REDIA, XCIX, 2016: 163-170 http://dx.doi.org/10.19263/REDIA-99.16.21

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BIO-ECOLOGY OF CEDAR SCALE INSECT *TOROSASPIS CEDRICOLA* (BALACHOWSKY & ALKAN) (HEMIPTERA DIASPIDIDAE) IN ANKARA, TURKEY ([1])

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Dostbil Ö., Ülgentürk S. – Bio-ecology of cedar scale insect *Torosaspis cedricola* (Balachowsky & Alkan) (Hemiptera Diaspididae) in Ankara, Turkey.

Lebanon cedar, *Cedrus libani* A. Rich. (Pinaceae) is a significant tree from the historical, cultural, aesthetic, scientific and economic perspectives. It is presently found primarily in the Taurus Mountains with extensive and magnificent forests. Also, it has been frequently used as ornamental tree in urban areas in Turkey and abroad. Cedar scale, *Torosaspis cedricola*, (Balachowsky & Alkan) (Hemiptera: Diaspididae) is one of the important pests of cedar trees particularly in urban ecosystem. The bio-ecology of *T. cedricola* on *C. libani* is examined four localities during the years 2008 and 2009 in Ankara. *T. cedricola* has two generations in a year and overwinters as mated females. The sex ratio of *T. cedricola* is changed 1.8:1-4.8:1 (♀:♂) all study areas in both generation and the sex ratio is strongly biased towards female that occur on cedar needles only. The first generation crawlers emerged in late May but the second brood L_1 in late July. *Adalia bipunctata* (L.), *Chilocorus bipustulatus* (L.), *Exochomus quadripustulatus* (L.), *Harmonia quadripunctata* (Pont) (Coleoptera: Coccinellidae) and *Cybocephalus fodori minor* (Endrödy) (Coleoptera: Cybocephalidae) were determined as predator of the scale, while *Diaspiniphagus moeris* (Walker) (Hymenoptera: Aphelinidae) was only parasitioid species as natural enemy of *T. cedricola*. Natural enemies had a negligible effect on populations of *T. cedricola* in Ankara.

KEY WORDS: *Cedrus libani*, *Diaspiniphagus moeris,* sex-ratio*,* damage, Taurus cedar, population dynamics.

INTRODUCTION

Cedrus libani A.Rich. (Pinaceae) is an evergreen woody plant that typically grows between 500 and 2400 m altitudes (EVCIMEN 1963; SENITZA, 1989). It occurs naturally in the Taurus Mountains of Southern Turkey, in Western Syria and the Lebanon Mountains. Century-long overexploitation has resulted in devastation or degradation of most forests, but small populations of the species survived in a well-preserved state in isolated areas (BOYDAK & ÇALIKOĞLU, 2008; MESSINGER *et al*., 2015). This kind of distribution and site conditions induce morphological, phenotypical and molecular differences among populations (BILGEN *et al.*, 2012). In the recent literature, *C. libani* is in most cases divided into subsp. *libani* in Western Syria and the Lebanon mountain ranges and subsp. *stenocoma* in Southern Turkey (QIAO *et al*., 2007; DAGHER-KHARRAT *et al*., 2007; MESSINGER *et al*., 2015), the latter is also known in Turkey as Taurus cedar or Turkish cedar. The range of cedar forest presently covers about 600,000 ha in Turkey (BILGEN *et al*., 2012). Because of its adaptability, high survival rate and unique wood properties, extended reforestation attempt with *C. libani* have been made outside its natural distribution for commercial purposes both in Turkey and other countries (BOYDAK, 2003; MESSENGER *et al.*, 2015). *C. libani* has been used frequently as ornamental trees in parks, gardens, recreations areas and city forest in Turkey. In addition to anthropogenic and climatic impacts, insect pests can have dramatic effects on tree growth and wood production of Turkish cedar especially in case of pest introduction in a novel area. Scale insects are an important group of pest insects on cedar trees. *Ceroplastes floridensis* Comstock, *Coccus hesperidum* Linnaeus (Coccidae), *Aspidiotus nerii* (Bouché), *Chionaspis kabyliensis* Balachowsky, *Dynaspidiotus abieticola* (Koroneos), *Dynaspidiotus britannicus* (Newstead), *D. jaapi* (Leonardi), *Gomezmenoraspis* nr. *pinicola* (Leonardi), *Lepidosaphes juniperi* Lindinger, *Leucaspis pini* (Harting), *Torosaspis cedricola* (Balachowsky & Alkan) (Diaspididae), *Marchalina hellenica* Gennaidus (Marchalinidae) and *Phenacoccus arambourgi* (Balachowsky) (Pseudococcidae) were recorded as pests in Turkey (BALACHOWSKY & ALKAN, 1956; SELMI, 1979; ÜLGENTÜRK *et al*., 2012; ÜLGENTÜRK *et al*.,. 2013; KAYDAN *et al.,* 2014). *D. britannicus* was as an important pest on cedar. It overwinters as second nymph stage and is bivoltine on *C. libani* in Ankara (AYHAN & ÜLGENTÜRK, 2011). Although *T. cedricola* a major pest in urban cedars, it does not cause serious damage in cedar forests in Turkey (ŞAHIN & ÜLGENTÜRK, 2011). It was described by BALACHOWSKY & ALKAN, (1956) as *Acanthomytilus* genus (Borchsenius, 1950), but due to on the basis of morphological differences between *Acanthomytilus* species feeding on woody plants and those feeding on Poaceae, with *A. farsianus* Balachowsky & Kaussari transferred to the *Torosaspis* Ülgentürk (ÜLGENTÜRK & KOZÁR, 2011). *T. cedricola* caused important precocious needle fall and dieback of *C. libani, C. atlantica var. glauca, C. deodora* where used as ornamentals and in natural cedar forests over most of Turkey (ÇANAKÇIOĞLU, 1977; ÜLGENTÜRK, & TOROS, 1996; ŞAHIN &

