BIONOMICS OF *CENOPALPUS IRANI*, *BRYOBIA RUBRIOCULUS* AND THEIR EGG PREDATOR *ZETZELLIA MALI* (ACARI:TENUIPALPIDAE, TETRANYCHIDAE, STIGMAEIDAE) IN NATURAL CONDITIONS

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ABSTRACT: Bionomics of *Cenopalpus irani* Dosse and *Bryobia rubrioculus* Scheuten and their egg predator *Zetzellia mali* (Ewing) was studied in Kermanshah (west of Iran) from 31st May till 7th November 2007 on apple leaves and interaction (density dependence) between phytophagous mites and their predator were determined. The reliable sample size (number of leaves) with maximum variation of 5.33% was about 130. Index of dispersion, regression models (Taylor and Iwao), Morisita's index and Lloyd's mean crowding to mean were used to estimate spatial distribution pattern of these mites. The results indicated that the highest population density of *C. irani*, *B. rubrioculus* and *Z. mali* was in 19th August (13.45 per leaf), 9th August (0.615 per leaf) and 9th August (1.161 per leaf), respectively. Index of dispersion, regression models (Taylor and Iwao), Morisita's index and Lloyd's mean crowding to mean showed an aggregated distribution for all species. The linear regression between predator and preys population densities showed a density-dependant predation by *Z. mali* on *C. irani* and *B. rubrioculus*. Spatial distribution parameters of tetranychoid mites and their predator can be used to outline a sampling program, estimate population density of these mites and efficiency of the predator for using in orchards IPM.

KEYWORDS: *Bryobia rubrioculus, Zetzellia mali, Cenopalpus irani,* population density, spatial distribution, density dependence interaction, optimum sample size

Mites of the superfamily Tetranychoidea are cosmopolitan and commonly distributed in all continents and climatic zones all over the world. They reach to high population levels in some perennial agro-ecosystems (Duso et al., 2004). By ingesting leaf cell contents, they can reduce plant photosynthesis and potentially decrease fruit quality (Prischmann et al., 2005). In case of no control measures, these mites may cause severe damage to a yield's quantity and quality (Kasap, 2005). Difficulties in spider mite management could be in part due to short a generation time, high reproductive potential, and rapidly acquired resistance or tolerance to acaricides (Tanigoshi et al., 1983; Beers et al., 1993). Orchard management practices usually cause outbreaks of spider mites followed by disrupted population of a natural enemy or induce mite migration from the ground cover into trees (Alston, 1994).

Cenopalpus irani Dosse is one of the false spider mites from Tenuipalpidae that is widely distributed in apple orchards located in Western part of Iran. It is one of the most important tenuipalpid pests on apple that completes 3 generations in Iran (Rashki et al., 2002). *Bryobia* mites (brown spider mite) feed on the upper surfaces of leaves by piercing cells and sucking out their contents. Attacks on newly emerged leaves can result in discolored leaves which failed to grow. They complete three generations per year in Iran (Sepasgozarian, 1971). Nevertheless, the number of yearly completed generations by *Bryobia* differs geographically in response to climatic differences.

There are different control methods for tetranychoid mites such as resistant varieties (Sedaratian et al., 2008), chemical or biological control. A current control method for these pests is using acaricides on calendar base programs (Greco et al., 2005), with the result of problems such as pest resistance and residue on the harvested and consumed products (Escudero and Ferragut, 2004). Biological control is a useful alternative to pesticides for managing various arthropod pests (Opit et al., 2005) and the predaceous mites are one of the most important factors in reducing tetranychoids and other mite pest populations.

The main predatory mites in apple orchards belong to the families Phytoseiidae and Stigmaeidae. The role of phytoseiid mites has been widely investigated; however, the influence of stigmaeids in commercial agricultural systems is not well known and is usually considered to be minor (Villanueva and Harmsen, 1998). Stigmaeids living on plants or in the soil feed on tetranychids, tenuipalpids or eriophyids (Kheradmand et al., 2007). *Zetzellia mali* (Ewing), one of the most important predator members of Stigmaeidae, has wide distribution in apple orchards (Croft and Slone, 1997). It can feed on *B. rubrioculus* (Croft & Slone, 1997) and *C. irani* eggs and their immature stages. A good characteristic for *Z. mali* is ability of surviving for long period of time with low density of prey (Villanueva and Harmsen, 1998). The importance of this predator for pest control in apple orchards is not well described.

