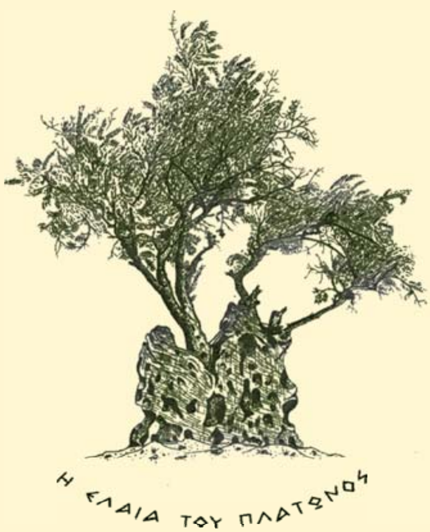
Volume 5, Issue 1, January 2012
ISSN 1791-3691

Hellenic Plant Protection Journal



A semiannual scientific publication of the
BENAKI PHYTOPATHOLOGICAL INSTITUTE

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Hellenic Plant Protection Journal **5:** 1-12, 2012

REVIEW ARTICLE

Bio-ecology and integrated management of the red palm weevil, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae), in the region of Valencia (Spain)

Ó. Dembilio[1]* and J.A. Jacas[2]

Summary The invasive red palm weevil, *Rhynchophorus ferrugineus* Olivier (Coleoptera: Curculionidae), is one of the most destructive pests of palms in the world. It is widely distributed in all continents and has been reported on 26 palm species belonging to 16 different genera. In the Mediterranean basin, *R. ferrugineus* has become the major pest of palms, mainly *Phoenix canariensis* hort. ex Chabaud, an endemic palm to the Canary Islands widely used as ornamental. In this manuscript we summarize the research that the UJI-IVIA Unit has carried out on this pest. The first objective of our work was to determine different bio-ecological parameters of *R. ferrugineus* under natural conditions in a Mediterranean climate. *Washingtonia filifera* is the only palm species included in our studies showing mechanisms of complete resistance against *R. ferrugineus*. Although *Chamaerops humilis* and *Phoenix theophrasti* show antixenotic and antibiotic mechanisms of resistance, respectively, they cannot be considered as resistant against *R. ferrugineus*. Under Mediterranean climate, the preimaginal development of *R. ferrugineus* in *P. canariensis* takes 666.5 DD and the weevil can complete 13 larval instars. Based on the results obtained, less than one generation per year can be expected in areas with a mean annual temperature (MAT) below 15ºC and more than two in those with MAT above 19ºC. Oviposition in *R. ferrugineus* is also strongly affected by temperature. The thresholds for oviposition and egg hatching obtained are very close to MAT registered in most of the northern shore of the Mediterranean basin. Under these circumstances, no new infestations would be expected during most of the winter. The second objective has been to improve chemical and biological control. Both imidacloprid and *Steinernema carpocapsae* in a chitosan formulation are highly effective against *R. ferrugineus* in the field. Different timings and product combinations were studied, and high efficacies were obtained in all cases. An indigenous strain of *Beauveria bassiana,* found naturally infecting pupae of *R. ferrugineus,* resulted highly virulent against all developmental stages of the weevil in the laboratory. Additionally, adults of either sex inoculated with the fungus efficiently transmitted the disease to healthy adults of the opposite sex and this result confirmed the potential of *B. bassiana* as a biological control agent against this pest. These results should help developing an integrated management program against this pest.

Additional Keywords: biological control, chemical control, host range, *Rhynchophorus ferrugineus*

1. Introduction

The invasive red palm weevil, *Rhynchophorus ferrugineus* Olivier (Coleoptera: Curculionidae), is one of the most destructive pests of palms in the world. It is extensively distributed in Oceania, Asia, Africa and Europe and it was found in the Caribbean in 2008 (Aruba and Curaçao) and in California in 2010 (EPPO, 2008; EPPO, 2009; EPPO, 2010). At the present time, this insect has been reported as a pest of 26 palm species belonging to 16 different genera (Malumphy and Moran, 2009). Since its introduction in the Mediter-

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ranean Basin in 1993, *R. ferrugineus* spread very quickly after 2004, when it was found for the first time in the Region of Valencia (eastern Spain) (Tejedo, 2006). At that time, the Universitat JaumeI-Institut Valencià d'Investigacions Agràries (UJI-IVIA) Unit started a research line aimed at the management of this weevil.

Henceforth we will present a summary of what was already known about the bio-ecology and the management of this pest combined with the new findings that our group achieved.

2. Bio-ecology of *R. ferrugineus*

2.1. Life cycle

Female *R. ferrugineus* weevils lay their eggs singly at the base of the palm fronds in separate holes made with their rostrum. Neonate larvae bore into the palm core making tunnels and feeding on its inner contents. As larvae molt, their appetite increases and they tend to feed primarily on the soft tissues surrounding the apical meristem. Mature grubs migrate to the periphery of the stem and prepare a cocoon made of palm fibers. After covering themselves with the cocoon, larvae enter a prepupal stage and then a pupal stage (Murphy and Briscoe, 1999). A new generation emerges and these adults may remain within the same host and reproduce until the palm meristem is destroyed resulting in the palm death. Subsequently, adults will fly away and look for new hosts.

2.1.1. Life cycle in Phoenix canariensis

The Canary Islands Date Palm, *Phoenix canariensis* hort. ex Chabaudis *R. ferrugineus* most susceptible host and its preferred host in the northern Mediterranean Basin. Although the life cycle of *R. ferrugineus* had been studied by some authors in different countries, on either artificial substrates or plant portions under controlled environmental conditions (Table 1), no results on the life cycle of *R. ferrugineus* in any of its hosts under natural conditions were available. Therefore, we decided to determine the thermal constant and the number of larval instars of *R. ferrugineus* when feeding in live *P. canariensis* palms under natural conditions in a Mediterranean climate (Dembilio and Jacas, 2011a). Based on measurements of the head capsule width, the existence of 13 larval instars in *R. ferrugineus* was established. Our results demonstrated that *R. ferrugineus* requires 40.4 DD for egg hatching under laboratory conditions, 666.5 DD for complete larval development in *P. canariensis* and another 282.5 DD to reach adulthood. Therefore, depending on mean temperatures, larval development can be completed in about 40 days in summer and up to 160 days in winter-spring. Likewise, pupae can complete their development in 13 days in summer but need several months to complete this stage from autumn to spring. Based on these results and on the temperatures in different climatic stations in the Iberian Peninsula, the mean number of generations of *R. ferrugineus* was estimated in the respective regions. These results indicated that less than one generation per year can be expected in areas with mean annual temperature (MAT) below 15ºC and more than two where MAT is above 19ºC (Dembilio and Jacas, 2011a). This is an important finding because we have observed that a minimum of two to three complete generations are necessary to kill an adult *P. canariensis*, and this means that at least two years would be necessary for *R. ferrugineus* to kill a palm in most of the Iberian Peninsula but more than these would be necessary in northern Spain and therefore a quarantine period of two years as it is nowadays required by EU laws (EU, 2007) could be insufficient to detect infested palms in that area. Should these results apply to other regions, a complete plus a partial generation per year would occur in most of the Northern shore of the Mediterranean Basin, whereas at least two complete generations per year would be expected in the Southern shore.

2.1.2. Lower temperature threshold for oviposition

Temperature is the main abiotic factor

Table 1. Development time and number of instars reported by different authors for *R. ferrugineus* feeding on different substrates.

Authors	Feeding substrate	Development time (days)				instars
		Egg	Larva	Pupa	Total	
Shahina *et al*., 2009	Honey in cotton	4-5	-	-	-	4
Shahina *et al*., 2009	Sugarcane lumps	4-5	50-80	20-30	74-115	9
Shahina *et al*., 2009	Apple slices	4-5	-	-	-	4
Abe *et al*., 2009	Apple slices	-	-	-	-	12
Salama *et al*., 2009	Banana slices	5	90	16-20	111-115	5
Salama *et al*., 2009	Sugarcane lumps	5	128	25-29	158-162	5
Salama *et al*., 2009	Squash fruit	5	83	20-24	108-112	5
Salama *et al*., 2009	Apple slices	5	103	16-18	124-126	5
Salama *et al*., 2009	Palm crown lumps	5	69	16-19	90-93	5
Kaakeh, 2005	Sugarcane lumps	3-4	82	19	108	-
Kaakeh, 2005	Palm Heart lumps	3-4	86	21	124	-
Kaakeh, 2005	Palm leaf base	3-4	84	18	119	-
Kaakeh, 2005	Artificial diet	3-4	70-102	16-23	93-131	-
Martín-Molina, 2004	Sugarcane lumps	3-4	88	25	116	11-17
Martín-Molina, 2004	Artificial diet	3-4	93	30	128	7-12
Martín-Molina, 2004	Palm lumps	-	-	-	-	8-15
Salama *et al*., 2002	Banana slices	-	-	13-22	-	-
Jaya *et al*., 2000	Sugarcane lumps	-	81-89	-	-	7
Esteban-Duran *et al*., 1998	Sugarcane lumps	-	76-102	19-45	139	-
Avand Faghih, 1996	Palm lumps	1-6	41-78	-	-	-
Kranz *et al*., 1982	NS	2-3	60	14-21	76-84	-
Kalshoven, 1981	Sago palm pith	-	-	-	105-210	-
Butani, 1975	Sugarcane lumps	2-4	24-61	18-34	44-100	-
Rahalkar *et al*., 1972	Sugarcane lumps	3-4	32-51	15-28	50-82	-
Nirula, 1956	Coconut slices	2-5	36-67	12-21	54-120	3
Viado and Bigornia, 1949	Coconut slices	3	35-38	11-19	49-70	9
Lepesme, 1947	NS	3	60	15	90-180	-
Dammerman, 1929	NS	3	60-120	14	74-134	-
Leefmans, 1920	Sago palm lumps	-	60	13-15	73-75	-
Ghosh, 1912; Ghosh, 1923	Palm lumps	3-4	25-61	18-33	48-82	-

NS: not specified

influencing the biology, ecology and population dynamics of poikilothermic organisms as arthropods. Once the thermal requirements of *R. ferrugineus* developing in live *P. canariensis* palms had been established, the next step focused on establishing the lower temperature thresholds for oviposition and egg hatching. The effect of temperatures in the range 10-25ºC on the reproductive parameters of laboratory-reared *R. ferrugineus*-was studied (Dembilio *et al*. 2011c). Highest fecundity and oviposition rate were observed at 25ºC, (33.25 eggs per female and 2.38 eggs per female and day, respectively), whereas no oviposition was observed for females kept below 15ºC. Interestingly, females moved from 25º to 15ºC at age 14 days old could lay a mean of 5.17 eggs during the entire experimental period (15 days) and those moved from 25º to 10ºC could lay

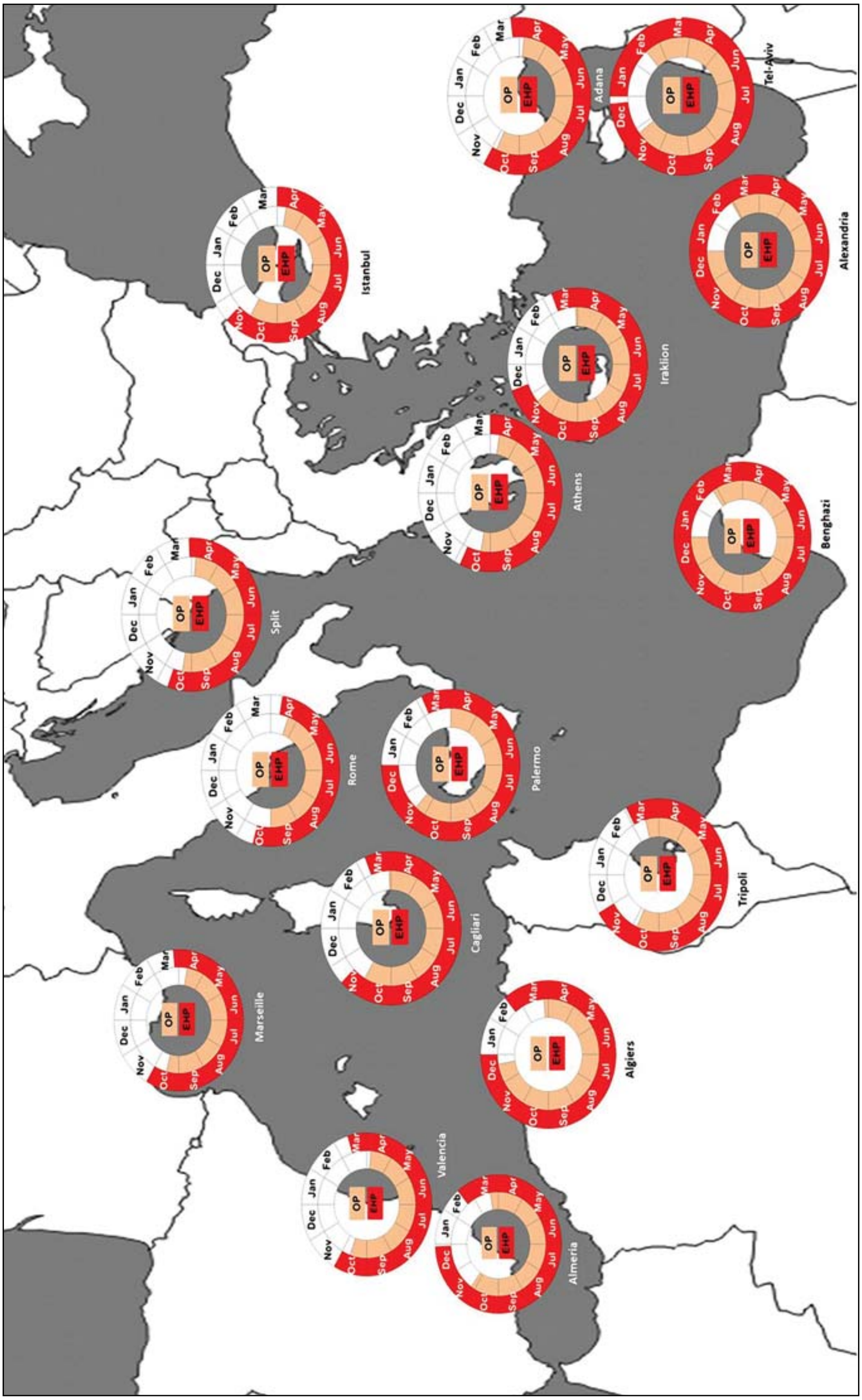

Figure 1. Estimated oviposition and egg hatching periods (OP and EHP, respectively) of *R. ferrugineus* based on mean monthly temperatures at some selected climatic stations in the Mediterranean basin.

