

Article

Spatial and temporal distribution of *Eotetranychus frosti* and *Cenopalpus irani* and their predator *Typhlodromus bagdasarjani* in an unsprayed apple orchard at Khorramabad, Western Iran

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Abstract

The spatial and temporal distribution of *Eotetranychus frosti* (McGregor), *Cenopalpus irani* Dosse, and their dominant predator *Typhlodromus bagdasarjani* Wainstein & Arutunjan were studied in an unsprayed apple orchard in Chaghalvandi region (Lorestan Province, Iran) during 2012. The population densities of these phytophagous mites and their predator were monitored from 3th May to 4th November 2012. For this purpose, samplings were done 17 times and at each of them, mite counts were made on 60 leaves (i.e. sampling unit). The spatial distribution pattern of *E. frosti*, *C. irani* and *T. bagdasarjani* was determined by using Taylor's power law method. Calculated RV (relative variation) and reliable sample size for the 25% variation from preliminary sampling for *E. frosti* were 16.22% and 53.86, respectively. The results demonstrated that population fluctuations of *E. frosti* and *T. bagdasarjani* passed through two peaks whereas *C. irani* had only one peak. The highest densities were observed on 23th August (28.68 per leaf), 11th September (28.88 per leaf) and 11th August (1.18 per leaf) for *E. frosti*, *C. irani* and *T. bagdasarjani*, respectively. The slopes of Taylor's power law were significantly greater than 1 indicating aggregated spatial distributions in the *E. frosti* and *C. irani*, but *T. bagdasarjani* had $b=1$, indicating random distribution. Our findings disclosed a positive correlation between population fluctuations of the two phytophagous mites and the predator, indicating a density-dependent reaction of predator to prey densities. The relationship between meteorological parameters and the three mite populations studied showed that the effect of temperature was insignificant, whereas the effect of relative humidity was significantly negative.

Keywords: Population fluctuations, prey, predator, Tetranychidae, Tenuipalpidae and Phytoseiidae.

Introduction

Spider mites in the family Tetranychidae are acknowledged as very harmful and widespread pests throughout apple growing areas. Unless controlled, these mites may

cause severe damage to crop both quantitatively and qualitatively (Jeppson *et al.* 1975; Kasap 2005). *Eotetranychus frosti* (McGregor), an injurious pest in apple orchards, has been reported from orchards in different regions of Iran (Kamali *et al.* 2001; Khodayari *et al.* 2010). In Kermanshah orchards it has been reported on apples, figs and plums in different parts of the province (Darbemamieh *et al.* 2012). The activity of this pest leads to reduction of the quality and quantity of harvested fruits and can also affect yield in the following season. Orchard management practices usually disrupt population of natural enemies or induce mite migration from the ground cover into trees thereby causing outbreaks of spider mites (Alston 1994). Under favorable conditions a spider mite population can grow up rapidly at a rate of up to 40% per day (Shih *et al.* 1976).

Cenopalpus is one of the largest genera of the family Tenuipalpidae and currently contains 60 species (Khanjani *et al.* 2012). *Cenopalpus irani* Dosse is one of the false spider mite species from Tenuipalpidae that is widely distributed in apple orchards located in the Western part of Iran (Darbemamieh *et al.* 2009). It has been found in large numbers in apple orchards in Iran (Khanjani *et al.* 2012). Rashki *et al.* (2002) reported that this pest completed three generations per year in an orchard at Mahdasht region of Karaj, Iran.

The main predatory mites in the apple orchards in Iran belong to the families Phytoseiidae and Stigmaeidae. The predatory mite species most frequently encountered in apple orchards of western and central provinces of Iran are *Typhlodromus bagdasarjani* Wainstein & Arutunjan, *Euseius finlandicus* (Oudemans) and *Zetzellia mali* (Ewing) (Acari: Stigmaeidae). *Typhlodromus bagdasarjani* is the predominant species in Lorestan province and feeds on eggs and nymphal stages of *T. urticae* (Jafari 2010). It was also found associated with colonies of *C. pulcher* in apple orchards in Zanzan province (Rahmani *et al.* 2010). This species is indigenous and is considered to be an important biological agent in the control of spider mites in Middle East, especially in apple orchards of Iran (Kamali *et al.* 2001). It was recorded for the first time by McMurtry (1977) on citrus trees in orchards of Fars province of Iran and named thereafter as *Typhlodromus (Anthoseius) kettanehi* (Dosse).

