ALİME BAYINDIR (*) (°) - ALİ KEMAL BİRGÜCÜ (**)

EFFECT OF TEMPERATURE ON LIFE HISTORY
OF *CHRYSOMPHALUS DICTYOSPERMI* (MORGAN) (HEMIPTERA DIASPIDIDAE) ([1])

(*) (°) *Organic Farming Business Management Department, School of Applied Sciences, Pamukkale University, 20600, Denizli-Turkey*
(**) *Plant Protection Department of Agricultural Faculty, Süleyman Demirel University, 32260, Isparta-Turkey*
(*) (°) *Corresponding author*: abayindir@pau.edu.tr

Bayındır A., Birgücü A.K. – Effect of temperature on life history of *Chrysomphalus dictyospermi* (Morgan) (Hemiptera Diaspididae).

This study documented the life table parameters of *Chrysomphalus dictyospermi* (Morgan) (Hemiptera: Diaspididae) reared on pumpkins at three different constant temperatures (22.5, 25, 27.5, and 30°C±1), constant relative humidity (65±5%) and long photoperiod (16:8 L:D). The intrinsic rate of increase (r_m) was 0.03 female/female/day at 22.5°C, 0.05 females/female/day at 25 °C, 0.04 females/female/day at 27.5°C, and 0.06 females/female/day at 30°C. The reproductive rate (R_o) was 22.89, 50.96, 24.79, and 70.58 females/female at 22.5, 25, 27.5, and 30°C, respectively. The generation time (T_o) was found 102.17, 67.04, 66.21, and 68.48 days at 22.5, 25, 27.5, and 30°C, respectively. In addition the gross reproduction rate (*GRR*) was calculated as 32.76, 66.96, 33.07, and 88.60 females/female, the doubling time (T_2) was 22.62, 11.82, 14.29, and 11.15 days, and the finite rate of increase (λ) was 1.03, 1.06, 1.04, and 1.06 females/female at 22.5, 25, 27.5, and 30°C, respectively.

KEY WORDS: *Chrysomphalus dictyospermi,* life table, pumpkin, temperature.

INTRODUCTION

The scale insect family Diaspididae (Hemiptera: Coccoidea) includes a number of important pests of wild and cultivated plants (ALFORD, 2007). *Chrysomphalus* Ashmead, 1880, includes 17 species worldwide, five of which are found in Europe: *C. aonidum* (Linnaeus), *C. bifasciculatus* Ferris, *C. dictyospermi* (Morgan), *C. diversicolor* Green, and *C. pinnulifer* (Maskell) (BEN-DOV, 2012). *C. dictyospermi* is native to southern China and distributed widely in the tropical and subtropical areas (LONGO *et al.*, 1995; GILL, 1997). Host list includes 234 species, 226 genera and 95 families. Principal hosts are *Citrus*, *Dracaena* and palms (USDA, 2014). In the Palaearctic region (DANZIG & PELLIZZARI, 1998), South Pacific (WILLIAMS & WATSON, 1988), Western Mediterranean and Florida (CHUA & WOOD, 1990; GILL, 1997). *C. dictyospermi* is an important pest of citrus. It is a pest of olive trees in Italy, Spain and Turkey (ARGYRIOU, 1990). It occurs primarily on leaves, sometimes on fruit and on branches. Toxic substances secreted during feeding leads to chlorosis on leaves, and in severe cases leading to desiccation, and even death of the branches (GILL, 1997; FOLDI, 2001). The female lives for several months and produces 1-200 eggs (CHKHAIDZE & YASNOSH, 2001). *C. dictyospermi* has 3-6 generations annually in Turkey; 3-4 generations in California and 2 generations in Egypt (GILL, 1997; FOLDI, 2001). Crawler development is completed in 71 days at 25°C and 91 days at 18°C (CABIDO-GARCIA, 1949). Temperature is an abiotic factor with important effects on population dynamics, ecology and biology of pests and natural enemies. This study reports on the biological parameters and reproduction values of *C. dictyospermi* when reared on pumpkin at four different constant temperatures ranging from 22.5 to 30°C at 2.5°C increments. Thus, trying to simulate how population levels of the pest will be affected against seasonal and global temperature changes.

