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Population Fluctuation and Spatial Distribution Pattern of *Sesamia cretica* Led. (Lepidoptera: Noctuidae) in Southeastern Tehran, Iran

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ABSTRACT

Population density and dispersion pattern of *Sesamia cretica* Led. was determined in maize fields in Varamin (Ahmadabad and Khaveh) and Rey (Aminabad and Talebabad) areas (Tehran, Iran) during two agricultural seasons, 2017 and 2018. A whole plant of maize was selected as a sampling unit to estimate the number of *S. cretica* larvae. The highest population density of *S. cretica* larvae per plant was recorded on the 4th and 8th October in Aminabad, 17th and 20th September in Talebabad, 6th and 17th September in Ahmadabad and Khaveh, in 2017 and 2018, respectively. Mean densities of the larvae per plant were 52.62±12.53, 10.50±2.85, 17.45±3.48, 7.57±1.55 in 2017 and 12.00±5.29, 1.00±0.30, 11.05±2.36, 12.00±3.41 in 2018 in Aminabad, Talebabad, Ahmadabad, and Khaveh, respectively. The population of captured male adults in all fields in the second year was less than the first one. Peak numbers of male moths had a difference of 10-22 days between the two studied years. Based on the index of dispersion, the spatial distribution of *S. cretica* larvae in all fields in both areas was aggregated during the two years of study, except for Aminabad in 2018. According to Taylor's power law, *S. cretica* in Ahmadabad and Aminabad in 2017 had a random pattern, while in all fields of the other regions it had an aggregated spatial distribution during 2017 and 2018. In Iwao's model, the regression between the mean crowding and the density was not significant in Aminabad and Khaveh in 2017 and Talebabad in 2018, while in the other fields indicated the aggregated spatial distribution. The lowest estimate of the sample size was computed by using Taylor's power law. The results revealed that population fluctuation of *S. cretica* was affected by the region, but in spatial distribution pattern, the oviposition behavior of the pest was a much more determining factor than the region. The coefficients of the spatial pattern can be used for improving the sampling program to calculate the population density of *S. cretica* precisely.

Keywords: Dispersal pattern, Maize, Pink stem borer, Population density.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important agricultural crops in the world that originated from southern Mexico about 10,000 years ago (Tollenaar and Dwyer 1999; Benz, 2001). *Sesamia cretica* Led. (Lepidoptera: Noctuidae) known as pink stem borer and corn stem borer is the main insect pest of maize and sugarcane fields worldwide (Moyal *et al*., 1997; Ranjbar Aghdam, 1999; Ranjbar Aghdam and Kamali, 2002). In Iran, it is distributed in all maize fields especially in Khuzestan, Fars, and Tehran provinces (Momeni *et al*., 2016). *Sesamia cretica* also feeds on other host plants e.g., *Avena sativa* L., *Hordeum vulgare* L., *Oryza sativa* L., *Pennisetum typhoideum* Rich., *Saccharum* spp. L., *Sorghum bicolor* L., *S. halpense* L., *Triticum*

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aestivum L., unidentified bamboo, bulrush, and palms (Soltani Orang *et al*., 2014). It deposits eggs under the leaf sheath and neonate larvae enter whorl or stem of plants. Severe damage to maize plantations may occur if infestation takes place soon after plant emergence (Semeada, 1985; 1988).

The implementation of pest management programs in agroecosystems is defined on population density estimation methods in arthropods (Kogan and Herzog, 1980). At this evaluating plan, a reliable sampling program includes identification of the appropriate sampling time, sampling unit, determination of the spatial pattern of sampling units and sample size along with suitable sampling techniques (Sedaratian *et al*., 2010). A precise sampling program provides valuable and useful information such as assessing crop loss, studying the population dynamics, and detecting pest levels that justify measures (Hughes, 1996; Jarosik *et al*., 2003; Arnaldo and Torres, 2005).

In insect populations, a typical aspect is spatial distribution, which is an important attribute of ecological communities (Debouzie and Thioulouse, 1986). To determine the spatial distribution pattern of an insect species, different methods can be used 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 and Taylor's power law (Sedaratian *et al.*, 2010; Darbemamieh *et al.*, 2011). Among the above-mentioned methods, Iwao's patchiness regression and Taylor's power law are widely used due to the high accuracy (Khodayari *et al.*, 2010; Rahmani *et al.*, 2010; Ghaderi *et al.*, 2018).

It has been revealed that the population density of stem borers on cereal crops is affected by many biotic and abiotic factors, e.g., temperature, relative humidity, precipitation, altitude and host species/cultivar (Moyal *et al*., 2002; Velasco *et al.*, 2007; Moyal, 2014; Degong *et al*., 2015; Sharma *et al.*, 2017). A great part of the variation in the density of maize stem borers was explained by temperature and rainfall, which were adapted to less humid conditions and had lower population densities in higher temperatures (Moyal, 2014). However, *Sesamia nonagrioides* (Lefèbvre) differs from the other maize borers in France, where the greater are these two abiotic factors, the higher is the pest density.

