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REVIEW ARTICLE

Eriophyoid mites (Acari: Eriophyoidea) in Greek orchards and grapevine: A review

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Summary Eriophyoid mites (Acari: Prostigmata: Eriophyoidea), one of the most diverse group of mites, are plant feeder specialists, causing various symptoms on plants, and many of them are economically important pests on orchards and grapevines. They are commonly known as gall, rust, bud, and blister mites. Up to date approximately a hundred species of eriophyoid mites have been reported in Greece, thirty three of them, belonging to the families Eriophyidae, Diptilomiopidae and Phytoptidae, in agricultural orchards and vineyards. Information about their hosts, damage and natural enemies is presented. Also, the subjects of monitoring and chemical control of eriophyoid mites are discussed.

Additional keywords: blister mites, bud mites, control, natural enemies, rust mites

Introduction

Among phytophagous mites, the eriophyoid mites (Acari: Prostigmata: Eriophyoidea) are the most diverse group and many of eriophyoid species are economically important pests (Van Leeuwen *et al*., 2010). Around 3,700 species are currently recognized (Amrine *et al*., 2003) on angiosperms, coniferous plants and ferns throughout the world. They are commonly known as gall, rust, bud, and blister mites.

Members of the Eriophyoidea are soft bodied, wormlike, or spindle shaped, unique among the mites because they have only two pairs of legs and size so small that they are almost invisible to the unaided eye. Eriophyoids are one of the most specialized groups of plant feeders. They are characterized by the intimate relationships they have with their hosts and the restricted range of plants upon which they can reproduce. Eighty per cent of eriophyoids have been reported on only one host species, 95% on one host genus, and 99% on one host family (Skoracka *et al*., 2010).

Symptoms of their feeding are varying from simple russeting to complex gall formation and may appear on buds, shoots, stems, twigs, flowers and leaves of the plants. Gall formation occurs as a result of mite attack on individual plant cells; it is a localized growth reaction of the host plant to the attack. Common examples are leaf galls, bud galls, and erineum. In some plants, elongation of flower stems and lateral branches is inhibited, causing the development of contorted foliage, flowers, and branches. One of the most conspicuous examples is witches'-broom, which is a cluster of brush like growth of stunted twigs or branches on trees. Some eriophyid species arrest shoot development, causing leaf sheaths to become enlarged, closely packed, and bunched at stem nodes. Others cause the well-known "big bud", which consists of an aggregation of swollen, thickened scale leaves. Eriophyids also cause an array of nongall abnormalities, such as leaf folding and twisting, blisters, and discoloration. Russeting and silvering or bronzing of leaves are also induced by eriophyid feeding. As a result of infestation flowers or young fruits maybe falling off (Keifer *et al*., 1982).

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Eriophyoid mites (Acari: Eriophyoidea) have been recognized as important pests in agriculture and forestry all over the world (Lindquist *et al.*, 1996). A number of eriophyoid species are considered to be main pests on some crops, while others are known to be a quarantine threat for several countries. Nevertheless, several eriophyoid species seldom attain high population levels and thus their economic importance is a matter of discussion (Duso *et al.*, 2010).

There are quite a few difficulties evaluating eriophyoid population densities and related yield losses in most cases of eriophyoid infestations. Their minute size and concealed way of life (several species live and reproduce well hidden in buds or in induced plant structures, like galls, erinea and blisters) represent an obstacle for detailed studies aiming at determining their impact on agricultural crops. The small size and the behavior of eriophyoids are frequently implied in misdiagnoses with implications for yield losses (Duso *et al.*, 2010). In contrast, their symptoms are sometimes spectacular but not of economic impact. Knowledge of the economic impact of eriophyoids on crop yields and threshold levels is a fundamental requirement for the improvement of IPM.

Up to date approximately 100 species of eriophyoid mites have been reported from Greece (Malandraki, 2012), thirty three of them in agricultural orchards and grapevines. In Table 1, the name of the mite species and the host plant species as well as the corresponding references are summarised. Most of the papers are dealing with the taxonomic status, distribution records and control. A few studies deal with their biology and control.

Eriophyoid species in Greek orchards

Eriophyoids of stone fruits

Acalitus phloeocoptes **(Nalepa) [*Phytoptus phloeocoptes* Nalepa, *Eriophyes phloeocoptes* (Nalepa)]**

Common name: plum blister mite

Damage: The plum blister mite infests mainly almond and plum. On almond, it causes permanent irregular galls of various sizes around the buds and deforms the fruit. Infested trees fail to form fruit buds and lose vigor. On plum, the mites form small, irregular, subsphaerical galls, 1.3-1.8 mm in diameter surrounding the buds and also deforming the fruit. The galls may appear singly or clustered around the buds and become woody.

On almond the damage appears to be progressive and irreversible resulting in death of the tree in 3-6 years. Unlike almond, infested plum trees often recover from mite attack and do not show permanent injury (Keifer *et al.*, 1982).

In the area of Magnesia (Central Greece) on "Skopelos" plum tree the mite starts to migrate from the galls to new buds in mid-April and the migration phase lasts 50 days. Population builts up until December with successive generations, not damaging the production or the tree (Papanikolaou and Bakoyiannis, 1991).

Aculus fockeui **(Nalepa and Trouessart) [*Phyllocoptes fockeui* Nalepa and Trouessart, *Vasates fockeui* (Nalepa and Trouessart)]**

Syn: *Phyllocoptes cornutus* Banks [*Aculus cornutus* (Banks); *Vasates cornutus* (Banks)]
Phyllocoptes paracornutus Keifer

Common name: plum rust mite

Damage: This is a pest mainly of plums, peaches/nectarines and cherries in orchards and nurseries. This mite produces asteroid chlorotic spots on leaves. When populations are high the leaf is wavy or slightly twisted about its longitudinal axis. Heavy infestations of *A. fockeui* may form rosette shoots and keep leaves from expanding to normal size. Deutogynes hibernate in niches or near the current season growth. They crawl into bark crevices, especially around injuries, but are also behind potentially active buds, or under available loose bud scales. As the buds expand in spring the deutogynes crawl to, and feed upon, emerging embryonic leaves and lay eggs. Trees are losing

Table 1. List of known Eriophyoidea in Greek orchards and grapevine.

