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Spatial Distribution and Seasonal Activity of *Panonychus ulmi* (Acari: Tetranychidae) and Its Predator *Zetzellia mali* (Acari: Stigmaeidae) in Apple Orchards of Zanjan, Iran

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ABSTRACT

Study of the spatial distribution of a pest and its natural enemies provides better decision tool for integrated pest management. The spatial distribution and seasonal activity of *Panonychus ulmi* (Koch) and its predator *Zetzellia mali* (Ewing) were studied in an apple orchard in Khoramdareh (Zanjan Province, Iran) during 2007. The interaction (density dependence) between the prey and its predator was determined. For *P. ulmi RV* (relative variation) and reliable sample size were calculated with 25 percent variation from primary sampling at 18.8% and 59 leaves, respectively. The distribution pattern of both species was analyzed using nine statistical formulae: Taylor's power law, Iwao's patchiness regression, index of dispersion, Morisita's coefficient of dispersion, Lloyd's mean crowding, David and Moore's index, Cole's index of dispersion, Green's index and coefficient of 'K' (coefficient of aggregation). The results indicated that the highest population density of *P. ulmi* and *Z. mali* were on 11 August (23.92 per leaf) and 11 September (8.2 per leaf), respectively. The slopes of Taylor's power law and Iwao's patchiness regression methods were 1.82 and 2.18 for prey and 1.39 and 1.92 for predator, respectively. These slopes had significant difference from one, indicating aggregated spatial distribution in prey and predator. The index of dispersion (I_D) showed that the spatial distribution of *P. ulmi* in apple orchards was aggregated but it showed random distribution for *Z. mali*. The Morisita's coefficient, Lloyd's mean crowding and Green's index showed an aggregated distribution for both species. The regressions between population densities of *P. ulmi* and *Z. mali* indicated a density independent reaction of predator to the prey. The effect of temperature and humidity on the prey and predator populations was estimated. Spatial distribution parameters of the prey and predator can be used in integrated pest management programs.

Keywords: Density dependence interaction, *Panonychus ulmi,* Seasonal activity, Spatial distribution, *Zetzellia mali*.

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INTRODUCTION

Spider mites (Acari: Tetranychidae) are very harmful and widespread pests throughout apple growing areas around the world (Kasap, 2005; Jepson *et al.,* 1975; Bolland *et al.,* 1998.). To reduce pesticide input and associated risks and costs, biological control of spider mites is widely used worldwide (Mo and Liu, 2006). Together with some insects, members of Stigmaeidae and Phytoseiidae are natural enemies of spider mites. Predaceous mites are important natural enemies of several phytophagous mites and are known to play an important role in the natural control of these pests (Kasap, 2005). At low prey densities, stigmaeids are more effective than some of phytoseiids because of their preference for prey eggs, higher oviposition related to prey consumption and the ability to consume their own eggs, while at high

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prey densities, phytoseiids are more effective (Clements and Harmsen, 1990).

Zetzellia is one of the most important predacious genis in the family Stigmaeidae (Krantz, 1978). Z. *mali* is the most common and best known species in Stigmaeidae, which feeds upon different stages of phytophagous mites, especially spider mites (Tetranychidae) and eriophyids (Eriophyidae) (Clements and Harmsen, 1990). It is native to palaearctic and nearctic regions (Delattre, 1971) and has been reported from Iran on apple, pear, quince, peach, cherry and sour cherry (Sepasgosarian, 1977). Clements and Harmsen (1990) reported differences in terms of predatory behavior and prey-stage preferences and mobility between the stigmaeid *Zetzellia mali* (Ewing) and the phytoseiid *Typhlodromus caudiglans* Schuster, when feeding on European red mite, *Panonychus ulmi* (Koch). Therefore, it is important to obtain information on the *P. ulmi* – *Z. mali* interaction that can be used to assess the pest control potential of this predator.