0.75 eggs during the first 2 days of exposure to the lower temperature. Based on the results obtained at constant temperature regimes, a lower temperature threshold of 15.45°C was estimated for oviposition. Taking into account all results obtained, a slightly lower value, 13.95°C, was calculated for egg hatching. When these values were compared with mean monthly temperatures in Valencia and other selected locations in the Mediterranean Basin, windows for oviposition and egg hatching could be established (Figure 1). In most of the northern shore of the basin, the oviposition period (OP) extended from early April to mid-October early November and the egg hatching period (EHP) from mid-March to mid/late October. However, these periods were much shorter in the southern shore and although oviposition would stop during the coldest winter months, egg hatching would continue during the whole year in the southwestern part of the Basin (i.e. Egypt) (Dembilio *et al.*, 2011c). Based on these results, any management practice producing wounds (such as pruning or the cutting of an inspection window in the crown), should be best performed in winter, when oviposition is notably reduced and immature mortality is highest (Dembilio and Jacas, 2011a). Importantly, even during this season, all wounds should be immediately protected with a tree wound seal and, if possible, with an insecticide (Faleiro, 2006). For the same reason, the frequency of preventative treatments against the weevil could decrease during the winter, thus reducing the non-target effects of these pesticides.

2.2. Host range

Chamaerops humilis L. and *Phoenix theophrasti* Greuter are the two European native palm species and their host status was not clear. Barranco *et al.* (2000) considered *C. humilis* as resistant to the attack of *R. ferrugineus*. Nevertheless, the European Union included this species in the list of *R. ferrugineus*-susceptible plants (EU, 2007). This list also included the genus *Washingtonia* spp. However, in assays carried out by our group in 2007 (Llácer *et al.*, 2012), *Washingtonia filifera* (Lindl.) Wendl could not be infested with *R. ferrugineus* whereas *W. robusta* could. Different semi-field trials (Dembilio *et al.*, 2009) demonstrated that *W. filifera* and *C. humilis* could not be naturally infested by *R. ferrugineus* adult females. Antibiosis was the main, and perhaps the only, mechanism operating in *W. filifera*, as a gummy secretion produced by the plant resulted in complete mortality of *R. ferrugineus* young instars. Antixenosis was the major mechanism of resistance in the case of *C. humilis*. The base of the fronds of this palm is very fibrous and therefore not appropriate for oviposition. However, this antixenotic mechanism of resistance could be by-passed by artificially infesting the palm with neonate larvae deposited in holes made with a drill (Barranco *et al.*, 2000) and the same phenomenon was observed for *P. theophrasti* (Dembilio *et al.*, 2011b). Therefore, *C. humilis* and *P. theophrasti* palms formerly harmed either naturally (e.g. attacked by *Paysandisia archon* (Burmeister), damaged by the wind, etc.) or artificially (e.g. after trimming or pruning) could be attacked by *R. ferrugineus*, and this fact should be taken into account when dealing with these palm species.

3. Management of the Red Palm Weevil

3.1. Detection

A serious problem associated with *R. ferrugineus* is the difficulty of detecting the early stages of infestation (Nakash *et al.*, 2000). Because of the cryptic habits of *R. ferrugineus*, it is very difficult to detect infestations in their early stage. Unless palms are continuously thoroughly inspected, this pest is generally detected only after the palm has been severely damaged. Careful observation may expose the following signs which are indicative of the presence of the pest: dieback in the apical leaves in the canopy, where broken or cut leaves (symptom of larval damage to the meristem tissue) become visible, holes in the crown or trunk from which chewed-up fibers are ejected (this may be accompanied by the secretion of brown viscid liquid with a characteristic bitter smell), crown or frondloss and appearance of a dried off shoot are usually only visible long after the palm has become infested. Secondary infections of opportunistic bacteria and fungi may occur within injured tissues, accelerating the deterioration of palms.

As mentioned above, early detection of infested palms is very difficult but it is essential to ascertain the first symptoms as soon as possible in order to take appropriate measures. Currently, the use of bioacoustics and infrared systems or even the use of dogs can be employed with the aim of detecting early infestations (Faleiro, 2006). Future developments are expected and urgently needed.

3.2. Control

Because it is difficult to detect damage by *R. ferrugineus* during the early stages of infestation, emphasis is generally focused onpreventive measures mostly relying on chemical applications. Control methods against *R. ferrugineus* range from general dusting of the leaf axils with insecticides after pruning, or spraying of the palm tree trunk, to localized direct injections of chemicals into the trunk (Faleiro, 2006). All these treatments are often complemented with cultural and sanitary methods that include early destruction of infested plant material (Kurian and Mathen, 1971) and prophylactic treatment of cut wounds (Pillai, 1987). During the latest years, in the Region of Valencia, an integrated pest management (IPM) strategy has been implemented. This strategy includes (a) plant quarantine and plant certification, (b) mass trapping of adult weevils using ferrugineol-based food baited traps (Hallett *et al*., 1993), (c) crop and field sanitation, (d) preventive chemical treatments of gashes,(e) filling frond axils of young palms with a mixture of insecticides and (f) curative treatments of infested palms in the early stages of attack, eradicating severely infested palms. These palms should be removed and destroyed by shredding. Burning is not recommended as destruction means because palms do not burn easily and complete destruction of *R. ferrugineus* cannot be guaranteed in this case.

3.2.1. Chemical control

The most common and practical measure in chemical control is mainly based on the repeated application of large quantities of synthetic insecticides employed in a range of preventive and curative procedures designed to contain the infestation. These procedures have been developed and refined since commencing in India in the 1970's when work on application of organophosphates and carbamates ensured these chemicals to become the mainstay of the chemical approach to control *R. ferrugineus* (Murphy and Briscoe, 1999). In Spain, a minimum of 8 preventive treatments per season (from March to November) are recommended by the Valencian Department of Agriculture. However, only 4 active substances are nowadays authorized in palms against *R. ferrugineus*. These are Chlorpyrifos, Imidacloprid, Phosmetand Thiamethoxam (MARM, 2011). Some of these pesticides can be applied as spray on the stipe, injected into the trunk, or as a drench.

3.2.1.1. Systemic insecticides

Imidacloprid is a chloronicotinyl nitroguanidine systemic insecticide that has both contact and ingestion activity and works by disrupting the transmission of impulses in the nervous system of insects. It appears in the MARM list (MARM, 2011) under two different formulation categories, soluble concentrate (SL) and oil dispersion (OD), and it can be applied by spraying, injection or irrigation. The formulation, imidacloprid SL, was successfully tested by Kaakeh (2006), in laboratory and semi-field assays against *R. ferrugineus*. The OD formulation was recently tested by our group (Dembilio *et al*., 2010a; Llácer *et al*., 2012). Preventive and curative semi-field trials with imidacloprid OD applied by soil injection to *P. canariensis* showed 100 % and 94 % efficacies, respectively (Llácer *et al*., 2012). Furthermore, preventative treatments had high efficacy values, mean of 95.4 ± 2.7 %, for at least 45 days after application (Llácer *et al*., 2012). In a field assay, two applications of imidacloprid OD per year successfully reduced mortality of *P. canariensis* palms to less than 27% compared to more than 84% for untreated control palms (Dembilio *et al*., 2010a). Similar results were obtained by Tapia *et al.* (2011) in Southern Spain.

3.2.1.2.Insecticidal paints

The efficacy of an insecticidal paint based on chlorpyrifos and pyriproxyfen (1.5% and 0.063%, respectively) in a microencapsulated formulation was also studied by our group (Llácer *et al*., 2010). This insecticidal paint was applied on the stipe and the base of the fronds of palms. Laboratory results showed that pyriproxyfen had no effect against *R. ferrugineus* when applied in this microencapsulated formulation and chlorpyrifos was the responsible of the efficacy of this product against the weevil. In semi-field assays, the paint was highly effective as preventive treatment. However, it was dismissed as curative insecticide. One single application of this paint could prevent infestation for up to 6 months with a mean efficacy of 83.3%.

3.2.2. Biotechnological control: semiochemicals

A very important component of any strategy against *R. ferrugineus* is mass trapping of adults using food baits. Ferrugineol (4-methyl-5-nonanol) is the major aggregation pheromone of the red palm weevil (Hallett *et al*., 1993) and has been used in conjunction with 4-methyl-5-nonanone (Abozuhairah *et al*., 1996) in mass-trapping programs which are widely practiced in several countries where red palm weevil is a problem (Abraham and Kurian, 1973; Hallett *et al*., 1993; Vidyasagar *et al*., 2000). Because (a) a trap set in an uninfested area can easily lead to its infestation by weevils responding to the attractive plumes coming from the trap and (b) a trap can highly increase the incidence of *R. ferrugineus* in an area if neighboring palms are not adequately protected, in Spain, mass trapping is only allowed under direct supervision of the local Department of Agriculture.

3.2.3. Biotechnological control: SIT

As a first step towards developing the Sterile Insect Technique (SIT) against *R. ferrugineus*, Al-Aydeh and Rasool (2010) studied the influence of gamma radiation on its mating behavior, and the efficacy of SIT under different levels of relative humidity. No adverse effects of gamma radiation were observed on the mating behavior parameters of theweevil. Furthermore, weevils were sexually stimulated during aggregation. However, as this weevil mates several times during its lifetime and its mass rearing is very expensive, the usefulness of this technique in this case remains quite doubtful.

3.2.4. Biological control

Reginald (1973) suggested that natural enemies do not play an important part in controlling *R. ferrugineus* and few studies have been conducted on *Rhynchophorus* spp. natural enemies (Faleiro, 2006; Murphy and Briscoe, 1999). There were some attempts in the laboratory and field using the predatory earwig *Chelisoches morio* (Fabricius) (Dermaptera: Chelisochidae) in India (Abraham and Kurian, 1973). However, it did not provide a measurable impact on the weevil. Although various mites have been reported in India as parasites of *R. ferrugineus* (Nirula, 1956; Peter, 1989), their impact on the population needs to be determined. Gopinadhan *et al.* (1990) reported that a cytoplasmic polyhedrosis virus infected all stages of the weevil in Kerala (India). Infected mature-larval stages resulted in deformed adults and severe suppression of the host population. In addition to these results, both entomopathogenic nematodes (EPN) and fungi (EPF) can provide an alternative to chemical control of *R. ferrugineus* (Dembilio *et al*., 2011b; Dembilio *et al*., 2010a; Dembilio *et al*., 2010b; Faleiro, 2006; Llácer *et al*., 2009; Tapia *et al*., 2011). Unlike EPNs, EPFs infect the host by contact, then germinate and penetrate the insect cuticle. The host can be infected both by direct treatment and by horizontal transmission from infected insects or cadavers to untreated insects or to subsequent developmental stages via the new generation of spores (Lacey *et al*., 1999; Quesada-Moraga *et al*., 2004). These unique characters make EPFs especially important for the control of concealed insects as *R. ferrugineus*. Different strains of *Metarhizium anisopliae* (Metschnikoff) Sokorin (Ascomycota: Clavicipitaceae) and *Beauveria bassiana* (Balsamo) Vuillemin (Ascomycota: Clavicipitaceae) have been found in association with the weevil. Some of these EPFs strains were tested against *R. ferrugineus* (Gindin *et al*., 2006). *Metarhizium anisopliae* proved more virulent than *B. bassiana*. However, none of the strains tested was originally obtained from diseased *R. ferrugineus* specimens. More recently, in preliminary studies, Sewify*et al*. (2009) successfully reduced the incidence of *R. ferrugineus* under field conditions in Egypt using a native strain of *B. bassiana* isolated from a *R. ferrugineus* cadaver.

