Türk. entomol. bült., 2012, 2 (1): 11-22
ISSN 2146-975X

Orijinal araştırma (Original article)

Current status of the red palm weevil in Canary Island date palms in Adana

Kırmızı palmiyeböceği'nin Adana ilinde Kanarya hurması ağaçlarında mevcut durumu

Ekrem ATAKAN[1*] Oğuz YÜKSEL[2] Victoria SOROKER[3]

Summary

The infestation of the red palm weevil, *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Curculionoidae: Dryophthoridae) in the Canary Island palm trees (*Phoenix canariensis* Hort. ex Chabaud) grown as ornamentals was the first time detected in Adana, Turkey in 2007. Between 2007-2010 preventative and curative treatments of chemical insecticides as well as weevils trapping and sanitation efforts were carried out in Adana. Additionally, natural infestations with the entomopathogenic nematodes, (EPN), *Heterorhabditis bacteriophora,* (Poinar, 1975) (Nematoda: Heterorhabditidae) on the weevil individuals were also evaluated. A significant decrease in number of captured beetles by traps was found in 2009 and continued following year. The sex ratio of captured adults was significantly female-biased (~ %70 of total catch was females). Seasonal mortality rate by the EPN in the total larval population of *R. ferrugineus* was 50%. EPN caused a significant mortality rate (85%) in the pupae population . EPN also killed a few adults, corresponding to 1-5% of the mortality rate. New infestation on date palm trees has not been recorded since 2010, indicating that control efforts including trapping, prophylactic chemical insecticide treatments and natural infestation of the EPN are effective in reduction of the RPW populations in Adana.

Key words: *Rhynchophorus ferrugineus,* date palm, trapping, insecticide treatment, entomopathogenic nematode

Özet

Kırmızı palmiyeböceği (KPB), *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Curculionoidae: Dryophthoridae)'un Kanarya hurması (yalancı hurma) ağaçlarındaki ağır zararı Adana ilinde ilk kez 2007 yılında saptanmıştır. Böceğin zararının saptanmasını takip eden 4 yıllık süreçte (2007-2010), koruyucu ve tedavi edici kimyasal insektisit uygulamaları, erginlerin tuzakla yakalanması ve sanitasyon çalışmaları sürdürülmüştür. İlave olarak, entomopatojen nematot (EPN), *Heterorhabditis bacteriophora* (Poinar, 1975) (Nematoda: Heterorhabditidae)'nın KPB üzerindeki doğal enfeksiyonları da değerlendirilmiştir. Tuzaklarda yakalanan ergin sayılarında azalma 2009 yılında saptanmış ve bu azalma takip eden yılda da devam etmiştir. Yakalanan erginlerin cinsiyet oranı önemli oranda (%70) dişi lehine olmuştur. *R. ferrugineus*'un toplam larva popülasyonunda EPN nedeniyle ölüm oranı %50 olarak bulunmuştur. EPN pupa popülasyonunda önemli oranda (%80) ölüme neden olmuştur. EPN, az sayıda ergin bireyi de öldürmüş olup, ölüm oranları %1-5 arasında değişmiştir. 2010 yılından bu yana Adana ili hurma ağaçlarında yeni infeksiyonların olmaması; tuzaklama, koruyucu kimyasal insektisit uygulamalarının ve ayrıca EPN'ın doğal infeksiyonlarının KPB popülasyonun azalmasında etkili olduğunu göstermektedir.

Anahtar sözcükler: *Rhynchophorus ferrugineus,* hurma ağacı, tuzaklama, insektisit uygulaması, entomopatojen nematot

[1] Plant Protection Department, Faculty of Agriculture, Çukurova University, Adana, Turkey
[2] Adana Great Municipality, Directorate of Parks and Gardens, Adana, Turkey
[3] Department of Entomology, ARO, The Volcani Center, Bet Dagan 50250, Israel
* Sorumlu yazar (Corresponding author) e-mail:eatakan@mail.cu.edu.tr
Alınış (Received):06.09.2011 Kabul ediliş (Accepted): 19.12.2011

Introduction

The red palm weevil, *Rhynchophorus ferrugineus* (RPW) (Olivier, 1791) (Coleoptera: Curculionoidae: Dryophthoridae) is a very harmful palm pest. In particular, date palm trees *Phoenix dactylifera* L in the Gulf region (Cox, 1993; Abraham et al., 1998) and the Middle-East (Cox; 1993; Kehat, 1999) and coconut crops in India and suffer heavy losses in date palm crop. Originate of this pest insect is southern Asia and Malaysia. RPW has been advancing westwards very quickly since the mid 1980s. This pest was the first time recorded in the Kingdom of Saudi Arabia and United Arab Emirates in the end of November 1992 in El-Hussinia, Sharquiya region (Cox, 1993). This pest was recorded in south of Spain (Barranco et al., 1996) Israel, Jordan in 1994 and in the Palestinian Authority Territories in 1999 (Kehat, 1999). In Italy, RPW was detected for the first time in 2004 and it caused 30.4% of damage to infested Canary palms (Conti et al., 2008).

The injury to palms is caused by larval stages tunnelling in palm trunks, which are clearly visible only after severe infection occurred. This creates serious problems in controlling of the pest in date palms due to late detection of *R. ferrugineus* infestations.