Knowledge of spatial distribution of prey and predators is important for evaluating the agro system's persistence and the potential of a natural enemy to reduce its prey (Slone and Croft, 1998). Field distribution of a pest is an important determinant of the number of samples required for estimating its population. Measurement of species aggregation is a central issue in ecology and applied biology, especially for sampling and density studies (Gutierrez, 1996). Croft and Slone (1997) studied European red mite density on apple. In order to develop sustainable biological control strategies, it is necessary to understand habitat structure effects on the ability of natural enemies (Stavrinides and Skirvin, 2003).

The main predatory mites in apple orchards belong to the families Phytoseiidae and Stigmaeidae. The role of phytoseiid mites has been broadly studied, but the role of stigmaeids in commercial agricultural systems is not well known (Villanueva and Harmsen, 1998). To fill this gap, we have investigated a scientific sampling program, spatial distribution, seasonal activity, density dependence interaction and evaluation of the effect of temperature and humidity on the population density and population fluctuation of *Panonychus ulmi* and *Zetzellia mali.*

MATERIALS AND METHODS

Sampling Program

Because the different life stages of *Z. mali* and its prey *P. ulmi* usually involve colonizing leaves, leaves were selected as the sampling units. Abundance of these mites was estimated from 9 June to 5 October 2007. In each sampling, 60 apple leaves were sampled randomly from 15 trees (four leaves from each tree) in the morning. Samples were taken twice per week from an apple orchard at Khoramdareh located in Zanjan province in northwestern Iran. No pesticide was used in the orchard. Leaves were sampled on the East, South, West and North sides of each tree in vials. All mites on the leaves were counted under a dissecting microscope. To determine the number of samples it was necessary to conduct random primary sampling in order to calculate RV (Relative Variation). Sample size can be determined if the *RV* value is less than 25%. Relative variance and sample size were calculated as follows (Buntin, 1994):

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

where *SE*= Standard error; m= Mean density of primary sampling data. Sample size formula is as follow: $N = \left(\frac{t \times s}{d \times m}\right)^2$

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

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Spatial Distribution

The distribution pattern of both species was analyzed by Iwao's patchiness regression (Iwao and Kuno, 1968) and Taylor's power law (Taylor, 1961) methods. Other methods were as follows: Index of dispersion (I_D) (Patil and Stiteler, 1974), Morisita's coefficient of dispersion (I_δ) (Morisita, 1959), Lloyd's mean crowding (x^*) (Lloyd, 1967), Cole's index of dispersion (I) (Cole, 1946), David and Moore's index (David and Moore, 1954) and Green's index (C_x) (Davis, 1994).

The clumping or dispersion parameter (K) was worked out by the following methods as given by Southwood and Henderson (2000):

(a) Moment estimate of '*K*'. This was computed using the following formula: $K=\frac{m^2}{S^2-m}$.

(b) Common '*K*'. Estimates of a common *K* (k_c) was made using the Bliss and Owen (1958) regression method, which estimates k_c by regressing $Y'=\left(S^2-m\right)$ on $X'=\left(m^2-\frac{S^2}{n}\right)$, and k_c is defined by $k_c=\frac{1}{Slope}$. For the two types of *K* estimates, a value of more than eight signifies that the distribution is random or Poisson, but values less than eight indicate aggregation of the population (Southwood and Henderson, 2000).

Cole's Index of Dispersion (I)

Cole (1946) developed the formula, $\mathrm{I}=\frac{\sum(\mathrm{x})^2}{(\sum \mathrm{x})^2}$ to study the dispersion of the population in nature. Cole's index value is greater than the value of maximum regularity and randomness, and indicates the aggregative nature of dispersion. A value of one indicates maximum clumping (all individuals in a single sample).

David and Moore's Index

This index (David and Moore, 1954) was computed using the formula $\frac{S^2}{m-1}$. Here values greater than zero indicate aggregation.

