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Population Fluctuation and Spatial Distribution Pattern of the Nut Scale, *Eulecanium tiliae* (L.) (Hem.: Coccidae) on Cherries of the West of Iran

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ABSTRACT

The nut scale, *Eulecanium tiliae* (L.) is a potential pest, infesting deciduous trees in Iran, where it is common in urban horticultural areas and usually present in high population on some stone fruit trees, such as *Prunus* spp., including *Prunus cerasus*. It has higher occurrence and population in sustainable orchards. This pest has one generation per year and second nymphs overwinter on one or two-years old branches. High populations of this pest can cause death of branches, twigs and degeneration of leaves chloroplasts. In this research, the spatial distribution pattern and population fluctuation for all stages of *E. tiliae* were investigated in a cherry orchard of Kermanshah region during two studied seasons from 2016 to 2018. Four different methods were used to calculate distribution pattern including index of dispersion, Morisita's index and regression methods (Taylor's and Iwao's). Sample size was determined for the first time, according to a primary sampling date and corrected for other sampling dates according to the data of the previous sampling date. Data analysis was performed using Minitab16 and Office Excel 2016 statistical softwares. Most used methods revealed aggregated distribution pattern of the pest in both years. The results obtained from the Morisita's index during activity showed the random distribution of the second nymphs (in 16 April 2016, Z= -1.218, I_{δ}= 0.440) (in 16 April 2017, Z= -0.179, I_{δ}= 0.942) (-1.96< Z< 1.96). These changes showed that the spatial distribution could change during the season. Knowledge of the pest spatial distribution pattern can be used to arrange sampling program in pest management.

Keywords: Iwao's Patchiness Regression, Morisita's index, Sampling program, Seasonal activity, Taylor Power Law.

INTRODUCTION

The nut scale, *Eulecanium tiliae* (Linnaeus, 1758) is very common on all fruit trees, but usually in low population. Its frequency was higher in unprotected orchards than in protected ones, amounting to 1.18 and 0.13%, respectively (Lagowska, 1984). High populations can cause death of branches, twigs, and degeneration of chloroplasts on leaves. Temperature and humidity are the main abiotic factors regulating the distribution and abundance of soft scales (Kosztarab, 1996). Similar to other insects, developmental rate of soft scales increases in case of temperature rising until an optimal temperature is reached, after which the developmental rate declines (Abd-Rabou *et al*., 2009).

Cosmopolitan soft scale insects may develop more than one generation in a warmer country or climatic zone within a country. In general, fecundity of soft scale species can vary enormously depending on temperature, scale abundance, body size of females and the condition of the host plant

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(Marotta, 1997).The mean fecundity of females in *Ceroplastes sinensis* Del Guercio was 3260±770 eggs per female (Stathas *et al*., 2003). Fecundity apiece was to 6,355 eggs for *C. destructor* Newstead (Wakgari and Giliomee, 2000), and 382–395 crawlers for *Phalacrococcus howertoni* Hodges and Hodgson (Amarasekare and Mannion, 2011). Fecundity also varies among individuals. Per capita fecundity for coccid scale, *Coccus hesperidum* L. counted from 70 to 1,000 eggs (Tereznikowa, 1981). Such variations might be related to the different host-plants and the different climatic conditions at the sampling sites. The growth and phenology of the scales may also be influenced by the nutrient contents of host plants (Beattie, *et al*., 1990).

Although diagnosing all interactions among individuals of a pest population is difficult, it is possible to identify the pattern of pest distribution as well as the changes in biological traits of a species after changes in population density. The distribution pattern is an intrinsic feature of the organisms and results from the interaction between the species and their habitat or environment and, may reflect behavioral characteristics of the species in an ecosystem (Taylor, 1984; Kuno, 1991; Moradi-Vajargah *et al*., 2011). The spatial distribution pattern of arthropods can provide informative description of a population and regulates the sampling program, methods of data analysis and decision-making (Iwao, 1968; Southwood and Henderson, 2000; Khaing *et al*., 2002). Therefore, the exact monitoring is needed in IPM tactics by performing proper sampling programs and estimating population density, which are prerequisites of effective pest control (Pedigo and Buntin, 1994; Castle and Naranjo, 2009). In most cases, spatial distribution, as one of the most important characteristic properties of insect populations in ecological communities, allows us to define them and is a typical quality in insect populations (Debouzie and Thioulouse, 1986). Knowledge of the spatial distribution provides useful information not only in theoretical population biology but also in field monitoring programs and ecology of insects (Binns *et al.*, 2000; Trumble *et al.*, 1987).

Sampling program as decision-making tool in pest management strategies plays an essential role, and spatial distribution is an integral part in sampling design (Boeve and Weiss, 1988). A change in the aggregation of a species needs an alternation for the sampling plan to have an accurate population count (Slone and Croft, 1998). Spatial distribution of each insect signifies its innate features formed by behavioral and environmental factors (Pedigo and Zeiss, 1996). Understanding the spatial distribution patterns of the insect population provides some information about behavioral and environmental factors of the population (Southwood and Henderson, 2000).