In Turkey, the first RPW infestation was reported on ornamentally grown date palms, *P. dactylifera* L. in Mersin in 2005 (Karut & Kazak, 2005). In 2007, destructive infestations of the RPW on the Canary Island date palm trees, *Phoenix canariensis* Hort. ex Chabaud, grown as an ornamental plant, occurred in Adana province. RPW has become widely distributed in the date palms grown in parks and gardens over most parts of the Mediterranean and Aegean regions of Turkey.

Information about the biology, ecology and damage of this pest species as well as its control by the various management tactics including biological control agents are reviewed in detail by Murphy & Briscoe (1999) and Ferry & Gomez (2002).

Different control tactic against RPW are employed in date palm and coconut plantations worldwide. Among those, pheromone and kairomone baited traps are widely used against this very harmful pest for monitoring and mass trapping (Murpy & Briscoe, 1999; Soroker et al., 2005). Cryptic preimaginal stages of RPW makes its control difficult. Therefore, the management strategy for the RPW include cultural, mass trapping, chemical and biological control (Peter, 1989; Gobinadhan et al., 1990; Rajan & Nair, 1997; Murphy & Briscoe, 1999; Hanounik, 1998; Hanounik et al., 2000; Abbas et al., 2000, 2001).

This paper summarizes various control tactics used against *R. ferrugineus* in public parks and in home gardens during 2007-2010. This paper presents also recent status of the natural infestations of entomopathogenic nematode (EPN), *Heterorhabditis bacteriophora* (Poinar, 1975) (Nematoda: Heterorhabditidae), which was detected for the first time in Turkey on the RPW in 2007 (Atakan et al., 2009).

Material and methods

Monitoring

The populations of adult weevils were monitored using male aggregation pheromone (ferrugineol) traps [Tripheron, Ryfer (trade name), Trifolio GmbH Company, Germany] set in various parts of the Adana province. First traps were hung up to trees in November in 2007. Scandinavian type of pheromone traps [4-methyl-5-nonanol, (3.09%) 198 mg; 4-methyl-5-nonanone (0.35%) 22 mg] with three funnels were placed at 178 points scattered over Centre of Adana province. No pesticide or no food bait was added in the traps. Trap numbers were 78, 400, 451 and 478 in 2007, 2008, 2009 and 2010, respectively. Trap numbers in the infestation points ranged between 1 and 34, according to infestation level of RPW and to numbers of date palms (*Phoenix canariensis* Hort. ex Chabaud and *Phoenix dactylifera* L.) grown in each trapping area. A range of 15-34 traps were placed in the boulevards such as “Turgut Özal”, “Kabasakal”, “Süleyman Demirel” and “Fuzili Street”. A total of 57 traps were placed in the Campus of Çukurova University where there were over 500 trees of *P. canariensis*. In other trapping points, numbers

of pheromone traps ranged between 1 and 10. Boulevard Kabasakal has a total of 260 trees of *Phonenix* (*P. canariensis* plus *P. dactylifera*). Numbers of date palms (mainly *P. canariensis*) vary from 1 to 40 in other infestation points after removal of the death palms. All traps were set to tree trunk at 2 m-height level from ground. Traps were randomly set up to trees in the parks or home gardens. Traps at the boulevards were hung up to tree trunks with a space of 50 or 80 m. The traps were replaced every 2-3 months with new one. The traps were inspected regularly from November 2007 to December 2010.

To determine percentage of adults (females + males) captured at traps trapping points were classified into 3 levels, according to proportions of palms destroyed in each area: (1) highly-infested area (totally 7 points), where over 80% of the palms were destroyed (i.e., hot spots), (2) partly-infested area (totally 24 points), where 10-15 % of the palms were destroyed (3) non-infested area (147 points), where there was no reported infested palms since 2007. Data from trapping points representing similar infestation level of RPW were pooled. Infestation levels at the points were determined by consideration of the damage levels of the RPW in 2007 i.e., numbers of deadly infested date palms in each area.

Sanitation

We removed absolutely destroyed palm trees in the infested areas in 2008-2009. Initially all leaves of deadly infested trees were pruned and sprayed. Crowns of trees were wrapped in thick black polyethylene plastic immediately to prevent possible escape of surviving adult weevils. The trunks were transported carefully to the designated area where trunks were chopped to reasonable pieces with 50-100 cm. After chopping, trunk parts, positioned horizantially on ground, were treated with a solution of kerosene plus alphacypermethrin EC 100 g/l prior to burial.

Chemical control

The various control strategies carried out against the red palm weevil were implemented by the Adana Great Municipality.

The insecticides were applied to both *P. canariensis* and *P. dactylifera* as preventive and curative treatments. In curative treatments, prior to applying of the direct injection method, old leaves of the partially infested trees were pruned and then sprayed with imidacloprid SC 350 or imidacloprid 210 g/l + betacyflutrin 90 g/l at dose of 250 g /100 l water. Curative method of infested trees included stem injection with imidacloprid SL 200 drilling trunks with 10-cm deep from 1.5-2 m level below of infested crown, at 4-5 different points of a trunk. In each hole, dose of 40 ml of the pure imidacloprid SL 200 was injected and then holes were plugged with the graft paste. As preventive treatments was pouring the imidacloprid SC 350 with dose of 40 cc/30 l water per tree, through the soil near to roots of the palms at 2-3 month intervals. Soil treatments of imidacloprid SC 350 were also applied to partially infested palms. We treated 3000 trees of date palms by both the stem injections and soil application of imidacloprid. Stem injections were carried out two months intervals i.e. October and January during 2008-2009. Soil applications of imidacloprid were done two months intervals during 2008-2010. We also sprayed 3000 trees of date palms with imidacloprid SC 350 or imidacloprid 210 g/l + betacyflutrin 90 g/l in May and October to prevent adult activities in 2008-2010. We did not apply any chemical treatments to other palms such as *Washingtonia* and scads in Adana province.

