A

EGYPTIAN ACADEMIC JOURNAL OF

BIOLOGICAL SCIENCES

ENTOMOLOGY

ISSN
1687-8809

WWW.EAJBS.EG.NET

Vol. 16 No. 4 (2023)

Citation: *Egypt. Acad. J. Biolog. Sci. (A. Entomology) Vol. 16(4) pp.99-116 (2023)*
DOI: 10.21608/EAJBSA.2023.329416

Egypt. Acad. J. Biolog. Sci., 16(4):99-116 (2023)

Egyptian Academic Journal of Biological Sciences
A. Entomology

ISSN 1687- 8809
http://eajbsa.journals.ekb.eg/

Distribution of Mites Inhabiting Agricultural Importance, with Emphasis on Predators Role in Pest Control

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ARTICLE INFO

Article History
Received:5/11/2023
Accepted:10 /12 /2023
Available: 14/12 /2023

Keywords:
Diversity,
Frequency,
Frugivorous mites,
IPM,
phytophagous
mites; Predators.

ABSTRACT

The current study demonstrated the frequency and prevalence of various mite species on various vegetation types in the Egyptian governorates of Giza and Monufia. Between June 2019 and July 2021, samples were collected monthly from leaves, litter, and soil of fruit trees, vegetable crops, and ornamental plants at both locations. Leave samples were examined directly; however, soil and litter samples were extracted using modified Tullgren funnels. The mite survey revealed the occurrence of 19 predatory mite species belonging to four mesostigmatic families and three prostigmatic families. Nine of which are predatory species belong to the family Phytoseiidae and some of these predators are commercially produced as biological control agents such as *Phytoseiulus persimilis* Athias-Henriot, *Euseius scutalis* (Athias-Henriot), *Neoseiulus californicus* (McGregor) and *Amblyseius swirskii* Athias-Henriot that have been successfully applied in many countries and play an important role in control of mite pests. The presence of them is related to six species of plant-feeding mites from two families (Tetranychidae and Tenuipalpidae). In addition to three mite species with uncertain feeding habits in the family Tydeidae. The relationship between predators and pest reduction is discussed. The frequency of different mite habitats inhabiting several cultivations was mentioned as well. Obtained results are necessarily being considered in biological control decisions.

INTRODUCTION

Plant-feeding mites are serious pests in agricultural ecosystems that cause economic damage to their host plants. They are usually controlled by synthetic pesticides, which is a critical point given the need to find alternatives to pesticides that pose a significant risk to people and the planet and whose use is illegal in many countries worldwide. Crop production has shifted in recent decades from yield to quality, safety, and sustainability. To that end, the concept of integrated pest management (IPM) strategies based on biocontrol agents has gained importance (Fathipour and Maleknia 2016).

Future demand for biocontrol agents is anticipated to be significant due to the increased demand for safe food (Fathipour and Maleknia 2016). The performance of natural enemies is influenced by host plant characteristics and environmental conditions (Gulati 2014).

Biological control and the use of predators are being highlighted as important and effective control methods, as well as an alternative to chemical pest control. Mite predators play an important role in mite pest control, with the families Phytoseiidae, Ascidae, and Stigmaidae leading the group (Akpinar *et al.*, 2017).

Phytoseiids are the best-known and most-studied predatory mites due to their success in controlling spider mites (van Lenteren 2001; Nomikou *et al.*, 2002), other mites, and thrips. Biological control of spider mites using natural enemies such as phytoseiid mites has grown in importance as an alternative to conventional chemical control (Gerson and Weintraub 2007).

Despite their reputation as predators of small arthropods and nematodes, most phytoseiids also consume fungi, plant exudates, pollen, and other food items. Some can even extract liquid from leaf cells. Other predators from Mesostigmata and Prostigmata are thought to be important natural enemies of mites and play an important role in biological control.

Therefore, the aim of this work is to do a convenient survey of species of predatory mites and their associated prey as well as study their diversity, frequency, and the role they play in biological control programs and suppress pest populations of different agricultural importance.

MATERIALS AND METHODS

Mite Diversity:

Various fruit trees, e.g., apple (*Malus domestica* Borkh.), apricot (*Prunus* spp.), peach (*Prunus persica* (L.) Batsch), pear (*Pyrus* spp.), quince (*Cydonia oblonga* Mill.), loquat (*Eriobotrya japonica* (Thunb.) Lindl.) (Rosaceae), citrus (*Citrus* spp., Rutaceae), grape (*Vitis* spp., Vitaceae), mango (*Mangifera indica* L., Anacardiaceae), guava (*Psidium guajava* L., Myrtaceae), and papaya (*Carica papaya* L., Caricaceae); vegetable crops, e.g., strawberry (*Fragaria* × *ananassa* Duchesne, Rosaceae), cucumber (*Cucumis sativus* L., Cucurbitaceae), eggplant (*Solanum melongena* L., Solanaceae), and beans (*Phaseolus vulgaris* L. Fabaceae); and ornamental plants, e.g., castor (*Ricinus communis* L., Euphorbiaceae) and rose (*Rosa* spp., Rosaceae) were studied.

