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DETERMINATION OF DEVELOPMENTAL AND LIFE TABLE PARAMETERS OF *RHYZOBIUS LOPHANTHAE* BLAISDELL (COLEOPTERA COCCINELLIDAE) ON THREE ARMORED SCALE INSECTS (HEMIPTERA DIASPIDIDAE) ([1])

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Şimşek B., Karaca İ., Kayahan A. – Determinatıon of developmental and life table parameters of *Rhyzobıus lophanthae* Blaisdell (Coleoptera Coccinellidae) on three armored scale insects (Hemiptera Diaspididae).

Scale insects are the most damaging pests of citrus production in Turkey. *Rhyzobius lophanthae* Blaisdell (Coleoptera: Coccinellidae), a polyphagous coccinellid, is one of the most important predators of these pests. In this study, the life tables of *R. lophanthae* on three different armored scale insects, *Aonidiella aurantii* (Maskell), *Aspidiotus nerii* Bouché, *Chrysomphalus dictiyospermi* (Morgan) (Hemiptera: Diaspididae), were produced. The study was conducted in a climate chamber under constant conditions of 26°C, 60% relative humidity and 16-hour photoperiod.

The net reproductive rate (R_0), intrinsic rate of increase (r_m) and mean generation time (T_0) were 36.027, 12.520 and 6.600 females/female/generation, 0.120, 0.061 and 0.041 females/female/day, and 30.005, 41.151, 45.826 days, respectively, when *R. lophanthae* was reared on *A. nerii, C. dictiyospermi* and *A. aurantii*, respectively. The doubling time (DT) and finite rates of increase (λ) were 5.803, 11.286 and 16.832 days, 1.127, 1.063 and 1.042 individuals/female/day, respectively, when *R. lophanthae* was reared on *A. nerii, C. dictiyospermi* and *A. aurantii*, respectively.

KEY WORDS: *Aonidiella aurantii, Aspidiotus nerii*, *Chrysomphalus dictiyospermi,* life table, *Rhyzobius lophanthae.*

INTRODUCTION

Fruit and vegetable production is an important segment of world agriculture. Citrus fruits are considered some of the most important due to the huge production area and commercial value. Originating from China, India and South-East Asia, citrus is now grown throughout areas with a temperate climate (AKGÜN, 2006). In Turkey, citrus production is approximately 3.7 million tonnes annually (FAO, 2013).

Among the many pests of citrus, scale insects cause significant economic losses everywhere that citrus is grown. *Aonidiella aurantii* (Maskell), *Aspidiotus nerii* Bouché and *Chrysomphalus dictiyospermi* (Morgan) (Hemiptera: Diaspididae) feed and cause damage on citrus fruits. In addition, *A. aurantii* infestation damages the trunk, branches and shoots (UYGUN *et al.*, 2013).

Chemical control of scale insects on citrus is very difficult due to the wax these pests. Therefore, comprehensive studies have been carried out recently to develop biological control methods against these armored scale pests. One of the most effective predators is the coccinellid, *Rhyzobius lophanthae* Blaisdell (Coleoptera: Coccinellidae) (STATHAS *et al.*, 2002).

This study examined the development and life table parameters of *R. lophanthae* when reared on three armored scale species, *A. aurantii*, *A. nerii* and *C. dictiyospermi*. The ultimate goal of this study was to identify the armored scale species on which *R. lophanthae* could be most efficiently reared.

MATERIALS AND METHODS

PREY SOURCE

The scale insects which were used as the prey in this study were obtained from a laboratory colony at Süleyman Demirel University in Isparta, Turkey, with production in weekly periods throughout the study. *Aspidiotus nerii* was produced on potato tubers (*Solanum tuberosum* L.) (Solanaceae), and infestation was initiated by putting potatoes infested with *A. nerii* next to clean potatoes. *Chrysomphalus dictiyospermi* and *Aonidiella aurantii* were produced on pumpkins (*Cucurbita moschata* Duch.) (Cucurbitaceae), and infestation was achieved by placing pumpkins infested with *A. aurantii* next to clean pumpkins.

SOURCE OF *RHYZOBIUS LOPHANTHAE*

Rhyzobius lophanthae individuals, collected from citrus orchards in Adana Province in southern Turkey with the shaking method of STEINER (1962), were used to establish a laboratory colony at the Biological Control Research and Application Laboratory of the Department of Plant Protection, Süleyman Demirel University, Isparta, Turkey. The conditions in the climate chamber were set at 25±1°C , 65±5% relative humidity and long-day lighting (16 h: 8 h). *Rhyzobius lophanthae* individuals were taken from this stock culture for experimental purposes.

