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Population Density and Spatial Distribution Pattern of *Thrips tabaci* (Thysanoptera: Thripidae) on Different Soybean Varieties

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ABSTRACT

Population density and spatial distribution of *Thrips tabaci* Lindeman on seven soybean varieties (Williams, Tellar, Sahar, Dpx, L_{17}, Sari and Zane) and one genotype (Ks3494) were studied in Tehran region, during 2007. The highest population density of the thrips per leaf was recorded on Dpx and on Ks3494 (0.81±0.05 and 0.80±0.05, respectively). The lowest population density was observed on L_{17} and Tellar (0.62±0.04 and 0.64±0.03, respectively). To estimate the spatial distribution pattern of this pest, data were analyzed through index of dispersion, Lloyd's mean crowding, Morisita's index as well as through regression models (Taylor and Iwao). The index of dispersion and Lloyd's mean crowding indicated an aggregated pattern for the spatial distribution of this insect in all the varieties and the genotype of soybean. Spatial distribution of *T. tabaci* using Morisita's index was aggregated in most of the sampling dates. In Taylor's model, regression between $log\ S^2$ and $log\ m$ was not significant for Dpx varieties (P> 0.05), but the *b* values of Taylor's power law on Zane, Sahar, Williams and Tellar varieties exceeded 1, indicating aggregated distribution. However, the other varieties had a *b* value equal to 1, indicating random distribution. Iwao's patchiness regression indicated that the spatial distribution of *T. tabaci* on Sari, Zane, Williams and Tellar varieties as well as on Ks3494 genotype was aggregated, but on the rest of varieties the pattern was of a random one. It is concluded that soybean varieties affect the population density and spatial distribution of *T. tabaci*. Spatial distribution parameters of this species can be employed to outline a sampling program as well as to estimate the population density of *T. tabaci*.

Keywords: *Glycine max* (L.), Population density, Spatial distribution, Thrips.

INTRODUCTION

In most countries the onion thrips, *Thrips tabaci* Lindeman (Thysanoptera: Thripidae), is the most damaging Thysanoptera species (Trdan *et al.,* 2007). This insect is an extremely polyphagous species and a serious pest of a wide range of economically important crops including soybean in many parts of the world (Theunissen and Schelling, 1998; Cho *et al.,* 2001; Macintyre-Allen *et al.,* 2005; Duchovskiene, 2006; Trdan *et al.,* 2007). Nymphs and adult thrips suck the sap of leaf buds, leaves, flower buds, flowers and fruits, which become deformed or remain underdeveloped, often showing scars. Furthermore, this species acts as a major vector of viral plant diseases (Larentzaki *et al.,* 2008).

The methods for estimating population densities in arthropods constitute the cornerstone of basic research in agricultural ecosystems and are the principal tool for implementation of pest management programs (Kogan and Herzog, 1980). At this

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estimating plan a reliable sampling program along with suitable techniques should be adopted (Pedigo and Buntin, 1994; Southwood and Henderson, 2000). A reliable sampling program includes an identification of the appropriate sampling time, sampling unit, a determination of the spatial distribution of sampling units as well as sample size (Pedigo and Buntin, 1994; Boeve and Weiss, 1998; Southwood and Henderson, 2000). A sampling program can be used in binomial sampling (Binns and Bostanian, 1990), assessing crop loss (Hughes, 1996), studying the population dynamics (Jarosik *et al.,* 2003) and detecting pest levels that justify measures (Arnaldo and Torres, 2005).

There are several methods employed in the sampling of Thysanoptera species in crops, some of these methods being the washing method (Higgins, 1992; Cho *et al.,* 2001), sticky traps (Macintyre–Allen *et al.,* 2005; Trdan *et al.,* 2007), white-colored traps (Lu, 1990), and shaking of the plant onto a white paper and then counting the thrips (Duchovskiene, 2006). A counting of thrips at all life stages on the plant leaflet is the most commonly recommended monitoring method in onion thrips management programs (Edelson *et al.,* 1989; Deligeorgidis *et al.,* 2002).

Organisms are all discrete entities that interact mainly with the neighboring individuals of their own or other species (Tilman *et al.,* 1997). The importance of spatial distribution comes from its central role in ecological theories and its practical role in population sampling theory as well as in the development of rational pest management strategies (Legendre and Fortin, 1989). For these reasons, a great deal of effort has been invested in characterizing the spatial distribution of insect populations (Liebhold *et al.,* 1991).

