Population Density and Spatial Distribution Pattern of Empoasca decipiens (Hemiptera: Cicadellidae) on Different Bean Species

B. Naseri¹, Y. Fathipour^{1*}, and A. A. Talebi¹

ABSTRACT

The population density and spatial distribution pattern of Empoasca decipiens Paoli were determined in Tehran area, Iran, during 2004-2005 on four species of common bean Phaseolus vulgaris (L.) var. Talash, lima bean P. lunatus (L.) Savi ex Hassk. var. Sadaf, rice bean P. calcaratus Roxb. var. Goli and cowpea Vigna sinensis (L.) var. Parastoo. The higher and lower mean population densities of E. decipiens per leaf were observed on Parastoo cowpea (18.85 in 2004 and 29.94 in 2005) and Talash common bean (1.08 in 2004 and 0.37 in 2005), respectively. Spatial distribution pattern of E. decipiens was described on these four bean species using variance to mean ratios, Taylor's power law coefficients and Iwao's patchiness regression methods. The spatial distribution pattern of this pest in most cases was aggregated and in a few cases random. In 2004, collected data were in a better fitting with Taylor's model in comparison with Iwao's model on Talash common beans ($r^2 = 0.879$) as well as on Goli rice bean ($r^2 = 0.967$). Iwao's model explained the distribution data of 2004 and 2005 on Sadaf lima beans ($r^2 = 0.746$ and 0.906, respectively) more appropriately than Taylor's model ($r^2 = 0.541$ and 0.828, respectively). It is concluded that bean species influence the population density and spatial distribution pattern of E. decipiens. Spatial distribution parameters can be employed to develop a sampling program and to estimate the population density of this pest.

Keywords: Bean species, *Empoasca decipiens*, Leafhopper, Population density, Spatial distribution.

INTRODUCTION

Greenhouse leafhopper, *Empoasca decipiens* Paoli is an extremely polyphagous species and serious pest to a wide range of economically important crops including bean in Iran (Kheyri 1989; Rassoulian *et al.*, 2005; Naseri *et al.*, 2007) as well as in many other parts of the world (Atlihan *et al.*, 2003; Jan *et al.*, 2003; Umesh and Rajak, 2004; Genceoylu and Yalcin, 2004). Adults and nymphs feed on the host plant leaves. This leafhopper usually colonizes the undersurface of leaves, inserting its mouthparts into the plant tissue to extract plant juice.

Females lay their eggs within the leaf vein tissue (Raupach *et al.*, 2002; Backus *et al.*, 2005).

The methods for estimating population densities in arthropods are the cornerstone of basic research on agricultural ecosystems and the principal tool for establishing the implementation of pest management programs (Kogan and Herzog, 1980). Therefore reliable sampling program includes identification of the appropriate sampling time, sampling unit, determination of pattern of sampling (randomness) as well as sample size (Pedigo and Buntin, 1994; Boeve and Weiss, 1998; Bins *et al.*, 2000; Southwood and Henderson, 2000). A sampling program

¹ Department of Entomology, Faculty of Agriculture, Tarbiat Modares University, P. O. Box: 14115-336, Tehran, Islamic Republic of Iran.

^{*} Corresponding author, e-mail: fathi@modares.ac.ir

can be used in ecological investigations (Faleiro *et al.*, 2002), study of population dynamics (Jarosik *et al.*, 2003), detecting pest levels that lead to a justification of control measures (Arnaldo and Torres, 2005) as well as in assessing crop loss (Haughes, 1996).

The most common methods employed to describe the patterns of dispersion of arthropod populations have been summarized by Southwood and Henderson (2000). Several estimates based on the dispersion coefficient, k, of the negative binomial distribution and on the relationship between variance and mean are employed as indices of aggregation (Ludwig and Reynolds, 1988; Krebs, 1999; Southwood and Henderson, 2000). Sampling plans based on these indices optimize the sampling effort as well as sampling precision (Kuno, 1991). Sequential sampling plans are employed to more efficiently identify mean pest populations at or above the economic threshold. These plans have reduced the time required for sampling up to 50%, in comparison with conventional sampling plans (Pedigo and Zeiss, 1996; Patrick et al., 2003). Although the objectives of sampling a finite population can differ, the development of a sampling procedure requires the knowledge concerning the spatial distribution of populations (Liu et al., 2002).