EXPERIMENTAL DESIGN

This study was conducted in a climate chamber at a temperature of 26±1°C, 60±5% relative humidity and long-day lighting (16 h light: 8 h darkness). The day before the establishment of the experiment, 20-30 *Rhyzobius lophanthae* individuals that had emerged from pupae on the

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same day were placed on potato tubers infested with *Aspidiotus nerii* and deposited in a plastic container. After ten days, the eggs laid by *R. lophanthae* on these potato tubers were removed with a soft sable brush without damage for use in in this study.

Aspidiotus nerii was used as the prey in the first experiment in which infested potato tubers were placed individually in plastic containers (10x10x5 cm). One *R. lophanthae* egg was placed on each potato tuber with a soft brush. *Aonidiella aurantii* and *C. dictiyospermi* were used as the prey in the second and third experiments in which infested pumpkins were placed individually in plastic containers (20x13.5x10). One *R. lophanthae* egg was placed on each pumpkin with a soft brush. *R. lophanthae* individuals, reared on the three different preys to the adult stage, were observed daily under a stereomicroscope (Leica S6D, x10 magnification) to determine their developmental periods.

Individuals were separated into males and females after developing into adults (STATHAS *et al.,* 2002). After this process, one male and one female *R. lophanthae* were placed in each plastic container for the three different groups. Then, the eggs produced by these individuals were counted daily. This process continued until all adult individuals had died so that life tables of females of *R. lophanthae* were able to be calculated for the 3 different preys.

The data from the experiments were used to develop age-related life tables for each prey used. All parameters in the life table were calculated with the Euler-Lotka equation (BIRCH, 1948) by using RmStat-3 (ÖZGÖKÇE & KARACA, 2010).

Parameters used for calculations:

Age-related survival rate (l_x) and fertility rate (m_x) (BIRCH, 1948);

Net production rate, (BIRCH, 1948);

$$R_0 = \sum l_x . m_x$$

Intrinsic rate of increase (r_m), (BIRCH, 1948)

$$\sum e^{(-r_m . x)} l_x . m_x = 1$$

Mean generation time, (BIRCH, 1948)

$$T_o = \frac{\ln R_0}{r_m}$$

Total productivity rate, (BIRCH, 1948)

$$GRR = \sum m_x$$

Daily maximum reproductive value, (BIRCH, 1948)

$$\lambda = e^{r_m}$$

Doubling time, (KAIRO and MURPHY, 1995),

$$T_2 = \frac{\ln 2}{r_m}$$

Reproductive value, (IMURA, 1987).

$$V_x = \frac{\sum_{y=x} \left(e^{r_m . y} . l_y . m_y \right)}{l_x . e^{-r_m . x}}$$

The pseudo-*rmij* values were calculated with the Jack-knife method (MEYER *et al.,* 1986; ÖZGÖKÇE & ATLIHAN, 2004) to include the use of intrinsic rate of increase values calculated for these populations in comparison tests. Furthermore, the developmental periods of immature stages for each prey were evaluated separately. The Tukey multiple comparison test was then used for the comparison of these with SPSS (ver. 17) program. The significance difference was set at $p<0.05$.

RESULTS AND DISCUSSION

The development period of the egg stage of *R. lophanthae* fed on three different prey was not significantly different (F=0.68, df=3, P=0.507). The first stage of *R. lophanthae* fed on *A. nerii* developed more rapidly than those fed on the other two armored scale species (F=119.02, df=3, P=0.0001). The second larval stage of *R. lophanthae* fed on *A. nerii* also showed more rapid development than those fed on the other armored scale insect species (F=24.85, df=3, P=0.0001). For the third stage, while the larvae of *R. lophanthae* fed on *A. nerii* developed more rapidly than on other two species, larvae of *R. lophanthae* fed on *C. dictiyospermii* developed faster than when fed on *A. aurantii* (F=28.48, df=3, P=0.0001). Results for the fourth larval stage were similar to the third larval stage. Overall, the larvae of *R. lophanthae* fed on *A. nerii* developed more rapidly than on the other two species, and larvae of *R. lophanthae* fed on *C. dictiyospermii* developed faster than on *A. aurantii* (F=32.66, df=3, P=0.0001). Larvae of *R. lophanthae* fed on *A. nerii* developed more rapidly than those fed on *C. dictiyospermii* (F=33.13, df=3, P=0.0001). For total development times, larvae fed with *A. nerii* developed more rapidly than those fed on A. *aurantii* and *C. dictiyospermii* (F=166.08, df=3, P=0.0001) (Table 1).