The spatial distribution pattern of insect populations is affected by the dispersal abilities of the species, interactions among individuals, or habitat selection. Linking these ecological processes to spatial patterns is very important for understanding insect population dynamics and prediction purposes (Vinatier *et al*., 2011). A small group of lepidopterans can lay eggs in large clusters (Lacey and Kaya, 2007), and an aggregated distribution pattern of larvae is common during the earlier instars due to gregarious feeding (Stamp, 1980). The host plant is another factor that can affect the abundance of stem borers. Govender *et al*. (2011) reported that stem borers abundance differs among plant species. The spatial distribution pattern is important because the minimal sample size is dependent on the spatial pattern of the sampled populations (Arbab, 2014).

Despite the importance of *S. cretica*, there is no detailed information about its population fluctuation and spatial distribution in the maize fields of Iran. Therefore, the present study was undertaken to provide a sampling procedure for population fluctuation studies and to determine the differences in spatial distribution and abundance of *S. cretica* on maize in different areas of Tehran province.

MATERIALS AND METHODS

Study Sites

This study was conducted in two areas of Ray and Varamin in Tehran province, during the growing seasons of 2017 and 2018. In each district, two maize fields were chosen with an area of one hectare (Rey: Aminabad 35° 34' 0" North, 51° 28' 50.7" East, 1,070 m height and Talebabad 35° 29' 44.5" North, 51° 32' 10.1" East, 1,000 m height; Varamin: Ahmadabad 35° 19' 34.6" North 51° 35' 24.7" East 923 m height and Khaveh 35° 13' 33.6" North, 51° 44' 07.9" East 862 m height). The maize cultivar was Single Cross 704 in all fields and plant density was about 100,000 per hectare. No insecticides were applied during the study. The population density and spatial distribution pattern of *S. cretica* were determined in all fields in both areas during the growing seasons of 2017 and 2018. It should be noted that in Ray, larval population fluctuations were recorded only during the second generation of the pest because wheat was planted as the first agricultural crop during each growing season in this area. Nevertheless, the larval population changes were recorded in maize fields of Varamin during both generations of the pest.

Sampling Procedure

In this study, the sampling unit was considered as a whole maize plant, which was selected randomly, and five samples were taken in every five steps in both diameters of the field. The samples were taken weekly from 12th May to 30th October 2017 and from 8th May to 8th November 2018, which started from Aminabad in the morning and ended in Khaveh in the evening.

To determine the sample size, a primary sampling was performed in the same number in different areas on 25th and 31st May 2017 and 2018, respectively. To determine the adequacy of the sample size, the Relative Variation (RV) was calculated as follows:

$$RV = \left(\frac{SE}{m}\right) \times 100 \quad (1)$$

Where, *SE* is the standard error of the mean and *m* is the mean of initial sampling data. The reliable sample size was determined by using the following equation:

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

Where, *N*= Sample size, *t*= t-student, *s*= Standard deviation, *d*= Desired fixed proportion of the mean (or range of accuracy), and *m*= Mean of initial sampling data (Pedigo and Buntin, 1994).

Population Fluctuation

Larval Population Fluctuation

To determine *S. cretica* larval population fluctuation in different areas, the collected samples were transferred to the laboratory for recording the number and stage of the maize stem borer larvae. The sampling started on 12th and 8th May and continued until 30th October and 8th November in 2017 and 2018, respectively.

Male Adult Population Fluctuation

Traps Description

The male adult population density was determined using funnel traps. A dark green funnel, as described by Guerrero *et al*. (2014) (bottom opening 3.2 cm), on top of the bucket and a cover (16 cm diam.) were attached to the funnel by four posts that allowed a 3-cm circular space between cover and funnel. A pheromone lure of *S. cretica* was placed in a green basket (5.3 cm long) hung in the middle of the green cover. Therefore, the moths attracted to the pheromone fell downwards (usually after flying inside the posts and bouncing off the top cover) through the green funnel into the bucket where they were killed by an insecticide (Sevin®, carbaryl 85 WP, Chimighahreman). *Sesamia cretica* pheromone lure was provided from Pesticides Research Department of Iranian Research Institute of Plant Protection. The

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pheromone capsules were replaced every month by a new one.

Trap Placement

Two traps were installed in the middle of each maize field and at least 150 m apart from each other and 50 m away from the edges of the field. Traps height increased by increasing the plants height during the growing season, but ultimately was set in 75 cm above the ground level. Traps were checked daily for recording the first capture of the male moths. Then, subsequent trap catches were done weekly. All the captured male moths were removed from the traps reservoir after recording.

Spatial Distribution Pattern

The spatial distribution of *S. cretica* larvae was determined using the index of dispersion, Morisita's coefficient of dispersion, Taylor's power law, and Iwao's patchiness regression.