Green's Index (C_x)

A modification of the variance to mean ratio was developed by Green. This index has the advantage of being independent of sample size and is calculated as follows: $C_x=\frac{\left(\frac{S^2}{m}-1\right)}{(n-1)}$ where C_x takes values of = 0, < 0 and > 0 for random, regular and aggregated distributions, respectively. Because the range of C_x is bounded by $\frac{-1}{(\sum x-1)}$, which indicates maximum uniformity, and a value of one, which indicates maximum clumping; C_x is a usual index for measuring the degree of aggregation. The upper value for a test of randomness at the significance level of α is $C_{x,(1-\alpha)}=\frac{\frac{\left(X^2_{(1-\alpha)}\right)}{(n-1)}-1}{nm-1}$. X^2 has *n-1* degrees of freedom. Calculated values of C_x are compared to $C_{x,(1-\alpha)}$ to determine if the data set differed from random (Davis, 1994).

Sample Size Model

Taylor's *a* and *b* coefficients, describe the relationship between variance and mean ($S^2=am^b$) for individuals distributed in a natural population. Wilson and Room (1982) incorporated Taylor's power law into Karandinos' equation to form the sample size model used in this study (Cullen *et al.,* 2000): $N = t_{\alpha/2}^{\ 2}\, d^{-2} a m^{b-2}$. Where, N= Sample size, $t_{\alpha/2}$ = Student's *t*-statistic for a two-tailed interval, m = Mean density of mites in each sampling unit, *d*= the range of accuracy and *a*, *b* are Taylor's coefficients.

Density Dependence Interaction

To determine the type of interaction between the prey and predator, analysis of linear regression was carried out between prey and predator densities. If *P*-value > 0.05 or *b*= 0, the predation would be density independent, but if *P*-value< 0.05 and b> 0 or b< 0, the predator would act as density dependent and inverse density dependent, respectively (Kidd and Jervis, 1996).

Temperature/Humidity Dependent Fluctuation of the Prey and Predator's Populations

To determine if the population density of prey and predator is dependent on temperature/ humidity, a linear regression was carried out between these parameters and the densities of the prey and predator.

RESULTS

Seasonal Activity

Population fluctuation curves of *P. ulmi* and *Z. mali* for determining seasonal activity are shown in Figure 1. The population of *P. ulmi* was observed from the beginning of the sampling period (9 June), but no *Z. mali* population was recorded until 7 July 2007, at which time the prey's population had built up. Mean density of *P. ulmi* per leaf ranged from 0.5±0.14 to 23.92±0.71. This range for *Z. mali* was 0.367±0.11 to 8.2±1.05. The results indicated that the highest population densities of *P. ulmi* occurred on 11 August (23.92 per leaf) and for *Z. mali* in 11 September (8.2 per leaf). During the sampling season, population of *P. ulmi* was greater and with irregular fluctuations compared to the predator population.

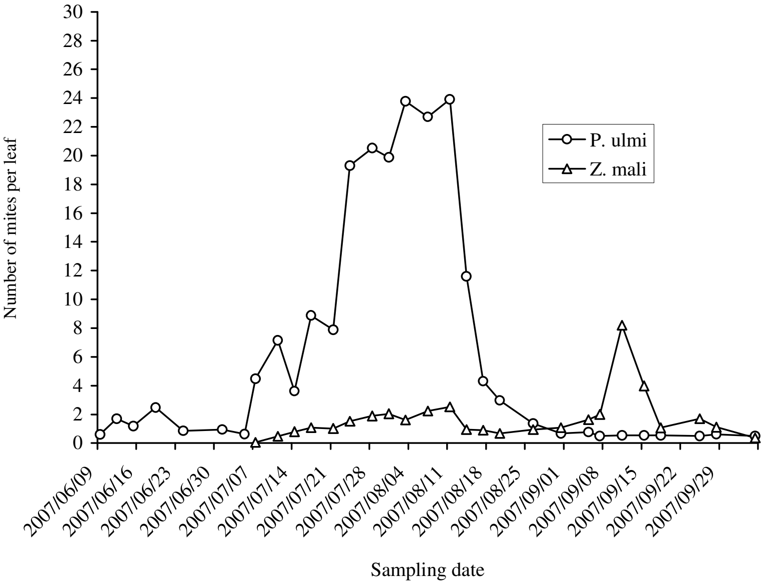

Figure 1. Population fluctuation of *Panonychus ulmi* and *Zetzellia mali* in an apple orchard of Khoramdareh in 2007.

