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Arthropod pests of pistachios, their natural enemies and management

*Mohammad Reza Mehrnejad**

Pistachio Research Institute, Rafsanjan, Iran

**Corresponding author: reza_mehrnejad@hotmail.com*

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Abstract: Commercial pistachio cultivation and production began about a century ago in Iran. The size of this industry has gradually increased and the pistachio nut production in Iran is now the largest worldwide, although it has declined over last few years due to long periods of harsh drought, the mismanagement of water resources and the impact of climate change. Research on pests and diseases was started in the 1940s due to the demands of the growers who were facing economic damage by herbivorous insects. Much research has been undertaken over the last 75 years to improve production procedures and the present article summarises the available information on pistachio pests, their natural enemies and management.

Keywords: *Pistacia*; Iran; pests control; predatory insects; parasitoids; review

The plant genus *Pistacia* Linnaeus (Anacardiaceae) is a mainly subtropical genus comprising some eleven species of wind-pollinated deciduous and dioecious trees and shrubs. Geographically, the largest concentration of *Pistacia* species is found in West Asia and in the Mediterranean region (Zohary 1995; Tous & Ferguson 1996). The cultivated pistachio, *Pistacia vera* Linnaeus, originated in the northern part of Afghanistan in Asia Minor, but is now found throughout the Mediterranean countries and the Middle East (Shrestha 1995). *P. vera* produces the valuable nut in the genus and has male and female trees. Other species, such as non-cultivated (wild) pistachios, produce small, un-split nuts with a hard shell and are mainly consumed by some native tribes in the Middle East and Asia Minor (Tous & Ferguson 1996). Natural forests of wild pistachio trees are still seen in many areas in West, Central and Northeast Iran (Mehrnejad 2006). However, many other *Pistacia* species grow wild in desert or semi-desert locations in the Mediterranean region, Afghanistan, the southern parts of the old Soviet Union and North Africa (Ferguson & Kallsen 2016). The current major growing areas for *P. vera* are the Middle East (Iran, Syria); the Mediterranean countries, including Turkey, Greece, Tunisia, Spain and Italy; southwest North America (California and Arizona); and Australia (Kaska 1995; Sheibani 1995; Ferguson 1997). The pistachio nut is one of the major agricultural products in Iran.

Although arthropod pests have been the main problem for Iranian pistachio growers for the last 80 years, the shortage of water, worsening of the salinity and global warming in recent decades are now considered to be the greatest cause of the lost production (Mehrnejad 2010a, 2014a, B; Salehi & Hosseinifard 2012; Pour-Mohammadali et al. 2019). Insects attack every part of the pistachio plant throughout its growth period. A wide range of chemicals have been used in pistachio plantations since the 1940s. Also, this was generally unsatisfactory due to its adverse effects on the nontarget fauna, humans and environment ecological balance. On the other hand, many insect and mite pests of pistachios can be very effectively controlled through integrated pest management techniques using different methods

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(*i*) Agricultural practices (e.g., sanitation as well as cultural and mechanical procedures, monitoring to determine the type of pest present and population density and optimising the trees' vigour). (*ii*) Conservation of natural enemies and (*iii*) Using selective and less harmful pesticides against the vulnerable stages of the target pests.

As a long-lived perennial plant in a desert climate condition, pistachio trees have provided a stable ecological habitat. The major arthropod pests that attack pistachio trees are mainly host-specific, although species with a wider host range can also be abundant, probably due to a lack of alternative host plants caused by a shortage of water and the alkaline soils. The arthropod pests of pistachio plantations in Iran include phytophagous insects and mites which may be considered as locally important pests (Table 1). These are placed in three groups based on the economic damage and distribution: (*i*) major pests. These are widespread key pests that occur frequently throughout the pistachio plantations, e.g., hemipteran sap-feeding insects, such as psyllids, plant bugs and stink bugs, and also the twig borer moth. (*ii*) local key pests, e.g., scale insects, fruit borers, bud, leaf and twig boring beetles and moths and leafhoppers, and (*iii*) minor pests, that occur rarely under certain conditions, e.g., galling aphids, seed wasps, thrips, leaf miners, root- and wood-boring beetles and phytophagous mites (Mehrnejad 2001, 2014b). Many other phytophagous insects attack pistachio trees, but they are not widespread and do not cause noticeable damage in the pistachio plantations nowadays.

The objective of this review is to highlight the arthropod pest problems on the pistachio trees in Iran, and to summarise the current knowledge on their control. The present information is compiled from many research projects that have been conducted both in the field and the laboratory over the past 80 years.

PEST STATUS IN PISTACHIO PLANTATIONS OF WORLD

The pest species that cause problems in pistachio plantations in the Middle East and the Mediterranean region are the same, but are different from those that cause damage to pistachios in California. Hemipteran plant-sap-feeding insects, e.g. psyllids, plant bugs, mealybugs, stink bugs, scale insects, leafhoppers, seed wasps and phytophagous mites are considered to be the major injurious agents worldwide. However, the twig borer moth and several beetle species attack the fruit clusters, buds, twigs, stem, trunks and roots throughout the Middle East and the Mediterranean regions.

WIDESPREAD PISTACHIO KEY PESTS

This group of pistachio pests are almost always frequently found throughout the main pistachio-producing areas and usually induce significant damage to pistachio yields by either attacking the pistachio leaves, fruits, branches or twigs every year. These insects generally reproduce heavily from early spring and control applications against them are usually difficult due to their biological and ecological features.

The common pistachio psylla, *Agonoscena pistaciae* Burckhardt & Lauterer (Hem.: Aphalaridae)

Economic importance, distribution and host range. Three psyllid species are associated with pistachio trees in Iran. The common pistachio psylla (CPP), *Agonoscena pistaciae* is indigenous to Iran and is now the most serious pest throughout the pistachio-producing regions of the country. An investigation demonstrated the great potential of CPP for a population increase at temperatures ranging from 15 to 35 °C, and such temperatures occur in the pistachio growing areas of Iran. Its adaptability to different habitats and host plants combined with its high population growth rate and strong dispersal capacity as well as its potential to develop resistance to synthetic insecticide makes it difficult to control (Mehrnejad 1998, 2003, 2016). It occurs in many countries along the southern borders of the old Soviet Union, and throughout most of the Middle East and the Mediterranean region and is restricted to *Pistacia* spp. This insect causes economic damage to pistachios in Turkey, Syria and Greece; however, it is not present in the pistachio plantations in the USA and Australia (Burckhardt & Lauterer 1989, 1993; Mart et al. 1995; Lauterer et al. 1998; Mehrnejad 1998; Bolu 2002; Malenovský et al. 2012). This species was first reported on wild and cultivated pistachio trees in Iran by Kiriukhin (1946). Due to the abundance, wide distribution and economic importance of *A. pistaciae* in comparison with other psyllids in the cultivated pistachio-growing areas, it was named the common pistachio psylla' (Mehrnejad 1998).

Life cycle. There are two distinct morphs for CPPs, differing morphologically as well as biologically. The

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Table 1. The pests of pistachio (*Pistacia vera*) plantations in Iran. The degree of importance is determined based on their economic damage and distribution, + least important, +++ greatest importance (Mehrnejad 2014b)

Common name	Scientific name	Degree of importance	Preferred plant organ
Psyllids	*Agonoscena pistaciae*	+++	leaves
	Megagonoscena viridis	+	
	Agonoscena bimaculata	+	
Plant bugs	*Campylomma verbasci*	+++	fruits
	Campylomma diversicorne	++	
	Campylomma unicolor	++	
Red bug	*Spilostethus pandurus*	+++	fruits
Stink bugs	*Acrosternum arabicum*	+++	fruits
	Acrosternum breviceps	++	
	Brachynema germarii	+++	
	Chroantha ornatula	+++	
	Dolycoris baccarum	++	
	Carpocoris coreanus	++	
Scale insects	*Lepidosaphes pistaciae*	+++	twigs, branches, flowering and fruit clusters, leaves
	Melanaspis inopinata	+++	
	Melanaspis pistaciae		
	Salicicola davatchii	+	
	Anapulvinaria pistaciae	+	
	Eulecanium rugulosum	+	
Leafhopper	*Sulamicerus stali*	+	new grown shoots, flowering clusters and tiny fruits
Galling aphids	*Forda hirsuta*	+	leaves
Aphids	*Aphis gossypii*	+	leaves, shoots
Twig borer moth	*Kermania pistaciella*	+++	clusters and twigs
Fruit borer moth	*Recurvaria pistaciicola*	++	fruits
Fruit hull borer moth	*Arimania komaroffi*	++	fruits
Carob moth	*Ectomyelois ceratoniae*	+	fruits
Seed wasps	*Eurytoma plotnikovi*	+	fruits
	Megastigmus pistaciae	+	
Thrips	*Thrips pistaciae* *Thrips iranicus* *Frankliniella occidentalis* *Liothrips austriacus*	+	leaves, flowering and fruit cluster
Weevil	*Polydrosus davatchii*	++	new opened buds and blossom
Leaf borers moth	*Ocneria terebinthina* *Thaumetopoea solitaria*	+	leaves
Leafminers	*Stigmella promissa* *Simplimorpha promissa*	+	leaves
Bud and twig borer beetle	*Chaetoptelius vestitus*	++	new formed buds and twigs
Bud borer moth	*Telphusa pistaciae*	+	buds
Root beetle	*Capnodis cariosa hauseri*	+	thick roots
Long-horned beetle	*Calchaenesthes pistacivora*	+	stems and branches

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Table 1. continue

The cotton bollworm	*Helicoverpa armigera*	+	young fruits
Eastern Bordered Straw	*Helicoverpa nubigera*	+	young fruits
Petals borer moth	*Gelechia pistaciae*	+	blossoms
Common pistachio mites	*Tenuipalpus granati*	++	leaves
Eriophyid mites	*Aceria* (= *Eriophyes*) *pistaciae* *Aceria* (= *Eriophyes*) *stephanii*	+	flower clusters and leaves
The false chinch seed bug	*Nysius cymoides* (*Spinola*)	+	twigs, branches, leaves
Wood borer	*Anthaxia kalalae* *Anthaxia farah* *Anthaxia parvula* *Anthaxia winkleri* *Agrilus chlorophyllus* *Chrysobothris parvipunctata*	++	unhealthy branches

summer-form requires moderately high temperatures and long days and is present throughout the mid-spring to early-autumn and readily mates and starts to lay eggs 1–2 days after emergence. In contrast, the winter-form is found throughout the winter, from about November onwards, in a reproductive diapause. The diapause incidence in adult CPPs is mainly initiated when the developing nymphs are exposed to a combination of a short-day photoperiod (12 h of light) and low temperatures (below 20 °C). However, the temperature (above 20 °C) and long photoperiod strongly influences the diapause completion in this species, resulting in the ovarian development in the winter-form. The overwintered CPPs emerge from overwintering sites starting very late February and continue for about 7 weeks. In general, the winter-forms are generally darker in colour, whereas the summer-forms are a light orange colour and have a smaller size than the winter-form CPPs. In addition, the interform adult CPP is also present. When the environmental conditions are not fully fixed for the diapause induction, the interform CPP appears. The interform CPP clearly appears in late September to late October in the field. They have developed ovaries and oviposit a huge number of eggs especially during the first two weeks. (Mehrnejad 1998, 2018; Mehrnejad & Copland 2005b, 2006b).

The reproductive pattern of both the winter and summer-forms is similar and also very high over a wide temperature range from 20 to 35 °C, on average 1 000 and 350 eggs, respectively. Such temperatures occur in the pistachio growing areas of Iran. The adaptation of both forms to a wide range of temperatures and the huge reproductive capability are important potentials for this insect species, particularly for the winter-forms to establish a very large colony in the early spring or even from late-winter. Winter-form CPPs can be considered as foundatrices of the summer population. This form can lay eggs at low temperatures (e.g., 20 °C) and are able to increase the population even over a wide range of temperature fluctuations. The optimum temperature for the development is 27.5 °C and theoretical lower thresholds for the development have been reported to be 10.90 and 10.71 °C for males and females, respectively. In addition, the amount of heat required to complete the transformation from egg to adult (thermal constant) was determined to be 227.27 for males and 238.10 for females (Mehrnejad 2003, 2014b; Mehrnejad & Copland 2005b, 2006b).

Mating is necessary for the egg production and it must be repeated every other day, otherwise the egg laying declines to zero. The females embed their eggs on the plant soft tissues like the leaves and newly growth twigs (having a succulent tissue) by a small pedicel. The pedicel may provide moisture to the egg, since the removal of the egg causes it to shrink within a day. The eggs are usually laid in clusters of 5–50 and are mainly deposited on the upper surface of the pistachio leaves, but egg laying on the young leaves' petiole and young succulent plant shoots occurs in early spring. Feeding and ovipositing of the winter-form on the stem's tissues or on the base of the buds of the pistachio trees have not been observed. The CPPs pass 5 nymphal instars which all are mobile followed by a sexually reproducing adult stage. It builds-up 5–6 generations per year. Both the nymphs and adults produce large amounts of

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a carbohydrate-rich concentrated honeydew of paste-like consistency, which solidifies immediately after secretion. The honeydew of *A. pistaciae* is a unique insect product, because immediately after secretion it becomes a solid white crystal granular material in the pistachio plantations of Iran where it is dry in the desert areas. The honeydew of the CPPs is a very good and long-term food source for its parasitoid as well ladybirds when the host is temporarily not available (Mehrnejad 1998; Mehrnejad & Copland 2005b, 2006a, b).

A. pistaciae overwinters within the orchards, preferentially concealed under the organic materials on the ground. Plant litter, including the old pistachio leaves and weed residue such as dead grass, support the greatest numbers of adult psyllids during the late-autumn through to the early spring. It has been reported that the number of psyllids that emerge from the fallen dead leaves mixed with the weed residue is about 15 times greater than the number that emerges from the bare ground (Mehrnejad 2018).

A high relative humidity acts as an important limiting factor on the population development of this species. Under humid conditions, the psyllid honeydew does not turn into dry granules, but turns into a liquid and the pistachio leaves become sticky. The psyllid nymphs are not able to walk freely and feed easily on the sticky leaves. Moreover, the presence of a liquid honeydew results in fungal moulds that grow on the ovipositor of the female psylla, resulting in the cessation of the oviposition process and the infected female psyllidae die (Mehrnejad 1998).

The leaves are considered as the preferred tissues for feeding in this insect, in addition, the insects usually feed and reproduce on the leaflets' upper surface, except at breakout when it is found on the lower leaflets' surface too. This psyllid displays a significant competition behaviour with the common pistachio mite, *Tenuipalpus granati* Sayed (Mehrnejad 2003b).

Damage. All the nymphal instars, as well as the adults, ingest large amounts of the nitrogen-poor phloem sap and this results in the excretion of large amounts of the concentrated honeydew. This sap removal causes severe problems in the pistachio trees. The presence of large populations of psyllid nymphs and adults during most of July and August causes severe problems in the kernel filling, with a subsequent bud drop and premature defoliation. This damage affects not only the yields in the current year, but also in the two subsequent years, and it, therefore, causes heavy economic losses. Under the high psyllid population pressure, particularly during July and August, the kernel development stops, although some pistachio cultivars, e.g., Akbari is very sensitive to a low psyllid density even through May and June (before the shell-hardening and the start of the kernel development). Damage at this time occurs by tough premature defoliation. In addition, the damage might be significant after the harvest in October and afterward in all the cultivated pistachio tree cultivars. This insect does not cause the deformation of the plant tissues, e.g., leaf-rolling, gall induction or by the injection of toxins into the feeding sites, and there are no records of it acting as a vector of plant diseases (Mehrnejad 2002, 2003b, 2010a, 2014b).

Natural enemies. Several laboratory and field studies have documented the diversity and biological parameters of the CPP's natural enemies (Mehrnejad 1998, 2003, 2008, 2014b; Mehrnejad & Ueckermann 2001, 2002; Mehrnejad & Jalali 2004; Mehrnejad & Copland 2005a, b, 2006a, b, c, 2007; Mehrnejad & Emami 2005; Hasani-Kabotarkhani et al. 2009; Pourali et al. 2010, 2011, 2012; Mehrnejad et al. 2011, 2013, 2015; Salehi et al. 2011, 2013; Jalali et al. 2014, 2018, 2019; Parish et al. 2015; Mirhosseini et al. 2015; Haitlinger & Mehrnejad 2017). At least, twenty-three beneficial insect and mite species attack the CPPs (Mehrnejad 2016).

Psyllaephagus pistaciae Ferrière (Hymenoptera: Encyrtidae) is the most common and widespread native parasitoid of CPPs. It is the primary, specific, solitary, koinobiont endoparasitoid of *A. pistaciae* nymphs and widely occurs in the pistachio plantation areas of the country. This parasitoid is considered the principal natural enemy attacking all five nymphal instars of *A. pistaciae* and is active from late April to November. There is no data on the status of this wasp in other pistachio growing regions of the world. While *P. pistaciae* might be sufficiently equipped to regulate the host density in theory, various factors are thought to decrease its impact, e.g., hyperparasitism, a low survival rate through overwintering difficulties and the side effects of pesticide applications throughout the growing season (Mehrnejad 1998, 2008, 2010a, 2016; Mehrnejad & Copland 2005a, 2006a, b, c, 2007; Mehrnejad & Emami 2005; Emami & Mehrnejad 2006).

