SPATIAL DISTRIBUTION PATTERN OF *TETRANYCHUS URTICAE* AND ITS EGG PREDATOR *SCOLOTHRIPS LONGICORNIS* ON DIFFERENT BEAN CULTIVARS

Hajar Pakyari*

* Department of Plant Protection, Faculty of Agriculture, Islamic Azad University, Takestan Branch-IRAN. E-mail: Pakyari@tiau.ac.ir

[Pakyari, H. 2012. Spatial distribution pattern of *Tetranychus urticae* and its egg predator *Scolothrips longicornis* on different bean cultivars. Munis Entomology & Zoology, 7 (1): 243-254**]**

ABSTRACT: Bionomics of two-spotted spider mite, *Tetranychus urticae* Koch, and its egg predator *Scolothrips longicornis* Priesner was studied in the southeast of the Tehran province, Varamin from 11th July to 22th September 2010 on six bean cultivars including Goli, Akhtar, Sadaf, Parastoo, Talash and Baker. The mean population densities of the overall life stages of *T. urticae* and *S. longicornis* per leaf on Goli (36.27 and 2.87, respectively) were significantly more than other cultivars. The spatial distribution of *T. urticae* and *S. longicornis* was determined by the following four methods: index of dispersion, Lloyd's mean crowing, Taylor's power law and Iwao's patchiness regression, whereas Morisita's coefficient of dispersion was calculated for *T. urticae* on different crops. The index of dispersion, Morisita's index and Lloyd's mean crowding indicated an aggregated pattern for spatial distribution of this mite and their predator on all bean cultivars. The spatial distribution pattern of *T. urticae* and *S. longicornis* using Taylor's power law and Iwao's patchiness in most cases was aggregated and in few cases random. The linear regression between the predator and prey population densities indicated a density-dependant predation by *S. longicornis* on *T. urticae*. Spatial distribution parameters of two-spotted spider mite and its predator can be used to outline a sampling program, estimate population density of these mites and efficiency of the predator for using in IPM programs.

KEY WORDS: *Tetranychus urticae*, *Scolothrips longicornis*, population density, spatial distribution, density dependence interaction, optimum sample size.

Spider mites (Acari: Tetranychidae) are wide-spread agricultural pests, which often cause severe damage on a cultivar of annual and perennial crops (Gerlach & Sengonca, 1986; Han et al., 2003; Jung, 2005; Jung et al., 2005). This species is adapted to various environmental conditions and distributed worldwide. *T. urticae* feeds using a piercing-sucking process that leaf cells to turn whitish or yellowish spots. Currently, natural enemies of spider mites are employed to avoid increase of these pests in both indoor and outdoor environments. Acarophagous ladybird beetles (Obrycki & Kring, 1998; Mori et al., 2005; Taghizadeh et al., 2008a,b), predatory anthocorids (Coll & Ridgway, 1995; Funao & Yoshiyasu, 1995; Cocuzza et al., 1997; Kohno & Kashio, 1998; Gitonga et al., 2002), and predatory mites (McMurtry & Croft, 1997; Marisa & Sauro, 1999) have received a great deal of research particularly on their impact on spider mites populations, but little attention has been paid to predatory thrips (e.g., Nakagawa, 1993; Kishimoto, 2003; Gotoh et al., 2004a,b). *Scolothrips longicornis* Priesner (Thysanoptera: Thripidae) is native to Iran (Pakyari et al., 2009) and also has been reported from many countries such as India, Turkey, Iraq and North America (Priesner, 1950; Gilstrap & Oatman, 1976). This species is common on bean (Aydemir & Toros, 1990), cucumber and eggplant (Pakyari and Fathipour 2009) and is an important predator of numerous spider mite species, so it is a good candidate for biological control of these mite pests (Aydemir & Toros, 1990; Chazeau, 1985).

Estimating the population density of arthropods is the cornerstone of basic research on agricultural ecosystems and the principal tool for building and implementing pest management strategies (Kogan & Herzog, 1980). At this estimating plan, the reliable sampling program conducted at specific times using a suitable sampling technique with a given sampling unit and sample size all based on the spatial distribution characteristics of the pest population (Pedigo & Buntin, 1994).

Quantitative knowledge about spatial distribution of a prey and predator is important to evaluate a natural enemy potential to reduce its prey density and system's persistence (Slome & Croft, 1998). Understanding spatial distribution is a prerequisite for ecological and behavioral studies (Faleiro et al., 2002), learning of population dynamics (Jarosic et al., 2003), binomial sampling (Binns & Bostanian, 1990) and population growth evaluation (Jarosik et al., 2003).

There are various studies that described the spatial distribution and population density of *T. urticae*. Aggregative spatial distribution of *T. urticae* was reported in different crop such as soybean (Sedaratian et al., 2008), bean (Ahmadi et al., 2005; Mehrkhou et al., 2008), strawberry (Greco et al., 1999), pear (Takahashi et al., 2001) and apple (Slone & Croft, 1998), but no studies were found about the spatial distribution of predatory thrips, *Scolothrips longicornis* on *T. urticae*. Takahashi et al. (2001) evaluated the role of the predatory thrips *S. takahashii* Priesner in an experimental pear orchard primarily to improve a new IPM program for the control of spider mites.