Sampling programs for E. decipiens and related species have been described. The effects of different host plants on several *Empoasca* spp. were evaluated under single and mixed crop conditions using the D-vac suction sampler in Nigeria in 1992-1994 (Bottenberg et al., 1998). Population fluctuations and diurnal activity of E. decipiens on some summer crops such as common bean, Phaseolus vulgaris (L.), a cowpea, Vigna unguiculata (L.) Walp, and a mung bean, Vigna radiata (L.) Wilczek, using the sweep net technique were studied in Egypt. Leafhopper population peaks occurred on 8th May 2001 on early summer crops and on 5th June and 31th July 2001 on late summer crops (Ebadah, 2002). Population densities of E. decipines were also determined in Egypt by means of sweep-net and light-trap

(Ammar et al., 1977). They suggested that E. decipiens populations were high in the warmer months regardless of relative humidity and that monthly sweep-net samples caught leafhoppers in 19 field crops, especially broad bean. The average aggregation levels of grape leafhopper Empoasca vitis (Goethe) were determined using the statistical coefficient of dispersion (CD) based on the variance to mean ratio ($CD = S^2/m$) (Decatne and Helden, 2006). A random spatial distribution pattern was recorded for green leafhopper Empoasca kraemeri Ross and Moore in a white bean field as well as its aggregation per bean leaf (Heyer and Dammer, 1996).

In spite of the importance of *E. decipiens*, an efficient sampling program has not been developed nor has the spatial distribution described. The objective of this study was to develop a sampling program for *E. decipiens* on beans and to note differences in spatial distribution and abundance of the pest on different bean species in Tehran area, Iran during two growing seasons. The results can be employed to optimize the monitoring methods for establishing IPM strategies against the pest.

MATERIALS AND METHODS

Experimental Protocol

The experiments were carried out in a research field of Tarbiat Modares University in the suburbs of Tehran, Iran, during 2004–2005. Common bean *P. vulgaris* (L.) var. Talash, lima bean *P. lunatus* (L.) var. Sadaf, rice bean *P. calcaratus* var. Goli and cowpea *Vigna sinensis* (L.) var. Parastoo were planted in a randomized complete block design. A field of 35×18 m was divided into four blocks of 4×32 m, each block being consisted of four plots of 4×8 m each. There was no other leafhopper host-plant in the plots' surroundings. The specimens counted on the leaves were left over on the bean species. For a duration of

Sampling Program

Sampling Unit

One leaf of a bean plant was selected as a sample unit. Randomly selected leaves were visually inspected to note the number of nymphs and adults of *E. decipiens* per leaf to get an unbiased estimate of the population mean (Pedigo and Buntin, 1994).

Pattern and Timing of Sampling

Sampling of bean leaves as well as the movement among plants were performed randomly. Sampling was conducted at time intervals of 3-4 days in 2004 and weekly in 2005. All the counts were performed in mid-morning. Sampling started on 7th August in 2004 and on 11th June in 2005 and continued until late October.

Sample Size

Primary sampling was carried out in an equal number of different bean species on 6th August and 10th June of 2004 and 2005, respectively. Relative variation (RV) has been employed to compare the efficiency of various sampling methods (Hillhouse and Pitre, 1974). RV for these leaf data was calculated as follows:

RV= (SE/m) 100

where *SE* is the standard error of the mean and *m* is the mean of primary sampling data. The 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 (Pedigo and Buntin, 1994).

Population Density

The population density of *E. decipiens* was determined in plots of different bean species from 7th August to 19th October in 2004 and from 11th June to 15th October in 2005. The mean densities of nymphs and adult leaf-hoppers were statistically analyzed through analysis of variance (ANOVA) and compared among four bean species within each sampling date and for overall dates.