The most commonly used methods to describe the pattern 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 based on the relationship between variance and mean are used as indices of aggregation (Krebs, 1999; Southwood and Henderson, 2000). Sampling plans based on these indices optimize the sampling effort as well as the sampling precision (Kuno, 1991). Although the objectives of sampling a finite population can differ, the development of a sampling procedure requires the knowledge of the spatial distribution of the population (Liu *et al.,* 2002).

There are several studies that have described the spatial distribution and population density of Thysanoptera species (Theunissen and Schelling, 1998; Cho *et al.,* 2001; Athanassiou *et al.,* 2002; Deligeorgidis *et al.,* 2002; Macintyre-Allen, 2005; Duchovskiene, 2006; Seal *et al.,* 2006) but published reports on the population density and spatial distribution of *T. tabaci* in soybean fields, are but a few.

Population density and spatial distribution of *T. tabaci* on different varieties of soybean, was examined in the ongoing study.

MATERIALS AND METHODS

Experimental Protocol

The studies were carried out in an experimental field of Tarbiat Modares University in the suburbs of Tehran, Iran (35° 43´ N, 51° 8´ E, 1,215 m above sea level) from May to September 2007. A field of 638.4 m^2 was divided into five blocks of 100.8 m^2, each block being consisted of eight plots of 4.2×3 m^2. A distance of 1.00 m was considered between each two blocks while in each block a distance of 0.70 m was assigned between each two plots. Seven soybean varieties namely: Willams, Tellar, Zane, Sahar, Dpx, L_{17}, Sari as well as a genotype, Ks3494, were planted in a randomized complete block design. A total rainfall of 15 mm was recorded during the growing season. Irrigation was performed on a weekly basis. Plants were taken care of by using standard cultural practices recommended for Tehran region. The plants were not treated with any insecticide but received the recommended fertilizer application. Furthermore, other thrip host-plants in the vicinity of 1-meter radius of the plots were removed.

Sampling Program

One apical leaf of any soybean varieties was selected as a sample unit. Leaves were randomly selected and the number of thrips (nymphs and adults) recorded using a pocket lens of 10X magnificationto get an unbiased estimate of the population mean.

The fundamental principle of sampling namely random collection was observed so that the sampling units could have an equal chance of being sampled. On this basis, sampling of leaves, as well as movement among plants were randomly performed. All counts were performed in mid-morning. Sampling frequency was weekly from 31th May to 4th September 2007.

In order to determine the sample size, primary sampling took place in an equal number of different soybean varieties on 31th May 2007. Relative Variation (RV) is employed to compare the efficiency of various sampling methods (Hillhouse and Pitre, 1974). *RV* for the sampling 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 employing 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 Dynamics

Population density of *T. tabaci* was determined in plots of different soybean varieties from 31th May to 4th September 2007. Mean density of total life stages (nymphs and adults) of *T. tabaci* was statistically analyzed using analysis of variance (ANOVA) and compared among soybean varieties within each sampling date and within the overall dates. Differences among the means were determined at a significance of $P< 0.05$ using HSD range test. The three-dimensional contour plot was drawn to display population fluctuation of *T.tabaci* over range of temperatures and humidity using MATLAB software (MATLAB, 2007). These graphs display three variables at a time.

Spatial Distribution Pattern

The spatial distribution of *T. tabaci* was determined by five methods: index of dispersion, Taylor's power law, Iwao's patchiness regression, Morisita's coefficient of dispersion and finally Lloyd's mean crowding.

Index of Dispersion

Dispersion of a population can be classified through a calculation of the variance to mean ratio; namely: $S^2/m = 1$ random, < 1 regular and > 1 aggregated. Departure from a random distribution can be tested by calculating the index of dispersion (I_D), where *n* denotes the number of samples:

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

I_D is approximately distributed as χ^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. This index can be tested by *Z* value as follows:

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

$$v = n-1$$

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

Taylor's Power Law and Iwao's Patchiness Regression

Taylor (1961) found a function between mean and variance as:

$$S^2 = am^b$$

where S^2 is the variance; m the sample mean; a is a scaling factor related to sample size and b measuring the species aggregation. When b= 1, < 1 and > 1, the distribution is random, regular and aggregated, respectively.

Through use of a log transformation, one can estimate the coefficients with linear regression as:

$$\text{Log}(S^2) = \text{Log}(a) + b\,\text{Log}(m)$$

where a and b are the parameters of the model, estimated by linearzing the equation by a log-log transformation (Taylor, 1961).

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

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

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

Test $b=1$ $t=(b-1)/SE_b$ and Test $\beta=1$ $t=(\beta-1)/SE_\beta$

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> t_t, the null hypothesis would be rejected and if b> 1 and < 1, the spatial distribution would be aggregated and uniform, respectively.

