

Spatial Distribution of Mulberry Thrips, *Pseudodendrothrips mori* Niwa (Thysanoptera: Thripidae)

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Abstract: *Pseudodendrothrips mori* is a serious pest to mulberry trees and its infestation affects the qualitative and quantitative characteristics of mulberry leaves consumed by silkworm. The spatial distribution of mulberry thrips within plant and orchard was assessed using Taylor's power law and Morisita's index of dispersion. The results showed that *P. mori* populations were localized in certain parts of the trees and fields. Distribution of thrips within plant showed that the larval instars were located on lower canopy (leaves 5–10 from top) of trees but adults preferred the upper canopy (leaves 1–5 from top). The thrips density did not vary significantly among the leaf direction inside the trees. The thrips tended to be more accumulated on the trees located in East, South and North than in Center and West of orchard. The distributions of *P. mori* adults and larvae on the leaves were aggregated.

Key words: Mulberry thrips; *Pseudodendrothrips mori*; spatial distribution; Taylor's power law; Iran

桑蓟马在桑树中空间分布的研究

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摘要: 桑蓟马 *Pseudodendrothrips mori* 是桑树的一种主要害虫。它的寄生直接影响供桑叶的质量和产量。我们通过泰勒幂法则和 Morisita 的散度指标对桑树蓟马在植株和桑园内的空间分布进行检验, 结果显示: *P. mori* 种群在植株内和桑园里的分布都存在局部化。桑树中蓟马的分布在树内显示出幼虫蓟马位于低层(从上面叶子起 5—10 层), 但成虫更喜欢上层(从上面叶子起 1—5 层)。同一植株叶子的不同方向上蓟马密度没有出现明显变化。桑园内蓟马主要分布在桑园东部、南部和北部的植株上, 中部, 西部植株上的蓟马密度较低。*P. mori* 的成虫和幼虫在叶子上的分布呈现明显聚集化。

关键词: 桑蓟马; *Pseudodendrothrips mori*; 空间分布; 泰勒幂规律; 伊朗

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The sericulture has a history of over 4000 years in east Asia and is an important part of the national economy. Mulberry leaves are the exclusive food for the silkworm, *Bombyx mori*. Feeding silkworms with mulberry leaves that have been damaged by mulberry thrips, *Pseudodendrothrips mori* (Niwa, 1908) causes

low development and increases larval mortality; consequently, there is a drop in the production of silkworm cocoons and a reduction in profit (Etebari et al, 2004).

P. mori was recorded for the first time in 1999 in mulberry orchards of Guilan province, North of Iran (Etebari et al, 1999). It was reported that feeding of

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thrips decreases the leaf protein and moisture contents by 17.8 and 3.57%, respectively. Other investigations demonstrated that the life cycle of this insect took 29.95 days from egg to adult under laboratory conditions and had four generations in a year in Guilan province of Iran (Jalali et al, 2001; Etebari et al, 1999). All stages caused damages to trees by sap extraction, which resulted in leaf necrosis, drying of growing shoots and dropping of premature leaves (Cappelozza, 1987). Laboratory and field investigations showed that Kemuchi variety was the most susceptible variety and Shin-Ichinose was relatively resistant to this insect in Guilan (Etebari et al, 2000).

The importance of spatial heterogeneity comes from its main role in ecological theories and its practical role in population sampling theory and in development of rational pests, management strategies as well as enhancement and conservation of natural enemies (Wang et al, 2004). The first step in the development of sequential sampling programs is to determine the spatial distribution of population being sampled. This determination is necessary to select the appropriate procedure for the development of sequential sampling system (Hamilton et al, 1998). Insect populations are known to follow three distinct distribution patterns (Southwood, 1978), viz. (i) binomial, uniform or regular, (ii) random or poisson, and (iii) negative binomial, aggregated or clumped. However there is no published information on within-plant and within-field distribution of *P. mori*. If thrips are highly aggregated, more samples will be needed than their regular distribution. The degree of aggregation may also reveal information about thrips behaviour (Kirk, 1997). So, knowledge of the spatial distribution of *P. mori* is needed to provide information for the possible management strategy. Also economic threshold needs a careful sampling consideration for both thrips distribution within the tree and the among different trees in mulberry orchards. The present research hoped to point out the spatial distribution of this thrips in orchard that can be used in developing a sampling plan with an acceptable precise level.