Having information about spatial distribution of prey and predator is critical to evaluate natural enemy potential to reduce its prey density and system's persistence (Slone and Croft, 1998). Determining spatial distribution is a prerequisite for ecological and behavioral studies (Faleiro et al., 2002), study of population dynamics (Jarosik et al., 2003), binomial sampling (Binns and Bostanian, 1990) and population growth evaluation (Jarosik et al., 2003). It also can be used to investigate population dispersion behavior, establish a precise sampling scheme and sequential sampling (Margolis et al., 1984), detect pest levels for justifying control measures (Arnaldo and Torres, 2005) and assess crop loss (Haughes, 1996). Since sampling is time-consuming and expensive, the goal is gathering information about pest abundance to reach the correct decisions without paying excessive costs. Meanwhile, using information of sample mean, variance and size, the variance-mean relationships of Taylor (1961) and Iwao (1968) have been effectively used for many sampling procedures (Beers and Jones, 2004; Hamilton and Hepworth, 2004).

Interactions between a predator and its prey are expected to be mixed and the varieties of observed responses are not a great surprise. An appropriate expected characteristic of an efficient specialist predator is high searching capacity for its preferred food item (Slone and Croft, 2001). Field and laboratory studies of prey-predator systems show remarkable density fluctuations of both populations (Greco et al., 1999). Villanueva and Harmsen (1998) evaluated the role of predatory mite *Zetzellia mali* (Ewing) in an experimental apple orchard primarily to improve a new IPM program for the combined control of the spotted tentiform leaf miner and spider mites. Responses of two predaceous mites, *Typhlodromus pyri* Scheuten and *Z. mali* to different prey densities were studied by Lawson and Walde (1993). Quantitative knowledge of spatial distribution patterns of phytophagous mites and their natural enemies is essential to understand their interactions and develop reliable sampling plans for monitoring pest and natural enemy abundance (Onzo et al., 2005).

Since there are few studies about the spatial distribution of tenuipalpids and stigmaeids and no study about C. *irani* and *Z. mali*, the result of this study can be used as a basis to develop and optimize reliable sampling plans, monitor methods and control of mites for establishing IPM strategies in apple orchards. Using generic, common parameters saves a tremendous amount of time and energy, decreases the cost of experiments and IPM, and also allows researchers to focus on the biology of the system instead of its statistics. Moreover, the calculated common coefficients of this study could be used in various apple cultivars and also some similar orchards.

MATERIALS AND METHODS

Sampling protocol

A basic rule for any sampling method is random collecting so that every sampling unit has an equal chance to be selected (Pedigo and Buntin, 1994).In this study, one apple leaf was selected as a sample unit. Leaves were selected randomly and from all parts of canopy avoiding biased estimate of the population mean. Samples were taken at 9-12 A.M. from May 31st till November 7th 2007 in 10-day intervals.

Each leaf was put in a separated zip-kip nylon pocket and kept in portable flask in 4°C. In laboratory, the number of motile stages of *C. irani, B. rubrioculus* and their predator, *Z. mali*, per leaf was counted using a stereomicroscope.

Since variation of primary sampling data is important to determine sample size, a primary sampling with 130 sample unites was conducted. The relative variation (*RV*) was calculated according to Hillhouse and Pitre (1974) to evaluate the efficiency of the primary sampling data:

$$RV = (SE / m)100$$

SE is standard error of mean and *m* is mean of primary sampling data. Reliable sample size was determined using the following equation:

$$N = [ts / dm]^2$$

Where *N* = sample size, *t* = t-student, s = standard deviation, *d* = desired fixed proportion of the mean and *m* = the mean of primary data.

Spatial distribution

The spatial distribution of *Z. mali* and its prey was determined by the following five methods: index of dispersion, Morisita's coefficient of dispersion, Lloyd's mean crowding and regression techniques including: Taylor's power law and Iwao's patchiness.