The aim of this research is to determine the population density and spatial distribution pattern of *T. urticae* and its predator *S. longicornis* and interaction between them on bean cultivars. The results of this study can be used to improve the management program of *T. urticae* on bean. This plan is critical to develop and optimize reliable sampling plans, monitor methods and control of mites for establishing IPM strategies on this crop.

MATERIALS AND METHODS

Experimental design

A screening trial was conducted from July to September 2009 to examine the population trend in *T. urticae* and its predator *S. longicornis* at experimental field at the southeast of the Tehran province, Varamin. Six bean cultivars including common bean *Phaseolus vulgaris* L. var. Talash; lima bean *P. lunatus* L. var. Sadaf; *P. acutifolius* var. Akhtar; *P. coccineus* var. Baker; Aduki bean *P. calcaratus* Roxb var. Goli and cowpea *Vigna sinensis* L. var. Parastoo were planted in a randomized complete block design in field.

Sampling program

The sampling method is random collecting so that every sampling unit has an equal chance to be chosen (Pedigo and Buntin, 1994). In this study, different life stages of *T. urticae* and *S. longicornis* colonized on the under-surface of leave thus one leaf of bean was selected as a sampling unit. The leaves were selected randomly and the number of different life stages of *T. urticae* and *S. longicornis* were measured by counting the number per leaf using a stereomicroscope in the laboratory. The sampling was conducted once a week from 11th July to 22th September 2010 at 8-12 A.M.

For determining the sample size, primary sampling with 60 samples unites of different bean cultivar was taken on 4th July 2010. The relative variation (*RV*) was calculated to compare the efficiency of various sampling methods (Hillhouse and Pitre, 1974) as:

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

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 of the mean and *m* = the mean of primary data (Pedigo & Buntin, 1994).

The mean density of total life stages of *T. urticae* and *S. longicornis* were statistically analyzed using ANOVA and compared among different bean cultivars within each sampling data and overall dates.

Response of *S. longicornis* to the population density of *T. urticae*

A linear regression analysis of the mean density of *S. longicornis* versus mean density of *T. urticae* was used to qualify the interaction between these two species on different cultivars of bean. If (b = 0) the linear regression among two variable is not significant, in reality the predator's response to its prey density is density independent. If the regression is significant where $b < 0$, the predator's response is inversely density dependent however, if $b > 0$, this predator's response is density dependent.

Spatial distribution

The spatial distribution of *T. urticae* and *S. longicornis* was determined by the following four methods: index of dispersion, Lloyd's mean crowing, Taylor's power law and Iwao's patchiness, whereas Morisita's coefficient of dispersion was calculated for *T. urticae* on different crops.

Index of dispersion

Dispersion of population can be classified by calculating the variance to mean ratio as follows:

$$S^2/m > 1 \text{ Aggregated}$$
$$S^2/m = 1 \text{ Random}$$
$$S^2/m < 1 \text{ Regular}$$

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

$$I_D = (n\text{-}1)\ S^2/m$$

The *Z* coefficient should be calculated to test the goodness-of- fit:

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

Where v is degree of freedom (n-1).

If 1.96 $\geq Z \geq$ -1.96 the spatial distribution will be random whereas if $Z < -1.96$ or $Z > 1.96$ it will be uniform and aggregated, respectively (Pedigo and Buntin, 1994).

Taylor's power law and Iwao's patchiness regression

The Taylor's power law a function between the variance (S^2) and the sample mean (m) as follows:

$$S^2 = am^b$$

where S^2 is the variance; m is the sample mean; a is a scaling factor related to sample size and b measure the species aggregation. If $b = 1$, <1 or >1, the distribution is random, regular and aggregated, respectively (Taylor, 1961).

By using a log transformation, we can calculate 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, which were calculated by linearzing the equation by a log-log transformation (Martinez-Ferrer et al., 2006).

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

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

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

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

where S_b and S_β are the standard error of slop of mean crowding regression. Estimated values compared with tabulated t-vales with n-2 degree of freedom.

Lloyd's mean crowding x^*

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

$$x^* = m + S^2 / m - 1$$

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

Morisita's coefficient of dispersion I_δ

Morisita (1962) suggested a hypothesis for testing the uneven distribution coefficient of I_δ and is calculated by 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 = the total number of individuals in n samples. To determine if the sampled population significantly differs from random, the following large sample test of significance was used (Hucheson and Lyons, 1989).

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

If 1.96 $\geq Z \geq$ -1.96 the spatial distribution will be random whereas if Z < -1.96 or Z > 1.96 it will be regular and aggregated, respectively (Pedigo and Buntin, 1994).