[1] Original scientific contribution presented and discussed at XIV International Symposium on Scale Insect Studies, Catania-Italy, 13-16 June 2016.

– Received 20 September 2016 Accepted 24 October 2016

ÜLGENTÜRK, 2011) and on *Cupressus sempervirens* in Iran (MOGHADDAM, 2004). There is very limited information about the biology of *T. cedricola*. To better manage populations of *T. cedricola,* a better understanding of its biology and ecology is needed. The purpose of this study was to determine the biology, population dynamics and effect of natural enemies on *T. cedricola* under natural conditions in Ankara, Turkey.

MATERIALS AND METHODS

Field studies were conducted in four localities in Ankara provinces during the years 2008 and 2009 (Fig. I). Samples were collected once a month between November-April and one a week between April-October from each cedar tree (from 4 sides), 144 needles (4 X 3 cluster X 4 needles) totalling 576 needles from 4 localities. The number of eggs, 1st- and 2nd- instar nymphs, pupae, empty tests and adult females (young and with eggs) were counted on each needle sample. The time of appearance of each stage, its duration, the sex ratio, changes in populations and overwintering stage were determined under natural conditions. For confirmation of particular instars, individuals were transferred to 70% alcohol and slide mounted as described by KOSZTARAB & KOZÁR (1988). Determination of effects of natural enemies on cedar scale, every stage was examined under a stereo microscope and counted as live, dead, parasitized or chewed upon by predators. Climatic data are supplied by Turkish State Meteorological Service. MINITAB 15 and Kruskal-Wallis test were used for statistical analyses.

RESULTS AND DISCUSSION

The life circles of *T. cedricola* were very similar all four localities in Ankara. Therefore mainly the results of bio-ecology of cedar scale at the campus of Agriculture Faculty site are presented below. *T. cedricola* is fed only on the needles of cedar. The overwintered adult females began feeding in early May and deposited their first eggs near the end of May (29.v.2008). *T. cedricola* is ovoviviparous and deposits its eggs under the scale test. The eggs are oval in shape and cream in colour (Fig. II, 3 and 7). Oviposition continues until the end of June (26.vi.2008) (Fig IV, VI). Both eggs and first instar nymphs are often seen together under the same adult female's scale (Fig. II, 7), indicating that eggs hatch in a very short time. Average number of eggs ranged between 2,61-4,96/ ♀ under the test (Table 1). Eggs within female's body numbered 8-15 eggs (Fig. II 1, 2). During oviposition time temperature was 15,52 (11,3-22,7) C° in Ankara (Fig. V). Oviposition required nearly four weeks in the spring season (Fig. VI). First instar nymphs remained on needles until late June (26.vi.2008). The maximum number of crawlers reached (150 nymphs/ on needles) at the beginning of June (5.vi.2008) (Fig. IV). They settled on young needles of the current year. Second stage nymphs were determined by the first week of June (5.vi2008) (Fig. II 5 and 8) and remained until the end of June (26.vi.2008). Pupae, adult males and adult females were found during nearly three weeks of July (2-27.vii.2008). Adult female numbers peaked at 432 scale/144 needle by the second week of July (16.vii.2008) (Fig. IV). The temperature during this period of time averaged 24,9 (21,4–30,3) C° in Ankara (Fig. V). The scale of the female is oyster-shell shaped, light to dark brown in colour, with the exuviae situated at the narrower end. The living adult female of *T. cedricola* is elongate in shape, derm membranous, cream in color, pygidium yellowish (Fig. II, 7). Eggs and crawlers of the second generation were detected at the end of July (23.vii.2008). The summer generation of *T. cedricola* completes oviposition in two weeks. First instar nymphs remained until the end of July (23.vii.2008). The second instar nymphs were seen between last week of July and third