Biological control is a useful tool for the management of various pests especially in garden. The predatory mites are the most important biological agents in reducing the tetranychids and tenuipalpid mite's populations (Gerson *et al.* 2003). To evaluate the potential of natural enemies to reduce their prey density and thereby increasing system stability, it is critical and essential to have information about the spatial distribution of the prey and their natural enemies (Slone & Croft 1998). A good knowledge of the spatial distribution patterns of plant feeding mites is essential to develop reliable sampling plans for monitoring pest abundance (Athanassiou *et al.* 2005; Onzo *et al.* 2005; Tomanovic *et al.* 2008). Moreover, estimating the population density of arthropods is the cornerstone of basic research on agricultural ecosystems and the principal tool for building and implementing pest management programs (Kogan & Herzog 1980).

A survey conducted during 2011 on phytophagous mites and their important predator associated with apple orchards in Lorestan province showed *E. frosti* and *C. irani* as the predominant pest species whereas *T. bagdasarjani* was the predominant predator species (Jafari & Rahmati, personal observation). Several studies have described the spatial distribution and population fluctuations of mites in Iran (Darbemamieh *et al.* 2007, 2009, 2011, 2012; Jafari 2010; Khodayari *et al.* 2010;

Rahmani *et al.* 2010); however, no reports have been published so far on the seasonal activity and spatial distribution of the predator mite *T. bagdasarjani* on apple orchards, despite its substantial population density. The aim of the present study was, therefore, to monitor the seasonal activity of *E. frosti* and *C. irani*, two major phytophagous mites on apple and of their dominant common predator *T. bagdasarjani*; and to determine their spatial distribution to establish a biological control program for these phytophagous mites on apple trees.

Materials and methods

Sampling procedure

To determine the spatial and temporal distribution of the mite species, an apple orchard (~0.5 hectare with 100 apple trees) was selected in the Chaghalvandi region located in the north of Khorramabad, southwestern Iran. No chemical pesticides were used in this orchard at least during the last 10 years. Population densities of the three mite species were monitored during six months from 3th May to 4th November 2012. After a primary sampling, the relative variation (*RV*) was calculated according to Hillhouse and Pitre (1974) to evaluate the accuracy of the data. Sample size can be determined if the *RV* value is less than 25%. Relative variation was calculated as follows (Buntin 1994):

$$RV = \left(\frac{SE}{m} \right) \times 100$$

where *SE* = Standard error; *m* = Mean density of primary sampling data.

The reliable sample size was determined using the following equation:

$$N = \left(\frac{t \times s}{d \times m} \right)^2$$

where *s* = Standard deviation, *t* = Student's *t*-statistics for a two-tailed interval and *d* = Range of accuracy. Mean densities and standard deviations for the entire population were estimated.

Calculated *RV* and reliable sample size for the 25% variation from preliminary sampling for *E. frosti* were 16.22% and 53.86, respectively. Therefore, on each sampling day, 60 apple leaves were taken randomly from the different sides and heights of the selected trees. Each apple leaf was considered as the sampling unit. All mobile stages of mites on the leaves were counted under a dissecting microscope.

Spatial distribution pattern

The spatial distribution pattern of the three species was determined by Taylor's power law method (Taylor 1961). Taylor (1961) presented a function between mean and variance as:

$$S^2 = am^b$$

where S^2 is the variance; *m* the sample mean; *a* is a scaling factor related to sample size and *b* measures the species aggregation. When *b* = 1, < 1 or > 1, the distribution is random, regular or aggregated, respectively. Through use of a log-transformation, one can estimate the coefficients with linear regression as follows:

$$\text{Log}(S^2) = \text{Log}(a) + b\text{Log}(m)$$

where a and b are the parameters of the model, estimated by linearizing the equation by a log- transformation (Taylor 1961). Student t-test can be used to determine whether the colonies are randomly dispersed. Calculated values are compared with tabulated t -values with $n-2$ degrees of freedom.

Density dependence in prey-predator interaction

To determine the correlation between the population density of the two prey species and the predator, analysis of correlation was carried out using MINITAB software.

Temperature and relative humidity dependent fluctuation of the prey and predator's population

To determine the correlation between the population density of the three mite species and temperature and relative humidity, analysis of correlation between the population densities of these mite species and the two environmental factors cited above was carried out using MINITAB software.

