

Spatial Distribution Pattern of *Tetranychus urticae* Koch (Acari: Tetranychidae) on Different *Rosa* Cultivars in Greenhouse Tehran

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The two-spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae), is an economically important pest of ornamental plant in Iran. The population abundance and spatial distribution were studied on five *Rosa* cultivars including Maroussia, Wendela, Elderado, Wenedetta, and Hot Lady during two growing seasons of 2011 and 2012 in greenhouse. The k parameter, index of dispersion, Lloyd's mean crowding, Morisita's index and regression methods (Taylor and Iwao) were used to estimate the spatial distribution pattern of mite. There was improved sampling program by k parameter and coefficients of regression models. The result indicated that the highest population density of *T. urticae* was early of July (2.47 per leaf) and early of September (4.11 per leaf). Also, a sequential sampling plan was developed using the fixed-precision method of Green for estimating the density of the mite. Populations on different *Rosa* cultivars, especially Maroussia, were aggregated during most of the growing season and negative binomial models fit data sets better than the Poisson series. The mean number of two-spotted spider mite per plant had significantly difference between all plant strata. The fitness percentage of cultivar Maroussia *Rosa* revealed a slight tendency towards the Poisson distribution, so that 58 and 14.1 percent of data sets from *T. urticae* on cultivar Wenedetta populations fit the Poisson distribution. These results fully support findings of distribution indices, indicating an aggregated distribution. Determining sampling program and spatial distribution pattern of the pest can effectively help to design and perform of IPM.

Abstract

Keywords: Density, *Rosa*, Spatial distribution, *Tetranychus urticae*.

INTRODUCTION

The two-spotted spider mite, *Tetranychus urticae*, is one of the main pests of agricultural crops due to its broad host range. This polyphagous species feeds on more than 1,100 plant species, from which about 150 are of great economic value. Thus, it represents a very important pest for field and greenhouse crops, ornamentals, annual and perennial plants especially shrub *Rosa*, all over the world (Grbic *et al.*, 2011).

Roses, *Rosa* spp. (Rosaceae) are an exceptionally valuable decorative element of green areas in the cities and important ornamental shrubs. It is the most popular perennial flowering plant in almost all countries. Some species represent an important aromatic plant providing volatile oils which are used for the production of medicines, perfumes, cosmetics and other aromatherapy products. It is cultivated as an agricultural crop in various countries of the northern hemisphere such as Bulgaria, China, Egypt, France, India, Iran, Morocco and Turkey (Demirozer, 2012).

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 estimating plan a reliable sampling program along with suitable techniques should be opted (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).

Spatial distribution is a behavioral response of the individuals of a species to habitat (Young and Young, 1998; Southwood, 1995). The information of spatial distribution (i.e., regular, random or aggregated) can determine what sampling program must be carried out, especially sequential sampling (Feng *et al.*, 1993).

In ecology, it is often difficult to study the movement of individual animal directly, because it is small in size and numerous in populations. Ecologists studied the spatial pattern of individuals of a particular species to infer the underlying behavior rules that govern their movement (Greig-Smith, 1952; Taylor, 1986). Spatial distribution pattern of a pest and its predator is essential information needed in order to analyze their relationships (Hassell and May, 1974).

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 and Croft, 1998). Despite the importance of two-spotted spider mite in ornamental greenhouse, adequate information on the spatial distribution and reliable sampling plans has not been developed for this two-spotted spider mite in *Rosa* greenhouse. The main objectives of this study were: (1) to determine the population density and seasonal dynamics of *T. urticae* on *Rosa* in greenhouse tehran, (2) to describe the within-field distribution characteristics of the *Rosa* two-spotted spider mite population and the effects of some cultivars of roses (*Rosa* spp.) (3) to develop fixed-precision sequential sampling plans (Green, 1970) for estimating *T. urticae* density on ornamental *Rosa*.