Samples from leaves, litter, and soil from each plant species were collected in two regions: the Faculty of Agriculture (26°29'25.26"N, 80°18'28.476"E), Cairo University, Giza governorate, and El Sadat City Desert (30°16'48.7"N, 30°41'50.0"E), Monufia governorates, Egypt, from June 2019 to July 2021. Mite samples were kept in polyethylene bags labelled with the habitat, location, and date of collection before being transported to the laboratory for extraction and examination. A stereo-microscope (ZEISS Microscope, Germany) was used to examine leave samples. Approximately 250g samples of soil and litter underneath each plant species were extracted using modified Tullgren funnels. The mites were cleared in Nesbitt's solution before being mounted on microscopic glass slides in Hoyer's medium (Krantz and Walter 2009). Zaher, (1984, 1986); Abo-Shnaf and Moraes, (2014, 2016); and Abo-Shnaf *et al.,* (2022a) were used to identify mite specimens at the species level.

Mite frequency:

Calculation of mite numbers of each taxon per sample were calculated as the method recommended by Platts-Mills *et al.*, (1990). The frequency of mite species from each mite group in different habitats was calculated using the adapted formula after Abo-Shnaf *et al.*, (2008) as below:

$$\text{Percentage of total count} = \frac{\text{Total number of mite species collected}}{\text{Total number of collected mite specimens}} \text{ X } 100$$

RESULTS AND DISCUSSION

Mite Diversity:

The current study reported the presence of 28 species of prostigmatid and mesostigmatid mites, belonging to 24 genera and ten families of different agricultural importance at Giza and Monufia governorates **(**Table 1).

Our findings are consistent with that of Heikal and Kassem, (2018), who collected similar mite families associated with citrus orchards in Monufia governorate. According to previous research, 44 mite species with different feeding habits were identified in citrus orchards in Fayoum governorate (Ata *et al.* 2016), compared to 33 mite species reported by Rahil and Abd El-Halim, (2000) on the same vegetation and location. Also, Abdelgayed *et al.*, (2017) reported that 39 mite species collected from citrus trees in the Assiut governorate, six of which are predatory species belonging to the family Phytoseiidae, and the presence of them are related to nine species of phytophagous mite belong to families (Tarsonemidae, Tenuipalpidae and Tetranychidae). Likewise, Hussian *et al.*, (2018) found 44 mite species belonging to 36 genera and 21 families collected from fruit trees in the Ismailia governorate.

The present work included four families of Mesostigmata, with the family Phytoseiidae being the most dominant among predatory mites with nine species in seven genera. The abundance of the mite species, *Euseius scutalis* (Athias-Henriot) and *Phytoseiulus persimilis* Athias-Henriot were the highest in this family on the studied vegetation, followed by *Amblyseius swirskii* (Athias-Henriot), *Neoseiulus californicus* (McGregor), *Typhlodromus* (*Anthoseius*) *egypticus* El-Badry, and *Neoseiulus zaheri* (El-Borolossy). Family Laelapidae has three genera and species, Ameroseiidae has two genera and species, and Melicharidae has only one species. Prostigmatid mites are represented by six families, including three predator mite families, two phytophagous mite families, and one with uncertain feeding habits (family Tydeidae with two genera and three species). Family Cheyletidae has two genera and species, Raphignathidae and Stigmaeidae each with a single species. Tetanychidae and Tenuipalpidae are plant-feeding mite families with three species each (Table 1). Previous research on citrus orchards collected the majority of phytophagous and predatory mites (Heikal and Kassem 2018). Likewise, from a previous study on mite species inhabiting some fruit trees Hussian *et al.*, (2018) found that the mite species belonging to 14 families: Tetranychidae (7 species), Tenuipalpidae (8 species), Eriophyidae (one species), Stigmaeidae (2 species), Neophyllobiidae (2 species), Caligonellidae (one species), Raphignathidae (one species), Cheyletidae (3 species), Eupalopsellidae (one species), Bdellidae (one species), Cunaxidae (one species), Eupodidae (one species), Tydeidae (3 species) and Tarsonemidae (one species) all of which are belonging to suborder Prostigmata. In addition to three families; Phytoseiidae (4 species), Ologamasidae (one species) and Ameroseiidae (one species) belonging to suborder Mesostigmata.

