Occurrence, population dynamics and winter phenology of spider mites and their phytoseiid predators in a citrus orchard in Syria

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OCCURRENCE, POPULATION DYNAMICS AND WINTER PHENOLOGY OF SPIDER MITES AND THEIR PHYTOSEIID PREDATORS IN A CITRUS ORCHARD IN SYRIA

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ABSTRACT — The present study aimed to clarify some bio-ecological aspects of phytoseiid and tetranychid mites in Syrian citrus orchard conditions. The main objective was to obtain preliminary data on diversity, population dynamics, and overwintering phenology of mites considered in a pesticide-free citrus orchard located in Latakia province. Mites were collected on citrus leaves, in Phyto traps attached to citrus twigs, and on wild plants within and around the orchard from mid-summer 2013 to early summer 2014. *Panonychus citri* was the main tetranychid species collected on citrus leaves, but in very low densities. Mobile stages of this phytophagous were absent during winter. Eight phytoseiid species were found on citrus leaves during all sampling dates, and their general mean density was four times higher compared to that of *P. citri*. *Euseius stipulatus*, *Euseius scutalis* and *Amblyseius andersoni* were the dominant species on citrus leaves and seemed to have different population dynamics, different overwintering sites and phenology in winter, apparently due to differences in climatic requirements (*i.e.* temperature and photophase). Some phytoseiid species were rarely observed on citrus leaves, but were collected in high number in Phyto traps. Others seemed to emigrate from wild plants to overwinter on citrus twigs. Several hypotheses were formulated to explain the results obtained.

KEYWORDS — *Panonychus citri*; *Euseius stipulatus*; *Euseius scutalis*; *Amblyseius andersoni*; population dynamic; overwintering; biological control

INTRODUCTION

Members of the family Tetranychidae have been widely recorded on citrus in different regions of the world (Vacante, 2010). Several species of this family [*i.e.* the citrus red mite *Panonychus citri* (McGregor), the oriental red mite *Eutetranychus orientalis* (Klein) and the two spotted spider mite *Tetranychus urticae* Koch] have a worldwide distribution and are considered as major pests of this culture worldwide (Jeppson *et al.*, 1975; Gotoh *et al.*, 2003; Vacante, 2010).

Several predatory mites of the family Phytosei-

idae are considered as the main biological control agents of tetranychid mites in citrus orchards, maintaining their population densities at low economic levels (McMurtry, 1977, 1992; Ferragut *et al.*, 1992; Abad-Moyano *et al.*, 2009). However, unfavourable climatic conditions (*i.e.* hot and dry summer ; cold winter), and mainly the application of broad-spectrum pesticides lead to decrease in population densities of these natural enemies, causing population outbreaks of several tetranychid mite species (McMurtry, 1977; Garcia-Mari *et al.*, 1983; Kasap, 2009).

In Syria, Latakia province is the main grow-

ing citrus region, producing about 0.72 million tons of citrus fruits annually according to data from Syrian Ministry of Agriculture and Agrarian Reform (2012). A recent survey conducted in fifty citrus orchards in this province, showed the presence of fifteen phytoseiid species on citrus trees and on wild plants within or around orchards (Barbar, 2013). The dominant species were *Euseius stipulatus* (Athias-Henriot), *Typhlodromus (Typhlodromus) athiasae* Porath and Swirski, *Amblyseius andersoni* (Chant) and *Euseius scutalis* (Athias-Henriot). Although, relatively high densities and diversity of these predators were reported, there was limited information about their potential role as biological control agents against tetranychid mites, in particular *P. citri*, associated with these natural enemies in some surveyed orchards (Barbar, 2013; Personal observations). This phytophagous mite is known as a non-diapausing species, cannot survive the winter without feeding and usually produces two peak population densities, one in spring or early summer and one in autumn (Gotoh and Kubota, 1997; Kasap, 2005). High levels of attack by this species may cause important quantitative and qualitative losses in citrus fruits (Jeppson *et al.*, 1975; Vacante, 2010).

As no study has been undertaken on bio-ecological aspects of tetranychid mites and their phytoseiid predators in Syrian citrus orchard conditions, and as mite population dynamics on citrus trees are poorly investigated during winter, the objectives of the present study were to (1) obtain preliminary data on diversity and population dynamics of phytoseiid and tetranychid mites on citrus leaves in a pesticide-free orchard; (2) provide information about species composition and phenology of phytoseiid mites during hibernation period using "Phyto traps" (Koike *et al.*, 2000); (3) evaluate the importance of wild plant species within or around citrus orchards as possible sources and potential overwintering sites of phytoseiid mites occurred frequently on citrus trees.

MATERIALS AND METHODS

Experimental citrus orchard. The study was carried out in a 12-year-old lemon [*Citrus limon* (L.) Burm] orchard, of approximately 1.500 m^2 located in Latakia province (1 km south of Latakia city, Syria, the area has a sub-humid Mediterranean climate). Several wild plant species (*i.e.* weeds, ground vegetation) were present within and around the orchard. The orchard is surrounded by three windbreak plants: *Acacia cyanophylla* Lindley, *Eucalyptus* sp. and *Cupressus sempervirens* L. No pesticide applications were carried out in the orchard since early spring 2010. Daily average temperatures and relative humidity were obtained from a weather station located at 1 km away from the orchard. Data of daily photoperiod (a photophase between the sunrise and sunset) in the orchard area were obtained from Al-Hashimi Calendar®, Syria.

Mite population dynamics study. Samplings were conducted 20 times from mid-august 2013 to the beginning of June 2014. Fifty citrus leaves were collected twice a month from different sides of five randomly selected and marked trees (ten leaves/ tree). Each collected leaf was considered as a replicate for statistical analysis. The samples were placed in plastic bags inside an icebox and transferred to the laboratory. All phytoseiid and tetranychid stages on upper and lower surfaces of each leaf were counted using a binocular microscope. Adult stage was mounted on slides in Hoyer's medium and dried in an oven at 45 °C for one week for identification. Phytoseiid females were examined using a microscope (Olympus, CH2O) and non-diapausing females were distinguished from diapausing ones by the presence of eggs inside their idiosoma (Veerman, 1992; Kim *et al.*, 2010).