MATERIALS AND METHODS

REARING OF *CHRYSOMPHALUS DICTYOSPERMI*

Twig parts, leaves and fruits infested with *C. dictyospermi* were collected from citrus orchards in Antalya in 2014. These infested plant parts were located on uninfested pumpkins in a climate room with the 25±1°C temperature, 60±5% relative humidity and 16:8 h. (L:D) photoperiod conditions. The pumpkin, *Cucurbita maxima* Duchesne (Cucurbitaceae), was used as host for *C. dictyospermi*. Newly hatched crawlers were transferred to pumpkin fruits and later, the infested citrus twig parts, leaves and fruits were removed. When these crawlers settled on pumpkin reached to oviposition period of adult stage, clean pumpkin fruits were added to the production chains of the scale pests. In this way, the increase and continuity of the scale pest production were ensured.

EXPERIMENTAL DESIGN

Newly infested pumpkins with crawlers were used in the experiments. After the crawlers had settled on the pumpkins, a 2x2 cm area was marked on each pumpkin using a sticky material (Tanglefoot® trademark). The cohorts isolated within the area were considered individual replicates, and they were examined daily for development and survival. The time of preoviposition, oviposition and

_____

postoviposition, the sex ratio of adults, the settlement rate of crawlers were recorded daily. To determine fecundity, all but two females were removed from each marked area, and the number of crawlers emerged from the two females were recorded daily.

The experiments were performed at four constant temperatures (22.5, 25, 27.5, and 30±1°C), 60±5% RH, and long photoperiod (16:8 L:D) in climate chambers. The experiments at 22.5, 25, 27.5, and 30±1°C were conducted with 73, 68, 60, and 59 replicates, respectively.

LIFE TABLES

Data on age-specific survival rate (l_x) and age-specific fecundity (m_x) obtained in the experiment were used to conduct life table analysis. Life table parameters were estimated with Euler-Lotka equation (BIRCH, 1948).

The life table parameters estimated in this study:

Net reproductive rate (Females/female),

$$R_0 = \sum l_x.m_x$$

(BIRCH, 1948), and Intrinsic rate of increase (females/female/day) (r_m) were determined by solving the equation

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

(BIRCH, 1948). Also, Mean generation time (Day),

$$GRR = \sum m_x$$

(BIRCH, 1948), Gross reproduction rate (crawlers/female),

$$T_0 = \frac{\ln.R_0}{r_m}$$

(BIRCH, 1948), Finite rate of increase (crawlers/female/day), $\lambda = e^{r_m}$ (BIRCH, 1948), and Doubling time (Day),

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

(KAIRO and MURPHY, 1995) were calculated.

The r_m rates obtained from the lifetable parameters, pseudo-r_{mj} were obtained as the number of replicates for different temperatures by using Jack-knife method (MEYER et al., 1986; ÖZGÖKÇE and ATLIHAN, 2005). Statistical differences were determined with One Way ANOVA analysis between the different temperatures. The statistical data analyses were done by using SPSS® Statistics (Version 20.0, August 2011, SPSS Inc., Chicago, IL, USA.) software package.

The linear model presented in CAMPBELL et al., (1974) was used to calculate developmental zero (C, the lower developmental threshold), and thermal constant (K, the total effective temperature required to complete a generation) of C. dictyospermi. In this model ($d_{(T)}=a+bT$), T is temperature (°C), $d_{(T)}$ is developmental rate (proportion of developmental time, 1/t), and the parameters a, and b are constants. The developmental zero (°C) are calculated according to the formula C=-a/b and thermal constant (degree days) are calculated according to formula K=1/b.

RESULTS AND DISCUSSION

Development periods of growing populations of C. dictyospermi were different from each other under different constant temperature conditions. The longest total nymphal development time was 82.00 days at 22.5°C, and the shortest was 52.00 days at 27.5°C. Developmental period decreased until 27.5°C depending on the temperature rise and it started to rise again at 30°C. The shortest preoviposition period occurred at 0.00 days and the longest oviposition period was 49.89 days at 30°C. The longest postoviposition time was 26.09 days at 27.5°C. It was determined that the longest generation time was 84.31 days at 22.5°C. The longest adult life time was 65.96 days at 27.5°C and the shortest time was 50.23 days at 25°C. The longest total life time was 101.91 days at 22.5°C. The highest daily number of crawlers was 3.45 crawlers at 25°C and 201.38 crawlers at 30°C (Table 1).