Prey-Predator Relationship:

Tetranychus urticae Koch (Tetranychidae) is a major pest of many crops globally (Alatawi *et al.*, 2011). Furthermore, *T. urticae* was found to be the most abundant plant-feeder mite on the majority of the plants studied. It was found on ornamental plants (e.g., castor and roses), vegetable crops (e.g., cucumber, eggplant, beans, and strawberry), and fruit trees (e.g., citrus, peach, apricot, and mango) in a high number, along with the most dominant predatory mite, *P. persimilis*. Our finding indicated that *P. persimilis* suppressed the *T. urticae* population, resulting in highly effective mite pest control on the studied vegetation. There is a large literature indicating the association of *Phytoseiulus* with *Tetranychus* species in the field.

According to McMurtry *et al.*, (2013), this species is a type I lifestyle that feeds exclusively on web-producing spider mites, specifically *T. urticae*, and whose survival is dependent on the presence and quality of its prey. Because of its ability to control spider mites, *P. persimilis* is being mass-produced and has become one of the first commercially available greenhouse biological control agents. Similar to our findings, *P. persimilis* utilized an active bioagent to control *T. urticae* (Blumel and Walzer 2002; Opit *et al.* 2004).

Neoseiulus californicus lives a type II lifestyle (McMurtry *et al.* 2013), it shows adaptations for living in spider mite colonies with heavy webbing; it has the ability to cut strands of webbing with the chelicerae (Shimoda *et al.* 2009). Our findings show *N. californicus* associated with *T. urticae* as prey on vegetable crops (e.g., eggplant and strawberry), and fruit trees (e.g., citrus and grape) in a moderate number. It suppressed the population of *T. uricae* as an important natural enemy of this mite pest. Because of the widely known efficiency of *N. californicus* as a control agent of tetranychid mites (i.e, Jolly 2000; Toldi *et al.* 2013), it is used as an effective predator in the integrated management of *T. urticae* (Walzer *et al.* 2007).

Euseius scutalis is commonly found in association with tetranychid mites, scale insects, whiteflies and various insect immatures, as well as pollens (McMurtry 1992; Raza *et al.* 2005) and appears to be a promising pest control agent (Al-Shammery 2010).

Corroborating previous findings by Abbassy *et al.*, (2012); Fouly *et al.*, (2013); El-Khouly and Abd-Elgayed, (2019), *E. scutalis* was found in a large number feeding on *T. urticae* on castor, papaya, pear, loquat, guava, apple mango, and orange cultivation and it is typically a significant natural enemy of this mite pest.

Table 1. Mites inhabiting fruit orchards, vegetable crops, and ornamental plants at Giza and Monufia governorates during June 2019 and July 2021.

Mite group	Family	Mite taxa	Host plant	Remark
Mesostigmata	Ameroseiidae	*Kleemannia wahabi* Ibrahim & Abdel-Samed	Citrus (litter, soil)	++
		Sertitympanum zaheri (El-Badry, Nasr & Hafez)	Litters and soil (citrus, apple)	+
	Laelapidae	*Androlaelaps casalis* (Berlese)	Citrus (soil)	+
		Gaeolaelaps orientalis (Hafez, El-Badry & Nasr)	Citrus (litter, soil)	+
		Laelaspis calidus Berlese	Soil	+
	Melicharidae	*Proctolaelaps pygmaeus* (Müller)	Litters and soil (citrus, mango)	+
	Phytoseiidae	*Amblyseius swirskii* (Athias-Henriot)	Apple, guava, mango, citrus (leaves and litter)	++
		Euseius scutalis (Athias-Henriot)	Papaya, pear, loquat, guava, apple, mango, orange, castor (leaves), ornamentals	+++
		Kuzinellus niloticus (El-Badry)	Citrus, loquat leaves, ornamentals	+
		Neoseiulus californicus (McGregor)	Eggplant, strawberry, grape (leaves), citrus	++
		N. zaheri (El-Borolossy)	Ornamental plants	++
		Paraseiulus talbii (Athias-Henriot)	Citrus, mango leaves	+
		Phytoseiulus persimilis Athias-Henriot	Mango, citrus (leaves and litter)	+++
		Typhlodromus (*Anthoseius*) *egypticus* El-Badry	Apple, mango (leaves)	++
		T. (*Typhlodromus*) *athiasae* Porath & Swirski	Apple, mango, orange (leaves), citrus	+
Prostigmata	Cheyletidae	*Cheletomimus bakeri* (Ehara)	Mango	+
		Cheyletus malaccensis Oudemans	Soil underneath fruit orchards	+
	Raphignathidae	*Raphignathus sayedi* Gomaa & Hassan	Litter, soil	+
	Stigmaeidae	*Agistemus exsertus* Gonzalez	Mango, citrus (leaves, litter, soil), loquat, apple, eggplant, pear (leaves)	++
	Tenuipalpidae	*Brevipalpus obovatus* Donnadieu	Citrus, pear, apple, (guava leaves), ornamental plants	+
		Cenopalpus lanceolatisetae (Attiah)	Pear, peach, apricot (leaves)	+++
		C. pulcher (Canestrini & Fanzago)	Apple, quince (leaves)	+++
	Tetranychidae	*Eutetranychus africanus* (Tücker)	Citrus, apple, peach, grape, papaya (leaves)	+
		Panonychus citri (McGregor)	Citrus	+
		Tetranychus urticae Koch	Castor, rose, cucumber, eggplant, beans, peach, citrus (leaves, litter), apricot (leaves), ornamental plants	+++
	Tydeidae	*Paralorryia zaheri* Baker	Soil	+
		Tydeus oregonenesis Baker	Mango (litter, soil)	+
		T. schusteri André & Naudo	Mango (litter, soil)	+++