Sampling of red palm weevil

One to three of died and cut trunks were carefully studied for numbers of the red palm weevil at each sampling date (in total 20 sampling dates throughout February 2008-December 2010). Dead palms of 2007 (totally 405 *P. canariensis* and one *P. dactylifera*) were removed in February 2008. Total 53 palm trees (*P. canariensis*) were dissected in 2008-2009. We classified the larvae into 3 stages base and head capsule widths; young (< 3 mm), medium (3-5 mm) and mature (> 5 mm) stages. The collected adults were sexed according to gender-specific external characteristics of the rostrum according to Booth et al. (1990). Dead and alive larvae, pupae and adults were examined carefully by dissecting of their bodies for

the presence of natural enemies including the entomopathogenic nematodes in the laboratory. We observed that bodies of the infested pre-adult stages by the nematode turned to dark brown or sometimes greenish-brown. Bodies of some larvae were apparently swollen. We also detected sometimes juvenile stage of the nematode in bodies of killed larvae or pupae. Morphological identification of the entomopathogenic nematode infestation on the weevil individuals was also confirmed by Dr. Uğur Gözel (Çanakkale Onsekiz Mart University, Çanakkale, Turkey).

To detect presence of nematodes, we implemented a bioassay using larvae of *Galleria mellonella* (L.) (Lepidoptera: Pyralidae) as recommended by Bedding & Akhurst (1975). These were artificially infested by using either larvae or pupae of the weevil which had symptoms of infection by an entomopathogenic nematode. Molecular detection of the *Heterorhabditis bacteriophora* (Poinar, 1975) (Nematoda: Heterorhabditidae) was described in detail in our prevous work (Atakan et al., 2009).

Results

Pest status of red palm weevil

While 11% of *P. canariensis* trees in 2007 were killed by *R. ferrugineus*, only one tree of *Washingtonia filifera* (L. Linden) and one *P. dactylifera* L. were killed (Table 1). Only 1% of the date palms were infested fatally in 2008. In 2009, only six trees of *P. canariensis* died due to RPW attacks and overall infection rate was lower than 1%. No infected palms was found in 2010 and during the manuscript preparations in 2011.

Table 1. Palm species killed by the *Rhynchophorus ferrugineus* in the recreation areas in Adana province, Turkey in 2007 - 2009

	No. of palm trees									
	2007				2008			2009		
Palm species	Total no.	Killed	Healthy	Mortality (%)	Killed	Healty	Mortality (%)	Killed	Healthy	Mortality (%)
Phoenix canariensis Hort.	3 600	405	3195	11	37	3158	1	6	3152	<1
Phoenix dactylifera L.	800	1	799	<1	0	799	0	0	799	0
Washintonia spp. [*W. robusta* H. Wendl. and *W. filifera* (L. Linden)]	110 246	1[a]	110 245	<0.001	0	110 245	0	0	110 245	0

[a] The tree killed was a *Washintonia filifera* (L. Linden)

Composition of red palm weevil at different developmental stages in *Phoenix canariensis* trees

We inspected composition of RPW at different developmental stages in 53 deadly infested *P. canariensis* trees that they were cut between February 2008 - December 2009 in Adana province. We collected 80 to 653 individuals from the nine trees whose tissues absolutely were destroyed in 2008 (Table 2). In these trees, adults dominated populations in February and December, accounting for 46% and 55% of total individuals respectively In 2009, we collected 300 to 1270 individuals in trees partially desiccated (these trees had still live plant tissues but their growing point was destroyed), (Table 2). Larvae was dominated the pupae and adult populations in four trees cut down at November-December period in 2009. Percentage of pupae and adults in cocoons in partially infested trees were very similar, excluding the data obtained in November 2008 and in December 2009. Larval composition varied; the larval population consisted of 0-11% of young - 13-30% of medium - and 59-88% of mature - stage of larvae.

Table 2. Percentages and total numbers of *Rhynchophorus ferrugineus* individuals at different stages in trunks of *Phoenix canariensis* in Adana province, Turkey in 2008-2009

Years	Months	Percentages of individuals				
		Larvae	Larvae in cocoon	Pupae in cocoon	Adults in cocoon	Adults
2008	Feb[a]	7 (49)[c]	3 (14)	38 (251)	6 (42)	46 (297)
	Oct[b]	73 (407)	2 (14)	5 (28)	6 (33)	14 (80)
	Nov[b]	28 (83)	25 (72)	22 (64)	25 (73)	0 (0)
	Dec[a]	0 (0)	26 (21)	15 (12)	4 (3)	55 (44)
2009	Nov[b]	57 (171)	12 (36)	12 (37)	1 (2)	18 (54)
	Dec[b]	35 (441)	6 (72)	21 (264)	25 (322)	13 (171)

[a] Palm trees were absolutely desiccated; [b] palm trees were partially desiccated (these trees had still live plant tissues but thereafter they were cut due down to death of the their growing points)
[c] Values in the parenthesis indicate total numbers of individuals

Trap catches

Monthly total numbers of weevils (females + males) captured at the traps are shown in Figure 1. First adult weevils were trapped in April or May. Seasonal mean numbers of trapped adults in 2008 were greater when compared to those of 2009 or 2010. The catches peaked twice a year in July and in September-\October. After this month, mean numbers of captured weevils decreased gradually, excluding high mean numbers of adults caught at the traps placed for the first time in November in 2007.