Index of Dispersion

The dispersion of *S. cretica* larval population was classified by calculating the variance to mean ratio, namely, S^2/m= 1 random, < 1 regular, and > 1 aggregated. Departure from a random distribution was tested by calculating the Index of Dispersion (I_D), where n is the number of samples:

$$I_D= \frac{(n-1)\,S^2}{m} \quad (3)$$

I_D is approximately distributed as χ^2 with $n-1$ degrees of freedom. By Z coefficient, I_D value was tested as follows:

$$Z= \sqrt{2\,I_D} - \sqrt{(2V-1)} \quad (4)$$

V= n-1

If 1.96≥ Z≥ -1.96, the spatial distribution of larvae would be random, uniform if Z< -1.96, and aggregated if Z> 1.96 (Patil and Stiteler, 1974).

Morisita's Coefficient of Dispersion I_δ

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

$$I_{\delta}= \frac{n\sum x_i(x_i-1)}{N(N-1)} \quad (9)$$

Where, n= Number of sample units, x_i= Number of individuals in each sample unit, and N= Total number of individuals in n samples. To determine if the sampled population significantly differs from random pattern, the following goodness-of-fit equation was applied:

$$Z= \frac{(I_\delta-1)}{(\frac{2}{nm^2})^{\frac{1}{2}}} \quad (10)$$

Where, m= Mean population density per leaf in each sampling date and n= number of sample units. The spatial distribution would be random if 1.96≥ Z≥ -1.96, but it would be uniform and aggregated if, respectively, Z< -1.96 and Z> 1.96.

Taylor's Power Law and Iwao's Patchiness Regressions

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

$$Log\ S^2= Log\ a+b\ Log\ m \quad (5)$$

Where, a is a scaling factor related to sample size and b measures the species aggregation. The distribution is random, regular, and aggregated when b= 1, < 1, and > 1, respectively (Taylor, 1961).

Iwao's patchiness, regression method was used to quantify the relationship between mean crowding index (m^*) and mean (m):

$$m^*= m+(\frac{S^2}{m}-1) \quad (6)$$

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

Where, α indicates the tendency to crowding (positive) or repulsion (negative) and β reflects the distribution of the population in space and is interpreted in the same manner as b of Taylor's power law (Iwao and Kuno, 1968). If the colonies are randomly dispersed, student t-test was used to determine it. Test b= 1, $t= \frac{(b-1)}{SE_b}$ (7)

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β= 1, $t= \frac{(\beta-1)}{SE_\beta}$ (8)

Where, SE_b and SE_β are the standard errors of the slope for the mean crowding regression. Calculated values are compared with tabulated *t*-values with *n-2* degrees of freedom. If the calculated t (t_c)< t-table (t_t), the null hypothesis (*b*= 1) would be accepted and spatial distribution would be random. If $t_c \geq t_t$, the null hypothesis would be rejected and the spatial distribution would be aggregated if *b*> 1 and regular if *b*< 1.

Optimum Sample Size

The smallest number of sample units that would persuade the objectives of the sampling program and accomplish the desired precision of estimates is the optimum sample size. The calculated Taylor's power law and Iwao's patchiness regression coefficients eliminate experimental needs for a large sample size (Ifoulis and Savopoulou-Soultani, 2006). By finding out Taylor's power law coefficients (*a* and *b*) the optimum number of sample size was calculated as follows:

$$N_{opt}= a \left(\frac{t_{\frac{\alpha}{2}}}{d}\right)^2 (m^{b-2}) \quad (11)$$

And using Iwao's patchiness regression coefficients (α and β) (Wilson, 1982) as follows:

$$N_{opt}= \left(\frac{t_{\frac{\alpha}{2}}}{d}\right)^2 (\frac{\alpha+1}{m} + (\beta - 1)) \quad (12)$$

Where, N_{opt}= Optimum sample size, $t_{\frac{\alpha}{2}}$= t Student of table, *m*= Mean density of primary sampling, and *d*= The range of accuracy.

RESULTS

Sampling Procedure

The primary sample size based on reasonable specified Relative Variation (RV) consisted of 150 samples (plants), which was the same for different sampling areas. Based on the estimated reliable sample size, 200 plants per field were sampled.