Index of dispersion

Variance (S^2) to mean (m) ratio indicates that mean and variance would be equal in a randomly distributed population. Dispersion of a population can be classified by calculating the variance to mean ratio as follows:

$S^2/m>1$ Aggregated
$S^2/m=1$ Random
$S^2/m<1$ Regular

Departure from a random distribution can be tested by calculating the index of dispersion, I_D, in which n is the number of samples:

$$I_D = (n-1)S^2 / m$$

In next stage, *Z* coefficient must be calculated to test the goodness-of-fit:

$$Z = \sqrt{2 I_D} - \sqrt{(2\nu - 1)}$$

where ν is degree of freedom (*n-1*).

If 1.96 ≥ Z ≥ -1.96, the spatial distribution will be random, but in case of z >1.96 and z < -1.96 this parameter will be aggregative and uniform, respectively (Patil and Stiteler, 1974).

Regression techniques

Two experimental formulae based on variance-mean relationships, Taylor's power law and Iwao's patchiness regression, have been widely used in spatial distribution estimates and sampling program establishment (Davis, 1994; Young and Young, 1998).

According to Taylor's power law, population variance (S^2) is proportional of a fractional power of the arithmetic mean (*m)*:

$$S^2 = am^b \quad \text{or} \quad \log S^2 = \log a + b \log m$$

In which *a* is sample size-related scaling factor and slope *b* is index of aggregation which in turn recalls uniform (*b<1*), random (*b=1*) and aggregated (*b>1*) dispersion of a population (Taylor, 1961).

Iwao's patchiness regression method quantifies relationship between mean crowding index (*m**) and mean (*m*) using the following equation:

$$m^* = \alpha + \beta m$$

where α indicates the tendency to crowding (positive) or repulsion (negative) and β reflects the distribution of population on space and is interpreted in the same manner as *b* of Taylor's power law (Iwao, 1968). Student t-test can be used to determine whether the colonies are randomly dispersed.

$$\text{Test } b = 1 \quad t = (b-1)/s_b \quad \text{and} \quad \text{Test } \beta = 1 \quad t = (\beta - 1)/s_\beta$$

Where s_b and s_β are the standard error of slop for mean crowding regression. Calculated values are compared with tabulated t-values with *n-2* degrees of freedom.

Morisita's coefficient of dispersion I_δ

Morisita (1962) proposed a hypothesis for testing the uneven distribution coefficient of I_δ which is calculated by the following equation:

$$I_\delta = \frac{n \sum x_i (x_i - 1)}{N(N-1)}$$

n = the number of sample unites, x_i = the number of individuals in each sample unit and *N* = total number of individuals in *n* samples.

The following large sample test of significance can be used to determine whether the sampled population significantly differs from random:

$$z = \frac{(I_\delta - 1)}{\left(\frac{2}{nm^2}\right)^{\frac{1}{2}}}$$

Random spatial distribution will be in case of 1.96 ≥ z ≥ -1.96, but z < -1.96, z > 1.96 indicate regular and aggregated distribution, respectively (Pedigo and Buntin, 1994).

Lloyd's mean crowding x^*

Mean crowding (x^*) was suggested by Lloyd to indicate the possible effect of mutual interference or competition among individuals. Theoretically mean crowding is the mean number of other individuals per individual in the same quadrate:

$$x^* = m + \frac{s^2}{m} - 1$$

As an index, mean crowding is highly dependent upon both the clumping degree and population density. To remove the effect of density changes, Lloyd introduced a patchiness index which is expressed as ratio of mean crowding to mean. Similar to variance to mean ratio, index of patchiness is dependent upon quadrate size, x^* / m =1: random, <1: regular and >1: aggregated (Lloyd, 1967).

Optimum number of sample units (sample size)

The optimum sample size, smallest number of sample units would safely achieved the desired precision of estimates.

Coefficients *a* and *b* within Taylor's power law describe relationship between variance and mean $(s^2 = am^b)$ for individuals distributed in a natural population. Mean and variance of sampled specimens was determined for each sampling date. Taylor coefficient of *a* and *b* calculated by log-log linear transformation of mean-variance data, where *b* is the slope of transformed data and *a* calculated as antilog of transformed intercept. An equation for estimating pest sample size was developed by Karandinos (1976). Ruesink (1980), Wilson and Room (1982) and Wilson (1985) incorporated Taylor's power law into Karandinos' equation to form the sample size model used in this study:

$$N_{opt} = a \left(\frac{t_{\alpha/2}}{D} \right)^2 \left(\mu^{b-2} \right)$$

Where N_{opt} = sample size, $t_{\alpha/2}$ = t- student of table, μ= mean density, *a* and *b* = Taylor's coefficients and *D* = the range of accuracy.