Species	Hosts	References
Eriophyidae		
Acalitus phloecoptes (Nalepa)	*Prunus domestica* L. *Prunus dulcis* (Mill.) D.A.Webb	Hatzinikolis, 1969b; Hatzinikolis, 1970a; Hatzinikolis, 1970b; Papanikolaou and Bakoyiannis, 1991; Papaioannou-Souliotis *et al.*, 1994
Aceria cretica Hatzinikolis	*Olea europaea* L.	Hatzinikolis, 1989; Papaioannou-Souliotis *et al.*, 1994
Aceria erineus (Nalepa)	*Juglans regia* L.	Issakides, 1936; Hatzinikolis, 1967; Hatzinikolis, 1969a; Hatzinikolis, 1969b; Hatzinikolis, 1970b; Papaioannou-Souliotis *et al.*, 1994
Aceria ficus (Cotte)	*Ficus carica* L.	Hatzinikolis, 1969b; Hatzinikolis, 1970a; Papaioannou-Souliotis *et al.*, 1994; Malandraki, 2012.
Aceria granati (Canestrini and Massalongo)	*Punica granatum* L.	Hatzinikolis, 1967; Hatzinikolis, 1969a; Hatzinikolis, 1969b; Hatzinikolis, 1970b; Koveos *et al.*, 2010; Malandraki, 2012.
Aceria oleae (Nalepa)	*Olea europaea* L.	Kavadas, 1927; Koroveos, 1939; Pelekassis, 1962; Bouchelos *et al.*, 1963; Hatzinikolis, 1967; Hatzinikolis, 1969a; Hatzinikolis, 1969b; Hatzinikolis, 1969c; Hatzinikolis, 1970b; Hatzinikolis,1970d; Hatzinikolis, 1971; Mourikis and Vassilaina – Alexopoulou, 1975; Emmanouel, 1981; Hatzinikolis, 1984; Hatzinikolis and Kolovos,1985; Hatzinikolis, 1986; Hatzinikolis, 1989; Papaioannou-Souliotis *et al.*, 1994; Papaioannou-Souliotis and Markoyiannaki, 2003; Tzanakakis, 2003; Malandraki, 2012.
*Aceria olivi (*Zacher and Abou-Awad)	*Olea europaea* L.	Hatzinikolis and Kolovos,1985
Aceria pistaciae (Nalepa)	*Pistacia terebinthus* L. *Pistacia vera* L.	Hatzinikolis, 1970c; Papaioannou-Souliotis *et al.*, 1994; Malandraki, 2012.
Aceria sheldoni (Ewing)	*Citrus limon* (L.) Burm, *Citrus sinensis* (L.) Osbeck	Soueref and Komblas, 1961; Pelekassis, 1962; Bouchelos *et al.*, 1963; Hatzinikolis, 1967; Hatzinikolis, 1969a; Hatzinikolis, 1969b; Hatzinikolis, 1970b; Mourikis and Vassilaina – Alexopoulou, 1975; Papaioannou-Souliotis *et al.*, 1994; Malandraki, 2012.
Aceria tristriatus (Nalepa)	*Juglans regia* L.	Pelekassis, 1962; Hatzinikolis, 1967; Hatzinikolis, 1969a; Hatzinikolis, 1969b; Hatzinikolis, 1970b; Papaioannou-Souliotis *et al.*, 1994; Malandraki, 2012.
Aculops benakii (Hatzinikolis)	*Olea europaea* L.	Hatzinikolis, 1968; Hatzinikolis, 1969c; Hatzinikolis, 1970b; Hatzinikolis, 1974; Emmanouel, 1981; Hatzinikolis and Kolovos,1985; Papaioannou-Souliotis *et al.*, 1994; Tzanakakis, 2003

Species	Hosts	References
Aculops pelekassi (Keifer)	*Citrus limon* (L.) Burm, *Citrus deliciosa* Ten. *Citrus sinensis* (L.) Osbeck *Citrus* spp.	Keifer, 1959; Pelekassis, 1962; Hatzinikolis, 1967; Hatzinikolis, 1969a; Hatzinikolis, 1969b; Hatzinikolis, 1970b; Mourikis and Vassilaina – Alexopoulou, 1975; Papaioannou-Souliotis *et al.*, 1994; Malandraki, 2012.
Aculus fockeui (Nalepa and Trouessart)	*Prunus persica* (L.) Batsh, *Prunus dulcis* Miller D.A. Webb *Prunus avium* L., *Malus domestica* Borkh	Hatzinikolis, 1969b; Hatzinikolis, 1970a; Hatzinikolis, 1978; Papaioannou-Souliotis *et al.*, 1994; Savopoulou-Soultani and Koveos, 1993; Malandraki, 2012.
Aculus olearius Castanogli	*Olea europaea* L.	Hatzinikolis and Kolovos,1985; Papaioannou-Souliotis *et al.*, 1994; Papaioannou-Souliotis and Markoyiannaki, 2003; Anagnou-Veroniki *et al.*, 2008
Aculus schlechtentali (Nalepa)	*Malus domestica* Borkh *Malus sylvestris* Mill.	Hatzinikolis, 1978; Papaioannou-Souliotis *et al.*, 1994; Savopoulou-Soultani and Koveos, 1993.
Calepitrimerus baileyi Keifer	*Malus domestica* Borkh, *Pyrus communis* L.	Hatzinikolis, 1978; Papaioannou-Souliotis *et al.*, 1994; Malandraki, 2012.
Calepitrimerus vitis (Nalepa)		Pelekassis, 1962; Bouchelos *et al.*, 1963; Hatzinikolis, 1969b; Hatzinikolis, 1970b; Hatzinikolis, 1970c; Papaioannou-Souliotis *et al.*, 1994
Cecidophyopsis vermiformis (Nalepa)	*Corylus avellana L.*	Koutroubas and Bakoyiannis, 1990
Colomerus vitis (Pagenstecher)	*Vitis vinifera* L.	Issakides, 1935; Pelekassis *et al.*, 1960; Pelekassis, 1962; Bouchelos *et al.*, 1963; Bouchelos *et al.*, 1965; Hatzinikolis, 1967; Hatzinikolis, 1969a; Hatzinikolis, 1969b; Hatzinikolis, 1970b; Mourikis and Vassilaina-Alexopoulou, 1975; Katsoyannos, 1992; Papaioannou-Souliotis *et al.*, 1994; Malandraki, 2012.
Coptophylla lamimani (Keifer)	*Corylus avellana* L.	Hatzinikolis, 1969b; Hatzinikolis, 1970c; Papaioannou-Souliotis *et al.*, 1994
Ditrymacus athiasella Keifer	*Olea europaea* L.	Hatzinikolis, 1969b; Hatzinikolis, 1969c; Emmanouel, 1981; Hatzinikolis, 1984; Hatzinikolis and Kolovos,1985; Katsoyannos, 1992; Papaioannou-Souliotis *et al.*, 1994; Papaioannou-Souliotis and Markoyiannaki, 2003; Tzanakakis, 2003; Malandraki, 2012.
Epitrimerus pyri (Nalepa)	*Pyrus communis* L.	Hatzinikolis, 1978; Papaioannou-Souliotis *et al.*, 1994; Malandraki, 2012.
Eriophyes padi (Nalepa)	*Prunus dulcis* Miller D.A. Webb	Hatzinikolis, 1967; Hatzinikolis, 1969a; Hatzinikolis, 1969b