+: Few numbers (1–4 individuals/leaf) ++: Moderate numbers (5–10 individuals/leaf) +++: High numbers (>10 individuals/leaf)

Typhlodromus (*Typhlodromus*) *athiasae* Porath & Swirski is a vital bio-control agent. It is found in Egypt on leaves and litter of citrus, mango and datura plants at Giza and Monufia governorates (Zaher 1986), as well as Fayoum governorate (Rhahil and Abd El-Halim 2000). In a recent study by Abo-Shnaf *et al.*, (2022b) it was collected on mango trees. Our findings reported *T. uricae* in a few numbers on citrus, apple, mango and orange orchards associated with *T.* (*T.*) *athiasae*. Laboratory studies confirmed the ability of this predator to feed on *T. urticae* eggs (Momen 2009; Basheer *et al,*. 2014; Abden *et al.*, 2021).

Eutetranychus africanus (Tücker) (Tetranychidae) was distributed on orange trees at Giza and Fayoum governorates (Attiah 1967). In the current study, *E. africanus* was collected in a few numbers on the leaves of different fruits trees such as citrus, apple, peach, grape, and papaya combined with the phytoseiid mites: *A. swirskii*, *E. scutalis*, *K. niloticus*, *N. californicus, T.* (*A.*) *egypticus*, and *T.* (*T.*) *athiasae* as well as the stigmaeid mite, *Agistemus exsertus* Gonzalez. It is expected that phytoseiid mites will help to suppress the population of this mite pest.

Euseius scutalis successfully developed and reproduced on *E. africanus*. It would be a far more promising agroecosystem predator of *E. africanus* (Al-Shammery 2010; Abo-Shnaf 2021).

The predatory mite, *T.* (*T.*) *athiasae* was observed feeding on *E. africanus* on the leaves of apple and citrus trees in the present study. Abden *et al.*, (2021) confirmed the efficacy of this predator feeding on the brown citrus mite, *Eutetranychus orientalis* (Klein).

Kiptoo *et al.*, (2022) used *Amblydromalus hum* (Pritchard & Baker), *Amblyseius sundi* Pritchard & Baker, *Typlodromalus denheyeri* (Zannou, Moraes & Oliveira), and *Euseius kenyae* (Swirski & Ragusa) to manage *E. africanus* on citrus orchards in Kenya. El-Badry *et al.*, (1969) and Abou-Awad and Elsawi (1993) reported the ability of *A. exsertus* to control *E. orientalis* in Egypt.

Typhlodromus (*A.*) *egypticus* distributed on different fruit orchards in Sinai (Zaher 1984). It was recorded at Giza governorate (El-Badry 1967; Zaher 1986, Abo-Shnaf *et al.*, 2022b), as well as at Cairo, Ismailia, and Matrouh governorates on mango (mentioned as *Typhlodromus mangiferus* according to Abo-Shnaf and Moraes 2014) (Zaher 1986). In the current work, it was found in a moderate number on the leaves of apple and mango trees, along with *Brevipalpus obovatus* Donnadieu, *Cenopalpus pulcher* (Canestrini & Fanzago), and *E. africanus*, which are common as prey on apple trees. *Typhlodromus* (*A.*) *egypticus* may have an impact on their management. This predator is feeding on *T. urticae* and *E. orientalis* (Zaher 1986).

Neoseiulus zaheri was collected in a moderate number on some ornamental plants associated with *T. urticae* and *B. obovatus* which could help in reducing both pests' populations. No previous studies used *N. zaheri* for biological control. However, pest control purposes have been reported in some studies by other *Neoseiulus* species, i.e., *N. californicus* for *T. urticae* in commercial greenhouse strawberries in Brazil (Sato *et al.* 2007); *Neoseiulus barkeri* Hughes for *T. urticae* on strawberries in China (Li *et al.*, 2022); and *Neoseiulus idaeus* Denmark & Muma for *B. obovatus* on cassava in Brazil (Tamai *et al.*, 1997). This gives the impression that *N. zaheri* may play a role in the management of both *T. urticae* and *B. obovatus*, but more investigation is warranted.