Common methods to describe spatial distribution of insect populations have been summarized by Southwood and Henderson (2000). There are different methods to calculate spatial distribution pattern including the index of dispersion (e.g., Variance-to-mean ratio, Lloyd's mean crowding, Morisita's coefficient, Cole's index of dispersion, David and Moore's index, Green's index, Coefficient of '*K*'), Iwao's Patchiness Regression, Taylor's Power Law, (Sedaratian *et al*., 2010; Darbemamieh *et al*., 2011). The use of dispersion indices seems to be convenient decision-making methods for management programs because of their simple procedure of calculation (Darbemamieh *et al*., 2011). Among the various methods, Iwao's Patchiness Regression and Taylor's Power Law were more accurate than the others to estimate the distribution pattern of the insects (Khodayari *et al*., 2010; Rahmani *et al*., 2010). In comparative studies of models, Taylor's Power Law model was mostly found to fit the spatial dispersion better than Iwao's model (Celini and Vaillant, 2004; Kapatos *et al.*, 1996), although both methods were used to model the relationship between the mean and the variance of different arthropods. The findings of spatial distribution (i.e., regular, random or aggregated) can determine which sampling program must be carried out, especially in sequential sampling (Feng *et al*., 1993). Having information about spatial distribution, density and changes in population of *E. tiliae* during two years, identification of factors affecting population fluctuations and determination of their effects will be helpful in management of this pest. Rare information in the literature concerning the seasonal activity of this pest led us to conduct this study in Kermanshah Province (Sahneh Region) of Iran where there is no report of a similar research.

MATERIALS AND METHODS

Sampling Procedure

Field studies were conducted in an infested cherry orchard of Sahneh (Kermanshah Province, Iran; 34º 29' 09" N, 47º 41' 29" E, Altitude: 1,376.5 m) covering an area of 300 trees ha^{-1}. The trees were about 10-years old. In this study, randomly selected 20 cm of cherry branch ends were used as a sampling unit to avoid biased estimate of population mean. Samplings were undertaken every 10 days from spring to autumn (April-October), and monthly from March 2016 till March 2018. In the laboratory, the number of motile stages of *E. tiliae* was counted on the same day using a stereomicroscope. Parasitized scales were put separately in a bottle with net lid and kept in 25ºC incubator to rear parasitoid wasps.

Spatial Distribution

The spatial distribution of *E. tiliae* was determined by the following five methods: index of dispersion, Morisita's coefficient of dispersion, Lloyd's mean crowding, and regression techniques of Taylor's Power Law, and Iwao's Patchiness Regression.

Index of dispersion

Dispersion of a population can be determined by calculating the variance to mean ratio as follows: $S^2/m > 1$ is classified as aggregated distribution, while $S^2/m = 1$ or < 1 are classified as random or regular distribution, respectively. Departure from a random distribution can be tested by calculating the Index of Dispersion (I_D), in which *n* is the number of samples as in Equation (1):

$$I_D = \chi^2 = \frac{s^2(n-1)}{m} \quad (1)$$

I_D is approximately distributed as x^2 with n-1 degrees of freedom. Values of $I_{D,}$ which fall outside a confidence interval bounded with n-1 degrees of freedom and selected probability levels of 0.95 and 0.05, for instance, would indicate a significant departure from a random distribution, and n is the number of samples. In order to test the goodness of fit, *Z* coefficient should be calculated according to Equation (2) shown below:

$$Z = \sqrt{2\chi^2} - \sqrt{2(v-1)} \quad (2)$$

Where, *v* is degrees of freedom (n-1). If $1.96 \geq Z \geq -1.96$, 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

According to Taylor's Power Law, population variance (S^2) is proportional to a fractional power of the arithmetic mean (m) as in Equation (3) (Taylor, 1961):

$$\log s^2 = \log a + b \log m \quad (3)$$

Where, *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 population (Taylor, 1961).

Iwao's Patchiness Regression method quantifies the relationship between mean crowding index (m^*) and mean (m) using Equation (4) (Iwao, 1968):

$$m^* = \alpha + \beta m \quad (4)$$

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). 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 distribution coefficient of I_δ, which is calculated using Equation (5) (Pedigo and Buntin, 1994):

$$I_\delta = \frac{n\sum x_i(x_i - 1)}{N(N-1)} \quad (5)$$

Where, 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.

Equation (6) can be used to determine significant differentiation of population from the random distribution:

$$Z = \frac{(I_\delta - 1)}{(\frac{2}{nm^2})^{\frac{1}{2}}} \quad (6)$$

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

Lloyd's Mean Crowding (m^*)

Theoretically, mean crowding (m^*) is the mean number of other individuals per individual in the same quadrate as given by Equation (7) (Lloyd, 1967):

$$m^* = m + \left(\frac{s^2}{m} - 1\right) \quad (7)$$

Similar to variance to mean ratio, index of patchiness expressed as the ratio of mean crowding to the mean. As with the variance-to-mean ratio, the index of patchiness expressed as the ratio of mean crowding to the mean is dependent upon quadrate size, x^*/m= 1: Random, < 1: Regular and > 1: Aggregated (Lloyd, 1967).