Species	Hosts	References
Eriophyes pyri (Pagenstecher)	*Pyrus communis* L. *Malus domestica* Borkh	Issakides, 1935; Pelekassis, 1962; Bouchelos *et al*., 1963; Hatzinikolis, 1967; Hatzinikolis, 1969a; Hatzinikolis, 1969b; Hatzinikolis, 1970b; Mourikis and Vassilaina – Alexopoulou, 1975; Papaioannou-Souliotis *et al*., 1994;Malandraki, 2012.
Oxycenus maxwelli (Keifer)	*Olea europaea* L.	Hatzinikolis, 1967; Hatzinikolis, 1969a; Hatzinikolis, 1969b; Hatzinikolis, 1969c; Emmanouel, 1981; Hatzinikolis and Kolovos,1985; Papaioannou-Souliotis *et al*., 1994; Papaioannou-Souliotis and Markoyiannaki, 2003.
Oxycenus niloticus Zacher and Abou-Awad	*Olea europaea* L.	Hatzinikolis and Kolovos,1985
Phyllocoptes abaenus Keifer	*Prunus domestica* L., *Prunus domestica* ssp. *insititia* (L.) C.K.Schneid.	Hatzinikolis, 1978; Papaioannou-Souliotis *et al*., 1994; Malandraki, 2012.
Phyllocoptruta oleivora (Ashmead)	*Citrus limon* (L.) Burm, *Citrus medica* L. *Citrus sinensis* (L.) Obseck	Hatzinikolis, 1970c; Papaioannou-Souliotis *et al*., 1994
Shevtchenkella oleae (Natcheff)	*Olea europaea* L.	Hatzinikolis, 1969b; Hatzinikolis, 1969c; Hatzinikolis and Kolovos,1985.
Tegolophus hassani (Keifer)	*Olea europaea* L.	Hatzinikolis, 1969b; Hatzinikolis, 1969c; Hatzinikolis, 1970d; Papaioannou-Souliotis and Markoyiannaki, 2003.
Diptilomiopidae		
Diptacus gigantorhynchus (Nalepa)	*Prunus domestica* L. *Prunus persica* (L.) Batsh	Hatzinikolis, 1983; Papaioannou-Souliotis *et al*., 1994; Malandraki, 2012.
Rhycaphytoptus ficifoliae Keifer	*Ficus carica* L.	Hatzinikolis, 1982; Papaioannou-Souliotis *et al*., 1994; Malandraki, 2012.
Phytoptidae		
Phytoptus avellanae Nalepa	*Corylus avellana* L.	Pelekassis, 1962; Hatzinikolis, 1967; Hatzinikolis, 1969a; Hatzinikolis, 1969b; Hatzinikolis, 1970b; Papaioannou-Souliotis *et al*., 1994; Malandraki, 2012.

their vigor, sometimes they produce small-sized fruits that drop off (Keifer *et al*., 1982).

The plum rust mite is a frequent pest on peaches in northern Greece and in some cases develops high populations in summer (July to August) mainly in upper young leaves (Savopoulou-Soultani and Koveos, 1993).

***Diptacus gigantorhynchus* (Nalepa) [*Phyllocoptes gigantorhynchus* Nalepa, *Epitrimerus gigantorhynchus* (Nalepa), *Rhyncaphytoptus gigantorynchus* (Nalepa), *Diptilomiopus gigantorhynchus* (Nalepa)]**
Syn: *Diptacus prunorum* (Keifer) [*Diptilomiopus prunorum* Keifer]
Common name: big-beaked plum mite
Damage: Mites are vagrants on under leaf surface causing no apparent symptoms. In some cases leaf discoloration or even defoliation (Carmona, 1973; Bayan, 1988; Schliesske, 1992) may occur. Alford (2007) reported similar leaf symptoms *to A. fockeui*. It is considered of not economic importance.

***Eriophyes padi* (Nalepa) [*Phytoptus padi* Nalepa]**
Syn: *Eriophyes eupadi* (Newkirk) [*Phytoptus eupadi* Newkirk]
Common name: plum leaf gall mite
Damage: It causes prominent, finger shaped, red or dark red galls on the upper surface of plum foliage. The galls are often clustered closely together but cause little or no distortion of leaves (Alford, 2007). It is considered of not economic importance.

***Phyllocoptes abaenus* Keifer**
Damage: It lives on undersides of plum leaves, including ornamentals and frequents basal hairs along midribs, causing not apparent symptoms. It is considered of not economic importance.

Eriophyoids of pome fruits

***Aculus schlechtendali* (Nalepa) [*Phyllocoptes schlechtendali* Nalepa, *Vasates schlechtendali* (Nalepa)]**
Common name: apple rust mite
Damage: This species is a widespread pest of apple worldwide. It causes patchy felt-like malformation and a yellowing of hairs below the leaves, the upper surface of foliage appearing speckly, dull and faded. In heavy infestations, it damages terminal growth; the leaves curl lengthwise and become rusty brown, which gives the tree the appearance of being affected by drought. It also produces fruit russeting. The deutogynes find resting places under lateral buds not far below terminals, or in crevices on old wood. In the spring they move to opening buds, especially during the bloom period (Jeppson *et al*., 1975).