Spatial Distribution Pattern

The spatial distribution of *E. decipiens* was determined through some three methods: the variance (S^2) to mean (m) ratio, Taylor's power law and Iwao's patchiness regression models (Pedigo and Buntin, 1994). Departure from a random distribution was tested by calculating the index of dispersion, I_D , where *n* is the number of samples: $I_D = (n-1) S^2/m$

D = (n-1) S / m

In the next stage, Z coefficient was calculated for testing the goodness-of-fit:

where v was the number of degree of freedom (n-1). Taylor's power law was calculated as follows:

$$Z = \sqrt{2I_b} - \sqrt{2v} - 1$$

S² = am² or log S² + b log m

where the parameter a is a scaling factor related to sample size (Southwood and Henderson, 2000) and the slope b is an index of aggregation. Iwao's patchiness regression method was used to quantify the relationship between mean crowding index (m^*) and mean (m) using the following equation:



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



RESULTS

Sampling Program

From the primary sampling, the reliable leaf sample size with a maximum variation for a precision of 20% was about 40 samples. The relative variation (RV) of the primary sampling data was about 10%, very appropriate for a sampling program (Table 1).

Population Density

The population density estimated as the mean number of insects (nymphs and adults) per leaf on four different bean species for years 2004 and 2005 is shown in Tables 2 and 3. The results indicate that the four bean species showed significant differences (P<0.01) in the densities of leafhopper in the overall dates. In both years, the highest and

Table 1. Estimated parameters by primary sampling of *E. decipiens* on different bean species during 2004 and 2005.

Date	n ^a	SE^b	SD^{c}	RV^d	m ^e	d^f	\mathbf{N}^{g}
2004	289	0.096	1.63	10.89	0.879	0.20	40
2005	460	0.021	0.398	10.65	0.197	0.20	40

^{*a*} Number of samples, ^{*b*} Standard error of the mean, ^{*c*} Standard deviation of the mean, ^{*d*} Relative variation, ^{*e*} Mean of primary data, ^{*f*} Desired fixed proportion of the mean and ^{*g*} Sample size.

Table 2. Mean (±SE) population density of nymphs and adults of *E. decipiens* on four bean species (varieties) in several sampling dates of the year 2004.