The linear equation $d_{(T)}$=0.0014T-0.0185 (R^2=0.8251) sufficiently described the relationship between the temperature and developmental rate of C. dictyospermi (Fig. I). The developmental zero (C) was estimated as 13.21°C and the total effective temperature required to

Table 1 – Development times (Day) and fecundity rates of *Chrysomphalus dictyospermi* at different temperatures*.

	n	22.5°C	n	25°C	n	27.5°C	n	30°C
The first nymphal stage	51	32.00	52	22.00	45	22.00	47	24.00
The second nymphal stage	51	50.00	52	32.00	45	30.00	47	32.00
Total nymphal development	51	82.00	52	54.00	45	52.00	47	56.00
Preoviposition	51	1.31±0.24a	52	0.12±0.05b	45	1.80±0.40a	47	0.00±0.00b
Oviposition	51	49.47±1.16a	52	41.31±1.03b	45	38.07±1.34b	47	49.89±2.36a
Postoviposition	51	9.22±1.11b	52	8.01±0.87b	45	26.09±1.26a	47	13.11±2.36b
Generation	51	84.31±0.24a	52	55.12±0.05c	45	52.80±0.40d	47	57.00±0.00b
Adult life time	51	60.00±0.00c	52	50.23±0.86d	45	65.96±0.03a	47	63.00±0.00b
Total life time	73	101.92±7.19a	68	82.29±4.87a	60	89.47±5.97a	59	96.22±5.92a
Daily number of crawlers	51	0.88±0.62b	52	3.45±0.17a	45	0.75±0.04b	47	3.20±0.19a
Total number of crawlers	51	52.84±3.71c	52	170.44±7.95b	45	49.27±2.86c	47	201.38±11.89a

* Means (±Standard errors) followed by different letters within columns are significantly different (Tukey's HSD; P<0.05; $F_{Preoviposition}$=15.574, df=3.191, P=0.00; $F_{Oviposition}$=14.573; df=3.191; P=0.00; $F_{Postoviposition}$=28.778, df=3.191, P=0.00; $F_{Generation}$=4518.658, df=3.191, P=0.00; F_{Adult_life}=238.142, df=3.191, P=0.00; F_{Total_life}=2.033, df=3.256, P=0.11; $F_{Daily\_number\_crawlers}$=119.505, df=3.191, P=0.00; $F_{Total\_number\_crawlers}$=109.068, df=3.191, P=0.00).
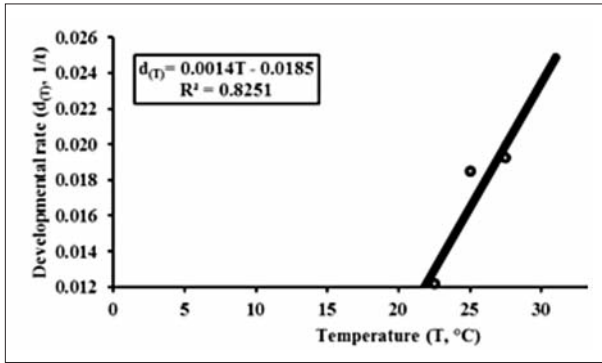
Fig. I – Temperature-dependent development rates of female population in *Chrysomphalus dictyospermi* at different temperatures.

complete a generation (K) was 714.29 degree days. CABIDO-GARCI (1949) reported that the developmental zero of *C. dictyospermi* population was 5.8°C in Portugal.

Life table parameters calculated over *C. dictyospermi* populations in different temperature conditions are given in

The longest net productive rate (R_0) of *C. dictyospermi* at 30°C was calculated as 70.58 females/female and its gross reproductive rate (*GRR*) was 88.61 females/female at 30°C. It was recorded that the longest mean generation rate (T_0) was 102.17 days and longest doubling time (T_2) was 22.62 days at 22.5°C. Finite rate of increase (*l*) was determined as 1.03 females/female at 22.5°C and was lower when compared to those at 25, 27.5 and 30°C (Table 2). Total life time of *C. dictyospermi* was strongly affected by high temperatures, lasted for 82.29 days at 25°C, while it was 101.91 days at 22.5°C (Fig. II).

Table 2 – Intrinsic rate of increase (r_m) were calculated between 0.03-0.06 females/female/day depending on temperature increase.