***Calepitrimerus baileyi* Keifer**
Syn: *Calepitrimerus aphrastus* (Keifer) [*Phyllocoptes aphrastus* Keifer]
Damage: This mite causes browning on the underside of apple leaves. It is considered to be of no importance.

***Diptacus gigantorynchus* (Nalepa) [see stone fruits]**
Damage: It is considered to be of no importance.

***Epitrimerus pyri* (Nalepa) [*Tegonotus pyri* Nalepa]**
Syn: *Epitrimerus pirifoliae* Keifer
Common name: pear rust mite
Damage: This mite attacks both pear leaves and fruit in the spring. High infestations cause severe browning of leaves and russeting of fruit. Lower populations may injure only the calyx end of fruit.

Clear-skinned fruit varieties show the most injury. In Greece the pear varieties "Kontoula" and "Krystalli" show great susceptibility to the infestation causing reduction of the product quality with economic impact (Papaioannou-Souliotis, 2001).

***Eriophyes pyri* (Pagenstecher) [*Phytoptus pyri* Pagenstecher]**
Common name: pear leaf blister mite
Damage: It causes small galls, green at the beginning of the infestation, that gradually turn to reddish and finally to dark brown. At first, the galls are along sides of the main

vein but as attack develops they cover most of leaf surface. Badly infested leaves die and fall off. It also damages the fruitlets and fruit stalks, which may drop prematurely.

Eriophyoids of Citrus

Aceria sheldoni (Ewing) [*Eriophyes sheldoni* Ewing]

Common name: citrus bud mite

Damage: The citrus bud mite feeds within the buds causing variable symptoms such as distortion of shoot growth, excessive and grotesque deformation of fruit, foliage, and blossoms, discoloration of fruit, and more commonly the production of numerous buds. The last may develop abortive twigs in tight clusters resembling "witches broom" and bunged terminal growth of distorted stems and leaves. Most malformed fruits drop prematurely. Mature lemon fruits show blackened areas on the rind beneath the sepals (buttons), where large colonies of mites are concealed. Deformed leaves and blossoms have various shapes; the leaf plates are constricted at their middle, curled, twisted, divided and divergent at the tips; the blossoms are stunted and abnormal. The symptoms of injury on oranges are similar to those on lemons except fruit deformation is not so grotesque. Affected oranges usually develop to maturity, but they are commonly flattened, resembling the shape of tomatoes; or they are skinfolds, seams and ridges, or small apertures in the stylar end.

Aceria sheldoni has been found in all Greek citrus-growing regions, causing damage mainly in lemons, which can be significant only during years with high population levels (Papaioannou-Souliotis, 1985; Papaioannou-Souliotis *et al*., 1999).

Aculops pelekassi (Keifer) [*Aculus pelekassi* Keifer, *Vasates pelekassi* (Keifer)]

Common name: pink citrus rust mite

Damage: Pink rust mites not only cause russeting of fruit and leaves, but also mild to severe distortion of new growth, brown lesions on lower surfaces and along midribs of immature leaves, and may produce mesophyll collapse, chlorosis, and leaf drop. It is potentially capable of causing more damage to its host than citrus rust mite *Phyllocoptruta oleivora* (Jeppson *et al*., 1975).

Aculops pelekassi was first found in Greece in 1958 and since then its presence is frequent all over the country (Papaioannou-Souliotis, 1985; Papaioannou-Souliotis *et al*., 1994). It is active during mild winters and can develop more than five generations per year. In population outbreaks it can cause up to 60% loss of yield (Papaioannou-Souliotis, 1985).

Phyllocoptruta oleivora (Ashmead)

Common name: citrus rust mite

Damage: Its feeding destroys the epidermal cells of the rind, producing silvering or russet effects. The ring of the affected fruit is thicker than normal, and the fruit tends to be smaller. Another result of the infestations on lemons and grapefruit is a condition known as "shark skin", in which the outer layer of the skin can be peeled. Heavy populations of mites feeding on leaves and twigs can also cause bronzing.

Greek citrus orchards are mainly infested by *A. pelekassi* and *A. sheldoni*, which can cause serious damage on fruit production when outbreaks of their population occur (Papaioannou-Souliotis, 1985, 1991, 1996; Papaioannou-Souliotis *et al*., 1992). *P. oleivora* only occur in limited part of orchards (Papaioannou-Souliotis *et al*., 1994).

Eriophyoids of Nut trees

Aceria erineus (Nalepa) [*Phytoptus tristriatus* var. *erineus* Nalepa, *Eriophyes tristriatus* var. *erineus* (Nalepa), *Eriophyes erineus* (Nalepa)]

Common name: persian walnut erineum mite

Damage: The infestation caused by this mite is most noticeable as shiny convex swellings on the upper surface of the leaf blade and on the underside as patches of shallow, large, solitary concavities lined with felty, yellowish hairs, among which the mites are found. These patches have well defined edges and

lie to the side of the midrib between the lateral veins; the erineum growths miss the small secondary veins and appear as thickened partitions. The erineum is particularly characteristic in that each structure is covered with short, minute, unicellular hairs. Although erineum patches are fewer on the leaves, they are easily recognized because of their size and color.

***Aceria tristriatus* (Nalepa) [*Phytoptus tristriatus* Nalepa, *Eriophyes tristriatus* (Nalepa)]**
Common name: persian walnut leaf gall/ blister mite
Damage: It infests leaves, preferably young and produces small, brown, hard pustules that are about 1¼ mm in diameter. The mites place these galls along midribs and larger lateral veins, but in heavy infestations blisters occur elsewhere. Badly galled leaves are twisted and misshapen (Castagnioli and Oldfield, 1996).

***Cecidophyopsis vermiformis* (Nalepa) [*Phytoptus vermiformis* Nalepa, *Cecidophyes vermiformis* (Nalepa), *Eriophyes vermiformis* (Nalepa)]**
Damage: It is found on common hazel tree usually in association with *Phytoptus avellanae*. It is considered of no economic importance.