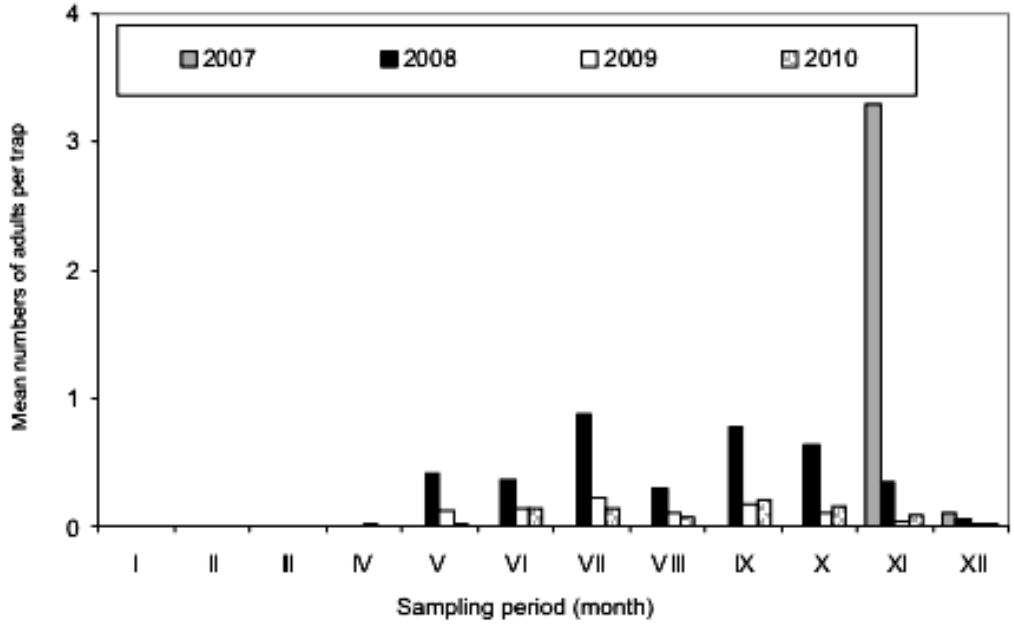

Figure 1. Monthly mean numbers of red palm weevil adults (female + male) captured by pheromone traps in Adana province, Turkey. In 2007, traps were hung up to trees in December. Traps numbers were 78, 400, 451, and 478 in 2007, 2008, 2009, and 2010, respectively.

Trap catches of RPW in pheromone traps placed in the three areas representing the different infestion levels of RPW are shown on Table 3. In 2007-2008, most numbers of adults were captured by traps in highly-infested areas (i.e., hot spots) (Table 3). After 2008, seasonal mean numbers of captured adult weevils in the all three areas decreased gradually (Table 3).

Table 3. Seasonal mean numbers of *Rhynchophorus ferrugineus* in pheromone traps placed in the three areas with the different infestion levels in Adana province, Turkey in 2007-2010

		Highly infested-area		Partly infested-area		Non infested-area	
Years	Total no of traps	No of traps	Mean no of adults per trap	No of traps	Mean no of adults per trap	No of traps	Mean no of adults per trap
2007[a]	78	n=45	21.66 (260)[b]	n=11	3.63 (40)	n=22	0.95 (21)
2008	400	n=98	7.09 (695)	n=128	2.42 (311)	n=174	0.54 (95)
2009	451	n=106	1.56 (166)	n=128	0.66 (85)	n=217	0.31 (69)
2010	478	n=110	0.75 (83)	n=134	1.04 (136)	n=234	0.18 (44)

[a] Traps were hung up to trees in November and December in 2007
[b] Values in the parenthesis indicate total numbers of individuals

Total numbers of red palm weevil adults at traps and in trunks of palm trees

The cumulative numbers of RPW recorded at traps and in trunks of *P. canariensis* are summarized in Table 4.

Overall, most of adults (females + males) was trapped in 2008 (Table 4). After 2008, numbers of trapped adults dropped clearly.. In trunks, cumulative numbers of adults (females + males) in 2008 and 2009 were similar.

Females dominated the weevil populations at traps in most of sampling months (data not shown) in three consecutive years. Numbers of females captured by traps outnumbered numbers of male adults significantly by ratios ranged between 2.01 to 2.56 in 2008-2010 (Table 4). Total number of female adults collected in trunks of died palms in 2007 significantly outnumbered the number of male adults by ratio 2.32. In 2009, total number of adult females was similar to number of adult males, and female:adult ratio was nearly 1.0.