Optimum number of sample units (sample size)

Taylor's a and b coefficients, taken from Taylor's power law explain the relationship between variance and mean ($S^2 = am^b$) for individuals distributed in a natural population. The mean and variance of sampled mites was determined for each sampling date. Taylor's a and b coefficient estimated by log-log linear transformation of the mean-variance data, where b is the slop 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), Wilson & Room (1982) integrated Taylor's power law into Karandinos' equation to form the sample size model used in this study (Cullen et al*.*, 2000):

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

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

RESULT

Sampling program

One leaf of the bean cultivars was selected as a sample unit, due to activity place of *T. urticae* and *S. longicornis*. The results from the primary sampling was used to calculate *RV*. The maximum calculated *RV* and reliable sample size were 12.15% and 85.28, respectively for parastoo cultivar (Table 1).

Population density of *T. urticae* and *S. longicornis*

Mean population densities of overall life stages of *T. urticae* (immatures and adults) per leaf on six cultivars are shown in Table 2. The results showed that there was a significant difference (P < 0.05) among population densities of *T. urticae* on different cultivars of bean in overall dates. The maximum population density of *T. urticae* per leaf was observed on Goli (36.27) during sampling dates, which was significantly different from other bean cultivars.

The minimum population density of the mite was observed on Akhtar and Sadaf cultivars 3.27 and 4.93 overall life stages per leaf, respectively, that was significantly different from other bean cultivars. The population density of *S. longicornis* peaked at 3 thrips per Goli leaf during the warm months from July to September.

Spatial distribution

The results of the variance to mean ratio (S^2/m), coefficient of dispersion (I_D) and Z test of *T. urticae* and *S. longicornis* are showed in Table 3. The results of sampling presented that the spatial distribution was aggregated for all bean cultivars.

In Taylor's model, the regression between log S^2 and log m *T. urticae* was significant for all bean cultivars (P < 0.05). Slope of this model was varied from 1.10 to 1.84 for *T. urticae* and varied from 1.09 to 1.71 for *S. longicornis* and it was significantly bigger than one on all bean cultivars (Table 4). The estimated t (t_c) was bigger than t-table (t_t) for all cultivars, indicating an aggregated spatial distribution of *T. urticae* and *S. longicornis*, however, Parastoo cultivar had a t_c less than t_t, showing a random spatial distribution of *T. urticae* and *S. longicornis*.

Iwao's model indicated that there was a significant relation between the mean crowding and the density of *T. urticae* and *S. longicornis* (Table 4). Iwao's slope was varied from 1.01 to 1.34 for *T. urticae* and varied from 1.06 to 1.57 for *S. longicornis* all bean cultivars had an aggregated (slope > 1) spatial distribution of *T. urticae* and *S. longicornis*, however, Parastoo cultivar had a random pattern with t_c less than t_t. Morisita's index (I_δ) and Lloyd's mean crowding showed an aggregated pattern for *T. urticae* on all cultivars of bean and Lloyd's mean crowding showed an aggregated pattern for *S. longicornis*. Calculated Z was significantly greater than 1.96 in all sampling dates for *T. urticae*. The m^*/m value for *T. urticae* and their predator, *S. longicornis* in all sampling dates was significantly greater than 1 indicated aggregated pattern in all examined cultivars (Table 6).

Optimum number of sample size units

Re-calculated sample size using Taylor's coefficient (a and b) on six cultivars are presented in Table 4. The sample size calculated with Taylor's coefficient for *T. urticae* lower than *S. longicornis*. These values of sample size can help to develop sampling program of *T. urticae* and *S. longicornis*.

Density dependence in prey-predator interaction

The correlation coefficient between population densities of *T. urticae* and *S. longicornis* was statistically significant for six cultivars indicating high relation between species fluctuations. Statistically significant linear regression was observed between *T. urticae* and their predator (Table 7) revealing that *S. longicornis* in interaction with *T. urticae* does have density-dependent activity.

DISCUSSION

Several methods are accessible for the sampling of spider mites in row crops such as individual plant unit observation, imprint on paper, machine brushing on to a plate, beat cloth, paper or funnel techniques. The most exact method is direct counting of all life stages of mite on plant leaflets using a stereomicroscope (Kogan & Herzog, 1980). Regarding the life stage of *T. urticae* and *S. longicornis*, bean leaves were selected as sampling units and counts made of individuals per sampling unit. Via stereomicroscope and visual counts techniques, respectively.

Shimoda and Ashihara (1996) used the stereomicroscope in order to count the number of each stage of *T. urticae* on the cedar leaves. The population density of *T. urticae* was determined on raspberry leaves using stereomicroscope (Roy et al., 2005).

In most sampling dates, the highest population density of the mite was significantly recorded on Goli in comparision with the other bean cultivars (Table 2), suggesting that of dense trichomes and large leaf size of this cultivar may be the most important factors for its suitability leading to increase the mite population density. The lack of trichomes and waxy leaves in Parastoo cultivar may be the most important reasons for decrease of the population density of the mite. Mehrkhou et al. (2008) reported the same results with *T. urticae* on bean.

Spatial distributionis one of the most important ecological characters of a population that can be used in extended sampling programs for pest managements (Kuno, 1991). In a extended sampling which is a quick and precise method for estimating mean population or decision of control time, spatial distribution data is crucial in determination of equations and necessary sample size for the decision (Young & Young, 1985). In this research aggregated spatial distribution pattern was found for *T. urticae* by using variance to mean ratio Morisita's coefficient regression methods (Taylor & Iwao) and Lloyd's mean crowding for all bean cultivars due to the limited mobility of *T. urticae* females (Table 3,5 and 6). This behavior has been reported for *T. urticae* on other crop systems (Kennedy and Smitley, 1985), and it implies that large samples are required to obtain density estimates at on acceptable level of precision (Nachman, 1985).