***Coptophylla lamimani* (Keifer) [*Phyllocoptes lamimani* Keifer]**
Damage: It lives as leaf vagrant on underside of hazel nut leaves causing no evident symptoms. It is considered of no economic importance.

***Phytoptus avellanae* Nalepa [*Phytocoptella avellanae* (Nalepa)]**
Syn: *Acarus pseudogalarum* Vallot [*Phytoptus pseudogalarum* (Vallot)]
Phytoptus coryli Frauenfeld
Phytoptus coryligallorum Targioti-Tozzeti [*Eriophyes coryligallorum* (Targioti-Tozzeti)]
Common name: filbert bud mite
Damage: This species is considered as a minor pest of cultivated hazelnut. It produces bud galls, known as big buds, consisting of an aggregation of swollen, thickened scale leaves, often containing hundreds of mites. Their feeding activities suppress the developing young leaves or inflorescences closed within the scales. Eventually the enlarged buds become dark and reddish brown as the immature.

***Aceria pistaciae* (Nalepa) [*Eriophyes pistaciae* Nalepa]**
Common name: pistachio bud mite
Damage: Lives on pistachio and turpentine trees causing flower stalk brooming and some leaf deformation on certain pistachio species. The brooms are reddish and noticeable.

Eriophyoids of Olive tree

***Aceria cretica* Hantzinikolis**
Damage: The mite is found on the under leaf surfaces causing subcircular patches (Hatzinikolis, 1989). It is a species that is reported only from Crete Island.

***Aceria olea* (Nalepa) [*Eriophyes oleae* Nalepa, *Phytoptus oleae* (Nalepa)]**
Common name: olive bud mite
Damage: This mite is a pest of all varieties of olive in the Mediterranean area and is especially injurious to young trees or the trees that have pollarded. It causes leaf and fruit deformation, and seriously reduces the amount and quality of olives available for pickling. As the result of mite infestations and due to the distraction of the normal silvery stellate hairs, mature leaves may show subcircular, irregular greenish patches that turn brown as necrosis progresses. These patches may bulge out as small chlorotic areas above the general leaf surface, giving the leaf an embossed appearance. In heavy infestations, the mites extend their feeding to leaf margins, which results in deformations. Damage on young fruit first appears as silvering, then browning and ends in fruit deformation. Mites congregate in large numbers at the stem end of the fruit, and find shelter under sepal rudiments. Most damage to fruit is confined to the stem.

Fruits that are fully developed before the mites become abundant do not show much damage. The species overwinters under the stellate hairs of the leaves and migrates early in spring in the flowers where it stays until the fruit is formed.

In Greece, this mite appears very frequently in high population densities mainly in regions with mild winters and humid summers. In many cases it is found associated with *A. benaki*, *D. athiasella*, *T. hassani* (Hatzinikolis and Kolovos, 1985), and it is considered an occasionally serious pest.

***Aceria olivi* (Zaher and Abou-Awad) [*Eriophyes olivi* Zaher and Abou-Awad]**

Damage: The mite forms characteristic concave patches on the undersides of the leaves, and may cause malformation to the succulent terminal leaves (Zaher and Abou-Awad, 1979). It is not considered of importance in Greece as its distribution is quite limited (Hatzinikolis and Kolovos, 1985).

***Aculops benakii* (Hatzinikolis) [*Aculus benakii* Hatzinikolis]**

Common name: olive yellow spot mite

Damage: It lives on the underside of olive leaves under the stellate hairs. As a result the stellate structures drop off, making yellow leaf spots.

In Greece it has been found mainly in coastal areas, with mild winters and relatively cool and humid summers. It attacks leaf and flower buds, flower and young fruits. It is of great economic importance in olive growing locations in Western Greece, Crete and Lesvos (Hatzinikolis and Kolovos, 1985).

***Aculus olearius* Castagnoli**

Damage: It is found only in the inflorescences from the emergence of the flower buds to the setting of the fruit. It causes the browning and withering of the flower and small fruits. It is not considered of importance in Greece as its distribution is quite limited (Papaioannou-Souliotis *et al*., 1994).

***Ditrymacus athiasella* Keifer**

Damage: It produces some leaf pitting, deformation and discoloration. It is usually found on the upper surface of young leaves, the flowering buds and small fruits (Hatzinikolis, 1982) and for a short period of time on flowers (Castagnoli and Papaioannou-Souliotis, 1982) and older leaves (Castagnoli and Pegazzano, 1986). It usually coexists with the other eriophyids and it is difficult to estimate the damage caused by this single species. Hatzinikolis (1982) reported deformation of leaves and flower and young fruit dropping due to the bud infestations.

Ditrymacus athiasella attacks on the buds causing malformed leaves and inflorescences that fall off before full development. On the leaves, mite attack is evident from the appearance of yellow-white spots on their upper surface which correspond with swellings on the lower surface. Attacks on the flowers result in drying and fall of flowers together with the secondary axes of inflorescences. Infestation of the fruits takes place only during the first stages of development, leading to premature drop of the fruits (Hantzinikolis, 1984). It has caused economic problems in Argolis and Arcadia (Hatzinikolis, 1991) and reported to occur in great population densities causing economic damage in the olive oil producing areas of Peloponnese and central Greece.

***Oxycenus maxwelli* (Keifer) [*Oxypleurites maxwelli* Keifer]**

Common name: olive leaf and flower mite

Damage: *O. maxwelli* feeds preferentially on the upper surface of terminal leaves, but in high infestations it also feeds on the lower leaf surface, buds, new shoots, flowers and stems (Jeppson *et al*., 1975). Heavy infestations may cause premature flower drop as well as leaf spotted discoloration and distortion. High infestation of the mite on young leaves can cause silvering and distortion, which reduces light absorption and decreases photosynthesis. Another problem attributed to infestations by *O. maxwelli* is the reduction in internodal length, leading to the formation of overbudding (bunchtop). In young plants, bud infestation can lead to deficient plant growth (Castagno-

li and Oldfield, 1996). Although *O. maxwelli* is frequently present in Greek olive groves, Hatzinikolis and Kolovos (1985) reported that it was found in small populations and that is not a pest of economic importance for Greece.