Optimum Number of Sampling Units

Finding out the generic coefficients eliminates experimental needs for large sample size (Ifoulis and Savopoulou-Soultani, 2006). The optimum sample size, i.e., the smallest number of sample units with precision of estimates calculated by using coefficients *a* and *b* within Taylor's Power Law in Equation (8):

$$N_{opt} = a\left(\frac{t_{\alpha/2}}{D}\right)^2\left(\mu^{b-2}\right) \quad (8)$$

Where, N_{opt}= Sample size, $t_{a/2}$= t-student of table, μ= Mean density, *a* and *b*= Taylor's coefficients and *D*= The range of accuracy. The optimum sample size is derived from Equation (9):

$$N_{opt} = \left(\frac{t_{\alpha/2}}{D}\right)^2\left(\frac{1}{\mu} + \frac{1}{k}\right) \quad (9)$$

This estimation is done by Iwao's coefficients (*a* and *b*) in Equation (10) (Wilson, 1985):

$$N_{opt} = \left(\frac{t_{\alpha/2}}{D}\right)^2\left(\frac{\alpha+1}{\mu} + (\beta - 1)\right) \quad (10)$$

Correlation coefficient values are tested for departure from zero by using the two tailed t test, at n-2 degrees of freedom.

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 the actual mean 95% of the time.

RESULTS AND DISCUSSION

The nut scale, *E. tiliae*, has one generation per year and overwinters as second nymph instar. The number of generation varies in different climates based on temperature and humidity and some soft scales, such as *Ceroplastes rubens* (Maskell) are univoltine in Japan and China (Itioka and Inoue, 1991; Xia *et al.*, 2005) or bivoltine in Australia (Loch and Zalucki, 1997) that may produce second generation, in warmer geographical regions.

Our observations showed that high population densities occasionally infested *Prunus* spp. in western parts of Iran. Examination of infested cherry twigs (samples) with stereomicroscope and observation of the eggs within the brood chamber in the laboratory showed that oviposition started in mid-April, peaked its population density in mid-May and ended in early June. First nymph instars emergence started at the second decade of May, maximized at late June and declined in mid-September. For the second nymph instar, early July and late August was recorded for the beginning of emergence and peak of its population density, respectively. Adults appeared in the first days of April, peaked in early May and disappeared in mid-June (Figure 1).

Both regression methods fit the data well for all the examined stages (Table 1). Evaluation of Taylor's index for all stages of nut scale *E. tillae* showed that slopes of regression line in Taylor's model and t-test were significantly larger than 1 in both 2016 and 2017, that means, spatial distributions were aggregated in both years. Taylor's regression of log S^2 on log x provided a good fit to the data from different *E. tiliae* stages and the values of r^2 ranged from 0.852 to 0.988 (Table 1). For all stages, the regression between log S^2 and log m was significant in Taylor's model (P< 0.05) for both years (Table 1), and can be the effect of host plant or species characters.

Data demonstrated good fitness to both Taylor's (r^2= 0.965), and Iwao's model (r^2= 0.924) for 1st instar, also better fitness with Taylor's model for 2nd instar (r^2= 0.989); and female (r^2= 0.972). Also Iwao's model had good fitness for 2nd instar (r^2= 0.973); and female (r^2= 0.948) during 2016. During 2017, Taylor's (r^2= 0.953) and Iwao's model (r^2= 0.962) for 1st instar had good fitness and even better fitness with Taylor's model for 2nd instar (r^2= 0.988) as well as female (r^2= 0.954). It was also observed for Iwao's model for 2nd instar (r^2= 0.948) and female (r^2= 0.947) (Table 1). Considering feeding status, ovipositional manner, different stages behaviors and presence of stages on the host leaves, the respective model can clearly describe the observed data. This aggregation was caused by two main reasons: (1)