STATHAS (2000) investigated the development of *R. lophanthae* at different temperatures and with *A. nerii* as the prey. The development times of all stages (larval, pupal and total time) of *R. lophanthae* were longer than in our study. However, for the other preys in our study, the development times of all stages of *R. lophanthae* were shorter. When this study was compared with the literature (STATHAS, 2000), the development times of immature stages of the individuals fed with *A. nerii* was different. This could have resulted from the difference of the temperatures at which the study was carried out. STATHAS *et al.* (2002) examined the development of *R. lophanthae* at four different temperatures under laboratory conditions, with *Chrysomphalus aonidum* L. as the prey. In our study, all stages of *R. lophanthae* fed on *A. nerii* developed more quickly than *C. aonidium* in their study. When the total development times were analyzed, it was determined that all three prey used in the present study developed in a shorter time than *C. aonidium*. When the development times of the immature stages of *R. lophanthae* from the two studies were compared, there were some differences. These may have resulted from the difference of the temperature at which the study was carried out and also the prey.

NAR *et al.* (2009) investigated the effects of 25°C temperature on the development of *R. lophanthae* fed on *A. nerii*. The development times of all stages (larval, pupal and total time) of *R. lophanthae* were slower than in our study. A difference was also seen between the development periods of the immature stages of the individuals fed with *C. dictiyospremi* and *A. aurantii* in the current study and reported by NAR *et al.* (2009). When the development times of the immature stages of the individuals fed with *A. nerii* in our study were compared with the development periods in the literature (NAR *et al.*, (2009), there were differences between periods. These differences may also have resulted from the different temperatures used.

In this study, the preoviposition periods of *R. lophanthae* fed on *A. nerii, C. dictiyospermi* and *A. aurantii* were 3.7,

Table 1 – Development times (days) of the immature stages of *Rhyzobius lophanthae* fed on three different prey.

	n	*Aspidiotus nerii*	**n**	*Chrysomphalus dictiyospermi*	**n**	*Aonidiella aurantii*
Egg	64	4.17±0.088 **a**	52	4.21±0.069 **a**	50	4.30±0.071 **a**
Larva 1	42	2.57±0.085 **a**	34	5.65±0.211 **b**	37	5.89±0.218 **b**
Larva 2	36	2.08±0.047 **a**	28	2.79±0.107 **b**	28	3.18±0.179 **b**
Larva 3	33	1.88±0.072 **a**	26	3.04±0.188 **b**	23	3.74±0.283 **c**
Larva 4	22	3.05±0.154 **a**	19	5.21±0.330 **b**	10	6.50±0.500 **c**
Pupa	20	3.65±0.109 **a**	12	6.75±0.329 **c**	9	5.11±0.564 **b**
Total development time	20	17.45±0.256 **a**	12	27.50±0.609 **b**	9	28.11±0.841 **b**

Different letters on the same line indicate a significant difference ($p<0.05$)

6.7 and 12.0 days, respectively, the oviposition periods were 30.5, 12.8 and 12.6 days, respectively, and the postoviposition periods were 3.4, 4.1 and 5.4 days, respectively. The adult longevities of *A. nerii, C. dictiyospermi* and *A. aurantii* were 37.6, 23.6 and 30.0 days, and the generation times were 22.35, 36.2 and 41.0 days, respectively. The number of eggs laid daily was 5.53, 5.16 and 2.75 eggs/female, respectively, and the total number of eggs laid was 201.75, 123.7 and 82.5 eggs/female (Table 2).

STATHAS (2000) examined the development of *R. lophanthae* on *A. nerii* and reported the development periods of the immature stages and preoviposition time of the adults at different temperatures. When compared with our study, the preoviposition time was longer. STATHAS *et al.* (2002) examined the development of *R. lophanthae* on *C. aonidium* at different temperatures. At 25 °C, the preoviposition time of *R. lophanthae* was 5.3±0.91 days. In the present study, the preoviposition time of the females fed with *A. nerii* was shorter than in other study (STATHAS *et al.*, 2002). When the other two preys (*C. dictiyospermi* and *A. aurantii*) were compared with STATHAS *et al.* (2002), the preoviposition time of the individuals fed with *C. aonidium* was shorter in our study. These differences may be a consequence of the different temperature at which the study was carried out and also the prey.