Fig. I – Study areas in Ankara.

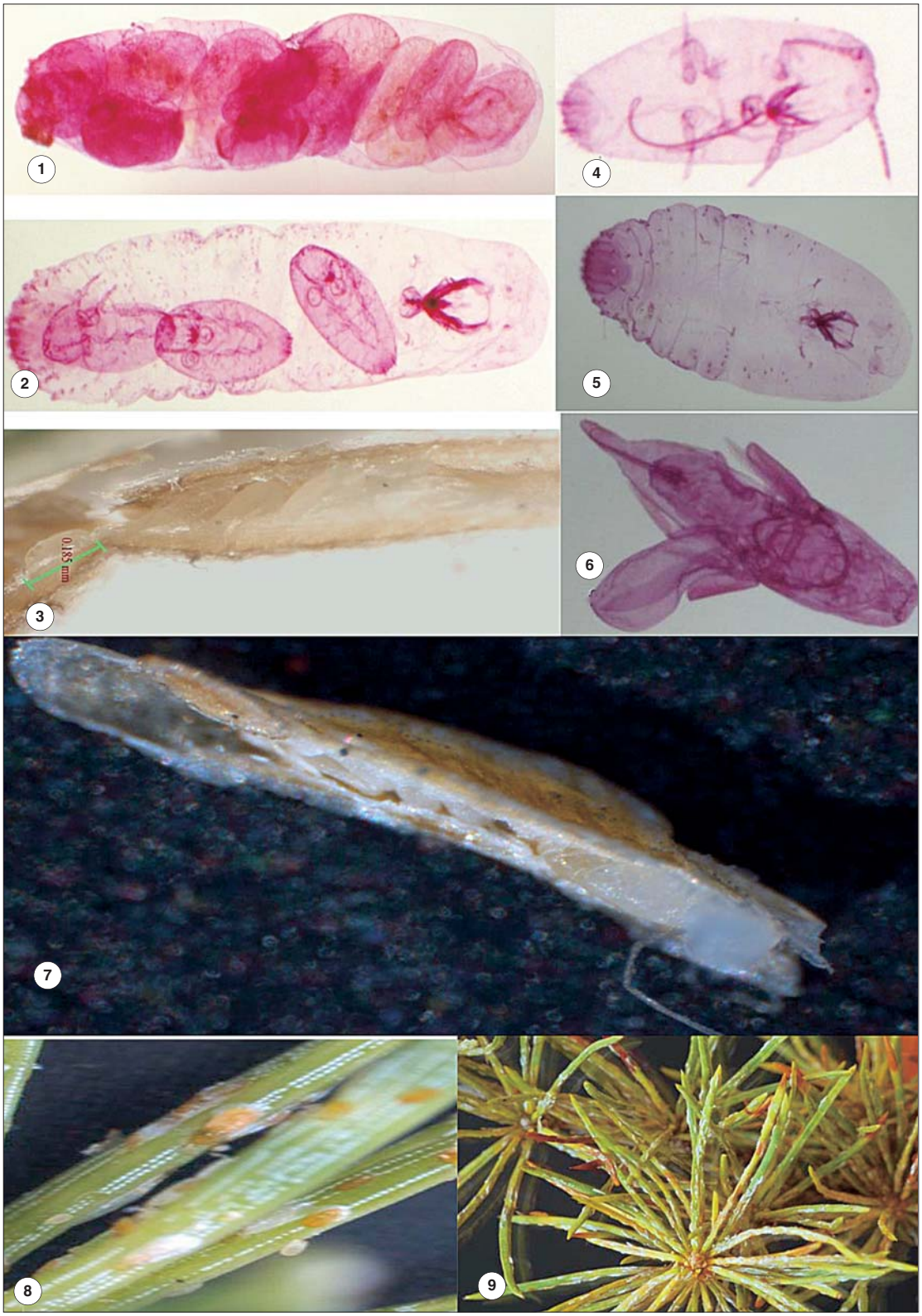

Fig. II – Eggs (1, 3) first instar (2, 4, 6) and second instar nymphs (5, 8), pupa (6), ovoposited female (7), and damage pf *Torosaspis cedricola* (9).

week of September (7 weeks). Pupae and males occurred in cedar population between 6.viii.2008 and 2.x.2008 (Fig. III, IV). The free-living adult males are yellow and possess a single pair of clear wings, one pair of ocelli, and antennae with ten segments. The first adult females of this generation were found the first week of August (Fig. III, IV). After copulation, males die, and mated females are overwinter. The overwintering period lasts more than 35 weeks and is the longest period in the life cycle of cedar scale (Fig. III, IV). Female remained in diapause up to climatic temperature in Ankara whereas the temperature is changed minus 9.8-19.4 