Phytoseiidae overwintering study. A total of 140 Phyto traps with size of 2.5 x 1 cm (Koike *et al.*, 2000; Kawashima and Amano, 2006; Kawashima *et al.*, 2006) (Figure 1) were attached to twigs of the same five marked trees in the study above (28 traps/ tree). Attachment of the traps took place on 1st October 2013. Twenty traps (four traps/ tree) were randomly collected once a month from 1st November 2013 to 1st May 2014 and each trap was considered as a replicate. Collected traps were transferred to the laboratory. Mites were counted and removed from traps using a binocular microscope. Adults were mounted on slides in Hoyer's

FIGURE 1: A Phyto trap attached to a twig of citrus tree in the orchard studied in Latakia province, Syria, on October 2013.

medium for identification and examination of diapausing females.

Mites on wild plants study. Fallen citrus leaves under tree canopies and leaves of at least 15 wild plant species (within or around the citrus orchard) were sampled four times (on mid-September and mid-December 2013, and on mid-February and mid-April 2014). Sample of each plant species was approximately equal in volume to that of 50 citrus leaves. Phytoseiid and tetranychid mites were removed from leaves using the "dipping-checking-washing-filtering" method (Boller, 1984) and treated in the same way as those on citrus leaves for mounting and identification.

Data analysis. During study, *P. citri* was the dominant tetranychid species and only two females of *T. urticae* were found on citrus leaves, therefore, this latter species was ignored in statistical analysis.

As data from citrus leaves (number of mites) were not normally distributed, a Kruskal-Wallis non-parametric analysis of variance followed by multiple comparisons between ranks (IBM® SPSS® version 20, 2011) were carried out to compare (1) phytoseiid and *P. citri* densities between sampling dates; (2) densities of the dominant phytoseiid mite species between sampling dates. Meteorological data (daily mean temperature, RH % and photophase) and those from phyto traps (number of mites) followed a normal distribution. One-way analysis of variance (ANOVA) followed by Duncan's test ($\alpha = 0.05$) were, therefore, carried out to compare these variables between sampling dates.

Linear regressions were used to evaluate the relationships between mean densities of all phytoseiid species (and these of the dominant ones) on citrus leaves in each date and the different independent variables (*i.e.* mean densities of *P. citri*; means of temperature, RH % and photophase). Significant

relationships were only presented.

RESULTS

Population dynamics of *Panonychus citri* and Phytoseiidae on citrus leaves. The citrus red mite *P. citri* was the dominant species (more than 98 %) on citrus leaves. The highest densities (mean ± SE mites per leaf) were observed on mid-January (0.20 ± 0.12), on mid-March (0.22 ± 0.12) and on mid-May 2014 (0.18 ± 0.08) compared to other sampling dates (H = 31.35; df= 19; P = 0.037) (Figure 2). Adults and immature stages were absent from mid-January to 1st May 2014.

Phytoseiid predatory mites were present in all sampling dates. The results of adult stage identifications showed the presence of eight species, three being dominant: *E. scutalis* (31.4 %), *E. stipulatus* (31.1 %) and *A. andersoni* (21.2 %). Other species [*T. (T.) athiasae*, *Paraseiulus talbii* (Athias-Henriot), *Iphiseius degenerans* (Berlese), *Typhlodromus (Anthoseius) foenilis* Oudemans and *Typhlodromus (Anthoseius) rickeri* Chant] were less frequent (Figure 3).

The highest densities of these predators (all species and all stages considered) were observed on 1st September 2013 (0.5 ± 0.1) and on mid-May and 1st June 2014 (0.88 ± 0.26 and 1.3 ± 0.24 respectively) (Figure 2). Their densities were very low from mid-December 2013 to mid-February 2014 [the lowest were on mid-January 2014: 0.02 ± 0.02] (H = 103.16; df= 19; P < 0.001). A significant relationship was observed only between mean phytoseiid mite densities and mean photophase ($R2$ = 0.49; F = 17.53; df = 19; P = 0.001) (Figure 4a). The results showed that the trend of egg and immature stages (when present) was almost similar to that of adults, even if their percentage was very low.

Density variation in time was different for each dominant species [only immature stages (when present) and adults were considered]. For *E. scutalis*, the population increased progressively from mid-September to mid-November 2013, decreased from December 2013 to May 2014 and re-increased and reached the highest densities on 1st June 2014 (0.28 ± 0.11; H = 52.24; df= 19; P < 0.001) (Figure 5). Examination of the slide-mounted females showed
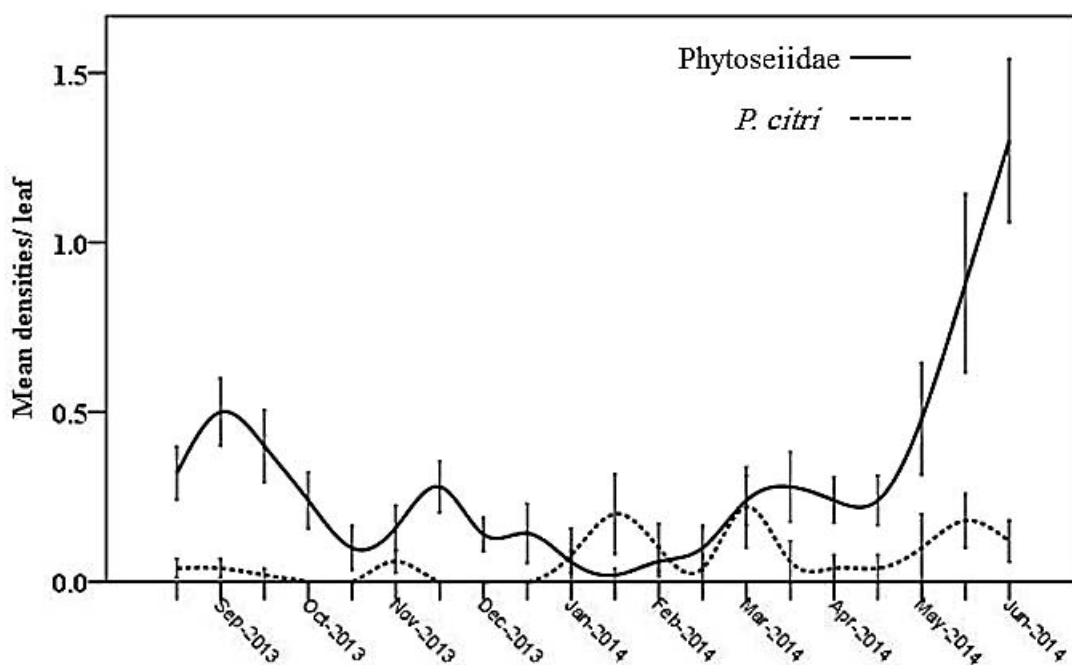