Sampling date	V. sinensis (Paras- too) cowpea	<i>P. calcaratus</i> (Goli) rice bean	<i>P. lunatus</i> (Sa- daf) lima bean	P. vulgaris (Ta- lash) common bean
7 August	$14.65 \pm 1.63 a^a$	0.53 ± 0.11 b	$1.80 \pm 0.36 \mathrm{c}$	$0.45 \pm 0.11 \mathrm{b}$
10 August	16.85 ± 2.29 a	$0.48 \pm 0.2 \mathrm{b}$	$2.23 \pm 0.31 \mathrm{c}$	$0.50 \pm 0.12 \mathrm{b}$
13 August	17.20 ± 2.82 a	$1.60 \pm 0.27 \mathrm{b}$	$2.73 \pm 0.69 \mathrm{b}$	$1.05 \pm 0.25 \mathrm{b}$
16 August	20.23 ± 2.41 a	$3.63 \pm 0.64 \mathrm{b}$	$3.72 \pm 0.63 \mathrm{b}$	$0.65 \pm 0.14 \mathrm{c}$
19 August	21.20 ± 2.33 a	$4.48 \pm 0.68 \mathrm{b}$	$2.90 \pm 0.48 \mathrm{b}$	$0.63 \pm 0.12 \mathrm{c}$
23 August	34.18 ± 3.01 a	$4.28 \pm 0.58 \mathrm{b}$	$2.30 \pm 0.48 \mathrm{b}$	$0.70 \pm 0.15 \mathrm{c}$
27 August	34.85 ± 2.32 a	4.28 ±0.58 b	1.90 ± 0.59 c	1.05 ± 0.25 c
1 September	33.48± 2.34 a	$4.40 \pm 0.80 \mathrm{b}$	$1.63 \pm 0.38 \mathrm{c}$	$1.10 \pm 0.20 \mathrm{c}$
4 September	23.60 ± 2.27 a	$4.95 \pm 0.61 \mathrm{b}$	$3.20 \pm 0.39 \mathrm{b}\mathrm{c}$	$1.68 \pm 0.21 \mathrm{c}$
7 September	35.08 ± 2.30 a	3.78 ± 0.43 b	$2.50 \pm 0.91 \mathrm{b}$	$3.08 \pm 0.36 \mathrm{b}$
10 September	34.85 ± 2.32 a	$2.50 \pm 0.39 \mathrm{b}$	$1.90 \pm 0.59 \mathrm{b}$	$2.25 \pm 0.34 \mathrm{b}$
14 September	30.08 ± 2.38 a	$2.73 \pm 0.38 \mathrm{b}$	$2.00 \pm 0.46 \mathrm{b}$	$1.50 \pm 0.25 \mathrm{b}$
18 September	24.50 ±1.78 a	$2.25 \pm 0.32 \mathrm{b}$	$2.80 \pm 0.56 \mathrm{b}$	$2.10 \pm 0.26 \mathrm{b}$
21 September	17.33 ±1.00 a	$1.45 \pm 0.21 \mathrm{b}$	$2.10 \pm 0.49 \mathrm{b}$	$1.30 \pm 0.20 \mathrm{b}$
25 September	14.40 ± 1.08 a	$1.05 \pm 0.19 \mathrm{b}$	1.23± 0.25 b	$0.75 \pm 0.16 \mathrm{b}$
29 September	9.15 ± 0.77 a	$0.95 \pm 0.17 \mathrm{b}$	$0.67 \pm 0.14 \mathrm{b}$	$0.60 \pm 0.12 \mathrm{b}$
2 October	8.48 ± 0.87 a	$0.08 \pm 0.17 \mathrm{b}$	$0.97 \pm 0.16 \mathrm{b}$	$0.78 \pm 0.16 \mathrm{b}$
6 October	4.45 ± 046 a	0.70 ± 0.15 b	$0.63 \pm 0.18 \mathrm{b}$	$0.60 \pm 0.18 \mathrm{b}$
11 October	3.95 ± 030 a	0.68 ± 0.12 b	$1.20 \pm 0.23 \mathrm{b}$	$0.65 \pm 0.14 \mathrm{b}$
15 October	2.55 ± 0.31 a	0.6 ± 0.12 b	$0.70 \pm 0.15 \mathrm{b}$	$0.75 \pm 0.13 \mathrm{b}$
19 October	1.83 ± 0.26 a	0.33 ± 0.08 b	$0.60 \pm 0.14 \mathrm{b}$	$0.43 \pm 0.09 \mathrm{b}$
Overall dates	18.85 ± 0.57 a	2.12 ± 0.10 b	$1.75 \pm 0.11 \mathrm{b}$	$1.08 \pm 0.05 \mathrm{c}$

^a The means followed by different letters in the same row are significantly different (p<0.01, LSD).

lowest population densities of the pest occurred in the warmer months (August and September) and in late October, respectively. During 2004 and 2005, the highest and lowest population densities of E. decipiens were recorded as significant on Parastoo cowpea and Talash common bean respectively, which were significantly different from those on the other two bean species. The highest population densities of E. decipiens on Parastoo cowpeas, Goli rice beans, Sadaf lima beans and Talash common beans were 35.08, 4.95, 3.72 and 3.08 individuals per leaf respectively in 2004, while 34.48, 2.92, 2.57 and 0.77 individuals per leaf respectively for 2005.

Spatial Distribution

The results of the variance to mean ratio (S^2/m) , coefficient of dispersion (I_D) and Z test are presented in Table 4. The results obtained of the two sampling years indicated

V. sinensis (Paras-

that the spatial distribution in all the bean species was aggregated.