***Oxycenus niloticus* Zaher and Abou-Awad**
Damage: The mite infests leaves preferring the upper surface around mid-vein (Zaher and Abou-Awad, 1979). It forms characteristic concave patches on the underside of leaf and may cause deformation to the succulent terminal leaves. Its distribution in Greece is limited (Hatzinikolis and Kolovos, 1985).

***Shevtchenkella oleae* (Natcheff) [*Tegonotus oleae* Natcheff, *Lovonotus oleae* (Natcheff)]**
Damage: It attacks leaves, stems, buds and inflorescences. It has been found in small populations, and it is considered of no economic importance in Greece.

***Tegolophus hassani* (Keifer) [*Tegonotus hassani* Keifer]**
Common name: olive rust mite
Damage: It lives on both surfaces of olive leaves and apparently causes russeting and some form of leaf deformation or defoliation.

It reaches high population levels in many regions of the country where it is found in association with the other eriophyid species (Hatzinikolis and Kolovos, 1985) and may cause loss of production (Hatzinikolis, 1972).

Eriophyids of fig tree

***Aceria ficus* (Cotte) [*Eriophyes ficus* Cotte]**
Syn: *Eriophyes fici* Ewing
Common name: fig bud mite
Damage: This mite not only injures fig buds, but it also transmits fig mosaic virus, a disease that is present in Greece (Martelli *et al*., 1993). Feeding by mites that carry no virus produces variable symptoms such as russeting or surface browning, bud blasting, impedance of new growth, bad distortion, leaf chlorosis, and in severe cases the result can be defoliation of branches or of whole trees. These mites make no galls (Keifer *et al*., 1982).

***Rhyncaphytoptus ficifoliae* Keifer**
Common name: fig leaf mite
Damage: It lives as a vagrant among the under surface leaf hairs, causing no apparent symptoms.

Eriophyoids of pomegranate

***Aceria granati* (Canestrini and Massalongo) [*Phytoptus granati* Canestrini and Massalongo, *Eriophyes granati* (Canestrini and Massalongo)]**
Common name: pomegranate leaf curl mite
Damage: Pomegranate leaf curl mite occurs throughout Mediterranean region. The mite tightly rolls the leaves from the sides down onto the undersurface; these leaves maybe so tightly rolled as to produce a nearly leafless appearance to the twig but the twigs continue to elongate, indicating the twig terminal is not damaged.

Pomegranate culture has become popular during the last decade in Greece. *Aceria granati* was reported to infest the orchards of northern Greece (Drama) (Koveos *et al*., 2010), however its status as a pest is not yet determined, as the extent of the infested orchards and damages has not been studied.

Eriophyoids of grapevine

***Calepitrimerus vitis* (Nalepa) [*Phytoptes vitis* Nalepa, *Epitrimerus vitis* (Nalepa)]**
Common name: grapevine rust mite
Damage: Heavy infestations of this species prevent vines from growing normally during the earlier parts of the season. Internodes are shortened, foliage becomes bunched, which interferes with proper pruning; grape production is reduced. Damage to grape clusters occurs either because flowers are injured or because development is delayed. The foliage has a browning and russeting aspect. The leaves present malformation followed by a premature dropping. As a result of the shortened internodes and the devel-

opment of additional shoots after the death of the main bud, the vine presents "witches broom" appearance.

***Colomerus vitis* (Pagenstecher) [*Phytoptus vitis* Pagenstecher, *Eriophyes vitis* (Pagenstecher)]**

Syn: *Eriophyes vitis* (Landois) [*Phytoptus vitis* Landois]

Common name: grape bud mite or grape erineum mite

Damage: Three forms of *C. vitis* have been reported to cause different types of injury to grape vines. One form feeds on the leaves and causes the appearance of patches of felty erineum on the lower surface, followed by blister-like swellings on the upper surface. The erineum patches are whitish at first, then yellow and finally reddish brown. At times they are abundant in early spring in commercial vineyards or throughout the season on abandoned and backyard vines. Another form of *C. vitis* attacks grape buds, causing deformation of the primordial bud clusters, distortion of the basal leaves, stunting of the main growing point, and often death of the overwintering buds. This form does not produce erineum on the leaves. The third form produces leaf curl and abnormal plant hairs at the colonies sites.

Natural enemies

Much of the ongoing research aiming at controlling eriophyoid mites in the last decade has been focused on biological control with the use or conservation of predatory mites (van Leeuwen *et al.*, 2010).

Predators of the eriophyoid mites include insects (Chalcidoidea, Thysanoptera) and predaceous mites of Phytoseiidae, Stigmaeidae and Anystidae (Jeppson *et al.*, 1975; Sabelis, 1996). The importance of the predatory phytoseiid and stigmaeid mites for the control of eriophyoid mite populations has been well documented by several authors (Abou-Awad and El-Banhawy 1986; Amano and Chant 1986; Abou-Awad *et al.*, 1998; Abou-Awad *et al.*, 2005).

Among the phytoseiid species that use mostly eriophyoid mites as a food source are *Iphiseius degenerans* (Berlese), *Euseius finlandicus* (Oudemans), *Euseius stipulatus* (Athias-Henriot), *Kampimodromus aberrans* (Oudemans), *Amblyseius andersoni* (Chant), *Typhlodromus* (*Typhlodromus*) *pyri* Scheuten, *Typhlodromus* (*Typhlodromus*) *exhilaratus* Ragusa, *Typhlodromus* (*Typhlodromus*) *athiasae* Porath and Swirski, *Paraseiulus talbii* (Athias-Henriot) and species of the genus *Neoseiulus* (Sabelis, 1996; McMurtry and Croft, 1997; Kreiter and Tixier, 2010). Also, stigmaeid mites, *Zetzellia mali* Ewing and *Agistemus* spp. are well-known predators of eriophyoid mites (Abou-Awad *et al.*, 1998; Childers *et al.*, 2001; Gerson *et al.*, 2003; Duso *et al.*, 2008).