Table 4. Cumulative numbers of *Rhynchophorus ferrugineus* from the trapped population and from trunks of *Phoenix canariensis* in Adana province, Turkey in 2007-2010

Populations	Total no of palms dissected or traps set up	Years	Total no	Females	Males	Ratio (F/M)	P value (t-test)
In traps	78	2007 [a]	166	111	55	2.01	0.038
	400	2008	1510	1038	472	2.19	0.028
	451	2009	489	352	137	2.56	0.010
	478	2010	388	265	123	2.15	0.041
In trees	45	2008	562	393	169	2.32	0.032
	8	2009	579	280	299	0.94	0.063

[a] Traps were hung up to trees in November and December in 2007

Natural enemies of *Rhynchophorus ferrugineus*

All the dead larvae or pupae of weevils were infected by an entomopathogenic nematode (EPN) and none of the healthy weevils was infected. All the nematodes had an ITS region with 818 bp in length. Comparison with ITS region present in genbank showed that the nematod species was *Heterorhabditis bacteriophora. H. bacteriophora* was the only entomopathogenic nematode species isolated from the specimens of *R. ferrugineus*. This identification also correlated with the morphological observations.

Monthly mortality rates due to the attacks of EPN on the larval stages ranged from 62 to 92% in 2008 (Table 5). In December 2009, only 10% of the larvae were deadly infected. EPN caused significant mortality rates in 2008-2009 (Table 6). Seasonal mortality rate of adult females varied from 1 to 3% in 2008-2009 (Table 7). The highest mortality rate in male population was 5% in February 2008 (Table 7).

Table 5. Total numbers and mortality rates (%) of pre-adult stages of *Rhynchophorus ferrugineus* in trunks of *Phoenix canariensis* in Adana province, Turkey in 2008-2009 due to *Heterorhabditis bacteriophora*

Years	Months	Larval stages			Pupal stage		
		Total no of larvae	Alive and uninfected	Dead	Total no of pupae	Alive and uninfected	Dead
2008	Feb	63	17	83	251	18	82
	Oct	421	33	67	28	43	57
	Nov	155	23	77	64	16	84
	Dec	26	8	92	12	17	83
2009	Nov	127	18	82	37	8	92
	Dec	512	10	90	264	13	87

Table 6. Mortality of different larval stages of *Rhynchophorus ferrugineus* in trunks of *Phoenix canariensis* in Adana province, Turkey in 2008-2009 due to *Heterorhabditis bacteriophora*

Years	Sampling months	Larvae-stage	Total no of larvae		Mortality (%)
			Alive and uninfected	Dead	
2008	Feb	Young-stage	0	0	0
		Medium-stage	0	0	0
		Mature-stage	12	51	81
	Oct	Young-stage	4	24	81
		Medium-stage	15	130	90
		Mature-stage	112	137	82
	Nov	Young-stage	4	9	69
		Medium-stage	4	20	83
		Mature-stage	28	90	76
	Dec	Young-stage	0	0	0
		Medium-stage	3	0	0
		Mature-stage	2	21	91
2009	Nov	Young-stage	0	8	100
		Medium-stage	0	16	100
		Mature-stage	17	86	83
	Dec	Young-stage	54	0	0
		Medium-stage	150	2	1
		Mature-stage	277	29	9

Table 7. Total numbers and mortality rates (%) of adults of *Rhynchophorus ferrugineus* in trunks of *Phoenix canariensis* in Adana province, Turkey in 2008-2009 due to *Heterorhabditis bacteriophora*

Years	Months	Females			Males		
		Total no of females	Alive and uninfected	Dead	Total no of males	Alive and uninfected	Dead
2008	Feb	295	97	3	44	95	5
	Oct	60	98	2	53	100	0
	Nov	31	100	0	42	100	0
	Dec	17	100	0	30	100	0
2009	Nov	31	68	3	25	100	0
	Dec	249	99	1	244	99	1

Some fungi were also detected on bodies of the few cadavers of the pupae or adults in 2009, which they had been formerly infected by the EPN. The species were identified to genus level: *Phoma* sp. *Fusarium* spp. *Aspergillus* spp. *Helminthosporium* sp. *Arthrobotyrs* sp. *Alternaria* sp. *Cercospora* sp. and *Trichotecum* sp. Most of identified fungi are well-known as plant pathogens. So, it was not known whether these pathogens were infective to the RPW.

Discussion

The serious damage on trees of *P. canariensis* (totally 405 trees) due to larval feeding of the *R. ferrugineus* was observed during period of summer 2007 in Adana province. This was probably due to the high availability of insect food in the larger trunks and leaf pedicels of *P. canariensis* compared to in those of *P. dactylifera*. Additionally, favourable microclimate conditions due to large plant crown on *P. canariensis* may be attractive to weevils. It was found that adults of *R. ferrugineus were* inside the dead desiccated palm trees. This result may indicate that weevil adults do not leave their habitats until their host plants are absolutely desiccated. Matured larvae especially in the absolutely destroyed trees in 2008 and 2009 were collected.. Few numbers of early-stage larvae were also detected in the *P. canariensis* destroyed partially. Results suggest that the composition of weevil individuals at different developmental stage in infested trees was depend on availability of food resource in trunks and petioles. Young- and medium-stage larvae probably had low chances to survive to adult stage due to lack of foods in absolutely destroyed trees. Our findings are agree with the findings of Abe et al. (2009), who worked life history of the RPW in the infested *P. canariensis* trees which cut down in Japan in 2003-2005.