NAR *et al*. (2009) investigated the effects of 5 different temperatures, including 25°C, on the development of *R. lophanthae.* Compared with our study, they reported a shorter preoviposition period, and a longer oviposition period, while the postoviposition period was similar. These differences may have resulted from the difference in temperature.

In the present study, the intrinsic rate of increase values for *R. lophanthae* fed with *A. nerii, C. dictiyospermi* and *A.*

Table 2 – The mean development time of adult individuals of *Rhyzobius lophanthae* fed on three different preys after maturity.

	Prey	N	Mean±SE
Preoviposition time	*A. nerii*	20	3.7±0.19
	C. dictyospermi	10	6.7±0.50
	A. aurantii	8	12±0.27
Oviposition time	*A. nerii*	20	30.5±1.77
	C. dictyospermi	10	12.8±0.63
	A. aurantii	8	12.63±0.57
Postoviposition time	*A. nerii*	20	3.4±0.15
	C. dictyospermi	10	4.1±0.18
	A. aurantii	8	5.38±0.18
Adult longevity(female)	*A. nerii*	20	37.6±1.81
	C. dictyospermi	10	23.6±0.72
	A. aurantii	8	30±0.42
Generation time	*A. nerii*	20	22.35±0.13
	C. dictyospermi	10	36.2±0.36
	A. aurantii	8	41±0.71
Number of eggs laid daily	*A. nerii*	20	5.53±2.25
	C. dictyospermi	10	5.16±0.40
	A. aurantii	8	2.75±0.07
Total number of eggs	*A. nerii*	20	201.75±7.66
	C. dictyospermi	10	123.7±12.27
	A. aurantii	8	82.5±2.75

aurantii were 0.120, 0.061 and 0.041 females/female/day, respectively, the net production rates (R_0) values were 36.027, 12.250 and 6.600 females/female/generation, respectively, and the mean generation time (T_0) values were 30.005, 41.151 and 45.826 days, respectively. Furthermore, the total production rate (*GRR*) values were 125.542, 65.111 and 41.369, respectively, the doubling time (T_2) values were 5.803, 11.286 and 16.832 days, and the finite rates of increment were 1.127, 1.063 and 1.042 individuals/female/day, respectively (Table 3).

The pseudo-*rmij* values calculated separately for each prey were analyzed with the Tukey multiple comparison test. The average pseudo-*rmij* value for *R. lophanthae* fed with *A. nerii* was significantly different from the average for those fed with other preys (F=32.01, df=3, P=0.0001) (Table 3).

Stathas *et al.* (2005) examined the reproductivity of *R. lophanthae* on *A. nerii* at 25°C under laboratory conditions. They calculated total productivity, net production rate and intrinsic rate of increase. The intrinsic rate of increase (r_m) calculated in our study was similar to that of Stathas *et al.* (2005). However, the net production rate (R_0) was different from this study. Nar *et al.* (2009) investigated the effects of different temperatures on the development of *R. lophanthae*. Its life table parameters (r_m, R_0, T_2 and T_0) were calculated, using *A. nerii* as the prey. The values for the individuals fed on *A. nerii*, *C. dictiyospermi* and *A. aurantii* in our study were different. The differences may have resulted from the prey difference.

The survival rate (l_x), fertility rate (m_x) and reproduction value (V_x) of *R. lophanthae* individuals fed on *A. aurantii*, *A. nerii* and *C. dictiyospermi* under laboratory conditions in the present study are given in Fig. I. On the first prey (*A. aurantii*), the survival rate, which was 1.00 at the beginning, began to decrease from the 4th day and was 0.02 at the end of the 61st day, with the production value (V_x) highest (32.28) on day 41. *Rhyzobius lophanthae* laid the maximum number of eggs on day 45 and produced 5.31 eggs on average. They stopped producing eggs on day 57. On the second prey (*A. nerii*), the survival rate, which was 1.00 at the beginning, began to decrease from the 3rd day and was 0.02 at the end of the 65th day, with the reproduction value (V_x) highest (46.75) on day 24. *Rhyzobius lophanthae* laid the maximum number of eggs on day 26, produced 8.34 eggs on average and stopped laying eggs on day 62.On the third prey (*C. dictiyospermi*), the survival rate, which was 1.00 at the beginning, decreased from the 4th day and was 0.02 at the end of the 55th day. The reproduction value (V_x) was highest (49.43) on day 38. *Rhyzobius lophanthae* laid the maximum number of eggs on day 41, produced 10.42 eggs on average, and stopped producing eggs on day 51 (Fig. I).