In Greece, many phytoseiid species are found in fruit orchards and vineyards. Among the phytoseids recorded in stone fruits, *E. finlandicus*, *E. stipulatus*, *A. andersoni* and *K. aberrans* are the more frequent and abundant. The stigmaeid predator *Z. mali* is also very frequent (Papaioannou-Souliotis *et al.*, 1994). Papanikolaou and Bakoyiannis (1991) reported a hymenopteran larva (unidentified species, probably belonging to the family Eulophidae) associated with galls of *A. phloeocoptes*, which showed very low predation.

Typhlodromus pyri, *A. andersoni* and *E. finlandicus* are frequent in apple orchards (Papaioannou-Souliotis *et al.*, 1994; Markoyiannaki-Printziou *et al.*, 2000; Papadoulis *et al.*, 2009) and may play a major role in keeping apple rust mite populations below economic damage levels (Easterbrook 1996; Duso and Pasini 2003; Fitzgerald *et al.*, 2003).

Phytoseiid predatory species found in citrus orchards in Greece include *E. stipulatus*, *Euseius scutalis* (Athias-Henriot), *Typhlodromus* (*Anthoseius*) *athenas* Swirski and Ragusa, *T.* (*T.*) *athiasae*, *P. talbii*, *A. andersoni* and *I. degenerans* (Papadoulis *et al.*, 2009). *Euseius stipulatus* is the main phytoseiid predator holding 80% of the phytoseiid population in citrus groves (Papaioannou-Souliotis, 1991). Generalist predators such as *E. stipulatus* can control the phytophagous mite populations at low densities (McMurtry *et al.*, 1992).

Ozman Sullivan (2006) evaluated the biology of the phytoseiid *K. aberrans*, a possible predator of the big bud mite *P. avellanae*, which is a common pest in Greek hazelnut orchards, and concluded that *K. aberrans* can play an important role in IPM programmes to control *P. avellanae* when it is released in early spring to boost the population before *P. avellanae* migration.

In olive groves, predatory species of Phytoseiidae comprise *A. andersoni*, *T.* (*A.*) *athenas*, *Typhlodromus* (*Anthoseius*) *foenilis* Oudemans, *Typhlodromus* (*Typhlodromus*) *cotoneastri* Wainstein and *K. aberrans* (Papaioannou-Souliotis *et al.*, 1994; Papadoulis *et al.*, 2009). *Euseius stipulatus*, *K. aberrans*, *E. finlandicus* and *Phytoseius plumifer* (Canestrini and Fanzago) are the most common species found on fig trees (Papaioannou-Souliotis *et al.*, 1994).

On pomegranate, the following phytoseiid species have been reported *T.* (*A.*) *athenas*, *Typhlodromus* (*Anthoseius*) *psyllakisi* Swirski and Ragusa, *T.* (*T.*) *athiasae* (Papadoulis *et al.*, 2009). Koveos *et al*. (2010) found an unidentified stigmaeid mite in association with *A. granati* on pomegranate.

On grapevine, the most common and abundant species of Phytoseiidae are *K. aberrans*, *E. finlandicus*, *P. plumifer*, *T.* (*A.*) *athenas*, *T.* (*T.*) *exhilaratus* and *P. talbii*, (Soulioti *et al.*, 1998; Papadoulis *et al.*, 2009). The stigmaeid mites *Zetzellia graeciana* Gonzalez and *Z. mali* have also been reported (Papaioannou-Souliotis *et al.*, 1994).

Monitoring

Monitoring eriophioid mites is a difficult task due to their minute size (average 100 μ) and concealed way of life. The presence of eriophyoids is usually transpicuous when the symptoms become apparent. In the case of rust mites, monitoring involves collection of leaves or fruits and counting the number of mites. To assess populations, leaves should be examined with a hand lens with at least 10x magnification. Although it is impractical to obtain accurate population counts with this method, if many individuals are noticed, more intensive sampling should be considered, ideally with a dissecting microscope. Hall *et al.* (2005, 2007) investigated the effects of reducing the sample size on the accuracy of estimation of citrus rust mite densities in oranges and proposed a binomial sampling based on the proportion of eriophyoid infested samples.

Chemical Control

In general, eriophyoid mites prove to be fairly susceptible to the most commonly used acaricides, as was demonstrated by Childers *et al.* (1996) who made a thorough review of the chemical control of eriophyoids. Since then there have been changes to registered acaricides mostly in Europe, and most of the substances tested are no longer in use. However, a rather limited amount of reports has investigated the suitability of modern crop protection compounds for controlling rust, gall, blister and bud mites. Moreover, these reports are mainly restricted to a number of major crops like citrus and apple orchards and major pests as *P. oleivora* and *A. schlechtendali*, respectively. The main reason for the lack of information on the toxicity and other aspects of new compounds can be probably brought back to the lower economic importance of these mites, in comparison to other mite pests such as the spider mites (Acari: Tetranychidae).

In Greece, there are no thresholds for the damage caused by eriophyoid mites. The usual practice is acaricide or sulfur treatment when the infestation is evident to affect the trees' vigor or yield. Registered acaricides (active substances) for control of mites in orchards and grapevine are given in Table 2.

The usual practice for the management of *A. phloeocoptes* and *A. fokeui* in stone fruit orchards is application of selective acaricides. For *A. phloeocoptes* application time is in early spring (March) at the opening of the buds when the mites are migrating to new buds while for *A. fokeui* it is in summer (Pa-

Table 2. Registered acaricides of tree orchards and grapevine in Greece (Authorized Plant Protection Products Data Base, Hellenic Ministry of Rural Development and Food, 2012) (http://wwww.minagric.gr/syspest/syspest_ENEMY_crops.aspx).

Crops	Active substance of registered acaricides
Stone fruits	
Plum	paraffin oil, clofentezine
	fatty acid potassium salt, paraffin oil, etoxazole and clofentezine
Almond	fatty acid potassium salt, paraffin oil, acequinocil, clofentezine, etoxazole, hexythiazox, spirodiclofen and pyridaben
Peach	paraffin oil
Cherry	paraffin oil, fatty acid potassium salt, clofentezine ,hexythiazox, tebufenpyrad, etoxazole, acequinocyl
***Citrus* spp.**	paraffin oil, fatty acid potassium salt, clofentezine, diflubenzuron, etoxazole, fenpyroximate, tebufenpyrad, pyridaben, milbemectin, acequinocyl
Olive	paraffin oil
Nuts	
Walnut	fatty acid potassium salt
Pistachio	none
Hazelnut	fatty acid potassium salt
Fig tree	none
Pomegranate	none
Grapevine	paraffin oil, fatty acid potassium salt, sulphur, copper oxychloride, hexythiazox

paioannou-Souliotis, 2001).