1 Materials and Methods

1.1 Study site and Sampling

The study was carried out in mulberry orchards of Iran Sericultural Research Center (ISRC), in Pasikhan region (North of Iran, Guilan Province). In the study

site, five individual trees were selected in each orientation (North, South, West and East) and also in the center of orchards. The sampling is started in July 20 and leaves were collected every week until September 20, also the previous studies showed that at this time, the population of thrips is in its highest density (Jalai et al, 2001). Each tree was divided into upper (leaves 1–5 from top) and lower canopy (leaves 5–10 from top) and in each canopy four leaves from different orientations (N, S, W, and E) were collected separately in plastic bags and kept in fridge for 2 hours. The number of first, second instar larvae and adults of *P. mori* was counted on leaves.

1.2 Statistical and Data analysis

The spatial distribution patterns of *P. mori* were determined by using Taylor's power law (Taylor, 1961). Taylor's power law parameters were obtained by the regression of \log_{10} -transformed variances, s^2 , on \log_{10} -transformed mean numbers of *P. mori* adults and larvae per sample, i.e., by means of the linear regression model: $\log s^2 = \log a + b \log x$ (Taylor 1961). According to this model b value > 1 denotes a population with an aggregated distribution, b value significantly < 1 denotes a regular distribution, and b value not significantly different from 1 denotes a random distribution. The fit of each data set to the linear regression model was evaluated by calculating the r^2 value. The Student t -test was used to determine if the slopes (b values) obtained by means of the linear regression procedure were equal to 1, significantly greater than 1 or significantly less than 1.

Also, Index of Dispersion (ID) was calculated for all series of data with the formulae $ID = S^2/m$, where if $ID = 1$ the dispersion is random, $ID = 0$ shows a uniform distribution and for clumped pattern ID should be more than 1. In order to compare different models MI (Morisita's Index of Dispersion) and MSI (Morisita's Standardized Index of Dispersion) indices were measured to check if MSI is more than zero the clumped situation or less than zero the uniform situation is shown (Pourbabaei, 2004).

Weekly thrips counts were analyzed to determine significant level of thrips density in the sampling parts ANOVA (SAS, 1997). For the analysis, data were transformed into natural logarithms, but all the data are presented in original units as means \pm SE. Means were separated using Duncan Multiple Range Test (DMRT).

2 Results and Discussion

The obtained results showed significant differences ($P < 0.05$, $df = 1$) among mulberry thrips population collected at two different heights (lower and upper canopy), five positions of trees in orchard (North, South, East, West and center), three different stages of thrips development (1st and 2nd larva and adult) and three varieties of mulberry. But there was no significant difference among thrips populations at four directions of the trees (Tab. 1).

Tab. 1 Analysis of variances for characters and interactions for mulberry thrips, *Pseudodendrothrips mori*

Parameters	df	F	P
Position of tree	4	6.01	0.0001*
Height of canopy	1	95.96	< 0.0001*
Thrips instar	2	64.39	< 0.0001*
Leaf direction	3	1.03	0.38
Variety	2	64.39	0.0001*
Height of canopy × Leaf direction	3	0.86	0.46
Height of canopy × Thrips instar	2	58.53	0.0001*
Height of canopy × Variety	2	40.46	0.0001*
Thrips instar × Leaf direction	6	0.70	0.65
Thrips instar × Variety	4	31.27	0.0001*
Variety × Leaf direction	6	1.22	0.29

* If $P < 0.05$, then the means are significantly different

Abundance of mulberry thrips was higher in East, South and North trees in orchard than Center and West trees especially in Km variety (Fig. 1). Pearsall and Myers (2001) showed that flight of Western flower thrips, *Frankliniella occidentalis* (Pergnade) in Nectarine orchards of British Columbia, appeared likely to be wind driven into some orchards. Also it was reported that western flower thrips densities were higher on sticky cards in orchards located in the South comparing with the North (Pearsall and Myers, 2001). From this