3.2.4.1. Entomopathogenic nematodes: Steinernema carpocapsae

Although no entomopathogenic nematode has been naturally recorded infecting *R. ferrugineus*, *Steinernema carpocapsae* (Weiser) (Nematoda: Steinernematidae) proved effective against *R. ferrugineus* in semi-field trials including both preventive and curative assays (Llácer *et al*., 2009). In a curative assay, efficacies around 80 % were obtained, and up to 98 % in a preventative treatment on *P. canariensis* (Llácer *et al*., 2009). We have also proved the high efficacy of this treatment in *P. theophrasti* (Dembilio *et al*., 2011b). Under field conditions, treatments using imidacloprid and *S. carpocapsae*, either alone or in combination were not significantly different from each other, with efficacies ranging from 73 to 95 % (Dembilio *et al*., 2010a). Tapia *et al*. (2011) reached similar conclusions in field trials in Southern Spain. Therefore, EPNs should not be forgotten when developing strategies for treatments against *R. ferrugineus*.

3.2.4.1. Entomopathogenic fungi: Beauveria bassiana

In 2007, *R. ferrugineus* pupae presumed to be infected with EPFs were collected in a date palm grove in Spain (Dembilio *et al*., 2010b). The *B. bassiana* strain isolated from these pupae proved to infect eggs, larvae and adults of *R. ferrugineus*. Furthermore, *B. bassiana* infection reduced adult lifespan from one half to almost one tenth. Adults of either sex inoculated with the fungus efficiently transmitted the disease to untreated adults of the opposite sex conferring rates of transmission between 55 and 60 %. In addition, treatment with this *B. bassiana* strain significantly reduced fecundity (up to 62.6 %) and egg hatching (32.8 %). Likewise, 30–35 % increase in larval mortality was observed in larvae obtained from eggs from fungus inoculated females or from untreated females coupled with inoculated males, resulting in an overall 78% progeny reduction compared to an untreated control. This strain was subsequently tested in semi-field preventive assays on potted 5-year old *P. canariensis* palms. Efficacies up to 85.7 % were obtained, and these results are indicative that contact infection of adults actually occurred and confirm the potential of this strain as a biological control agent against *R. ferrugineus*. Consequently, adults should be considered as the targets of any treatment involving this entomopathogenic fungus because are actually the only free-living stage. Strategies aimed at attracting and infecting adult weevils could prove the most effective way to spread the disease, and this is one of the works that our group is developing at this moment.

4. Conclusions

Washingtonia filifera is the only palm species included in our studies showing mechanisms of complete resistance against *R. ferrugineus*. This resistance is based on the production of an antibiotic exudate. However, the existence of additional mechanisms of resistance in this species cannot be excluded. Although *C. humilis* and *P. theophrasti* show antixenotic and antibiotic mechanisms of resistance, respectively, and larvae of the weevil suffer higher mortality in these host palms compared to *P. canariensis*, these mechanisms are not enough to prevent infestation. Therefore, these species cannot be considered as resistant against *R. ferrugineus*.

Under Mediterranean climate, the preimaginal development of *R. ferrugineus* in *P. canariensis* takes 666.5 DD and the weevil can complete 13 larval instars. Development under these conditions is faster than when fed on an artificial diet. Likewise, the number of larval instars is also lower. Based on the results obtained, less than one generation per year can be expected in areas with a mean annual temperature (MAT) below 15ºC and more than two in those with MAT above 19ºC. Because a minimum of 2-3 generations are necessary for the weevil to kill a *P. canariensis* palm, a minimum of two years are necessary for a new infestation to result lethal for a Canary Island date palm in most of the northern shore of the Mediterranean basin but shorter times would be expected in areas with higher MAT.

Oviposition in *R. ferrugineus* is strongly affected by temperature. The thresholds for oviposition and egg hatching obtained are very close to MAT registered in most of the northern shore of the Mediterranean basin and clearly below mean monthly temperatures in winter in this area. Under these circumstances, no new infestations would be expected during most of the winter. These results should be taken into account when planning some palm management practices such as pruning or pesticide treatments.

Both imidacloprid and *S. carpocapsae* in a chitosan formulation are highly effective against *R. ferrugineus* in the field. Different timings and product combinations were studied, and high efficacies were obtained in all cases. *Steinernema carpocapsae* was applied on a monthly basis and therefore resulted more expensive and time consuming than the drench applications of imidacloprid. However, this invertebrate biological control agent would be most suitable for ornamental palms in public areas.

An indigenous strain of *B. bassiana,* found naturally infecting pupae of *R. ferrugineus,* resulted highly virulent against all developmental stages of the weevil in the laboratory. Additionally, adults of either sex inoculated with the fungus efficiently transmitted the disease to healthy adults of the opposite sex. Furthermore, *B. bassiana* infection resulted in reduced fecundity and egg hatching. Semi-field preventive treatments on *P. canariensis* palms with this strain were highly effective against *R. ferrugineus* and this result confirmed the potential of *B. bassiana* as a biological control agent against this pest.

The UJI-IVIA group has received financial support from the Spanish Ministry of Science and Innovation (MCINN projects TRT2006-00016-C07-01 and AGL2008-05287-C04/AGR) and the Valencian Department of Agriculture, Fisheries and Food (CAPA, project IVIA-5611). Ó. Dembilio was recipient of a predoctoral grant from IVIA.

Literature Cited

Abozuhairah, R.A., Vidyasagar, P.S.P.V. and Abraham, V.A. 1996. Integrated management of red palm weevil, *Rhynchophorus ferrugineus* F., in date palm plantations of the Kingdom of Saudi Arabia. *20th International Congress of Entomology*, Florence, Italy, August 1996, Paper 17-033.

Abe, F., Hata, K. and Sone, K. 2009. Life history of the Red Palm Weevil, *Rhynchophorus ferrugineus* (Coleoptera: Dryophthoridae), in Southern Japan. *Florida Entomologist*, 92: 421-425.

Abraham, V.A. and Kurian, C. 1973. *Chelisoches morris* (Forficulidae: Dermaptera), a predator on eggs and early instar grubs of *Rhynchophorus ferrugineus*. *Journal of Plantation Crops*, 1: 147-152.

Al-Aydeh, H.Y. and Rasool, K.G. 2010. Determination of the optimum sterilizing radiation dose for control of the red date palm weevil *Rhynchophorus ferrugineus* Oliv. (Coleoptera: Curculionidae). *Crop Protection*, 29: 1377-1380.

Avand Faghih, A. 1996. The biology of red palm weevil, *Rhynchophorus ferrugineus* Oliv. (Coleoptera: Curculionidae) in Saravan region (Sistan and Balouchistan Province, Iran). *Applied Entomology and Phytopathology*, 63: 16-18.

Barranco, P., De La Peña, J.A., Martín, M.M. and Cabello, T. 2000. Rango de hospedantes de *Rhynchophorus ferrugineus* (Olivier, 1790) y diámetro de la palmera hospedante. (Coleoptera, Curculionidae). *Boletín de Sanidad Vegetalde Plagas,* 26: 73-78.

Butani, D.K. 1975. Insect pests of fruit crops and their control, sapota-11. *Pesticides Research Journal*, 9: 40-42.

Dammerman, KW. 1929. The agricultural zoology of the Malay Archipelago, In: Bussy J. H. (Ed) Amsterdam, pp. 493.

Dembilio, Ó. and Jacas, J.A. 2011a. Basic bio-ecological parameters of the invasive Red Palm Weevil, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae), in *Phoenix canariensis* under Mediterranean climate. *Bulletin of Entomological Research,* 101: 153-163.

Dembilio, Ó., Jacas, J.A. and Llácer, E. 2009. Are the palms *Washingtonia filifera* and *Chamaerops humilis* suitable hosts for the red palm weevil, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae). *Journal of Applied Entomology*, 133: 565-567.

Dembilio, Ó., Karamaouna, F., Kontodimas, D.C., Nomikou, M. and Jacas, J.A. 2011b. Susceptibility of *Phoenix theophrasti* to *Rhynchophorus ferrugineus* (Col.: Curculionidae) and its control using *Steinernema carpocapsae*. Spanish *Journal of Agricultural Research*, 9(2): 623-626

Dembilio, Ó., Llácer, E., Martínez de Altube, M.M. and Jacas, J.A. 2010a. Field efficacy of imidacloprid and *Steinernema carpocapsae* in a chitosan formulation against the red palm weevil *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) in *Phoenix canariensis*. *Pest Management Science*, 66: 365-370.

Dembilio, Ó., Quesada-Moraga, E., Santiago-Álvarez, C. and Jacas, J.A. 2010b. Biocontrol potential of an indigenous strain of the entomopathogenic fungus *Beauveria bassiana* (Ascomycota; Hypocreales) against the red palm weevil, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae). *Journal of Invertebrate Pathology,* 104: 214-221.

Dembilio, Ó., Tapia, G.V., Téllez, M.M. and Jacas, J.A. 2011c. Lower temperature thresholds for oviposition and egg hatching of the Red Palm Weevil, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae) in a Mediterranean climate. *Bulletin of Entomological Research*. doi:10.1017/S0007485311000411.

EPPO (European and Mediterranean Plant Protection Organization) 2008. Data sheets on quarantine pests. *Rhynchophorus ferrugineus*. *EPPO Bulletin*, 38: 55-59.

EPPO (European and Mediterranean Plant Protection Organization) 2009. EPPO Reporting Service. 2009/002 - First record of *Rhynchophorus ferrugineus* in Curaçao, Netherlands Antilles, January 26, 2009.

EPPO (European and Mediterranean Plant Protection Organization) 2010. EPPO Reporting Service. 2010/176 - First record of *Rhynchophorus ferrugineus* in the USA, November 1, 2010.

Esteban-Duran, J., Yela, J.L., Beitia-Crespo, F. and Jiménez-Álvarez, A. 1998. Biología del curculiónido ferruginoso de las palmeras *Rhynchophorus ferrugineus* (Olivier) en laboratorio y campo: Ciclo en cautividad, peculiaridades biológicas en su zona de introducción en España y métodos biológicos de detección y posible control (Coleoptera: Curculionidae: Rhynchophorinae). *Boletín de Sanidad Vegetal – Plagas*, 24: 737-748.

EU (European Union) 2007. Commission decision of 25 May 2007 on emergency measures to prevent the introduction into and the spread within the Community of *Rhynchophorus ferrugineus* (Olivier). 2007/365/EC. *Official Journal of the European Union L* 139: 24-27.

Faleiro, J.R. 2006. A review of the issues and management of the red palm weevil *Rhynchophorusferrugineus* (Coleoptera: Rhynchophoridae) in coconut and date palm during the last one hundred years. *International Journal of Tropical Insect Science*, 26: 135-154.

Gindin, G., Levski, S., Glazer, I. and Soroker, V. 2006. Evaluation of the entomopathogenic fungi *Metarhizium anisopliae* and *Beauveria bassiana* against the Red Palm Weevil *Rhynchophorus ferrugineus*. *Phytoparasitica*, 34: 370-379.

Gopinadhan, P.B., Mohandas, N. and Nari, K.P.V. 1990. Cytoplasmic polyhedrosis virus infecting red palm weevil of coconut. *Current Science*, 59: 577-580.

Ghosh, C.C. 1912. Life-histories of Indian insects, III. The rhinoceros beetle (*Oryctes rhinoceros*) and the red or palm weevil (*Rhynchophorus ferrugineus*). *Memoires of the Department of Agriculture of India*, 2: 193-217.

Ghosh, C.C. 1923. The palm beetles in Burma with notes on other pests. *Bulletin of the Department of Agriculture*, Burma, 19: 1-40.

Hallett, R.H., Gries, G., Gries, R., Borden, J.H., Czyzewska, E.,Oehlschlager, A.C., Pierce, H.D., Angerilli, N.P.D. and Rauf, A. 1993. Aggregation pheromones of two Asian palm weevils, *Rhynchophorus ferrugineus* and *R. vulneratus*. *Naturwissenschaften*, 80: 328-331.

Jaya, S., Suresh, T., Sobhitha-Rani, R.S. and Sreekumar, S. 2000. Evidence of seven larval instars in the red palm weevil, *Rhynchophorus ferrugineus* Olivier reared on sugarcane. *Journal of Entomological Research*, 24: 27-31.

Kaakeh, W. 2005. Longevity, fecundity, and fertility of the red palm weevil, *Rhynchophorus ferrugineus* Olivier (Coleoptera: Curculionidae) on natural and artificial diets. *Emirates Journal of Agri-*

cultural Sciences,17: 23-33.

Kaakeh, W. 2006. Toxicity of imidacloprid to developmental stages of *Rhynchophorus ferrugineus* (Curculionidae: Coleoptera): Laboratory and field tests. *Crop Protection*, 25: 432-439.

Kalshoven, L.G.E. (1981) Pests of crops in Indonesia. P.T. Ichtiar Baru-Vanhoeve, Jakarta. Indonesia, pp. 720.