Regression models of Taylor's power law and Iwao's patchiness were more exactly than the variance to mean ratio, since the mean and variance of each sampling date was used separately. Spatial distribution pattern of *T. urticae* using Taylor's power law and Iwao's patchiness were obtained random on Parastoo cultivar and were recorded aggregated on all bean cultivars (Table 4), suggestion that the different statistical methods have various results and accuracy in estimating spatial distribution of an organism.

Aggregated spatial distribution of *T. urticae* on a four bean cultivars was evaluated by Ahmadi et al. (2005). Shih & Wang (1996) evaluated that the aggregated spatial distribution of *T. urticae* in a carambula orchard. Greco et al. (1999) indicated that spatial distribution of *T. urticae* on strawberry was aggregated. Yasuyuki et al. (2004) determined that spatial distribution of *T. urticae* on apple orchard was aggregated. These results were similar to those found by So (1991) on rose and Raworth (1986) on strawberries.

The spatial distribution pattern of predatory thrips, *S. longicornis* using a variance to mean ratio was random on Akhtar, Parastoo and Talash and was aggregated on other three bean cultivars, suggesting that different plant cultivars can influence spatial distribution of the predator. Regression methods (Taylor & Iwao) and Lloyd's mean crowding indicated that the aggregated spatial distribution pattern of *S. longicornis* on bean cultivars. This behavior of *S. longicornis* is a positive response to the aggregative behavior of *T. urticae* for enhancing the predation efficiency. These results demonstrated that due to similarity of spatial distribution pattern of *T. urticae* and *S. longicornis* (aggregated pattern) on some plant cultivars, it could be a beneficial agent for biological control of the mite on these plants. Yasuyuki et al. (2004) studied the spatial distribution pattern and sampling technique for the predatory thrips *S. takahashii* in apple orchards and observed an aggregated spatial distribution pattern for this predator and its prey, *T. urticae* using regression analysis method to estimate the spatial distribution.

This study showed that the different plant cultivars had distinct effect on population density of *T. urticae* and its predator *S. longicornis*. The population density of the mite during the growing season, on different cultivars was significantly different. The highest and lowest population density of *T. urticae* was observed on Goli and Akhtar, respectively. The reaction of *S. longicornis* to population of *T. urticae* on various cultivars was density dependent. Therefore it seems that *S. longicornis* can act as a suitable predator for controlling spider mites in IPM on various bean cultivars. The coefficient acquired from spatial distribution models can be used in developing a sampling program of *T. urticae* on each crop. To upgrade the management of *T. urticae* on agricultural crops an exact sampling program is needed. Additionally, our finding may provide essential information for comprehensive IPM of *T. urticae* on bean species.

ACKNOWLEDGEMENTS

This work was financially supported by the Department of Plant Protection, Islamic Azad University of Takestan Branch. The authors are grateful to Mr. Sedaratian for their assistance in statistical analysis.

LITERATURE CITED

Ahmadi, M., Fathipur, Y. & Kamali. K. 2005. Population density and spatial distribution of *Tetranychus utticae* Koch (Acari: Tetranychidae) on different bean cultivars in Tehran region. Iranian Journal of Agricultural Sciences, 36: 1087-1092.

Aydemir, M. & Toros, S. 1990. Natural enemies of *Tetranychus urticae* on bean plant in Erzinca. Proceedings of the Second *Turkish* National *Congress* of *Biological control*, 261-271.

Chazeau, J. 1985. Predacious insects. In: Helle, W. and Sabelis, M. W. (eds.). World crop pest, Spider mites: Their biology, natural enemies and control. Elsevier Publications Amesterdam, IB: 211-246.

Faleiro, J. R., Kumar, J. A. & Ranjekar, P. A. 2002. Spatial distribution of red palm weevil *Rhynchophorus ferrugineus* Oliv. (Col: Curculionidae) in coconut plantations. Crop Protection, 21: 171-176.

Gerlach, S. & Sengonca, C. 1986. Feeding activity and effectiveness of the predatory thrips, *Scolothrips longicornis* Priesner (Thysanoptera: Thripidae). Journal of Applied Entomology, 101, 444-452.

Gilstrap, F. E. & Oatman, E. R. 1976. The bionomics of *Scolothrips sexmaculatus* (Pergande) (Thysanoptera: Thripidae) an insect predator of spider mites. Hilgardia, 44: 27-59.

Gitonga, L. M., Overholt, W. A., Lohr B., Magambo, J. K. & Mueke, J. M. 2002. Functional response of *Orius albidipenis* (Hemiptera: Anthocoridae) to *Megalurothrips sjostedti* (Thysanoptera: Thripidae). Biological Control, 24: 1-6.

