Takasu K, Buntin GD, Eger Jr. JE, Gardner WA, Greene JK, Jenkins TM, Jones WA, Olson DM, Roberts PM, et al. From Asian curiosity to eruptive American pest *Megacopta cribraria* (Hemiptera:Plataspidae) and prospects for its biological control. Appl. Entomol. Zool. 2013;48:3-13.
26. Bellows Jr. TS, van Driesche RG, Elkinton JS. Life table construction and analysis in the evaluation of natural enemies. Annu. Rev. Entomol. 1992;37:587-614.