In Taylor's model, the regression between $\log S^2$ and $\log m$ was significant for the four bean species (P< 0.01). For year 2004, Taylor's slope was significantly greater than unity for all the four bean species (Table 5). The calculated $t(t_c)$ was greater than t-table (t_t) for Parastoo cowpeas and Talash common beans indicating an aggregated spatial distribution of E. decipiens, whereas Goli rice beans and Sadaf lima beans had t_c 's less than t_t , indicating a random spatial distribution of E. decipiens. In 2005, Taylor's slope was varied from 1.0 to 1.59. On Parastoo cowpeas and Goli rice beans the spatial distribution of E. decipiens was aggregated, as against random on Talash common beans and Sadaf lima beans (Table 5).

Iwao's model showed that there was a significant relationship between the mean crowding and the density of E. decipiens (Table 5). During these two sampling years, Parastoo cowpeas, Goli rice beans and Sadaf

P. lunatus

P. vulgaris

Table 3. Mean (±SE) population density of nymphs and adults of *E. decipiens* on four bean species (varieties) in several sampling dates of the year 2005.

P. calcaratus

Sampling date	too) cowpag	(Coli) rice heen	(Sodof) lime been	(Talash) com-
	too) cowpea	(0011) fice beam	(Sauar) Illia Deall	mon bean
11 June	$0.45 \pm 0.09 a^a$	$0.12 \pm 0.05 \mathrm{b}$	$0.02 \pm 0.02 \mathrm{b}$	$0.02 \pm 0.02 \mathrm{b}$
18 June	0.70 ± 0.13 a	$0.05 \pm 0.03 \mathrm{b}$	$0.05 \pm 0.03 \mathrm{b}$	$0.05 \pm 0.03 \mathrm{b}$
25 June	2.32 ± 0.45 a	$0.15 \pm 0.27 \mathrm{b}$	$0.60 \pm 0.17 \mathrm{b}$	$0.10 \pm 0.05 \mathrm{b}$
2 July	7.65 ± 1.07 a	$0.47 \pm 0.11 \mathrm{b}$	$0.20 \pm 0.11 \mathrm{b}$	$0.17 \pm 0.12 \mathrm{b}$
9 July	11.83 ± 1.65 a	$1.92 \pm 0.22 \mathrm{b}$	$1.10 \pm 0.24 \mathrm{b}$	$0.15 \pm 0.08 \mathrm{b}$
16 July	13.98 ± 1.63 a	$1.82 \pm 0.21 \mathrm{b}$	$0.80 \pm 0.15 \mathrm{b}$	$0.20 \pm 0.09 \mathrm{b}$
23 July	17.00 ± 2.23 a	$2.02 \pm 0.22 \mathrm{b}$	$1.00 \pm 0.19 \mathrm{b}$	$0.35 \pm 0.09 \mathrm{b}$
30 July	10.33 ± 1.29 a	$0.60 \pm 0.14 \mathrm{b}$	$0.32 \pm 0.08 \mathrm{b}$	$0.13 \pm 0.07 \mathrm{b}$
6 August	34.48 ±3.67 a	$1.20 \pm 0.21 \mathrm{b}$	$0.95 \pm 0.17 \mathrm{b}$	$0.77 \pm 0.16 \mathrm{b}$
14 August	29.70 ± 3.96 a	$1.40 \pm 0.29 \mathrm{b}$	$2.57 \pm 0.52 \mathrm{b}$	$0.62 \pm 0.14 \mathrm{b}$
20 August	25.25 ± 2.81 a	$1.85 \pm 0.36 \mathrm{b}$	$1.17 \pm 0.27 \mathrm{b}$	$0.52 \pm 0.12 \mathrm{b}$
27 August	20.05 ±1.87 a	$2.92 \pm 0.56 \mathrm{b}$	$1.72 \pm 0.32 \mathrm{b}$	$0.70 \pm 0.14 \mathrm{b}$
3 September	23.20 ±1.69 a	$2.75 \pm 0.49 \mathrm{b}$	$1.30 \pm 0.28 \mathrm{b}$	$0.72 \pm 0.14 \mathrm{b}$
10 September	13.90 ± 1.57 a	$1.45 \pm 0.32 \mathrm{b}$	$1.47 \pm 0.32 \mathrm{b}$	$0.52 \pm 0.15 \mathrm{b}$
17 September	14.70 ±1.83 a	$2.02 \pm 0.38 \mathrm{b}$	$1.55 \pm 0.35 \mathrm{b}$	$0.60 \pm 0.16 \mathrm{b}$
24 September	11.65 ± 1.14 a	$1.10 \pm 0.21 \mathrm{b}$	$0.70 \pm 0.16 \mathrm{b}$	$0.50 \pm 0.13 \mathrm{b}$
1 October	$5.87 \pm 0.82 \mathrm{a}$	$0.47 \pm 0.11 \mathrm{b}$	$0.57 \pm 0.12 \mathrm{b}$	$0.27 \pm 0.09 \mathrm{b}$
8 October	1.72 ± 0.43 a	$0.37 \pm 0.11 \mathrm{b}$	$0.22 \pm 0.0.7b$	$0.57 \pm 0.09 \mathrm{b}$
15 October	0.70 ± 0.18 a	$0.20 \pm 0.07 \mathrm{b}$	$0.12 \pm 0.05 \mathrm{b}$	$0.10 \pm 0.05 \mathrm{b}$
Overall dates	$29.94 \pm 0.55 \mathrm{a}$	$0.21 \pm 0.07 \mathrm{b}$	$0.87 \pm 0.06 \mathrm{c}$	$0.37 \pm 0.03 \mathrm{d}$