Table 1. Estimated values of parameters of *P. ulmi* and *Z. mali* by regression analysis of Taylor's power law and Iowa's patchiness regression.

Species	Taylor's power law					Iwao's patchiness regression				
	a	b	$SE_{(b)}$	r^2	P_{value}	α	β	$SE_{(\beta)}$	r^2	P_{value}
P. ulmi	0.198	1.82	0.039	0.98	0.000	-1.58	2.18	0.102	0.94	0.000
Z. mali	0.355	1.39	0.106	0.88	0.000	0.339	1.92	0.159	0.86	0.000

Table 2. Estimated parameters by Lloyd mean crowding, index of dispersion, Lloyd mean crowding to mean, Green's index, common *k* and calculated sample size for *P. ulmi* and *Z. mali*.

Species	m	S^2	m^*	I_D	Z	m^*/m	K(a)	K(b)	C_x	$C_{x\,(1-a)}$	Sample size (N)
P. ulmi	6.32	66.91	15.96	317.61	17.51	2.52	0.66	0.82	2.31	1.57	77.80
Z. mali	1.66	2.61	2.61	36.1	1.79	1.34	2.90	1.08	0.025	0.011	23.85

Spatial Distribution and Sample Size Model

Calculated *RV* and reliable sample size for the 25 percent variation from primary sampling for *P. ulmi* were 18.8% and 58.95, respectively, but we took 60 samples on each date. Iwao's α and β and Taylor's *a* and *b* coefficients for each species are listed in Table 1. The results of Iwao's regression method showed that the mean crowding was linearly related to mean density of the prey. This was also the case for the predator, indicating aggregated spatial distribution patterns for *P. ulmi* and its predator. These results are not surprising and can be explained in part by behavioral characteristics such as the relative immobility of immatures and also by host type and structural feature preferences. In both species, slopes for both Taylor's and Iwao's methods were significantly greater than one (Taylor's: for *P. ulmi* t_c = 20.51> t_t =2.75; for *Z. mali* t_c =3.66> t_t =2.80 and Iwao's: for *P. ulmi* t_c= 11.55> t_t=2.75; for *Z. mali* t_c= 5.75> t_t=2.80). As indicated in Table 1, Taylor's power law fits the data better with a higher value of r^2 (0.98) than Iwao's regression model (0.94) for *P. ulmi* and 0.88 versus 0.86 for *Z. mali*. The index of dispersion (I_D) showed that the spatial distribution of *P. ulmi* in apple orchards was aggregated (calculated *z* was 17.51 that was greater than 1.96) but it showed random distribution for *Z. mali* (z= 1.79, which was within -1.96 and +1.96). The I_D values for each population are shown in Table 2. The Green's index (C_x) for both species is also presented in Table 2. Comparing C_x with $C_{x\,(1-a)}$ for each species indicated aggregated distribution for them (in both species C_x is greater than $C_{x\,(1-a)}$). Variance and mean estimates obtained from prey and predator data were used to estimate the mean crowding values which departed from the Poisson series. As presented in Table 2, the m^*/m value for each population was significantly greater than one. All values for *z* of Morisita's index for *P. ulmi* were significantly greater than 1.96 except on 5 October when it was 1.18. This indicated spatial distribution changes over time. This rule was also demonstrated for *Z. mali* (z= 1.06 in 17 August). The *z* value for all data showed aggregated distribution for both species (Table 3). The results of David Moore's and Cole's indices for *P. ulmi* in different sampling dates during 2007 presented in Table 4 showed that the observed Cole's index value for most dates (except 18 September) was within the values of maximum regularity and randomness, indicating random distribution for *P. ulmi*. From this table it is evident that the observed values of David and Moore's index for *P. ulmi* were greater than the table value of maximum regularity (-1) and randomness (0), indicating aggregated distribution for the prey.