Agistemus exsertus is a generalist predator that feeds on phytophagous mites (tetranychids, tenuipalpids, and eriophyids), scale insects, whiteflies, stored product moths, and pollen grains (Saber and Rasmy 2010). The present study indicated the incidence of *T. uricae* in moderate numbers on the leaves of eggplant, mango, citrus, loquat, apple, eggplant, and pear, as well as in soil and citrus litter associated with this predatory mite. It decreased the *T. uricae* population, resulting in highly effective control of this pest. Biological experiments confirmed the effectiveness of *A. exsertus* in feeding on *T. urticae* (Afify *et al.*, 1969; Waked 2016), making it a promising biological control agent against tetranychid mites (Al-Shammery 2011).

Citrus spider mite, *Panonychus citri* (McGregor) (Tetranychidae), is a mite pest on citrus trees that supports the findings of our study, in which it was recorded in a few numbers as prey for *A. swirskii*, *E. scutalis*, *N. californicus*, and *T.* (*T.*) *athiasae* on citrus trees. They significantly reduced the population of *P. citri*.

Kasap, (2011) demonstrated that *T.* (*T.*) *athiasae* effectively control *P. citri* on citrus trees in Turkey, reducing its population which is consistent with our findings. Kasap and Şekeroğlu, (2004) and Xiao and Henry, (2010) reported some phytoseiid mites, such as *N. californicus* and *E. scutalis* as effective natural enemies of *P. citri*. According to Bounfour and McMurtry, (1987), nymphs and adults of *E. scutalis* fed on all stages of *P. citri*.

In Egypt, Abbassy *et al.*, (2012) indicated that *E. scutalis* fed *Panonychus ulmi* (Koch) at different temperatures.

Amblyseius swirskii is a type III generalist predator that feeds on a variety of insects, phytophagous mites, plant pollen, and plant exudates (McMurtry *et al.*, 2013). The results herein recorded this predator as an effective natural enemy of *P. citri* on citrus. It not only successfully reduces pest populations, but also controls a wide range of pests, including spider mites (El-Laithy and Fouly 1992). Hussian *et al.*, (2018) found that it was associated with mango spider mite, *Oligonychus mangiferus* (Rahman and Sapra, 1940) on mango trees. Ji *et al.*, (2013) explained the ability of this predator to feed on *P. citri* which resamples to our findings. *Scapulaseius newsami* (Evans) and *Amblyseius eharai* Amitai & Swirski are effective natural enemies of *P. citri*, reducing their population to less than one mite per leaf in China (Wu *et al.*, 2010).

Other studies mentioned *N. cucumeris* (Oudemans) and *N. barkeri* as effective *P. citri* control agents (Zhang *et al.*, 2001; Li and Zhong 2007).

The current result also investigated *P. citri* on citrus trees in a low number along with the stigmaeid mite, *A. exsertus*. It decreased the *P. citri* population in citrus. Yue and Childers, (1994) reared *A. exsertus* on *P. citri* in Florida with the best results in terms of prey consumption and egg production at 25°C.

Brevipalpus mites are major pests of crops and ornamental plants worldwide (Meyer 1979; Evans *et al.*, 1993). Although this genus is regarded as the most important group of species within the family Tenuipalpidae, but is not as important as spider mites (Childers *et al.* 2003a). The three most economically important *Brevipalpus* species are *B. californicus* (Banks), *B. obovatus*, and *B. phoenicis* (Geijskes) which have been reported on citrus in the same geographical areas worldwide including Egypt (Childers *et al.* 2003b; Zaher 1984).

The findings show that *B. obovatus* was found in low numbers on citrus, pear, apple, and guava trees as well as some ornamental plants associated with both phytoseiids, *E. scutalis* and *Typhlodromus* (*T.*) *athiasae*, and stigmaeid, *A. exsertus* which has significantly reduced the population of this mite pest and effectively controlled on such vegetation. *Amblyseius largoensis* (Muma) and *Galendromus* (*Galendromus*) *occidentalis* (Nesbitt) can feed on *Brevipalpus* spp. (Palomares-Pérez *et al.*, 2021), which is similar to our results even with different predators. In Mexico, *P. persimilis*, *Amblyseius largoensis* (Muma), *E. scutalis*, and *N. cucumeris* have all been identified as natural enemies of *B. californicus* on citrus (Cortez-Mondaca *et al.*, 2022).