Kranz, J.H., Schmutterer, H. and Koc, W. 1982. Enfermedades, plagas y malezas de los cultivos subtropicales, Verlag Paul Parey, Berlin, pp. 722.

Kurian, C. and Mathen, K. 1971. Red palm weevil - hidden enemy of coconut palm. *Indian Farming*, 21: 29-31.

Llácer, E., Martínez, J. and Jacas, J.A. 2009. Evaluation of the efficacy of *Steinernema carpocapsae* in a chitosan formulation against the red palm weevil, *Rhynchophorus ferrugineus*, in *Phoenix canariensis*. *BioControl*, 54: 559-565.

Llácer, E., Dembilio, Ó. and Jacas, J.A. 2010. Evaluation of the Efficacy of an Insecticidal Paint Based on Chlorpyrifos and Pyriproxyfen in a Microencapsulated Formulation against *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae). *Journal of Economic Entomology*, 103: 402-408.

Llácer, E., Negre, M. and Jacas, J.A. 2012. Evaluation of an Oil Dispersion formulation of Imidacloprid against *Rhynchophorus ferrugineus* (Coleoptera, Curculionidae) in young palm trees.*Pest Management Science*. DOI: 10.1002/ps.3245

Lacey, L.A., Kirk, A.A., Millar, L., Mereadier, G. and Vidal, C. 1999. Ovicidal and larvicidal activity of conidia and blastospores of *Paecilomyces fumosoroseus* (Deuteromycotina: Hyphomycetes) against *Bemisia argentifolii* (Homoptera: Aleyrodidae) with a description of a bioassay system allowing prolonged survival of control insects. *Biocontrol Science Technology*, 9: 9-18.

Leefmans, S. 1920. De palmsnuitkever (*Rhynchophorus ferrugineus* Olivier). Mededelingen van Institute voor Plantenziekten, Buitenzorg, 43: 1-90.

Lepesme, P. 1947. Les insectes des palmiers, P. Lechevalier, Paris, pp. 904.

Malumphy, C. and Moran, H. 2009. Red palm Weevil, *Rhynchophorus ferrugineus*. Plant Pest Factsheet. Available online at www.fera.defra.gov.uk/plants/publications/documents/factsheets/redPalmWeevil.pdf (accessed 7 June 2011).

MARM 2011. Registro de productos fitosanitarios. http://www.marm.es/es/agricultura/temas/medios-de-produccion/productos-fitosanitarios/registro/menu.asp (Data of accession: May 12, 2011).

Martín-Molina, M.M. 2004. Biología y ecología del curculiónido rojo de las palmeras, *Rhynchophorus ferrugineus* (Olivier, 1790) (Coleoptera: Dryophthoridae). *Unpublished PhD Thesis*. Universidad de Almería, 203 pp.

Murphy, S.T. and Briscoe, B.R. 1999. The red palm weevil as an alien invasive: biology and prospects for biological control as a component of IPM. *BioControl*, 20: 35-45.

Nakash, J., Osem, Y. and Kehat, M. 2000. A suggestion to use dogs for detecting Red Palm Weevil (*Rhynchophorus ferrugineus*) infestation in date palms in Israel. *Phytoparasitica*, 28: 153-155.

Nirula, K.K. 1956. Investigations on the pests of coconut palm. Part .*Rhynchophorus ferrugineus*. *Indian Coconut Journal*, 9: 229-247.

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

Pillai, GB.1987. Integrated pest management in plantation crops. *Journal of Coffee Research*, 17: 150-153.

Quesada-Moraga, E., Santos-Quiros, R., Valverde-Garcia, P. and Santiago-Álvarez, C. 2004. Virulence, horizontal transmission, and sublethal reproductive effects of *Metarhizium anisopliae* (anamorphic fungi) on the German cockroach (Blattodea: Blattellidae). *Journal of Invertebrate Pathology*, 87: 51-58.

Rahalkar, G.W., Harwalkar, M.R. and Rananavare, H.O. 1972. Development of red palm weevil, *Rhynchophorus ferrugineus* Oliv. on sugarcane. *Indian Journal Entomology,* 34: 213-215.

Reginald, C. 1973. Principal insect pests. In: Coconuts. *Tropical Agriculture Series*. Longmans, London (GB),

Sewify, G.H., Belal, M.H. and Al-Awash, S.A. 2009. Use of the Entomopathogenic Fungus, *Beauveria bassiana* for the Biological Control of the Red Palm Weevil, *Rhynchophorus ferrugineus* Olivier. *Egyptian Journal of Agricultural Research*, 19: 157.

Salama, H., Hamdy, M. and Magd El-Din, M. 2002. The thermal constant for timing the emergence of the red palm weevil, *Rhynchophorus ferrugineus* (Oliv.), (Coleoptera, Curculionidae). *Journal of Pest Science*, 75: 26–29.

Salama, H.S., Zaki, F.N. and Abdel-Razek, A.S. 2009. Ecological and biological studies on the red palm weevil *Rhynchophorus ferrugineus* (Olivier). *Archives of Phytopathology and Plant Protection*, 42: 392-399.

Shahina, F., Salma, J., Mehreen, G., Bhatti M.I. and-Tabassum, K.A.2009. Rearing of *Rhynchophorus ferrugineus* in laboratory and field conditions for carrying out various efficacy studies using EPNs. Pakistan Journal of Nematology 27, 219-228.

Tapia, G., Ruiz, M.A. and Téllez M.M. 2011. Recommendations for a preventive strategy to control red palm weevil (*Rhynchophorus ferrugineus*, Olivier) based on the use ofinsecticides and entomopathogenic nematodes. *Bulletin OEPP/EPPO Bulletin*, 41: 136-141.

Tejedo, V. 2006. Currentsituation of the Red Palm

Weevil (*Rhynchophorus ferrugineus*) in the Comunidad Valenciana, In: Jornada Internacional sobre el Picudo Rojo de las Palmeras. *Fundación Agroalimed*, Valencia, Spain, 9-17 p.

Viado, G.B. and Bigornia, A.E. 1949. A biological study of the Asiatic palm weevil, *Rhynchophorus ferrugineus* (Olivier), (Curculionidae, Coleoptera). *Philippine Agriculturist*, 33: 1-27.

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

Received:21 November 2011; Accepted:18 January 2012

ΑΡΘΡΟ ΑΝΑΣΚΟΠΗΣΗΣ

Βιο-οικολογία και ολοκληρωμένη αντιμετώπιση του ρυγχοφόρου των φοινικοειδών, *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae), στην περιοχή της Βαλέντσια (Ισπανία)

Ó. Dembilio και J.A. Jacas

Περίληψη Ο ρυγχοφόρος των φοινικοειδών, *Rhynchophorus ferrugineus* Olivier (Coleoptera: Curculionidae), είναι ένας από τους πιο καταστρεπτικούς εντομολογικούς εχθρούς των φοινικοειδών στον κόσμο. Έχει εξαπλωθεί σε όλες τις ηπείρους και έχει αναφερθεί σε 26 είδη φοινικοειδών από 16 διαφορετικά γένη. Στην λεκάνη της Μεσογείου, ο ρυγχοφόρος έχει αναδειχθεί στον σημαντικότερο εχθρό των φοινικοειδών, κυρίως του *Phoenix canariensis* hort. ex Chabaud, ενδημικό είδος των Καναρίων Νήσων που χρησιμοποιείται ευρέως ως καλλωπιστικό. Στην παρούσα εργασία συνοψίζονται τα αποτελέσματα ερευνητικής μελέτης που έχει γίνει για τον ρυγχοφόρο στο Πανεπιστήμιο UJI και το Ερευνητικό Ινστιτούτο IVIA της Ισπανίας. Πρώτος στόχος αυτής της μελέτης αυτής ήταν ο προσδιορισμός διαφορετικών βιο-οικολογικών παραμέτρων του *R. ferrugineus* στις συνθήκες του Μεσογειακού κλίματος. Από τα φοινικοειδή που μελετήθηκαν, μόνο το *Washingtonia filifera* εμφανίζει μηχανισμούς ανθεκτικότητας στο *R. ferrugineus*. Αν και τα φοινικοειδή *Chamaerops humilis* και *Phoenix theophrasti* εμφανίζουν μηχανισμούς άμυνας αλλά δεν μπορούν να θεωρηθούν ανθεκτικά στο *R. ferrugineus*. Η ανάπτυξη του *R. ferrugineus* στον Κανάριο φοίνικα, *P. canariensis,* στο Μεσογειακό κλίμα διαρκεί 666,5 ημεροβαθμούς και το έντομο μπορεί να συμπληρώσει 13 προνυμφικά στάδια. Σε περιοχές με μέση ετήσια θερμοκρασία μικρότερη από 15° C αναμένεται μια μόνο γενεά ενώ σε περιοχές με μέση ετήσια θερμοκρασία μεγαλύτερη από 19°C, περισσότερες από δύο γενεές. Η ωοτοκία του *R. ferrugineus* επηρεάζεται επίσης από την θερμοκρασία. Η κατώτερη θερμοκρασία για ωοτοκία και εκκόλαψη των ωών του ρυγχοφόρου είναι κοντά στην μέση ετήσια θερμοκρασία στο μεγαλύτερο μέρος της βόρειας ακτής της Μεσογειακής λεκάνης. Κάτω από αυτές τις συνθήκες, δεν αναμένονται νέες προσβολές κατά το μεγαλύτερο μέρος του χειμώνα. Ο δεύτερος στόχος της μελέτης ήταν να βελτιωθεί η χημική και βιολογική αντιμετώπιση του εντόμου. Σκευάσματα φυτοπροστατευτικών προϊόντων με δραστική ουσία imidacloprid ή εντομοπαθογόνο νηματώδη *Steinernema carpocapsae* με χιτοζάνη ήταν πολύ αποτελεσματικά κατά του *R. ferrugineus* σε συνθήκες υπαίθρου. Δοκιμάστηκαν διάφοροι χρόνοι εφαρμογής και συνδυασμοί σκευασμάτων που έδειξαν υψηλή αποτελεσματικότητα σε όλες τις περιπτώσεις. Ένα ιθαγενές στέλεχος του *Beauveria bassiana,* το οποίο βρέθηκε να προσβάλλει νύμφες του *R. ferrugineus,* αποδείχτηκε πολύ αποτελεσματικό έναντι όλων των βιολογικών σταδίων ανάπτυξης του ρυγχοφόρου στο εργαστήριο. Επιπρόσθετα, ενήλικα άτομα και των δύο φύλων που είχαν εμβολιαστεί με τον μύκητα μετέδωσαν την ασθένεια σε υγιή ενήλικα του αντίθετου φύλου επιβεβαιώνοντας ότι το *B. bassiana* είναι εν δυνάμει παράγοντας βιολογικής αντιμετώπισης του εντόμου. Τα αποτελέσματα αυτά μπορούν να συμβάλλουν στην ανάπτυξη ενός προγράμματος ολοκληρωμένης αντιμετώπισης του ρυγχοφόρου.

Hellenic Plant Protection Journal **5:** 1-12, 2012

Hellenic Plant Protection Journal **5:** 13-21, 2012

Natural alternatives to copper and low-rate copper formulations to control grape downy mildew in organic farming

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Summary To control plant diseases in organic farming, growers can use preventive measures together with a few plant protection products. The control of downy mildew is based on the use of copper compounds, however copper can cause environmental problems due to its accumulation in the soil. In this study natural alternatives to copper and formulations with low rates of copper were evaluated in organic farming in order to control *Plasmopara viticola*. All of the products tested ensured effective control of grape downy mildew under the experimental conditions of the trial, characterized by moderate disease pressure. The best levels of protection were observed with copper products. Low-copper formulations (Glutex Cu 90 and Labicuper) with similar efficacy to the reference product offer benefits including lower quantities of copper. This paper recommends a cultural management of downy mildew in accordance with the risk of infection in order to reduce environmental copper input. We suggest that organic growers can minimize the use of copper in organic viticulture by using copper-alternatives when downy mildew infection is intermediate or low. On the other hand in years with high disease pressure new copper formulations can be used to reduce the amount of copper.

Additional keywords: copper, natural products, organic farming, plant protection, *Vitis vinifera* L.

Introduction

Downy mildew, caused by the oomycete *Plasmopara viticola* (Berk. & M.A. Curtis) Berl. & De Toni, is one of the world's most destructive grapevine diseases (2, 24, 12, 27, 23). In organic farming, the control of *P. viticola* is based on the use of copper, together with all preventive management measures necessary to minimize the development of disease. Copper is still a very important tool to manage the diseases in conventional agriculture and is actually indispensable in organic farming (24, 21).