Morisita's Coefficient of Dispersion I_δ

Morisita (1962) reported a hypothesis for testing the uneven distribution coefficient of I_δ and it is calculated through the following equation:

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

where n= The number of sample units, x_i= The number of individuals in each sample unit and N = Total number of individuals in n samples.

To determine if the sampled population differs significantly from random, the following large sample test of significance can be applied:

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

where m= Mean population density per leaf in each sampling date and n= The number of sample units.

Compare the value of Z with tabulated values for a random distribution and reject the hypothesis that sampled population is dispersed randomly if |Z|> z (α/2) (Pedigo and Buntin, 1994).

Lloyd's Mean Crowding X^*

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

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

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

Sample Size Model

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

$$N = z_{\alpha/2}{}^2\ d^{-2} a m^{b-2}$$

The model contains either one of the variable and constant factors. The variable factors are: N = Sample size, $z_{\alpha/2}$ = Standard normal variance for a two-tailed interval, m = Mean density of thrips in each sampling unit, *d*= The range of accuracy and finally *a, b*= Taylor's coefficients.

RESULTS

Sampling Program

The results from primary sampling showed that the reliable sample size with maximum variation of 20% was 60, 60, 50, 100, 45, 50, 55 and 60 for Williams, Tellar, Zane, Sahae, Dpx, Ks3494, L_{17} and Sari, respectively. The relative variation (RV) of the primary sampling date was 11.89, 12.04, 10.93, 15.33, 10.36, 10.71, 11.46 and 12.03 for the above-mentioned varieties, respectively, which was counted as very appropriate for a sampling program (Table 1).

Population Dynamics

The population of *T. tabaci* was observed from the beginning of the sampling period (31th May) on all soybean varieties. The population density of the pest on all varieties showed a peak at the beginning of the season and was gradually reduced during the sampling period. Figure 1 shows a three-dimensional contour plot of the predicted population fluctuation of *T. tabaci* over a

Table 1. Estimated parameters by primary sampling of *Thrips tabaci* on different soybean varieties in 2007.

Var. and gen.[a]	n[b]	SE[c]	SD[d]	RV[e]	m[f]	d[g]	N[h]
Williams	40	0.53	3.38	11.89	4.5	0.20	60
Tellar	40	0.33	2.09	12.04	2.75	0.20	60
Zane	40	0.44	2.8	10.93	4.05	0.20	50
Sahar	40	0.57	3.61	15.33	3.72	0.20	100
Dpx	40	0.39	2.52	10.36	3.85	0.20	45
Ks3494	40	0.37	2.35	10.71	3.47	0.20	50
L_{17}	40	0.35	2.22	11.46	3.07	0.20	55
Sari	40	0.57	3.61	12.03	3.72	0.20	60

[a] Varieties and the genotype of soybean; [b] Number of samples; [c] Standard error of the mean; [d] Standard deviation; [e] Relative variation; [f] Mean of primary data, [g] Desired fixed proportion of the mean, [h] Sample size.