The predatory insects are considered the major cause of mortality in the spring population of CPPs (Mehrnejad et al. 2011, 2015), particularly in wild pistachios where no chemicals are used (Mehrnejad et al. 2013). Based on the available references, coccinellids

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are the most common predators of CPPs in pistachio orchards (Mehrnejad 2016). Twenty-five coccinellid species have been recorded in the planted and wild pistachio plantations in southern Iran (Salehi et al. 2013), with eight species, e.g., *Adalia bipunctata* (Linnaeus), *Coccinella septempunctata* (Linnaeus), *Coccinella undecimpunctata aegyptica* (Reiche), *Coccinula elegantula* Weise, *Exochomus nigripennis* (Erichson), *Hippodamia variegata* (Goeze), *Menochilus sexmaculatus* (Fabricius) and *Oenopia conglobata contaminata* (Menetries) proving to be psyllophagous (Mehrnejad et al. 2011, 2015). *Adalia bipunctata* is considered the most abundant coccinellid in the planted pistachio trees followed by *O. conglobata contaminata*. Twelve morphs of *A. bipunctata* were identified whose prevalent melanic form was the morph *sexpustulata* and the most frequent non-melanic forms were the morph *typica* and the morph *revelierei* (Salehi & Mehrnejad 2014). Based on investigations, these two predatory coccinellids were verified to be the biocontrol candidates for CPPs (Mehrnejad & Jalali 2004; Arab-Hormozabadi 2005; Hasani-Kabotarkhani et al. 2009; Atiqi 2010; Mehrnejad et al. 2011, 2015; Vahabzadeh et al. 2014; Jalali et al. 2018, 2019).

Three predatory bugs, e.g., *Anthocoris minki pistaciae* Wagner, *Farsiana pistaciae* Linnavuori, and *Pseudoloxops sangrudanus* Linnavuori are the active predatory bugs in colonies of the CPP on both cultivated and wild pistachio trees. These bugs attack different nymphal instars of the *A. pistaciae* and successfully develop on this prey. *Anthocoris minki pistaciae* are active through the spring and autumn on pistachio trees either in plain or mountainous areas; however, the other two bugs are found in spring, particularly on wild pistachio trees in mountainous areas (Mehrnejad & Linnavuori 2012; Pourali et al. 2012; Mehrnejad et al. 2013).

The species in the *carnea* complex of the common green lacewing are predators of the CPP in both cultivated and wild pistachio plantations in Iran. The predatory lacewing *Chrysoperla lucasina* (Lacroix) is known as the dominant species that feed on *A. pistaciae* nymphs in pistachio plantations. Adults of *C. lucasina* are present throughout the growing season in pistachio orchards; however, its population density drastically declines through a warm season. At least seven green lacewing species live in pistachio orchards and their food regimes need to be investigated (Jafari-Nodoshan 1998; Hasani-Sadi et al. 2010; Kazemi & Mehrnejad 2011b; Mehrnejad 2014b).

Predatory mites are also considered as tiny and very active natural enemies for the CPP; however, the population density, distribution, prey-range preferences and biological parameters of these predators remain unclear. Six mite species were recorded attacking CPP eggs and nymphs, including: four phytoseiid mite species, e.g., *Paraseiulus porosus* Kolodochka, *Phytoseius corniger* Wainstein, *Neoseiulus barkeri* (Hughes), *Typhlodromus* (*Anthoseius*) *bagdasarjani* (Wainstein & Arutunjan) which live in CPP colonies. In addition, the generalist predatory mite *Anystis baccarum* (Linnaeus) are encountered in CPP colonies throughout the growing season over the pistachio plantations, while *Erythraeus* (*Erythraeus*) *pistacicus* Haitlinger, Mehrnejad & Šundić attacks the CPP in wild pistachio trees in mountainous areas (Mehrnejad & Ueckermann 2001, 2002; Haitlinger et al. 2016; Haitlinger & Mehrnejad 2017).

Management. Psyllid infestations have received particular attention from pistachio-growers, who insist on spraying to reduce the damage to pistachios. Due to the tendency of *A. pistaciae* to develop resistance against insecticides, several synthetic insecticides have been used for a certain period and then were replaced with another over the last several decades. For example, Endosulfan (organochlorine insecticide) arrived in Iranian pistachio plantations in the late 1960s, and was effective against this pest for around 5 years. It was replaced with Phosalone (an organothiophosphate insecticide). However, by late 1980, Phosalone lost its effectiveness and then Amitraz, an amino compound, caused good mortality to CPPs. The most recent pesticide that was widely used to control CPP outbreaks was Movento (a two-way systemic action and spirotetramat ingredient) which was effective for a few years only. Therefore, besides the several disadvantages of using insecticides, such as harsh side effect on natural enemies and the environment as well as the development of resistance, chemical applications have failed more and more frequently to prevent CPP outbreaks. At least two sprays are usually needed through the growing season, although it occasionally increases to four times or even more (Mehrnejad 2003b, 2010a, 2014b). Recently, sulfur (a non-metallic chemical element) is widely being used against the common pistachio psylla through spraying. It is highly effective to keep the psyllid's population at a very low level for a relatively long period. In fact, sulfur acts as a very long-lasting repellent substance. Sulfur keeps adult psyllids away from the pistachio leaves resulting in no egg-laying

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on the leaves and helps to prevent the subsequent population growth. Field surveys clearly confirmed that this material does not cause any side effect on the pistachio trees' growth, the bud bearing of either vegetative or reproductive buds if it applied after the shell hardening. Although this compound must be used precisely, it is being sprayed widely against CPPs in Iran now. Different dosages of sulfur (95–99%) is applied, e.g., 3 to 5 kg/100 L water. When a high dosage is applied, the trees remain psyllid free for about 50 days (Mehrnejad, unpublished).

CPPs must be managed carefully to prevent outbreaks. The CPP overwinters within the orchards and usually migrates onto the pistachio trees from early March. Field investigations verified that CPPs might be controlled whilst overwintering. Winter ploughing of the orchards' floor from late December till late February to a depth of 30 cm both beneath the canopy and between the rows cause a significant reduction of the psyllids' population density. In addition, orchard sanitation, such as the removal and burial of any organic materials left on the orchard's floor and margins is also considered critical. Furthermore, adequate and regular irrigation and fertilisation regimes are recommended to keep the pistachio trees in a vigorous condition. The nuts should be harvested as soon as they are mature. For cultivars with a low sensitivity to psyllid feeding, it is not recommended to apply insecticides repeatedly to make the survival of beneficial agents possible. The conservation of existing natural enemies of CPPs is highly recommended. Under harsh conditions when the likelihood of severe damage is high, chemical controls might be necessary, particularly through the kernel development stage (Mehrnejad 2003, 2006, 2014b, 2018; Najafpour et al. 2010). The capture effects of yellow sticky card traps on CPPs was reported (Emami & Yazdani 1993; Hadian & Seyedoleslami 2001); however, the efficiency of this method in the reduction of the CPP population in wide field sites is still obscure. In addition, the treatment of pistachio trees by a kaolin particle film to prevent the CPP colonisation has been examined (Hassanzadeh et al. 2014; Farazmand et al. 2015; Sheibani et al. 2016), although the use of this compound has not been supported by pistachio growers yet.

Stink and sucking bugs

Economic importance, distribution and host range. A variety of phytophagous Hemiptera species (families Lygaeidae, Miridae and Pentatomidae) may be associated with pistachio trees. They can cause considerable damage to the pistachio nut wherever pistachios grow around the world. Some of the smaller plant bugs (Miridae) attack the very young and soft pistachio fruits soon after pollination and continue to feed on the nut tissue until the shells harden. On the other hand, some of the larger stink bugs (Pentatomidae) may damage the developing fruits from early spring until the time of harvest, and perhaps even longer as long as the nuts remain on the trees. Hemipteran bugs are widely distributed throughout the pistachio plantations in Iran and are considered to be the second most important pests of cultivated pistachio trees. They are often general feeders and may be associated with several other herbaceous plant species in pistachio plantations (Mehrnejad et al. 2013).

So far, three species of the smaller plant bugs (Miridae), including *Campylomma diversicorne* Reuter, *Campylomma verbasci* (Meyer-Dür), and *Campylomma unicolor* Poppius, six species of the larger stink bugs (Pentatomidae), including *Acrosternum arabicum* Wagner, *Acrosternum breviceps* (Jakovlev), *Brachynema germarii* Kolenati, *Carpocoris coreanus* Distant, *Chroantha ornatula* (Herrich-Schäffer), *Dolycoris baccarum* (Linnaeus), and one species of seed bug (Lygaeidae), *Spilostethus* (= *Lygaeus*) *pandurus* (Scopoli) (Table 1) are known to injure pistachio nuts in Iran (Mehrnejad 2001, 2014a, b, 2016; Mehrnejad et al. 2013). Based on the available literature, stink bugs have caused severe problems to pistachio nuts since the 1960s. Five stink bug species, namely *Acrosternum heegeri* Fieber, *Acrosternum millieri* (Mulsant & Rey), *Apodiphus amygdali* (Germar), *Brachynema germarii*, and *Brachynema segetum* Jah. (Pentatomidae) were recorded in pistachio orchards in the 1970s (Ershad & Barkhordary 1974a, b, 1976; Samet & Akbary 1974). However, extensive field surveys during the last ten years have captured only one (*Brachynema germarii*) of the above five listed species. At present, *A. arabicum* and *B. germarii* are the dominant species in pistachio plantations in Iran. Additionally, four other species (*A. breviceps*, *C. coreanus*, *Ch. ornatula* and *D. baccarum*) are considered to be potential pests of pistachio nuts in Iran (Rider & Mehrnejad, unpublished). In California, a variety of mirid bugs attack pistachios and cause economic damage, including *Lygus hesperus* Knight, *Neurocolpus longirostris* Knight, *Calocoris norvegicus* (Gmelin), *Phytocoris relativus* Knight, *P. californicus* Knight, and *Psallus vaccinicola* Knight. Also, leaf-footed

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plant bugs, *Leptoglossus clypealis* Heidemann and *L. occidentalis* Heidemann (Coreidae) cause injuries to the pistachios both before the shell hardening and afterward. In addition, three green stink bugs have been recorded as being injurious in California; *Thyanta pallidovirens* (Stål), *Chlorochroa uhleri* (Stål) and *Acrosternum hilare* (Say) (Michailides et al. 1987; Bentley et al. 2016). In Turkey, the mirid *Campylomma lindbergi* Hoberlandt and the stink bug *Dolycoris baccarum* (Linnaeus) were reported as being injurious pests of nuts in early spring causing epicarp lesions (Yanık &Yücel 2001).

Life cycles. Miridae. Among the three species of *Campylomma* present in Iranian pistachio plantations, *C. verbasci* is the most common species, and it is considered to be a difficult pest problem for pistachio trees. Adults are about 4 mm in length. Both the adults and nymphs are light green in colour, and they walk very fast when disturbed. The other two species resemble *C. verbasci* closely in regards to size and colour, hence, it is very difficult to discriminate among them on pistachio trees. Based on the available information, these bugs overwinter in the egg stage on the pistachio trees, inside succulent tissues such as at the base of the buds' scales. In the Kerman province, southern Iran, nymphs appear promptly after pollination on very young fruit clusters in early April, and then adults appear before the middle of May, wandering on the trees' twigs until early June, and then they disappear. Their biology needs to be studied carefully (Mehrnejad et al. 2013; Mehrnejad 2014b).

Lygaeidae. In addition to the plant bugs, the pistachio red bug (or seed bug), *S. pandurus* is also considered to be an early-spring pistachio pest in Iran. Adults have appeared on the pistachio trees at irregular intervals over the past several decades in Iran. They can cause heavy damage to the young and fleshy nuts just before the shell hardening, which causes epicarp lesions (Samet & Akbary 1974; Khajah-Pour 1993; Mehrnejad 2001, 2014b; Mehrnejad et al. 2013). It appears that this species does not reproduce on the pistachio trees, and it usually leaves the pistachio plantation by late spring or early summer. Information concerning the main factors responsible for the changes in population dynamics, and in particular, what factors allow for outbreaks under natural conditions are poorly understood; these aspects need to be investigated.

Pentatomidae. Pistachio stink bugs overwinter in the adult stage, usually under herbaceous range-land plants near the pistachio plantations. Some of the herbaceous plants include, *Alhagi maurorum* (= *camelorum*) Medikus, *Alhagi persarum* Boiss. & Buhse, *Peganum harmala* Linnaeus, *Salsola kali* Linnaeus, *Seidlitzia rosmarinus* Ehrenb., *Zygophyllum fabago* Linnaeus, and *Anabasis cf. Brachiata* Fisch. & Mey. They usually live and reproduce in the same places during the spring and summer. However, when ample food resources occur due to sufficient rainfall in late winter and early spring, bug populations may increase rapidly, resulting in the migration of the bugs into the pistachio plantations by late June. When they arrive in the pistachio orchards, they feed and reproduce on herbaceous plants, such as *P. harmala* and *S. kali*, usually on the orchards' floor and margins. At this new site, they reproduce highly and then soon attack the pistachio fruit clusters. These bugs may live on the trees for a few months, then they usually leave the pistachio plantations during October and November, moving towards the overwintering sites. During winter, a few *A. breviceps* have been found hiding under the loose bark of trees such as *Elaeagnus angustifolia* Linnaeus (Elaeagnaceae), which is a common woody-plant near the orchards. The overwintering individuals may exhibit a different colour form, turning from light green to pink (Mehrnejad 2014a, b; Tavanpour et al. 2016).

Damage. Miridae. From late April to early May, plant bug nymphs attack the very young fruits prior to the shell-hardening, which causes epicarp lesions. The tiny injured nuts darken and subsequently drop. These bugs are unable to pierce the hardened pistachio shell (Mehrnejad 2001, 2014). Bolkan et al. (1984) and Bentley et al. (2016) stated that the piercing of the soft-shelled pistachios by the stylets of sucking bugs causes necrotic lesions on the hulls (epicarp and mesocarp) in the early season. Sunken areas at the base or sides of the nut often exude a gummy substance; this phenomenon is termed an "epicarp lesion". This injury leads to the desiccation and dropping of the damaged nuts from the trees due to the peroxidase activity in the wounded pistachio fruits (Bostock et al. 1987). The damage usually declines as the shells begin to harden. However, epicarp lesions are considered to be one of the most important problems in pistachio orchards in Iran.

Lygaeidae. The pistachio red bug, *S. pandurus* have appeared on pistachio trees at irregular intervals over the last several decades. However, when they attack pistachio plantations, they can cause heavy damage to the young and fleshy nuts just before the shell hardening. These bugs also cause epicarp lesions,

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and the attacked nuts fade to brown, dry, and then finally drop (Samet & Akbary 1974; Khajah-Pour 1993; Mehrnejad 2001).

Pentatomidae. Although stink bugs may feed on the nuts before the shell hardening, causing epicarp lesions, they also can be injurious through the kernel development period by feeding on the developing kernel through the shell. This can cause a "kernel necrosis" or deformity right up to the time of harvest. In addition, stink bugs may cause indirect damage by vectoring the causative agent for stigmatomycosis. This occurs when their mouthparts are contaminated with the fungus *Nematospora coryli* Peglion (Ershad & Barkhordary 1974a; Michailides et al. 1987; Michailides 1990; Daane et al. 2005, 2016; Bentley et al. 2010). Stigmatomycosis is characterised by a wet, smelly, decayed and slimy appearance of the pistachio kernel (Michailides & Morgan 1990; Michailides et al. 2016). The levels of stigmatomycosis usually increase during the kernel developing period, and the damage rises during August and September, but the amount of the infection usually depends on the weather and environmental conditions. Therefore, during a large bug outbreak, heavy damage to the pistachio yield can be expected (Mehrnejad 2014b; Daane et al. 2016).

Natural enemies. At present, there is no reliable information on the natural enemies of injurious mirid bugs on pistachio trees. However, pistachio green stink bugs have been proven to be suitable hosts for a number of Encyrtidae and Scelionidae egg parasitoids. The parasitoid complex that actively regulate bug populations from early July to late October includes several scelionid wasp species, namely *Psix saccharicola* (Mani), *Trissolcus agriope* (Kozlov & Lê), *Trissolcus basalis* (Wollaston), and *Trissolcus volgensis* (Viktorov) (Mehrnejad 2013, 2014b; Mohammadpour et al. 2016; Tavanpour et al. 2017), as well as three encyrtid egg parasitoids, *Ooencyrtus iranicus* Hayat & Mehrnejad, *Ooencyrtus pistaciae* Hayat & Mehrnejad, and *Ooencyrtus telenomicida* (Vassiliev) (Hayat & Mehrnejad 2016). However, three of these species, *T. agriope*, *T. volgensis*, and *O. pistaciae*, are the most dominant and wide distributed species throughout the pistachio plantations in Iran. The role of predatory insects and mites on the mortality of bug eggs is not well known.