With Commission Directive 2009/37/EC, copper compounds have been included in Annex I to Directive 91/414/EEC (concerning the placing of plant protection products on the market). "Therefore, it is necessary that Member States introduce monitoring plans in vulnerable areas, where the contamination of the soil compartment by copper is a matter of concern, in order to set, where appropriate, limitations as maximum applicable rates" (Commission Directive 2009/37/EC) (7). In organic farming, limitations such as maximum applicable copper rates have already been defined (Regulation EC No 889/2008) (6). The use of copper, in fact, may have long-term consequences due to its accumulation in the soil (4, 26, 28, 14, 9, 22) and this is incompatible with the principles of organic farming. In the near future the current legal amount of copper will probably be reduced, so that alternatives to copper compounds need to be developed. Several research programs have been carried out to find appropriate alternative solutions (24, 8, 16, 17, 31, 18, 32, 30, 5, 35).

In order to evaluate the possibility of replacing or reducing the use of copper, a field trial in an organic vineyard was carried out and the activity of natural products and

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low rate copper formulations was estimated against grape downy mildew.

Materials and Methods

Experimental trial

The experiment was conducted in 2010 in an organic vineyard near Rome (lat. 41.4°N, long. 12.3°E, 180 m a.s.l.). The grape variety tested was Malvasia di Candia, and the rootstock (44 years old) employed was Kober 5BB (*Vitis berlandieri* x *Vitis riparia*). The training system was "tendone", consisting of a continuous overhead canopy under which the bunches are disposed (25). Plots were prepared, each containing 12 plants and repeated four times in randomized blocks. Spacings between vines were 2.50 m x 2.50 m, with a buffer row between treatments. The test organism was *P. viticola*.

Products were sprayed until near run-off with a pulled sprayer (Martignani K.W.H. electrostatic sprayer system) at a pressure of 1.5 bar. The trial was carried out in accordance with the EPPO/OEPP PP1/31 (3) guidelines (11).

Environmental data

A weather station was placed at the trial site to record weather data such as precipitation, air temperature, soil moisture (at a depth of 20 cm and 40 cm), leaf wetness, solar radiation, relative humidity, soil temperature, and wind speed and direction. These data were acquired through the GSM modem that was on board the weather station for remote transmission to a WeatherLink software program.

Treatments

Table 1 reports commercial name of tested products, commercial manufacturers, composition, active ingredient, rate of appli-

Table 1. Commercial name, active ingredient, dosage and number of applications of the products tested against grape downy mildew.

Treatment	Commercial name	Manufacturer	Composition	Active ingredient (%)	Rate of application	Number of applications /treatment
RP[a]	Bentoram Cuproxat SDI	Dal Cin Gildo (IT) Nufarm Italia(IT)	Copper hydroxide Tribasic copper sulphate	10 15.2	2-3-4[b] 3[b]	13
1	Labicuper	Labin Italia (IT)	Copper gluconate	8	2-2.5[b]	10
2	Glutex Cu 90	Socoa Trading S.r.l. (IT)	Copper hydroxide	9	4-4.25[b]	11
3	Biplantol agrar Biplantol mycos V forte	Plantosan (CH) Plantosan (CH)	Homeopathic preparation Homeopathic preparation	- -	1[b] 1[b]	6 5
4	Sporatec	Brandt Consolidated (US)	Rosemary Oil - Clove Oil - Thyme Oil	18-10-10	1[c]	14
5	Myco-Sin VIN	Andermatt Biocontrol (CH)	Aluminium sulphate	75	0.5[c]	11
6	BM-608	Biomor (IL)	*Malaleuca alternifolia* essential oil	23.8	0.75[c]	13
7	Stimulase	Agronutrition (FR)	Purified enzymes extracted from *Trichoderma* sp.	-	1[b]	8

[a] Reference product (Standard)
[b] l/ha
[c] %

cation and number of applications per treatment. The products tested included new copper formulations with low metallic copper (Labicuper and Glutex CU 90) and natural substances (Biplantol, Sporatec, Myco-Sin VIN, BM-608, Stimulase). The commercial products were used according to the manufacturer's information. The products were compared with an untreated control and a reference product containing copper (standard).

Grape downy mildew assessment

The assessments were made at intervals of seven days starting from the first appearance of disease symptoms until harvest. Phenology was described according to the Biologische Bundesanstalt, Bundessortenamt and CHemical industry (BBCH) scale (3), in which grapevine phenological development stages are described by Lorenz *et al.* (1994) (19). Grapevine leaves and bunches were visually assessed, 100 leaves and 100 bunches were picked randomly from the central 10 vines of each plot. The percentage of leaves and bunches diseased out of a total number assessed (disease incidence) and the area of leaves and bunches showing symptoms of disease (disease severity), were estimated. Disease severity (infection degree, ID) was calculated using a scale of nine classes (0-8) using the Townsend-Heuberger formula (33):

$$\text{ID (\%)} = \Sigma^{i}_{1}(n_i \times v_i) \;/\; N \times V$$

where v_i is the damage class, n_i is the number in one class, N is the total number, V is the highest class, i is the number of classes. The area under disease progress curves (AUDPC) based on disease severity was calculated for each treatment according to Shaner & Finney (1977) (29). The AUDPC was assessed with the formula:

$$\text{AUDPC} = \sum_{i=1}^{n-1} \left(\frac{y_i + y_{i+1}}{2} \right) (t_{i+1} - t_i)$$

where y_i is the disease severity at the i^{th} observation, y_{i+1} is the disease severity at the i^{th} $+1$ observation, n is the total number of assessments and $t_{i+1} - t_i$ is the number of days between the two assessments.

AUDPC values were normalized by dividing each AUDPC value by the total area of the graph (= the number of days from the first to last assessment of the disease × 1.0) (13). The normalized AUDPC was referred to as the relative area under disease progress curve (RAUDPC).

The index effectiveness was calculated at harvest using Abbott's formula (1):

$$\%\ \text{effectiveness} = [(I_c - I_t)/I_c] \times 100$$

where I_c is the disease incidence of the untreated control, I_t is the disease incidence of the treatment.

Observations for the presence of phytotoxic effects of all tested products were made after each spray on the shoots, leaves, bunches and flowers.

Yields

The effect of the investigated products on annual production was recorded at harvest time. Grape yield was calculated as t/ha/treatment.

Statistical analysis

Data in percentages were transformed to arcsine square roots according to the formula Y=arcsin(√(x%/100)) to correct normality before analysis. The data obtained were subjected to statistical analysis using ANOVA, a parametric statistical method and Tukey's test (34) at 5% of probability. Duncan's multiple range test ($P \leq 0.05$) (10) was used to determine significant differences among treatments in terms of grape fruit yield. Statistics were performed with GraphPad InStat version 3.00 for Windows.

Results and discussion

Environmental data

In 2010 there was high spring rainfall,

concentrated mainly in May, when there was 99.8 mm of rain. In June and August rainfall was average for that period, while in July and September rainfall was low (Figure 1).

Fungicidal effect and amount of copper provided with the treatments

The spring weather conditions led to the appearance of symptoms of primary infection of downy mildew in the last week of May. The first oil-spots appeared on the 24th of May (BBCH 57-Inflorescences fully developed; flowers separating) due to the presumed infection by the rain of May 17th, which was the date of the first infection event. With regard to the fruits, the first symptoms of grapevine downy mildew were observed on June 23rd (BBCH 75-Berries pea-sized, bunches hang). The phytosanitary situation did not show a particularly critical framework. Continuous monitoring and prompt applications, as required by the organic production method, guaranteed that all of the products tested achieved an effective anti-downy mildew control.

Figure 2 reports the assessment of disease incidence on leaves and bunches at the harvest. The best protection was achieved with copper formulations used as reference product and with the Glutex Cu 90 formulation. The Labicuper formulation showed a lower control of *P. viticola* than the reference product and Glutex Cu 90 although there were no significant differences among these products. The experimental products that did not contain copper (Stimulase, Myco-Sin VIN, Sporatec, Biplantol and BM-608) provided a control of infection on leaves significantly different in comparison with the untreated control.

Disease severity measured using RAUDPC for both leaves and bunches is reported in Figures 3 and 4 respectively. RAUDPC values in plots treated with copper formulations were lower than the values in plots treated with alternatives to copper. The ANOVA showed that there was no significant differences between reference product, Glutex Cu 90 and Labicuper. Although protection based on the application of natural alternatives to copper did not guarantee the same level of control achieved with formulated copper compounds, it was nevertheless acceptable.

Figure 5 shows the relationship between the amount of metallic copper applied and the effectiveness of the treatments. Glutex Cu 90 formulation guaranteed similar results

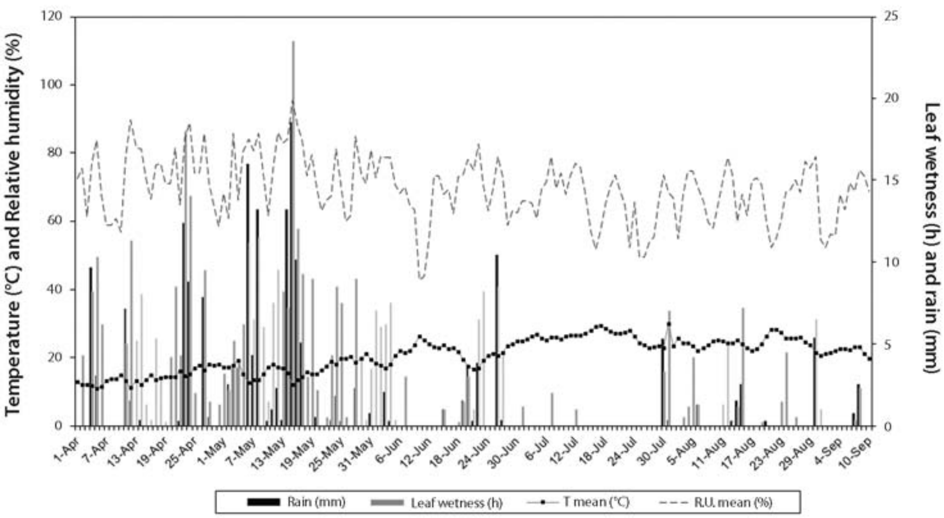

Figure 1. Climatic conditions during the experimental field trial .

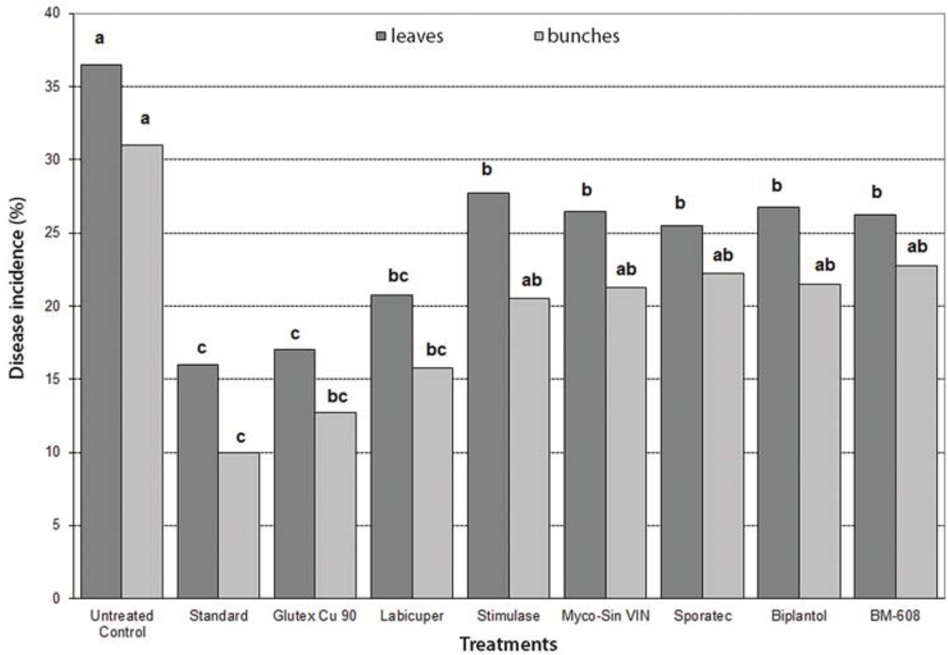

Figure 2. Disease incidence (expressed as % of infected leaves or bunches) at the harvest. Columns with the same letter are not significantly different according to Tukey's test ($P \leq 0.05$).

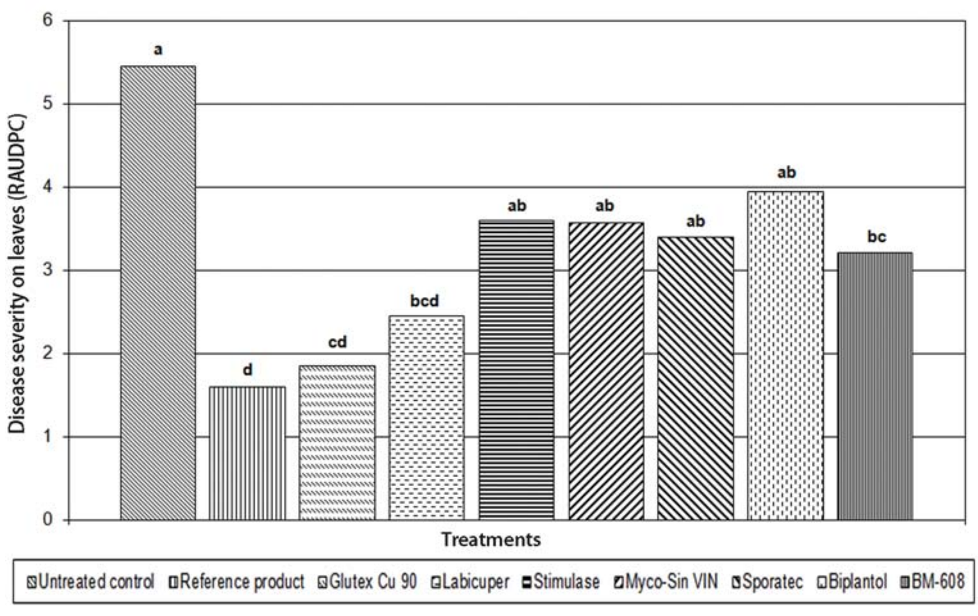

Figure 3. Downy mildew severity on leaves, expressed as relative area under the disease progress curve (RAUDPC). Columns with the same letter are not significantly different according to Tukey's test ($P \leq 0.05$).