Parameters	22.5°C	25°C	27.5°C	30°C
Intrinsic rate of increase, r_m*	0.0306±0.000014d	0.0586±0.000018b	0.0475±0.000025c	0.0622±0.000022a
Net reproduction rate, R_o	22.89	50.96	24.79	70.58
Mean generation time, T_o	102.17	67.04	66.21	68.49
Gross reproductive rate, GRR	32.76	66.96	33.07	88.61
Doubling time, T_2	22.62	11.82	14.30	11.15
Finite rate of increase, λ	1.03	1.06	1.05	1.06
N	73	68	60	59

* Means (±Standard errors) followed by different letters within columns are significantly different (Tukey's HSD; P<0.05; $F_{Intrinsic\_rate\_increase}$=539764.409, df=3.252, P=0.00).
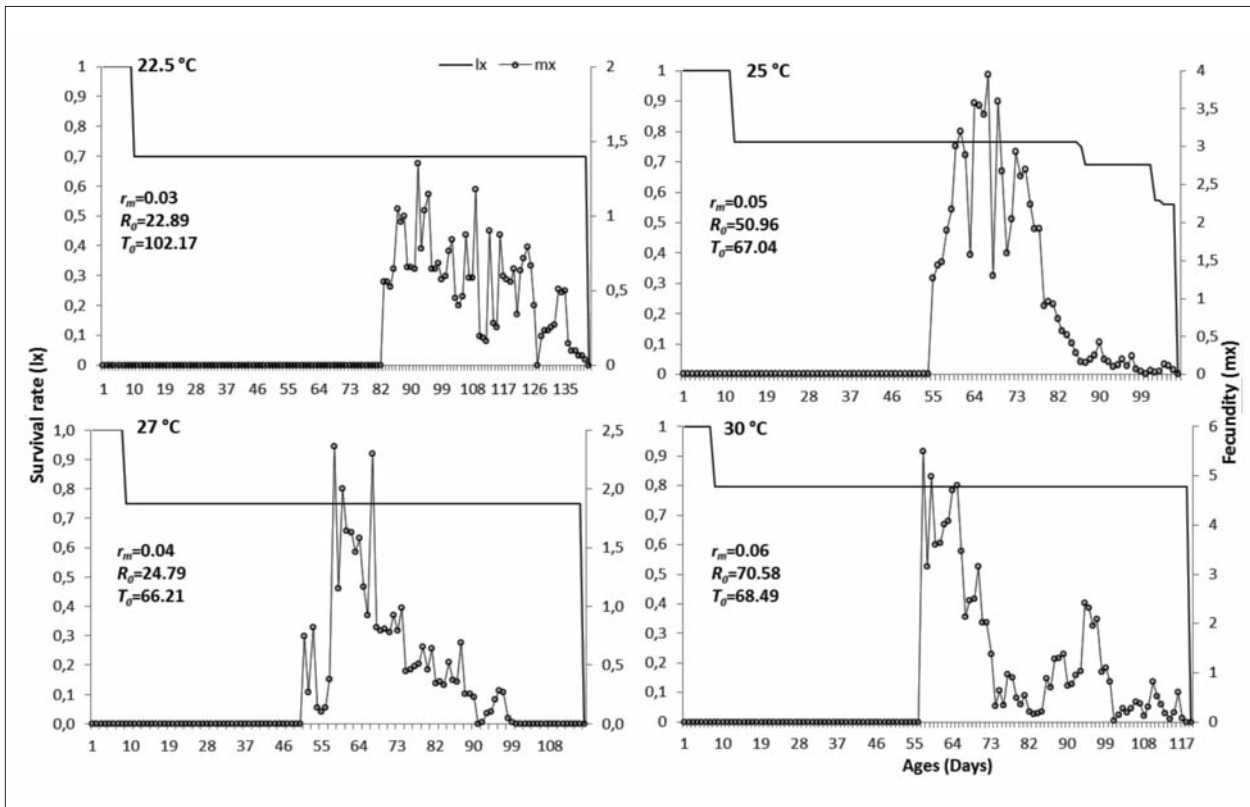

Fig. II – Survival rates (l_x), and fecundities (m_x) of *Chrysomphalus dictyospermi* at different temperatures.

A study on effective temperature requirement of *Aspidiotus nerii* Bouché (Hemiptera: Diaspididae) by GONZÁLEZ-ZAMORA *et al.* (2012) reported that the first- and second stage nymphs, and young female individuals require 24.4, 11.1, and 13.2 days, respectively, to complete their developments at 25°C, but showed no development at 30°C. However, in the present study *C. dictyospermi* showed development at 30°C. Thus, it is possible to say that *A. nerii* is more susceptible against seasonal and global temperature rise than *C. dictyospermi*. RAVUIWASA *et al.* (2012) conducted a two-sex life table study of *Aulacaspis yasumatsui* Takagi (Hemiptera: Diaspididae), at 20, 23, 25, 28, and 31°C; the intrinsic rate of increase (r_m) under these temperatures was 0.06, 0.07, 0.09, 0.10, and 0.08 d^{-1}, respectively. *A. yasumatsui* does well at warmer temperatures (25-28°C); however, lower temperatures adversely affects it performance. In a study of the life cycle of *Parlatoria blanchardii* (Hemiptera: Diaspididae), the preoviposition period, first-, and second nymph stage periods, and oviposition period were recorded as 6-13, 7-18, 9-26, and 28-59 days, respectively, at 22.5–25.5°C, under laboratory conditions (ABD EL-RAZZIK, 2000).