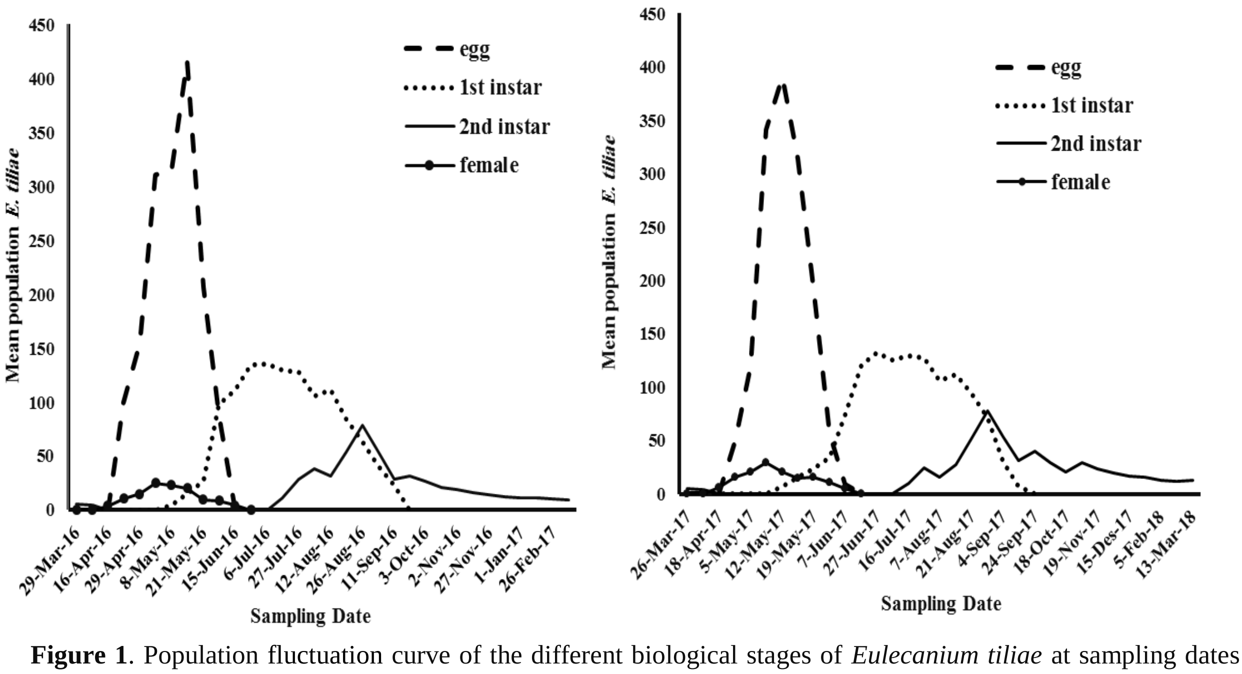

Figure 1. Population fluctuation curve of the different biological stages of *Eulecanium tiliae* at sampling dates from 2016 to 2018.

Table 1. Estimated values of intercept and slope for *Eulecanium tiliae* from March/2016 to March/2018 by regression analysis of Taylor's Power Law and Iwao's Patchiness Regression (t test for goodness of fit).

		Taylor's Power Law				
		A	*B*	t_b	r^2	*P-value*
March/2016 To March/2017	Egg	1.028±0.601 (-0.516-2.574)	1.594±0.245 (1.012-2.225)	6.50	0.894	0.001**
	1st Instar	0.507±0.162 (0.157-0.857)	1.688±0.089 (1.496-1.881)	18.94	0.965	0.000**
	2nd Instar	0.331±0.049 (0.227-0.436)	1.877±0.043 (1.786-1.968)	43.13	0.989	0.000**
	Female	0.488±0.130 (0.180-0.798)	1.692±0.109 (1.433-1.951)	15.46	0.972	0.000**
March/2017 To March/2018	Egg	1.173±0.603 (-0.303-2.650)	1.556±0.264 (1.920-2.204)	5.89	0.852	0.001**
	1st Instar	0.878±0.149(0.557-1.120)	1.423±0.084 (1.243-1.604)	16.91	0.953	0.000**
	2nd Instar	0.183±0.055 (0.068-0.299)	1.940±0.048 (1.839-2.043)	39.97	0.988	0.000**
	Female	0.045±0.209 (-0.541-0.451)	2.036±0.168 (1.639-2.434)	12.12	0.954	0.000**
	Iwao's Patchiness Regression					
March/2016 To March/2017	Egg	78.401±0.588(-202.087-358.821)	1.808±0.085 (1.001-2.637)	5.61	0.863	0.002**
	1st Instar	23.880±7.919(0.098-47.659)	1.492±0.049 (1.236-1.748)	12.60	0.924	0.000**
	2nd Instar	2.343±1.099(-2.842-7.528)	2.270±0.016 (2.093-2.447)	26.70	0.973	0.000**
	Female	5.504±2.073 (-3.072-14.081)	1.862±0.045 (1.472-2.252)	11.30	0.948	0.000**
March/2017 To March/2018	Egg	12±48.87 (-318.843-342.755)	2.439±0.060 (1.409-3.47)	5.79	0.848	0.001**
	1st Instar	18.668±5.178 (-5.367-8.297)	1.346±0.037 (1.929-2.403)	18.89	0.962	0.000**
	2nd Instar	1.465±1.477 (-5.367-8.297)	2.166±0.022 (1.929-2.403)	19.06	0.948	0.000**
	Female	4.593±2.324 (-4.587-13.774)	1.735±0.048 (1.368-2.103)	11.18	0.947	0.000**

* Significant at α= 0.05, ** Significant at α= 0.01.

Disharmony between habitats and environment and (2) Behaviors and factors not dependent on environmental conditions (Table 1). Compared to Iwao procedure, Taylor's Power Law mainly results in reduction of sample size measurements (Darbemamieh *et al*. 2011; Ifoulis and Savopulou-Soultani, 2006); and fits better in showing the distribution pattern (Afshari *et al*., 2009). In comparison with Iwao's method, the obtained r^2 from Taylor's model showed higher correlations with data. Therefore, it is better to use Talyor's index for the data on *E. tillae*, since it seems to be more appropriate for determining the type of the pest population distributions (Table 1). Taylor's Power Law as well as Iwao's Patchiness Regression have been extensively used in many arthropods for evaluation of spatial distribution, normalizing the data for statistical analysis, and sampling procedures (Davis, 1994; Deligeorgidis *et al*., 2002). Taylor's Power Law index must be estimated in priority and then used in practical studies. This is practically done by fitting the model to data set of estimated means and variances (Ifoulis and Savopoulou-Soultani, 2006).