^a The means followed by different letters in the same row are significantly different (p < 0.01, LSD).

Table 4. Spatial distribution patterns of *E. decipiens* on four bean species during 2004-2005 using the variance to mean ratio (index of dispersion), and the Z coefficient for testing the goodness-of-fit.

Year	Bean species	Variety and common name	S ² /m	I _D	Z
2004					
	P. vulgaris	Talash common bean	1.88	1499.72	14.81
	P. lunatus	Sadaf lima bean	3.07	2453.48	30.09
	P. calcaratus	Goli rice bean	3.99	3192.01	39.94
	V. sinensis	Parastoo cowpea	13.74	10978.26	108.22
2005		-			
	P. vulgaris	Talash common bean	1.49	1130.91	8.61
	P. lunatus	Sadaf lima bean	2.87	2178.33	27.05
	P. calcaratus	Goli rice bean	2.89	2193.51	27.28
	V. sinensis	Parastoo cowpea	17.88	13570.72	125.80

Table 5. Spatial distribution of *E. decipiens* on different bean species in 2004 and 2005 using Taylor's power law and Iwao's patchiness regression analysis.

	December 2010	Parameters estimation					Test for	Test for slope	
	Bean species (variety)	$a \pm SE$	Slope \pm SE	r ²	Pa	P _{slope}	t _c	t _t	
2004 Taylor's	P. vulgaris (Talash)	0.12 ± 0.03	1.24 ± 0.11	0.879	0.000	0.000	2 277	2 093	
Taylor 3	common bean P. lunatus (Sadaf) lima bean	0.12 ± 0.03 0.19 ± 0.09	1.24 ± 0.11 1.24 ± 0.26	0.541	0.054	0.000	0.934	2.093	
	P. calcaratus (Goli) rice bean	0.14 ± 0.03	1.60 ± 0.06	0.967	0.000	0.000	0.767	2.093	
	V. sinensis (Parastoo) cowpea	-0.18 ± 0.16	1.72 ± 0.13	0.896	0.275	0.000	5.448	2.093	
Iwao's	<i>P. vulgaris</i> (Talash) common bean	0.10 ± 0.16	1.24 ± 0.13	0.828	0.564	0.000	1.860	2.093	
	P. lunatus (Sadaf) lima bean	-0.44 ± 0.50	1.87 ± 0.25	0.746	0.391	0.000	3.508	2.093	
	P. calcaratus (Goli) rice bean	-0.44 ± 0.29	1.73 ± 0.11	0.928	0.142	0.000	6.636	2.093	
	V. sinensis (Parastoo) cowpea	1.40 ± 1.46	1.18 ± 0.07	0.943	0.351	0.000	2.727	2.093	
2005									
Taylor's	P. vulgaris (Talash) common bean	-0.22 ± 0.06	1.00 ± 0.09	0.880	0.003	0.000	0.000	2.110	
	P. lunatus (Sadaf) lima bean	-0.12 ± 0.08	1.20 ± 0.13	0.828	0.129	0.000	1.562	2.110	
	P. calcaratus (Goli) rice bean	-0.09 ± 0.05	1.26 ± 0.09	0.918	0.071	0.000	2.954	2.110	
	V. sinensis (Parastoo) cowpea	-0.09 ± 0.06	1.59 ± 0.06	0.972	0.163	0.000	9.365	2.110	
Iwao's	P. vulgaris (Talash) common bean	-0.30 ± 0.12	0.84 ± 0.263	0.336	0.022	0.005	0.619	2.110	
	P. lunatus (Sadaf) lima bean	-0.65 ± 0.12	1.537 ± 0.12	0.906	0.000	0.000	4.568	2.110	
	P. calcaratus (Goli) rice bean	-0.64 ± 0.139	1.40 ± 0.01	0.932	0.000	0.000	4.494	2.110	
	V. sinensis (Parastoo) cowpea	-0.21 ± 0.49	1.21 ± 0.03	0.989	0.670	0.000	7.000	2.110	

lima beans hosted an aggregated (slope> 1) spatial distribution of *E. decipiens*, while Talash common beans bore a random pattern with t_c less than t_r .

DISCUSSION

The most commonly employed methods for sampling leafhoppers are direct observa-