Gotoh, T., Nozawa, M. & Yamaguchi, K. 2004a. Prey consumption and functional response of three acarophagous species to egg of the two-spotted spider mite in the laboratory. Applied Entomology and Zoology, 39(1): 97-105.

Gotoh, T., Yamaguchi, K., Makiko, F. & Mori, K. 2004b. Effect of temperature on life history traits of the predatory thrips, *Scolothrips takahashii* Priesner (Thysanoptera: Thripidae). Applied Entomology and Zoology, 39(3): 511-519.

Greco, N. M., Liljesthrom, G. G. & Sanchez, N. E. 1999. Spatial distribution and coincidence of *Neoseiulus californicus* and *Tetranychus urticae* (Acari: Phytoseiidae, Tetranychidae) on strawberry. Journal of Experimental and Applied Acarology, 23: 567-580.

Han, S. H., Jung, C. & Lee, J. H. 2003. Release strategies of *Amblyseius womersleyi* and population dynamics of *Amblyseius womersleyi* and *Tetranychus urticae*: I. Release position in pear. Journal of Asia-Pacific Entomology, 6: 221–227.

Hillhouse, T. L. & Pitre, H. N. 1974. Comparison of sampling techniques to obtain measurements of insect populations on soybeans. Journal of Economic Entomology, 67: 411-414.

Hutcheson, K. & Lyons, N. I. 1989. A significance test for Morisita's index of dispersion and the moments when the population is negative binomial and Poisson. In: McDonalds, L., Manly, B. & Lockwood, J., (Esd.). Estimate and Analysis of Insect Population, Spring-Verlag, Berlin, 335.

Iwao, S. & Kuno, E. 1968. Use of the regression of mean crowding on mean density for estimating sample size and the transformation of data for the analysis of variance. Journal of Research Population Ecology, 10: 210.

Jarosik, V., Honek, A. & Dixon, A. F. G. 2003. Natural enemy ravine revisited: the importance of sample size for determining population growth. Ecological Entomology, 28: 85-91.

Jung, C. 2005. Some evidences of aerial dispersal of twos-potted spider mite from an apple orchard into a soybean field. Journal of Asia-Pacific Entomology, 8: 279–283.

Jung, C., Kim, D. S., Park, Y. S. & Lee, J. H. 2005. Simulation modeling of two spotted spider mite population dynamics in apple and pear orchards in Korea. Journal of Asia-Pacific Entomology, 8: 285–290.

Karandinos, M. G. 1976. Optimum sample size and comments on some published formulae. Bulletin of the Entomological Society of America, 22: 417-421.

Kennedy, G. C. & Smitley, D. R. 1985. Dispersal. In: Helle, W. & Sabelis, M. W. [Eds.], Spider Mites: their Biology, Natural Enemies and Control. Vol. 1A. Elsevier, Amsterdam, The Netherlands, 233-242.

Kishimoto, H. 2003. Development and oviposition of predacious insects, *Stethorus japonicus* (Coleoptera: Coccinellidae), *Oligota kashmirica benefica* (Coleoptera: Staphylinidae), and *Scolothrips takahashii* (Thysanoptera: Thripidae) reared on different spider mite species (Acari: Tetranychidae). Applied Entomology and Zoology, 38: 15-21.

Kogan, M. & Herzog, D. C. 1980. Sampling Methods in Soybean Entomology. Springer Verlag, New York, 587 pp.

Kohno, K. & Kashio, T. 1998. Development and prey consumption of *Orius sauteri* Poppius and *O. minutus* L. (Heteroptera: Anthocoridae) fed on *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). Applied Entomology and Zoology, 33: 227–230.

Kuno, E. 1991. Sampling and analysis of insect populations. Annual Review of Entomology, 36: 285-304.

Lloyd, M. 1967. Mean crowding. Journal of Animal Ecology, 36: 1-30.

Martinez-Ferrer, M. T., Jacas, J. A., Piolles-Moles, J. L. & Aucejo-Romero, S. 2006. Approaches for sampling the two spotted spider mite (Acari: Tetranychidae) on clementines in Spain. Journal of Economic Entomology, 99: 1490-1499.

McMurtry, J. A. & Croft, B. A. 1997. Life-style of Phytoseiidae mites and their roles in biological control. Annals Review of Entomology, 42: 291-321.

Mehrkhou, F., fathipour, Y., Talebi, A. A., Kamali, K. & Naseri, B. 2008. Population density and Spatial distribution patterns of *Tetranychus urticae* (Acari: Tetranychidae) and its predator *Stethorus gilvifrons* (Col.: Coccinellidae) on different crops in Tehran area. Journal of Entomology Research Society, 10(2): 23-36.

Morisita, M. 1962. Iδ–index a measure of dispersion of individuals. Research Population Ecology Journal, 4: 1-7.

Nachman, G. 1985. Sampling Technique, In: Helle W., Sabelis, M. W. (Eds.). Spider Mites, Their Biology, Natural Enemies and Control, World Crop Pests. Volume IB, Elsevier, Amsterdam, The Netherlands, 175-182.