Results

Population dynamics

Figure 1 illustrates the population fluctuations of *E. frosti*, *C. irani* and *T. bagdasarjani* and figure 2 illustrates the fluctuation of temperature and relative humidity of Khorramabad meteorological station throughout the sampling period. Mean *E. frosti* densities ranged from 0.76 to 28.68 per leaf. Density of *E. frosti* was low (0.88 per leaf) at the beginning of the sampling period (3th May), and reached the highest level on 23th August (28.68 per leaf). The population of this species showed two peaks, the first peak occurred on 23th August while the second peak was recorded on 11th September, after which its population decreased (Fig. 1). Mean densities of *C. irani* per leaf ranged from 0.06 to 28.88 per leaf. First individual of *C. irani* was observed on 29th May and the population remained low (less than 1 per leaf) until 22th July when *C. irani* population started increasing, and reached its only one peak on 11th September (28.88 per leaf). The first observation of *T. bagdasarjani* was made at 16th June 2012. Mean *T. bagdasarjani* densities per leaf ranged from 0.06 to 1.18 per leaf. The highest population density of *T. bagdasarjani* was observed on 12th August (1.18 per leaf). The population of *T. bagdasarjani* showed two peaks, the first peak on 12th August and the second peak (that occurred simultaneous with the second peak of *E. frosti*) was observed on 11th September and then population of this predator decreased.

Density-dependent interactions between predator and prey populations

The coefficient of the Pearson correlations between the population density of *T. bagdasarjani* with *E. frosti* and with *C. irani* were 0.899 and 0.812, respectively, which showed a significantly positive density-dependent reaction of the predator to its prey densities ($P < 0.001$) (Table 1).

*Effects of meteorological parameters on population densities of *E. frosti*, *C. irani* and *T. bagdasarjani**

The results revealed that the correlation between temperature and population densities of *E. frosti*, *C. irani* and *T. bagdasarjani* was insignificant ($P > 0.05$) (Table 1).

Also, our results demonstrated that the coefficients of the correlation between the relative humidity and population densities of *E. frosti*, *C. irani* and *T. bagdasarjani* were significantly negative values (-0.558, -0.527 and -0.608, respectively) ($P < 0.05$) (Table 1).

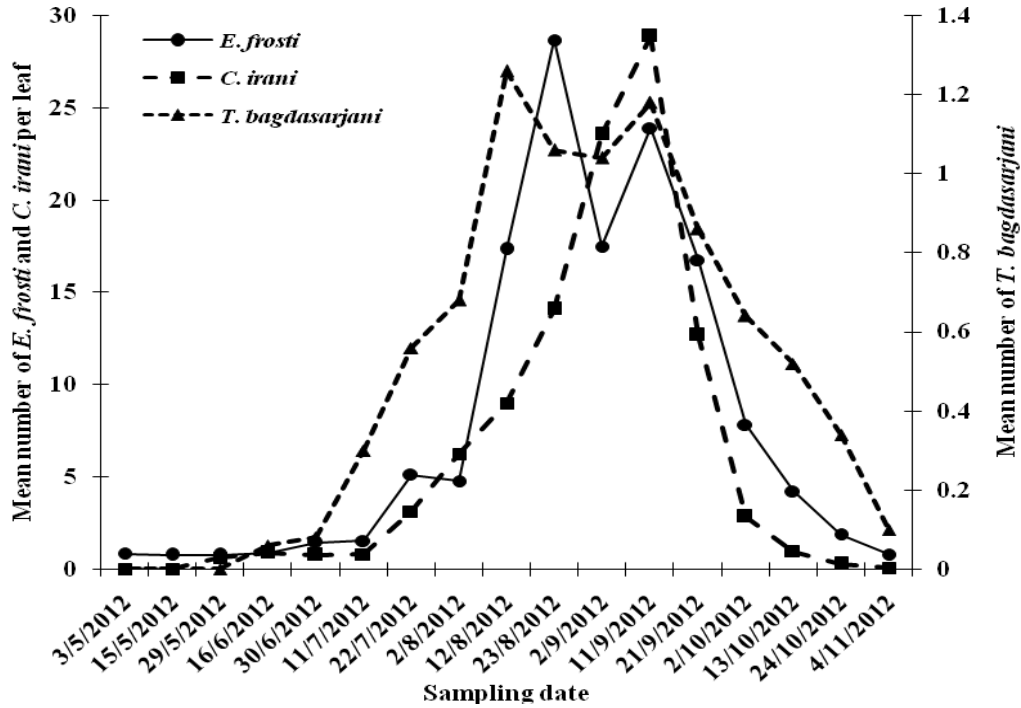


Figure 1. Population fluctuations of *Eotetranychus frosti*, *Cenopalpus irani* and *Typhlodromus bagdasarjani* in an unsprayed apple orchard of Khorramabad in 2012.