tions and suction net in soybean fields (Kogan and Herzog, 1980) and sweep-net in bean crops (Ebadah, 2002). Here, bean leaf was selected as the sampling unit to estimate the number of *E. decipiens*. Direct observation of single plants is particularly useful for sampling nymphal stages of leafhoppers (Mayse *et al.*, 1978).

The observed differential population densities on different beans are likely to be somehow related to the presence of densely hooked trichomes on the leaves. Robbins and Daugherty (1969) found that glabrous varieties of soybean Glycine max (L.) Merr., bore both the highest numbers of Empoasca fabae (Harris) and highest ovipositional rates, while densely pubescent varieties had the lowest number and The lowest incidence of oviposition. More specifically, it appears that the length and orientation of leaf hairs rather than density alone (Broersma et al., 1972), contribute to protection of most commercial soybean varieties from serious leafhopper damage. The absence of trichomes, softness of leaf tissues, the large size of the leaves and long growing period of Parastoo cowpea may be the most important reasons for host-plant suitability, which leads to an increase in the population density of E. decipiens.

The variance to mean ratio indicated that E. decipiens had an aggregated distribution on all bean species. But, regression models of Taylor's power law and Iwao's patchiness showed the random distribution pattern on some bean species, suggesting that the different statistical methods have various results and accuracies in calculating spatial distribution of E. decipiens. The random distribution can be due to the lower population density of E. decipiens on some of the bean species. By calculating the coefficient of dispersion (CD), Decante and Helden (2006) determined that the grape leafhopper E. vitis is of an aggregated spatial distribution in vineyards. This result is similar to our findings of E. decipiens on Parastoo cowpeas, Goli rice beans and Sadaf lima beans using Iwao's regression model for 2004. Their results are also in

agreement with the results of Taylor's power law model for 2004 samples on Talash common beans and Parastoo cowpeas as well as for 2005 samples on Parastoo cowpeas and Goli rice beans. Heyer and Dammer (1996) reported that the spatial distribution of green leafhopper E. kraemeri may be either random or aggregated depending on its type of habitat. At higher population densities, random spatial patterns of potato leafhopper, E. fabae nymphs were noted after using Poisson statistical distribution on curly pubescent soybean (Kogan and Herzog, 1980). This is the same as our results of E. decipiens on Talash common beans using Iwao's regression model and also similar to our results using Taylor's model for 2004 samples on Goli rice beans and Sadaf lima beans as well as for 2005 samples on Talash common beans and Sadaf lima beans.