The optimum sample size derived from formula $N_{opt} = \left(\frac{t_{\alpha/2}}{D} \right)^2 \left(\frac{1}{\mu} + \frac{1}{k} \right)$, by using k in negative binomial distribution equation $\frac{1}{k} = \frac{\sigma^2 - \mu}{\mu^2}$ and this estimation can also be done by Iwao's patchiness regression method coefficients (α and β) in formula

$$N_{opt} = \left(\frac{t_{\alpha/2}}{D} \right)^2 \left(\frac{\alpha + 1}{\mu} + (\beta - 1) \right)$$

The *D* represents the desired fix proportion of the mean. In case of *D* = 0.20, sample mean may be 20% higher or lower than actual mean 95% of the time.

Density dependence in prey-predator interaction

To determine the type of interaction between prey and predator, analysis of simple linear regression was carried out between prey and predator population densities. Predator would be density independent in case of *P-value* > 0.05 ($b = 0$), but if *P-value* ≤ 0.05 and $b > 0$ or $b < 0$, predator would act as density dependent and inverse density dependent in its predation activity, respectively. Correlation between population changes can also show relations with high values of *r* and *P-value* ≤ 0.05.

RESULTS

Sampling protocol

Data set from primary sampling was used to calculate *RV*. The biggest calculated *RV* and reliable sample size were 5.33% and 130, respectively.

Population fluctuation

Population fluctuation of *C. irani, B. rubrioculus* and *Z. mali* are shown in Figure 1. The population of *C. irani* and *B. rubrioculus* was observed from the beginning of the sampling period (31st May), but no *Z. mali* was recorded until 10th June. The results indicated that the highest population density of *C. irani, B. rubrioculus* and *Z. mali* was in 19th August (13.45 per leaf), 9th August (0. 615 per leaf) and 9th August (1.161 per leaf), respectively. During the sampling season, populations of *C. irani* had greater and irregular fluctuations compared to the other species (Fig. 1).

Spatial distribution

Iwao's α and β and Taylor's *a* and *b* coefficients for each species are shown in Table1. Both of the regression methods fit the data well for all examined species. The results of Taylor and Iwao regression methods showed that the spatial distribution pattern of false spider mite, brown spider mite and their predator were aggregated. The determination coefficients of Taylor's power law ranged from 0.93 to 0.97, whereas for Iowa's patchiness regression they ranged from 0.74 to 0.94 (Tab.1). The index of dispersion (I_D) showed that the spatial distribution of all species on apple was aggregated. The I_D values for all populations were significantly greater than 1 (Tab.2), which means this species exhibited aggregated behavior in the habitat.

There were some differences in Morisita's index values of each species but in most sampling dates, the index was significantly greater than 1.96 (Tab.3), suggesting that the spatial distribution of all species was aggregated. For *C. irani*, changes in Morisita's index results from aggregated to random distribution(Tab.3) indicates that spatial distribution can change in different dates. The m^*/m value for each population in all sampling dates was significantly greater than 1 (Tab.2) indicated aggregated pattern in all examined species.

Optimum number of sample units

The sample size was re-calculated using *k* in negative binomial distribution and Taylor's and Iwao's coefficient (*a*, *b*, α and β) (Tab.5). The lowest estimate of sample size calculated with Taylor's equation for *Z. mali* and *C. irani*, but for *B. rubrioculus* this value recalled with Iwao's model. Calculated aggregation coefficients for all species are shown in Table2.

Density dependence in prey-predator interaction

The correlation coefficient between population densities of *C. irani* and *Z. mali* was statistically significant ($r = 0.921$, $P < 0.001$) and for *B. rubrioculus* and *Z. mali* was statistically significant too ($r = 0.827$, $P < 0.001$) suggesting high relation between species fluctuations. Statistically significant linear regression was observed between each of two preys and stigmaeid (Tab.4) showing that *Z. mali* in interaction with *C. irani* and *B. rubrioculus* does have density-dependent activity.