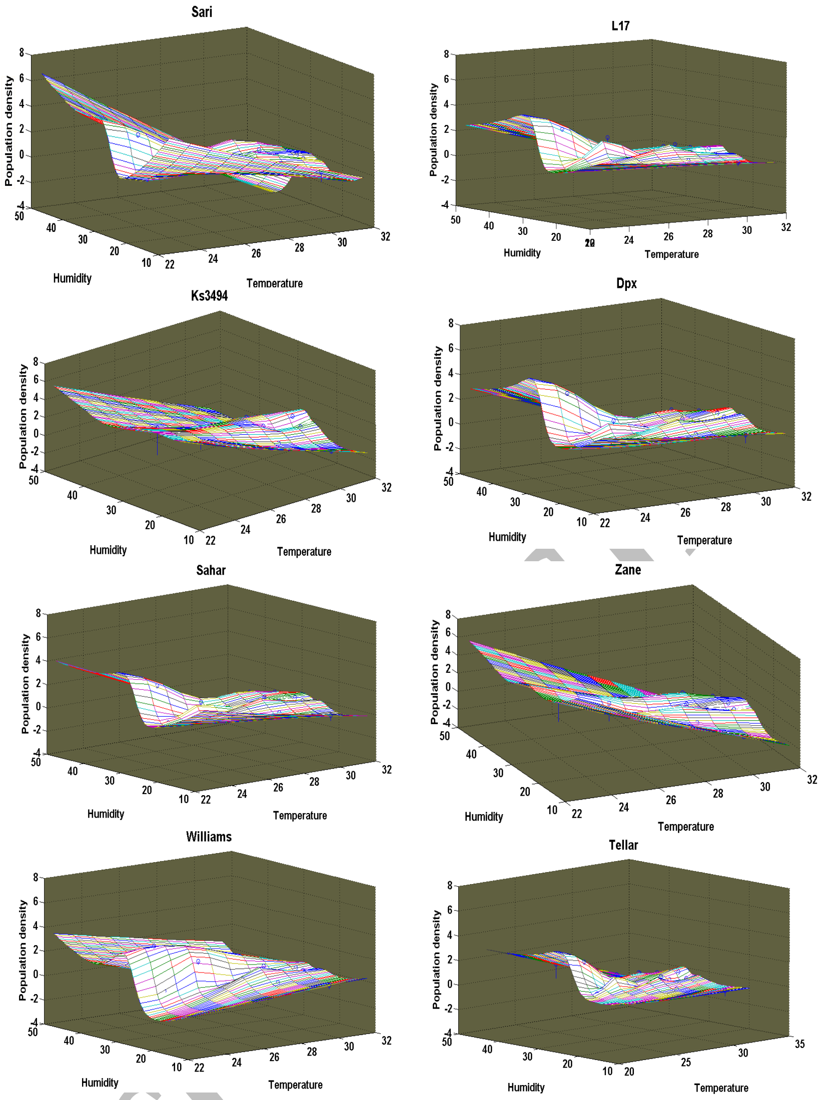

Figure 1. Three-dimensional contour plot showing the effect of temperature and humidity on population density of *Thrips tabaci* on soybean varieties in 2007.

range of temperatures as well as humidity. According to this figure, temperature and humidity exert a converse and direct effect on population density of this pest, respectively.

The population density, considered as the mean number of overall life stages of *T. tabaci* (nymphs and adults) per leaf on all soybean varieties is shown in Table 2. The results indicate that there is a significant difference ($P< 0.05$) observed in the population densities of *T. tabaci* among different soybean varieties at different dates. Moreover, population densities of this pest in different varieties were significantly different in most sampling dates (Table 2). The highest population density per leaf was recorded on Dpx and Ks3494 (0.81 and 0.80, respectively) during the sampling dates, followed by Williams, Zane, Sahar and Sari (0.70, 0.68, 0.68 and 0.76, respectively). During the sampling dates, the lowest population densities of the thrips were observed in Tellar and L_{17} varieties (0.64 and 0.62 overall life stages per leaf) (Table 2).

Table2. Mean (±SE) number of *Thrips tabaci* (per leaf) on different soybean varieties in 2007.

Date	Williams	Tellar	Zane	Sahar	Dpx	Ks3494	L_{17}	Sari
31 May	3.45±0.41a*	2.46±0.26a	3.56±0.34a	2.96±0.23a	3.68±0.37a	3.00±0.32a	2.76±0.28a	3.16±0.35a
7 Jun.	2.01±0.30ab	1.36±0.19b	1.98±0.25ab	1.31±0.14b	1.33±0.30b	2.40±0.33a	2.03±0.28ab	1.13±0.17b
14 Jun.	1.13±0.16a	0.88±0.16a	1.28±0.18a	1.18±0.18a	1.06±0.20a	1.30±0.17a	1.20±0.21a	1.41±0.22a
26 Jun.	0.86±0.12a	1.13±0.15a	0.74±0.17a	1.00±0.12a	0.75±0.16a	1.08±0.14a	0.94±0.17a	1.31±0.20a
1 Jul.	0.51±0.09b	0.93±0.15ab	0.52±0.11b	0.57±0.08b	1.00±0.25ab	1.12±0.11a	0.56±0.10b	0.55±0.08b
7 Jul.	0.76±0.14a	0.66±0.09a	0.72±0.15a	0.80±0.09a	1.00±0.20a	0.62±0.14a	0.60±0.13a	1.10±0.16a
16 Jul.	0.51±0.07ab	0.56±0.09ab	0.48±0.09ab	0.55±0.08ab	0.80±0.12a	0.42±0.08b	0.49±0.08ab	0.65±0.09ab
25 Jul.	0.51±0.08ab	0.58±0.09ab	0.26±0.07b	0.63±0.09ab	0.80±0.17a	0.28±0.09b	0.47±0.11ab	0.55±0.09ab
1 Aug.	0.20±0.05b	0.50±0.08ab	0.36±0.08ab	0.58±0.07ab	0.57±0.12ab	0.44±0.11ab	0.45±0.13ab	0.73±0.14a
8 Aug.	0.43±0.08ab	0.51±0.09ab	0.18±0.05b	0.48±0.10ab	0.86±0.24a	0.26±0.07b	0.25±0.07b	0.43±0.09ab
15 Aug.	0.33±0.08bc	0.41±0.08abc	0.12±0.04c	0.47±0.08abc	0.66±0.16ab	0.22±0.06c	0.27±0.07c	0.76±0.13a
22 Aug.	0.20±0.05ab	0.30±0.06ab	0.10±0.04b	0.37±0.06ab	0.31±0.07ab	0.10±0.05b	0.32±0.07ab	0.38±0.08a
29 Aug.	0.13±0.05b	0.11±0.04ab	0.00±0.00b	0.27±0.07ab	0.35±0.12a	0.04±0.02b	0.00±0.00b	0.40±0.11a
4 Sep.	0.06±0.03ab	0.13±0.04ab	0.02±0.01b	0.15±0.03ab	0.15±0.05ab	0.02±0.01b	0.09±0.03ab	0.21±0.05a
12 Sep.	0.03±0.02ab	0.16±0.04ab	0.02±0.01b	0.13±0.03ab	0.17±0.05a	-	0.09±0.03ab	0.06±0.03ab
19 Sep.	0.01±0.01b	0.08±0.03ab	-	0.08±0.03ab	0.15±0.06a	-	0.00±0.00b	0.05±0.03ab
26 Sep.	-**	0.06±0.03a	-	0.05±0.02a	0.06±0.03a	-	0.00±0.00a	0.10±0.03a
Overall dates	0.70±0.04abc	0.64±0.03bc	0.68±0.04abc	0.68±0.03abc	0.81±0.05a	0.80±0.05ab	0.62±0.04c	0.76±0.04abc