FIGURE 2: Mean densities of Phytoseiidae and *P. citri* per citrus leaf (± SE) in the orchard studied in Latakia province, Syria, from mid-August 2013 to the beginning of June 2014.
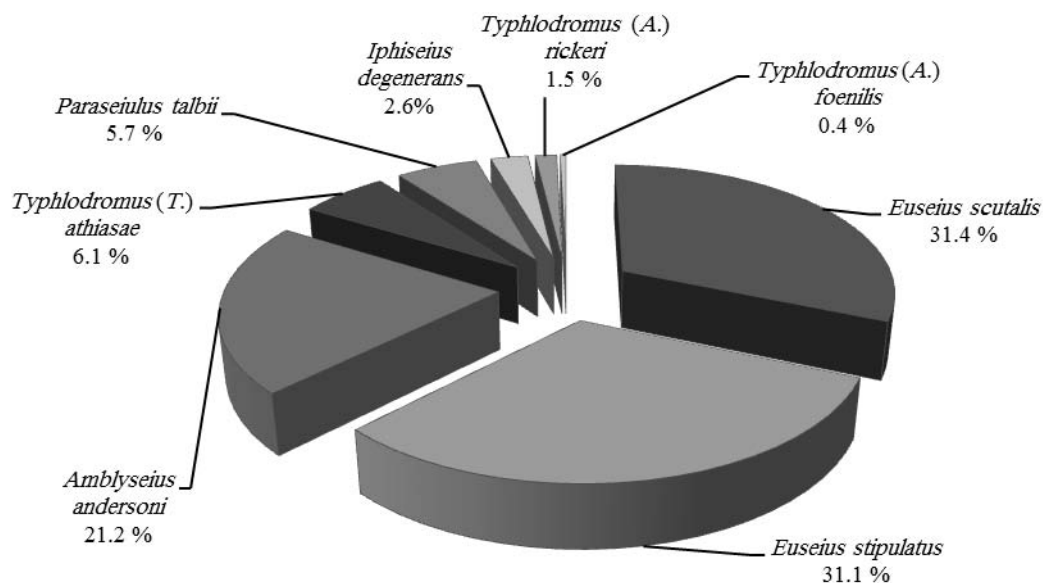
FIGURE 3: Relative abundance of phytoseiid mite species on citrus leaves in the orchard studied in Latakia province, Syria, from mid-August 2013 to the beginning of June 2014.

the absence of eggs inside their idiosoma during January 2014.

The densities of second dominant species, *E. stipulatus*, were very low during autumn and winter, increased from March 2014 and fluctuating afterward until the end of samplings (0.52 $\pm$ 0.13; H = 135.99; df= 19; P < 0.001) (Figure 5). A significant relationship was observed between its mean densities and mean photophase ($R2$ = 0.37; F = 10.39; df = 19; P = 0.005) (Figure 4b). Examination of the slide-mounted females showed the presence of eggs inside their idiosoma during winter.

Population densities of *A. andersoni* were significantly higher in the beginning of autumn 2013 (0.28 $\pm$ 0.09 on 1st September) than other sampling dates (H = 93.75; df= 19; P < 0.001) (Figure 5). This species was absent on citrus leaves from mid-October 2013 to 1st February 2014 when it re-appeared and remained in low densities afterword. A significant relationship was observed between its mean densities and mean temperature and photophase ($R2$ = 0.61; F = 28.24; df = 19; P < 0.001; $R2$ = 0.27; F = 6.53; df = 19; P = 0.02, respectively) (Figures 4c and 4d).

Phytoseiidae in Phyto traps. Approximately 80 % of attached traps were occupied by these preda-

tors. A total of 499 mites were collected including adult females (70.1 %), adult males (10.1 %), immature stages (7.8 %), eggs (3.6 %) and dead mites (8.4 %) from the beginning of November 2013 to the beginning of May 2014. High percentage (50.9 %) of traps were occupied by 1-3 phytoseiid mite individuals (Figure 6). Examination of the slide-mounted females showed the absence of eggs inside their idiosoma during January 2014.

The results of adult identifications showed the presence of five phytoseiid mite species, three being dominant: *A. andersoni* (61.7 %), *T. (A.) foenilis* (18.9 %) and *T. (T.) athiasae* (17.1 %). Other species [*Phytoseius finitimus* Ribaga and *P. talbii*] were less frequent (Figure 7).