Management. Currently, small plant bugs and seed bugs are mainly controlled by using insecticides in the pistachio orchards through April and early May. A single insecticide application should be applied as soon as these bugs appear on the young clusters. Regarding green stink bugs, the exploitation of naturally high levels of parasitism induced by several wasps is the best way how to manage the populations of these pests. The impact of natural enemies on the annual populations of the pistachio green stink bugs clearly shows that the egg parasitism can even reach an average 95% mortality rate (Mehrnejad 2013, 2016). Despite the fact of a high rate of parasitism during the summer, the immigration of adult stink bugs into the pistachio orchards may cause heavy damage to the nuts in late June. This indicates the need for a very precise prediction and control programme. In this case, a chemical application is usually required one time. Endosulfan, a chlorinated hydrocarbon insecticide was effective on pistachio bugs and had been used for long time. Several years ago, it (chlorinated hydrocarbon) was banned and replaced with Fenitrothion, a phosphorothioate (organophosphate) insecticide that has been used over the past several years. Recently, Acetamiprid (an insecticide belonging to the chloropyridinyl neonicotinoids) has also been applied to control these pests. These chemicals are being used against small bugs (mirids) too. The removal of alternate herbaceous host plants at appropriate times, both inside and around the orchards, may also help reduce the stink bug populations. The growing of wild rue (so called esfand in Farsi), *P. harmala*, near the orchard margins may attract the stink bugs, and induce them to stay there instead of moving on into the pistachio trees, particularly in large orchards, or those that are located in adjacent to range-lands or deserts. Therefore, *P. harmala* could be used as a trap-plant for immigrant bugs at arrival.

Monitoring the bug populations (all species) at all stages is of the utmost importance. This can be accomplished by using beating trays, trap crops, or by the direct visual examination of both alternative plant hosts and the pistachio trees themselves. It is necessary to monitor the population changes to help assist in making treatment decisions. Sex pheromones have been discovered for a few stink bug species in California which allows for the better monitoring of these pests (McBrien et al. 2001).

The pistachio twig borer moth, *Kermania pistaciella* Amsel (Lepidoptera: Tineidae: Oinophilini)

Economic importance, distribution and host range. *Kermania pistaciella* is a native and an univoltine pest of pistachio trees all over the pistachio growing

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areas of Iran (Taghizadeh & Djafaripoor 1965; Mehrnejad 2001). It was first collected from pistachio orchards in the early 1960s and later described as a newly identified pest (Amsel 1964). It had been a minor pest for pistachio trees, but the population has increased considerably since late 1970s, possibly due to the frequent spraying of chemicals. It occurred in a high abundance particularly during the late winter and early spring periods in the course of 1970–1990. At present, *Kermania pistaciella* is known as the third the most important insect pest of cultivated pistachio trees throughout the country. It is also an important pest in pistachio plantations of Turkey (Mart et al. 1995; Bolu 2002) and Syria (Khoja et al. 2009). Apart from *P. vera*, it attacks *P. atlantica* subsp *mutica* and *P. khinjuk*, without any economic importance in wild pistachio plantations.

Life cycle. The adult moth appears in late March – early April and lay eggs singly in flower and fruit clusters preferably; however, at a high population, it may also oviposit on succulent new shoots and petioles. The newly hatched larvae directly penetrate into the plant tissues just below of the eggs' site, and bore a tunnel in the cluster towards the twig where it lives for about 10 months. The fully-developed moth larva emerges from the twigs from early March and spins a cocoon on the twigs or branches. Some larvae drop to the soil under the tree canopy, but these can still pupate and develop through to the adult stage. The period for the larvae emergence from the twigs lasts about 40 days, but the adult population usually increases to a peak when the pistachio flower clusters are fully developed and tiny fruits appear (Taghizadeh & Djafaripoor 1965; Mehrnejad 2002b, 2014b).

Damage. The earliest damage appears in the very young succulent clusters when the whole cluster turns black and falls off the trees. However, while the larvae bore a tunnel in the cluster towards the twigs, typically 4–7 developing unripen nuts at the cluster apex decease and later turn a white colour. Hence, apart from causing a fruit drop, weakening of the twigs occur (Mehrnejad & Basirat 2009; Mehrnejad 2016).

Natural enemies. Eighteen hymenopterous parasitoid species were reported to suppress the development of the egg, larvae and pupae of *K. pistaciella*. The natural parasitisation rates reach up to 72% in some pistachio plantations. The average rate of parasitism was reported to be 45.5% in the main cultivated pistachio plantations of the country, of which three species are the primary parasitoids, two are obligatory hyperparasitoids and the remaining thirteen species are facultative hyperparasitoids (Mehrnejad & Basirat 2009). Among them, the primary egg pupal parasitoid, *Chelonus kermakiae* (Tobias) (Hymenoptera: Braconidae), is the most abundant species that emerges from the moth cocoons followed by the larval facultative hyperparasitoids *Dibrachys boarmiae* (Walker) (*D. cavus* (Walker)) (Hymenoptera: Pteromalidae). In addition to parasitism, an average of 2.8% of the moth cocoons are attacked by generalist predators such as ants and spiders. These predators climb up the trees and make an irregular hole in the cocoons, then feed upon the larvae and pupae of both the moth and wasp (Achterberg & Mehrnejad 2002; Mehrnejad 2003a, 2016; Manickavasagam et al. 2008).

Management. The population density of the twig borer moth, *K. pistaciella*, is highly variable from one plantation to another. The pest abundance on cultivars with early blooming is higher, while cultivars showing a delayed beginning of the flowering period are less attractive for this insect pest. In addition, the level of infestation in old pistachio orchards is usually lower than junior plantations due to establishment of natural enemies over a long time. Control measures targeted at this pest must be applied in early spring at the time of blooming and they are only recommended if the populations density recorded at harvest time in the previous September proved be sufficiently high. The estimation of population levels at harvest time within the clusters helps growers to make appropriate decisions for treatment in early spring. Therefore, chemical applications might be planned based on the pest population intensity as well as the according to the abundance of the susceptible stage of *K. pistaciella*. The susceptible stages of the moth are; 1. pupa, just before blooming, mixture of the mineral oil (Volck) and an organophosphate pesticide like Ethion is effective, 2. egg and new emerged larva (exactly at the hatching time), before the larva penetrates into the plant tissues, for example Hexaflumuron (a benzoylphenyl urea), an insect growth regulator is effective. In this regard, several other chemicals have been registered. Moreover, a high level of parasitism and predation, could strongly reduce the moth population, therefore, a conservation strategy in the pistachio growing areas where the infestation rates are less than 25% is highly recommended (Mehrnejad 2001, 2014a, b, 2016; Basirat & Mehrnejad 2019). In addition, commercial traps baited with synthetic sex pheromones should also be considered for the control procedure of this pest (Gries et al. 2006).

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LOCALISED KEY PESTS

The second group of pistachio pests comprises phytophagous insects and mites which are locally important. Sometimes they appear as a key pest in a small plantation, but these species are considered as minor pistachio pests overall. Some of these can be very damaging when allowed to increase over a number of seasons, but they are controlled readily with insecticides.

The pistachio fruit-hull borer moth, *Arimania komaroffi* Ragonot (Lepidoptera: Pyralidae)

Economic importance, distribution and host range. The pistachio fruit hull borer moth, *Arimania komaroffi* Ragonot (Lepidoptera: Pyralidae) was first discovered in 1939 in the Fars province, southeast Iran by Brandt (Amsel 1954) and then was collected from cultivated pistachio trees, *P. vera* in Rafsanjan, the biggest producer of pistachios in Iran in 1972 by Samet (1974, 1985). It causes damage to the pistachio fruits by feeding on the fruits' hull or soft skin (pericarp + mesocarp) throughout the growing seasons, but can also act as a leaf borer, particularly on wild pistachio trees, e.g. *P. khinjuk*. The population of this moth has increased over the recent two decades, and is now distributed in almost all the pistachio plantations in the south of country. Although it is also known from Armenia, Iraq and Turkey, the damage caused by this pest has only been recorded in Iran. It is known as "Krash" by the native pistachio growers in Kerman province, south of Iran (Mehrnejad 2001, 2014b; Mehrnejad & Speidel 2011).

Life cycle. The larvae spin white silk where they feed and remain hidden inside amongst the fruits. They may also bore in the leaf parenchyma while sticking leaves to each other by silky webs; however, the fruit clusters are the preferred site for living. The fully developed larvae leave the feeding site and drop into the soil. They pupate inside delicate greyish silken cocoons under the trees' canopy, or in other shelters around the base of the trees. This insect overwinters in a pupal stage beneath the surface of the ground in an obligatory diapause from early October. The adults emerge around late April and usually lay eggs on the newly formed fruits singly. The adult of all other generations usually lays eggs on the damaged fruits preferably in intense pistachio fruit clusters. During the day, the moths remain quiet, and about dusk, they become active. *A. komaroffi* produces 3 to 4 generations a year (Mehrnejad 2014b; Mehrnejad & Speidel 2011). *A. komaroffi* develops and reproduces on a wide range of temperatures, although 30 to 32.5°C is considered optimum, they also feed on almost all of the commercial pistachio cultivars (Basirat et al. 2015, 2016).

Damage. On cultivated pistachio trees, the larvae almost exclusively live within the fruit clusters by feeding on the fruits' hull (fruits' soft skin); however, they may also bore in the leaf parenchyma in both the cultivated and wild pistachios. The larvae cause different types of damage to the fruits depending on the part of the season when they occur in an orchard, but the injury is almost always severe enough to destroy the entire fruit. The larva may attack several fruits in a cluster to reach the pupal stage. The first-generation attacks the newly formed pistachio fruits by boring into the young fruits from late April to about mid-May. These injuries are usually mixed with those induced by the pistachio fruit moth, *Recurvaria pistaciicola* Danilevsky (Lepidoptera: Gelechiidae). However, in later generations, they feed on the fruits' hull tissues (pericarp and mesocarp), and may attack the leaves when the fruit is unavailable (Mehrnejad & Speidel 2011; Basirat et al. 2015).

Natural enemies. At least three hymenopterous parasitoids attack *A. komaroffi* on both the cultivated and wild pistachio trees and they are active in pistachio orchards through July to September. *Iconella myeloenta* (Wilkinson) (Hym.: Braconidae), is a widespread and the most common primary parasitoid of *A. komaroffi*. It develops solitarily on the moth larvae as a larval endoparasitoid. While, *Habrobracon telengai* Muljarskaya (Hym.: Braconidae) acts as a gregarious ectoparasitoid on the larvae of this moth with minor importance. However, *Elasmus nudus* (Nees) (Hym.: Eulophidae) is the second most dominant parasitoid species on *A. komaroffi* after *I. myeloenta*. This is a gregarious ectoparasitoid, which attacks the fully developed larvae prior to its pupation in its cocoon, and also attacks the cocoons of the braconid *I. myeloenta*, the primary parasitoid of *A. komaroffi*. The parasitism rates of *Iconella myeloenta* and *Elasmus nudus* are highly variable, ranging from 12 to nearly 40%. Predators also play a role in putting pressure on the *A. komaroffi* population. The green lacewings, *Chrysoperla* spp. attack the eggs and young larvae of this moth on the pistachio trees. Phytoseiid mites like, *T.* (*Anthoseius*) *bagdasarjani* feed on the moth eggs in the pistachio fruit clusters (Mehrnejad 2010b, 2012, 2016).

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Management. Winter cultural practices, such as tilling and ploughing the orchard's floor, particularly under the trees' canopy, reduce the overwintering populations of *A. komaroffi, as well as several other pistachio pests.* However, under harsh circumstances, spraying with an appropriate chemical like Teflubenzuron (a benzoylurea insecticide) might be necessary. The chemical control against the first generation's broods might be managed around early May, a week after pollination while the young fruits appear. Usually, one insecticide spray applied in the course of spring or early summer is sufficient to control the insect pest.

The pistachio bud and twig borer beetle, *Chaetoptelius* (= *Hylesinus*) *vestitus* (Mulsant & Rey) (Coleoptera: Curculionidae; Scolytinae)

Economic importance, distribution and host range. It is a very ancient pest of pistachio trees throughout the Middle East and the Mediterranean regions. It considered as an important pest in Turkey, Syria, Algeria, Tunisia and Greece, (Kirjukhin 1946; Mart et al. 1995; Mourikis et al. 1998; Braham 2009; Chebouti-Meziou et al. 2009; Khoja et al. 2009), and is now a major localised pest in Iran causing damage into the vegetative and reproductive buds by the adult beetles. The beetle's population is increasing mainly due to the water shortage and poor-quality of the water resources. *C. vestitus* attack *Pistacia* spp. including the cultivated pistachio *P. vera* (Davatchi 1958; Farivar-Mehin 1983; Mehrnejad 2001).

Life cycle. Adults appear in mid-April and afterward, flying towards the healthy young twigs and bore feeding tunnels into the buds either terminally or laterally (floral), and destroy them. The adult beetles remain in these so-called feeding tunnels until October and then emerge to locate appropriate sites for reproduction, either inside or outside the pistachio orchards. During the late autumn and winter, the beetle reproduces in the pruned, damaged, weakened and unhealthy twigs, branches or trunks by digging a hole into the bark and boring a double-sided tunnel under the bark. This period may extend to late winter, and both the male and female beetles participate to prepare the site for egg laying. The female lays its eggs on both sides of the tunnel and the larvae bore galleries by feeding under the bark and pupate early in the following spring. The beetle is univoltine and overwinters in egg, larval or pupal stages (Farivar-Mehin 1983, 2002; Ziaaddini et al. 2002).

Damage. The adults are known to have an injurious stage since they mainly attack the healthy trees' buds and then burrow a tunnel about half an inch just beneath the buds. An adult beetle usually destroys one bud by drilling the twig in the leaf petiole base or the terminal buds; however, about 10% of the adults may feed upon more than one bud to start the tunnel. They destroy the buds and also cause a hard weakness in the infested twigs (Farivar-Mehin 1983, 2002).

Natural enemies. Several biocontrol agents including, predators, parasitoids and entomopathogenic nematodes and fungus have been reported as natural enemies of scolytid bark beetles around the world. In Iran, little information is available on *C. vestitus*; however, *Cheiropachus colon* (Hymenoptera: Pteromalidae) Linnaeus was recorded as attacking the larvae of *C. vestitus* (Ziaaddini et al. 2002).

Management. C. vestitus oviposits in weak and unhealthy trees only, therefore, efforts should be directed to keep the pistachio trees in a state of vigorous growth. Improving the trees' health by suitable irrigation, pruning, fertilisation and other horticultural practices is considered effective to reduce the beetle population. In addition, removing and destroying dead and damaged trees as well as pruning twigs and branches during winter is highly necessary in the pistachio plantations (Farivar-Mehin 1983, 2002).

The yellow pistachio hard scale, *Lepidosaphes pistaciae* (Archangelskaya) (Hem.: Diaspididae)

Economic importance, distribution and host range. The yellow pistachio hard scale, locally known as pistachio twig and fruit scale in Iran, which lives on the leaves, fruit, twigs and branches of *P. vera* (Mehrnejad 2001). This insect is distributed throughout Iran and the neighbouring countries as well as the Mediterranean region and the Middle East. It is a narrow and elongate, straight or wavy, light or dark brown scale, which is considered as one of the most widely distributed and destructive scales in pistachio plantations (Taghizadeh & Safavi 1960; Farahbakhsh 1961; Mehrnejad 2001; Hosseininaveh et al. 2016). It attacks *Pistacia* spp including cultivated pistachio trees. Furthermore, García et al. (2016) stated that it affects several other host plant species belonging to different genera either woody plants or shrubs too. This scale insect was reported in pistachio plantations in Turkey (Bolu, 2002) and Greece (Mourikis et al., 1998). Contrary to the situation in Iran, *Sturaspis pistaciae* Lindinger has been

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recorded as the most common scale species in Turkey (Bolu & Uygun 2003) and Syria (Khoja et al. 2009).

Life cycle. The broods of the first generation emerge almost mid-April and infest the twigs, the base of the fruits cluster and leaf petioles, but in subsequent generations, the young nymphs move towards the pistachio leaves and nuts. This scale insect completes two generations per year and overwinters as a fully developed female adult under its scale on the pistachio twigs (Masjedian & Seyedoleslami 2003).

Damage. These minute, sap-sucking insects injure the branches, shoots, leaves and fruits, and can also retard shoot growth and cause shell splitting. The infested foliage and nuts turn yellow and purple about the areas where the scales are feeding. The infested nuts are relatively smaller, ripening is delayed, and the kernel is not fully developed. Usually, this insect causes a general weakness in its host plant; however, under high density, it may kill the branches and twigs (Mehrnejad 2014b).

Natural enemies. Several predatory insects and mites as well as parasitoid wasps were reported as being natural enemies of *L. pistaciae* throughout the pistachio plantations in Iran. Three parasitoid species were found as parasitoids of *L. pistaciae* such as; *Coccobius annulicornis* Ratzeburg (Hym.: Aphelinidae), *Aphytis sp.* near *aonidiae* (Mercet) (Hym.: Aphelinidae) and *Zaomma lambinus* (Walker) (Hym.: Encyrtidae) through a wide field survey in pistachio plantations in the Kerman province, in southern Iran (Emami & Mehrnejad unpublished). Furthermore, Jalaeian et al. (2013) reported three parasitoid wasp species, e.g., *C. annulicornis*, *Z. lambinus* and *Ablerus* sp. that parasitise this scale in central parts of the country. From the group of predators, particularly mites, e.g., *Neophyllobius pistaciae* Bolland & Mehrnejad (Acarina: Camerobiidae) and *Cheletogenes ornatus* (Canestrini & Fanzago) (Acarina: Cheyletidae) (Bolland & Mehrnejad 2001; Mehrnejad & Ueckermann 2001) as well as predatory ladybirds including *Chilocorus bipustulatus* (Linnaeus), *Exochomus nigripennis* (Erichson) (both Col.: Coccinellidae) (Mehrnejad 2014b) are important. The predatory beetle, *Cybocephalus fodori minor* Endrödy-Younga, 1968 (Coleoptera: Cybocephalidae) (Kolahdooz-Shahroodi et al. 2006) widely lives on contaminated trees throughout the country.