Table5 shows the values of David Moore's and Cole's indices for *Z. mali*. The observed

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Table 3. Morisita's index and *Z* values for *P. ulmi* and *Z. mali* on different sampling dates in 2007.

Date	I_δ (*P. ulmi*)	Z (*P. ulmi*)	I_δ (*Z.mali*)	Z (*Z.mali*)
7 Jul.	4	1.64	10	3.28
17 Jul.	1.53	5.84	1.64	3.82
3-Aug.	2.62	35.53	1.29	3.31
17 Aug.	1.79	32.25	1.20	1.06
5 Sept.	2.58	201.72	1.58	3.48
18 Sept.	3.04	42.66	3	11.72
5 Oct.	2.18	1.18	2	7.99
Overall dates	2.40	35.54	1.33	1.99

Cole's index value for all times showed random distribution for this predator, but David and Moore's index indicated aggregated distribution for most dates (except 17 August). A common *K* of 0.82 (for *P. ulmi*) and 1.08 (for *Z. mali*) was calculated by the regression method. Values of *K* from moment estimated and regression methods are shown in Table 2. The calculated *N* from sample size model for *P.ulmi* and *Z. mali* were 77.8 and 23.85 and are shown in Table 2. These values of sample size can help to improve the samplings program of *P. ulmi* and its predator.

Density Dependence Interaction and Meteorological Parameters Effects

The *P*-value of the regressions between population densities of *P. ulmi* and *Z. mali* was 0.995, which is greater than 0.05, indicating a density independent reaction of the predator to the prey's population (Table 6). Regression between prey or predator populations with temperature or humidity are shown in Table 6. Regression was significant only in one case, indicating that increasing temperature resulting in increasing of population density of the prey.

DISCUSSION

As presented in Table 2, the variance among prey and predator populations was greater than the mean, suggesting the aggregative nature of distribution of *P. ulmi* population in the field. Faleiro *et al*. (2002) have used Lloyd's test to determine the distribution pattern of pest populations on different crops. Different statistical methods that were used to determine the spatial distribution of these mites resulted either in aggregated or random patterns. Some studies

Table 4. David Moore's and Cole's indices for *P. ulmi* on different sampling dates in 2007.

Date	Cole's index				David Moore's index		
	Maximum regularity (1/n)	Random $(1/n)+n-(1/n(1/\sum x))$	Maximum contagion	I	Maximum regularity	Random	Observed index
7 Jul.	0.016	0.056	1	0.047	-1	0	10.10
17 Jul.	0.016	0.051	1	0.031	-1	0	8.60
3 Aug.	0.016	0.040	1	0.025	-1	0	11.02
17 Aug.	0.016	0.048	1	0.031	-1	0	10.75
5 Sept.	0.016	0.059	1	0.123	-1	0	5.04
18 Sept.	0.016	0.059	1	1	-1	0	0.03
5 Oct.	0.016	0.059	1	0.183	-1	0	0.03

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Table5. David Moore's and Cole's indices for *Z. mali* on different sampling dates in 2007.

Date	Cole's index				David Moore's index		
	Maximum regularity (1/n)	Random (1/n)+n – {1/(n 1/∑x))}	Maximum contagion	I	Maximum regularity	Random	Observed index
7 Jul.	0.016	0.059	1	0.021	-1	0	0.004
17 Jul.	0.016	0.058	1	0.028	-1	0	14.13
3 Aug.	0.016	0.057	1	0.024	-1	0	4
17 Aug.	0.016	0.058	1	0.025	-1	0	-1.47
5 Sept.	0.016	0.058	1	0.028	-1	0	14.13
18 Sept.	0.016	0.055	1	0.039	-1	0	5.31
5 Oct.	0.016	0.058	1	0.033	-1	0	10.66

have described the spatial distribution of tetranychid and stigmaeid mites in apple orchards using dispersion indices. Aggregative spatial distribution of *T. urticae* in a Carambula orchard has been reported by Sih and Wang (1996).