The densities (mean $\pm$ SE mites per trap) of those predators (all species and all stages considered) were not significantly different between sampling dates (F = 1.20; df = 6; P = 0.31) (Figure 8). However, similar to what was observed on citrus leaves, density variation in time was different for each dominant species. Population densities of *A. andersoni* were significantly higher in the beginning of November 2013 (3.85 $\pm$ 0.51), slightly decreased on December 2013 and remained stable until May

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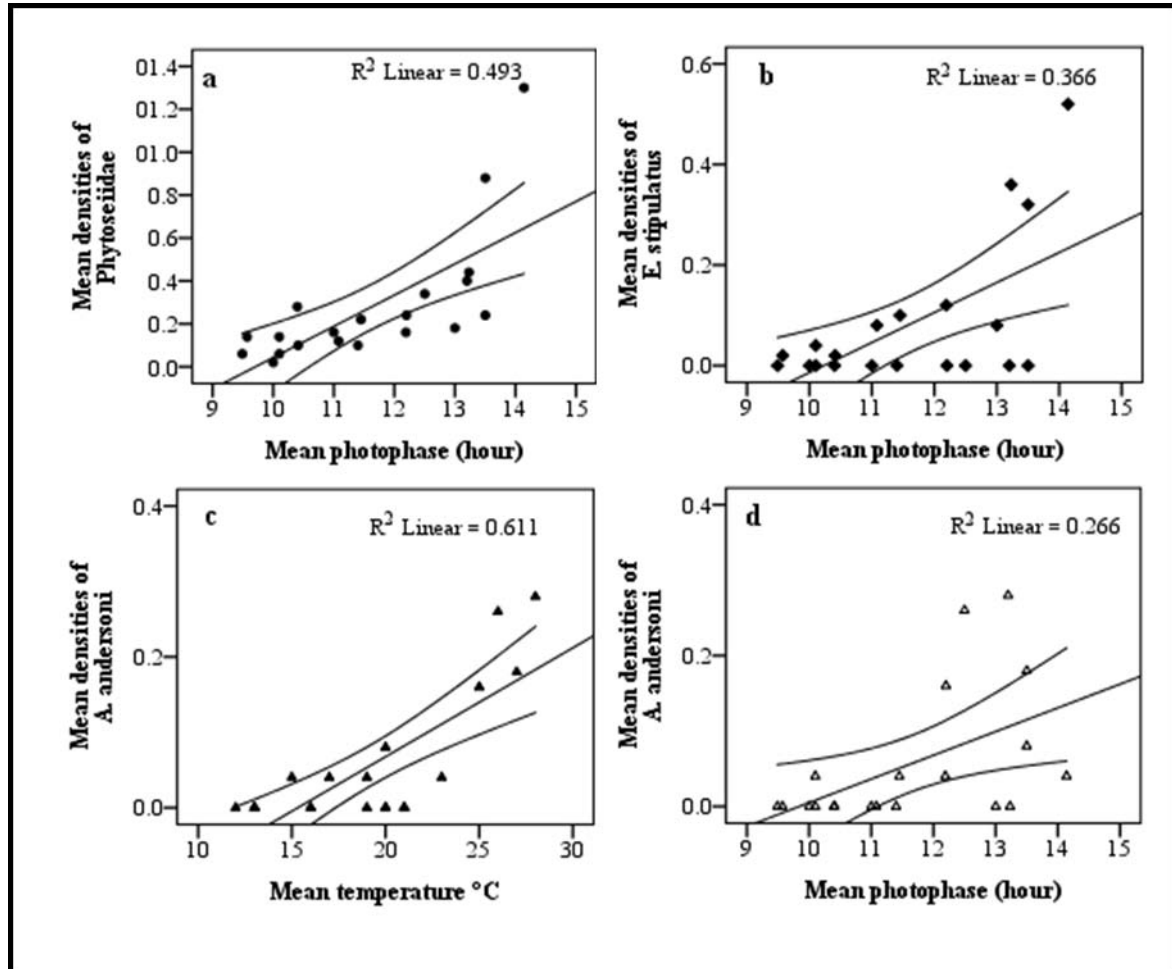
FIGURE 4: Relationships between mean densities of Phytoseiidae (all species), *E. stipulatus* and *A. andersoni* and mean photophase (a, b, d, respectively); mean densities of *A. andersoni* and temperature (c).