Based on Lloyd's distribution index to the mean values, variance to mean ratios and values of *Z* for *E. tillae* were higher than 1.96 for both years, indicating aggregated distribution (Table 2). (S^2/m), Index of Dispersion (I_D), 1/*k* and *Z* test is presented in Table 3. There was a significant relationship between the mean crowding and the density of *E. tiliae* (P< 0.05) based on Iwao's model of March 2016 to March 2017 (Table 4).

Based on the index of dispersion, the spatial distribution in all stages was aggregated during the two study years. The Index of Dispersion (I_D) and the m^*/m values for all populations were significantly greater than 1 (Table 2), which means that this species exhibited aggregated behavior in habitat, and presence of a scale insect individual at one place may increase the probability of another individual existance nearby. Comparing 1/k values among the different stages of this species showed that the aggregation in egg stage was bigger than

Table 2. Estimated parameters by Lloyd mean crowding, index of dispersion, Lloyd mean crowding to mean and common *k* for *Eulecanium tiliae* from March/2016 to March/2018.

	Species	*m*	S^2	*m**	S^2/m	I_D	*Z*	*m*/m*	*1/k*
March/2016	Egg	68.033	45763.82	739.698	672.664	1419995	1620.266	10.872	9.872
To	1st Instar	37.884	5507.162	182.251	145.367	306870.3	718.454	4.810	3.810
March/2017	2nd Instar	13.769	1179.838	98.452	85.682	180875.7	536.496	7.149	6.149
	Female	5.199	258.155	53.846	49.647	104804.9	392.870	10.355	9.355
March/2017	Egg	65.505	57348.26	939.972	875.466	1905890	1886.408	14.349	13.349
To	1st Instar	36.719	4536.596	159.265	123.545	268959.4	667.459	4.337	3.337
March/2018	2nd Instar	13.258	1046.159	91.165	78.907	171781.8	520.173	6.876	5.876
	Female	5.641	293.545	56.671	52.029	113268.9	409.990	10.044	9.044

Table 3. Morisita's index and *Z* values for *Eulecanium tiliae* in different sampling dates from March/2016 to March/2017 (*Z* test for goodness of fit).

	Egg		1st Instar		2nd Instar		Female	
Date	I_δ	z	I_δ	z	I_δ	z	I_δ	z
29/March/16	-	-	-	-	1.023	2.798	-	-
10/April/16	-	-	-	-	1.254	2.593	-	-
16/April/16	-	-	-	-	0.440	-1.218	1.77	17.886
25/April/16	2.045	1200.930	-	-	-	-	2.296	154.970
29/April/16	2.303	1909.163	-	-	-	-	1.953	136.946
05/May/16	2.427	3363.032	-	-	-	-	1.908	193.175
08/May/16	1.918	2121.853	2.548	37.479	-	-	2.360	218.865
12/May/16	1.844	2501.975	1.994	86.612	-	-	1.814	142.700
21/May/16	1.558	982.643	1.669	102.326	-	-	2.856	115.347
06/June/16	2.953	987.241	1.872	491.011	-	-	2.799	92.387
15/June/16	-	-	1.701	447.975	-	-	3.864	21.440
26/June/16	-	-	1.492	379.501	-	-	-	-
06/July/16	-	-	1.667	521.085	-	-	-	-
15/July/16	-	-	1.591	441.120	2.536	99.772	-	-
27/July/16	-	-	1.571	419.128	2.458	236.610	-	-
06/August/16	-	-	1.439	268.019	2.040	230.626	-	-
12/August/16	-	-	1.929	595.341	1.857	154.564	-	-
20/August/16	-	-	2.035	503.336	2.596	492.570	-	-
26/August/16	-	-	2.391	545.349	2.216	553.398	-	-
03/September/16	-	-	2.484	351.353	2.032	325.773	-	-
11/September/16	-	-	2.795	239.508	2.699	288.083	-	-
23/September/16	-	-	-	-	2.402	252.766	-	-
03/October/16	-	-	-	-	2.786	274.005	-	-
17/October/16	-	-	-	-	2.962	235.774	-	-
02/November/16	-	-	-	-	3.051	133.408	-	-
18/November/16	-	-	-	-	2.474	81.131	-	-
27/November/16	-	-	-	-	2.661	47.274	-	-
14/December/16	-	-	-	-	3.410	23.708	-	-
01/January/17	-	-	-	-	2.133	4.438	-	-
04/February/17	-	-	-	-	1.454	2.372	-	-
26/February/17	-	-	-	-	1.761	4.438	-	-
12/March/17	-	-	-	-	2.409	4.416	-	-

that of the other stages because higher value of the 1/*k* index that might be due to aggregated oviposition under scales. All of the calculated 1/*k* values suggest aggregated pattern of dispersion for both years in all stages (Table 2).