C° (November- March) in Ankara (Fig. V). They began to feed near the end of April, and their bodies grew slightly. In 2009, the first eggs were found at the end of May.

Table 1 – Eggs number of *Torosaspis cedricola* (Balachowsky&Alkan) on *Cedrus libani* in Ankara.

Localities	2008		2009	
	I. generation	II. generation	I. generation	II. generation
AF[1]	4,22 (1.68–5,30)	2,61 (1,69–3.50)	4,39 (1,72–5,52)	3,41 (1,66–5.08)
Kurtuluş Park	4,96 (3,75–5,44)	2,73 (1,78–4,90)	4,86 (2,00–5,45)	3,88 (1.78–4.75)
IFR[2]	3,76 (2,81–4,89)	3,33 (0,93–5,08)	3,98 (2,81–4,83)	3,97 (2,45–5,14)
METU[3]	4,37 (2,56–5,18)	3,78 (0,57–5,04)	4,38 (2,54–5,18)	4,04 (1,25–5.02)

[1]Faculty of Agriculture, [2]Institute of Forestry Research, [3]Middle East Technical University.

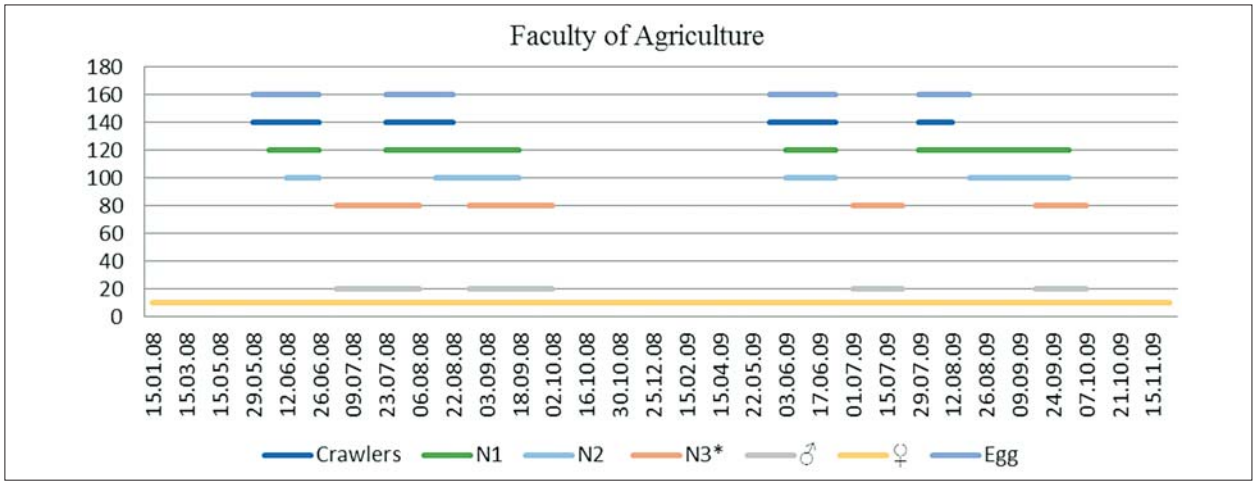

Fig. III – Duration of *Torosaspis cedricola* (Balachowsky&Alkan) in Ankara (*Prepupa+pupae).