Comparing the r^2 values obtained with Taylor and Iowa's analytical methods (Table 1) revealed that Taylor's power law gave more accurate estimations of populations than Iwao's patchiness regression; the data proved to be a good fit to Taylor's power law for *P. ulmi* (r^2= 0.98) and *Z. mali* (r^2= 0.88). Hence, regression methods (Iwao's and Tylor's methods) have a higher accuracy and, together with most of the other methods, indicated aggregative distribution for prey and predator and we consider their distributions as an aggregation distribution. Comparing *K* values among these two species showed that *P. ulmi* was more inclined to aggregation than its predator because of the low value of the *K* coefficient in *P. ulmi*. This is due to the higher differences between the variance and mean of the pest sampling data.

The spatial distribution parameters of *P. ulmi* and its natural enemies can be used to outline a sampling program and to estimate the population density of these organisms to use in integrated pest management programs. The current study represents merely some preliminary steps in understanding aspects of biological control by *Z. mali*. A wide array of further experiments is suggested by these initial results. Future studies should attempt to determine more factors that are capable of influencing subsequent behaviors in this predatory mite.

The population density of *P. ulmi* increased and reached 23.92 individuals per leaf in early August. Furthermore, the severe decline in the *P. ulmi* population from mid August could mainly be due to the predator's action or plant-pest interaction after which the population density of the pest did not increase again on most dates except once in September (Figure 1). Because of the weather conditions or likely plant-predator interactions on the population of *Z. mali*, it had irregular population fluctuations during the sampling season. The population density of *Z. mali* per sample unit was much lower than that of the pest. Lawson and Walde (1993) estimated that *Z. mali* which has been thought to be less important in the control of *P. ulmi*, showed a stronger response than *Typhlodromus pyri* Scheuten to the presence of *P. ulmi*.

From Figure 1, it is evident that when the population of *P. ulmi* started to increase (7 July), *Z. mali* was also supposed to increase its population in order to have an effect on prey density but it seems that the predator was not very effective because of other factors such as temperature which have influenced the prey population positively. The effect of temperature on the prey population as shown in Table 6 confirms this claim. Croft and Slone (1997) supported the general hypothesis that control of *P. ulmi*

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Table 6. Statistics of the linear regression between the mean population densities of *P. ulmi* and *Z. mali* in 2007; their relationship with temperature and humidity.

X-Y[a]	a	b	r^2	P_{value}
P. ulmi - *Z.mali*	1.66	0.0003	0	0.995
Temperature - *P. ulmi*	-14.8	1.02	13.5	0.043[b]
Temperature - *Z. mali*	1.51	0.0069	0	0.94
Humidity - *P. ulmi*	15.8	-0.173	0	0.354
Humidity - *Z. mali*	-0.09	0.037	1.2	0.27

[a] Y and X are dependent and independent parameters, respectively.
[b] The regression between X and Y is significant at 0.05 level.

occurred at the lowest equilibrium levels in plots with a high diversity of predators.

Stigmaeids may play a supplementary role (Santos and Laing, 1985), which may be especially important when phytoseiids are absent on apple trees such as when the prey density is low or during fall when stigmaeids feed on the winter eggs of *P. ulmi* (White and Laing, 1977). Clements and Harmsen (1993) showed that combination of stigmaeids and phytoseiids has a greater efficacy than the predators alone at different prey densities

In general, *Z. mali* exhibited lower aggregation than *P. ulmi*. This result supports other empirical evidence claiming that predator clumping is not strongly linked to prey distribution (Strong *et al.,* 1997), a characteristic which would create refuges for the prey and consequently increase the agro system persistence (Chesson and Murdoch, 1986). This persistence could also be favored due to the existence of alternative prey and prey–predator dispersal' among these spatially structured populations (Walde, 1995). Following a reduction in prey density, stigmaeids would tend to dominate in terms of both predation and numbers of predators, as seen in Clements *et al.* (1991).

The regression between predators and prey densities (Table 6) was not significant, suggesting density independent predation due to the predator's polyphagous behavior, feeding on eggs and immature stages of other tetranychid and eriophyid mites, and the existence of alternative prey on the apple trees of Khoramdareh. The regression between temperature and prey density was significant, indicating the effect of this factor on the prey's increase in density.