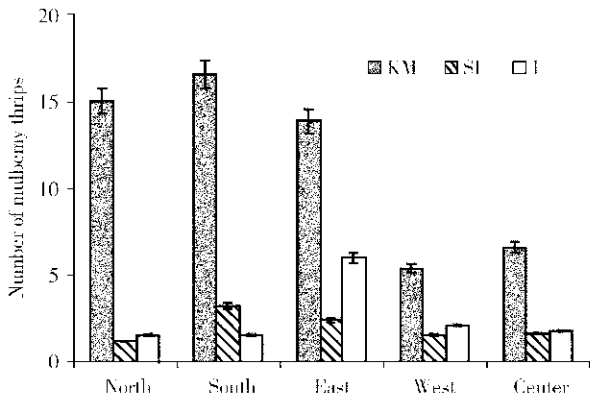


Fig. 1 Mulberry thrips density in five positions of different varieties in orchard

research it is suggested that the average thrips densities in all varieties were higher on Eastern (Mean \pm SE: 7.553 ± 18.11), Southern (7.091 ± 24.11) and Northern (5.954 ± 20.966) parts of trees. Although the thrips population on Eastern and Southern parts of trees were higher than North, these differences were statistically not significant ($P > 0.05$, $df = 4$).

In all mulberry varieties, larval instars had the highest density on the lower canopy, while adults preferred the upper parts of the plant canopy (Fig. 2). Kirk (1997) reported that the site occupied by thrips can differ between adult and larvae, in which adults are often nearer the top of the plant and larvae lower down. At finer scale, there can be differences between leaf ages and between the upper and lower sides of leaves. It suggested that the distribution patterns are mainly related to feeding behavior but oviposition and mating behavior have an important role in thrips distribution.

Pearsall and Myers (2001) showed that western flower thrips moved into orchards equally at ground level and at the 1 m height, which was the height of the tree canopy. This might be due to the tendency of avoiding the effects of wind at higher levels of ground and tree for the thrips. Temperature is another factor known to influence aerial dispersal of invertebrates (Taylor, 1963). That could be responsible for establishment of thrips in different tree height levels. Since adult thrips are thought to make flights just above the plant canopy (Brodsgaard, 1989), it is reasonable to expect that most adults would be found in the upper canopy. The limited distribution of immatures within the lower canopy suggests that *P. mori* may prefer a protected habitat from direct sunlight and wind, as do other species of thrips (Picket et al, 1988). In this

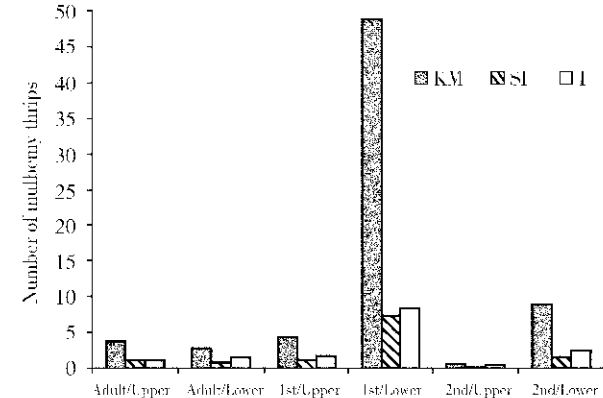


Fig. 2 Mulberry thrips density in three different developmental stages at two heights (lower and upper canopy) in three varieties

case, Seal et al (2006) found that *Scirtothrips dorsalis* Hood adults and larvae were abundant on terminal leaves of ‘Scotch Bonnet’ pepper plants followed by middle leaves, lower leaves, and reproductive parts, while Reitz (2002) mentioned that adults of *Frankliniella* species tended to be in flowers in the upper part of tomatoes whereas more immature thrips occur in the lower parts of the plant canopy.

The analysis of thrips densities on the leaves in the four directions of the trees showed that there was no difference between directions of leaves in the trees (Fig. 3) ($P = 0.38$, $df = 3$). Also interactions of leaf direction with other variations were not significantly different (Tab. 1).