* The means followed by different letters in the same row are significantly different (P<.0.05, LSD).

** Dashes in the columns indicate the end of sampling.

Table 3. Estimated parameters by Lloyd's mean crowding, Lloyd's mean crowding to mean and Variance to mean ratios for *Thrips tabaci* on different varieties of soybean in 2007.

	Williams	Tellar	Zane	Sahar	Dpx	Ks3494	L_{17}	Sari
	Variace to mean ratio							
S^2/m	3.06	1.87	2.69	2.36	2.67	2.47	2.55	2.37
I_D	2940.00	1909.57	2019.54	4023.96	2040.95	1729.37	2384.00	2421.28
Z	32.90	16.66	24.86	31.43	24.80	21.43	25.85	24.45
	Lloyd's mean crowding and Lloyd's mean crowding to mean ratio							
X^*	2.76	1.51	2.38	2.04	2.48	2.28	2.17	2.14
X^*/m	3.95	2.36	3.46	3.00	3.06	2.82	3.49	2.74

Spatial Distribution

The results of the variance to mean ratio (S^2/m), index of dispersion (I_D) and *Z* test are presented on Table 3. These results indicate that the spatial distribution of *T. tabaci* in all soybean varieties is of an aggregated nature.

According to *P* values in Taylor's model, with one exception (Dpx variety) the regression between log S^2 and log *m* was significant for all soybean varieties. The calculated *t* (t_c) was greater than *t*-table (t_t) for Zane, Sahar, Williams and Tellar varieties indicating an aggregated spatial distribution of *T. tabaci*, but for other varieties t_c was less than t_t, indicating a random spatial distribution of *T. tabaci* (Table 4).

Iwao's model showed that there was a significant relationship between mean crowding and the density of *T. tabaci*. In this model, the values of β varied from 1.24 to 1.98. During the sampling period, same soybean varieties namely: Sari, Zane, Williams, Tellar and the Ks3494 genotype had an aggregated spatial distribution ($t_c > t_t$) of *T. tabaci*, while other varieties exhibited a random pattern with t_c less than t_t (Table 4).

Spatial distribution pattern of *T. tabaci* using Morisita's index (I_δ) in most sampling dates was aggregated and "calculated *Z*" was significantly greater than z (α/2), but in a few cases it was random and "calculated *Z*" less than z (α/2) (Table 5).

Lloyd's mean crowding revealed an aggregated pattern for *T. tabaci* in all varieties of soybean (Table 3).

Re-calculated sample sizes, using Taylor's coefficient (*a* and *b*) on Williams, Tellar, Zane, Sahar, Dpx , L_{17} and Sari varieties and Ks3494 genotype were 8.23, 13.29, 8.31, 19.73, 27.71, 12.94, 5.16 and 18.99, respectively.

DISCUSSION

In developing a sampling program for either research or management purposes,

Table 4. Spatial distribution of *Thrips tabaci* on different varieties of soybean during 2007 using Taylor's power law and Iwao's patchiness regression analysis.