The recommended practice for infestations of apple rust mite is pre-blossom treatment with paraffin oil and/or summer spraying with acaricides (Papaioanou-Soulioti, 2001). No threshold limit is established in Greece for *A. schlechtendali*. Ontario Ministry of Agriculture, Food and Rural Affairs reports a threshold on apple rust mite population, which is 200-500 mites per leaf (Solymar and Walker, 2011). In lower population, application must be avoided because the apple rust mite provides valuable prey for predatory mites.

In citrus groves in Greece, *A. pelekassi* and *A. sheldoni* may develop high populations when weather conditions are favorable. In the case of high infestation of *A. pelekassi* and *A. sheldoni* in citrus orchards, selective acaricides should be applied against *A. pelekassi* in summer (beginning of June) and autumn (mid-September to mid-November) and against *A. sheldoni* in spring and at the beginning of June (Papaioannou-Souliotis, 1985).

In olive groves when outbreaks of eriophyoids occur under favorable weather conditions, two applications with sulfur or paraffin oil are recommended, the first early in spring before flowering and the second 10-15 days later (Broumas and Katsoyiannos, 2009).

In grapevine, it is well demonstrated that sulfur sprayings applied early in the spring can control mite populations e.g. sulfur sprayings applied at the onset of the

wooly bud stage when mites become active, followed by a second spraying approximately 10 days later when late-developing buds open. Papaioannou-Souliotis *et al*. (1998) investigated the effect of some commonly used fungicides and insecticides on phytoseiid populations in vineyards in four regions of Greece.

There are no registered acaricides in Greece for fig and pomegranate cultivations. The cultivation of fig tree is traditional in southern parts of mainland Greece and the Aegean islands, yet yield loss due eriophyoid infestation has been reported (Vachamidis and Vemmos, 2010). Pomegranate culture has become popular during the last decade in Greece. *Aceria granati* has been reported to infest cultivations in northern Greece recently (Koveos *et al*., 2010) but the possible effect on yield is not yet determined.

Discussion

The economic importance of eriophyoid mites has been estimated in some countries but the variability of environmental conditions, cultural practices, cultivar features and market standards make a generalisation based on these studies difficult. A number of eriophyoid species emerged as economically important and their pest status has been reconfirmed recently, mainly in crops like citrus, apples, grapes, hazelnuts, coconuts and tomatoes (Van Leeuwen *et al*., 2010). In Greece, the economic importance of eriophyoid mites as pests of orchards and grapevine has not been much exploited. Most of them are considered occasional pests whereas outbreaks often occur after warm winters and springs with high rainfalls. The change in control strategies mainly towards the use of fungicides lacking acaricidal activity and of insecticides having a detrimental effect on predatory mites might cause outbreaks of rust mites and result in the permanent pest status of the species (Easterbrook, 1996; Croft and Slone 1998). In addition, the climate change might be important of future outbreaks of the eriophyoid mite pests.

In general, eriophyoid mites are susceptible to most commonly used acaricides, some insecticides and fungicides (especially sulphur). The European Union review programme of the existing active substances under the Directive 91/414/EEC, resulted in the reduction of the available substances with acaricidal effect. The lack of registered acaricides for some cultivations such as pomegranate in Greece, may cause a problem in the future.

The main problem with the control of eriophyoids is getting the compounds in contact with the mites due to hidden lifestyle of a number of important species. Mites hiding in galls, blisters and buds are not easily accessible. In these cases, an accurate timing of the applications is crucial, in order to reach the life stages that (temporarily) leave the hiding places, and can, only at those times, be reached with pesticides. That is why, in most cases, control is directed against the adults which are searching for spots to induce their hiding places for the immature life stages (gall mites) or for existing shelters (bud mites) and for a limited time, few days or weeks. Hence, control is best succeeded with acaricides providing long residual activity. On the other hand, rust mites have a more superficial lifestyle on the underside of leaves, leaving them exposed throughout their life cycle and resulting in easier control. In cropping systems where eriophyoid mites cause economic damage, such as apple and citrus orchards, and Tetranychidae are also main pests, application timing and product choice should reflect concerns on the economic damage of both species. (Van Leeuwen *et al*., 2010).

The conservation of indigenous natural enemies for controlling eriophyoid mites is gaining more attention in the last decade (Smith and Papacek, 1991). Morover, the search for exotic natural enemies and release remains an option, in cases that local predators fail or are less successful in controlling these mite pests (Argov *et al*., 2002).

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ΑΡΘΡΟ ΑΝΑΣΚΟΠΗΣΗΣ

Ακάρεα της υπεροικογένειας Eriophyoidea σε δενδρώδεις καλλιέργειες και αμπέλι στην Ελλάδα

Ε.Β. Καπαξίδη

Περίληψη Τα ακάρεα της υπεροικογένειας Eriophyoidea απαντώνται σε όλες τις δενδρώδεις καλλιέργειες και αμπελώνες της Ελλάδας. Είναι εξειδικευμένα παράσιτα φυτών και κάποια είδη μπορεί να προκαλέσουν ζημιές στην παραγωγή. Τα συμπτώματα που προκαλούν ποικίλουν από παραμορφώσεις φύλλων, βλαστών ή καρπών μέχρι και μεταχρωματισμούς. Μέχρι σήμερα τριάντα τρία είδη έχουν αναφερθεί στις δενδρώδεις καλλιέργειες και το αμπέλι στην Ελλάδα, τα οποία ανήκουν στις οικογένειες Eriophyidae, Diptilomiopidae και Phytoptidae. Στην παρούσα εργασία δίδονται στοιχεία για τους ξενιστές, την συμπτωματολογία, τους φυσικούς εχθρούς και την αντιμετώπισή τους ως εχθρούς των Ελληνικών οπωρώνων και αμπέλου.

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