MATERIALS AND METHODS

Sampling program

Samples were taken twice weekly on Pakdasht in Tehran Province on 34 dates from 4 July to 29 September 2011 and 26 dates from 12 July to 20 September 2012 on five *Rosa* cultivars including Maroussia, Wendela, Elderado, Wenedetta, Hot Lady. The greenhouse were divided into 10 blocks of the same size; then inside each block, plants were randomly selected along a diagonal transect and three leaves from the upper, middle and bottom strata of the plants were taken randomly on side branches from each plant. The number of leaves (n) sampled on each sampling date was calculated using equation 1: (Southwood, 1995)

$$n = \left(\frac{ts}{d\bar{x}}\right)^2 \quad (1)$$

Where N , t , s , d and m are sample size, t-student, standard the individuals of a species to habitat (Southwood, 1995; Young and Young, 1998). The deviation, desired fixed proportion of the mean and the information of special distribution (i.e., regular, random or mean of primary data, respectively (Southwood, 1995).

Relative variation (RV) was used to compare to be carried out, especially sequential sampling (Feng *et al.*, 1993). Efficiency of various sampling methods (Hillhouse and Pitre, 1974). The RV was a successful management of two-spotted spider mite strongly calculated using equation 2:

$$RV = \left[\frac{S_E}{m}\right] 100 \quad (2)$$

Where S_E and m are the standard error of the mean and the need to be considered (Pedigo, 1994). For example, compared with mean of primary sampling data, respectively. Leaves were transported to the laboratory and the number of two-spotted spider mite was counted separately under the stereomicroscope.

Spatial distribution

Distribution of population was useful for estimating two-spotted spider mite density on five cultivars *Rosa* including Maroussia, Wendela, Elderado, Wenedetta, Hot Lady classified using calculation of the variance to mean, which in turn, would be valuable for (S^2/m) . Departure from the random distribution was then ecological and pest management studies. Tested by calculating the index of distribution (I_d), as The objectives of the present study were to determine using equation 3:

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

Where n denotes the number of samples (Southwood and Hendrson, 2000). This index was tested by Z values to determine using equation 4:

$$Z = \sqrt{2I_d - \sqrt{2v - 1}} \text{ and } v = n - 1 \quad (4)$$

Morisita's coefficient of distribution: The uneven distribution coefficient (I_6) was calculated through the equation 5:

$$I_6 = \frac{n \sum xi(xi-1)}{N(N-1)} \quad (5)$$

Where n , xi and N are the number of sample units, the i number of individuals in each sample unit and total number of individuals in n samples, respectively. To determine whether the sampled population was significantly different from random distribution; the large sample test of significance was applied using Z values as follows equation 6:

$$Z = \frac{I_6 - 1}{\left[\frac{2}{nm^2}\right]^{\frac{1}{2}}} \quad (6)$$

Where m and n are the mean population density per leaf in each sampling date and the number of sample units, respectively (Pedigo and Buntin, 1994).

The spatial distribution of the *T. urticae* was evaluated by using the parameters of **Taylor's power law**. This law describes the regression between logarithm of population variance and logarithm of population mean according to the equation 7:

$$\text{LOG}(S^2) = a + b\text{LOG}(\bar{X}) \quad (7)$$

Where, S^2 is the population variance, \bar{X} is population mean, a is the Y-intercept and b is slope of regression line. This equation can transform as equation 3:

$$S^2 = a\bar{x}^b \quad (8)$$

Iwao's patchiness regression models: Iwao's patchiness regression method was applied to quantify the relationship between mean crowding index (m^*) and mean (m) using the following equation 9:

$$m^* = \alpha + \beta m \quad (9)$$

Where α and β refer to the tendency to crowding/repulsion and the distribution of population on space.