Var. and gen.*	Taylor						Iwao						
	a	b	SE_b	r^2	P_{reg}	t_c	α	β	SE_β	r^2	P_{reg}	t_c	t_t
Williams	0.14	1.16	0.06	96.00	0.000	2.62	0.72	1.98	0.42	58.30	0.03	2.32	2.14
Tellar	0.09	1.18	0.04	98.10	0.000	4.39	0.15	1.44	0.09	93.20	0.00	4.58	2.13
Zane	0.09	1.13	0.03	98.50	0.000	3.33	0.01	1.24	0.07	96.00	0.00	3.28	2.20
Sahar	0.22	1.20	0.06	95.30	0.000	2.94	0.26	1.36	0.17	79.00	0.00	2.02	2.14
Dpx	0.30	0.43	0.31	54.00	0.187	-1.81	0.48	1.30	0.22	67.00	0.00	1.34	2.13
Ks3494	0.23	0.86	0.25	45.10	0.005	0.55	0.03	1.29	0.12	89.10	0.00	2.23	2.17
L_{17}	0.13	1.11	0.13	84.00	0.000	0.827	0.18	1.35	0.16	83.30	0.00	2.10	2.17
Sari	0.06	0.87	0.11	79.40	0.000	-1.09	0.04	1.46	0.12	89.40	0.00	3.70	2.13

* Varieties and the genotype (soybean).

Table 5. Parameters of Morisita's index and *Z* calculated for *Thrips tabaci* on different soybean varieties in 2007.

	Williams		Tellar		Zane		Sahar		Dpx		Ks3494		L_{17}		Sari	
Date	I_δ	Z	I_δ	Z	I_δ	Z	I_δ	Z	I_δ	Z	I_δ	Z	I_δ	Z	I_δ	Z
31 May	1.57	83.87	1.26	28.05	1.19	24.66	1.31	65.30	1.18	21.36	1.24	30.12	1.21	23.32	1.43	57.77
7 Jun.	1.85	72.82	1.53	31.02	1.30	21.63	1.53	49.83	2.61	26.21	1.56	48.19	1.57	45.45	1.47	22.59
14 Jun.	1.39	18.98	2.00	37.53	0.00	-45.23	2.59	75.47	1.75	48.01	1.17	8.13	1.97	27.26	1.76	45.68
26 Jun.	1.17	6.47	1.23	11.39	0.67	-8.46	1.53	37.83	1.84	20.30	0.94	-2.15	1.74	6.59	1.69	38.55
1 Jul.	1.29	6.35	1.55	22.09	1.69	18.10	1.50	20.27	2.81	26.02	0.68	-12.44	1.30	6.79	0.68	-7.42
7 Jul.	1.97	31.59	0.84	-4.32	2.06	27.05	1.26	14.99	0.18	-0.78	2.25	5.65	2.29	-13.19	1.39	18.20
16 Jul.	0.38	-13.39	0.96	-0.87	1.08	1.45	1.41	16.10	0.78	-5.43	0.04	-14.08	0.62	3.67	0.72	-7.46
25 Jul.	0.77	-4.90	0.80	-4.76	1.28	2.59	1.58	26.14	2.00	25.45	2.74	7.39	2.20	15.02	0.90	-2.29
1 Aug.	0.90	-0.65	0.82	-3.62	1.30	3.90	0.90	-3.78	0.96	-0.51	2.38	5.91	3.85	4.12	1.36	11.28
8 Aug.	0.73	-4.76	0.90	-2.08	0.00	-6.206	3.36	80.37	3.46	67.87	1.28	2.59	2.41	0.49	1.66	12.13
15 Aug.	1.89	12.65	1.00	0.00	0.00	-4.00	2.40	46.69	2.17	24.86	0.90	-0.57	1.04	-0.20	1.44	14.31
22 Aug.	0.90	-0.65	0.392	-7.66	0.00	-3.25	1.65	17.03	0.49	-4.90	5.00	15.55	0.71	0.00	1.66	10.73
29 Aug.	4.28	18.57	0.00	-4.74	0.00	0.00	5.12	78.81	0.37	-6.98	0.00	-0.70	0.00	-3.25	3.69	11.70
4 Sep.	0.00	-2.47	0.00	-5.47	0.00	0.70	0.00	-10.51	0.00	-4.47	0.00	0.70	0.00	-3.25	0.00	-9.08
12 Sep.	0.00	-0.70	0.00	-6.93	0.00	0.70	1.28	2.59	0.00	-5.48	-	-	0.00	0.00	0.00	-2.49
19 Sep.	0.00	0.70	0.00	-3.25	-	-	3.57	14.54	2.14	5.65	-	-	0.00	0.00	20.00	40.3
26 Sep.	-*	-	0.00	-2.47	-	-	0.00	-3.25	0.00	-1.65	-	-	0.00	0.00	0.00	-4.006

* Dashes in the columns indicate the end of sampling.

one must determine two characteristic features of any population, its density as well as its dispersion (Pedigo and Buntin, 1994).