DISCUSSION

The first population of *C. irani* observed by the end of May and reached to peak till 19th August, 2007 (13.45 per leaf). The population density of this false spider mite increased in late July and early August as a result of increase in weather temperature and dryness. Furthermore, the sharp decline in *C. irani* population was observed from mid August till mid September that could have been mainly due to the predator's activity. Meanwhile, the peak of *Z. mali* population was observed on 9th August. Since the predator feeds on eggs, resulted decrease in prey population trough next generation which in turn would be the probable reason for the gap between two observed peaks. The next decrease in population of *Z. mali* may be in part due to sever decrease in *C. irani* population at the end of summer. The population of *C. irani* could not surely increase again in lack or scarcity of predator due to the cold weather after September (Fig. 1). Population density of *C. irani* per sample unit was higher than *B. rubrioculus* and also remained in longer duration, suggesting that *C. irani* might be the most abundant and serious acari pest in apple orchards of the region.

The population of *B. rubrioculus* is much more sensitive to predation compared to *C. irani* and could be controlled readily because of the bigger size of adults and less capacity for population increase. It seems that more predator species can affect the population of *B. rubrioculus*. So in low density of this pest the egg predator can easily control its population under the damage boundary.

Spatial distribution, the distribution of individuals in habitat, is one of the most important ecological characters of a population that can be used in protracted sampling programs for pest managements (Kuno, 1991). In a protracted sampling which is a quick and exact method for estimating mean population or decision of control time, spatial distribution data is essential in determination of equations and necessary sample size for the decision (Young and Young, 1998). In this study, aggregated spatial distribution pattern was found for *C. irani*, *B. rubrioculus* and their predator by using regression methods (Taylor and Iwao). High values of Taylor model, suggests that this model can be properly fitted for these mites. The data had a good equivalence with both Taylor's (r^2 = 0.979) and Iwao's model (r^2 =0.94) for *C. irani*, and also better equivalence with Taylor's model compared to Iwao's model for *B. rubrioculus* (r^2 = 0.938) and *Z. mali* (r^2 = 0.972). The α value was significantly greater than 0 for the predator, indicating that colonies or clumps were the basic component of these populations and the patch size decreased throughout the whole developmental period. Taylor's power law as well as Iowa's patchiness regression has been widely used for dispersion evaluating, data normalizing for statistical analysis and sampling protocols for many insects (Davis, 1994). Taylor's power law should be estimated beforehand using in practice. This is done by fitting the model to data that includes set of estimated means and variances (Ifoulis and Savopoulou-Soultani, 2006).

Observed aggregation in spatial distribution for all examined species with the index of dispersion and Lloyd mean crowding suggests that the presence of an individual mite at one point may cause an increase in the probability of being another individual nearby. In addition, probability of habitat occupation by individuals would not be the same. Based on these results population distribution of the predator is tightly linked to the prey distribution, a characteristic which would create refuges for the prey and consequently increase the persistence of the system.

The spatial distribution of population individuals in an ecosystem can be a result of behavioral characters or environment. Despite parameters such as rate of population increase and reproduction that will change from one generation to another, spatial distribution is partially constant and is a character of species (Taylor, 1984). Clump laying behavior and slow movement of *C. irani*, *B. rubrioculus* and *Z. mali* could be accounted as a possible reason for their aggregated spatial distribution. Furthermore, the tolerance of a species to the environmental factors such as temperature, relative humidity and low food density which in turn refers to population genetic can determine the spatial distribution being used as a distinguishing factor of near species.

Since Morisita's coefficient estimates spatial distribution using the mean and variance of each sampling date separately, this index is more accurate than the dispersion index. Showing one distribution per each date it can be used to understand details of dispersion in different sampling dates that would be useful for research strategies more than management programs. Changes in distribution of *C. irani* in late Jun, early July and all August from aggregated to random can be partly due to increase in population density or movement of nymphs from clumped egg location. It seems that distribution pattern in most of the sampling dates could be used as basis for management decisions. Although Taylor's indices have been widely used by many researchers; others suggest Morisita's index because of its higher determination coefficient as well as better dispersion interpretation for the species. Spatial distribution of the studied mites using different analytical methods showed aggregated or random pattern, suggesting that the different statistical methods have various accuracies in calculating spatial distribution of an organism.