The value of F and P acquired from regression equation were used to test whether the Taylor's (b) and Iwao's (β) coefficients were significantly different from 0. In addition, to test for their difference from 1, the statistic t (as $t = \text{slope} - 1 / SE_{\text{slope}}$) was used. Here, slope and SE_{slope} are Taylor's or Iwao's coefficient and their standard errors in regression equations, respectively. Since Taylor's and Iwao's coefficient were estimated by two-year, the difference between year's distribution coefficients, were tested by the statistic t equation 10 (Feng *et al.*, 1993; Iwao and Kuno, 1968):

$$t = \frac{b_1 - b_2}{\sqrt{SE_1^2 - SE_2^2}} \quad (10)$$

Here, b_1 (and SE_1) and b_2 (and SE_2) are the Taylor's and Iwao's coefficient (and its standard error) for the first and the second year, respectively.

The data of two years were integrated and a total distribution coefficient was estimated only when the difference between coefficients of two years was not significant.

RESULTS AND DISCUSSION

Data sets from counts of different cultivars *Rosa* including Maroussia, Wendela, Elderado, Wenedetta, Hot Lady, of *T. urticae* fit the negative binomial better than the Poisson series (Table 1). When T-statistics were used for spatial analysis, 62 percent of total population data sets fit the negative binomial distribution. The percentage fit of the negative binomial was obviously reduced (28 percent) when the Chi-square test was used to test the fit between observed and expected frequencies. The fitness percentage of cultivar Maroussia *Rosa* revealed a slight tendency towards the Poisson distribution, so that 58 and 14.1 percent of data sets from *T. urticae* on cultivar Wenedetta populations fit the Poisson distribution.

Table 1. Percentage fit of *T. urticae* different cultivars *Rosa* to negative binomial and Poisson frequency distributions, using two *Chi-square* and T-statistics goodness of fit tests.

Cultivars	Goodness of fit test			
	Chi-square		T-statistics	
	NB ^a	P ^b	NB ^a	P ^b
Maroussia	62	12.1	51	10.8
Wendela	58	21.2	54	12.1
Elderado	56	26.1	48	18.3
Wenedetta	28	2.1	34	6.2
Hot lady	47	7.3	45	8.2
Total	28	1.3	31	9.5

a Negative binomial, b Poisson

Table 2. Estimated parameters from primary sampling of *T. urticae* on shrub rosa during 2011-2012.

Growing season	<i>n</i> ^a	<i>S</i> _c ^b	<i>Sd</i> ^c	<i>RV</i> ^d	<i>m</i> ^e	<i>d</i> ^f	<i>N</i> ^g
2011	41	0.041	0.18	9.1	0.31	0.35	38
2012	41	0.035	0.11	8.6	0.23	0.35	36

(a) Number of samples; (b) Standard error of the mean; (c) Standard deviation; (d) Relative variation; (e) Mean of primary data (f) Desired fixed proportion of the mean, (g) Sample

Table 3. Regression statistics of Taylor's power law for of *T. urticae* populations on shrub Rosa during growing season 2011-2012.

Growing season	<i>b</i> ± <i>SE</i>	Loga± <i>SE</i>	<i>R</i> ²	F	T	Df
2011	1.321±0.057	0.345±0.047	0.973	1204.7**	11.25*	41
2012	1.345±0.036	0.311±0.078	0.968	644.9**	8.51*	38
Oveall	1.421±0.047	0.451±0.023	0.962	231.451**	4.21*	79

*and** show significant difference at 0.05 level with 0 and 1, respectively.