Table 1. Statistics of the correlation between the mean population densities of *E. frosti* and *C. irani* with *T. bagdasarjani* in 2012 and their relationship with temperature and relative humidity.

X-Y ^a	r^2	P value	Pearson correlation coefficients
<i>E. frosti</i> - <i>T. bagdasarjani</i>	0.807	0.000	0.899**
<i>C. irani</i> - <i>T. bagdasarjani</i>	0.659	0.000	0.812**
Temperature- <i>E. frosti</i>	0.167	0.104	0.408 ^{ns}
Temperature- <i>C. irani</i>	0.093	0.233	0.305 ^{ns}
Temperature- <i>T. bagdasarjani</i>	0.216	0.060	0.465 ^{ns}
Humidity- <i>E. frosti</i>	0.311	0.020	-0.558*
Humidity- <i>C. irani</i>	0.278	0.030	-0.527*
Humidity- <i>T. bagdasarjani</i>	0.370	0.010	-0.608*

Spatial distribution

Taylor's a and b coefficients, t -calculated and t -table for the three species are shown in Table 2. According to P -values in Taylor's model, the regression between $\log S^2$ and $\log m$ was significant for the three species. The results of Taylor's regression method showed that the spatial distribution patterns of *E. frosti* and *C. irani* were of the aggregated type ($b > 1$ and $t_c > t_t$), but the spatial distribution of *T. bagdasarjani* was of the random type (although the b value was slightly greater than 1, but $t_c < t_t$).

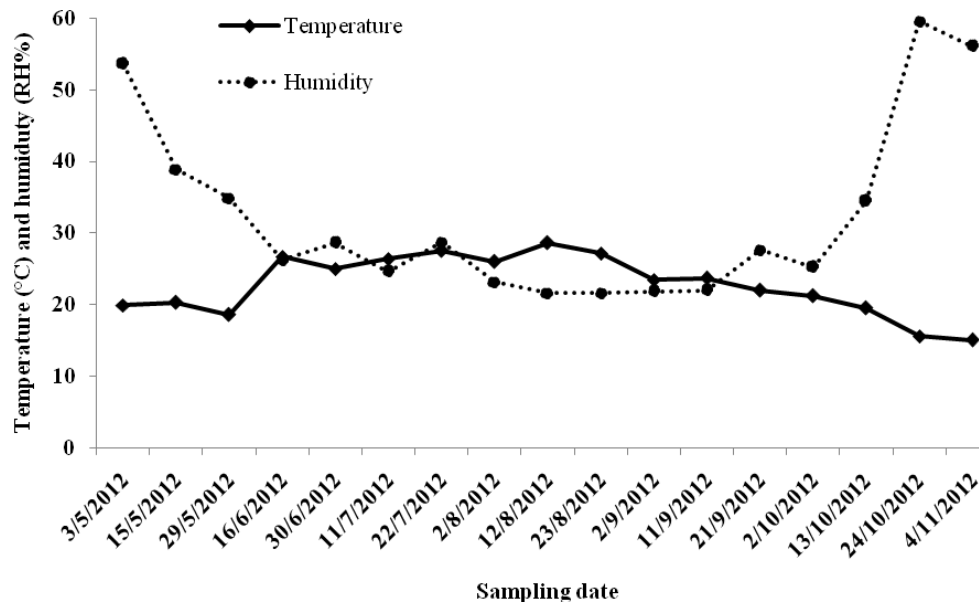


Figure 2. Temperature and humidity records of Khorramabad meteorological station during the sampling period.

Table 2. Estimated parameters by regression analysis of Taylor's power law for *E. frosti*, *C. irani* and *T. bagdasarjani* in an apple orchard of Khorramabad in 2012.