The use of pheromone traps appeared to be a good tool in population monitoring and mass trapping of the adult weevils in the recreation areas of Adana. The number of trapped adults dropped apparently from 1510 individuals in 2008 to 388 individuals in 2010, and no infested palm trees has been reported since 2010, may indicate a partial success in reduction of RPW population density in Adana province. Apparently, mass trapping by use of the pheromone traps contributed to reduction in the RPW population attacking date palm plantations in Israel (Soroker et al., 2005). Studies conducted in the Kingdom of Saudi Arabia (KSA) and in India also showed that mass trapping of RPW contributed to reduction in the local pest population in the plantations (Faleiro et al., 2002; Vidyasakar et al., 2000a, b).

No individual was captured in the traps until April or May, but subsequently two population peaks occurred in July and in September-October. Two population peaks were previously reported by others, but the timing was different in KSA (Vidyasagar, 2000a) and in United Arab Emirates (Kaakeh et al., 2001). These differences among the studies are more likely due to different ecological conditions (e.g. different temperatures).

As reported by Hallett et al. (1999) and Soroker et al. (2005), the sex ratio of captured adults was significantly female-biased (~70% of total catch was females). Female weevils are the main target of trapping, it is often debated whether pheromone traps catch young virgin females with high egg-laying capacity or old mated females with low egg-laying capacity. Soroker et al. (2005) concluded that both unmated and mated females were caught in the traps. Faleiro et al. (2003) reported that young and mated females of the red palm weevil with ability of high egg-laying potential were captured at pheromone traps. Higher numbers of females than males in the traps may be due to dispersing of females more than males in order to seek a suitable food sources for their generation (Kaakeh et al., 2001).

Trap catches in the region may show movements of adults from the highly-infested areas, due to removal of the dead palms, to uninfected or partially infested areas within-three years, indicating adults still being a threat for the palms in our region. In 2010, nearly 40% of total adults captured by traps were recorded only in one location namely, Boulevard “Süleyman Demirel” established in the northern part of Adana province and near to the Seyhan Lake. A reason of capturing high numbers of adults in the traps set in this location might be due to favourable ecological conditions for survivals of adults such as, high plant diversity including date palms in home gardens.

Routine curative and preventative treatments of the palms by application of systemic insecticide in soil have been continued in the region for a long time. No record of new infestation of RPW since 2010 may indicate that this spraying method is effective in preventing new infestations of RPW. However, we are not successful in recovery of the partially infested date palms, with application of the insecticide in soil, due to vascular system of the trunks being damaged. Application of the systemic insecticide into soil as preventive treatment may be used preferably by hotel owners during the summer period. We were successful in the sanitation efforts by removing of died palms and burring them into deep soil in the designated area. Direct injections of the chemicals to trunks was not effective due to recruits of the pure insecticide from the holes inside the trunks in the region. This is due to lack of effective equipments for direct injection in our region. Pouring insecticides through the crown of the tall palms was not used due to lack of special spraying and other equipments. It must be noted that in our case, date palm trees were not grown under plantations such as commercial date palm gardens in Middle-east and Arabic Gulf countries. Instead, palms were dispersed and used for ornamental purposes in public gardens, parks and in home gardens. Therefore, difficulties to manage the routine control efforts in the recreation areas were experinced.

Members of the Committee on sustainable management of the red palm weevil of Adana province discussed the control efforts for RPW and they coordinated all activities in pest management of RPW in Adana province. In addition, leaflets were prepared by Republic of Turkey, Ministry of Agriculture and Rural Affairs, General Directorate of Protection and Control Vision, with general instructions for some parties of management of RPV such as the pruning methods for the palms, cleaning the crown (at January – February period, when daily mean temperature is < 14 ^{o}C), avoiding injuries to plants and guidance for the insecticide treatments. A public awareness campaign was also initiated by providing necessary knowledge about the control tactics of RPW with the local television programs in Adana.

Heterorhabditis bacteriophora is very infective entomopathogenic nematode species causing considerable natural mortality rates in populations of larval and pupal stages of the red palm weevil in our two years-study (Table 5). There was no much information about successful biological control of RPW in date palm plantations. However, some promising results were achieved by the EPN including Steinernematids and Heterorhabditids on the RPW individuals under laboratory conditions (Abbas & Hanounik, 1999; Abbas et al., 2000; 2001; Hanounik et al., 2000; Shamseldean, 2004; Elawaad, 2007). However, control of the RPW by injecting the *Heterorhabditis indicus* (Poinar), *Steinernema abbasi* and several species of EPN into palm trees in the fields did not give promising control results (El-Bishry et al., 2000). This case was probably due to deleterious physical effect of palm tissues and dense sap on nematode behaviour (El-Bishry et al., 2000) and neurotropic and nematotoxic effects of the chemicals (e.g. ethanol, acetic acid and ethyl acetate) occurred during fermentation of palm tissues (Monzer & Abd-El-Rahman, 2003). In our study, most of larvae and pupae were infested fatally by the EPN in absolutely destroyed trunks of trees and infection rates of EPN in the larvae and pupae were very low in trees partially infested by RPW in 2009 (Table 3). Intact trunks may contain substances toxic to the nematodes. This issue requires further study. In the present study, the reason of high mortality rate found in larvae or pupae population may attributable to transmission of this nematode species by the adult weevils between the date palm trees.

Some fungal pathogens on the cadavras of pupae or adult killed by the nematodes was detected..It was not clearly known whether these pathogens were infective for the RPW. It was assumed that they were probably saprofitic organisms grow in cadavras of the weevil individuals. However, Soroker et al. (2006) reported the virulence of some fungal pathogens of RPW such as *Metarhizium anisopliae* and three *Beauveria bassiana* isolates from the RPW isolated from soil.