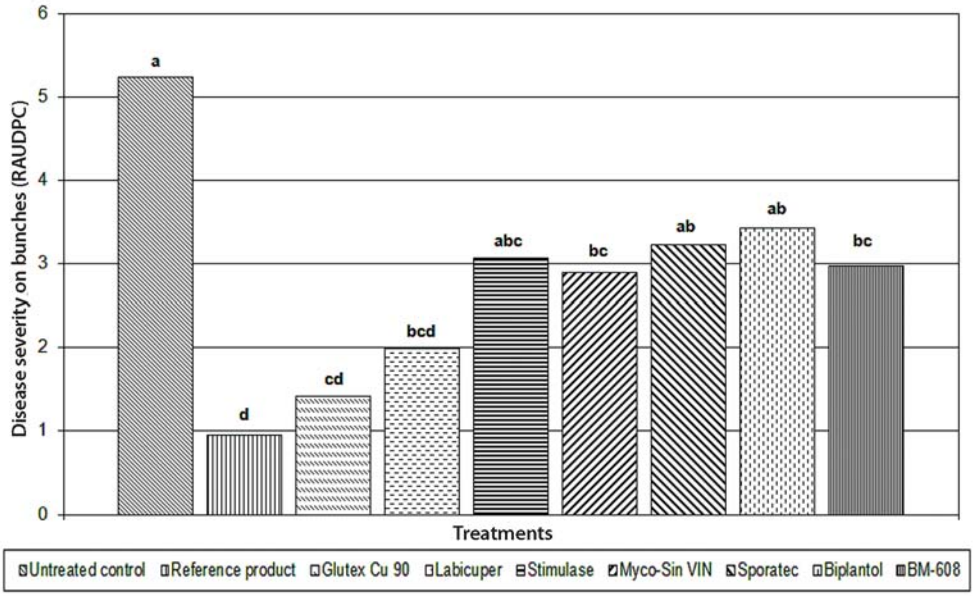

Figure 4. Downy mildew severity on bunches, expressed as relative area under the disease progress curve (RAUDPC). Columns with the same letter are not significantly different according to Tukey's test ($P \leq 0.05$).

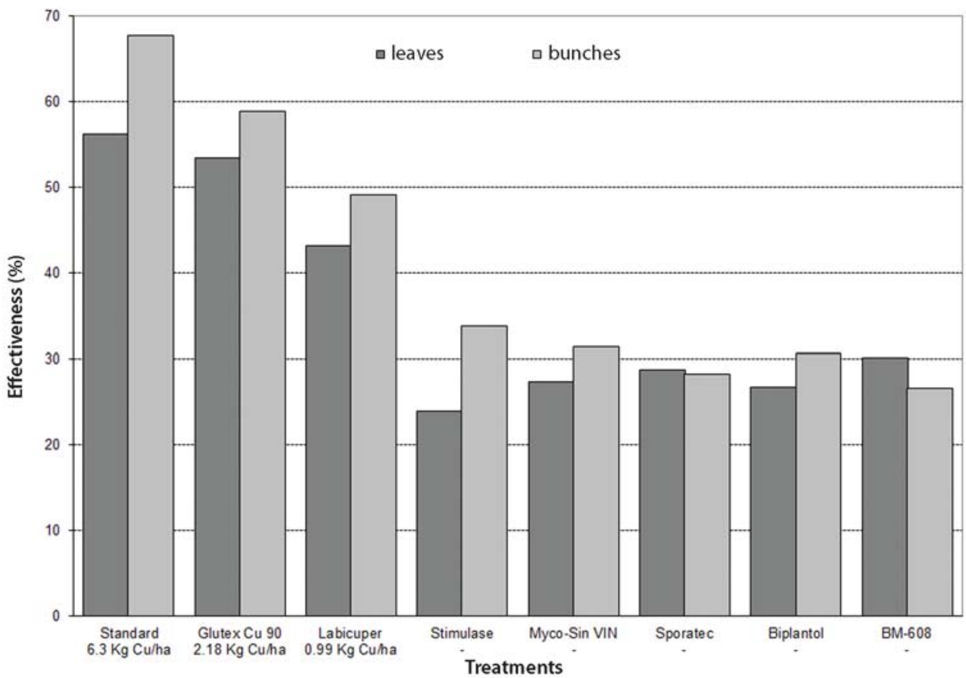

Figure 5. Effectiveness at the harvest of different products and total amount of copper applied with the treatments.

to the reference product but provided lower quantities of elemental copper (the total copper applied was about 2.2 kg/ha compared with approximately 6.3 kg/ha for the reference product). The total metallic copper applied with the Labicuper formulation was extremely low (0.99 kg/ha). Clearly, the quantities of elemental copper depend on the formulation used. Copper formulations used as reference product provided 482 g/ha of metallic copper per application, Glutex Cu 90 provided 200 g per ha per application, and Labicuper provided 99 g per ha per application. All non-copper based alternative products were essentially equally effective at harvest (Figure 5).

No visual signs of phytotoxicity were observed at any stage during this experiment.

Yield

Figure 6 shows the effect of different treatments on total yields (t/ha). The highest yields were obtained with reference product followed by the Glutex Cu 90 formulation. These two formulations were statistically different in comparison with the untreated control. There were also statistically different compared with the other tested products. Plants treated with Sporatec formulation BM-608 did not show significantly different results when compared with yields obtained with untreated control.

Conclusions

Under the experimental conditions of the trial, characterized by moderate disease pressure, all of the products tested gave an effective control of *P. viticola*. The best results were obtained with copper formulations, which were all very effective. The results showed that copper formulations (Glutex Cu 90 and Labicuper) were able to control grape downy mildew in the field using a third (Glutex Cu 90) or a sixth (Labicuper) of the amount of copper in comparison with the reference product (Figure 5). With the results obtained it was possible to identify alternatives to copper compounds that were less effective than copper but nevertheless showed an acceptable level of activity against *P. viticola* under medium disease pressure.

The overall conclusion from this study suggests that in order to minimize copper accumulation in the soil, flexible control

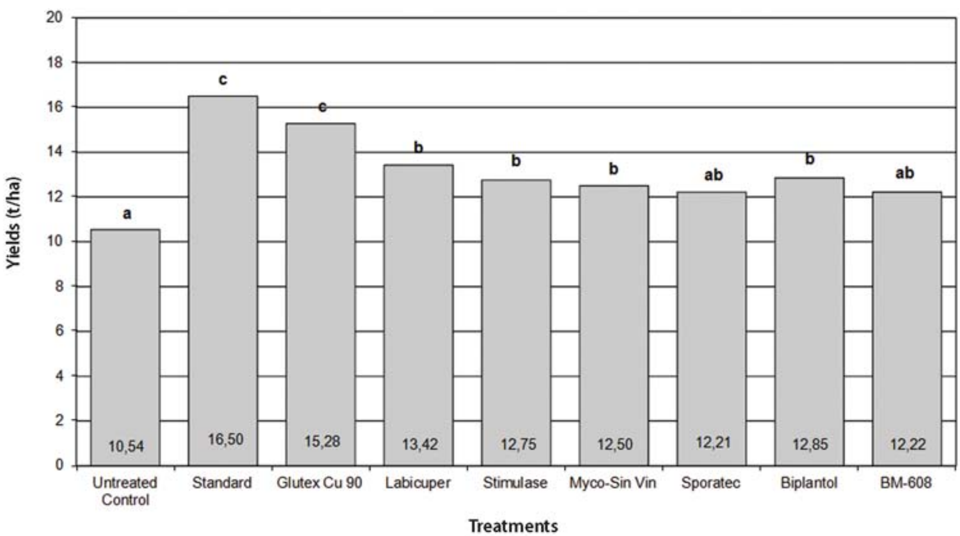

Figure 6. Effect of tested products on annual production: yields (t/ha). Values with the same letter are not significantly different according to Duncan's multiple range test ($P \leq 0.05$).

strategies should be adopted, which should be determined on the basis of the real risk of disease in the vineyard (20, 15). When downy mildew infection is low-intermediate, chemical control should include copper-alternatives and the use of copper compounds should be avoided. In this way the organic growers can economize on copper compounds under moderate infection pressure and to apply copper, using new improved copper formulations developed by agrochemical companies in order to help lower the total amount of copper, when *P. viticola* pressure is high. This approach has less of an environmental impact and is in accordance with EU restrictions on copper use.

This study was conducted within the project "Protezione della Vite e delle Sementi in Agricoltura Biologica" funded by the Italian Ministry of Agriculture and Forestry.

Literature Cited

1. Abbott, W.S. 1925. A method of computing the effectiveness of an insecticide. *Journal of Economic Entomology,* 18: 265-267.
2. Agrios, G.N. 2005. Plant Pathology. Fifth ed. Elsevier Academic Press, London.
3. BBA , BSA, IGZ, IVA, AgrEvo, BASF Bayer, Novartis 1997. Compendium of Growth Stage Identification Keys for Mono- and Dicotyledonous Plants. *Extended BBCH scale; 2nd Edition.*
4. Brun, L.A., Le Corff, J. and Maillet, J. 2003. Effects of elevated soil copper on phenology, growth and reproduction of five ruderal plant species. *Environmental Pollution,* 122: 361-368.
5. Cohen, Y., Wang, W., Ben-Daniel, B.H. and Ben-Daniel, Y. 2006. Extracts of *Inula viscosa* Control Downy Mildew of Grapes Caused by *Plasmopara viticola*. *Phytopathology,* 96: 417-424.
6. Commission of the European Union. 2008. Commission Regulation (EC) No 889/2008. *Official Journal of the European Union,* L 250: 1-84.
7. Commission of the European Union. 2009. Commission Directive 2009/37/EC. *Official Journal of the European Union,* L 104: 23-27.
8. Dagostin, S., Ferrari, A., Gessler, C. and Pertot, I. 2006. New alternatives to copper against *Plasmopara viticola* in organic viticulture. *Atti Giornate Fitopatologiche,* 2: 193-198.
9. Deluisa, A., Giandon, P., Aichner, M., Bortolami, P., Bruna, L., Lupetti, A., Nardelli, F. and Stringari, G. 1996. Copper pollution in Italian vineyard soils. *Communications in Soil Science and Plant Analysis,* 27: 1537-1548.
10. Duncan, D.B. 1955. Multiple range and multiple F tests. *Biometrics,* 11: 1-42.
11. EPPO/OEPP 2004. 2nd Edition. Guidelines for the efficacy evaluation of plant protection products, Fungicides & Bactericides, 2: 47.
12. Fourie, P.H. 2004. Metalaxyl Sensitivity Status of Downy Mildew Populations in Western Cape Vineyards. *South African Journal for Enology and Viticulture,* 25(1): 19-22.
13. Fry, W.E., 1978. Quantification on general resistance on potato cultivars and fungicide effects for integrated control of potato late blight. *Phytopathology*, 77: 1650-1655.
14. Giller, K.E., Witter, E. and McGrath, S.P. 1998. Toxicity of heavy metals to microorganisms and microbial processes in agricultural soils: a review. *Soil Biology and Biochemistry,* 30: 1389-1414.
15. Hofmann, U. 2002. Copper reduction and copper replacement - results and experiences of 12 years on farm research. *Proceedings of the 10th International Conference on Cultivation Technique and Phytopathological Problems in Organic Fruit-Growing and Viticulture*, Weinsberg, Germany, 4-7 Feb. 2002, p. 181-184.
16. La Torre, A., Gianferro, M. and Spera, G. 2008. Optimization of plant protection products treatments against *Plasmopara viticola*. *Communications in agricultural and applied biological sciences,* 73(2): 159-168.
17. La Torre, A., Spera, G., Gianferro, M. and Scaglione, M. 2007. More years of field trials against *Plasmopara viticola* in organic viticulture. *Communications in agricultural and applied biological sciences,* 72(4): 901-908.
18. La Torre, A., Spera, G. and Lolletti, D. 2005. Grapevine downy mildew control in organic farming. *Communications in agricultural and applied biological sciences,* 70: 371-379.
19. Lorenz, D.H., Eichhorn, K.W., Blei-Holder, H., Klose, R., Meier, U. and Weber, E. 1994. Phänologische Entwicklungsstadien der Weinrebe (*Vitis vinifera* L. ssp. *vinifera*). *Viticulture and Enology Science,* 49: 66-70.
20. Madge, D. 2007. Organic Farming: Managing Grapevine Downy Mildew. *Organic viticulture: an Australian manual,* 9: 13-15.
21. Matasci, C.L., Gobbin, L., Schärer, H.J., Tamm, L. and Gessler, C. 2008. Selection for fungicide resistance throughout a growing season in populations of *Plasmopara viticola*. *European Journal of Plant Pathology,* 120: 79-83.
22. Musetti, R., Polizzotto, R., Vecchione, A., Borselli, S., Zulini, L., D'Ambrosio, M., Sanità di Toppi, L. and Pertot, I. 2007. Antifungal activity of dike-

topiperazines extracted from *Alternaria alternata* against *Plasmopara viticola*: an ultrastructural study. *Micron,* 38: 643-650.