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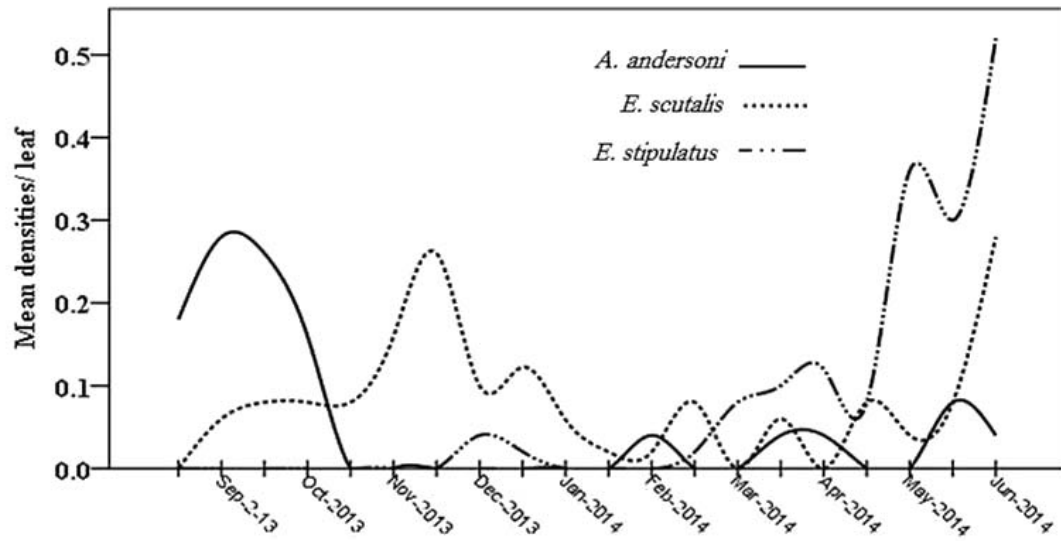
FIGURE 5: Mean densities of phytoseiid dominant species per citrus leaf (± SE) in the orchard studied in Latakia province, Syria, from mid-August 2013 to the beginning of June 2014.
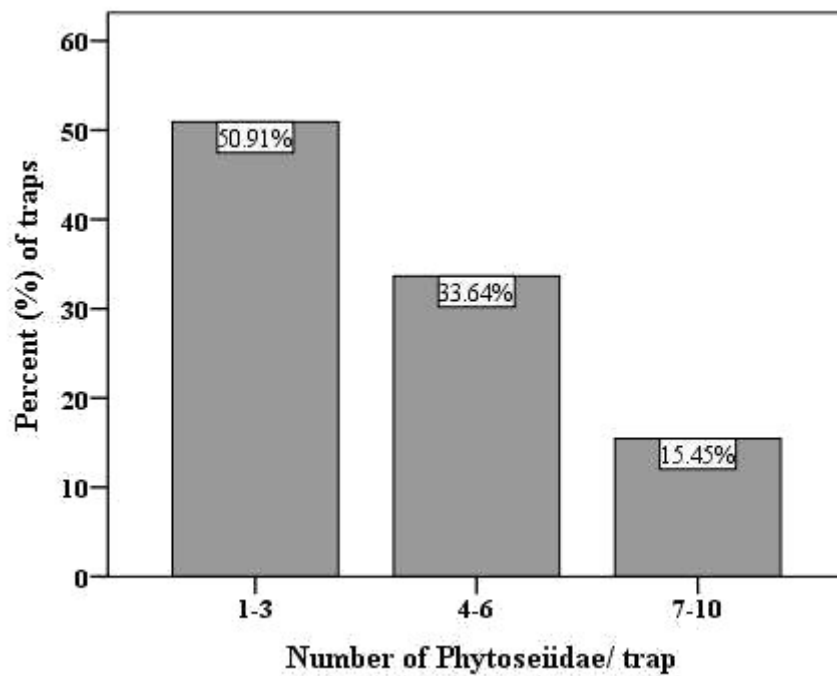
FIGURE 6: Percentage of Phyto traps attached to citrus twigs occupied by different number of phytoseiid individuals from November 2013 to May 2014.

FIGURE 7: Relative abundance of phytoseiid mite species in Phyto traps attached to citrus twigs in the orchard studied in Latakia province, Syria, from November 2013 to May 2014.

FIGURE 8: Mean densities of Phytoseiidae per trap ($\pm$ SE) attached to citrus twigs in the orchard studied in Latakia province, Syria, from the beginning of November 2013 to the beginning of May 2014.

FIGURE 9: Mean densities of phytoseiid dominant species per trap (± SE) attached to citrus twigs in the orchard studied in Latakia province, Syria, from the beginning of November 2013 to the beginning of May 2014.
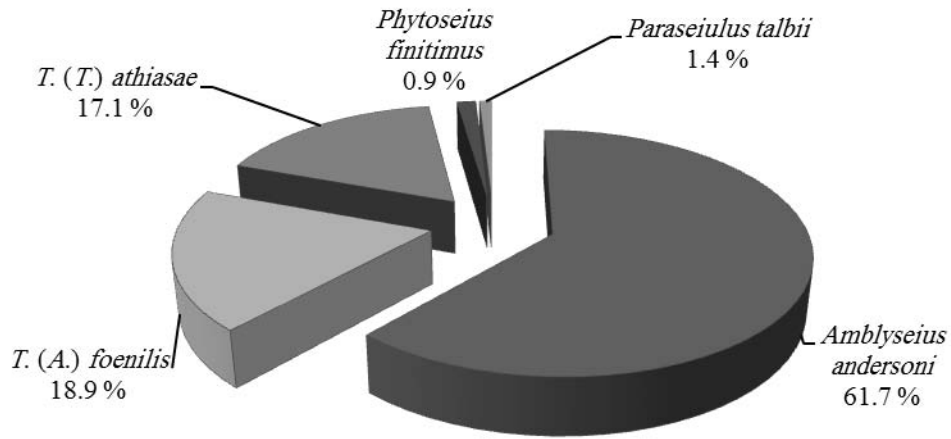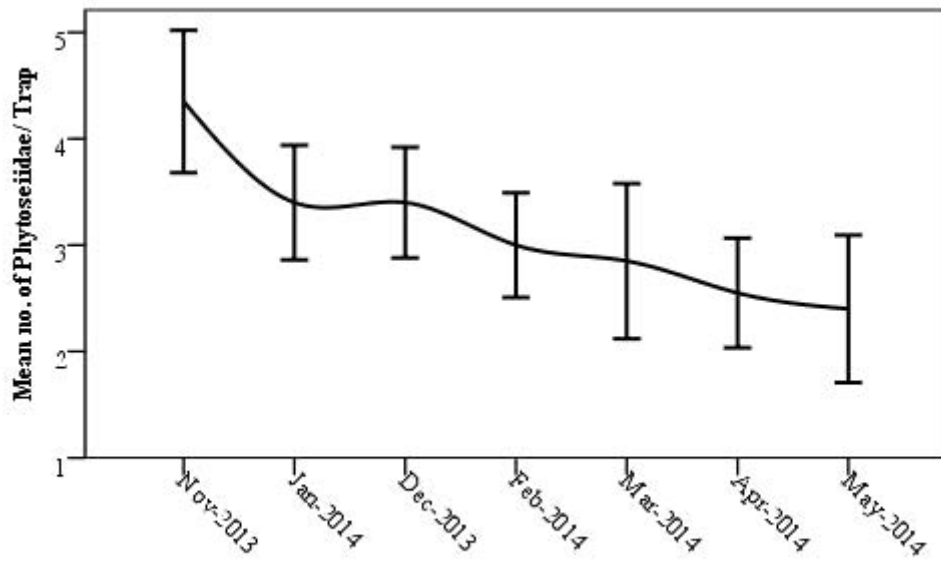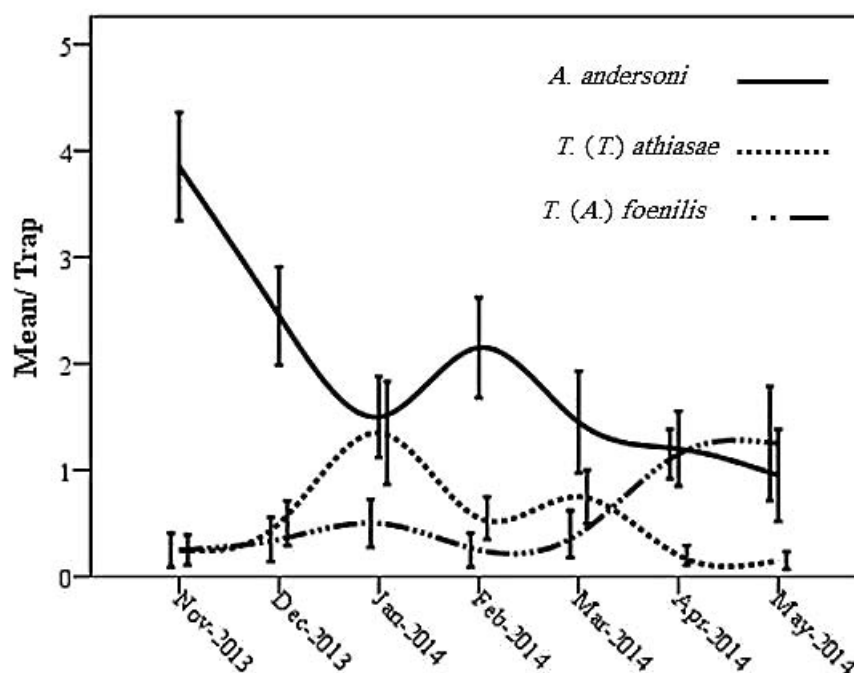
TABLE 1: Number and percentage of Phyto traps where *A. andersoni* co-occurred with other Phytoseiidae species.