GERSON & HAZAN (1979) reported that oviposition periods of *A. nerii* were 39.70, 37.20, and 33.10 days on potato at 19, 24, and 28°C; . the total number of crawlers was 91.30, 99.70, and 55.10 crawlers at the same temperatures. HABIB *et al.* (1969) stated that egg production of *Parlatoria oleae* (Colvée) (Hemiptera: Diaspididae) also decreased with higher temperatures. According to this study, the egg number of *P. oleae* was 126, and 105.1 eggs per female at 24, and 30ºC, respectively. Although insects live in a variety of changing biotic and abiotic factors with different temperature regimes, studies on the effect of temperature can be very useful to understand the population dynamics of various insects. For example, a study by STATHAS *et al.* (2011) demonstrated the effect of temperature and prey on the development of a predator, *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae). *H. axyridis* has similar degree-day requirements on both preys, *Aphis fabae* Scopoli and *Dysaphis crataegi* (Kaltenbach) (Hemiptera: Aphididae) (STATHAS *et al.*, 2011). The development of all immature stages of *H. axyridis* were shorter on *D. crataegi* than on *A. fabae* at most temperatures (STATHAS *et al.*, 2011). The last point is important to predict that the predator can be established in a place. Likewise, another study on the temperature-dependent development of predators, *Nephus includens* (Kirsch) and *N. bisignatus* (Boheman) (Coleoptera: Coccinellidae) reared on *Planococcus citri* (Risso) (Hemiptera: Pseudococcidae) by KONTODIMAS *et al.* (2004) suggested the linear model as the most efficient method for the description of temperature-dependent development of these predators, and possibly for other coccinellids. The linear equation was indeed very well-fitted to experimental data obtained from the present study, as well. The results of this research proved that different temperatures have an important effect on the biological characteristics of *C. dictyospermi*. The biological characteristics provide population growth rates of an insect (TAZEROUNI & TALEBI, 2014; FREI *et al.*, 2003) and therefore, understanding them is important when establishing pest management programs. According to the predicted population growth parameters, the optimum temperature for outbreaks of *C. dictyospermi* seems to be 30°C. Accordingly, our results provide essential information and when this information is used in association with other ecological data, it can be important to predict how population of this pest will be affected by seasonal and global temperature changes. Also, the data can be used to improve pest management programs for *C. dictyospermi*.

ACKNOWLEDGMENTS

REFERENCES

ABD EL-RAZZIK M.E., 2000 – *Survey of date palm in North Sinai with special reference to the ecology and biology of the species,* Parlatoria blanchardii (Targ.-Tozz) *superfamily Coccidea*. - M. Sc., Thesis, Faculty of Agriculture. Cairo University, pp. 97.

ALFORD D.V., 2007 – *Pests of Fruit Crops*. -Manson Publishing, London, 461 pp.

ARGYRIOU L.C., 1990 – Olive. In. Rosen, D. (Eds.). *Armored Scale Insects, Their Biology, Natural Enemies and Control*. -World Crop Pests, vol 4B. Elsevier, Amsterdam, London, pp. 579-583.

BEN-DOV Y., 2012 – Scale Net, Chrysomphalus. http://www.sel.barc.usda.gov/catalogs/diaspidi/Chrysomp halus-All.htm (accessed 24 April 2012).

BIRCH, L.C., 1948 – *The intrinsic rate of natural increase of an insect population*. - J. Anim. Ecol, 17: 15-26.

CABIDO-GARCIA R., 1949 – *A contribution to the study of the systematics, morphology, biology and ecology of the yellow scale* (Chrysomphalus dictyospermi). -*Bolletin Jta. Nac. Frutas.,* 9(3): 374-465.

CAMPBELL A., FRAZER B.D., GILBERT N., GUTIEREZ A.P., MACKAUER M., 1974 – *Temperature requirements of some some aphids and their parasites*. - J. Appl. Ecol, 11: 431-438.

CHUA T.H., WOOD B.J., 1990 – *Other tropical fruit trees and shrubs*. *In.* Rosen, D. (Eds.), Armored scale insects, their biology, natural enemies and control, 4B. Elsevier, New York, pp.543-552.