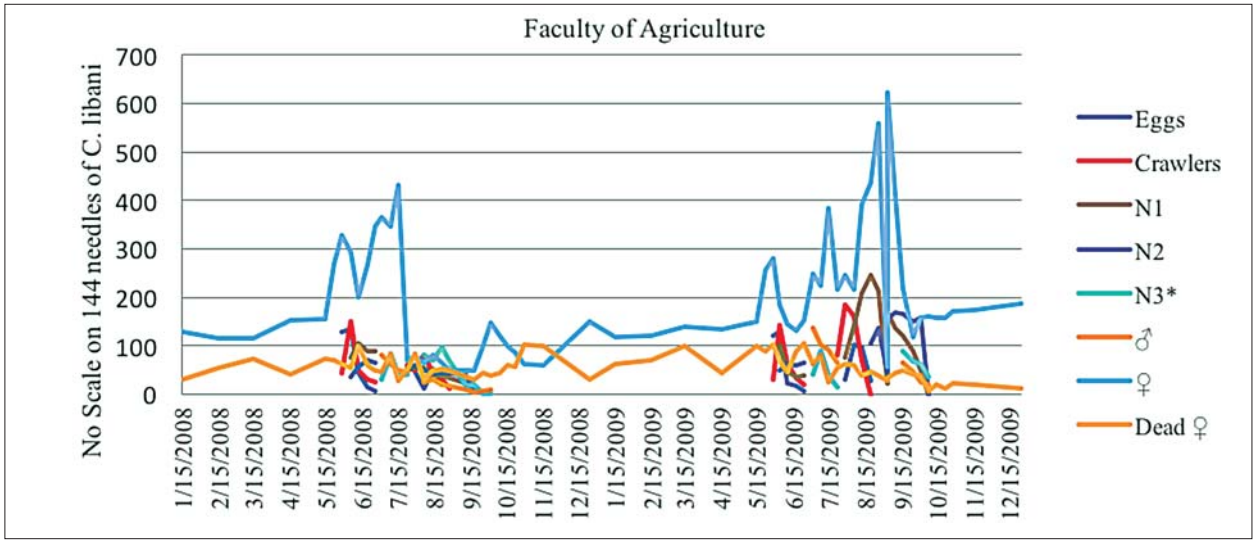

Fig. IV – Population fluctuation of *Torosaspis cedricola* (Balachowsky & Alkan) in Ankara (*Prepupa+pupae).

Crawlers emergence and male flight occurred on nearly similar dates as the previously year. According to these results, *T. cedricola* has two generations per year in Ankara.

The population densities of *T. cedricola* female were significantly higher in 2009 than 2008 in all study areas (Table 2; Fig. III) but no significant differences between the sites within each year.

The sex ratio of *T. cedricola* ranged from 1.8:1-4.8:1 (♀:♂) across all study areas through both generations and the sex ratio was strongly biased towards the female. In Agriculture Faculty, it was 64,59% female, 35,41% male for the first generation and 77,11% female, 22,89% male for the second generation (Table 3). An extremely female-biased sex ratio was reported by Alstad & Edmunds (1983) in *Dynaspidiotus* (=*Nuculaspis*) *californiaca* (Coleman) growing on *Pinus ponderosa*. Additionally, Rasekh *et al.* (2011) reported that *Dynaspidiotus abietis* (Schrank) was female–biased in both second instar nymphs and adults.