Co-occurred species	Number of traps	Percent %
A . andersoni x *T . (T .) athiasae*	13	32.5
A . andersoni x *T . (A .) foenilis*	13	32.5
A . andersoni x *P . finitimus*	1	2.5
A . andersoni x *P . talbii*	1	2.5
A . andersoni x *T . (T .) athiasae* x *T . (A .) foenilis*	8	20
A . andersoni x *T . (T .) athiasae* x *P . finitimus*	2	5
A . andersoni x *T . (A .) foenilis* x *P . finitimus*	1	2.5
A . andersoni x *T . (T .) athiasae* x *T . (A .) foenilis* x *P . finitimus*	1	2.5

2014 when another decrease was observed (F = 5.00; df= 6; $P < 0.001$) (Figure 9). Immature stages of this species formed a percentage of 84.6 % of all immatures found in traps. These immatures were absent during January 2014. Finally, 42 % of attached traps were occupied by *A. andersoni* alone and 36 % were co-occupied by this species and other one(s) (Table 1).

For *T. (A.) foenilis*, only adults were observed.

The population remained in low densities during autumn and winter, increased progressively from March 2014 and reached the highest densities on 1st May 2014 (1.25 ± 0.54; $F = 2.35$; df= 6; $P = 0.034$) (Figure 9).

The highest densities of *T. (T.) athiasae* were found on 1st January 2014 (1.35 ± 0.48; $P = 2.96$; df= 6; $P = 0.01$) (Figure 9). Immature stages of this species were only found on March 2014.

TABLE 2: Number of specimens of Phytoseiidae and Tetranychidae found on wild plants within and around citrus orchard studied in Latakia province (Syria) in 2013 and 2014

| | Number of specimens per plant | | | | | | | | | | | | | | | |
| | Phytoseiid mite species | | | | | | | | | | | | Tetranychid mite species | | | |
Sampled plants	*Amblyseius andersoni*	*Euseius scutalis*	*Euseius stipulatus*	*Iphiseius degenerans*	*Neoseiulus barkeri*	*Neoseiulus bicaudus*	*Cydnodromus californicus*	*Phytoseiulus persimilis*	*Proprioseiopsis messor*	*Phytoseius finitimus*	*Typhlodromus (Anthoseius) rhenanus*	*Typhlodromus (Typhlodromus) athiasae*	*Bryobia* sp.	*Bryobia graminum*	*Panonychus citri*	*Tetranychus urticae*
Amaranthus retroflexus L.	53	1			1	1	1				11	1	5			7
Cichorium intybus L.			1	1	1						2					
Cirsium arvense L.								1			23	2				10
Cupressus sempervirens L.												41				
Cynodon dactylon (L.)						1					1	1				
Ficus carica L.												3				
Malva sylvestris L.	2							2	2		1	8		7		>150
Ricinus communis L.			5													
Sonchus oleraceus L.		1	5					1								
Urtica urens L.			2					4				1	4			20
Xanthium strumarium L.	13	2	2								1				2	
Unidentified herb	4				1					21		7		1		
Fallen citrus leaves	1					3			4		1					
Total number	73	4	15	1	3	5	1	8	6	21	40	64	9	8	2	>150