Based on the studies performed up to now, it is possible to say that *R. lophanthae* is one of the most important agents in biological control programs (Stathas, 2000; 2001; Stathas *et al.*, 2002; 2005; Nar *et al.*, 2009). Also, the present study demonsrated that *A. nerii* can be used as a prey to conduct the mass production of *R. lophanthae*.

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REFERENCES

Akgün C., 2006 – *Turunçgiller Sektör Profil. Dış Ticaret Şubesi Uygulama Servisi [Citrus fruits Industry Profile. Foreign Trade Branch Application Service]*. Ankara (htp:/www.ito.org.tr/Dokuman/Sektor/197.pdf).

Birch L.C., 1948 – *The intrinsic rate of natural increase of an insect population*. - Journal of Animal Ecology, 17: 15-26.

Deevey E.S., 1947 – *Life tables for natural populations*. - Quarterly Review of Biology, 22: 283-314.

Enkegaard A., 1993 - *The poinsettia strain of the cotton whitefly*, Bemisia tabaci *(Hom.; Aleyrodidae), biological and demographic parameters on poinsettia (*Euphorbia pulcherrima*) in relation to temperature*. - Bulletin of Entomological Research, 83: 535-546.

FAO, 2013 – Food and Agriculture Organization of the United Nations. http://faostat.fao.org/site/291/default.aspx.

Hansen D.L., Brodsgaard H.F., Enkegaard A., 1999 – *Life table characteristics of* Macrolophus caliginosus *preying upon* Tetranychus urticae. - Entomologia Experimentalis et Applicata, 93: 269-275.

Imura O., 1987 – *Demographic attributes of* Tribolium freemani *Hinton (Coleoptera: Tenebrionidae)*. - Applied Entomology and Zoology, 22 (4): 449-455.

Table 3 – The life table parameters of *Rhyzobius lophanthae* fed on three different preys.

Life table parameters	*Aspidiotus nerii*	*Chrysomphalus dictiyospermi*	*Aonidiella aurantii*
Intrinsic rate of increase, r_m	0.120	0.061	0.041
Pseudo-rmij values	0.12125±0.00695**a**	0.06288±0.00769**b**	0.04291±0.00754**b**
Net production rate, R_0	36.027	12.520	6.600
Mean generation time, T_0	30.005	41.151	45.826
Total production rate *GRR*	125.542	65.111	41.369
Doubling time, *T2*	5.803	11.286	16.832
Finite rates of increase, λ	1.127	1.063	1.042
n	64	52	50

Different letters on the same line show a significant difference ($p<0.05$)