The present result indicated also that *Cenopalpus lanceolatisetae* (Attiah) was collected in high numbers on apricot, pear, and peach orchards with the predatory mite, *A.*

exsertus. The number of *A. exsertus* increase was synchronized with the decrease in *C. lanceolatisetae*, implying that *A. exsertus* has the potential to control this mite pest effectively. According to El-Laithy and Fouly, (1992), *A. exsertus* feeds on tenuipalpid, tetranychid, and eriophyid mites on apple orchards; that contradicts a previous study in which *A. exsertus* feeds on tetranychoid mite eggs and immature stages (El-Bagoury *et al.*, 1989).

Cenopalpus pulcher was found in a high number of leaves of apple and quince associated with *E. scutalis*, indicating that *E. scutalis* feeds on this phytophagous mite as a good source of food and successfully controls it.

Across a wide range of prey densities, a combination of stigmaeids and phytoseiids outperformed either predator alone in some studies (Croft and MacRae 1993). This result is consistent with other research by Yousef and Shehata, (1971) and Rasmy *et al.*, (1991) who mentioned that populations of *C. pulcher* may be regulated by natural enemies including the phytoseiid mite, *E. scutalis* (mentioned as *Amblyseius gossipi* El-Badry), and the stigmaeid mite, *A. exsertus*. *Agistemus exsertus* preys on *C. pulcher*, a pest of quince orchards (Hassan *et al.*, 1970). *Euseius scutalis* (mentioned as *Amblyseius gossipi*) and *A. exsertus* are feed eggs of *Tenuipalpus granati* Sayed which are effectively controlled by *E. scutalis* than *A. exsertus* (Yousef *et al.*, 1982).

Paraseiulus talbii (Athias-Henriot) is the most extensively studied member of phytoseiid group that feeds tydeoids (McMurtry *et al.*, 2013). It occurred in small numbers on the leaves of citrus and mango trees, along with the tetranychoid mites, *T. urticae*, *E. africanus*, and *B. obovatus*, as well as tydeid mites, *Tydeus schusteri* André & Naudo and *Tydeus oregonenesis* Baker. Zaher and Shehata, (1970) collected *P. talbii* in a citrus orchard in Giza governorate, which is parallel to our findings. It was previously found in Gharbia and Fayoum governorates (El-Badry 1967). In Italy, Camporese and Duso, (1995) showed that *P. talbii* is associated with *Tydeus caudatus* (Dugès) and had a higher reproductive potential on this mite species. *Paraseiulus talbii* have been reported as predators of *E. orientalis* (Vacante 2010).

Kuzinellus niloticus was first recorded in Egypt in Shubra, Cairo governorate (El-Badry 1970), and was later recorded at Sohag governorate associated with citrus pests (Abo-Shnaf and Attia 2022). It is collected in the current work on citrus mixed with the tetranychoid mites, *T. urticae*, *E. africanus*, and *B. obovatus*, suggesting that *K. niloticus* has the ability to manage their population. However, no previous studies indicate the possibility of this predator feeding on citrus pests; but further biological research is needed to confirm this hypothesis.

Twelve species of the family Ameroseiidae have been reported from Egypt (Abo-Shnaf *et al.*, 2022a). Ameroseiids can occur in a variety of habitats, including those associated with fungi, flowers, animal nests, and humid soils, where they feed on fungi (Flechtmann 1985), pollen, and nectar. Ameroseid mites have not been identified as pest predators (Castilho *et al.*, 2015). However, other research suggests their role as biological control agents for plant pathogenic fungi (Moustafa and El-Hady 2006). More research on the biology and relationship with fungi is needed to understand their importance as pathogen control agents.

This family is represented by two species in two genera: *Kleemannia wahabi* Ibrahim & Abdel-Samed and *Sertitympanum zaheri* (El-Badry, Nasr & Hafez) in litter and soil underneath citrus and apple trees. Previous research recorded *S. zaheri* in the litter at Kafr-El-Sheik governorate (Zaher 1986). Other ameroseiid mites, *Kleemannia kosi* El-Badry, Nasr & Hafez and *Kleemannia plumosa* (Oudemans) were reported on citrus litter at Qena and Aswan governorates (Zaher 1986) and Fayoum governorate (Rahil and Abd El- Halim 2000).

Mites of the family Melicharidae live in a wide range of habitats, including soil and moist environments (Gerson *et al.,* 2003); they could prey on small arthropods (Moraes *et al.* 2015). Determination of their ecological role and potential as biological control agents is necessary (Abo-Shnaf and Moraes 2016). Six species of *Proctolaelaps* were collected in Egypt by Abo-Shnaf and Moraes, (2016). Only a single species, *Proctolaelaps pygmaeus* (Müller) was collected in litter and soil underneath citrus and mango trees in the current work. This species previously mentioned as *Proctolaelaps hypudaei* (Oudemans) was collected on citrus leaves, fruits, and litter in Lower Egypt (Rasmy *et al.*, 1972). The phytophagous mites, *T. urticae*, *E. africanus*, *P. citri*, and *B. obovatus* have been found in the litter of those trees which could be a good food source for *P. pygmaeus*. Similarly, other *Proctolaelaps* species and prey sources, i.e., Lawson-Balagbo *et al.,* (2007) mentioned *P. bickleyi* as a natural and biological control of the coconut mite, *Aceria guerreronis* Keifer (Eriophyidae).