Both Taylor's and Iwao's models indicated an aggregated distribution on Parastoo cowpeas for years 2004 and 2005 (Table 5). This is probably due to the high population density on bean leaves or to some particulars of the leafhopper behavioral characteristics. However, in 2004, the data obtained for Talash common beans fitted better Taylor's model than Iwao's model (r^2 = 0.879, Taylor's) and the same was true for Goli rice beans (r^2 = 0.967, Taylor's). In the two sampling years, data from Sadaf lima beans fitted better Iwao's model (r^2 = 0.746 and 0.906) in contrast with Taylor's (r^2 = 0.541 and 0.828).

CONCLUSIONS

In this research it was demonstrated that the different bean species had significant effects on the population density and spatial distribution pattern of *E. decipiens*. The coefficients of the spatial distribution models can be used in developing a sampling program, detecting pest levels that justify control measures as well as in assessing crop loss of different species of beans.



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Empoasca decipiens (Homoptera: تراکم جمعیت و الگوی توزیح فضایی زنجرک Cicadellidae)

ب. ناصري، ي. فتحي پور و ع. ا. طالبي

چکیدہ

تراکم جمعیت و الگوی توزیع فضایی زنجر ک Empoasca decipiens Paoli روی چهار گونه لوبیا شامل لوبیا چیتی (P. lunatus L.) رقم تلاش، لوبیا سفید (Vigna sinensis L.) رقم صدف، لوبیا قرمز (P. calcaratus Roxb) رقم گلی و لوبیا چشم بلبلی (Ligna sinensis L.) رقم پرستو طی سالهای ۱۳۸۳ و ۱۳۸۴ در منطقه تهران مورد بررسی قرار گرفت. بیشترین و کمترین میانگین تراکم جمعیت زنجر ک InA و ۱۳۸۹ در سال ۸۴ و ۲۹/۹۰ در سال ۲۸۹ مشاهده شد. الگوی توزیع فضایی زنجر ک روی ۱۹۸۹ و لوبیا چیتی (۱۰۰۸ در سال ۸۳ و ۲۹/۰۰ در سال ۸۴) مشاهده شد. الگوی توزیع فضایی زنجر ک روی چهار گونه لوبیا با استفاده از روش نسبت واریانس به میانگین و مدلهای رگرسیونی تیلور و آیواو تعیین شد. نتایج نشان داد که الگوی توزیع فضایی این آفت در اغلب موارد از نوع تجمعی و در مواردی نیز از



نوع تصادفی میباشد. در سال ۱۳۸۳ داده های جمع آوری شده، با مدل تیلور در مقایسه با مدل آیواو برازش بهتری روی لوبیا چیتی (۲۷۹۹ داده های جمع آوری شده، با مدل تیلور در مقایسه با مدل آیواو روی لوبیا سفید داده های حاصل از مدل آیواو (² به ترتیب ۲۶۴۶ و ۲۰۹۶) برازش بهتری در مقایسه با مدل تیلور (² به ترتیب ۱۹۵۱ و ۲۸/۸۷ داشتند. نتایج به دست آمده حاکی از آن است که گونه لوبیا می تواند بر تراکم جمعیت و الگوی توزیع فضایی زنجرک *E. decipiens تا و*رد معیت الگوی موجود الگوی توزیع فضایی می تواند در توسعه برنامه نمونه برداری و بر آورد دقیق تراکم جمعیت یک موجود زنده مورد استفاده قرار گیرد.