Dispersion indices

The results of primary sampling showed that the reliable sample size with maximum variation of 35% was 38 and 36 for 2011-2012 growing seasons, respectively. The relative variation (*RV*) of the primary sampling was 9.1 and 8.6 for the previous growing seasons, respectively. These *RVs* were very appropriate for the sampling program (Table 1). The Taylor's equations for the growing seasons were obtained as $\log S^2 = 0.256 + 1.421 \log m$ ($F_{38} = 1204.7$, $P < 0.05$; Table 3) and $\log S^2 = 0.311 + 1.345 \log m$ ($F_{38} = 644.9$, $P < 0.05$), both with a great degree of fit (> 0.90). In addition, the coefficient *b* was significantly greater than 1 (2011: $t_{41} = 11.25$, $P < 0.05$; 2012: $t_{38} = 8.51$, $P < 0.05$; Table 3), implying an aggregated distribution. The Iwao's equation for the growing seasons were obtained as $m^* = 0.458 + 1.367m$ ($F_{41} = 1448.4$, $P < 0.05$; Table 4) and $m^* = 0.378 + 1.356m$ ($F_{38} = 709.4$, $P < 0.05$), both with a great degree of fit (> 0.90). In addition, the coefficient was significantly greater than 1 (2011: $t_{41} = 11.20$, $P < 0.05$; 2012: $t_{38} = 10.85$, $P < 0.05$; Table 4), implying an aggregated distribution.

Previous studies have been stated an aggregated form for the spatial distribution pattern of *T. urticae*. Population on other crops such as cotton (Ahmadi *et al.*, 2005; Mehrkhou *et al.*, 2008) and strawberry (Greco *et al.*, 1999). Here, the estimated Taylor index *b* was between 1.36 and 1.35. In other studies, the estimated values of this index has been ranged from 1.4 to 1.6, for example 1.3 on apple (Slone and Croft, 1998), 1.4 on pear (Takahashi *et al.*, 2001) 1.5 *T. urticae* on soybean (Sedaratian *et al.*, 2008).

The interaction between plant strata and sampling dates significantly influenced the mean number of two-spotted spider mite per strata Rosa plant ($F = 12.43$, $df = 79$, $p = 0.002$). The mean number of two-spotted spider mite per plant between all plant strata was significantly different ($F = 127.32$, $df = 79$, $p = 0.0006$). The lower stratum had the highest mean number of two-spotted

Table 4. Regression statistics of Iwao's power law for of *T. urticae* populations on shrub Rosa during growing season 2011-2012.

Growing season	<i>b</i> ± <i>SE</i>	Loga± <i>SE</i>	<i>R</i> ²	F	T	Df
2011	1.367±0.043	0.458±0.049	0.930	1448.324**	11.20*	41
2012	1.356±0.051	0.378±0.066	0.944	709.413**	10.85*	38
Oveall	1.231±0.061	0.523±0.051	0.951	961.330**	22.29*	79

*and** show significant difference at 0.05 level with 0 and 1, respectively.

spider mite per plant and was significantly different ($p < 0.05$) than the middle and upper strata. The number of two-spotted spider mite per plant was also found to differ significantly ($F = 84.39$, $df = 79$, $p = 0.0011$) between the sampling dates.

To explain these differences, some researchers believe that the spatial distribution of *T. urticae* on other crop aggregated than on other host plants. But considering the result of similar studies in various parts of the world, It might be concluded that the differences are at least partly caused by the different host plants, pest population density and environmental conditions such as weather and pesticide applications (Zenjun, 1997; Yan, 1998).

The density of per stratum per plant was significantly higher at the lower stratum ($p < 0.05$) than the other two strata throughout the cropping period except at 79, where the number of two-spotted spider mite at the middle stratum was higher than the other two strata. This indicated that two-spotted spider mite generally prefer the lower leaves of plant than leaves of middle and upper strata of the plant. Similar result was also reported by (Pakyari, 2012) who evaluated similar aspects on several bean varieties.