Nakagawa, T. 1993. Studies on the seasonal occurrence and predatory activity of the predators of Kanzawa spider mite, *Tetranychus kanzawai* Kishida in tea fields. Bulletin Saga Prefecture Tea Experimental Station, 1: 1-40.

Obrycki, J. J. & Kring, T. J. 1998. Predaceous coccinellidae in biological control. Annul Review of Entomology, 43: 295–321.

Pakyari, H. & Fathipour, Y. 2009. Mutual interference of *Scolothrips longicornis* Priesner (Thysanoptera: Thripidae) on *Tetranychus urticae* Koch (Acari: Tetranychidae). IOBC/wprs Bulletin, 50: 65-68.

Pakyari, H., Fathipour, Y., Rezapanah, M. & Kamali, K. 2009. Temperature-dependent functional response of *Scolothrips longicornis* Priesner (Thysanoptera: Thripidae) preying on *Tetranychus urticae* Koch. Journal of Asia-Pacific Entomology, (Acari: Tetranychidae). 12: 23-26.

Pedigo, L. P. & Buntin, G. D. 1994. Handbook of Sampling Methods for Arthropods in Agriculture. CRC Press, Florida, 714 pp.

Priesner, H. 1950. Studies on the genus *Scolothrips*. *Bulletin* of the *Entomological Society* of *Egypt*, 34, 39-68.

Raworth, D. A. 1986. Sampling statistics and a sampling scheme for the two-spotted spider mite, *Tetranychus urticae* (Acari: Tetranychidae), on strawberries. The Canadian Entomologist, 118: 807-814.

Roy, M., Brodeur, J. & Cloutier, C. 2005. Seasonal activity of the spider mite predators *Stethorus punctillum* (Coleoptera: Coccinellidae) and *Neoseiulus fallacies* (Acarina: Phytoseiidae) in raspberry, two predators of *Tetranychus mcdanieli* (Acarina: Tetranychidae). Biological Control, 34: 47-57.

Ruesink, W. G. 1980. Introduction to sampling theory, In M. Kogan and D. C. Herzog [eds.], Sampling Methods in Soybean Entomology. Springer, New York. pp. 61-78.

Sedaratian, A., Fathipour, Y., Moharramipour, S. & Talebi, A. A. 2008. Effect of different soybean cultivars on bionomics of *Tetranychus urticae* (Acari: Tetranychidae). Munis Entomology & Zoology, 3 (2): 716-730.

Shih, C. I., & Wang, C. J. 1996. Spatial distribution of *Tetranychus urticae* (Acari: Tetranychidae) with special inferences from its behavior of collective egg deposition, life type and dispersal activities. Chinese Journal of Entomology, 16: 287-302.

Shimoda, T. & Ashihara, W. 1996. Seasonal population trends of spider mites and their insect predator, *Oligota kashmirica benefica* Naomi (Col: Staphilinidae), in Satsuma mandarin groves and in Japanese cedar windbreaks around the orchards. . Proceeding Associate of Plant Protection Kyushu, 42: 133-137 (in Japanese).

Slone, D. H. & Croft, B. A. 1998. Spatial aggregation of apple mites (Acari: Phytoseiidae, Stigmaeidae, Tetranychidae) as measured by a binomial model: effects of life stage, reproduction, competition and predation. Environmental Entomology, 27: 918-925.

So, P. M. 1991. Distribution patterns and sampling plans for *Tetranychus urticae* Koch (Acari: Tetranychidae) on roses. Journal of Researches on Population Ecology, 33: 229-243.

Taghizadeh, R., Fathipour, Y. & Kamali, K. 2008a. Influence of temperature on life-table parameters of *Stethorus gilvifrons* (Mulsant) (Coleoptera: Coccinellidae) fed on *Tetranychus urticae* Koch. Journal of Applied Entomology, 132: 638-645.

Taghizadeh, R., Fathipour, Y. & Kamali, K. 2008b. Temperature-dependent development of Acarophagous ladybird, *Stethorus gilvifrons* (Mulsant) (Coleoptera: Coccinellidae). Journal of Asia-Pacific Entomology, 11: 145-148.

Takahashi, H., Takafuji, A., Takabayashi, J., Yano, S. & Shimoda, T. 2001. Seasonal occurrence of specialist and generalist insect predators of spider mites and their response to volatiles from spider-mite-infested plants in Japanese pear orchards. Experimental and Applied Acarology, 25: 393-402.

Taylor, L. R. 1961. Aggregation, variance to the mean. Nature, 189: 732-735.

Wilson, L. T. & Room, P. M. 1982. The relative efficiency and reliability of three methods for sampling arthropods in Australian cotton fields". Journal of Australian Entomology Society, 21: 175-181.

Yasuyuki, N., Tomoyuki, J. & Hiroshi, N. 2004. Seasonal prevalence of occurrence and the spatial distribution of spider mites and their natural enemies at the apple orchard of AFC Campus Station. Bulletin Shinshu University Alpine Field Center, 2: 23-30 (in Japanese).

Young, L. J. & Young, L. H. 1998. Statistical Ecology. Kluwer Academic Publication, 565 pp.

Table 1. Estimated parameters by primary sampling of *T. urticae* on different bean cultivars in 2010.