Population Density

Population fluctuation curves of *S. cretica*, in Aminabad, Talebabad, Ahmadabad, and Khaveh in 2017 and 2018 are shown in Figure 1, respectively. The larval population was monitored from 12th and 8th May and continued until 30th October and 8th November in 2017 and 2018. Mean density of the larvae per plant was 52.62±12.53, 10.50±2.85, 17.45±3.48, 7.57±1.55 in 2017, and was 12.00±5.29, 1.00±0.30, 11.05±2.36, 12.00±3.41 in 2018 in Aminabad, Talebabad, Ahmadabad and Khaveh, respectively. The male adult population was monitored from 12th May 2017 to 15th October 2017 and from 20th April to 19th October 2018. Mean density of male adult insects per trap (in the morning in Aminabad up to evening in Khaveh) was 50.20±22.03, 14.60±5.93, 5.08±1.32, 13.00±0.76 in 2017 and 5.50±1.37, 3.85±0.93, 3.54±0.71, 2.48±0.59 in 2018 in Aminabad, Talebabad, Ahmadabad and Khaveh, respectively. The results indicated that the highest population densities of *S. cretica* larvae per plant occurred in early October in Aminabad, mid-September in Talebabad, 6th and 17th September in Ahmadabad and Khaveh and for male adult insects per trap was 9th and 20th September in Aminabad, 9th September, 31th August in Talebabad, 30th and 31st August in Ahmadabad, and 25th May and 20th September in Khaveh, in 2017 and 2018, respectively.

Spatial Distribution

The results of the variance to mean ratio (S^2/m), Index of Dispersion (I_D) and, *Z* test are presented in Table 1. Based on the index of dispersion, the spatial distribution of *S. cretica* in all fields in both areas was aggregated during the two growing years, except for Aminabad in 2018.

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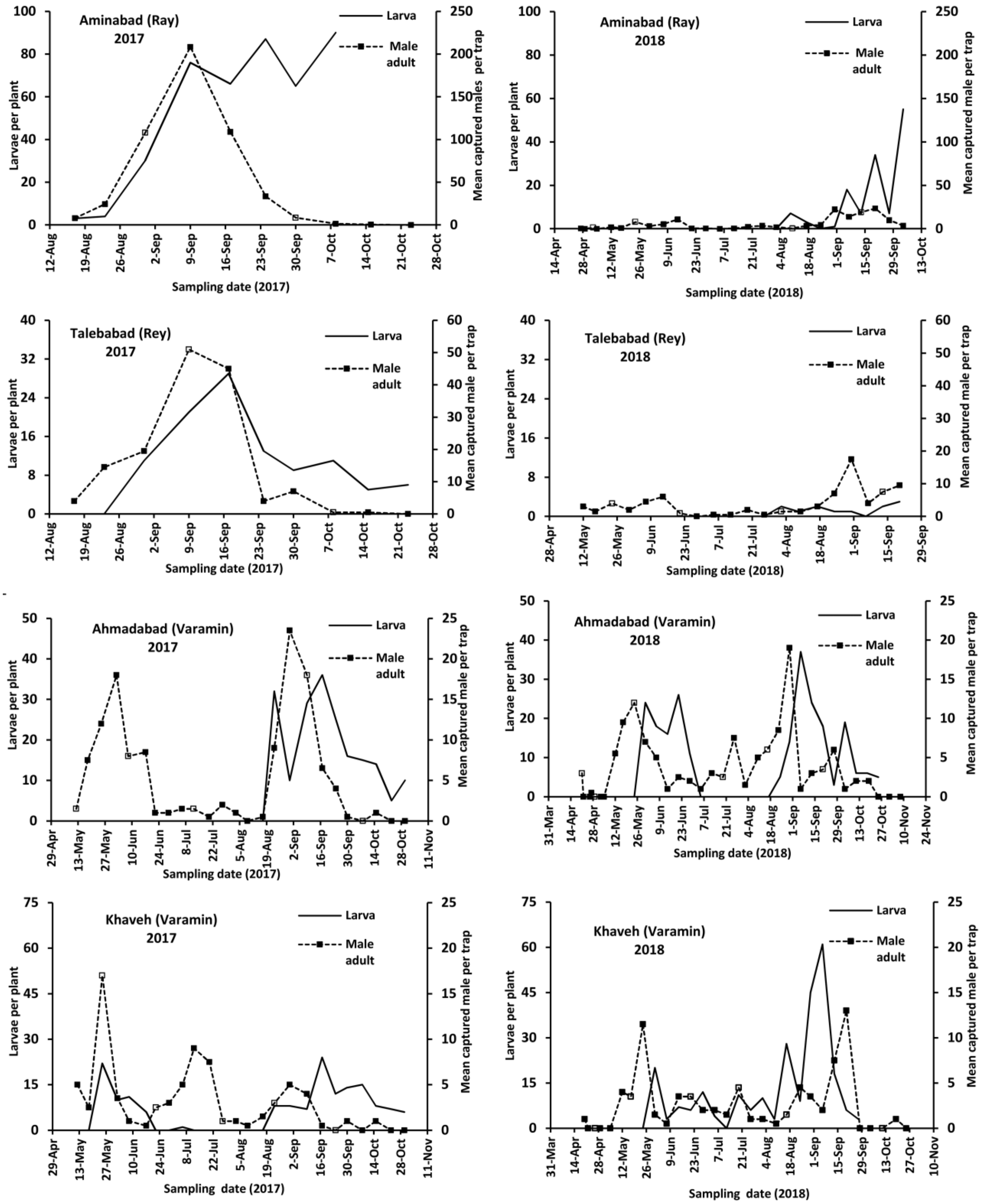

Figure 1. Population fluctuation of *Sesamia cretica* in Aminabad (Ray), Talebabad (Rey), Ahmadabad (Varamin) and Khaveh (Varamin) in 2017 and 2018. Hollow squares represent the time of pheromone replacement.