Results of population fluctuation showed that the peak of population of onion thrips, due to favorable climatic conditions, was observed to be synchronized for all soybean varieties at the beginning of the growing season (the end of May and the beginning of June). Macintyre-Allen *et al.* (2005) reported that overwintered adult onion thrips entered fields early in the season but waited for some cue(s), abiotic (e. g., weather conditions) and biotic (e. g., host cues), before feeding and beginning reproduction on onion plants. When the weather was warmer and humidity reduced in June upto the end of growing season, the population density of *T. tabaci* on all soybean varieties decreased, reaching near to zero. This result is against those concluded by Macintyre-Allen *et al.* (2005) in Ontario and Duchovskiene (2006) in Lithuania. However, this can not be explained in our study, additional studies being needed to evaluate the influence of soybean varieties on population dynamics of onion thrips.

In our study there was a significant difference (P< 0.05) observed among population densities of *T. tabaci* on different soybean varieties (Table 2), suggesting that leaf structure (density of trichomes, softness of tissues and size of leaves) as well as growth features (such as growing period) of soybean varieties can affect the population density of *T. tabaci*. The effect of leaf structure or growth feature of the varieties on population density of *T. tabaci* was not examined in this study, and therefore further work is necessary to determine whether the differences observed in population density of onion thrips are due to the leaf structure or emanate from growth feature of the plants.

Duchovskiene (2006) reported that morphological structure of leek varieties can affect population density of *T. tabaci*. Trdan *et al.* (2007) revealed that even in years with similar weather conditions, different levels of infestation by onion thrips on the same strain of the same host may be expected. They suggested that the population dynamics of *T. tabaci* depends not only on weather conditions and host type but also on numerous other factors such as the co-occurrence of different Thysanoptera species (Deligeorgidis *et al.,* 2002), weed management (Booij, 2003), etc. Similar conclusions were also made when the population dynamics of some other pests studied (Kavallieratos *et al.,* 2002a, b; Athanassiou *et al.,* 2003; Smyth *et al.,* 2003; Athanassiou *et al.,* 2005; Kavallieratos *et al.,* 2004a, b; 2005; 2008).

The results of variance to mean ratio and of Lloyd's mean crowding indicated that *T. tabaci* had an aggregated distribution on all soybean varieties as well as on the genotype (Table 3). Spatial distribution of this pest using Morisita's index was aggregated at most sampling dates (Table 5). This result suggests that the presence of an individual at one point leads to an increased probability of another individual being nearby, and habitat occupation probability is not likely to be the same for all individuals (Ahmadi *et al.,* 2005).

Aggregated distribution of *T. tabaci* is probably due to its mode of reproduction. The most common mode of onion thrips reproduction is the lyotoky parthenogenesis whereby unmated females produce only female progeny (Kendall and Capinera, 1990), implying that large samples are required to obtain density estimate at an acceptable level of precision.

There are several studies that have described aggregated distribution of Thysanoptera species. Cho *et al.* (2001) demonstrated that spatial distribution of *Frankliniella occidentalis* (Pergande) on greenhouse cucumber was aggregated. Similarly, Steiner (1990) demonstrated that *F. occidentalis* was aggregated on cucumber plants. According to Deligeorgidis *et al.* (2002) *Aeolothrips intermedius* Bagnall, *Frankliniella intonsa* (Trybom), *F. occidentalis, Thrips angusticeps* (Uzel) and *T. tabaci* presented aggregated distribution among cotton sampling units. Seal *et al.* (2006) reported that the spatial distribution pattern of Chilli thrips, *Scirtothrips dorsalis*

Hood, in pepper fields, using the index of dispersion and Lloyd's mean crowding was, aggregated.

Regression models of Taylor's power law and Iwao's patchiness were more accurate than the variance to mean ratio, since the mean and variance of each sampling date was used separately. The *b* values of Taylor's power law on Zane, Sahar, Williams and Tellar varieties, being > 1, indicated aggregating distribution, but other varieties had b=1, indicating random distribution. Iwao's patchiness regression model showed that spatial distribution of *T. tabaci* on Sari, Zane, Wiliams and Tellar varieties and on Ks3494 genotype was aggregated while on other varieties (Dpx, Sahar and L_{17}) was of a random pattern (Table 4). These results suggest that different plant varieties can affect the spatial distribution of onion thrips. Furthermore, the random distribution pattern of *T. tabaci* on some varieties using Taylor's power law and Iwao's patchiness method, suggest that different statistical methods produce varied results and accuracy in calculating the spatial distribution of an organism.