Management. Scale insects including *L. pistaciae* are widely attacked by predators, e.g., predatory mites and coccinellids as well as parasitoids. Under certain circumstances, when the scale population densities are high, a chemical application is required. However, due to the high abundances of natural enemies, broad-spectrum insecticides must be avoided. Any chemical control programme must be targeted at the first nymphal instars which are highly susceptible due to lack of a mummified body. At present, Ethion and Diazinon (both non-systemic organophosphate insecticides) are applied against pistachio scales around mid-May. In addition, keeping pistachio trees in a state of vigorous growth is recommended (Mehrnejad 2014b).

The pistachio trunk and branch scale, *Melanaspis inopinata* Leonardi (Hem.: Diaspididae)

Economic importance, distribution and host range. This hard scale is a grey, robust, sub-circular and convex with a black centre scale, which occurs on pistachio trunk and branches. It particularly appears in high density on trees with an age above 20 years. The insect causes a general weakness in the pistachio trees, under heavy infestation, causing significant delay on the bud break and regrowth in early spring. This polyphagous diaspid attacks *Pistacia* spp. including the cultivated pistachio *P. vera*, as well as many shrubs and trees, e.g., acer, acacia, apple, astragalus, fraxinus, pear, plum, populus, rose and walnut trees (Kiriukhin 1946; Taghizadeh & Safavi 1960; Mehrnejad 2001; Shirazi et al. 2013; Hosseininaveh et al. 2016). It is distributed throughout Iran and was recorded in Armenia, Cyprus, Egypt, Greece, Iraq, Israel, Italy, Lebanon, Pakistan, Sardinia, Sicily and Turkey too (García et al. 2016).

Life cycle. This species overwinters as a fully developed non-reproductive adult female. *M. inopinata* is ovoviviparous, its crawlers are dark brown to red in colour, appears in late-April and early-May, disperse around, but not far from, their emergence point. This species is bisexual, and bears one generation a year (Mehrnejad 2014b).

Damage. This scale insect causes a general weakness in the contaminated trees. Under high population intensity, it retards the bud opening in early spring, causes a significant decrease in the pistachio yield and branches may die (Mehrnejad 2016).

Natural enemies. The natural enemies are almost the same as for the yellow pistachio hard scale, *L. pistaciae*.

Management. The management for *M. inopinata* is almost the same as for the yellow pistachio hard scale, *L. pistaciae*.

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***Melanaspis pistaciae* Hosseininaveh & Kaydan (Hem.: Diaspididae)**

Melanaspis pistaciae, in fact, is considered as either the 2nd or 3rd most important economic scale insect species that lives on pistachio trees' trunks and branches. Through the more recent investigation on the molecular and morphological characters of pistachio armoured scale insects (Hem.: Diaspididae), *M. pistaciae* was found to be a new species (Hosseininaveh et al. 2016). This research confirmed that there is a very close relation and resemblance between the *M. pistaciae* and *M. inopinata*. *M. pistaciae* was discovered in the colonies of *M. inopinata* on *P. vera* and *P. atlantica* subsp. *mutica* in pistachio plantations of the Kerman province, widely throughout southern Iran. It was declared that these two species may have been existed together for a long time; however, they were probably not separated due to their misidentification. Definitely, several studies on the bio-ecological and behavioural aspects of this new species are needed. The status of this scale insect in other pistachio growing areas particularly the neighbouring countries is unclear.

The pistachio fruit moth, *Recurvaria pistaciicola* [= *Schneidereria pistaciicola*] (Danilevsky) (Lep.: Gelechiidae)

Economic importance, distribution and host range. Recurvaria pistaciicola, is known as an ancient pistachio pest in Iran (Taghizadeh & Safavi 1960; Samet 1984). Although it is distributed widely in pistachio plantations all over the country, it still is locally important and may occasionally appear as a key pest in small plantations, usually on old trees, e.g., over 30 years old, but it is generally considered to be a minor pest now. This moth is known as an early spring pest for newly formed pistachio fruits, although it also feeds on the mesocarp of fully developed nuts in August and September when the moth larvae open a passage for the mould (*Aspergillus* spp.) penetration into the kernel (Samet 1984; Mehrnejad 2001, 2016). This species was recorded in Iraq, Syria and Turkey (Abu Yaman & Jarjes 1969; Mart et al. 1995; Khoja et al. 2009).

Life cycle. This moth hibernates as a fully developed larvae that appear green in colour inside the delicate greyish cocoons. The adult moth emerges in very early spring to lay eggs on the tiny fruits and clusters. The young larvae penetrate the tiny pistachio fruits. The second generation appears in early August and the larvae usually feed on the fruits' soft skin (mesocarp). The fully developed larvae leave the feeding sites and hide under the tree stems' loose bark and remain inactive. Alternatively, the fully-developed larvae may make a nest around the trees' collar base and under plant litter on the ground. This species makes two generations per year (Samet 1984; Mehrnejad 2014b). However, Qomi-Nejad (2006) reported that a part of the moth population may complete only one generation a year while the fully developed larvae from the first generation pass the summer, autumn and winter inactive under the loose bark of trees' stem and pupate in late winter and early next spring.

Damage. This moth attacks newly formed fruits just after pollination and it may continue till the fruits grow to around 10 mm in diameter. It may cause serious damage in old pistachio orchards, where there are good sites and safe shelter for the overwintering larvae under the loose bark of the trunk and large branches. In early spring, the larvae penetrate tiny pistachio fruits and feed on the embryo at the base of nuts, then the larva moves to other fruits. The injured fruits stop growing, turn brown and subsequently dry and fall off the tree. Each larva destroys several young fruits until full development. However, in August, the larvae feed on the fruits' soft skin (mesocarp). It causes black and brown wide spots on the shell surface due to faeces produced by the larvae. In split nuts, the larvae may feed on the pistachio kernels slightly. The damaged fruits generally become susceptible to fungal and mould infection (Samet 1984; Mehrnejad & Panahi 2006).

Natural enemies. Limited information is available on the natural enemies of this moth. Aydogdu and Beyarslan (2009) stated *Phanerotoma* (= *Bracotritoma*) *permixtellae* Fischer (Hymenoptera: Braconidae), as a parasitoid of *R. pistaciicola* in Turkey. In addition, although parasitoid wasps belonging to Pteromalidae and Eulophidae were mentioned as natural enemies for this moth in general, a detailed field investigation is definitely needed.

Management. Direct observation and checking the fruit clusters for symptoms of damage in early spring is necessary to make control decisions particularly in those areas, where an infestation was previously recorded. Currently, a chemical application is the usual manner to prevent any economic damage induced by this moth. Winter cultural practices, such as tilling and ploughing of the orchards' floor, particularly under the trees' canopy, cause a decrease in the overwintering populations of *R. Pistaciicola* (Mehrnejad 2014b).

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The pistachio weevil, *Polydrusus* (*Orodrusus*) *davatchii* Hoffmann (Coleoptera, Curculionidae)

Economic importance, distribution and host range. The adult pistachio weevil attacks the pistachio trees immediately after the bud break and feeds on the swollen and newly opened buds in the very early spring (late March). Under high population densities, the beetles cause heavy damage to the immature and developing flowers. The larvae are not a pest. It is distributed in almost all pistachio plantations in the central and southern parts of Iran nowadays. Based on the available references, it also appears in Syria (Davatchi 1958; Mehrnejad 2001; Farivar-Mehin 2002; Khoja et al. 2009). No other host was found for this weevil until now. Only females of this species are known. *Polydrusus davatchii* was a minor pest for pistachio trees until the first decade of the 21st century, then its population density has increased gradually, and the area contaminated by this pest has widely expanded through the present decade (Mehrnejad et al. 2017).

Life cycle. The adults emerge from the soil covered with plant litters and only under the pistachio trees' canopy from mid-March and continues for about a month. The beetles walk on the soil surface for one or two days after emergence and then flit for a short distance. The weevils feed on the newly opened reproductive and vegetative buds as well as the developing flower clusters. The adults live for about 40 days. The female deposits eggs through April at the base of the fruit clusters or new shoots. After hatching, the legless larva falls onto the ground under the pistachio tree's canopy, and buries itself into the soil where plant litter and other organic materials are usually present. The food sources for the larvae remain unknown, probably the larvae are scavengers in their habitat. The larval development and pupation proceed in the soil. This weevil overwinters at the pupal stage. *Polydrusus davatchii* Hoffmann, 1956, produces one generation per year (Mehrnejad et al. 2017).

Damage. The weevil *P. davatchii*, is considered as a potential pest for pistachio buds and developing flower clusters in early spring. Both the reproductive and vegetative buds are attacked when they begin to open, in addition, the feeding usually continues on the developing flower clusters, causing significant crop losses. The adults are the only stage of their development that cause damage to the pistachios (Mehrnejad & Mirzaei 2017).

Natural enemies. No natural enemy was recorded for this weevil till now.

Management. The weevil emergence can be monitored by using emergence traps or checking for symptoms of damage on the buds and developing flower clusters by direct observation in early spring. The application of insecticides like Phosalone is the current ordinary means of control, however winter ploughing (30 cm depth) of pistachio orchards could be used to significantly reduce its population as this practice disturbs the weevils' pupae just before the adult emergence (Mehrnejad & Mirzaei 2017).

The common pistachio mite, *Tenuipalpus granati* Sayed (Acari, Tenuipalpidae)

Economic importance, distribution and host range. *Tenuipalpus granati* is an occasional pest in pistachio plantations; however, it may appear locally as an economically important herbivore in pistachio orchards in Iran. It is distributed throughout the cultivated and wild pistachio plantations of country, although its population densities are usually low (Mehrnejad & Ueckermann 2001, 2002; Mehrnejad 2014b). This mite species was reported in vineyards and pomegranates orchards in Azerbaidzhan, Egypt, Greece, Georgia, Kazakhstan, India, Iraq, Pakistan, Turkey, North Africa, the Mediterranean region and Asia-minor (Khalil-Manesh 1973; Jeppson et al. 1975; Yousef et al. 1980; Ananda et al. 2009).

Life cycle. This mite overwinters in an adult stage, near the base of the buds and under the buds' scales, but it can also be found in crevices on the trees' branches and twigs. It does not weave a silken web on the leaves or the fruits, therefore, it is also called false spider mite. The eggs are reddish and laid around the mid- and sub-veins on the upper-surface of the pistachio leaves, and the broods feed at the same site. The larvae and nymphs are red to orange in colour, but the adults turn pale orange with numerous tiny black spots. It produces several generations through a growing season; however, its population drastically rises in the warm months like August and September. *Tenuipalpus granati* and the common pistachio psyllid, *A. pistaciae* act as competing (rivals), though only one of them appears on the pistachio leaves and makes a considerable population in summer.

Damage. Under heavy infestation, the leaves turn light red, the kernels do not develop properly and subsequently a bud and leaf drop occurs. Severe damage may occur by defoliation in late summer (Mehrnejad 2014b).

Natural enemies. This species is heavily attacked by predatory mites which belong to the families of

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Phytoseiidae and Ascidae, as well as by the coccinellid beetles.

Management. This mite has a scattered distribution, and usually lives in low densities. However, a visual examination of the leaves is necessary, particularly in those areas, where an infestation was previously recorded. Under harsh circumstances, a chemical application might be necessary particularly in July and August.

The pistachio leafhopper, *Sulamicerus* (= *Idiocerus*) *stali* (Fieber) (Hemiptera: Cicadellidae)

Economic importance, distribution and host range. The pistachio leafhopper was the most serious pest of cultivated pistachio trees in Iran about 70 years ago, but its position was replaced by the common pistachio psylla, *A. pistaciae,* thereafter (Kiriukhin 1946; Davatchi 1958; Taghizadeh & Safavi 1960). The presence of CPPs on cultivated pistachio trees was reported in 1946 by Kiriukhin (1946) as a minor pest. In the early 1940s, Dichlorodiphenyltrichloroethane (DDT) was used against the pistachio leafhopper, followed by organophosphate pesticides like Parathion and Dimethoate (Samet, personal communication). Due to application of these broad-spectrum chemicals, the population density of the univoltine leafhopper, *S. stali* sharply decreased; however, the population of the multi-voltine *A. pistaciae* gradually increased and was widely distributed. There are at least two reasons for this change (replacement); 1: Leafhopper nymphs produce a heavy amount of liquid honeydew which can completely cover the surface of the trees' branches, leaves and clusters. Nevertheless, this liquid honeydew, in fact, causes a limitation for the CPP activity (walking, jumping, moving), but under the absence of leafhoppers, the CPPs had no preventive pests to control them. 2: Continuous insecticide applications caused a negative effect on the beneficial insects and mites which were natural enemies for the CPPs. Currently, this hopper is not a common pest for the cultivated pistachio trees throughout the country, but it is considered as a local injurious pest. It is usually abundant in the pistachio orchards adjacent to wild pistachio plantations (e.g., *P. atlantica* subsp. *mutica*). This leafhopper is still considered as a major pest in wild pistachio plantations in mountainous areas where the CPP population fluctuates at a very low level. In wild pistachio plantations, no any chemical applications have been used yet. The hopper's nymphs live on the newly grown aerial parts of trees, sucking up the plant sap and producing large quantities of liquid honeydew in the early spring (Mehrnejad 2001). This species was found throughout the Mediterranean countries and the Middle East (Mourikis et al. 1998; Yanik & Yücel 2001; Khoja et al. 2009).

Life cycle. The insects overwinter in an adult stage in the pistachio orchards, under the crevices on the trees' branches and loose bark of the trees' stems, also under the plant litter on the orchard's floor and in the cracks of the walls which surround the orchards. The adults appear in late winter and early spring and feed on the swollen buds. The hoppers embed their eggs in the green and flashy tissues. The hopper nymphs feed on the young parts of the pistachio plants, but prefer the tiny fruits. All the nymph's instars produce a kind of liquid honeydew. The insect has one generation a year (Mehrnejad 2014b).

Damage. The adult causes heavy damage to the fleshy tissues like the flower clusters and shoots due to tearing the tissues by the ovipositor. The nymphs feed on the young green parts of the plants, although they prefer the newly formed fruits, where the injured young fruits subsequently turn brown, black, dry out and then consequently fall off. This insect causes epicarp lesions in fact. The wet and sugary materials that is secreted by the nymphs contaminate the aerial parts of the trees and a mould infection may subsequently occur. At high populations, the hoppers cause heavy damage to the pistachio trees and a significant reduction in the yield occurs.

Natural enemies. This species is attacked by predatory mites as well as a predatory bug; however, detailed studies need to determine and identify its natural enemies.

Management. When a large population appears in the early spring, a chemical treatment is recommended.

The pistachio leaf borer, *Ocneria terebinthina* Staudinger (Lep.: Lymantriidae)

Economic importance, distribution and host range. This insect is a whitish moth and appears on the pistachio trees in early spring. It is generally a local injurious pest on cultivated pistachio trees. However, it is considered as a major pest for wild pistachio trees in Iran. Two leaf borer moths, *O. terebinthina* and *Thaumetopoea solitaria* (Freyer) (Lepidoptera; Thaumetopoeinae) are well-known pistachio defoliators. Both are found throughout the Middle East and the Mediterranean regions (Davatchi 1958; Halperin 1983; Mart et al. 1995; Mourikis et al. 1998; Mehrnejad 2014a). However, their populations are

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scattered on cultivated pistachio trees and are generally not thought to be significant now.

Life cycle. The adults lay their eggs in a batch on both the upper and lower surfaces of the pistachio leaves. The young caterpillars feed on the leaf parenchyma and upper epidermis, they produce large skeletonised patches and brown spots on the pistachio leaves. The older larvae show a markedly higher eating activity, only the mid-vein can stay on the leaves at the end of their development. This species is multivoltine and they usually hibernate in the pupal stage in the soil near the trunk collar and under the plant litter as well as inside crevices on the trees' trunk (Taghizadeh & Safavi 1960; Omid et al. 2005, 2006).

Damage. The larvae feed on all parts of the leaves except the main veins and the infested trees become seriously defoliated.

Natural enemies. Several natural enemies have been recorded for this moth in Iran, e.g., the egg parasitoid wasp, *Ooencyrtus ocneriae* Hayat & Mehrnejad (Hym.: Encyrtidae) (Hayat & Mehrnejad 2018), two pupal parasitoids, *Brachymeria intermedi* (Nees) (Hym.: Chalcididae) and *Exorista* sp. (Dip.: Tachinidae), the predatory bug, *Rhinocoris iracundus* (Poda) (Het.: Reduviidae) (Omid et al. 2005; Askary et al. 2006), *Brachymeria tibialis* (Walker) (Hym.: Chalcididae) exits from the moth pupae, the predatory mite *T.* (*Anthoseius*) *bagdasarjani* feeds on the moth eggs (Mehrnejad 2014b). In addition, the influence of *Bacillus thuringiensis* var. *kurstaki* on the first three larval instars of *O. terebinthina* had been reported (Sheibani-Tezerji 2010).