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Table 1. Variance to mean ratio (index of dispersion) and the *Z* coefficient for *Sesamia cretica* in four areas of Tehran Province in 2017 and 2018 (*Z* test for goodness of fit).

Year	Area		S^2/m	I_D	Z
2017	Varamin	Khaveh	2.98	12533.60	66.69
		Ahmadabad	3.59	8624.12	62.07
	Rey	Talebabad	3.997	7990.24	63.19
		Aminabad	3.75	6004.05	53.04
2018	Varamin	Khaveh	3.70	13332.02	78.46
		Ahmadabad	3.55	14908.68	81.04
	Rey	Talebabad	1.49	2388	12.57
		Aminabad	1.01	1818.93	0.34

In Morisita's index, the *Z* value for *S. cretica* in most sampling dates was greater than 1.96 in four fields and two areas in 2017 and 2018, indicating spatial distribution pattern was aggregated, but in few cases, it was random and the *Z* value was between -1.96 and 1.96 (Table 2).

According to P-values in Iwao's model, the regression between the mean crowding and the density was significant ($P< 0.05$) for all fields in both areas and two years, except for Aminabad and Khaveh in 2017 and Talebabad in 2018. The calculated t (t_c) was greater than t-table (t_t) indicating an aggregated spatial distribution of *S. cretica* in all fields (Table 2). The regression between log S^2 and log m was significant based on Taylor's power law ($P< 0.05$) for all fields in both areas in the two years. During the two sampling years, Ahmadabad and Aminabad in 2017 had a random pattern while the other fields in both areas had an aggregated spatial distribution pattern (Table 3).

The sample size was recalculated using Taylor's and Iwao's coefficient (Table 4). Comparison of the two different equations used for calculating the optimal sample size demonstrated that the lowest estimate of the sample size in all of them was calculated using Taylor's equation in four fields and both areas in 2017 and 2018.

DISCUSSION

Sesamia cretica causes economic losses to commercial varieties of maize and sugarcane and damages them directly and indirectly (Askarianzadeh *et al.*, 2008; Nikpay and Volpe 2016). In the present study, the appropriate sampling method was the direct observation of plants for the larval stage. Therefore, a whole plant of maize was selected as a sampling unit to estimate the number of *S. cretica* larvae. The population fluctuation of *S. cretica* during each year and between two years (2017 and 2018) displayed differences in the studied locations. Peak of the larval population was almost the same in the two years (with a slight difference in the range of 4-11 days). However, the mean density of the larvae varied in the two years, the population declined in all areas, except in Khaveh in the second year. This was true for male adults such that the population of captured male adults in all areas in the second year was less than the first one. The highest capture in Khaveh was in the first generation in 2017, while in the other areas the peak of capture was observed in the second generation of *S. cretica*. Peak numbers of male moths had a difference of 10-22 days, between two studied years. In contrast with the present study, Moyal *et al.* (2002) found that population fluctuation of *S. cretica* in the different locations of the Nile delta was rather similar both during one year and in different years of the study. Several factors such as temperature at the beginning of spring, rate of egg parasitism, survival of larval stages, and pupal mortality may explain the changes observed in the pest density (Moyal *et al.*, 2002). Sharma *et al.* (2017) reported that the larval population of *Sesamia inferens* (Walker) had a

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Table 2. Morisita's index and Z value for *Sesamia cretica* in southeastern Tehran in different dates of 2017 and 2018 (Z test for goodness of fit).