23. Pearson, R.C. and Goheen, A.C. 1988. *Compendium of Grape Diseases*. The American Phytopathological Society, St. Paul, MN.
24. Pellegrini, A., Prodorutti, D., Frizzi, A., Gessler, C. and Pertot, I. 2010. Development and evaluation of a warning model for the optimal use of copper in organic viticulture. *Journal of Plant Pathology,* 92(1): 43-55.
25. Rana, G., Katerji, N., Introna, M. and Hammami, A. 2004. Microclimate and plant water relationship of the "overhead" table grape vineyard managed with three different covering techniques. *Scientia Horticulturae,* 102: 105-120.
26. Ranella, G., Chaudri, A.M. and Brookes, P.C. 2002. Fresh additions of heavy metals do not model long-term effects on microbial biomass and activity. *Soil Biology and Biochemistry,* 34: 121-124.
27. Reuveni, M. 2003. Activity of the New Fungicide Benthiavalicarb Against *Plasmopara viticola* and its Efficacy in Controlling Downy Mildew in Grapevines. *European Journal of Plant Pathology,* 109: 243-251.
28. Rhoads, F.M., Olson, S.M. and Manning, A. 1989. Copper toxicity in tomato plants. *Journal of Environmental Quality,* 18: 195-197.
29. Shaner, G. and Finney, R.E. 1977. The effect of nitrogen fertilization on the expression of slow-mildewing resistance in Knox wheat. *Phytopathology,* 67: 1051-1056
30. Sivčev, B.V., Sivčev, I.L. and Ranković-Vasić, Z.Z. 2010. Plant protection products in organic grapevine growing. *Journal of Agricultural Sciences,* 55: 103-122.
31. Tamm, L., Häselei, A., Amsler, T., Jiménez, S., Thüerig, B. and Lèvite, D. 2003. Crop protection strategies in European organic. *Proceedings of the 54th Annual Meeting of the American Society for Enology and Viticulture (ASEV)*, Reno, Nevada, 20 Jun. 2003.
32. Thüerig, B., Binder, A., Boller, T., Guyer, U., Jiménez, S., Rentsch, C. and Tamm, L. 2006. An aqueous extract of the dry mycelium of *Penicillium chrysogenum* induces resistance in several crops under controlled and field conditions. *European Journal of Plant Pathology,* 114: 185-197.
33. Townsend, G.R. and Heuberger, J.W. 1943. Methods for estimating losses caused by diseases in fungicide experiments. *Plant Disease Reporter,* 27: 340-343.
34. Tukey, J.W. 1953. The problem of Multiple Comparisons. Mimeographed monograph. Princeton University, Princeton NY (US).
35. Wilson, C.L., Solar, J.M., El Ghaouth, A. and Wisniewski, M.E. 1997. Rapid Evaluation of Plant Extracts and Essential Oils for Antifungal Activity Against *Botrytis cinerea*. *Plant Disease,* 81: 204-210.

Received: 7 June 2011; Accepted: 10 January 2012

Χρήση φυσικών φυτοπροστατευτικών προϊόντων και σκευασμάτων με μειωμένη περιεκτικότητα σε χαλκό για καταπολέμηση του περονόσπορου σε βιολογικές καλλιέργειες αμπέλου

A. La Torre, C. Mandalà, F. Caradonia και V. Battaglia

Περίληψη Στα πλαίσια της φυτοπροστασίας, οι βιοκαλλιεργητές μπορούν να εφαρμόσουν μόνο προληπτικά καλλιεργητικά μέτρα σε συνδυασμό με χρήση μερικών εγκεκριμένων σκευασμάτων. Στη συγκεκριμένη μελέτη αξιολογήθηκαν σκευάσματα βιολογικής φυτοπροστασίας εναλλακτικά του χαλκού, που αποτελεί το κύριο μέσο καταπολέμησης του *Plasmopara viticola*, παθογόνου αιτίου του περονόσπορου της αμπέλου. Στο σύνολο των πειραμάτων τα χαλκούχα παρουσίασαν τα καλύτερα αποτελέσματα. Παρόλα αυτά, τα σκευάσματα ήταν αποτελεσματικά στο σύνολό τους στην περίπτωση ήπιων προσβολών και μάλιστα αυτά που περιείχαν μειωμένη περιεκτικότητα χαλκού σε σχέση με το σκεύασμα αναφοράς παρουσιάστηκαν το ίδιο δραστικά. Στη συγκεκριμένη ερευνητική μελέτη παρουσιάζουμε μια εναλλακτική μέθοδο φυτοπροστασίας- για τον περονόσπορο- προκειμένου να αντιμετωπιστεί το αυξανόμενο περιβαλλοντολογικό πρόβλημα της βιο-συσσώρευσης του χαλκού λόγω της συνεχής χρήσης του. Προτείνουμε τη χρήση σκευασμάτων εναλλακτικών του χαλκού σε περιπτώσεις ήπιας προσβολής και χρήση σκευασμάτων με χαμηλή περιεκτικότητα σε χαλκό όταν οι συνθήκες είναι ευνοϊκές για επιδημία.

Hellenic Plant Protection Journal **5:** 13-21, 2012

Hellenic Plant Protection Journal **5:** 23-25, 2012

SHORT COMMUNICATION

Coccus hesperidum (Hemiptera: Coccidae) on *Ocimum basilicum*: A new record of host plant in Greece

S.C. Papadopoulou

Summary The brown soft scale, *Coccus hesperidum* (Hemiptera: Coccidae), was found on sweet basil, *Ocimum basilicum (*Lamiaceae*),* topically named "hagioritikos", for the first time in northern Greece at the regions of Thessaloniki and Kavala. The scale was mainly observed on the stems and also the leaves of *O. basilicum*.

Additional keywords: brown soft scale, Lamiaceae, Greece, invasive pest

The ever-increasing demand of aromatic plants on behalf of consumers has resulted in their large-scale cultivation in Greece. This, in turn, has led to a pressing demand for surveying and recording insect pests that cause damage on aromatic plants and reduce production. This communication reports for the first time sweet basil*, Ocimum basilicum (*Lamiaceae*),* as a host plant of the brown soft scale, *Coccus hesperidum* Linnaeus, 1758 (Hemiptera: Coccidae), in Greece.

Ocimum basilicum, locally known in Greece as "hagioritikos", is an aromatic plant known from the ancient times, which is mostly used for medical and religious purposes in Greece. Scientific studies *in vitro* have established that compounds in basil oil have potent antioxidant, antiviral and antimicrobial properties as well as the potential for use in treating cancer (3, 5, 7, 11).

Coccus hesperidum is one of the most widespread and polyphagous scale insects. It occurs on the leaves and twigs of many important plants such as cottonwood, palm, strawberry tree but not on grasses (6, 9). Host plants reported in Hawaii include *Citrus* spp., loquat, *Moraea bicolor, Moraea iridioides,* orchids, papaya, rubber and *Santalum haleakalae* (17). In Fiji, it has been recorded as a pest of coconuts (18). Gill (9) reported that in California the brown soft scale is an annoying insect that feeds on a wide variety of hosts i.e. aspen, avocado, citrus, cottonwood, holly, manzanita, palm, poplar, stone fruit, strawberry tree and willow. Almost a decade later, Dreistadt *et al.* completed the insect's host-plant list (8). Neither this list nor the recent one of scale insects of Slovenia, Iran, Bulgaria and China (13, 14, 15) comprise *O. basilicum* as a host plant. In Greece, *C. hesperidum* has been recorded on various hosts, especially citrus, but not on *O. basilicum* (2, 12, 16).

Following several years of insect pest surveys on aromatic plants, *C. hesperidum* was observed on isolated plants of an organic culture of *O. basilicum*, in northern Greece, namely Thessaloniki region, in 2003. Since then, the infestation was spread in the rest of Thessaloniki Prefecture, then to Kavala Prefecture and other regions of Greece. Samples of the scale insect were collected, brought to the laboratory and slide mounted by using Wileky's method (10). Identification was primarily made by the author using the adult's morphological characteristics according to Kosztarab and Kozár (10), Gill (9) and verified by Dr G. Watson in Natural History Museum of London.

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The overall body shape of female adults of *C. hesperidum* is symmetrically oval, dome-like, and 1/8 to 1/6 inch long. They are pale yellowish brown to greenish and flecked with irregular brown spots. Overall colour darkens as the insect ages (17). Adult females are ovoviviparous, producing nymphs that hatch from eggs within several hours after these are laid (1). Five to 19 eggs are laid per day over a series of 30-65 days by the adult female and each female lays 80-250 eggs in her life time (4). The young nymphs, born within the adult female, remain in her brood chamber for a few hours before starting to disperse (dispersive crawlers). The crawlers search until they find a suitable spot to feed from the plant and then settle. There are three nymphal instars, before the scale reaches adulthood. The second and third nymphal instars are distinguished by the size of the scale. The development time is about two months at cool temperatures (1).

Coccus hesperidum, like other soft scales, feeds from the phloem of the host plant and on sweet basil it was found mainly on the stems (Figure 1) and also the leaves (Figure 2) in 20% of the infested organic culture. The population density of *C. hesperidum* on *O. basilicum* peaked in summer, particularly from June to September.

In general, heavy infestations by the brown soft scale cause development of sooty mould on host-plant surfaces, sometimes resulting in defoliation.

Figure 1. *Coccus hesperidum* feeding on stem of *Ocimum basilicum.*

Figure 2. *Coccus hesperidum* feeding on leaf of *Ocimum basilicum.*

Literature cited

1. Annecke, D.P. 1959. The Effect of Parathion and Ants on *Coccus hesperidum* L. (Coccidae: Homoptera) and its Natural Enemies. *Journal of the Entomological Society of South Africa*, 22: 245-274.
2. Argyriou, L.C. 1983. Faunal analysis of some scale insects in Greece. *Proceedings of the 10th International Symposium of Central European Entomofaunistics*, Budapest, 15-20 August 1983 364-367.
3. Bozin, B., Mimica-Dukic, N., Simin, N. and Anackov, G. 2006. Characterization of the volatile composition of essential oils of some lamiaceae spices and the antimicrobial and antioxidant activities of the entire oils. *Journal of Agricultural and Food Chemistry*, 54: 1822–1828.
4. Cancela da Fonseca, J. 1954-1956. Contribuicao para o estudo do *Coccus hesperidum* L. II. Subsidios para o estudo da sua biologia e ecologia. Broteri, 50: 53-93; 51: 38-51; 51: 161-173; 52: 19-35.
5. Chiang, L.C., Ng, L.T., Cheng, P.W., Chiang, W. and Lin, C.C. 2005. Antiviral activities of extracts and selected pure constituents of *Ocimum basilicum*. *Clinical and Experimental Pharmacology and Physiology*, 32: 811–816.
6. Copland, M.J.W. and Ibrahim, A.G. 1985. Biology of Glasshouse Scale Insects and Their Parasitoids. pp 87-90. In: *Biological Pest Control The Glasshouse Experience.* Eds. N. W. Hussey and N. Scopes. Cornell University Press; Ithaca, New York.
7. de Almeida, I., Alviano, D.S. and Vieira, D.P. 2007. Antigiardial activity of *Ocimum basilicum* essential oil. *Parasitology Research,* 101: 443–452.