There were some differences in Morisita's index values of each stage, but in most sampling dates, the index was significantly more than one and *Z* was greater than 1.96 (Tables 3 and 4), suggesting that the spatial distribution of all stages was aggregated. The results obtained from Morisita's index when *E. tillae* was present and active were significantly higher than one for all dates, except for the second instar nymphs. The spatial distributions were random on the dates of 16 April 2016 and 18 April 2017. This was because the second instar nymphs were molting on those dates and some of them changed their sheath and became immature females (Tables 3 and 4).

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 date, it can be used to understand details

Table 4. Morisita's index and *Z* values for *Eulecanium tiliae* in different sampling dates from March/2017 to March/2018 (*Z* test for goodness of fit).

	Egg		1st Instar		2nd Instar		Female	
Date	I_δ	**z**	I_δ	**z**	I_δ	**z**	I_δ	**z**
26/March/17	-	-	-	-	1.26	2.576	-	-
07/April/17	-	-	-	-	1.13	1.972	-	-
18/April/17	-	-	-	-	0.942	-0.179	1.434	15.356
25/April/17	1.879	757.105	-	-	-	-	1.809	72.548
05/May/17	2.165	1647.7	-	-	-	-	1.730	172.532
09/May/17	1.766	2119.799	-	-	-	-	1.721	190.873
12/May/17	2.676	4916.712	3.390	100.072	-	-	2.199	209.469
15/May/17	3.24	5332.203	2.408	130.553	-	-	2.411	120.391
19/May/17	2.178	1992.21	1.583	78.162	-	-	2.4003	126.152
28/May/17	1.411	132.787	1.565	110.717	-	-	2.267	81.994
07/June/17	17.21	835.740	1.469	200.735	-	-	1.607	17.774
16/June/17	-	-	1.394	274.110	-	-	-	-
27/June/17	-	-	1.423	321.601	-	-	-	-
07/July/17	-	-	1.561	405.851	-	-	-	-
16/July/17	-	-	1.591	441.120	2.155	63.344	-	-
28/July/17	-	-	1.556	407.980	2.13	160.398	-	-
07/August/17	-	-	1.401	244.737	1.815	72.099	-	-
13/August/17	-	-	1.380	243.741	1.685	108.961	-	-
21/August/17	-	-	1.554	299.263	1.847	253.986	-	-
27/August/17	-	-	1.912	372.719	1.991	445.768	-	-
04/September/17	-	-	2.839	320.436	2.779	545.028	-	-
12/September/17	-	-	4.049	123.972	2.619	292.001	-	-
24/September/17	-	-	-	-	2.004	299.214	-	-
04/October/17	-	-	-	-	2.575	262.511	-	-
18/October/17	-	-	-	-	2.92	232.504	-	-
03/November/17	-	-	-	-	2.207	201.942	-	-
19/November/17	-	-	-	-	3.033	132.905	-	-
28/November/17	-	-	-	-	2.738	26.632	-	-
15/December/17	-	-	-	-	2.433	23.951	-	-
31/December/17	-	-	-	-	1.605	9.638	-	-
05/February/18	-	-	-	-	1.488	2.424	-	-
27/February/18	-	-	-	-	1.846	4.860	-	-
13/March/18	-	-	-	-	1.770	3.152	-	-

of dispersion in different sampling dates that would be useful for research strategies more than management programs. It shows that distribution pattern can change as the result of some factors during the season, and distribution pattern in most of the sampling dates can be considered as a base for management decisions. Although Taylor's indices have been widely used by many researchers, we suggest Morisita's index for research programs because of its higher determination coefficient as well as better dispersion interpretation for these species (Tables 3 and 4). Different statistical methods have various accuracies in calculating spatial distribution of an organism.

One of the major reasons for having aggregate distributions is the proximity between the place of aggregated eggs and the place of feeding, which provides larva with sufficient and proper food, suggesting that such a pattern of spatial distribution is of the reproductive type distributions (Taylor, 1961). The study on the spatial distributions of 3 species of scale insects indicated that phenology and the part of the host plant had no effects on intra-species distributions, and levels of aggregation index were fixed within a species. For those three species of studied scales, spatial distributions were aggregated (Nestel *et al*., 1995). Coefficients *a* and *b* are related to the host plants and appropriateness of some parts of habitats in addition to being dependent on insect species (Jones, 1990; Raworth, 1986). In general, it appears that spatial distribution patterns of populations are caused by innate behavior patterns, morphological features of host plants, and

Table 5. Calculated sample size of egg, 1st instar, 2nd instar and female populations on cherry leaves based on *k* in negative binomial distribution and Taylor's Power Law and Iwao's Patchiness coefficients from March/2016 to March/2018.

	n_{opt}	Egg	1st Instar	2nd Instar	Female
March/2016	*K*	818.762	317.752	515.281	790.658
To	*Taylor*	18.590	16.376	24.068	29.487
March/2017	*Iwao*	470.120	904.526	95.880	214.289
March/2017	*K*	1339.142	337.127	596.358	924.053
To	*Taylor*	18.426	11.0135	15.779	4.834
March/2018	*Iwao*	3575.440	1075.581	9.019	168.947