Area			2017																					
			18May	25May	2 Jun	8 Jun	17Jun	22Jun	29Jun	6 Jul	12 Jul	20Jul	9Aug	17 Aug	23 Aug	31 Aug	9 Sep	17 Sep	24 Sep	30 Sep	8 Oct	15 Oct	23 Oct	30 Oct
Varamin	Khaveh	I_δ	-	25.97	57.78	18.18	13.33	-	-	-	-	-	-	107.14	28.57	85.71	57.14	19.56	9.09	59.34	24.76	7.14	19.05	133.33
		Z	-	27.47	28.39	9.45	3.70	-	-	-	-	-	-	42.46	11.03	33.89	19.65	22.28	4.85	40.84	17.82	2.46	6.32	39.70
	Ahmadabad	I_δ	-	-	-	-	-	-	-	-	-	-	-	-	64.92	31.11	5.00	18.10	11.33	3.33	15.00	13.19	9.52	22.22
		Z	-	-	-	-	-	-	-	-	-	-	-	-	102.27	15.06	13.61	30.77	12.92	1.87	11.20	8.53	6.39	10.61
Rey	Talebabad	I_δ	-	-	-	-	-	-	-	-	-	-	-	-	-	80	27.62	43.35	17.95	27.78	10.91	0	80	-
		Z	-	-	-	-	-	-	-	-	-	-	-	-	-	43.45	27.95	61.41	11.02	12.05	5.45	-0.25	23.7	-
	Aminabab	I_δ	-	-	-	-	-	-	-	-	-	-	-	-	21.21	42.30	15.09	6.62	6.84	8.65	2.00	-	-	-
		Z	-	-	-	-	-	-	-	-	-	-	-	-	12.13	61.95	53.53	18.55	25.42	24.88	4.49	-	-	-
			2018																					
Area			31 May	7 Jun	14 Jun	21 Jun	28 Jun	5 Jul	12 Jul	19 Jul	26 Jul	2Aug	9Aug	16 Aug	24 Aug	30 Aug	6 Sep	13 Sep	20 Sep	27 Sep	4 Oct	11 Oct	18 Oct	25 Oct
Varamin	Khaveh	I_δ	61.05	0.00	19.05	133.33	48.48	33.33	-	98.18	53.33	53.33	0.00	24.83	33.33	10.71	10.27	49.67	13.33	0.00	-	-	-	-
		Z	60.05	-0.15	6.32	39.70	28.49	6.47	-	53.45	15.70	26.17	-0.15	35.74	14.55	21.84	28.28	43.81	3.70	-0.15	-	-	-	-
	Ahmadabad	I_δ	33.33	11.76	6.67	11.69	40.00	-	-	-	104.76	33.47	53.33	-	40.00	54.95	13.81	7.25	52.29	0.00	17.54	13.33	13.33	40.00
		Z	38.80	9.69	4.53	13.90	21.45	-	-	-	77.82	51.95	15.70	-	9.75	37.76	23.71	7.50	46.16	-0.15	15.72	3.70	3.70	9.75
Rey	Talebabad	I_δ	-	-	-	-	-	-	-	-	-	200	-	0.00	-	-	-	200	66.67	-	-	-	-	-
		Z	-	-	-	-	-	-	-	-	-	19.90	-	-0.10	-	-	-	19.90	9.85	-	-	-	-	-
	Aminabab	I_δ	-	-	-	-	-	-	-	-	-	-	38.10	0.00	-	-	37.91	19.05	24.24	38.10	26.94	-	-	-
		Z	-	-	-	-	-	-	-	-	-	-	12.98	-0.15	-	-	33.22	6.32	39.51	12.98	71.32	-	-	-

Table 3. Estimated parameters by Taylor's power law and Iwao's patchiness regression models for *Sesamia cretica* in southeast of Tehran Province in 2017 and 2018.

Year		Area		Parameter estimation				Test for slope	
				$a \pm SE$	$b \pm SE$	r^2	P_{reg}	t_c	t_t
2017	Taylor	Varamin	Khaveh	0.886±0.236	1.369±0.169	0.823	0.0001	2.18	1.76
			Ahmadabad	0.780±0.308	1.435±0.279	0.815	0.0021	1.56	1.94
		Rey	Talebabad	1.387±0.403	1.773±0.317	0.839	0.0014	2.44	1.94
			Aminabad	0.529±0.225	1.012±0.340	0.638	0.0311	0.35	2.015
	Iwao	Varamin	Khaveh	-	-	-	0.1935	-	-
			Ahmadabad	-0.156±0.492	15.594±5.041	0.615	0.0216	2.89	1.94
		Rey	Talebabad	-0.371±0.967	39.357±12.773	0.613	0.0216	3.00	1.94
			Aminabad	-	-	-	0.2049	-	-
2018	Taylor	Varamin	Khaveh	1.091±0.170	1.519±0.124	0.910	0.0001	4.20	1.75
			Ahmadabad	0.985±0.201	1.483±0.162	0.839	0.0001	2.97	1.75
		Rey	Talebabad	1.264±0.509	1.545±0.241	0.891	0.0014	2.26	2.01
			Aminabad	1.141±0.103	1.560±0.071	0.988	0.0001	7.91	1.94
	Iwao	Varamin	Khaveh	1.104±0.623	16.511±7.611	0.252	0.0478	2.04	1.76
			Ahmadabad	0.369±0.602	18.118±6.424	0.346	0.0129	2.66	1.75
		Rey	Talebabad	-	-	-	0.1174	-	-
			Aminabad	-0.003±0.231	26.512±1.912	0.970	0.0001	13.34	1.94

Table 4. Calculated sample size of *Sesamia cretica* populations in southeastern Tehran Province based on Taylor's power law and Iwao's patchiness coefficients during 2017 and 2018.