Cultivar	n	SE	SD	RV	m	d	N
Goli	60	1.567	12.141	4.289273	36.533	0.2	10.60695
Akhtar	60	0.365	2.824	8.939505	4.083	0.2	45.94336
Sadaf	60	0.421	3.261	9.020784	4.667	0.2	46.88977
Parastoo	60	0.156	1.209	12.159	1.283	0.2	85.28083
Talash	60	0.996	7.715	8.064777	12.35	0.2	37.47918
Baker	60	0.179	1.384	11.93333	1.5	0.2	81.76018

n = Number of samples, SE = Standard error of the mean, SD = Standard deviation of the mean, RV = Relative variation, m = Mean of primary data, d = Desired fixed proportion of the mean and N = Sample size

Table 2. Mean (±SE) population density of overall life stages of *T. urticae* (per leaf) on different bean cultivars in 2010.

Date	Goli	Akhtar	Sadaf	Parastoo	Talash	Baker
11Jul.	41.90 ± 2.53^{a}	6.12 ± 0.50^{cd}	8.22 ± 0.89^{c}	1.40 ± 0.17^{e}	16.24 ± 0.79^{b}	2.56 ± 0.29^{de}
18Jul.	86.44 ± 3.17^{a}	1.02 ± 0.18^{d}	8.54 ± 0.74^{bc}	0.86 ± 0.17^{d}	11.38 ± 1.04^{b}	5.96 ± 0.66^{cd}
23Jul.	81.60 ± 1.44^{a}	1.12 ± 0.20^{d}	4.46 ± 0.49^{c}	1.50 ± 0.23^{d}	7.94 ± 0.67^{b}	10.38 ± 0.87^{b}
30Jul.	55.68 ± 2.64^{a}	1.22 ± 0.14^{c}	3.84 ± 0.48^{c}	3.02 ± 0.31^{c}	10 ± 0.74^{b}	14.32 ± 0.86^{b}
5Aug.	42.96 ± 1.39^{a}	0.56 ± 0.10^{d}	8.52 ± 0.64^{c}	3.78 ± 0.32^{d}	7.90 ± 0.76^{c}	16.40 ± 1.38^{b}
13Aug.	23.64 ± 0.73^{a}	3.42 ± 0.38^{e}	4.56 ± 0.38^{de}	6.48 ± 0.36^{cd}	8.42 ± 1.61^{c}	11.66 ± 0.59^{b}
19Aug.	20.52 ± 0.83^{a}	5.16 ± 0.39^{d}	5.46 ± 0.49^{d}	9.46 ± 0.78^{c}	5.32 ± 0.53^{d}	15.38 ± 1.33^{b}
28Aug.	33.84 ± 0.68^{a}	3.82 ± 0.29^{d}	3.02 ± 0.28^{d}	13.58 ± 0.57^{b}	3.68 ± 0.39^{d}	11.76 ± 0.35^{c}
2Sep.	30.64 ± 1.26^{a}	7.54 ± 0.43^{d}	1.74 ± 0.16^{e}	10.62 ± 0.49^{c}	13.32 ± 0.75^{b}	11.46 ± 0.68^{bc}
10Sep.	8.06 ± 0.48^{ab}	3.24 ± 0.33^{d}	4.98 ± 0.46^{c}	7.80 ± 0.33^{ab}	6.68 ± 0.52^{b}	8.48 ± 0.52^{a}
16Sep.	7.32 ± 0.38^{bc}	4.47 ± 0.41^{d}	3.02 ± 0.25^{e}	12.10 ± 0.62^{a}	8.40 ± 0.60^{b}	6.60 ± 0.45^{c}
22Sep.	2.68 ± 0.27^{bc}	1.26 ± 0.26^{d}	2.82 ± 0.34^{bc}	3.62 ± 0.30^{ab}	4.06 ± 0.34^{a}	2.32 ± 0.30^{cd}
Overalls dates	36.27 ± 3.87^{a}	3.27 ± 0.32^{d}	4.93 ± 0.33^{cd}	6.18 ± 0.63^{bcd}	8.61 ± 0.52^{bc}	9.77 ± 0.66^{b}

* The means followed by different letters in the same row are significantly different ($p<0.01$, LSD)

Table 3. Spatial distribution parameters (variance to mean ratio) of *T. urticae* and *S. longicornis* on different bean cultivars during 2010.

Cultivars	S^2/m	I_D	Z
T. urticae			
Goli	3.581	175.497	8.886
Akhtar	1.598	78.312	2.666
Sadaf	2.596	127.226	6.103
Parastoo	1.477	72.368	2.182
Talash	3.679	180.271	9.139
Baker	3.076	150.720	7.513
S. longicornis			
Goli	1.705	83.556	3.078
Akhtar	1.091	53.449	0.490
Sadaf	1.431	70.141	1.995
Parastoo	1.086	53.233	0.496
Talash	1.189	58.242	0.944
Baker	1.337	65.531	1.599

Table 4. Spatial distribution of *T. urticae* and *S. longicornis* on different bean cultivars during 2010 using Taylor's power law and Iwao's patchiness regression analysis.