Management. This pest usually appears in cultivated pistachio plantations having a shortage of water or having an inappropriate irrigation programme. Keeping pistachio trees in a state of vigorous growth is considered effective to reduce the moth damage. A visual examination of the leaves is recommended to monitor the populations and for making control decisions. Although several biocontrol agents have been recorded for this defoliator, they have not been used commercially yet. At present, chemicals like Phosalone are usually applied against *O. terebinthina* under harsh conditions.

MINOR PESTS

This group includes phytophagous insects and mites which are only minor pistachio pests. Because of their rare occurrence, these insects are not considered important pests of pistachio trees. However, under certain conditions they occur as injurious pests, although they are distributed in a limited area.

The leaf-roller pistachio psyllid, *Megagonoscena viridis* (Baeva) (Hem.: Aphalaridae)

Economic importance, distribution and host range. It is an old pest on cultivated pistachio trees in Iran, and known as a locally injurious pest. This insect occurs on both cultivated and wild pistachio trees throughout the country. This psyllid was also recorded in Azerbaijan, Bulgaria, Jordan, Tajikistan and Turkey on *Pistacia* spp. (Burckhardt & Lauterer 1989, 1993; Mehrnejad 2001, 2003, 2014c).

Life cycle. The adult psyllid emerges in late spring and deposits a batch of elongated pinkish eggs in the angle between the bud and the twig. They cover the batch with a whitish fur. The eggs pass through the summer, autumn and winter when they hatch the following April. Usually, several light green nymphs develop inside a rolled leaflet, where they produce the liquid honeydew and also secrete wax. It is univoltine (Mehrnejad 2014c).

Damage. This psyllid causes a deformation in the very young leaflets in early spring. The infested leaflets appear as a roll, then gradually turn brown, and finally dry out (Mehrnejad 2014c).

Natural enemies. A parasitoid wasp, *Psyllaephagus* sp. attacks the nymphs of the psyllid (Mehrnejad 2014b). No information is available on any other natural enemies.

Management. No guideline for the management of this psyllid is available, but a systemic insecticide like Imidacloprid (a neonicotinoid) applied immediately after the bud break is effective.

The pistachio root beetle, *Capnodis cariosa hauseri* Obenberger (Col.: Buprestidae)

Economic importance, distribution and host range. This beetle is an ancient pistachio pest widespread throughout the Middle East and the Mediterranean regions. It causes heavy damage in pistachio plantations under water shortages and a poor agricultural application. The beetles' larvae bore a tunnel at the collar site (the base of the tree's stem) of the trees, where pathogenic fungi (e.g. *Phytophthora* spp.) penetrate into the trees' roots and stem. This beetle attacks *Pistacia* spp. and has been reported in Turkey, Syria and Tunisia as an important pest of pistachio trees (Kiriukhin 1946; Davatchi 1958; Mart et al. 1995; Farivar-Mehin 2002; Khoja et al. 2009).

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Life cycle. This beetle particularly attacks weakened trees for its egg laying and larval development. Female beetles prefer to lay eggs in a batch on the collar stems, although they may oviposit on the soil surface close to the trees' stems. The newly hatched larvae dig a hole through the bark of the trunk towards the roots. The newly hatched larvae feed upon the cambium and then gradually bore into the xylem tissues. The larval and pupal development lasts almost two years. The adults emerge through spring to early autumn; however, this beetle overwinters in both the larval and adult stages. The adults overwinter under different shelters, e.g., under the loose bark of trees or in the plant litter inside the orchards (Farivar-Mehin 1991, 2002).

Damage. It causes hard weakness in pistachio trees and even may kill the infected trees.

Natural enemies. No information is available.

Management. The cultural control, including optimising the tree vigour through appropriate and regular irrigation, fertilisation regimes as well as annual soil cultivation are considered to be the most effective treatments against xylophagous beetles. Recently, the biocontrol potential of two entomopathogenic nematodes, e.g., *Heterorhabditis bacteriophora* and *Steinernema carpocapsae* on the larvae of this beetle have been examined under laboratory conditions (Salari et al. 2015).

Pistachio seed wasps, *Eurytoma plotnikovi* Nikolskaya (Hym.: Eurytomidae) and *Megastigmus pistaciae* Walker (Hym.: Torymidae)

Economic importance, distribution and host range. Two species of pistachio seed wasps, *E. plotnikovi* and *M. pistaciae* are known as very ancient pistachio pests widespread throughout the Mediterranean regions, Middle East and Asia Minor. Both seed wasps have been serious pests of pistachio nuts in the past, but they are no longer considered to be important pests in 95% of the cultivated pistachio trees in Iran, although these wasps are abundant in wild pistachio plantations of the country. These wasps attack the fruits of *Pistacia* spp. (Nikol'skaya 1934; Kiriukhin 1946; Davatchi 1958; Bouček 1977; Melifronides & Zyngas 1982; Mart et al. 1995; Gregoriou 1998; Mourikis et al. 1998; Grissell & Prinsloo 2001; Mehrnejad 2001). *M. pistaciae*, was also found on pistachio nuts in California (Robinson 1968) and also on the ornamental pistachio tree, *Pistacia chinesis* Bunge (Vettel & Harper 1969), and on *Pistacia* sp. in Mexico (Grissell & Prinsloo 2001).

Life cycle. Both seed wasp species overwinter inside the infested nuts in pistachio plantations in either those remaining on the trees after harvest, or those that have dropped onto the ground. The adult wasps appear in May-June and lay a single egg inside the young fruits. The larva feeds on the pistachio kernel. The damaged fruits stop development and dry out. The larvae remain inside the nuts over the year and turns into a pupa early in the next spring. *E. plotnikovi* is univoltine, but *M. pistaciae* produces two generations a year (Radjabi 1959; Taghizadeh & Safavi 1960; Basirat & Seyedoleslami 2008).

Damage. Both wasps cause direct damage to the kernel and destroy the nuts.

Natural enemies. No information is available.

Management. Orchard sanitation, such as the removal of the unharvested nuts and the destruction of all the nuts left on the soil surface, is critical to control seed wasps.

Pistachio gall aphid, *Forda hirsuta* Mordvilko (Hemiptera: Aphididae: *Eriosomatinae*)

Economic importance, distribution and host range. Pistachio trees, *Pistacia* spp. are the hosts for several species of gall aphids belonging to Fordini. These aphids cause deformations in their hosts' tissues and produce a wide variety of galls. Galling aphids are common pests for wild pistachio trees in the Mediterranean region and the Middle East (Davatchi 1958; Wool & Ben-Zvi 1998; Rezvani 2004; Martinez 2008; Aphids on the world's plants 2013). At least sixteen species of gall-inducing aphids attack *Pistacia* spp. in Iran. The majority of them occur on the wild pistachio trees, e.g., *P. atlantica* subsp. *mutica* and *P. khinjuk*, almost exclusively in the mountainous areas (Rezvani 2004). *Forda hirsuta* is a dominant species of gall aphid in the cultivated pistachio plantations in the country. It causes irregular contaminations and does not show a uniform distribution. This aphid causes deformation on the leaflets' edges, and usually does not cause any economic damage to the cultivated pistachio nowadays, although is an important pest on wild pistachio trees (Mehrnejad 2014b).

Life cycle. The galls at the edge of the leaflets appear in early May and continue to grow throughout the summer while the numbers of parthenogenetically-produced female aphids increase drastically. From late summer, a crack appears on the galls and the emigrant alatae from the last generation disperse (Mohammadi et al. 2007; Mehrnejad 2014b).

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Damage. This aphid causes several galls at the leaflets' margin, the galls change colour from green to red and pinkish gradually through the summer. The deformation may negatively influence or decrease the rate of photosynthesis (Rezvani 2004; Mohammadi et al. 2007).

Natural enemies. The predatory bug, *Anthocoris minki pistaciae* Wagner frequently attacks the aphids inside the *Forda*'s galls in wild pistachio growing areas throughout the country (Mehrnejad 2014b).

Management. The damage caused by galling aphids varies in cultivated pistachio plantations, but does not usually need treatment.

The cotton bollworm *Helicoverpa armigera* (Hübner) (Lep. Noctuidae)

Economic importance, distribution and host range. This species is a highly polyphagous pest that feeds on a variety plant species. It is a well-known important pest of cotton and tomatoes, and is a cosmopolitan insect species (CABI Invasive Species Data 2019). This moth also attacks pistachio fruits in early spring before shell-hardening in Iran. It occasionally appears in some cultivated pistachio plantations and causes heavy damage in the very young developing nuts. The status of this moth is not of an economic importance now, except in limited localities and under particular circumstances. *Helicoverpa nubigera* (Herrich-Schäffer) was also found on very young developing pistachio fruits too, although it rarely appears on this plant (Mehrnejad 2001, 2014b). The status of this pest in pistachio plantations of other countries is unclear.

Life cycle. It produces several generations a year and has a facultative pupal diapause. In pistachio plantations, the larvae only feed on the newly formed, soft and young nuts. This moth completes one generation through the first half of spring in pistachio plantations and then the adult moth disappears. Because of the saline and alkaline soil in pistachio growing areas, the variety of herbal plants belonging to Malvaceae and Solanaceae, which are the preferred host plants for this moth, are not growing well. Therefore, usually no suitable alternative host is available for this moth in pistachio plantations and the adjacent areas. This moth is usually transferred into pistachio plantations together with animal manure at a pupal stage during winter (Mehrnejad 2014b).

Damage. The moth larvae bore into young pistachio fruits and feed on the embryo area at the base of the fruits. The larva attacks many fruits until their full development. The punctured fruits turn brown, shrink and dry out (Mehrnejad 2016).

Natural enemies. A wide range of natural enemies, e.g., predators, parasitoids and pathogens have been recorded. All of them can influence the population of *H. armigera*. However, the density and abundance of natural enemies vary based on the crops and countries (CABI Invasive Species Data 2019).

Management. The larvae of this moth are voracious, therefore, in most cases where *H. armigera* attack pistachio fruits, the application of insecticides is necessary.

The pistachio longhorn beetle, *Calchaenesthes pistacivora* Holzschuh (Col.: Cerambycidae)

Economic importance, distribution and host range. In 1999, a longhorn beetle (Col.: Cerambycidae) was collected from pistachio trees including *P. vera* and *P. atlantica* subsp. *mutica* at Sirjan, in southern Iran (Hashemi-Rad 2005). Later it was described as a new species and was named as *C. pistacivora* by Holzschuh (2003). It is considered as a potential pest in pistachio plantations on both water-stressed cultivated or wild pistachio trees, generally due to the lack of adequate irrigation; however, this beetle has a limited distribution in cultivated pistachio plantations nowadays. This xylophagous beetle is endemic to Iran and has not been reported in other countries yet. It attacks *P. atlantica* subsp. *mutica*, *P. khinjuk* as well as *P. vera* (Mehrnejad 2014a, b).

Life cycle. The development lasts almost two years. The adult appears on the pistachio trees early April and usually feeds on the fresh pistachio leaves. The damage caused by the adults is considered insignificant. The beetles lay their eggs on the twigs, branches or stems of weakened pistachio trees, preferably on the pruned sites where the tiny larvae promptly penetrate into the twigs or branches (Hashemi-Rad 2005).

Damage. C. pistacivora, in the same way as other xylophagous beetles, colonises the weakened, dead, and dying trees, which are stressed with a lack of adequate irrigation or damaged by primary pests in native environments. The larvae can cause very severe damage to the weakened pistachio trees (Achterberg & Mehrnejad 2011).

Natural enemies. The parasitoid wasp, *Megalommum pistacivorae* Achterberg & Mehrnejad (Hym.: Braconidae) has been reared from the pistachio longhorn beetle (Achterberg & Mehrnejad 2011).

Management. The cultural control, including optimising the tree's vigour through appropriate and

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regular irrigation as well as fertilisation regimes are considered to be the most effective treatments.

The carob moth, *Ectomyelois* (= *Apomyelois*) *ceratoniae* (Zeller) (Lep.: Pyralidae)

Economic importance, distribution and host range. The carob moth, formerly in the genus *Spectrobates*, is an extremely polyphagous moth. It was known as the pomegranate fruit neck worm in Iran. This moth attacks a variety of fruits and nuts in nature and is distributed worldwide. It also attacks stored fruits and nuts. *E. ceratoniae* attacks pistachio nuts from mid-summer when a crack occurs in the shelled nuts (early hull split) on trees in late June and afterwards and feeds on the kernel only. It is considered as a potential pest for pistachios in Iran (Mehrnejad 1993, 1995) and has been reported in Greek pistachio plantations too (Mourikis et al. 1998). This species occasionally appears on pistachio nuts where the alternative host, e.g., pomegranates or figs for larval development are not available in pistachio growing areas. The feeding behaviour, damage and biology of *E. ceratoniae* is similar to that of the navel orange worm, *Amyelois transitella* (Walker) which attacks pistachio nuts in California (Mehrnejad 2014a; Haviland et al. 2016).

Life cycle. The pistachio nut is susceptible to infestation by *E. ceratoniae* as soon as the hull split occurs, which is almost from early July when small and deformed nuts split. The moth lay eggs only beneath the cracks in the split nuts and larvae penetrate toward the kernel through the shell tears. The larvae are unable to complete development without feeding on the kernel. The moth complete 4 to 5 generations over a year in pomegranate plantations; however, in pistachio orchards, it produces at least 2 generations. The larvae are transferred into storage together with the infested nuts. The pistachio storage conditions are usually not fit for its regeneration due to the very low humidity, although the larvae are able to feed on dry kernels to complete their development. Overwintering occurs in the nuts remaining on trees or the orchards' floor.

Damage. The damage is caused by the larvae, which also facilitate the introduction of fungi into the nuts, therefore, this moth reduces the nut quality and assists in the aflatoxin contamination (Mehrnejad & Panahi 2006).

Natural enemies. Several parasitoid wasps attack different stages of *E. ceratoniae*. In Iran, eleven wasp species were recoded as larval parasitoids of carob moths on pomegranates. From these, *Apanteles myeloenta* (Wilkinson) is one of the most important parasitoids (Kishani-Farahani et al. 2011; Kishani-Farahani & Goldansaz 2013). In addition, egg parasitoids, e.g., *Trichogramma embryophagum* Hartig and *Trichogramma brassicae* Bezdenko also attack this moth (Mirkarimi 2000; Moezipour et al. 2008).

Management. Orchard sanitation, such as the removal of unharvested nuts and the destruction of all the nuts left on the orchard floor, is critical to control the carob moth in pistachio orchards (Mehrnejad 1993, 1995).

The pistachio bud-borer moth *Telphusa pistaciae* Sattler (Lepidoptera: Gelechiidae)

Economic importance, distribution and host range. A pistachio bud moth, *Telphusa pistaciae,* was collected in a pistachio plantation at Rafsanjan, southern Iran in 1969 (Samet 1982) and then described as a new species by Sattler (1982). The larvae of this moth feed upon and destroy both the reproductive (flower) and vegetative buds in late winter and early spring, resulting in bud loss. In Iran, it is a localised pest nowadays (Samet 1982; Mehrnejad 2001, 2014a). No information is available on its presence in other pistachio growing areas of world.

Life cycle. It was found that the adult moths appear in nature from early and lay egg just close to the leaflets' veins, particularly the mid-vein. The first-instar larvae bore directly through the upper epidermis, producing short and twisting galleries. It feeds on the parenchyma for 4 months. Then the second instar larvae disperse out of the galleries and penetrate into the buds. The 2nd instar larvae overwinter inside the buds, and then become active from early March, when they feed on the buds' internal tissues. The life cycle of this moth is completed through a year (Samet 1982; Mehrnejad & Mirzaei 2016).

Damage. The larvae attack any available buds consecutively and cause severe damage to both the flower and vegetative buds, resulting in a yield loss and tree weakness.

Natural enemies. Two parasitoid wasps, e.g., *Pteromalus* (= *Habrocytus*) sp. and *Conella* (= *Apanteles*) sp. (Hymenoptera: Braconidae) attack the moth's larvae inside the trees' buds (Mehrnejad & Mirzaei 2016).

Management. A chemical control causes high mortality to the first-instar larvae in the second half of June.

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The pistachio Noqi scale, *Suturaspis davatchi* (Balachowsky & Kaussari) (Hem.: Diaspididae)

Economic importance, distribution and host range. Although this pest is well-known as *Salisicola davatchi* in former references, it is currently introduced as *Suturaspis davatchi* (Hosseininaveh et al. 2016). It locally called "Noqi scale", according to the name of a district (Noq, about 60 km north from Rafsanjan, southern Iran) where the species is distributed widely and has been abundant in pistachio plantations for several decades. It now forms relatively large populations on the trunks and branches of *P. vera* in some pistachio orchards in southern Iran and is also distributed on wild pistachio trees including *P. khinjuk* and *P. atlantica* subspec. *mutica*. The scales are white, relatively elongated and narrow (Mehrnejad 2014b; Kazemi et al. 2017). Based on the available references, *S. davatchi* was recorded in Afghanistan, Iran and Turkey. This species attacks *Ficus carica* Linnaeus and *Prunus lycioides* (Spach.) Schneider also (Seghatoleslami 1977; Kozár et al. 1996; Danzig & Pellizzari 1998; Moghaddam 2013).