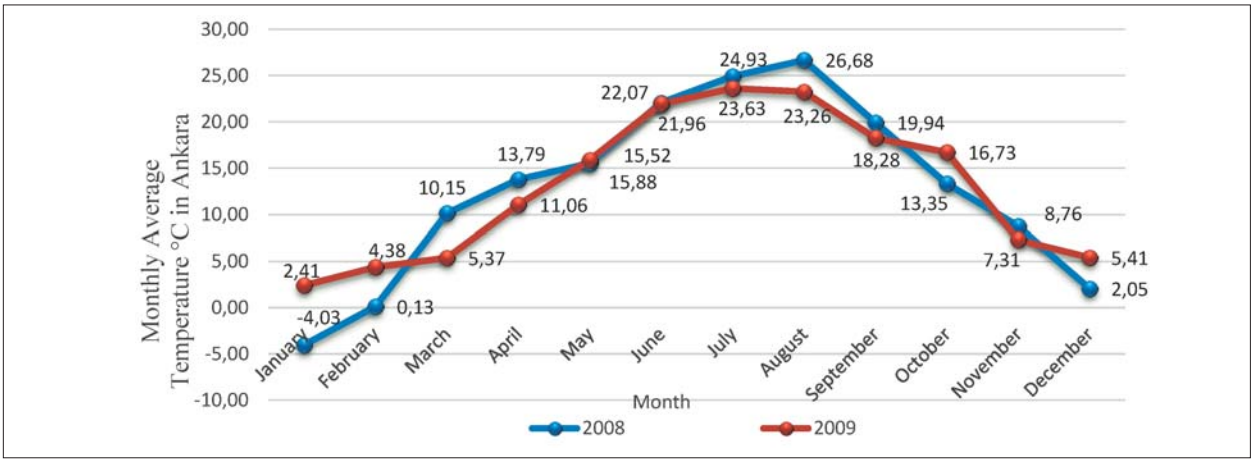

Fig. V – The monthly average temperature of Ankara in 2008-2009

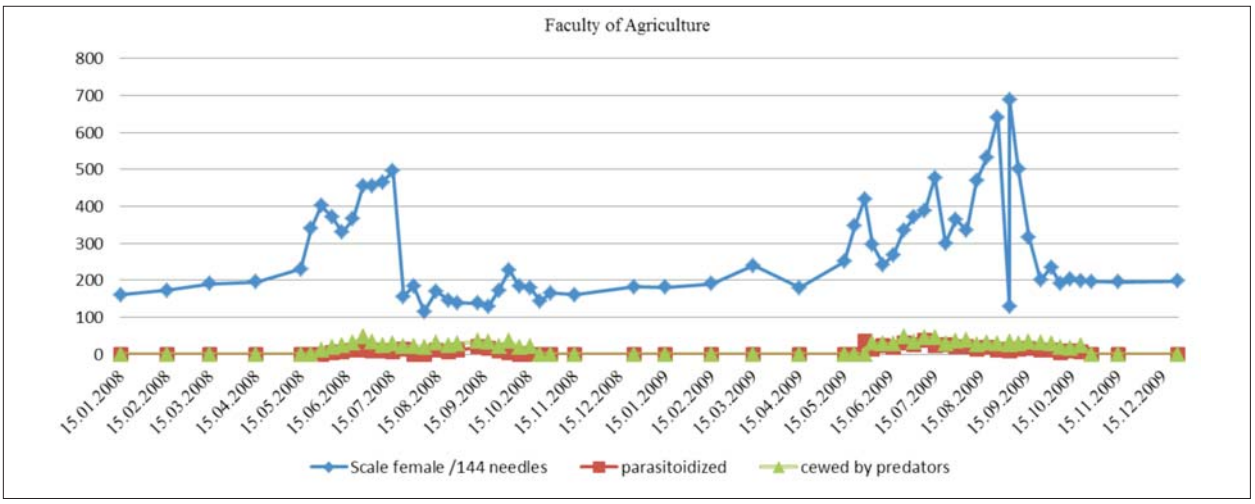

Fig. VI – Effects of natural enemies on *Torosaspis cedricola* (Balachowsky & Alkan) population on *Cedrus libani*, in Ankara.

Table2 – Adult female number *Torosaspis cedricola* (Balachowsky&Alkan) per needle of *Cedrus libani* in Ankara.

Localities	n	2008	n	2009
AF[1]	31	158,5±20,3(49–432)b	31	234,8±23,4(118–622)a
Kurtuluş Park	31	80,58±5,13(37–141)b	31	218,4±17,8(108–458)a
IFR[2]	31	92,55±6,93(45–180)b	31	263±25,9(100–630)a
METU[3]	31	107,03±8(40–210)b	31	262,5±27,2(110–631)a

[1]Faculty of Agriculture, [2]Institute of Forestry Research, [3]Middle East Technical University.
* In different rows and the difference between the mean values with different letters were significant (P<0.05).