8. Dreistadt, S.H., Morse, J.G., Phillips, P.A. and Rice, R.E. 2007. *Some Common Soft Scales (Coccidae). Their Impact in California and the Principal Hosts*. Publications, University of California Statewide IPM Program.
9. Gill, R.J. 1988-1997. *The Scale Insects of California* Parts 1–3. Sacramento: California Department of Food and Agriculture.
10. Kosztarab, M. and Kozár, F. 1988. *Scale insects of Central Europe*. Akademiai Kiado, Budapest, Hungary, 456 pp.
11. Manosroi, J., Dhumtanom, P. and Manosroi, A. 2006. "Anti-proliferative activity of essential oil extracted from Thai medicinal plants on KB and P388 cell lines". *Cancer Letters*, 235: 114–120.
12. Milonas, P.G., Kozár, F. and Kontodimas, D.C. 2008. New data on the scale insects (Homoptera:Coccoidea) of the greek entomofauna. *Hellenic Plant Protection Journal*, 1: 32-34.
13. Seljak, G. 2010. A checklist of scale insects of Slovenia. *Entomologia Hellenica*, 19: 99-113.
14. Torabi, M. Vahedi, H.A. and Hodgson, C.J. 2010. Preliminary survey of the scale insects fauna in Kermanshah, western Iran. *Entomologia Hellenica*, 19: 153-162.
15. Trencheva, K., Trenchev, G., Tomov, R. and Wu, S.-A. 2010. Non-indigenous scale insects on ornamental plants in Bulgaria and China: A survey. *Entomologia Hellenica*, 19: 114-123.
16. Tzanakakis, M.E. and Katsoyannos, B. 2003. *Insects of fruit crops and vine*. Agrotypos Press, Athens, Greece p 360 (in Greek language).
17. Zimmerman, E.C. 1948. *Coccus hesperidum* Linnaeus pp. 301, 304-306. In: Insects of Hawaii. A Manual of the Insects of the Hawaiian Islands, including Enumeration of the Species and Notes on Their Origin, Distribution, Hosts, Parasites, etc. Volume 5. Homoptera: Sternorhyncha p 464.
18. William, D.J. and Watson, G.W. 1990. *The Scale Insects of the Tropical South Pacific Region Part 3. The Soft Scales (Coccidae) and Other Families*. C.A.B. International Institute of Entomology, 267 pp.

Received: 7 October 2011; Accepted: 15 December 2011

ΣΥΝΤΟΜΗ ΑΝΑΚΟΙΝΩΣΗ

Πρώτη καταγραφή του *Coccus hesperidum* (Hemiptera: Coccidae) σε φυτά *Ocimum basilicum* (Lamiaceae) στην Ελλάδα

Σ. Παπαδοπούλου

Περίληψη Τα τελευταία έτη στη Βόρεια Ελλάδα αρχικά στους νομούς Θεσσαλονίκης και Καβάλας και αργότερα και σε άλλους νομούς της χώρας, βρέθηκε το κοκκοειδές *Coccus hesperidum* Linnaeus, 1758 (Hemiptera: Coccidae) να προκαλεί ζημίες σε βιολογική καλλιέργεια αγιορείτικου βασιλικού *Ocimum basilicum* (Lamiaceae). Στη διεθνή και ελληνική βιβλιογραφία το *C. hesperidum* (soft brown scale) καταγράφεται ως ξενιστής πολλών φυτών, κυρίως του γένους *Citrus*, αλλά δεν αναφέρεται ως εχθρός του *O. basilicum*. Με την παρούσα εργασία, γίνεται η ως άνω πρώτη αναφορά.

Hellenic Plant Protection Journal **5:** 23-25, 2012

Hellenic Plant Protection Journal **5:** 27-29, 2012

SHORT COMMUNICATION

First record of the cotton bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae), on the oil-bearing rose, *Rosa damascena* Miller, in Turkey

O. Demirözer

Summary The cotton bollworm, *Helicoverpa armigera,* was recorded for the first time on the oil-bearing rose, *Rosa damascena*, at Isparta and Burdur, Turkey in May 2010. Cotton bollworm was found to cause damages not only on oil-rose plants in the field but also on dried rose petals in rose oil factories. As *H. armigera* is a cosmopolitan pest, the potential risk posed to the oil-bearing rose crop should be considered.

Additional keywords: Helicoverpa armigera, *Rosa damascena*, pest, Turkey

The oil-bearing rose (*Rosa damascena* Miller) (*R. gallica* L. and *R. phoenicia* Boiss hybrid) is an important aromatic plant providing volatile oils which are used for the production of medicines, perfumes, cosmetics and other aromatherapy products. It is cultivated as an agricultural crop in various countries of the northern hemisphere such as Bulgaria, China, Egypt, France, India, Iran, Morocco and Turkey. Among these countries, Turkey and Bulgaria are the largest producers of this crop all over the world. The annual production of oil-bearing rose is approximately 1.5–2 tons and 1-1.5 tons in Turkey and Bulgaria respectively (2, 8, 16).

Helicoverpa armigera (Hübner, 1808) (Lepidoptera: Noctuidae) is a cosmopolitan pest with a wide host plant range of more than 200 species. It is a polyphagous pest and many of its host plants are economically important crops in Africa, Asia, Oceania and Europe (6). Among other crops, tomato, cotton, pigeon pea, chickpea, sorghum and cowpea are the most important hosts. Additionally, groundnut, okra, peas, field beans, soybeans, lucerne, *Phaseolus* spp., tobacco, potatoes, maize, flax, *Dianthus* spp., *Rosa* spp., *Pelargonium* spp., *Chrysanthemum* spp., a number of fruit trees and forest trees could also be potential hosts for *H. armigera* (7, 9, 15).

Many insects are considered pests for *R. damascena*. In Bulgaria, Nikolova reported 14 specific and 56 polyphagous species in Kazanlika (11, 12, 13, 14) and Natskova recorded 9 aphid species in Sophia (10). In Isparta-Turkey, two armoured scale insects were recorded for the first time in 2009 increasing the number of pests on *R. damascena* to 25 (1, 5).

In 2011, Demirözer and Karaca conducted a comprehensive survey of arthropods in oil-bearing rose orchards in Isparta, the results of which bring the total number of phytophagous arthropods to 62 species. However, only three species of moths have been recorded as pests on oil-bearing rose in Turkey: *Notocelia rosaecolana* (Doubleday), *Archips rosana* (L.) (Lepidoptera: Tortricidae) and *Cnaemidophorus rhododactyla* (Denis & Schiffermüller) (Lepidoptera: Pterophoridae) (1, 3, 4).

The present study is a first record of in-

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festations by *H. armigera* on flowers of *R. damascena* in Aglasun-Burdur and Atabey-Isparta, Turkey (Figures 1, 2). During May and June 2010, 53 oil-bearing rose orchards were inspected and four of them were found infested. Larvae of *H. armigera* were collected from flowers of *R. damascena* in different localities, which are listed in Table 1. All the collected specimens were moved into a growth chamber at 26±1°C and 60% relative humidity and fed daily with fresh oil-bearing rose flowers. Both laboratory and field observations have displayed that the pest attacks principally carpels and stamens and less petals. Furthermore, *H. armigera* larvae were observed feeding on dried rose petals located on drying racks in rose oil factories. These rose petals were being dried for personal use and the feeding activity of the pest affected their value. As *H. armigera* is a pest having world-wide distribution, the oil-bearing rose growers and agricultural advisers need to be alerted and the potential risk posed to the oil-bearing rose crop should be considered.

Figure 1. Flower of *Rosa damascena*, Turkey, Isparta, damaged by *Helicoverpa armigera*.

I would like to thank Dr Alberto Zilli (Museum of Zoology, Rome, Italy) for identification of Cotton Bollworm. Special thanks to Dr Serkan Boyar (Suleyman Demirel University, Faculty of Agriculture, Department of Agricultural Machinery, Isparta, Turkey) for his contributions in this study. And another special thanks to Kara Tyler Julian (University of Florida, IFAS-North Florida Research and Education Center, Quincy, Florida-USA) for language assistance.

Figure 2. Larva of *Helicoverpa armigera* on rose petals of *Rosa damascena.*

Table 1. Regions, collection period and number of *Helicoverpa armigera* specimens collected on *Rosa damascena* in Turkey.

Region	Coordinates	Altitude	Collection period	Number of Specimens
Isparta-Atabey (Onac district)	N 37° 36′ 7.2″ E 30° 30′ 36″	990m	13May, 2010 19 May, 2010	2 6
Isparta-Atabey (Onac district)	N 37° 46′ 46.1″ E 30° 27′ 36.1″	1030m	28 May, 2010 4 June, 2010	3 4
Burdur-Aglasun (Kiprit village)	N 37° 55′ 59.52″ E 30° 38′ 22.56″	1100m	22 May, 2010	5
Burdur-Aglasun (City Center)	N 37° 39′ 35.9″ E 30° 31′ 26.8″	1093m	29 May, 2010	6

Literature Cited

1. Acatay, A. 1969. Schadlinge von *Rosa damascena* Mill. in der Turkei. *Journal of Pest Science,* 42(4): 49-53 (Deutsch).
2. Baydar, H. 2006. Oil-bearing rose (*Rosa damascena* Mill.) cultivation and rose oil industry in Turkey. *Euro Cosmetics,* 14: 13-17.
3. Demirözer, O. 2008. Pests, Their Natural Enemies and Population Fluctuations of Some Important Species Found In Oil-Bearing Rose (*Rosa Damascena* Miller) Production Areas In Isparta Province, Süleyman Demirel University, 165p. PhD Thesis.
4. Demirözer, O. and Karaca, I. 2011. Phytophagous arthropod species associated with oil bearing rose, *Rosa damascena* Miller, in Isparta province with distributional remarks. *Suleyman Demirel University, Journal of Science,* 6: 9-25.
5. Demirözer, O., Kaydan, M.B., Karaca, I. and Ben-Dov, Y. 2009. First records of armoured scale insects (Hemiptera: Coccoidea: Diaspididae) from the oil-rose, *Rosa damascena*, in Turkey. *Hellenic Plant Protection Journal,* 2(1): 33-35.
6. EPPO 2006. Distribution Maps of Quarantine Pests. *Helicoverpa armigera*. Retrieved online from: http://www.eppo.org/QUARANTINE/insects/Helicoverpa_armigera/HELIAR_ds.pdf (last visit:23/11/2011).
7. Fitt, G.P. 1989. Ecology of *Heliothis* species in relation agro-ecosystems. *Annual Review of Entomology,* 34: 17-52.
8. Güneş, E. 2005. Turkey rose oil production and marketing: A review on problem and opportunities. *Journal of Applied Sciences,* 5(10): 1871-1875.
9. Multani, J.S. and Sohi, A. S. 2002. *Helicoverpa armigera* (Hübner) on carnation, *Dianthus caryophyllus* Linn. in Punjab. *Insect-Environment,* 8(2): 82 (Abstract).
10. Natskova, V. 1970. The parasites and predators of aphids on roses. *Rastitelna Zashchita*, 19(11): 19-22 (Russian).
11. Nikolova, V. 1967. Entomocaenological and biological studies in *Rosa damascena* Mill. plantations. I. Lepidoptera. *Bulletin de L'institut de Zoologie et Musée, Sofia*, 24: 101-128 (Russian).
12. Nikolova, V. 1968. Entomocaenological and biological studies in *Rosa damascena* Mill. plantations. II. Coleoptera. *Bulletin de L'institut de Zoologie et Musée, Sofia*, 26: 119-151 (Russian).
13. Nikolova, V. 1969. Entomocaenological and biological studies in *Rosa damascena* Mill. plantations. III. Homoptera. *Izvestiya Zoologia Institute Sofia*, 29: 191-210 (Russian).
14. Nikolova, V. 1972. Entomocaenological and biological studies in *Rosa damascena* Mill. plantations. IV. Hymenoptera and Diptera. *Bulletin de L'institut de Zoologie et Musée, Sofia*, 30: 107-135 (Russian).
15. Venette, R.C., Davis, E.E., Zaspel, J., Heisler, H. and Larson, M. 2003. Mini Risk Assessment, Old World Bollworm, *Helicoverpa armigera* Hübner (Lepidoptera: Noctuidae). Department of Entomology University of Minnesota p. 27. Retrieved online from: http://www.aphis.usda.gov/plant_health/plant_pest_info/pest_detection/downloads/pra/slittoralispra.pdf (last visit 11/23/2011).
16. Weiss, E.A. 1996. Essential oil crops. *CABI Pub*, 608 p.

Received: 7 November 2011; Accepted: 29 November 2011

ΣΥΝΤΟΜΗ ΑΝΑΚΟΙΝΩΣΗ

Πρώτη καταγραφή του πράσινου σκουληκιού, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae), στην τριανταφυλλιά *Rosa damascena* Miller στηνΤουρκία

O. Demirözer

Περίληψη Προνύμφες του πράσινου σκουληκιού, *Helicoverpa armigera*, διαπιστώθηκαν για πρώτη φορά σε καλλιέργεια τριανταφυλλιάς *Rosa damascena*, από την οποία παράγεται το ροδέλαιο, στην Τουρκία τον Μάϊο του 2010. Το έντομο βρέθηκε να προκαλεί ζημιές τόσο στην καλλιέργεια όσο και σε αποξηραμένα ροδοπέταλα σε μονάδα παραγωγής ροδελαίου. Δεδομένου ότι το πράσινο σκουλήκι έχει παγκόσμια εξάπλωση, θα πρέπει να ληφθεί σοβαρά υπόψη η πιθανή επικινδυνότητά του στη συγκεκριμένη καλλιέργεια.

Hellenic Plant Protection Journal **5:** 27-29, 2012

Τόμος 5, Τεύχος 1, Ιανουάριος 2012
ISSN 1791-3691

Περιεχόμενα

Volume 5, Issue 1, January 2012
ISSN 1791-3691

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Hellenic Plant Protection Journal

www.bpi.gr