In conclusion, the natural infestations of the *H. bacteriophora* significantly and negatively affected the survival of larvae and pupae of the *R. ferrugineus*. The present study suggests that this nematode species could be a promising candidate for biological control of *R. ferrugineus* in the recreation areas in the eastern Mediterranean region of Turkey. It is not known whether *H. bacteriophora* is a indegenous or

exotic strain i.e. coming from the imported date palms from the Arabic Gulf countries. Further study is required to describe the infective strain of this nematode species for its use as a bio-pesticide for field applications. Soil and floral applications of the systemic and contact insecticides as curative and preventive pest management activities are widely used against this pest in the region. A combination of the different control strategies including sanitation is an important tool in reduction of RPW infestation in palms in the recreation areas of Adana province. A large number of ornamental palms and Date and Canary palms in particular, scattered in parks and gardens and on refuges in Adana province, are still under threat. Therefore, sustainability of all control efforts employed against the RPW is crucial for protecting the palms and effective controlling the RPW in the region.

Acknowledgements

We would like to express our thanks to Associate Prof. Dr. Uğur Gözel (Çanakkale 18 Mart University, Faculty of Agriculture, Department of Plant Protection, Çanakkale-Turkey) for identifications of the entomopathogenic nematodes and to Prof. Dr. Mehmet Biçici (Çukurova University, Faculty of Agriculture, Department of Plant Protection, Adana-Turkey) for identifications of fungi. We also thank to Ahmet Güneş (Director of Plant Protection Division, Agricultural Directorate of Adana Province, Ministry of Turkish Food, Agriculture and Animal Breeding) for providing the pheromone traps.

References

Abbas, M. S. T. & S. P. Hanonik, 1999. Pathogenicity of entomopathogenic nematodes to red palm weevil, *Rynchophorus ferrugineus*. International Journal of Nematology, 9: 84-86.

Abbas, M. S. T., S. B. Hanounik, S. A. Mousa & S. H. Al-Bagham, 2000. Soil application of entomotaphogenic nematodes as a new approach for controlling *Rynchophorus ferrugineus* on date palm. International Journal of Nematology, 10: 215-218.

Abbas, M. S. T., M. M. E. Saleh & A. M. Akil, 2001. Laboratory and field evaluation of the pathogenic of entomopathogenic nematodes to the red palm weevil, *Rhynchophorus ferrugineus* (Oliv.) (Col: Curculionidae) Anzeiger fur Schadlingskunde, 6: 167-168.

Abe, F., K. Hata & K. Sone, 2009. Life history of the red palm weevil, *Rynchophorus ferrugineus* (Coleoptera: Dryophtoridae), in Southern Japan. Florida Entomologist, 92 (3): 421-425.

Abraham, V. A., M. A. Shuaibi, J. R. Faleiro, R. A. Abozuhairah & P. S. P. V. Vidyasagar, 1998. An integrated management approach for red palm weevil *Rhynchophorus ferrgineus* Oliv. – A key pest of date palm in the middle east**.** Agricultural Science, 3: 77-83.

Anonymous, 1998. Slow death in Arabia. Date palm face extinction. The middle East, February**,** 49-50.

Atakan, E., H. Elekçioğlu, U. Gözel, & O. Yüksel. 2009. First Report of *Heterorhabditis bacteriophora* (Poinar, 1975) (Nematoda: Heterorhabditidae) Isaloted from *Rhynchophorus ferrugineus* (Oliver, 1790) (Coleoptera: Curculionidae) in Turkey. Bulletin OEPP/EPPO, 39: 155-160.

Barranco, P., J. De La Peña & T. Cabello. 1996. El picudo rojo de las palmeras, *Rhynchophorus ferrugineus* (Olivier), nueva plaga en Europa. (Coleoptera, Curculionidae). Phytoma España, 76: 36–40.

Bedding, R. A., & R. J. Akhurst, 1975. A simple technique for the detection of insect parasitic rhabditid nematodes in the soil. Nematologica, 21: 109-110.

Booth, R. G., M. L. Cox & R. B. Madge, 1990. IIE Guides to Insects of Importance to Man. 3 New Guinea Records of Economically Important Beetles (Coleoptera). CABI Publishing, Walllingford, UK. 384 pp.

Conti, F., F. Sesto, E. Raciti, & Tamburino, V. 2008. Ecological factors affecting the spread of *Rhynchophorus ferrgineus* (red palm weevil) in Eastern Sciliy. Palms, 52(3): 127-132.

Cox, M. L. 1993. Red palm weevil, *Rhynchophorus ferrugineus* in Egypt . FAO Plant Protection Bulletin, 41: 30-31.

Elawad, S. A., S. A. Mousa , A. S. Shahbad, S. A. Alawaash & A. M. A. Alamari, 2007. Efficacy of entomopathogenic nematodes aganist red palm weevil in UAE. Acta Horticulture, 736: 415-420.

El-Bishry, M. E., Y. El-Sebay & M. H. Al-Elimi, 2000. Impact of environment in date palm infested with *Rhynchophorus ferrugineus* on five entomopathogenic nematodes (Rhabditida). International Journal of Nematology, 10: 75-80.