Life cycle. This scale usually lives on trees' branches, although the nymphs can occasionally be found on the leaves and fruits. The crawlers move very slowly and just for a very short distances, therefore, shields of scales are usually found in piles on the branches. The males continuously appear on the pistachio branches from late March for 20 days. Eggs usually appear form around mid-April and are well hidden under the female's shield. The first stage nymphs appear on the branches from early May. Those scales that develop on either the leaves or fruits produce a second generation, although they are unable to complete their lifecycle due to fruit harvesting as well as leaves falling off the trees. This species produces one successful generation within a year including two nymphal stages. This scale hibernates at the second nymphal stage (Kazemi et al. 2017).

Damage. This insect sucks up the plant sap and causes the trees' weakness as well as decreases the yield quantity and quality (Mehrnejad 2016).

Natural enemies. No information is available on natural enemies of *S. davatchi*, although predatory mites and coccinellid as well as parasitoid wasps are observed in colonies of this scale insect on contaminated pistachio trees either in cultivated pistachio plantations or wild pistachio growing areas in southern Iran.

Management. The management for *S. davatchi* is the same as for the yellow pistachio hard scale, *L. pistaciae*.

The pistachio cushion scale, *Anapulvinaria* (= *Pulvinaria*) *pistaciae* (Bodenheimer) (Hem.: Coccidae)

Economic importance, distribution and host range. The pistachio cushion scale (pistachio soft scale) occurs locally and in relatively limited number of pistachio plantations throughout Iran. It is always found at low population levels on both sides of the pistachio leaves as well as on young twigs where it excretes a liquid honeydew. The status of this species is not of economic importance now (Taghizadeh & Safavi 1960; Mehrnejad 2016). It is native to the eastern Mediterranean countries, Iraq and the southern part of the old Soviet Union (Bodenheimer 1953; Davatchi 1958; Abu Yaman 1970; Santas 1985; Bolu & Uygun 2003). This soft scale was recorded on *Pistacia* spp. and Sicilian sumac, *Rhus coriaria* Linnaeus, *Juglans regia* and *Tamarix* sp (Bodenheimer 1953; Potaeva 1993; Ben-Dov 2012; Moghaddam 2013). In California, four soft scales species attack pistachio trees: *Coccus hesperidum* (Linnaeus), *S. oleae*, *Parthenolecanium pruinosum* (Coquillett) and *Parthenolecanium corni* (Bouché). They are currently under control by native parasitoid wasps and plant bugs, such as *Phytocoris* spp.

Life cycle. The first nymphal instars appear in about early June and feed on the plant phloem fluid on both sides of the leaves as well as the young twigs. The second instar nymphs appear early in autumn and overwinter on the twigs. Both nymphal instars are able to move and secrete honeydew. This species produces one generation a year (Mehrnejad 2014b).

Damage. In cases of high abundance, *Anapulvinaria pistaciae* can cause a general weakness in trees. Fortunately, it usually has low population densities in plantations (Mehrnejad 2014b).

Natural enemies. Two parasitoid wasps were reported attacking this soft scale in Iran, e.g., *Blastothrix sericea* (Dalman) (Hym.: Encyrtidae) (Yazdani & Rajabi 1993) and *Coccophagus piceae* Erdös (Hym.: Aphelinidae) (Tavakkoli-Korghond & Lotfalizadeh 2018). No information is available on the rate of parasitism induced by the two parasitoids in pistachio plantations. The predatory mites and coccinellids are observed in colonies of this scale insect on the contaminated pistachio trees.

Management. The management for *S. davatchi* is the same as for the yellow pistachio hard scale, *L. pistaciae*.

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The pistachio spherical scale, *Eulecanium rugulosum* (Archangelskaya) (Hem.: Coccidae)

Economic importance, distribution and host range. This species has a limited distribution in pistachio plantations and is not considered as an economic important phytophagous insect nowadays. *E. rugulosum* is a polyphagous and lives on many plant genera including, *Corylus*, *Crataegus*, *Cydonia, Ficus*, *Fraxinus*, *Juglans*, *Malus*, *Prunus*, *Pyrus*, *Pistacia*, *Populus*, *Rosa*, *Salix* and *Ulmus*. It is distributed in Iran, Turkey and throughout Asia Minor (Bodenheimer 1939; Kiriukhin 1946; Kaussari 1957; Ben-Dov 1993; Kaydan et al. 2007; Moghaddam 2013).

Life cycle. This species is a sap-sucking plant pest that secretes a lot of wet honeydew. It overwinters in nymphal stage on the trees' twigs and then develops into an adult in May. The nymphs are crawlers through the first and second nymphal instars. Those that live on the leaves move towards the twigs in early autumn for overwintering. It produces one generation a year.

Damage. Eulecanium rugulosum appears irregularly in small plantations and usually in low densities. In most cases, the damage induced by this scale is negligible.

Natural enemies. This soft scale was reported as the host for several parasitoid wasps in Iran, e.g., *Metaphycus dispar* (Mercet) (Hym.: Encyrtidae) attacks this species in pistachio plantations of the Kerman province, southern Iran (Emami & Mehrnejad 2009). *Blastothrix aprica* Sugonjaev and *Cheiloneurus claviger* Thomson, attack *E. rugulosum* on *P. atlantica*, *Leptomastix flava* Mercet on *P. vera* (Fallahzadeh et al. 2016). In addition, *Eurytoma iranica* Narendran & Lotfalizadeh (Hym.: Eurytomidae) have been reared from *E. rugulosum* on hawthorns, *Crataegus persica* Pojark. (Rosaceae) in Shiraz, southwest Iran (Narendran & Lotfalizadeh 1999). The rate of parasitism for the mentioned wasps on pistachio trees is obscure.

Management. Wherever a colony of *E. rugulosum* occurs in the pistachio orchards, different species of predatory insects such as ladybirds as well as birds are found feeding on them. Usually, a chemical application is not needed.

Others

Several other phytophagous insects and mites are considered as potential or minor pests for cultivated pistachio trees including: khinjuk psyllid *Agonoscena bimaculata* Mathur, which now lives on wild pistachio trees, e.g., *P. khinjuk* (Mehrnejad 2014c); the thrips species, e.g., *Liothrips austriacus* (Karny), *Thrips pistaciae* Yakhontov, *Thrips iranicus* (Yakhontov) and *Frankliniella occidentalis* (Pergande) (Kazemi & Mehrnejad 2011a; Taghizadeh & Safavi 1960); the petal borer moth, *Gelechia pistaciae* Filipjev (Kuznetzov 1999; Mehrnejad 2014b); leaf miners, *Simplimorpha promissa* (Staudinger), *Leucoptera* sp., *Phyllonorycter* sp. and *Acalyptris* sp. (Kiriukhin 1946; Davatchi 1958; Van Nieukerken 2007; Mehrnejad 2014b); eriophyid mites, *Aceria* (= *Eriophyes*) *pistaciae* (Nalepa), *Aceria* (= *Eriophyes*) *stephanii* (Nalepa) (Mehrnejad & Daneshvar 1991; Mehrnejad & Ueckermann 2001, 2002;) and *Shevtchenkella recki* (Bagdasarian) (Botimar & Sadeghi-Namaghi 2011), xylophaegous beetles, *Anthaxia* (*Haplanthaxia*) *kalalae* Baiocchi & Magnani, *Agrilus chlorophyllus* Abeille and *Chrysobothris parvipunctata* Obenberger, which, in fact, are secondary invaders of the trees that are weakened, dead, and dying (Taghizadeh & Safavi 1960; Mehrnejad 2016). The false chinch seed bug, *Nysius cymoides* (Spinola) (Hemiptera: Lygaeidae), makes large colonies on the lower parts of young pistachio trees, particularly on the twigs, leaves and buds, as well as on the fruit clusters (Mehrnejad, unpublished). These harmful organisms appear either in very limited densities in cultivated plantations or they currently live in wild pistachio plantations.

CONCLUSION

The monitoring of pistachio orchards is critical to determine the presence and population density of each pest species. In pistachio plantations, early-, mid- and late-seasons are all critical periods for the appropriate pest management because of the wide range of insects and mite species present, each with their own feeding and reproduction behaviour. The yield loss due to arthropod pests varies greatly from one orchard to another. In addition to the loss in yield, these pests cause a significant reduction in tree growth and in some cases, significant loss in the nut production over the following three years.

Over the last 7 decades, continuous applications of synthetic, non-specific, insecticides have caused epidemics of numerous phytophagous insects, probably, at least, in part, to their adverse effects on their natural enemies. Nevertheless, pistachio pests might be managed by developing an IPM (integrated pest management) programme. When the use of insecticides is necessary, pistachio growers would prefer the ones, which show

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less disruptive and more selective effects. Sanitation and cultural practices must be the primary means of control. The tilling and ploughing of the orchards' floor significantly reduce the overwintering populations of at least seven pistachio pest species, e.g., *A. pistaciae, A. komaroffi, R. pistaciicola, E. ceratoniae, P. davatchii, L. austriacus* and seed wasps. In addition, collecting and removing all the pruned, dead, damaged and deformed pistachio twigs, branches and trunks cause an effective reduction in the population density of several pests during winter, e.g., *C. vestitus*, *C. pistacivora*, different species of the xylophagous beetles, *Anthaxia* spp. and the eriophyid mite. Also, the removal of the unharvested nuts and the destruction of all of the nuts left on the soil surface had been proven to be successful in controlling seed wasps and carob moths. Nevertheless, appropriate and regular irrigation and fertilisation regimes are highly recommended to keep the pistachio trees in a vigorous condition.

At present, in spite of reasonable information being available on the native biocontrol agents of many pistachio pests, the mass release of commercially produced parasitoids or predators is not currently undertaken. Because of the global demand for food safety and for the absence of insecticide residues on agricultural products, pistachio producers will have to face difficult challenges in the coming decade. The future management of pistachio pests must rely on an improved integration of different methods and on creating new management techniques. In order to achieve this, it is essential to train pistachio growers and extension officers on ways of integrating all present (and future) recommended control measures. Efforts should be made to prevent several potential phytophagous pest species from becoming actual key pests. Further investigations are necessary to develop an IPM programme, particularly to characterise the main factors responsible for changes in the population dynamics of both the pests and biocontrol agents. Among the pistachio growing countries, an IPM programme has only been developed in California.

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REFERENCES

Abu Yaman I.K. (1970): The pistachio cushion scale. *Anapulvinaria pistaciae*, and its control in Iraq. Zeitschrift fuer Angewandte Entomologie, 66: 242–247.

Abu Yaman I.K., Jarjes S.J. (1969): Bionomics of the Pistachio Fruit-Moth, *Recurvaria pistaciicola* Danil., in Iraq. Zeitschrift für Angewandte Entomologie, 64: 260–265.

Achterberg C. Van, Mehrnejad M.R. (2011): A new species of *Megalommum* Szépligeti (Hymenoptera: Braconidae: Braconinae); a parasitoid of the pistachio longhorn beetle (*Calchaenesthes pistacivora* Holzschuh; Coleoptera: Cerambycidae) in Iran. Zookeys, 112: 21–38.

Achterberg C.V., Mehrnejad M.R. (2002): The braconid parasitoids (Hymenoptera: Braconidae) of *Kermania pistaciella* Amsel (Lepidoptera: Tineidae: Hieroxestinae) in Iran. Zoologische Mededelingen Leiden, 76: 27–40.

Amsel H.G. (1954): Die Microlepidopteren der Brandt'schen Iran-Ausbeute. 4. Teil. Arkiv för Zoologi (2), 6: 255–326.

Amsel H.G. (1964): Ein neuer kleinschmetterling als pistazien-schädling aus Iran. Beiträge zur naturkundlichen Forschung in Südwestdeutschland, 23: 107–109.

Ananda N., Kotikal Y.K., Balikai R.A. (2009): Sucking insect and mite pests of pomegranate and their natural enemies. Karnataka Journal Agricultural Science, 22: 781–783.

Aphids on the world's plants (2013): Available at http://www.aphidsonworldsplants.info/C_HOSTS_Pip_Pon.htm?LMCL=WHenoc#Pistacia

Arab-Hormozabadi A. (2005): The influence of common pistachio psylla, *Agonoscena pistaciae*, as a prey on biological characteristics of the two spotted ladybird, *Adalia bipunctata*, in Rafsanjan. [MSc Thesis.] Ahvaz, Shahid Chamran University.

Atiqi R. (2010): Study of form's abundance, food consumption, development and reproduction of the coccinellid beetle *Adalia bipunctata* in the Sirjan's pistachio plantation regions. [MSc Thesis.] Islamic Azad University, Tehran.

Askary H., Omid R., Al-Mansour H. (2006): Rearing *Ooencyrtus* cf. *masii*, (Hym.: Encyrtidae), the egg parasitoid of *Ocneria terebinthina* (Lep.: Lymantridae) on non-target hosts. Iranian Journal of Forest and Range Protection Research, 3: 129–144.

Aydogdu M., Beyarslan A. (2009): A review of the tribe Phanerotomini (Hymenoptera, Braconidae, Cheloninae) in Turkey, with a new host record for *Phanerotoma* (*Bracotritoma*) *permixtellae*. Biologia, 64: 748–756.

Basirat M., Mehrnejad M.R. (2005): The study of lower threshold temperature and thermal constant for two insect pests of stored nuts *Plodia interpunctella* and *Apomyelois ceratoniae* (Lep.: Pyralidae). Journal of Entomological Society of Iran, 24: 19–34.

Basirat M., Mehrnejad M.R. (2019): Population density of the pistachio twig borer moth, *Kermania pistaciella* Amsel on pistachio cultivars. Applied Entomology and Phytopathology, 86: 9–22.

Basirat M., Golizadeh A., Fathi S.A.A., Hassanpour M. (2015): Demography of pistachio fruit hull borer moth, *Arimania*

https://doi.org/10.17221/63/2019-PPS

komaroffi (Lepidoptera: Pyralidae) under different constant temperatures. Journal of Asia-Pacific Entomology, 18: 501–505.

Basirat M., Golizadeh A., Fathi S.A.A., Hassanpour M. (2015–2016): Demography of pistachio fruit hull borer moth, *Arimania komaroffi* (Lepidoptera: Pyralidae) on three pistachio cultivars under laboratory condition. Iranian Journal of Plant Protection, Vol. 46: 249–258.

Ben-Dov Y. (2012): The scale insects (Hemiptera: Coccoidea) of Israel-checklist, host plants, zoogeographical considerations and annotations on species. Israel Journal of Entomology, 41–42: 21–48.

Bentley W.J., Goodell P.B., Beede R.H. (2016): Small bugs: *Neurocolpus*. *Phytocoris*, *Calocoris* and *Lygus*. In: Ferguson L., Haviland D. (eds): Pistachio Production Manual, 1st ed. Oakland, University of California – Agriculture & Natural Resources, 3545: 215–224.

Bentley W.J., Beede R.H., Daane K.M., Haviland, D.R. (2010): UC IPM, Pest Management Guidelines: Pistachio. University of California ANR, Publication No. 21452.

Bolland H.R., Mehrnejad M.R. (2001): *Neophyllobius pistaciae* spec. nov. (Acari: Camerobiidae) from Iran. International Journal of Acarology, 27: 49–53.

Bolu H., Uygun N. (2003): Determination of *Coccoidea* species, their distribution, infestations and natural enemies in Southeastern Anatolia Region. Bitki Koruma Bülteni, 43: 111–123.

Bodenheimer F.S. (1953): The Coccoidea of Turkey III. Istanb. Univ. Fen. Fuk. Mecm., 18: 91–164.

Botimar M., Sadeghi-Namaghi H. (2011): The first record of the eriophyid, *Shevtchenkella Recki* (Bagd.) (Acari: Eriophyidae) on pistachio in Iran. Iranian Biology Society, 24: 442–445.

Bouček Z. (1977): A faunistic review of the Yugoslavian Chalcidoidea (Parasitic Hymenoptera). Acta Entomologica Jugoslavica, 13 (Suppl.): 1–145.

Braham M. (2009): Contribution to the study of the biology and ecology of the pistachio twig borer *Chaetoptelius vestitus* Muls & Rey (Coleoptera, Scolytidae) in the centre and south regions of Tunisia. In: Proceedings 5th International Symposium on Pistachios and Almonds, Sanliurfa, Oct. 6–10, 2009: 99.

CABI Invasive Species Data (2019): *Helicoverpa armigera* (cotton bollworm). Invasive species compendium. Available at https://www.cabi.org/isc/datasheet/26757

Chebouti-Meziou N., Doumandji S.E., Chebouti Y. (2009): The damage of *Chaetoptelius vestitus* (Mulsant & Rey) Coleoptera, Scolytidae in three orchards of fruit pistachio (*Pistacia vera* L.) in Algerians semi-arid area (Bouira-Tlemcen-Timgad). In: Proceedings of the 5th International Symposium on Pistachios and Almonds, Sanliurfa, Oct 6–10, 2009, Sanliurfa: 88.

Daane K.M., Yokota G.Y., Krugner R., Steffan S.A., da Silva P.G., Beede R.H., Bentley W.j., Weinberger G.B. (2005): Large bugs damage pistachio nuts most severely during midseason. California Agriculture, 59: 95–102.

Daane K.M., Yokota G.Y., Bentley W.J., Weinberger G., Millar J.G., Beede R.H. (2016): Stink bugs and leaffooted bugs. In: Ferguson L., Haviland D. (eds): Pistachio Production Manual, 1st ed. Oakland, University of California – Agriculture & Natural Resources, 3545: 225–239.