CHKHAIDZE L., YASNOSH V., 2001 – *The dictyospermum scale* Chrysomphalus dictyospermi *(Morgan) (Coccinea: Diaspididae), pest of fruit and ornamental plants in the Black Sea coast of Georgia: a review*. - Bollettino di Zoologia Agraria e Bachicoltura, 33(3): 495-499.

DANZIG E.M., PELLIZZARI G., 1998 – Diaspididae. *In:* Kozár F. (Eds.). *Catalogue of Palaearctic Coccoidea*. - Hungarian Academy of Sciences. Budapest, Hungary: Akaprint Nyomdaipari Kft,, pp.172-370.

FOLDI I.,2001 – *Liste des cochenilles de France (Hemiptera, Coccoidea). [List of scale insects of France (Hemiptera, Coccoidea)]*. - Bulletin de la Société Entomologique de France, 106: 303-308.

FREI A., GU H., BUENO J.M., CARDONA C., DORN S., 2003 – *Antixenosis and antibiosis of common beans to* Thrips palmi *Karny (Thysanoptera: Thripidae)*. - J. Econ. Entomol., 96 (5):1577-1584.

GERSON U., HAZAN A., 1979 – *A biosystematic study of* Aspidiotus nerii *Bouché (Homoptera: Diaspididae) with the description of one new species*. - Journal of Natural History, 13: 275-284.

GILL, R.J., 1997 – *The scale insects of California: Part 3. The armored scales (Homoptera:Diaspididae)*. - California Department of Food and Agriculture, Sacramento, CA. 307 pp.

González-Zamora J.E., Castillo M.L., Avilla C., 2012 – *Assessment of life history parameters of* Aspidiotus nerii *(Hemiptera: Diaspididae) to improve the mass rearing of* Aphytis melinus *(Hymenoptera: Aphelinidae)*. - Biocontrol Science and Technology, 22(7): 791-801.

Habib A., Salama H.S., Amin A., 1969 – *The biology of the plum scale,* Parlatoria oleae *(Colvée) (Coccoidea: Diaspididae)*. - Bull. Soc. Ent. Egypt, 53: 283-297.

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*. - J. Appl. Entomo., 119: 487-491.

Kontodimas D.C., Eliopoulos P.A., Stathas G.J., Economou L.P., 2004 – *Comparative temperature-dependent development of* Nephus includens *(Kirsch) and* Nephus bisignatus *(Boheman) (Coleoptera: Coccinellidae), preying on* Planococcus citri *(Risso) (Homoptera: Pseudococcidae): Evaluation of a linear and various non-linear models using specific criteria*. - Environmental Entomology, 33 (1): 1-11.

Longo S., Marotta S., Pellizzari G., Russo A., Tranfaglia A., 1995 – *An annotated list of the scale insects (Homoptera: Coccoidea) of Italy*. - Isr. J. Entomol, 29: 113-130

Meyer J.S., C.G., Ingersoll L.L., McDonald, Boyce M.S., 1986 – *Estimating uncertainty in population growth rates: Jackknife vs. Bootstrap techniques*. -Ecology, 67: 1156-1166.

Özgökçe M. S., Atlıhan R., 2004 – *Biological features and life table parameters of mealyplum aphid,* Hyalopterus pruni *on different apricot cultivars*. - Phytoparasitica, 33 (1): 7-14.

Ravuiwasa K.T., Tan C.W., Bezirganoğlu İ., Hwang S.Y., 2012 – *Temperature-dependent demography of* Aula caspis yasumatsui *(Hemiptera: Diaspididae)*. - J. Econ. Entomol, 105 (5), 1581-1590.

Williams D.J., Watson G.W., 1988 – *The scale insects of the tropical south Pacific Region: Part 1, The armored scales (Diaspididae)*. - CAB International Institute of Entomology; London, 290 p.

Stathas G.J., Kontodimas D.C., Karamaouna F., Kampouris S., 2011 – *Thermal requirements and effect of temperature and prey on the development of the predator* Harmonia axyridis. - Environmental Entomology, 40 (6): 1541-1545.

USDA, 2014 – ScaleNet database. USDA project. http://www.sel.barc.usda.gov/scalenet/scalenet.html (Accessed 24 April 2014).

Tazerouni Z., Talebi A.A., 2014 – *Temperature-dependent life history of* Sipha maydis *(Hemiptera: Aphididae) on wheat*. –J. Plant Prot. Res., 54 (4): 374-382.