El Ezaby, F. A., O. Khalifa & A. El Assal, 1998. "Integrated pest management for the control of red palm weevil *Rhynchophorus ferrugineus* Oliv. in the United Arab Emirates, Eastern Region, 269–281". Proceedings of the First International Conference on Date Palms. Al-Ain, U. A. E, (8-10 March 1998) Faculty of Agricultural Sciences, UAE University.

Faghih, A. A., 1996. The biology of red palm weevil, *Rhynchophorus ferrugineus* Oliv. (Coleopter, Curculionidae) in Savaran region (Sistan province, Iran). Applied Entomology and Phytopathology, 63: 16–86.

Faleiro, J. R., P. A. Kumar & P. A. Rangnekar, 2002. Spatial distribution of red palm weevil *Rynchophorus ferrugineus* Oliv. (Coleoptera: Curculionidae) in coconut plantation. Crop Protection, 21: 171-176.

Faleiro, J. R., P. A. Rangnekar & V. R. Satarkar, 2003. Age and fecundity of female red palm weevis *Rynchophorus ferrugineus (*Olivier) (Coleoptera: Rhynchophoridae) captured by pheromone traps in coconut plantations of India. Crop Protection, 22: 999-1002.

Ferry, M. & S. Gomez, 2002. The red palm weevil in the Mediterranean area. Palms, 46: 1-16.

Gobinadhan, P. B., N. Mohandas, & K. P. V. Nair, 1990. Cytoplasmic polyhedrosis virus infecting red palm weevil in coconut. Current Science, 59: 577-580.

Hallet, R. H, A. C. Oehlsclager & J. H. Borden, 1999. Pheromone trapping protocols for the Asian palm weevil, *Rynchophorus ferrugineus* (Coleoptera: Curculionidae) International Journal of Pest Management, 45: 231-237.

Hanounik, S. B., 1998. Steinernematids and Heterorhabditis as biological control agents for the red palm weevil *Rynchophorus ferrugineus*. Sultan Qabus University Journal for Scientific Research Agricultural Science, 3: 95-102.

Hanounik, S. B., S. B. Saleh, R. A. Abuzuhairah, M. Alheji, H. Aldhahir & Z. Alijarash 2000. Efficacy of entomopathogenic nematodes with antidesiccants in controlling the palm weevil, *Rynchophorus ferrugineus* on date palm trees. International Journal of Nematology, 10: 131-134.

Kaakeh, W., F. El-Ezaby, M. M. Aboul-Nour, and A. A Khamis, 2001. "Management of the red palm weevil, *Rynchophorus ferrugineus* Oliv., by pheromone/ food-based rapping system, 325-343". U. A. E Second International Conference on Date Palms, (March), Al-Ain, UAE.

Karut, K. & C. Kazak, 2005. A new pest of date palm trees (*Phoenyx dactylifera* L.): *Rynchophorus ferrugineus* (Olivier, 1790) (Coleoptera: Curculionidae) in Mediterranean region of Turkey. Türkiye Entomoloji Dergisi*,* 29: 295-300. (In Turkish, with English abstract)

Kehat, M., 1999. Threat to date palms in Israel, Jordan and the Palestinian Authority by the red palm weevil. Phytoparasitica, 27: 241-242.

Monzer, A. E. and R. Abd El-Rahman, 2003. Effect on *Heterorhabditis indica* of substance occurring in decomposing palm tissues infested by *Rynchophorus ferrugineus.* Nematology, 5(5): 647-657.

Murphy, S. T. & B. R. Briscoe, 1999. The red palm weevil as an alien invasive: biology and the prospects for biological control as a component of IPM. Biocontrol News and Information, 20: 35-46.

Peter, C., 1989. A note on the mites associated with the red palm weevil, *Rynchophorus ferrugineus* in Tamil Nadu. Journal of Insect Science, 2: 160-161.

Rajan, P., & C. P. Nair, 1997. Red palm weevil-the tissue borer of coconut palm. Indian Coconut Journal Cochin 27(12): 2-3.

Shamseldean, M. M. 2004. Laboratory trials and field applications of Egyptian and foreign entomopathogenic nematodes used against the red palm weevil, *Rynchophorus ferrugineus*. International Journal of Nematology, 14: 44-45.

Soroker, V., D, Blumber, A. Haberman, M. Hamburger-Rishard, S. Reneh, S. Talebaev, L. Anshelevich, & A. R. Harari, 2005. Current status of red palm weevil infestation in date palm plantations in Israel. Phytoparasitica 33: 97-106.

Soroker, V., G, Gindin, I. Glazer, J. Pinhas, S. Levsky, M. Eliahu, S. Biton, A. Haberman, Y. Nakache, D. Gerling, A. Mizrach & A. Hetzroni,2006. "The red palm weevil infestation in Israel: occurrence and management, 59–79". Proceedigs of I Jornada International sobre el Picudo Rojo de la Palmeras. Agroalimed, Generalitat Valenciana.

Vidyasagar, P. S. P. V., A. A. Al Saihati, O. E. Al Mohanna, A. I. Subbei, & A. M. Abdul Mohsin, 2000a. Management of red palm weevil. Journal of Plantation Crops, 28: 35-43.

Vidyasagar, P. S .P. V., M. Hagi, R. A. Abozuhairah, O. E. Al Mohanna, & A. A. Al Saihati, 2000b. Impact of mass pheromone trapping on red palm weevil: adult population and infestation level in date palm gardens of Saudi Arabia. Planter, Kuala Lumpur, 76: 347-355.