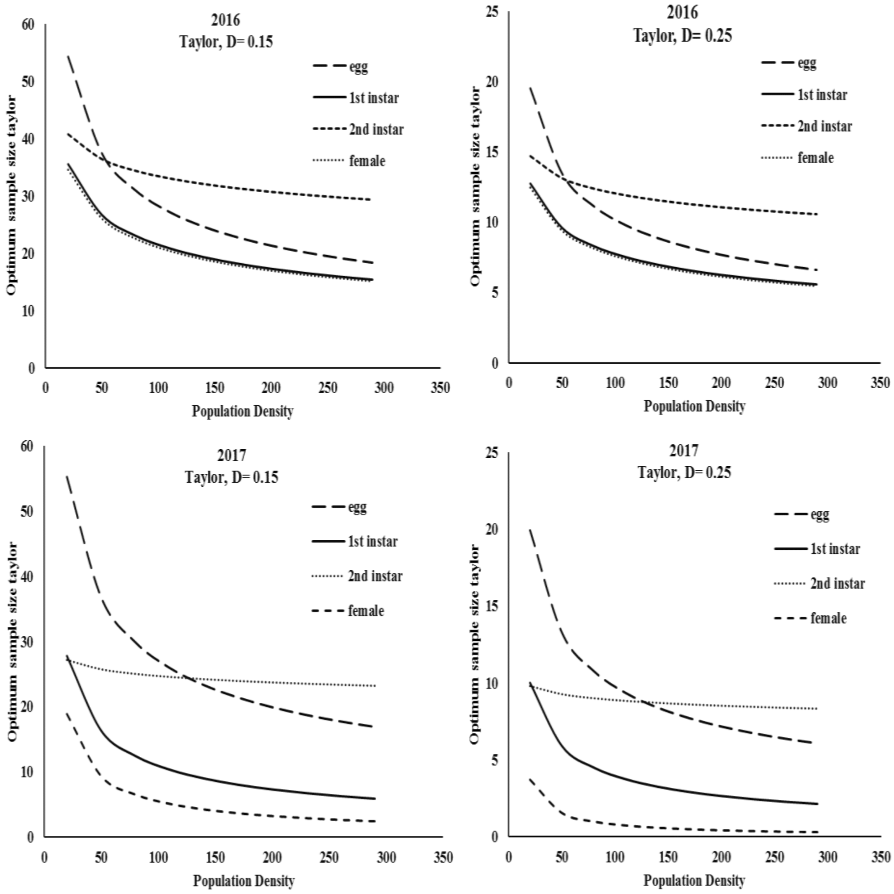

Figure 2. Estimated optimum sample sizes for different stages of *Eulecanium tiliae* based on Taylor's coefficients in two levels of 15 and 25% accuracy for 2016 to 2017 sampling years

overall effects of the major factors involved in their mortality (Nestel *et al*., 1995).

In this survey, the separate counts of *E. tiliae* stages were used to develop generic coefficients of regression techniques based on large amount of data in each stage. The sample sizes for each stage were re-calculated using Taylor's and Iwao's coefficient, i.e. *a*, *b*, *α* and ß (Table 5). The lowest estimated sample sizes for different stages were calculated by using Taylor's Equation, for all species. For example, when the mean density of nit population was 50 insects per sample unit, optimal sample number obtained by Taylor's method with precision of 15% and 25% were 35 and 15, respectively, in 2017, but the obtained figures by Iwao's method with the same precision in the same year were 130 and 50, respectively (Figures 2 and 3). According to Figures 2 and 3, optimum sample size for any of different pest stages varies by a specified mean, after which optimum sample size becomes fixed for each stage.

In comparative studies of models, Taylor's Power Law model usually showed to fit the spatial dispersion better than Iwao's model and achieved an appropriate precision of estimates (Afshari *et al.*, 2009). Taylor's method reduces the necessary sample size