From the results presented and discussed in this paper, it is clear that population of *P. ulmi* and its predator, *Z. mali* in the apple orchards of Khoramdareh region is aggregated and follows the negative binomial distribution pattern. Apple plantations in the vicinity of infested orchards were prone to attack by *P. ulmi*. This is probably due to the aggregated distribution of its population. Hence, plantations in the vicinity of infested orchards by *P. ulmi* need to be protected using prophylactic control measures.

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الگوی توزیع فضایی و فعالیت فصلی کنه قرمز اروپایی (*Panonychus ulmi*) و شکارگر آن *Zetzellia mali* در باغهای سیب منطقه زنجان، ایران

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چکیده

بررسی نوع توزیع فضایی آفت و عکس‌العمل دشمن طبیعی آن درک بهتری از روابط متقابل بین آنها فراهم می‌کند و این امر در مدیریت تلفیقی آفت می تواند نقش موثری داشته باشد. بدین منظور توزیع فضایی و فعالیت فصلی کنه‌های *Panonychus ulmi* (Koch) (Acari: Tetranychidae) و *Zetzellia mali* (Ewing) (Acari: Stigmaeidae) در باغ سیب خرمدره در استان زنجان طی سال ۱۳۸۶ بررسی و تعیین شد و بین شکارگر و طعمه آن مقایسه گردید. نمونه‌برداری از جمعیت کنه‌های مذکور دو بار در هفته انجام گرفت. برگهای سیب به عنوان واحد نمونه‌برداری انتخاب شدند و اندازه نمونه و *RV* محاسبه شده برای کنه قرمز اروپایی پس از انجام نمونه‌برداری اولیه، در سطح احتمال ۵ درصد و خطای ۲۵ درصد به ترتیب ۵۹ برگ و ۱۸/۸ درصد تعیین گردید. بالاترین تراکم جمعیت کنه های *P. ulmi* و *Z. mali* به ترتیب در تاریخ های ۱۱ آگوست (۲۳/۹۲ در هر برگ) و ۱۱ سپتامبر (۸/۲ در هر برگ) ثبت شد. داده‌های حاصل از نمونه‌برداری با استفاده از نه روش مورد تجزیه قرار گرفتند که عبارتند از: روش رگرسیونی تیلور، روش رگرسیونی آیوائو، شاخص

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پراکندگی، شاخص های ضریب K، موریسیتا، کول، گرین، لوید و دیوید مورس. توزیع فضایی کنه آفت و شکارگر هر دو از نوع تجمعی تشخیص داده شد. شیب خط رگرسیون لگاریتم واریانس و لگاریتم میانگین جمعیت در روشهای تیلور و آیوائو به ترتیب ۱/۸۲ و۲/۱۸ برای آفت و ۱/۳۹ و۱/۹۲ برای شکارگر تعیین شد. شیب های به دست آمده در این رگرسیون ها اختلاف معنی داری از یک داشتند که موید توزیع تجمعی برای آفت و کنه *Z. mali* می‌باشد. رگرسیون بین جمعیت آفت و شکارگر در سطح احتمال ۵ درصد معنی‌دار نبود. با توجه به این نتایج می‌توان چنین استنباط کرد که توزیع فضایی این شکارگر تابعی از توزیع فضایی *P. ulmi* نیست و به صورت مستقل از تراکم جمعیت این طعمه عمل می‌کند لذا جمعیت آن تابعی از جمعیت آفت دیگری است از جمله دلایل این امر می‌توان به پائین بودن جمعیت کنه شکارگر در مقایسه با جمعیت کنه قرمز اروپایی اشاره کرد. همچنین ارتباط جمعیت این دو گونه با دما و رطوبت مورد مطالعه قرار گرفت. رگرسیون بین این دو عامل با جمعیت گونه های فوق معنی دار نبود. لذا جمعیت آنها به طور مستقیم وابسته به این دو عامل نیست.

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