Natural enemies and their effects on populations of cedar scale

Predators; *Adalia bipunctata* (L.), *Chilocorus bipustulatus* (L.), *Brumus quadripustulatus* (L.), *Harmonia quadripunctata* (Pont) and (Coleoptera: Coccinellidae) *Cybocephalus fodori minör* (Endrödy) (Coleoptera: Cybocephalidae) were associated with *T. cedricola* in Ankara (Table 2). *A. bipunctata* and *H. quadripunctata* were found in few numbers with Cedar scale. The reason for this is possibly that generalist and facultative predators. They feed on aphids and other small, soft bodied insects (Uygun, 1980; Ülgentürk & Toros, 2001; Erler *et al*., 2001; Kaydan *et al*., 2006). Likewise, *B. quadripustulatus* was rarely found with cedar scale. Although *B. quadripustulatus* mainly feeds on mealybugs and soft scales, there records of it preying on diaspidids including *T. cedricola* (as *A. cedricola*) (Uygun, 1980; Drea & Gordon, 1990; Ülgentürk. 2001). The coccinelids, *C. bipustulatus* and *C. fodori minor* were more common and occurred in higher numbers than the above predators with cedar scale. All predators fed upon *T. cedricola* during May-the end of October both years. Predator activities increased

Table 3 – The sex ratio of *Torosaspis cedricola* (Balachowsky&Alkan) in Ankara.

Localities	I. generation			II. generation		
	♀	♂	♀:♂	♀	♂	♀:♂
AF[1]	%64,59	%35,41	1.8:1	%77,11	%22,89	3.3:1
Kurtuluş Park	%68,16	%31,84	2.1:1	%65,46	%34,54	1.8:1
IFR[2]	% 72,52	%27,48	2.6:1	% 82,61	% 17,39	4.8:1
METU[3]	% 76.01	% 23,99	3.1:1	% 75,420	% 24,58	3:1

in the middle of May and peaked in the middle of June. This corresponds to periods of oviposition and crawler emergence for cedar scale. Predation is slightly decreased during summer and autumn but continued until the end of October (Fig. VI). This possibly occurred for two reasons. Firstly, these predators are generalist, and they can immigrate to feed on other prey. Secondly, they could aestivate during hot, dry periods (Drea & Gordon, 1990). Activities are reduced during the cold period, but they could feed under warmer condition. After winter period they are begun to feed with cedar scale in the middle of March slowly. Unfortunately, predators did not control effectively cedar scale in Ankara (Table 4, Fig. VI). *C. bipustulatus* was a predator of *Aonidiella aurantii* (Maskell), *Chionaspis salicis* L., *Epidiasaspis leperii* (Signoret), *A. cedricola, Carulaspis juniper* (Bouché), *Diaspidiotus perniciosus* Comstock, *Dynaspidiotus (=Nuculaspis) abietis* (Schrank), *D. britanicus, Lepidosaphes ulmi* Linnaeus, *Leucaspis riccae* (Targ.-Tozz.), *Pseudaulacaspis pentagona* Targ. Tozz., *Salicicola africana* (Newstead) and *Unaspis euonymi* (Comstock) (Hemiptera: Diaspididae) in Turkey (Schumutterer, 1953; Uygun, 1981; Kosztarab & Kozár, 1988; Erler & Tunç, 2001, Ülgentürk & Toros, 2001; Özyurt & Ülgentürk, 2007; Ayhan & Ülgentürk, 2011; Mohammed *et al*., 2016).

C. fodori minör is a very small beetle and that preys on armored scale insects worldwide (Drea & Gordon, 1990) *T. cedricola, A. aurantii, Chrysomphalus dictyospermi* (Morgan), *Carulaspis minima* (Signoret), *D. europaea, D. perniciosus, E. leperii, L. ulmi, L. riccae, L. striata, Parlatoria oleae* (Colveé), *P. pentagona*, and *U. eunoymi* were preyed upon *C. fodori minör* (Erkiliç & Uygun, 1995; Erler & Tunç, 2001, Ülgentürk & Toros, 2001)). In Iran, *C. fodori minör* was consumed 20.81, 39.18 and 42.01% of *Lepidosaphes pistaciae* Arch. (Hemiptera: Diaspididae) settled on twigs, leaves and fruits of pistachio trees, respectively (Kolahdooz *et al*., 2012).