Year	Area		d	N_{opt}	
				Taylor	Iwao
2017	Varamin	Khaveh	0.15	174.37	-
	Rey	Ahmadabad	0.15	150.26	3453.52
		Talebabad	0.15	603.11	2096.57
		Aminabad	0.15	140.91	-
2018	Varamin	Khaveh	0.15	401.63	4820.07
	Rey	Ahmadabad	0.15	208.30	1917.87
		Talebabad	0.15	2166.84	-
		Aminabad	0.15	556.78	6225.21

significant negative correlation with the maximum and minimum temperature and rainfall on maize. A multiple regression analysis of *Sesamia nonagrioide*s Léfèvbre and *S. inferens* population with weather parameters revealed that there was about 80 percent variability in larval population due to various climate factors (Moyal, 2014; Sharma *et al.*, 2017). Another factor that can affect the population density of a pest is altitude. Velasco *et al.* (2007) showed a clear relationship between the altitude of different areas and abundance of two borer species, *S. nonagrioide*s and *Ostrinia nubilalis* (Hübner). They also reported that population of the borers had a significant relationship with temperature.

The spatial distribution of pink stem borer was aggregated based on the results of variance-to-mean ratio in all areas during the two studied years, except for Aminabad in 2018. Using Morisita's index, the spatial distribution pattern was aggregated, but in few sampling dates, it was random in four fields and two areas in 2017 and 2018. According to Taylor's method, Ahmadabad and Aminabad in 2017 had a random pattern, while the other fields in two areas had an aggregated spatial distribution during these two sampling years. Based on Iwao's model, the regression between the mean crowding and the density was not significant in Aminabad and Khaveh in 2017 and Talebabad in 2018, while the other fields indicated an aggregated spatial distribution pattern. Results of other scientists support this research. Hall (1986) showed that sugarcane borer, *Diatraea saccharalis* (F.) had an aggregated distribution pattern at high population densities in Florida. Schulthess *et al.* (1991) revealed the aggregated dispersal pattern of *Sesamia calamistis* Hampson on maize in West Africa. Aggregated distribution pattern of *Mussidia nigrivenella* (Lepidoptera: Pyralidae) in maize fields in Benin (West Africa) has been demonstrated by Setamou *et al*. (2000). Parian *et al.* (2012) reported that spatial dispersion of *Sesamia* spp. in sugarcane fields in Khuzestan province (southwestern Iran) in each sampling stage by variance-to-mean ratio, index of patchiness, and Green's index was aggregated. Dispersal pattern of *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae), *Maliarpha separatella* Rag (Lepidoptera: Pyralidae) and *Sesamia calamists* Hampson (Lepidoptera: Noctuidae) in rice fields in Kahama district (Tanzania) was defined aggregated by Morisita's index, Taylor's power law, and Iwao's mean crowding regression (Leonard, 2015). Furthermore, determination of the dispersal pattern of overwintering larvae of *S. inferens* in rice fields revealed that it was aggregated (Degong *et al.*, 2015). Nikpay and Volpe (2016) showed that the spatial distribution pattern of *Sesamia* spp. in all varieties (CP69-1062 and CP48-103) and phonological stages of sugarcane in southwestern Iran was aggregated. In general, several factors contribute to development of the spatial distribution pattern of insect pests, including

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reproductive conditions, oviposition patterns, an egg mass hatching, and the emergence of neonates or aggregation around the parents, socialization characteristics (from mating to advanced socialization states), nutrition (reaction to nutrients), behavioral characteristics of immature stages, aggregated pheromones, host kairomones, host densities, the efficiency of natural enemies, abiotic factors (such as light, heat, humidity, etc.), rate of homogeneity and quality of host plants (Parian *et al*., 2012). In addition, it is affected by the species dispersal abilities, individuals' interactions, or selection of habitat (Arbab, 2014). Most of insect pest populations show some degree of aggregation (Taylor, 1984). The aggregation distribution pattern is influenced by the two factors of oviposition behavior and food preference (Pedigo and Buntin, 1994). Different sampling areas of a farm can affect the distribution of a pest, for example, Hall (1986) explained that the sugarcane borer populations did not show a random or regular distribution in large fields. Actually, the distribution in large sugarcane fields is usually aggregated compared with small farms. Schulthess *et al.* (1991) suggested that high aggregation of *S. calamistis* is related to its limited migration as well as oviposition behavior. Setamou *et al*. (2000) pointed out that corn ear size affects the degree of aggregation of *M. nigrivenella*. Furthermore, Leonard (2015) confirmed that borers' degree of aggregation along the edges of rice fields was different from the middle parts. Degong *et al*. (2015) suggested that environmental factors might affect the spatial distribution pattern of *S. inferens* larvae in rice fields. Some aspects of ongoing research are not in line with some of the other studies; for instance, Meagher *et al*. (1996) indicated that the spatial distribution pattern of small larvae of *Eoreuma loftini* Dyar (Lepidoptera: Crambidae) was aggregated and medium and large larvae had a randomized distribution pattern on Texas sugarcane. Furthermore, Schexnayder *et al.* (2001) confirmed that the distribution pattern of sugarcane borer larvae, *D. saccharalis*, on sugarcane was random in Louisiana. In addition, the spatial distribution pattern of *O. nubilalis* was defined as random by Taylor's power low in sweet corn ear near harvest time (O'Rourke and Hutchison, 2003). The discrepancy between the results of some researchers with our study is mainly because of differences in ecological conditions, host plants, pest species, and behavioral characteristics of pests, etc.