Species	$b \pm SE$	$a \pm SE$	t_c	t_t	r^2	P value
<i>E. frosti</i>	1.781±0.08	0.204±0.06	9.76	1.746	0.971	<0.0001
<i>C. irani</i>	1.567±0.098	0.338±0.08	5.78	1.746	0.941	<0.0001
<i>T. bagdasarjani</i>	1.047±0.05	0.050±0.03	0.94	1.746	0.975	<0.0001

Discussion

For developing a sampling program for research or management purpose of an arthropod population, the two characteristic features needed are its population density and its dispersion pattern (Pedigo & Buntin 1994). The occurrence and distribution of a pest mite on apple trees in a region are affected by different number of factors such as environmental conditions, food supply, competition and natural enemies. Also, for the choice of a habitat by the predators, in addition to prey, availability of alternative food

sources such as nectar or pollen, microclimate or other physical aspects of the plant part are very important (Roda *et al.* 2000). In this paper, we present the influence of two important abiotic factors including temperature and relative humidity and of the predator on the population density of two phytophagous mites under natural conditions with minimal interference of man.

According to figure 1, the highest population density of *E. frosti* was observed on 23th August (28.68 per leaf) in Khorramabad conditions after which, with the decreasing temperature, the population density of *E. frosti* also decreased. Furthermore, the severe decline in *E. frosti* population was observed from October 2th which may have been due to the combination of a decreased temperature, predator's activity or plant-mite interaction. Other authors (Darbemamieh *et al.* 2012) reported that the highest population density of *E. frosti* was observed on 9th August in 2007 under Kermanshah conditions, with lower mean density (4.938 per leaf). Khodayari *et al.* (2010) observed this peak for *E. frosti* in mid-September with much lower population density (2.46 per leaf) in Maragheh region. It seems the population of this pest on apple trees decreased as the latitude increased.

In our study, it seems that more predator species had affected the population of *E. frosti*, because in addition to *T. bagdasarjani* that feed on all the developmental stages of *E. frosti*, *Zetzellia mali* (Acari: Stigmaeidae) have been collected with noticeable population especially late in the season on apple leaves in studied orchards while previously reported as an active predator of *E. frosti* in apple orchards of Maragheh, northwestern of Iran (Khodayari *et al.* 2010).

Our results showed that the density of *C. irani* was at least equal to that of *E. frosti*, although its peak occurred later than that of *E. frosti*, but suggesting that *C. irani* may become a serious pest in apple orchards in similar regions. However, *C. irani* compared to *E. frosti* seems more sensitive to low temperatures as shown by the delayed onset of its population increase and earlier decline. Also, in the present study the time span during which population density of *C. irani* was greater than 4 individuals per leaf was more than eight weeks (from 2th August to 21th September) before its population declined. But Darbemamieh *et al.* (2011) reported that the time span during which population density of *C. irani* was greater than 4 per leaf was shorter than three weeks (from 20th July to 9th August) under Kermanshah conditions, indicates the more important of this pest in Lorestan provinces and regions with similar conditions.

Our results showed a significantly positive density-dependent reaction of the *T. bagdasarjani* to its prey population (more than 0.80). No chemical pesticides were used in the studied orchard at least during the last 10 years. Therefore, we have expected a positive correlation between the population densities of pests and their natural enemies. But, since *T. bagdasarjani* is a common predatory mite (Gerson *et al.* 2003) and can feed on pollen and broad range of small arthropods, it is natural that changes in populations of the predatory mite *T. bagdasarjani* is not completely dependent on *E. frosti* and *C. irani* population densities.

In the present study the correlation between population densities of the studied mites with temperatures and relative humidity was insignificant and significant, respectively. These results are in conflict with those reported by Darbemamieh *et al.* (2011). Also, Rahmani *et al.* (2010) studied the seasonal activity of *Z. mali* and *Panonychus ulmi* (Koch) and found a significant relation only between temperature and the population density of *P. ulmi* and reported that increasing the temperature resulted in

increasing population density of this mite. Therefore it can be concluded that both of temperature and relative humidity play an important role in the population fluctuations of mites.