Tydeidae are small, soft-bodied mites that can be found on plants and in litter. They eat diverse plant diets, including fungi, and may also eat arthropods such as eriophyid mites. Three tydeid species: *Tydeus schusteri*, *Tydeus oregonenesis*, and *Paralorryia zaheri* Baker were collected from leaves, litter, and soil of mango trees. *Tydeus schusteri* is the most common tydeid mite species found in numerous numbers, while the other two species were found in smaller numbers. This finding is parallel with that of Mohamed and Nabil, (2014) and Abo-Shnaf *et al.,* (2022b) who collected *T. oregonensis* on mango trees respectively at Sharkia and Giza governorates according to those authors.

Because the bioecological aspects of tydeid mites are poorly understood, their importance may be underestimated; however, they can play an important role as alternative prey for phytoseeids and other predators (Pallini Filho *et al.*, 1992; Vela *et al.*, 2017).

Some laelapid mite species are pest predators; they live in soil, stored products, or humid habitats rich in organic matter. Only a few members of this family are biocontrol agents (Kazemi 2014). Three laelapid mite species, *Androlaelaps casalis* (Berlese), *Gaeolaelaps orientalis* (Hafez, El-Badry & Nasr), and *Laelaspis calidus* Berlese were collected in a small number in citrus litter and soil in the current work. The tetranychoid mites, *T. urticae*, *B. obovatus* and *E. africanus* have been reported on citrus leaves from where the laelapid mites were collected, assuming that these mites could be good prey for laelapid mites once the leaves have fallen. *T. urticae* was found on citrus litter associated with *G. orientalis* in small numbers, it could have contributed to reducing the population of *T. uricae*. Lobbes and Schotten, (1980) reported that *Gaeolaelaps* species can feed on a mixture of *Drosophila melanogaster* Morgan (Drosophilidae) and *T. urticae*. *Gaeolaelaps aculeifer* (Canestrini) is a common soil-borne species used to control soil-dwelling pests such as nematodes, acarid mites, fly larvae, bulb mites, and thrips; species of the genus *Androlaelaps* have been observed predating on insects and mites (Mihm and Chiang 1976).

Some cheyletid family members are free-living predators that can be found in different habitats such as soil, litter, under tree bark, and on foliage. In Turkey, Akpinar *et al.*, (2017) mentioned the potential for using this family in biological control. *Cheletomimus bakeri* (Ehara) was collected on mango trees in the current study as did in a recent study by Abo-Shnaf *et al.*, (2022b), while *Cheyletus malaccensis* Oudemans was collected on other fruit trees and soil; both species were found in small numbers in the present work as did Rahil and Abd El-Halim, (2000), who collected both species on citrus at Fayoum governorate. *Cheletomimus bakeri* numbers increased with *T. urticae* numbers decrease, indicating its role in mite pest control (Ray and Hoy 2014; Abo-Shnaf *et al.*, 2022b).

Raphignathid mites are commercially important because many are useful for biological pest control. They are reared and released to control plant pests such as Eriophyidae, Tetranychidae, and scale insects (Fan and Zhang 2005). In the current study, *Raphignathus sayedi* Gomaa & Hassan were collected in low numbers in litter and soil underneath various fruit trees. Rahil and Abd El-Halim, (2000) collected another raphignathid species, *Raphignathus niloticus* Rakha & Mohamed from citrus leaves in Fayoum governorate. Some other *Raphignathus* species were collected on different plants in Dakahlia, Giza, and Ismailia governorates (Zaher and Gomaa 1979).

Mite Frequency:

Van de Vrie, (1964) investigated the frequency distribution of predatory and phytophagous mites on apple trees' leaves and shots, which is quite similar to the current study. Based on different mite habits, plant-feeder mites accounted for (42.9%) of the collected mite population, followed by the predatory mites (40.7%), miscellaneous (11%), fungivorous (4%), and parasitic (1%) mites (Fig. 1). Plant-feeding mites found included *C. pulcher* (14), *T. urticae* and *C. lanceolatisetae* (9.8 %) per each, *B. obovatus* (5.2%), *E. africanus* (3.1%), and *P. citri* (1%) (Table 2).