The only parasitoid species emerging from cedar scale was *Diaspiniphagus moeris* (Walker) (Hymenoptera: Aphelinidae). *Diaspiniphagus* is considered a valid genus distinct from *Coccophagoides* and *Coccophagoides moeris* (Walker) was transferred to *Diaspiniphagus* Silvestri by Hayat, (2011). Oval emergence holes of this parasitoid on cedar scale were first seen in the middle of May and continued until the second week of September. *D. moeris* hibernated inside female bodies as fully-fed larvae or pupae and adult wasps emerged the middle of May. Initial ratio of parasitism was relatively high but decreased at summer and autumn seasons (Fig 4). Parasitoids were ineffective in controlling *T. cedricola* populations. Possibly this was due to the high sulphur dioxide and dust levels on Cedar trees in Ankara (Dostbil, 2011). According to Viggiani (1990), female of *D. moeris* (=*Coccophagoides. similis* (Masi)) deposited fertilized eggs into young host female, rarely in second instar hosts and the larvae develop as primary parasites, whereas male development was period after hyperparasitic. In Turkey, *D. moeris* (as *C. similis*) attacked to *A. aurantii* in Antalya (Erler & Tunç, 2001), and before *Torosaspis* (as *Acanthomytilus*) *cedricola, Diaspidiotus ostreaformis* (Curtis) and *Salicicola kermanensis* (Lindinger) in Isparta provinces (Japosvilli & Karaca, 2002). In central Europe, this parasitoid (*as C. similis*) attacked to *Chionaspis lepineyi* Balachowsky, *Diaspidiotus hungaricus* Kosztarab, *Diaspidiotus gigas* (Thiem & Gerneck), *D. ostreaformis*, *D. abietis, E. leperii*, *Lepidosaphes conchiformis* (Gmelin), *L. ulmi*, *Leucaspis*

Table 4 – Predators and parasitoid of *Torosaspis cedricola* (Balachowsky & Alkan) on *Cedrus libani*, in Ankara.

Species	Localities
Harmonia quadripunctata (Pont) (Coleoptera: Coccinellidae)	Campus of Forestry Institute, 2 ♀♀; 23.v.2008
Adalia bipunctata (L.) (Coleoptera: Coccinellidae)	Campus of Agriculture 5 ♀♀;2♂♂, 23.v.2008; 11 adet 04.07.2008;
Chilocorus bipustulatus (L.) (Coleoptera: Coccinellidae)	Campus of Agriculture, ♀♀;4♂♂14.vi.2008; 21.06.2008; 16 ♀♀, 21.vi.2008; 10.07.2009 16 ♀♀; 8 29.07.2009; ODTÜ-10 30.07.2009; OGM -6 5.08.2009; Fakülte-17 OGM -6 5.08.2009;5.08.2009 Fakülte-17; ODTÜ-15; ODTÜ 10, 13.08.2008; OGM 8 01.11.2008; ODTÜ-7; 01.11.2008
Brumus quadripustulatus (L.) (Coleoptera: Coccinellidae)	Faculty of Agriculture Campus, 7 ♀♀,
Cybocephalus fodori minor (Endrödy) (Coleoptera: Cybocephalidae)	Faculty of Agriculture campus 5♀♀ 18.vi.2008; Kurtuluş Park 5♀♀, 20.vi.2008; Institute of Forest Research campus 5♀♀, 21.vi.2008; 6♀♀, 5.viii.2009; Middle East Technical University, 21.vi.2008
Diaspiniphagus moeris (Walker) (Hymenoptera: Aphelinidae)	ODTÜ, 04.07.2008; 10.07.2008; 22.07.2008; 10.08.2008; Cebeci, 15.vii.2009; Kurtuluş Park, 15.vii.2009; ODTÜ 17.viii.2009; Cebeci, 1.ix.2009

pusilla Löw, *P. oleae*, *Targioni vitis* (Signoret) and *Unaspis euonymi* (Comstock) (Hemiptera: Diaspididae) (KOSZTARAB & KOZAR, 1988).

In conclusion, even though *Cedrus libani* is high adaptability and high survival rate, high populations of *T. cedricola* have a very harmful effect on the trees, especially young cedar trees in parks and gardens in Ankara. High levels of Sulphur dioxide and dust limited the activities of natural enemies in urban planting of cedar. The very thin and small cedar scale is often difficult to detect on cedar needles, therefore it is many times too late to apply treatments for control once they are discovered. Treatments of insecticides should be directed at the crawler stages, at first in June and again if necessary, in August in parks and gardens in Ankara.

ACKNOWLEDGEMENT

The authors are grateful to Ankara University, Foundation of Scientific Research for supporting and identification of Aphelinidae and Coccinellidae species Prof. Dr Miktat Doğanlar and Prof. Dr Nedim Uygun respectively.

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