In a lower population level, the optimal sample size proposed by Iwao's model was much larger than Taylor's power law and the number of samples used in this survey is roughly close to that estimate. Ifoulis and Savopoulou-Soultani (2006) confirmed that Taylor's power law, compared with Iwao's model, reduced the number of samples needed. In the present study, Taylor's method estimated a lower number of samples for the larval stage. Ongoing results are in agreement with the findings of other scientists (Ifoulis and Savopoulou-Soultani, 2006; Darbemamieh *et al*., 2011; Ghaderi, *et al*., 2018).

The results of this study indicated that there were slight differences in the pattern of *S. cretica* distribution in different regions and years. It seems that, in determining the type of distribution, some factors such as aggregative oviposition behavior and behavioral characteristics of immature stages are more important than environmental factors such as altitude, but population fluctuation of *S. cretica* was affected by the region.

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تغییرات جمعیت و الگوی پراکنش پهنه‌ای ***Sesamia cretica*** **Led.** **(Lepidoptera: Noctuidae)** در جنوب شرقی تهران، ایران

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چکیده

انبوهی جمعیت و الگوی پراکنش پهنه‌ای *Sesamia cretica* Led. روی ذرت در طول فصل زراعی سال های ۱۳۹۶ و ۱۳۹۷ در منطقه ورامین (احمدآباد و خاوه) و ری (امین آباد و طالب آباد) (استان تهران) بررسی شد. برای تخمین تعداد لاروهای *S. cretica* در مزرعه، کل بوته ذرت به عنوان واحد نمونه‌برداری انتخاب شد. بالاترین انبوهی جمعیت لاروهای *S. cretica* در هر بوته در تاریخ‌های ۱۲ و ۱۶ مهر در امین آباد، ۲۶ و ۲۹ شهریور در طالب آباد و ۱۵ و ۲۶ شهریور در احمدآباد و خاوه به ترتیب در سال های ۱۳۹۶ و ۱۳۹۷ رخ داد. میانگین انبوهی لارو در هر گیاه به ترتیب در امین آباد، طالب آباد، احمد آباد و خاوه عبارت بود از: ۱۲/۵۳ ± ۵۲/۶۲، ۲/۸۵ ± ۱۰/۵۰، ۳/۴۸ ± ۱۷/۴۵، ۱/۵۵ ± ۷/۵۷ در سال ۱۳۹۶ و ۵/۲۹ ± ۱۲/۰۰، ۰/۳۰ ± ۱/۰۰، ۲/۳۶ ± ۱۱/۰۵، ۳/۴۱ ± ۱۲/۰۰ در سال ۱۳۹۷. جمعیت شب پره‌های شکار شده در همه مزارع، در سال دوم کمتر از سال اول بود. زمان بروز حداکثر تعداد شب‌پره‌های نر در دو سال بررسی، ۱۰– ۲۲ روز تفاوت داشت. الگوی پراکنش پهنه‌ای با استفاده از شاخص پراکندگی در همه مزارع در هر دو منطقه و هر دو سال، به غیر از امین آباد در سال دوم به

صورت تجمعی بود. بر اساس مدل تایلور، الگوی پراکنش پهنه‌ای در احمد آباد و امین آباد در سال ۱۳۹۶ از نوع تصادفی بود در حالی که در سایر مزارع در هر دو منطقه و هر دوسال از نوع تجمعی بود. در مدل Iwao، رگرسیون بین میانگین ازدحام و تراکم در امین آباد و خاوه در سال ۱۳۹۶ و طالب آباد در سال ۱۳۹۷ معنی دار نبود در حالی که در سایر مزارع الگوی پراکنش از نوع تجمعی بود. کمترین تخمین اندازه نمونه با استفاده از قانون تیلور محاسبه شد. این نتایج نشان داد که تغییرات جمعیت *S. cretica* تحت تاثیر منطقه قرار دارد اما در الگوی پراکنش پهنه‌ای رفتار تخمگذاری بسیار تعیین کننده تر از منطقه است. شاخص های پراکنش پهنه‌ای را می توان برای بهبود برنامه های نمونه برداری در راستای تخمین دقیق انبوهی جمعیت *S. cretica* استفاده کرد.

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