Danzig, E.M., Pellizzari G. (1998): Diaspididae. In: Kozár, F. (eds): Catalogue of Palaearctic Coccoidea. Budapest, Plant Protection Institute, Hungarian Academy of Sciences: 172–370.

Davatchi G.A. (1958): Étude biologique de la faune entomologiques Des *Pistacia* sauvages et cultivés. Revue de pathologie végétale et d'Entomologie agricole de France, 37: 1–166.

Emami S.Y., Yazdani A. (1993): Response of pistachio psylla to sticking colored traps. In: Proceedings of the 11th Iranian congress of plant pathology, Rasht, Aug 28– Sept 2, 1993: 42.

Emami S.Y., Mehrnejad M.R. (2006): Weed aphids and their parasitoids in pistachio orchards in Kerman province. Acta Horticulturae, 726: 437–439.

Emami S.Y., Mehrnejad M.R. (2009): The study of pistachio scale insects' parasitoids and the host acceptance behaviors of important species in Kerman province. Final research project report. Iranan, Pistachio Research Institute.

Ershad D., Barkhordary M. (1974a): Host range and vectors of *Nematospora coryli* Peglion in Kerman of Iran. Iranian Journal of Plant Pathology, 10: 34–39.

Ershad D., Barkhordary M. (1974b): Study of three fungi causing stigmatomycosis in Iran. Iranian Journal of Plant Pathology, 10: 1–8.

Ershad D., Barkhordary M. (1976): Investigations on stigmatomycosis (Massu disease) of pistachio. Iranian Journal of Plant Pathology, 12: 17–23.

Fallahzadeh M., Japoshvili G. (2010): Checklist of Iranian Encyrtids (Hymenoptera: Chalcidoidea) with descriptions of new species. Journal of Insect Science, 10: 68. doi: doi.org/10.1673/031.010.6801

Fallahzadeh M., Japoshvili G., Saghaei N. (2016): A contribution to the knowledge of the encyrtid wasps (Hymenoptera: Chalcidoidea, Encyrtidae) from southern Iran, with four new records. Journal of Insect Biodiversity and Systematics, 2: 309–319.

Farazmand H., Hassanzadeh H., Sirjani M., Mohammadpour K., Moshiri A., Valizadeh S.H., Jafari-nodooshan A. (2015): Effect of Kaolin clay on pistachio psylla nymph, *Agonoscena pistaciae*. Applied Entomology and Phytopathology, 82: 146–137.

Farahbakhsh Q. (1961): The list of major pests on agricultural crops in Iran. Plant Protection Organisation, 1: 153.

https://doi.org/10.17221/63/2019-PPS

Farivar-Mehin H. (1983): Study of the pistachio twig beetle in the Kerman province. In: Proceedings of the 7th Plant Protection Congress of Iran, Karadj, 1983: 65.

Farivar-Mehin H. (1991): The Important Pests and Diseases of the Pistachio Trees in Kerman Province. Tehran, Department of Education and Extension, Ministry of Agriculture.

Farivar-Mehin H. (2002): The important beetle pests of the pistachio trees in Iran. Acta Horticulturae, 591: 549–552.

Ferguson L., Kallsen C.E. (2016). The Pistachio Tree: Physiology and Botany. In: Ferguson L., Haviland D. (eds): Pistachio Production Manual, 1st ed. Oakland, University of California – Agriculture & Natural Resources, 3545: 19–26.

García M. M., Denno B.D., Miller D.R., Miller G.L., Ben-Dov Y., Hardy N.B. (2016): ScaleNet: A literature-based model of scale insect biology and systematics. Database. doi: 10.1093/database/bav118

Gregoriou C. (1998): Collection, conservation and utilization of *Pistacia* genetics resources in Cyprus. In: Padulosi S., Hadj-Hassan A. (eds): Towards a comprehensive documentation and use of *Pistacia* genetic diversity. Report of the IPGRI workshop, Irbid, Dec 14–17, 1998: 40-45.

Gries R.; Khaskin G., Daroogheh H., Mart C. Karadag S., Kubilay Er, Britton R. Gries G. (2006): (2S,12Z)-2-Acetoxy-12-heptadecene: Major sex pheromone component of pistachio twig borer, *Kermania pistaciella*. Journal of Chemical Ecology, 32: 2667–2677.

Grissell E.E., Prinsloo G.L. (2001): Seed-feeding species of *Megastigmus* (Hymenoptera: Torymidae) associated with Anacardiaceae. Journal of Hymenoptera Research, 10: 271–279.

Hadian A.R., Seyedoleslami H. (2001): Efficacy of yellow sticky board traps and limb jarring in the capture of adult pistachio psylla *Agonescena pistaciae* Burkhardt & Lauterer (Hom: Psyllidae). Journal of Science and Technology of Agriculture and Natural Resources, 6: 159–168.

Haitlinger R., Mehrnejad M.R. (2017): First record of hosts and new metric data for *Erythraeus* (*Erythraeus*) *pistacicus* Haitlinger, Mehrnejad & Šundić 2016 with notes on *Erythraeus* hosts. International Journal of Acarology, 43: 320–324.

Haitlinger R., Mehrnejad M.R., Šundić M. (2016): *Erythraeus* (*Erythraeus*) *pistacicus* sp. n. (Trombidiformes: Erythraeidae) from southern Iran, and notes on other *Erythraeus* spp. Biologia, 71: 804–808.

Halperin J. (1983): *Thaumetopoea solitaria* Freyer (Lepidoptera: Thaumetopoeidae) in Israel. Phytoparasitica, 11: 71–82.

Hasani-Kabotarkhani M.R., Mehrnejad M.R., Ostovan H. (2009): Some biological and predation characteristics of *Oenopia conglobata contaminata* (Col.: Coccinellidae) on the common pistachio psylla in laboratory conditions. Iranian Journal of Forest and Range Protection Research, 6: 110–117.

Hassani-Sadi M., Mehrnejad M.R., Shojaei M. (2010): The effect of diet and temperature regimes on development and reproduction of green lacewing, a natural enemy of the common pistachio psyllid. Journal of Entomological Research, 2: 179–194.

Hashemi-Rad H. (2005): Study on the biology and distribution of the Long-horned beetle *Calchaenesthes pistacivora*, a new cultivated and wild pistachio pest in Kerman province. Final project report. Rafsanjān, Pistachio Research Institute.

Hassanzadeh H., Farazmand H., Oliaei-Torshiz A., Sirjani M. (2014): Effect of kaolin clay (WP 95%) on oviposition deterrency of pistachio psylla (*Agonoscena pistaciae* Burckharat & Lauterer). Journal of Pesticides in Plant Protection Sciences, 1: 76–85.

Haviland D.R., Bentley W.J., Siegel J.P., Holtz B.A., Daane K.M., Higbee B.S (2016): Navel Orangeworm and Obliquebanded Leafroller. In: Ferguson L., Haviland D. (eds): Pistachio Production Manual, 1st ed. Oakland, University of California – Agriculture & Natural Resources, 3545: 197–210.

Hayat M., Mehrnejad M.R. (2016): *Ooencyrtus* (Hymenoptera: Encyrtidae), egg parasitoids of the pistachio green stink bugs (Hemiptera: Pentatomidae) in Iran. Zootaxa, 4117: 198–210.

Hayat M., Mehrnejad M.R. (2018): A new species of *Ooencyrtus* (Hymenoptera: Encyrtidae), parasitoid in eggs of *Ocneria terebinthina* (Lepidoptera: Lymantriidae) infesting pistachio plants in Iran. Journal of Insect Systematics, 5: 14–18.

Holzschuh C. (2003): Beschreibung von 72 neuen Bockkäfern aus Asien, vorwiegend aus China, Indien, Laos und Thailand (Coleoptera, Cerambycidae). Entomologica Basiliensia, 25: 147–241.

Hosseininaveh F., Nozari J., Kaydan M.B., Hosseininaveh V. (2016): Molecular and morphological identification of pistachio armored scale insects (Hemiptera: Diaspididae), with description of a new species. Zootaxa, 4200: 523–543.

Jafari-Nodoshan A. (1998): Investigation on efficiency of the green lacewing, *Chrysoperla carnea* as a pistachio psyllid predator. [MSc Thesis.] Tehran, The University of Tarbiat-Modares: 102.

Jalaeian M., Mansouri M., Karimi-Malati A. (2013): Distribution and morphological characteristics of parasitoids and hyperparasitoids of *Lepidosaphes pistaciae* (Hem.: Diaspididae) in Isfahan Province. Plant Pests Research, 3: 19–31.

Jalali M.A., Mehrnejad M.R., Kontodimas D.C. (2014): Temperature-dependent development of the five psyllophagous ladybird predators of *Agonoscena pistaciae* (Hemiptera: Psyllidae). Annals of the Entomological Society of America, 107: 445–452.

Jalali M.A., Mehrnejad M.R., Ellsworth P.C., Ranjbar F., Ziaaddini M. (2018): Predator performance: inferring predator switching behaviors based on nutritional indices in a coccinellid-psylla-aphid system. Pest Management Science, 74: 2851–2857.

https://doi.org/10.17221/63/2019-PPS

Jalali M.A., Reitz S., Mehrnejad M.R., Ranjbar F., Ziaaddini M. (2019): Food utilization, development, and reproductive performance of *Coccinella septempunctata* L. feeding on an aphid or psylla prey species. Journal of Economic Entomology, 112: 571–576.

Jeppson L.R., Keifer H.H., Baker E.W. (1975): Mites Injurious to Economic Plants. Berkeley, University California Press.

Kaska N. (1995): Pistachio nut growing in Turkey. Acta Horticulturae, 419: 161–164.

Kazemi F., Mehrnejad M.R. (2011a): Population fluctuations and damage of the pistachio fruit thrips, *Liothrips austriacus* (Thy.: Phlaeothripidae) on cultivated and wild-pistachio trees. Iranian Journal of Forest and Range Protection Research, 8: 165–177.

Kazemi F., Mehrnejad M.R. (2011b): Seasonal occurrence and biological parameters of the common green lacewings, predator of the common pistachio psylla *Agonoscena pistaciae* (Hemiptera: Psylloidea). European Journal of Entomology, 108: 63–70.

Kazemi F., Mehrnejad M.R., Rajabi A., Salmani Nejad H. (2017): Biology of Noghi scale, *Salicicola davatchi*, in the pistachio-growing areas of Rafsanjan, Iran. Journal of Entomological Research, 9: 111–122.

Khalil-Manesh B. (1973): Phytophagous mite fauna of Iran (I). Applied Entomology and Phytopathology, 35: 30–38.

Khoja S., Mozaik M.F., Azar Y., Hokan K. (2009): Plant protection survey for the most important insect pests of pistachio in Aleppo Governorate (Syria). In: 5th International Symposium on Pistachios and Almonds, Sanliurfa, Oct 6–10, 2009: 96.

Kiriukhin G. (1946): Les insectes nuisibles au pistacier en Iran. (Entomologie et Phytopathologie Appliquees) Applied Entomology and Phytopathology, 1: 8–24.

Kishani-Farahani H., Goldansaz S.H. (2013): Is host age an important factor in the bionomics of *Apanteles myeloenta* (Hymenoptera: Braconidae)? European Journal of Entomology, 110: 277–283.

Kishani-Farahani H., Goldansaz S.H., Sabahi Q., Shakeri M. (2011): A study on the larval parasitoids of carob moth, *Ectomyelois ceratoniae* in Varamin, Qom and Saveh. Iranian Journal of Plant Protection Science, 41: 337–344.

Kolahdooz-Shahroodi J., Seyedoleslami H., Ebadi R., Hatami B. (2006): Laboratory study of cycle and feeding rate of the beetle *Cybocephalus fodori minor* (Col.: Cybocephalidae) predator of pistachio oyster shell scale *Lepidosaphes pistaciae* (Hom.: Diaspididae). Journal of Science and Technology of Agriculture and Natural Resources, 10: 255–267.

Kozár F., Fowjhan M.A., Zarrabi M. (1996): Check-list of Coccoidea and Aleyrodoidea (Homoptera) of Afghanistan and Iran, with additional data to the scale insects of fruit trees in Iran. Acta Phytopathologica et Entomologica Hungarica, 31: 61–74.

Manickavasagam S., Mehrnejad M.R., Noyes J.S. (2008): *Cheiloneurus pistaciae* sp. nov. (Hymenoptera: Encyrtidae) a facultative hyperparasitoid of *Kermania pistaciella* Amsel (Lepidoptera: Tineidae), a pest of pistachio trees in Iran. Zootaxa, 1958: 61–64.

Mart C., Erkilic L., Uygun N., Altin M. (1995): Species and pest control methods used in pistachio orchards of Turkey. Acta Horticulturae, 419: 379–386.

Martinez J.-J.I. (2008): Impact of a gall-inducing aphid on *Pistacia atlantica* Desf. trees. Arthropod-Plant Interactions, 2: 147–151.

Masjedian H., Seyedoleslami H. (2003): Bioecology of pistachio oyster shell scale, *Lepidosaphes Pistaciae* Archangelskaya (Hom: Diaspididae) in Isfahan. Journal of Crop Production and Processing, 6: 181–194.

McBrien H.L., Millar J.G., Gottlieb L., Chen X. (2001). Male-produced sex attractant pheromone of the green stink bug, *Acrosternum hilare* (Say). Journal of Chemical Echology, 27: 1821–1839.

Mehrnejad M.R. (1993): Biology of the carob moth (*Apomyelois ceratonia*e) a new pest of pistachio in Rafsanjan. Applied Entomology and Phytopathology, 60: 1–12.

Mehrnejad M.R. (1995): The carob moth, a pest of pistachio nut in Iran. Acta Horticulturae, 419: 365–372.

Mehrnejad M.R. (1998): Evaluation of the parasitoid *Psyllaephagus pistaciae* (Hymenoptera: Encyrtidae) as a biocontrol agent of the common pistachio psylla *Agonoscena pistaciae* (Hemiptera: Psylloidea). [Ph.D. Thesis], London, The University of London: 271.

Mehrnejad M.R. (2001): The current status of pistachio pests in Iran. Cahiers Options Méditerranéennes, 56: 315–322.

Mehrnejad M.R. (2002b): The natural parasitism ratio of the pistachio twig borer moth, *Kermania pistaciella*, in Iran. Acta Horticulturae, 591: 541–544.

Mehrnejad M.R. (2002a): Bionomics of the common pistachio psylla, *Agonoscena pistaciae*, in Iran. Acta Horticulturae, 591: 535–539.

Mehrnejad M.R. (2003a): Influence of host species on some biological and behavioural aspects of *Dibrachys boarmiae*, parasitoid of *Kermania pistaciella*. Biocontrol Science and Technology, 13: 219–229.

Mehrnejad M.R. (2003b): Pistachio Psylla and Other Major Psyllids of Iran. Tehran, Agricultural Research and Education Organization.

Mehrnejad M.R. (2006): Three pistachio species evaluated for resistance to the common pistachio psylla, *Agonoscena pistaciae*. In: Proceedings International Symposium "Forest Insect Population Dynamics and Host Influences", Kanazawa, Sept 14–19, 2003: 58–62.

https://doi.org/10.17221/63/2019-PPS

Mehrnejad M.R. (2008): Seasonal biology and abundance of *Psyllaephagus pistaciae* (Hymenoptera: Encyrtidae), a biocontrol agent of the common pistachio psylla *Agonoscena pistaciae* (Hemiptera: Psylloidea). Biocontrol Science and Technology, 18: 409–417.

Mehrnejad M.R. (2010a): Potential biological control agents of the common pistachio psylla, *Agonoscena pistaciae*, a review. Entomofauna, 31: 317–340.

Mehrnejad M.R. (2010b): The parasitoids of the pistachio fruit hull borer moth, *Arimania komaroffi*. Applied Entomology and Phytopathology, 78: 129–130.

Mehrnejad M.R. (2011): Difficulties of biological control development in pistachio plantations of Iran. In: Proceedings of the Biological Control Development Congress in Iran, Tehran, Jul 27–28, 2011: 161–168.

Mehrnejad M.R. (2012): Biological parameters of *Elasmus nudus* (Hymenoptera, Eulophidae), a parasitoid of the pistachio fruit hull borer moth, *Arimania komaroffi* (Lepidoptera, Pyralidae). Biocontrol Science and Technology, 22: 659–670.

Mehrnejad M.R. (2013): Abundance of parasitoids associated with two major stink bugs on pistachio trees. Applied Entomology and Phytopathology, 81: 83–84.

Mehrnejad M.R. (2014a): Pest problems in pistachio producing areas of world and their current means of control. Acta Horticulturae, 1028: 163–169.

Mehrnejad M.R. (2014b): The pests of pistachio trees in Iran, natural enemies and control. Tehran, Sepehr publication.

Mehrnejad M.R. (2014c): The psyllids of pistachio trees in Iran. Acta Horticulturae, 1028: 191–194.

Mehrnejad M.R. (2016): Colour Atlas of Pistachio Trees Pests in Iran. Tehran, Agricultural Education and Promotion.

Mehrnejad M.R. (2018): Investigation into the overwintering and winter-management of the common pistachio psyllid, *Agonoscena pistaciae* (Hemiptera: Aphalaridae), a major pest in pistachio plantations, Zoology and Ecology, 28: 384–388.