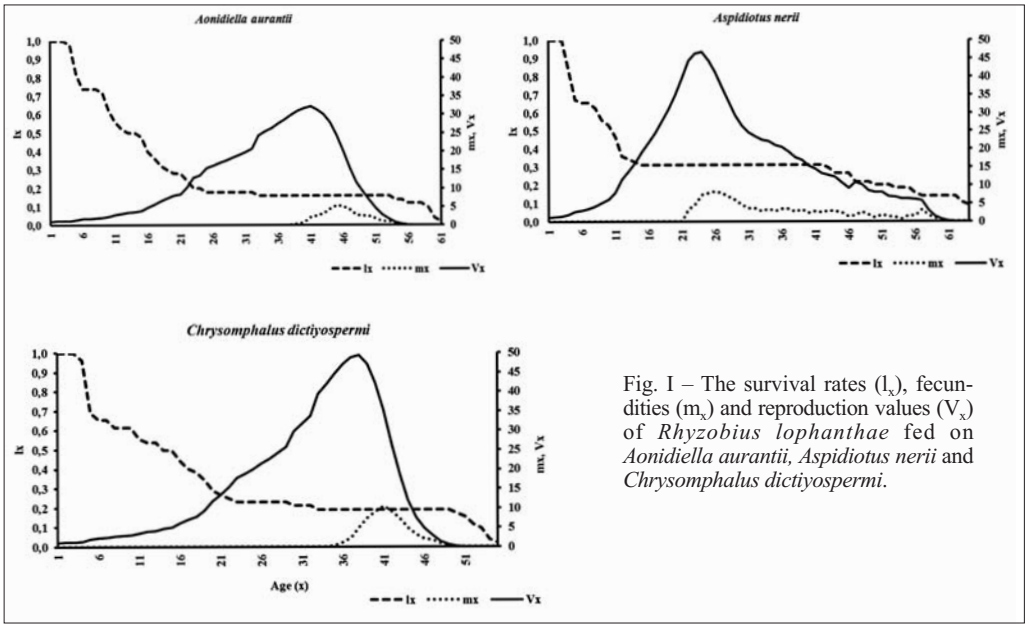

Fig. I – The survival rates (l_x), fecundities (m_x) and reproduction values (V_x) of *Rhyzobius lophanthae* fed on *Aonidiella aurantii, Aspidiotus nerii* and *Chrysomphalus dictiyospermi*.

KAIRO M.T.K., MURPHY S.T., 1995 – *The life history of* Rodolia iceryae *Janson (Coleoptera: Coccinellidae) and the potential for use in innoculative releases against* Icerya pattersoni *Newstead (Homoptera: Margarodidae) on coffee*. - Journal of Applied Entomology, 119: 487-491.

MEYER J.S., INGERSOLL C.G., MCDONALD L.L., BOYCE M.S., 1986 – *Estimating uncertainty in population growth rates: Jackknife vs. Bootstrap techniques*. - Ecology, 67: 1156-1166.

NAR E., ULUSOY R. VE KARACA İ., 2009 – *Farklı Sıcaklıkların Avcı Böcek,* Rhyzobius lophantae *Blaisdell (Coleoptera: Coccinellidae)'nin Gelişmesi Üzerine Etkisi [Effect of Different Temperatures on the Development of Predator Insect,* Rhyzobius lophantae *Blaisdell (Coleoptera: Coccinellidae)]*. Süleyman Demirel Üniversitesi, Fen Dergisi, 4 (1), 59-74.

ÖZGÖKÇE M.S., ATLIHAN R., 2004 – *Biological Features and Life Table Parameters of Mealy Plum Aphid,* Hyalopterus pruni *on Different Apricot Cultivars*. - Phytoparasitica, 33 (1):7-14.

ÖZGÖKÇE M.S., KARACA İ., 2010 – *Yaşam Çizelgesi: Temel Prensipler ve Uygulamalar [Life Table: Basic Principles and Applications]*. Türkiye Entomoloji Derneği 1. Çalıştayı, Ekoloji Çalışma Grubu, Isparta.

PINDER J.E., WIENER J.G., SMITH M.H., 1978 – *The Weibull distribution: a new method of summarizing survivorship data*. - Ecology 59: 175-179.

STATHAS G.J., 2000 – *The effect of temperature on the development of the predator* Rhyzobius lophanthae *and its phenology in Greece*. - BioControl, 45 (4): 439-451.

STATHAS G.J., 2001 – *Studies on morphology and biology of immature stages of the predator* Rhzobius lophanthae *Blaisdell (Col.: Coccinellidae)*.- Anzeiger für Schadlingskunde / Journal of Pest Science 74, 113-116.

STATHAS G.J., ELIOPOULOS P.A., KONTODIMAS D.C., TIAMOS D.TH., 2002 – *Adult morphology and life cycle under constant temperatures of the predator* Rhyzobius lophanthae *Blaisdell (Col., Coccinellidae)*. - Anz. Schädlingskunde / Journal Pest Science 75, 105-109.

STATHAS G.J., KONTODIMAS D.C., BOURAS S.L., ECONOMOU L.P., 2005 – *Life table parameters of* Rhyzobius lophanthae *Blaisdell (Coleoptera: Coccinellidae*). Integrated Protection of Olive Crops, IOBC/WPRS Bulletin, 28 (9), 147-155.

STEINER H., 1962 – *Metoden zur Untersuchungen des. Population dynamik in Obstanlangen*. - Entomophaga, 7: 207-214.

UYGUN N., ULUSOY M.R., KARACA İ., 2013 – *Meyve ve Bağ Zararlıları [Fruit and Vineyard Pests]*. Çukurova Üniversitesi Ziraat Fakültesi Yayınları, Genel Yayın No: 252, Ders Kitapları Yayın No: A-81, 347s, Adana.