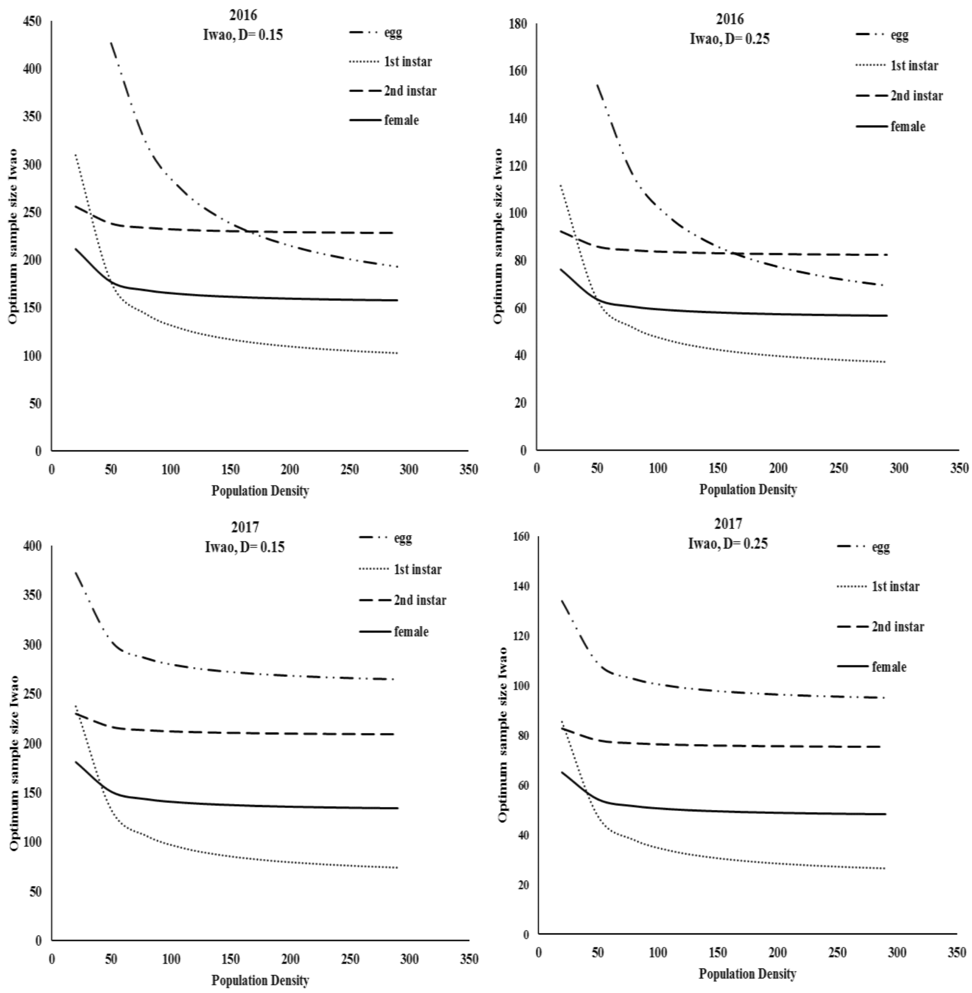

Figure 3. Estimated optimum sample sizes for different stages of *Eulecanium tiliae* based on Iwao's coefficients at two levels of 15 and 25% accuracy for 2016 to 2018 sampling years.

by almost half compared to the Iwao's method. In order to acquire greater precision, the 15% level was adopted, whereas in IPM programs 25% level is acceptable. The optimum number of samples suggested by Taylor's lines, taking into account a desired accuracy of 25%, is typically higher at low population level. The information of spatial distribution can determine sampling program, especially in sequential sampling. The use of dispersion indices seems to be a convenient decision-making method for management programs because of the easy calculation procedure and simple results. The result of this study can be used in places with similar climate.

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نوسانات جمعیت و الگوی توزیع فضایی شپشک نخودی *Eulecanium tiliae* (L.) (Hem.: Coccidae) روی گیلاس در غرب ایران

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چکیده

شپشک نخودی *Eulecanium tiliae* (L.) (Hem.: Coccidae)، در اکثر مناطق ایران به عنوان یک آفت بالقوه برای انواع درختان میوه است و در مناطق عمده باغداری در ایران روی هسته داران *Prunus* spp. و از جمله *Prunus cerasus* به شمار می‌آید. این آفت حضور و جمعیت بیشتری در باغات سمپاشی نشده دارد. این بررسی نشان داد که این آفت یک نسل در سال دارد و زمستان‌گذرانی آن به صورت پوره سن دوم بر روی سرشاخه‌های یک یا دو ساله است. مشاهدات نشان داده که آلودگی شدید باعث زرد شدن زودرس برگ و ضعف درختان می‌شود. در این تحقیق ، الگوی توزیع فضایی ، نوسانات جمعیت و تغییرات فصلی برای تمام مراحل *E. tiliae* در یک باغ گیلاس در

استان کرمانشاه طی دو فصل رشد در سال های 1395 و 1396 بررسی شد. برای تعیین الگوی توزیع فضایی حشرات مورد مطالعه از چهارروش شاخص پراکندگی، موریستا و روشهای رگرسیونی (تیلور و آیوائو) استفاده شد. برای تعیین تعداد نمونه‌ی مورد نیاز، در ابتدا یک نمونه‌برداری مقدماتی انجام شد و برای سایر تاریخها با توجه به داده های نمونه برداری تاریخ قبلی، تعداد نمونه مورد نیاز اصلاح شد. تجزیه و تحلیل داده ها با استفاده از نرم افزارهای آماری Minitab16 و Microsoft office excel 2016 انجام شده است. در بیشتر روش‌های مورد استفاده، الگوی توزیع فضایی آفت در هر دو سال تجمعی نشان داده شد. نتایج به دست آمده از شاخص موریستا نشان داد که توزیع تصادفی پوره سن دوم (در 28 فروردین 1395، $I_b = 0.440$ ، $Z = -1.218$)، (در 27 فروردین 1396، $Z = -0.179$، $I_b = 0.942$)، ($-1.96 < Z < 1.96$) میباشد که این تغییرات نشان می دهد که توزیع فضایی در طول فصل تغییر میکند. آگاهی از الگوی توزیع فضایی آفت می تواند در تعیین بهترین تصمیم گیری جهت کنترل آفت در برنامه های مدیریت تلفیقی آفات کمک کند.