Cultivar	Taylor							Iwao						
	a	b	SE_b	r^2	P_{reg}	t_c	N_{opt}	a	b	SE_β	r^2	P_{reg}	t_c	t_t
Mite														
Goli	-0.179	1.55	0.21	80.8	0.00	2.64	65.46	0.20	1.37	0.12	99.5	0.00	2.99	2.23
Akhtar	0.149	1.28	0.13	88.2	0.00	2.24	111.51	0.58	1.21	0.06	95.2	0.00	3.68	2.23
Sadaf	-0.243	1.84	0.19	89.7	0.00	4.25	129.58	-0.45	1.31	0.09	94.7	0.00	3.26	2.23
Parastoo	0.148	1.11	0.13	85.7	0.00	0.83	97.47	0.39	1.09	0.15	98.1	0.00	0.58	2.23
Talash	0.194	1.69	0.23	47.4	0.01	3.01	75.64	2.37	1.71	0.16	50	0.01	4.37	2.23
Baker	0.099	1.57	0.22	61.6	0.00	2.64	86.28	-0.17	1.29	0.11	93.5	0.00	2.56	2.23
Thrips														
Goli	0.009	1.24	0.02	91.4	0.00	10	7.98	-0.23	1.26	0.08	95.8	0.00	3.13	2.23
Akhtar	-0.034	1.12	0.05	74.6	0.00	2.35	58.91	-0.23	1.23	0.04	72.3	0.00	5.61	2.23
Sadaf	0.139	1.34	0.10	72.7	0.00	3.4	55.04	0.47	1.58	0.25	60.8	0.00	2.33	2.23
Parastoo	0.053	1.01	0.04	42.6	0.01	0.23	27.03	0.44	1.07	0.23	52.2	0.00	0.28	2.23
Talash	-0.147	1.33	0.13	57.6	0.00	2.62	42.14	-0.54	1.40	0.10	68	0.00	3.82	2.23
Baker	0.028	1.19	0.08	71.4	0.00	2.44	29.58	-0.39	1.27	0.10	82.1	0.00	2.62	2.23

Table 5. Parameters of Morisita's index and *Z* calculated of *T. urticae* on different bean cultivars during 2010.

	Goli		Akhtar		Sadaf		Parastoo		Talash		Baker	
Date	I_δ	Z	I_δ	Z	I_δ	Z	I_δ	Z	I_δ	Z	I_δ	Z
11Jul.	1.16	230.36	1.17	37.26	1.45	131.23	1.12	5.84	1.06	31.36	1.22	20.29
18Jul.	1.05	167.28	1.65	23.33	1.25	75.36	1.77	23.47	1.33	131.47	1.43	92.36
23Jul.	1.01	9.15	1.69	27.26	1.37	57.63	1.48	25.32	1.22	63.01	1.25	92.22
30Jul.	1.09	182.64	1.07	2.83	1.51	69.70	1.18	19.09	1.17	59.66	1.11	55.84
5Aug.	1.03	42.86	1.32	6.39	1.16	47.67	1.10	13.42	1.33	91.83	1.29	167.7
13Aug.	1.01	4.47	1.30	36.73	1.13	20.38	1.11	2.54	2.68	499.99	1.23	93.03
19Aug.	1.03	24.39	1.09	16.49	1.22	42.49	1.23	75.72	1.30	56.32	1.31	165.9
28Aug.	1.03	31.04	1.03	3.39	1.08	8.72	1.01	6.30	1.27	35.66	1.03	14.51
2Sep.	1.01	7.46	1.03	6.86	1.38	22.64	1.01	5.43	1.08	38.72	1.09	35.41
10Sep.	1.05	15.64	1.21	23.80	1.21	38.06	1.02	6.34	1.15	36.26	1.07	19.81
16Sep.	1.05	13.39	1.15	25.67	1.12	2.71	1.05	20.23	1.13	32.02	1.08	19.19
22Sep.	1.15	12.24	2.25	55.82	1.37	36.67	1.07	9.51	1.10	14.68	1.40	32.96

Table 6. Estimated parameters by Lloyd's mean crowding to mean for *T. urticae* and *S. longicornis* on different bean cultivars during 2010.

	Goli	Akhtar	Sadaf	Parastoo	Talash	Baker
Mite						
m^*	38.85	3.87	6.53	6.66	11.29	11.84
m^*/m	1.07	1.18	1.32	1.08	1.31	1.21
Thrips						
m^*	3.57	1.12	1.76	1.41	1.92	2.07
m^*/m	1.25	1.09	1.33	1.07	1.11	1.19

Table 7. Statistics of the linear regression between the mean population density of *T. urticae* and *S. longicornis* on different bean cultivars during 2010.

Cultivar	a	b	SE_b	r^2	P_{reg}
Goli	1.08	0.049	0.32	82.7	0.00
Akhtar	0.37	0.203	0.22	56.3	0.00
Sadaf	0.96	0.075	0.37	10.6	0.00
Parastoo	0.65	0.109	0.11	83.6	0.02
Talash	0.97	0.088	0.30	43.1	0.00
Baker	0.67	0.109	0.26	67	0.03