Southwood (1978) observed that when a population in an area becomes sparse, the chance of an individual occurring in any sample unit is so low that the distribution is in effect random. In the present work, the random distribution of *T. tabaci* on some varieties using regression models indicated that the presence of an individual on a leaf was not affected by the presence of other individuals, with all leaves hving similar chance of being occupied by an individual. However, the data obtained for Sahar and Williams varieties had a better fit with Taylor's power law (r^2= 95.3 and 96, respectively) in comparison with Iwao's model (r^2= 79 and 58.3, respectively). In contrast, the data on Sari, Dpx and Ks3494 proved to be a good fit to Iwao's model (r^2= 89.4, 67 and 89.1, respectively) as compared to Taylor's power law (r^2= 79.4, 54 and 45.1) (Table 4).

Re-calculated sample size using Taylor's coefficients (a and b) can help one to improve the sampling program of *T. Tabaci* in soybean fields. Taylor's power law has been utilized for the development of a thrips sampling plan on various crops (Steiner, 1990; Cho *et al.,* 1999; Deligrorgidis *et al.,* 2002). Taylor's power law should be calculated under the assumption that individual sample values are spatially independent (Midgarden *et al.,* 1993) because Taylor's power law did not account for the relative position of sample values within data sets. Therefore, samples should be independent of each other to avoid a biased estimate of mean densities in the sampling plant as based on the coefficients of Taylor's power law.

The population density and spatial distribution of onion thrips on soybean varieties, identified in this study, poses important issues for the development of sampling plans which are among the key elements in pest management strategies.

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ویژگی‌های جمعیتی تریپس پیاز *Thrips tabaci* (Thysanoptera: Thripidae) روی ارقام مختلف سویا

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چکیده

تغییرات جمعیت و الگوی توزیع فضایی تریپس پیاز روی هفت رقم سویا (Williams، Tellar، Sahar، Dpx، L_{17}، Sari و Zane) به همراه یک ژنوتیپ آن (Ks3494) در طول سال زراعی ۱۳۸۶، در منطقه تهران مورد مطالعه قرار گرفت. بیشترین میانگین جمعیت آفت به ازای هر برگ روی رقم Dpx و ژنوتیپ Ks3494 ثبت گردید (به ترتیب، ۰۰/۸۱±۰/۵۰ و ۰/۸۰±۰/۵۰). کمترین میانگین جمعیت نیز روی سایر ارقام سویا مشاهده شد که اختلاف معنی‌داری میان آن‌ها از نظر آماری وجود نداشت. به منظور تعیین الگوی توزیع فضایی این آفت روی ارقام مختلف سویا از روش‌های شاخص پراکندگی، روش لویدز، شاخص موریسیتا و مدل‌های رگرسیونی تیلور و آیوائو استفاده گردید. الگوی توزیع فضایی این آفت با استفاده از روش‌های شاخص پراکندگی و روش للوید روی همه ارقام سویا از نوع تجمعی محاسبه گردید. استفاده از شاخص موریسیتا الگوی تجمعی را برای این آفت روی ارقام سویا در بیشتر تاریخ‌های نمونه برداری مشخص نمود. در روش تیلور، رگرسیون میان $\log S^2$ و $\log m$ روی رقم Dpx از نظر آماری معنی دار نبود ($P> 0.05$). با استفاده از این روش الگوی توزیع فضایی تریپس پیاز روی ارقام Zane، Sahar، Williams و Tellar از نوع تجمعی و روی سایر ارقام از نوع تصادفی ثبت شد. الگوی توزیع فضایی تریپس پیاز با استفاده از روش آیوائو روی ارقام Sari، Zane، Williams، Tellar و ژنوتیپ Ks3494 از نوع تجمعی محاسبه گردید، در حالیکه این آفت روی سایر ارقام الگوی توزیع فضایی تصادفی داشت. تحقیق حاضر نشان می‌دهد که ارقام مختلف سویا قادرند تراکم جمعیت و الگوی توزیع فضایی تریپس پیاز را تحت تاثیر قرار دهند. پارامترهای به دست آمده از الگوی توزیع فضایی این گونه می‌تواند در طراحی برنامه نمونه برداری و تخمین تراکم جمعیت این آفت در مزارع سویا مورد استفاده قرار گیرد.