Phytoseiidae and Tetranychidae on wild plant species. A total of 241 specimens of Phytoseiidae belonging to 12 species were found on wild plant species and in fallen citrus leaves (Table 2). Among these species, two are recorded for the first time from Syria: *Cydnodromus californicus* (McGregor) and *Neoseiulus bicaudus* (Wainstein). The species *A. andersoni* was the dominant and was found on four plant species and in fallen citrus leaves on mid-September 2013 and on mid-February 2014 respectively. Relatively high numbers of this species were observed in particular on *Amaranthus retroflexus* L. and on *Xanthium strumarium* L. (Table 2). *Typhlodromus* (*T.*) *athiasae* was also dominant and was collected on eight plant species during all sampling dates and tended to be more abundant on *C. sempervirens*. The species *P. finitimus* was observed only on a non-identified herb in relatively high numbers. For *E. scutalis*, *E. stipulatus* and *I. degenerans* speci-

mens, low numbers of these species were collected on few plant species (Table 2). Other species [*i.e. Neoseiulus barkeri* Hughes, *N. bicaudus*, *C. californicus*, *Phytoseiulus persimilis* Athias-Henriot, *Proprioseiopsis messor* (Wainstein) and *Typhlodromus* (*Anthoseius*) *rhenanus* (Oudemans)] were found in fallen citrus leaves and on several plant species as *A. retroflexus*, *Cirsium arvense* L., *Malva sylvestris* L. and *Urtica urens* L. infested by relatively high densities of one or more tetranychid mites species [*i.e. Bryobia* sp., *Bryobia graminum* (Schrank), *P. citri*, and (or) *Tetranychus urticae* Koch] (Table 2).

DISCUSSION

Mites on citrus leaves. As already said, significant *P. citri* population peaks were observed on mid-January, mid-March and on mid-May 2014. However, these observations cannot be generalized due

to very low densities found in all sampling dates. Relative cold weather during December 2013 in orchard region (temperatures ≤ 6 °C during several days) could be a factor involved in low abundance of this phytophagous. Indeed, eggs of this species were the unique stage observed on citrus leaves from mid-January to 1st May 2014. This result suggests that females and immature stages could not survive during winter despite the presence of continuous source for feeding (citrus leaves) (Jeppson *et al.*, 1975; Kasap, 2009). Furthermore, the occurrence of other predatory arthropods (in addition to Phytoseiidae) on citrus leaves as Stigmaeidae and Neuroptera (Chrysopidae and Coniopterigidae) (Barbar, 2013; Personal observations) could be another factor negatively influences population abundances of *P. citri* (Gerson *et al.*, 2003; Abad-Moyano *et al.*, 2009).

Relatively high diversity and densities of Phytoseiidae were collected on citrus leaves by the absence of pesticide applications in the orchard studied (Garcia-Mari *et al.*, 1983; Tuovinen, 1994; Barbar *et al.*, 2007). The general mean of these predators during study was four times (0.31 ± 0.03) higher than that of *P. citri* (0.07 ± 0.01), thereby, suggesting that they maintain the citrus red mite populations in very low levels. Indeed, the species collected (in particular the dominant ones) are considered to be important natural enemies of *P. citri* (Ferragut *et al.*, 1992; McMurtry, 1992; Kasap and Şekeroğlu, 2004). However, their abundance did not appear to be related to the availability of *P. citri* on citrus leaves due to lifestyles of these predators (generalist or pollen feeding generalist predators) (Duso and Camporese, 1991; McMurtry, 1992; Nomikou *et al.*, 2003; McMurtry *et al.*, 2013), and thus other factors (*i.e.* climatic conditions, food suitability) could be involved in their abundance.

Population dynamic data showed that phytoseiid densities (all species considered) were at least three times lower in winter than in autumn or in spring (May and June 2014). A percentage of 49 % of the abundance observed was most probably related to the day-length (the photophase) which was shorter in winter (10 hours) than this in autumn or in spring (14 hours) (Veerman, 1992; Broufas, 2002).

Regarding each of the dominant species, the abundance of *E. scutalis* did not seem to be correlated to climatic conditions and *P. citri* densities. In autumn, relatively high densities were found and about 40 % of specimens were collected on colonies of no identified whitefly species which could serve as food favouring so its abundance (Nomikou *et al.*, 2003). In winter, the abundance was low and the females collected were flatted, devoid of eggs in their idiosoma and staying close to the main vein of citrus leaf in a process of overwintering. These observations disagree with the results of Wysoki and Swirski (1971), showed that all developmental stages of *E. scutalis* were found on plants during winter and the species seemed to reproduce throughout the cold season, with only a temporary slowing down or cessation of oviposition. Differences between results could be due to differences between species strains collected from various geographical regions (Veerman, 1992; Kasap and Şekeroğlu, 2004).

For *E. stipulatus*, the photophase seemed to influence its population dynamics. However, this factor could have a little importance due to very low abundance observed in autumn and in winter when the photophase varied from about 14 to 10 hours respectively. Furthermore, the highest densities observed during spring 2014 could be explained by the presence of a suitable temperature for its development (mean during May and June 2014 >17 °C) (Ragusa, 1986; Ferragut *et al.*, 1988), and also by the availability of pollen, in particular those of *Eucalyptus* sp. which are considered as 'good food' (McMurtry; Personal communication, 2014) and seem to be more important for its development compared with tetranychids (Ferragut *et al.*, 1987; Bouras and Papadoulis, 2005, McMurtry *et al.*, 2013). Indeed, pollen was found on lower surface of citrus leaves during spring. Even if these leaves are glabrous, curl and cavities caused by citrus leafminer and also secretions of whiteflies and scale insects formed 'micro-structures' potentially have a role in pollen retentions (Barbar, 2014; Personal observations).