A good knowledge of the spatial distribution pattern of the mite species studied could help us in the implementation of pest management strategies targeting IPM. In this study, aggregated spatial distribution pattern was found for *E. frosti* and *C. irani* using Taylor's Power Law. Aggregated spatial distribution for examined species suggests that presence of an individual of mites at one point may cause increased probability of another individual being nearby. The aggregated distribution of tetranychids mite is reported in several previous studies (Liu *et al.* 2002; Rahmani *et al.* 2010; Jafari 2010; Darbemamieh *et al.* 2012). Similar to our finding, Darbemamieh *et al.* (2009) reported the aggregate distribution for *C. irani* which attributed to clump laying behavior and slow movement of *C. irani*.

High values of Taylor model, suggests that this model can be properly fitted for these mites. The data had a good equivalence with Taylor's model ($r^2 = 0.941$) for *C. irani*, and also better equivalence with for *E. frosti* ($r^2 = 0.971$) and *T. bagdasarjani* ($r^2 = 0.975$). According to our finding, although the b value for *T. bagdasarjani* was slightly greater than 1, because the calculated t (t_c) < t table (t_t), the null hypothesis ($b = 1$) was accepted and spatial distribution determined as random type. These results showed that predator clumping is not strongly linked to prey distribution. Greco *et al.* (1999) found that *N. californicus* exhibited lower aggregation than its prey *T. urticae*, which is agreement to our finding.

The population density of *T. bagdasarjani* reached its peak before its prey, revealed reaction the population density of *T. bagdasarjani* to increasing temperature and reduction of humidity is faster (Figs. 1 & 2), therefore it can act as an effective predator in biological control programs based on conservation or augmentation in IPM strategies.

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توزیع فضایی و زمانی کنه‌های *Eotetranychus frosti* و *Cenopalpus irani* و شکارگر آنها *Typhlodromus bagdasarjani* در باغ سیب سمپاشی نشده در شهرستان خرم‌آباد

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چکیده

تغییرات جمعیت و نوع الگوی توزیع فضایی کنه شکارگر *Typhlodromus bagdasarjani* و *Eotetranychus frosti* (McGregor) و طعمه‌های آن کنه‌های

Cenopalpus irani Dosse در باغی سمپاشی نشده سیب در منطقه چغلوندی در شمال شهرستان خرم‌آباد در سال ۱۳۹۱ مورد بررسی قرار گرفت. برای انجام آزمایش در هر بار نمونه برداری تعداد ۶۰ برگ (واحد نمونه برداری) سیب مورد شمارش قرار گرفتند. به همین منظور ۱۷ بار نمونه برداری از تاریخ ۹۱/۲/۱۳ تا ۹۱/۸/۱۳ انجام شد. برای تعیین نوع الگوی توزیع فضایی از روش رگرسیونی تیلور استفاده شد. نتایج بررسی تغییرات کنه شکارگر و طعمه‌های آن نشان داد که اوج میانگین تراکم جمعیت کنه‌های *E. frosti*، *C. irani* و *T. bagdasarjani* به ترتیب در تاریخ‌های ۱۳۹۱/۶/۱۱ (۲۸/۶۸ فرد روی هر برگ)، ۱۳۹۱/۶/۲۰ (۲۸/۸۸ فرد روی هر برگ) و ۱۳۹۱/۵/۲۰ (۱/۱۸ فرد روی هر برگ) مشاهده شد. شیب خط رگرسیونی به دست آمده در روش رگرسیونی تیلور برای هر دو گونه کنه گیاه‌خوار به طور معنی‌داری بزرگتر از ۱ بود که نشان داد الگوی پراکندگی آنها از نوع الگوی تجمعی است، ولی الگوی پراکندگی کنه شکارگر از نوع تصادفی تعیین شد. یافته‌های این پژوهش نشان داد که همبستگی مثبت و معنی‌داری بین نوسانات جمعیت کنه شکارگر و کنه‌های گیاه‌خوار وجود دارد که نشان داد واکنش شکارگر به تغییرات جمعیت طعمه‌ها از نوع وابسته به تراکم است. همچنین بررسی همبستگی بین آماره‌های هواشناسی با جمعیت کنه‌ها نشان داد که تاثیر دما بر نوسانات جمعیت کنه‌ها غیر معنی‌دار ولی تاثیر رطوبت نسبی بر جمعیت کنه‌ها معنی‌دار و منفی است.

واژگان کلیدی: الگوی توزیع فضایی، تغییرات جمعیت، Tenuipalpidae، Tetranychidae، Phytoseiidae

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