Comparing $1/k$ values among three species showed that the aggregation of *B. rubrioculus* was more than the other species because of the high value of $1/k$ index in *B. rubrioculus*. This might be due to higher differences between the variance and mean of this mite sampling data. All of the $1/k$ values approved aggregation pattern of dispersion for these three species. Aggregated distribution of spider mites has been exploited in many studies (Nuchman, 1984; Strong et al., 1997). Spatial distribution of prey can determine its natural enemy's ditribution especially the predators. Searching rate of phytoseiids in aggregated populations of spider mites is more than populations with random distribution (Kim and Lee, 1993).

Many biological and statistical factors affect the precision of Taylor's coefficients; so that a large data set of at least several hundred samples are usually required to generate robust estimates of these coefficients (Jones, 1990). It has been reported by other researchers that finding out the generic coefficients eliminate experimental needs for large sample size. Furthermore, Taylor's power law can be appropriately estimated just in case of data availability from a wide range of pest densities and also when the estimated means and variances are reasonably precise. The range of means must cover the critical density and the densities that might occur in practical management (Binns *et al.*, 2000).

In this study, absolute counts of *Cenopalpus irani*, *Bryobia rubrioculus* and *Zetzellia mali* motile stages were used to develop generic coefficients of regression techniques based on large amount of data. For the majority of mean population densities, Taylor's power law coefficients showed lower well-defined number of sample units to achieve a desired precision of estimates. Basically, Taylor's method results in almost half the necessary sample size compared to common k or Iwao's method. Iwao's method was originally derived with close reference to theoretical distribution models (Davis, 1994). This may count as a good reason for observed similarity with the calculated amounts using the common k and Iwao's method. In contrast, as a purely empirical model, Taylor's power law doesn't have such definite theoretical bases (Kuno, 1991). However, Taylor's power law has been widely used because of its statistical stability. In this study to achieve greater precision, we adopted the 20% level, whereas in IPM programs, 25 or 30% level is acceptable. Optimal sample size suggested by Taylor's model is typically higher at low population levels.

The non-linear response of *Z. mali* to *Tetranychus turkestani* density has been previously revealed (Khodayari, 2007); however, population fluctuation curves showed delayed-density dependent response of predator to its prey density. Lawson and Walde (1993) reported that *Z. mali*, which has been thought to be less important in control of *P. ulmi*, have a stronger response than *T. pyri* to the prey density. The significant linear regression model between prey and predator densities in our study suggestes density dependent predation by *Z. mali* due to its oligophagous behavior and existence of alternative prey mites on apple. According to Villanueva and Harmsen (1998) studies, *Z. mali* was more abundant in the pyrethroid sprayed plots than control plots. Therefore it seems that *Z. mali* can act as an effective predator for controlling spider mites in IPM programs via using pyrethroids to reduce other pest densities in apple orchards.

The predation activity of *Z. mali* on tetranychoid eggs and sessile forms suggests the usage of pesticides with less effects on this predator in orchard management. Spatial distribution parameters of the *Z. mali* and its two preys can be used as a foundation for sampling programs. It can also be used in estimates of these mites' population density using in integrated pest management programs through the implementation of conservation and/or augmentation techniques for apple orchards.

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Table 1. Estimated values of intercept and slope for *Cenopalpus irani, Bryobia rubrioculus* and *Zetzellia mali* in 2007 by regression analysis of Taylor's power law and Iwao's patchiness regression

Species	**Taylor's power law**				**Iwao's patchiness regression**			
	a	b	r^2	P_{value}	α	β	r^2	P_{value}
Cenopalpus irani	0.529	1.290	0.979	0.000	0.636	1.900	0.945	0.000
Zetzellia mali	0.448	1.140	0.972	0.000	0.551	2.730	0.738	0.000
Bryobia rubrioculus	0.639	1.391	0.938	0.000	-0.063	7.159	0.760	0.000

Table 2. Estimated parameters by Lloyd mean crowding, index of dispersion, Lloyd mean crowding to mean and common *k* for *Cenopalpus irani, Bryobia rubrioculus* and *Zetzellia mali* in 2007

Species	m	S^2	m^*	I_D	Z	m^*/m	$1/k$
Cenopalpus irani	4.017	48.104	14.991	17122.33	131.593	3.731	2.731
Bryobia rubrioculus	0.289	0.953	8.962	4718.217	43.681	8.961	7.961
Zetzellia mali	0.691	2.278	4.316	4709.713	43.593	4.316	3.316

Table 3. Morisita's index and *Z* values for *Cenopalpus irani, Bryobia rubrioculus* and *Zetzellia mali* in different sampling dates of 2007