Amblyseius andersoni seemed to be abundant on citrus leaves during late summer and early autumn 2013. Similar trends were observed by Duso *et al.*

(2003) in vineyards, but abundance was strongly correlated to the presence of an alternative food of downy mildew. According to climatic data from citrus orchard region, high levels of density variations in time of this species could be explained firstly, by the temperature (61 %) and secondly, by the photophase (27 %). The highest population densities were found in the beginning of September when the means temperature and photophase were 28 °C and 13.2 hours respectively. This abundance decreased progressively and the species virtually abandoned citrus leaves to overwintering sites on mid-October when the means temperature and photophase decreased to 20 °C and 11.4 hours respectively. Similar results obtained by van Houten and Veenendaal (1990) and by Veerman (1992) under laboratory conditions showed that temperature and photoperiod are the major factors involved in diapause for many strains of this species.

Phytoseiidae in Phyto traps. In this study, Phyto traps provided important information about overwintering phenology of at least three phytoseiid species: *A. andersoni*, *T. (A.) foenilis* and *T. (T.) athiasae.*

Amblyseius andersoni was the dominant species in traps attached to citrus twigs, suggesting their importance as overwintering sites for this species. Duso (1989) found similar results on branches of wine in northern Italy. During autumn, *A. andersoni* was active on citrus leaves until 1st October 2013 and its highest density in traps was observed on 1st November 2013. These results suggest thus, that *A. andersoni* had begun entering hibernation sites during October. Furthermore, the stability in population densities in traps from January to May 2014 suggests that it had completed the movement to the traps during November 2013. Similar results have been observed by Kawashima and Amano (2006) for *Typhlodromus (Anthoseius) vulgaris* Ehara on Japanese pear trees. Although females of *A. andersoni* were always found in the traps until 1st May 2014, the first re-appearance of few females on citrus leaves was observed on 1st February 2014. At that time, the mean temperature was 15 °C, significantly higher of those recorded on January 2014 (13 °C) or on December 2013 (12 °C). These results con-

firmed previous ones showed that temperature is an important factor influencing phytoseiid females to abandon their overwintering sites (Hoy and Flaherty 1975; Ivancich-Gambaro, 1990; Broufas, 2002).

All mobile stages of *A. andersoni* were found in traps throughout autumn and winter, suggesting that this species did not overwinter. These results could be explained by (1) the fact that the traps are approximately in total darkness and with microclimatic conditions potentially more favourable for the development of *A. andersoni* than those on leaf surfaces during winter as shown also by Overmeer *et al.* (1989); by (2) the fact that, many females of *A. andersoni* had clearly visible intestines and seemed to be reared on potential alternative prey species present in many traps as different stages of Stigmaeidae, Tydeidae, mealybugs and whiteflies. Duso (1989) mentioned that the success of the winter introduction of *Typhlodromus (Typhlodromus) pyri* Scheuten and *Kampimodromus aberrans* (Oudemans) in vineyards may be partially related to the presence of various prey species under the grapevine bark that enhanced survival and development of these two species, and finally by (3) the fact that interspecific predation between phytoseiid species inside the traps was not excluded, favouring so *A. andersoni*. Several studies proved the voracity of this species against different stages of other phytoseiids under laboratory conditions (Zhang and Croft, 1995; Schausberger and Croft, 1999). More specific studies, thus, are required to test these hypotheses.

Two other phytoseiid species were also dominant in traps: *T. (A.) foenilis* and *T. (T.) athiasae*. The population increase of *T. (A.) foenilis*, contrarily to what observed for *A. andersoni*, was found on April and May 2014. Favourable conditions during spring seem thus, did not induce this species to abandon traps to citrus leaves. This result suggests that interspecific differences in climatic requirements and (or) in food suitability for the two species on citrus leaves could be present (Kawashima and Amano, 2006).

The highest densities of *T. (T.) athiasae* in traps were found on 1st January 2014. It is possible that, this species completed the movement to traps during December 2013. Moreover, observations of pop-

ulation dynamics of this species suggest that the species abandoned the traps in the beginning of April 2014 when high decreasing in densities were found in traps and the species was re-observed on citrus leaves on mid-April 2014.

Mites on wild plant species.   Wild plants seemed to have a direct positive influence on phytoseiid species composition observed on citrus trees and have to be considered, as already well known, as reservoirs and distributors of phytoseiid mites into the orchard (Tuovinen, 1994; Tixier *et al.*, 2006).

Amblyseius andersoni was observed in high numbers on *A. retroflexus, X. strumarium* in autumn, and it was also found in fallen citrus leaves in late winter. These different habitats constitute reservoirs and also additional overwintering sites for this species (Putman, 1959; Duso, 1989). Contrarily to what observed for *A. andersoni*, it seems that *E. scutalis* and *E. stipulatus* prefer citrus leaves as habitats and overwintering sites due to their low numbers found on few wild plant species (Sahraoui *et al.*, 2014). *Typhlodromus* (*T.*) *athiasae* was the only species found in high numbers on *C. sempervirens*, suggesting a positive role of this plant as overwintering site and a reservoir of this phytoseiid as already observed by Barbar (2013). The two remaining common species were *I. degenerans* and *P. finitimus*. The former was sporadically observed on citrus leaves and on natural vegetation. However, high numbers of the latter (*P. finitimus*) was observed on a non-identified herb having pubescent leaves and growing under citrus tree canopies. This species was not found on citrus leaves, but it was observed in low numbers in traps during winter, suggesting possible emigrations from its host plant to overwintering on citrus twigs during autumn.

Conclusion

Although the period of present search was about only one year, interesting results were obtained. Very low densities of *P. citri* associated with relatively high diversity and densities of phytoseiid mites were observed. Favourable climatic conditions in the studied region, unsprayed citrus trees and wild plant species present within and around

citrus orchard seem the main factors involved in these positive general results. However, differences in climatic requirements (in particular, temperature and photophase) and availability of suitable food could explain variation in population dynamics, overwintering sites and overwintering timing between the dominant species collected (*E. stipulatus*, *E. scutalis* and *A. andersoni*). Such data, should be confirmed by multiyear field observations and laboratory simplified test in order to enhance the potential of these predators in biological control of citrus spider mites.

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