Mehrnejad M.R., Daneshvar H. (1991): Two species of pistachio eriophyid mites from Kerman and Yazd provinces. Applied Entomology and Phytopathology, 58: 78–79.

Mehrnejad M.R., E. Ueckermann (2001): Mites (Arthropoda, Acari) associated with pistachio trees (Anacardiacae) in Iran (I). Systematic and Applied Acarology Special Publication, 6: 1–12.

Mehrnejad M.R., E. Ueckermann (2002): Phytophagous and predatory mites of the pistachio trees in Iran. Acta Horticulturae, 591: 545–547.

Mehrnejad M.R., Jalali M.A. (2004): Life history parameters of the coccinellid beetle, *Oenopia conglobata contaminata*, an important predator of the common pistachio psylla. Biocontrol Science and Technology, 14: 701–711.

Mehrnejad M.R., Copland M.J.W. (2005a): Diapause strategy in the parasitoid *Psyllaephagus pistaciae*. Entomologia Experimentalis et Applicata, 116: 109–114.

Mehrnejad M.R., Copland M.J.W. (2005b): The seasonal forms and reproductive potential of the common pistachio psylla, *Agonoscena pistaciae* (Hem.: Psylloidea). Journal of Applied Entomology, 129: 342–346.

Mehrnejad M.R., S.Y. Emami (2005): Parasitoids associated with the common pistachio psylla, *Agonoscena pistaciae* in Iran. Biological Control, 32: 385–390.

Mehrnejad M.R., Copland M.J.W. (2006c): Host-stage selection and oviposition behaviour of *Psyllaephagus pistaciae*, parasitoid of the common pistachio psylla *Agonoscena pistaciae*. Biological Control, 36: 139–146.

Mehrnejad M.R., Copland M.J.W. (2006b): Biological parameters of parasitoid *Psyllaephagus pistaciae* and its host *Agonoscena pistaciae* in relation to temperature. Journal of the Entomological Research Society, 8: –20.

Mehrnejad M.R., Copland M.J.W. (2006a): Behavioral responses of the parasitoid *Psyllaephagus pistaciae* (Hymenoptera: Encyrtidae) to host plant volatiles and honeydew. Entomological Science, 9: 31–37.

Mehrnejad M.R., Panahi B. (2006): The influence of hull cracking on aflatoxin contamination and insect infestation in pistachio nuts. Applied Entomology and Phytopathology, 73: 105–123.

Mehrnejad M.R., Copland M.J.W. (2007): Host discrimination by the endoparasitoid *Psyllaephagus pistaciae* (Hymenoptera: Encyrtidae): A case of time-dependent ability. Biocontrol Science and Technology, 17: 401–411.

Mehrnejad M.R., Basirat M. (2009): Parasitoid complex of the pistachio twig borer moth, *Kermania pistaciella*, in Iran. Biocontrol Science and Technology, 19: 499–510.

Mehrnejad M.R., Speidel W. (2011): The pistachio fruit hull borer moth *Arimania komaroffi* Ragonot, 1888 (Lepidoptera, Pyralidae). Entomofauna, 32: 5–16.

Mehrnejad M.R., Linnavuori R.E. (2012): Four major mirid bugs of pistachio trees in Iran. Applied Entomology and Phytopathology, 79: 277–279.

Mehrnejad M.R., Mirzaei R. (2016): Life cycle, damage and control of the pistachio bud-borer moth *Telphusa pistaciae* Sattler (Lepidoptera: Gelechiidae). Applied Entomology and Phytopathology, 83: 201–208.

Mehrnejad M.R., Mirzaei R. (2017): The effect of winter ploughing on reduction of pistachio weevil population density. Applied Entomology and Phytopathology, 85: 11–20.

Mehrnejad M.R., Jalali M.A., Mirzaei R. (2011): Abundance and biological parameters of psyllophagous coccinellids in pistachio orchards. Journal of Applied Entomology, 135: 673–681.

Mehrnejad M.R., Linnavuori R.E., Alavi S.H. (2013): Hemipteran bugs associated with pistachio trees and notes on major species, Zoology and Ecology, 23: 29–40.

https://doi.org/10.17221/63/2019-PPS

Mehrnejad M.R., Vahabzadeh N., Hodgson C.J. (2015): Relative suitability of the common pistachio psylla, *Agonoscena pistaciae* (Hemiptera: Aphalaridae) as prey for the two-spotted ladybird, *Adalia bipunctata* (Coleoptera: Coccinellidae). Biological Control, 80: 128–132.

Mehrnejad M.R., Meleshko J.Ye., Korotyaev B.A. (2017): Morphological description and observations on the biology of *Polydrusus davatchii* (Coleoptera: Curculionidae: Entiminae), a pest of pistachio trees in Iran. Biologia, 72: 1067–1074.

Melifronides I.D., Zyngas J.Ph. (1982): Control of the pistachio wasp (*Eurytoma pistaciae*) in Cyprus. Geoponica, 290–291, 157–161.

Michailides T.J., Morgan D.P. (1990): Etiology and transmission of stigmatomycosis disease of pistachio in California (Abstract). Phytopathology, 80: 973.

Michailides T.J., Morgan D.P., Doster M.A. (2016): Foliar, Fruit, and branch Diseases. In: Ferguson L., Haviland D. (eds): Pistachio Production Manual, 1st ed. Oakland, University of California – Agriculture & Natural Resources, 3545: 265–292.

Michailides T.J., Rice R.E., Ogawa J.M. (1987): Succession and significance of several hemipterans attacking a pistachio orchard. Journal of Economic Entomology, 80: 398–406.

Mirhosseini M.A., Hosseini M.R., Jalali M.A. (2015): Effects of diet on development and reproductive fitness of two predatory coccinellids (Coleoptera: Coccinellidae). European Journal of Entomology, 112: 446–452.

Mirkarimi A. (2000): Biological control of carob moth with mass release of *Trichogramma embryophagum* Hartig for pomegranata worm control, the *Ectomyelois* (*Spectrobates*) *ceratoniae* Zell. Iranian Journal of Agricultural Sciences, 31: 103–110.

Moezipour M., Kafil M., Allahyari H. (2008): Functional response of *Trichogramma brassicae* at different temperatures and relative humidities. Bulletin of Insectology, 61: 245–250.

Moghaddam M (2013): An annotated checklist of the scale insects of Iran (Hemiptera, Sternorrhyncha, Coccoidea) with new records and distribution data. ZooKeys, 334: 1–92.

Mohammadi R.S., Samih M.A., Rezvani A., Talebi A.A. (2007): Demographic parameters of wrinkling aphid of pistachio leaf, *Forda hirsuta* Mordv. (Hem.: Pemphigidae) insitu of Rafsanjan's orchards. Communications in Agricultural and Applied Biological Sciences, 72: 475–485.

Mohammadpour M., Ziaaddini M., Jalali M.A., Hashemirad H., Mohammadi-Khoramabadi A. (2016): Egg parasitoids of the pistachio green stink bug, *Brachynema germarii* (Hemiptera: Pentatomidae) in Kerman province, Iran. Zoology and Ecology, 26: 28–34.

Mourikis P.A., Tsourgianni A., Chitzanidis A. (1998): Pistachio nut insect pests and means of control in Greece. Acta Horticulturae, 470: 604–611.

Najafpour F., Mehrnejad M.R., Fallahzadeh M. (2010): Population dynamics and density of the common pistachio psylla, *Agonoscena pistaciae* (Hemiptera: Psylloidea) on two pistachio cultivars, Badami-riz Zarand and Momtaz. Plant Protection Journal, 2: 209–222.

Narendran T.C., Lotfalizadeh H. (1999): A new species of *Eurytoma* Illiger (Hymenoptera: Eurytomidae) parasitic on *Eulecanium rugulosum* Arch. (Homoptera: Coccidae) from Iran. Iran Agricultural Research, 18: 197–204.

Nikol'skaya M.N. (1934): List of Chalcid flies (Hym.) reared in U.S.S.R. Bulletin of the Entomolgical Research, 25: 129–143.

Nyman E., Sharif Q., Zalpor N., Qanea S.M., Samet Kh. (1966): The massu diseases and isolation of *Nematospora coryli*, in fruits of the pistachio trees. Applied Entomology and Phytopathology, 25: 58–65.

Omid R., Azizkhani E., Askary H., Moniri V.R. (2005): Biological investigation of *Ocneria terebinthina* in Khojir protected area. Iranian Journal of Forest and Range Protection Research, 2: 209–211.

Omid R., Azizkhani E., Askary H., Moniri V.R. (2006): Study on key pests of wild pistachio, *Pistacia atlantica*, and their natural enemies in Khojir protected area, Iran. Acta Horticulturae, 726: 525–528.

Parish H., Mehrnejad M.R., Fallahzadeh M., Basirat M. (2015): Thermal requirements and biological parameters of *Coccinula elegantula* (Col., Coccinellidae), predator of *Agonoscena pistaciae* (Hem.: Psylloidea) in laboratory conditions. Journal of Entomological Research, 7: 115–122.

Potaeva A.G. (1993): Soft scale insects (Homoptera, Coccoidea, Coccidae) of southern Turkmenistan. Akademii Nauk Turkmenistana, 4: 33–39.

Pourali Z., Mehrnejad M.R., Kheradmand K. (2011): Effect of temperature and prey density on prey consumption and fecundity of the predatory bug, *Anthocoris minki pistaciae* (Hemiptera: Anthocoridae). Applied Entomology and Phytopathology, 79: 71–86.

Pourali Z., Kheradmand K., Mehrnejad M.R. (2012): Effects of temperature on biological parameters of *Anthocoris minki pistaciae* (Hemiptera: Anthocoridae). Zoology and Ecology, 22: 240–245.

Pour-mohammadali B., Hosseinifard S.J., Shirani H., Esfandiarpour-Boroujeni I. (2019): Effects of soil properties, water quality and management practices on pistachio yield in Rafsanjan region, southeast of Iran. Agricultural Water Management, 213: 894–902.

Qomi-Nejad R. (2006): Bioecology of the pistachio fruit moth, *Recurvaria pistaciicola* (Danilevsky) in Rafsanjan region. [MSc Thesis.] Ahvaz, Shahid Chamran University: 156.

Radjabi Gh. (1959): Pistachio seed wasps. [MSc Thesis.] Tehran, The University of Tehran: 48.

https://doi.org/10.17221/63/2019-PPS

Rezvani A. (2004): Aphids on trees and shrubs in Iran. Tehran, Plant Pests and Diseases Research Institute.

Robinson D.W. (1968): Pistachio Seed Chalcid. Progress Report, California Department of Agriculture.

Salari E., Karimi J., Sadeghi H. (2015): Biocontrol potential of the entomopathogenic nematodes *Heterorhabditis bacteriophora* and *Steinernema carpocapsae* on pistachio root beetle larvae, *Capnodis cariosa hauseri* (Coleoptera: Buprestidae), under laboratory conditions. In: Proceeding of the 5th Entomopathogens and Microbial Control Congress, Ankara, Sept 9–11, 2015: 115.

Salehi M.H., Hosseinifard S.J. (2012): Soil and groundwater relationships with pistachio yield in the Rafsanjan area, Iran. Communications in Soil Science and Plant Analysis, 43: 660–671.

Salehi T., Mehrnejad M.R. (2014): Polymorphism of *Adalia bipunctata* (Coleoptera: Coccinellidae) on the cultivated- and wild-pistachio trees in Kerman province. Applied Entomology and Phytopathology, 81: 135–142.

Salehi T., Pashaei-Rad Sh., Mehrnejad M.R., Shokri M.R. (2011): Ladybirds associated with pistachio trees in part of Kerman province, Iran (Coleoptera: Coccinellidae). Iranian Journal of Animal Biosystematics, 7: 157–169.

Salehi T., Mehrnejad M.R., Pashaei-Rad Sh. (2013): Diversity pattern of adult ladybird (Coleoptera: Coccinellidae) communities on pistachio trees in southern parts of Iran in different months. Zoology and Ecology, 23: 286–292.

Samet Kh. (1974): Three injurious butterflies of pistachio trees in Kerman province. In: Proceedings of the 5th plant protection congress of Iran, Tabriz, 1974 : 11–12.

Samet Kh. (1982): The life history and pest status of the pistachio bud moth, *Telphusa pistaciae* Sattler, on *Pistacia vera* in Iran. Entomologist's Gazette, 33: 33–35.

Samet Kh. (1984): The pistachio fruit moth, *Recurvaria* sp. Zeiton, 34: 30–31.

Samet Kh. (1985): The life cycle of *Arimania komaroffi* (Ragonot, 1893) (Lepidoptera: Pyralidae) a new pest of *Pistacia vera* in Iran. Entomologist's Gazette, 36: 113–115.

Samet Kh., Akbary P. (1974): The bugs, vector of the pistachio stigmatomycosis in Iran. In: Proceedings of the 5th Plant Protection Congress of Iran, Tabriz, 1974: 10.

Santas L.A. (1985): *Anapulvinaria pistaciae* (Bod.), a pistachio tree scale pest producing honeydew foraged by bees in Greece. Entomologia Hellenica, 3: 29–33.

Sattler K. (1982): A review of the western palaerctic Gelechiidae (Lepidoptera) associated with *Pistacia*, *Rhus*, and *Cotinus* (Anacardiacae). Entomologist's Gazette, 33: 13–32.

Seghatoleslami H. (1977): List of scale insects (fam. Diaspididae) of Iran. Journal of the Entomological Society of Iran, 4: 5–19.

Sheibani-Tezerji Z. (2010): The effects of *Bacillus thuringiensis* var. *kurstaki* on the first, second and third larval instars of pistachio white leaf moth *Ocneria terebinthina* (Lep.: Lymanteridae). Journal of Research in Agricultural Science, 6: 83–92.

Sheibani A. (1995): Distribution, use and conservation of pistachio in Iran. In: Padulosi S., Caruso T., Barone E. (eds): Taxonomy, distribution, conservation and uses of *Pistacia* genetic resources – Report of a workshop. Rome, June 29–30, 1995: 51–56.

Sheibani Z., Shojaii M., Shojaaddini M., Imani S., Hassani M.R. (2016): Repellency of kaolin particle film to common pistachio psyllid, *Agonoscena pistaciae* under field conditions. Bulletin of Insectology, 69: 7–12.

Shirazi M., Vahedi H-A., Mirmoayedi A-N., Masoumi S.M., Jalilvand K. (2013): Scale insects recorded on ornamental plants in urban areas of Kermanshah, Iran. African Journal of Agricultural Research, 8: 1381–1383.

Taghizadeh F., Safavi M. (1960): Pistachio Pests of Iran and Means of Control. Tehran, Plant Protection Research Department.

Taghizadeh F., Djafaripoor M. (1965): New pistachio woodborer *Kermania pistaciella* Amsel. Entomologie et Phytopathologie Appliquees, 23: 1–9.

Tavakkoli-Korghond Gh.R., Lotfalizadeh H. (2018): Pistachio mealybug, *Anapulvinaria pistaciae* (Bodenheimer) (Hem.: Coccidae) new host record for *Coccophagus piceae* Erdös (Hym.: Chalcidoidea, Aphelinidae). Journal of plant protection, 32: 445–448.

Tavanpour T., Sarafrazi A., Mehrnejad M.R., Imani S. (2016): Distribution scenario of two species of green bugs *Brachynema germarii* and *Nezara viridula* (Hemiptera; Pentatomidae) in Kerman Province. Applied Entomology and Phytopathology, 84: 67–78.

Tavanpour T., Mehrnejad M.R., Sarafrazi A., Imani S. (2017): Distribution modelling of four scelionid egg parasitoids of green stink bugs (Hemiptera: Pentatomidae). Biologia, 72: 53–61.

Vahabzadeh N., Mehrnejad M.R., Goldasteh S. (2014): Effects of temperature on development, fecundity and life table parameters of *Adalia bipunctata* (Coleoptera: Coccinellidae), the predator of *Agonoscena pistaciae*. Journal of Entomological Research, 6: 101–116.

Vettel W.G., Harper R.W. (1969): California Department of Agriculture Pistachio Seed Chalcid Progress Report.

Wool D., Ben-zvi O. (1998): Population ecology and clone dynamics of the galling aphid *Geoica wertheimae* (Sternorrhyncha: Pemphigidae: Fordinae). European Journal of Entomology, 95: 509–518.

Yanık E., Yücel A. (2001): The pistachio (*P. vera* L.) pests, their population development and damage state in Sanliurfa province. Cahiers Options Mediterraneenes, 56: 301–309.

https://doi.org/10.17221/63/2019-PPS

Yazdani A., Radjabi A. (1993): The first record of Hymenoptera parasitoids of scale insects on pistachio in Iran. In: Proceeding of the 11th Plant Protection Congress of Iran, Rasht, Aug 28–Sept 2, 1993: 212.

Yousef A.A., Zaher M.A., Abd-el-Hafiez A.M. (1980): Effect of season and grapevine variety on the biology of *Tenuipalpus granati* Sayed, with description of its immature stages, (Acari: Prostigmata: Tenuipalpidae). Acarologia, 21: 384–388.

Ziaaddini M., Seyedoleslami H., Hatami B. (2002): Biology and seasonal occurrence of pistachio twig borer, *Hylesinus vestitus* Rey (Coleoptera: Scolytidae). Iranian Journal of Agricultural Sciences, 33: 475–487.

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