	C.irani		***Z. mali***		***B.rubrioculus***	
	I_δ	Z	I_δ	Z	I_δ	Z
31-May-07	3.355	79.616	-	-	6.190	362.674
10-Jun-07	6.753	78.311	8.667	803.538	13.788	1116.908
20-Jun-07	2.502	9.371	3.709	76.729	8.598	284.403
30-Jun-07	1.566	1.510	1.464	7.726	3.573	56.175
10-Jul-07	1.718	1.921	1.714	7.130	2.631	43.847
20-Jul-07	1.796	2.287	2.319	11.920	5.312	145.781
30-Jul-07	2.860	3.727	3.188	18.796	9.335	182.000
9-Aug-07	2.366	1.269	3.719	18.874	8.187	94.154
19-Aug-07	1.843	0.505	3.672	19.183	7.851	128.216
29-Aug-07	1.519	0.731	3.733	23.103	6.734	127.879
8-Sep-07	2.280	7.665	4.303	30.108	10.833	1145.139
18-Sep-07	4.489	98.846	7.894	185.290	13.000	2515.424
28-Sep-07	-	-	-	-	-	-
8-Oct-07	-	-	-	-	-	-
18-Oct-07	43.333	14789.76	130.000	67602.03	-	-
28-Oct-07	7.222	724.608	130.000	67602.03	-	-
7-Nov-07	-	-	130.000	67602.03	-	-

Table 4. Statistics of the linear regression between the mean population density of *Cenopalpus irani, Bryobia rubrioculus* and *Zetzellia mali* on apple leaves in 2007

Species	a	b	r^2	P_{value}
C. irani-Z. mali	-0.434	6.527	0.647	0.000
B.rubrioculus-Z. mali	0.025	0.349	0.698	0.000

Table 5. Calculated sample size of for *Cenopalpus irani, Bryobia rubrioculus* and *Zetzellia mali* populations on apple leaves based on, *k* in negative binomial distribution and Taylor's power law and Iwao's patchiness coefficients in 2007

Species	n_{opt}		
	K	*Taylor*	*Iwao*
Cenopalpus irani	404.50	26.14	177.42
Bryobia rubrioculus	1550.52	184.77	34.727
Zetzellia mali	646.32	126. 78	539.26

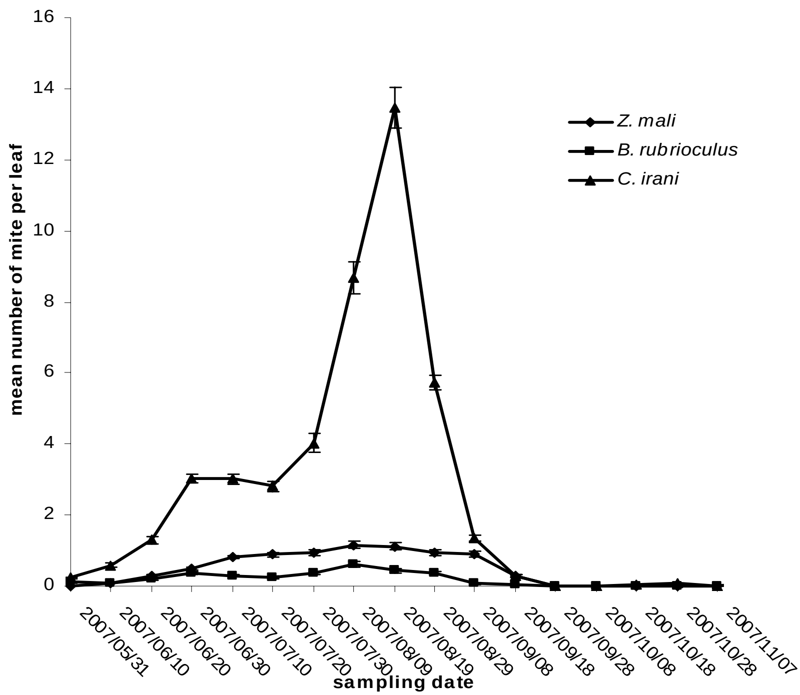

Fig . 1. Population fluctuation of *Cenopalpus irani*, *Zetzellia mali* and *Bryobia rubrioculus* on apple leaves in 2007