Sixteen of the mite individuals collected was predators, while only two was parasite (Table 2). These predatory mites were determined (40.7%) and considered as a large group to attack phytophagous mites to reduce their population. Błoszyk *et al.*, (2016) classified the laelapid mite, *A. casalis* (0.5%) as a parasitic mite. Furthermore, both ameroseiid mites, *K. wahabi* and *S. zaheri* (2.6 and 1.6% of the total mites, respectively), are fungivorous mites. These mites may consume harmful and pathogenic fungi that live in the soil underneath cultivation (Mašán 2017).

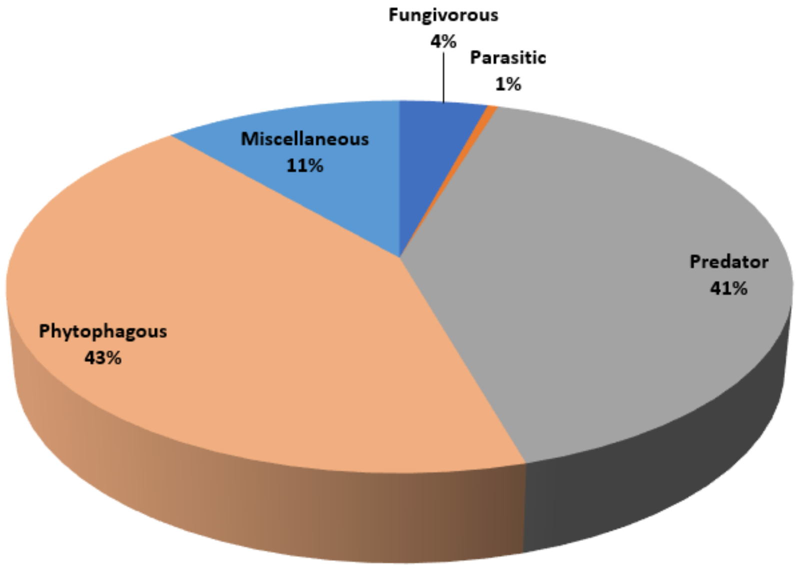

Fig. 1: Percentage of total mite count inhabiting fruit orchards, vegetable crops, and ornamental plants at Giza and Monufia governorates during June 2019 and July 2021**.**

Table 2: Frequency of mites inhabiting fruit orchards, vegetable crops, and ornamental plants at Giza and Monufia governorates during June 2019 and July 2021.

Habitat	**Mite taxa**	**Frequency**			
		No. of samples	**Total number of mite species collected**	**% of the total count**	**Mean no. of mite species/sample**
Fungivorous	*Kleemannia wahabi*	03	05	2.6	1.7
	Sertitympanum zaheri	02	03	1.6	1.5
Total			**08**	**4.2**	
Parasitic	*Androlaelaps casalis*	01	01	0.5	1.0
Total			**01**	**0.5**	
Predator	*Gaeolaelaps orientalis*	01	01	**0.5**	1.0
	Laelaspis calidus	01	01	**0.5**	1.0
	Proctolaelaps pygmaeus	01	01	**0.5**	1.0
	Amblyseius swirskii	01	08	4.1	8.0
	Euseius scutalis	13	37	19.2	2.8
	Kuzinellus niloticus	02	03	1.6	1.5
	Neoseiulus californicus	01	01	**0.5**	1.0
	N. zaheri	05	05	2.6	1.0
	Paraseiulus talbii	01	01	**0.5**	1.0
	Phytoseiulus persimilis	03	05	2.6	1.7
	Typhlodromus (*Anthoseius*) *egypticus*	02	02	1.0	1.0
	T. (*Typhlodromus*) *athiasae*	02	02	1.0	1.0
	Cheletomimus bakeri	01	01	**0.5**	1.0
	Cheyletus malaccensis	02	02	1.0	1.0
	Raphignathus sayedi	01	01	**0.5**	1.0
	Agistemus exsertus	05	08	4.1	1.6
Total			**79**	**40.7**	
Phytophagous	*Brevipalpus obovatus*	03	10	5.2	3.3
	Cenopalpus lanceolatisetae	02	19	9.8	9.5
	C. pulcher	02	27	14	13.5
	Eutetranychus africanus	02	06	3.1	3.0
	Panonychus citri	01	02	1.0	2.0
	Tetranychus urticae	09	19	9.8	2.1
Total			**83**	**42.9**	
Miscellaneous	*Paralorryia zaheri*	01	02	1.0	2.0
	Tydeus oregonenesis	02	03	1.6	1.5
	T. schusteri	06	17	8.8	2.8
Total			**22**	**11.4**	

CONCLUSION

It can be concluded that predatory mites from different groups play an important role as natural enemies for the associated plant-feeding mites, who are a good source of food. These predators may be used in the biological control of pests on various agroecosystems as an alternative way for synthetic chemicals. More research is needed to confirm the potential of the poorly studied predatory mites on their associated prey.

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