Spatial distribution models

When the spatial distribution models were fitted on the population density of *T. urticae*, negative binomial model showed the best fit (2012: $\chi^2=21.08$, $P>0.95$; 2013: $\chi^2=14.51$, $P>0.95$). These results fully support findings of distribution indices, indicating an aggregated distribution. Although distribution indices showed random distribution in some planting, total population distribution during growing season matched the aggregated model. The aggregated distribution of a population is likely to be confirmed by aggregated indices, but its frequencies might not be correspondent to negative binomial distribution. Further studies are needed to evaluate *T. urticae* population distribution fitting is by other aggregated distributions than negative binomial distribution. In this case, the recommendations about the kind of spatial distribution and proper test for their fitting are more reliable. There are some studies that describe the spatial distribution of *T. urticae* on rose and other crops, using dispersion indices that only show the aggregation or randomness of behavior of the two-spotted spider mite population. In this study, we examined in addition the fitness of the population data of the *T. urticae* to the negative binomial and poisson frequency distribution in order to obtain the mathematical distribution models.

Spatial distributions is one of the most important ecological characters of a population that can be used in extended sampling programs for pest managements (Kuno, 1991). In an 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 and Young, 1998).

CONCLUSION

Our study indicated that the spatial distribution of *T. urticae* in *Rosa* greenhouse was of aggregated from and the fixed precision sampling scheme developed using Green's method was acceptable for estimating two-spotted spider mite densities in commercial *Rosa* greenhouses. Therefore, the sampling strategies provided here can be used to obtain a rapid estimate of two-spotted spider mite densities with minimal effort. In addition, the knowledge of density level of *T. urticae* would provide the solid basis for optimal decision- making in IPM programs.

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الگوی توزیع فضایی کنه دو نقطه‌ای *Tetranychus urticae* Koch Acari: Tetranychidae روی ارقام مختلف رز در گلخانه تهران

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کنه دو نقطه‌ای (*Tetranychus urticae* Koch (Acari: Tetranychidae) یکی

از آفات مهم اقتصادی گیاهان زینتی در ایران می‌باشد. فراوانی جمعیت و توزیع فضایی پنج رقم رز شامل *Maroussia*، *Wendela*، *Elderado*، *Wenedetta* و *Hot Lady* در طول دو فصل رشد در سال‌های ۱۳۹۰ و ۱۳۹۱ در گلخانه رز پاکدشت تهران مطالعه شد. پارامتر *k*، شاخص پراکندگی، میانگین تراکم لیود، شاخص مورسیتا و روش‌های رگرسیون (*Iwao* و *Taylor*) برای تخمین الگوی توزیع فضایی بکار برده شد. برنامه‌های اصلاحی نمونه‌برداری توسط پارامتر *k* و ضرایب مدل‌های رگرسیون وجود داشت. نتایج نشان داد که بیشترین تراکم جمعیتی *T. urticae* اوایل تیر (۲/۴۷) در هر برگ) و اوایل شهریور (۴/۱۱ در هر برگ) بودند. هم‌چنین یک برنامه نمونه‌برداری دنباله‌ای بصورت گسترده با استفاده از مدل گرین برای تخمین تراکم کنه استفاده شد. جمعیت روی ارقام مختلف رز به‌ویژه *Maroussia*، در اکثر فصل رشد بصورت تجمعی بود و مدل‌های دو جمله‌ای منفی مجموعه داده‌ها را بهتر از مدل پویسون تطبیق دادند. میانگین تعداد کنه دو نقطه‌ای در هر گیاه بین قسمت‌های مختلف آن اختلاف معنی‌داری داشت. درصد تطبیق رقم رز *Maroussia* نشان داد گرایش کمی به سمت مدل پویسون هم دارد. هم‌چنین ۵۸ و ۱۴/۱ درصد از مجموعه داده‌های *T. urticae* بر روی رقم *Wenedetta* تطبیق بیشتری با توزیع پویسون داشت. این نتایج بطور کامل یافته‌های شاخص پراکنش را تأیید می‌کند و نشان‌دهنده توزیع تجمعی است. تعیین برنامه نمونه‌برداری و الگوی توزیع فضایی آفت بر روی طراحی و اجرای مدیریت تلفیقی آفت می‌تواند اثرگذار باشد.

چشم‌پند

کلید واژگان: تراکم، توزیع فضایی، رز، *Tetranychus urticae*