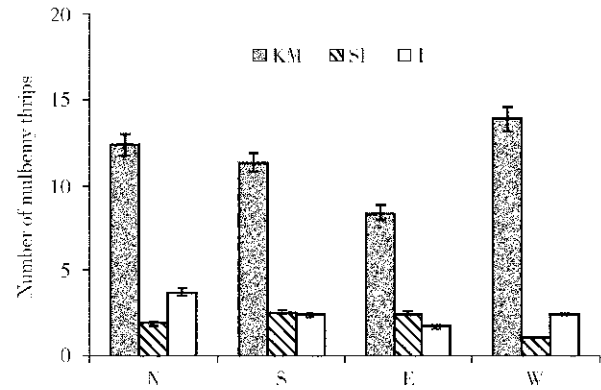


Fig. 3 Mulberry thrips density in four directions of each variety of mulberry trees

The results showed that the thrips was available in larger numbers in KM variety (Mean ± SE: 11.583 ± 28.434) than the two other varieties (I: 2.5685 ± 8.784, SI: 1.9789 ± 7.319). Etebari et al (2000) with field and laboratory experiments revealed that KM was the most susceptible and SI was the most resistant to *P. mori*. Underwood et al (2005) suggested that induced and constitutive resistance could affect the spatial distribution of herbivore damage differently.

In recent study, the most abundant thrips stage was the 1st instar larva (mean: 12.0617) in comparison of the 2nd instar (mean: 2.2724) and adult (mean: 1.7968), as has been noted by other researchers (Jalali et al, 2001). It may be because of presence and efficiency of the thrips’ natural enemies on 2nd instar larva.

In all of the thrips life stages (1st and 2nd larva and adult) b value was higher than 1st, hence the thrips were aggregated on the trees (Tab. 2). The highest slope value was noted for the adult ($b =$

6.4281). Also the values of r^2 obtained with Taylor’s power law were higher for all stages. This indicates a good fit of model to the data on thrips using leaves as the sampling unit. Because thrips tend to aggregate in certain location for mating (Reitz, 2002), maybe it is reasonable to explain significant difference of adults aggregation in comparison of larval instars in Tab. 2. This aggregated pattern of distribution in field is also typical for other thrips species such as *Scirtothrips dorsalis* (Seal et al, 2006), *Thrips palmi* (Seal 1996, Seal and Stansly, 2000) and *Frankliniella occidentalis* (Rhainds and Shipp, 2003).

Tab. 2 Distribution of mulberry thrips based on Taylor’s Power Law

Stage	r^2	a	b
Adult	0.803	6.473	6.428 AGG*
1st larva	0.954	0.182	1.947 AGG
2nd larva	0.944	1.35	2.774 AGG

* AGG: $b > 1$ shows aggregated distribution.

The data in Tab. 3, which outline MSI, MI, ID indices also shows the aggregate dispersion in all the larval stages and adults. ID is not unique in all cases. The first instar larvae has more indices and this demonstrates aggregate dispersion in this stage of insect life (Tab. 3). Therefore, all models presented an aggregate dispersion for mulberry thrips.

Understanding the causes and consequences of dispersal, it is crucial to determine the impact of dispersal on the spatial structure of animal populations (Nathan 2001). In several phytophagous insects, crowding of the host plant is correlated with a high incidence of dispersal, either as a result of high population density per se or intense feeding by herbivores on their host plant (Denno and Peterson 1995, Herzig 1995, Herzig and Root 1996, Dixon 1998, Rhainds et al, 2002). Density-dependent dispersal has a strong influence on the population dynamics of phytophagous insects because it stabilizes local populations and relatively generates uniform, synchronous distribution of insects, especially when adults preferentially colonize hosts with a low abundance of conspecifics (Ruxton and Rohani 1998).

Spatial distribution of insects within trees may be affected by numerous factors including parasitism and predatism (Hassell, 1978; Ehler, 1986), including dispersal ability of immatures or adults (Witham, 1981), competition (Hails and Crawley, 1991), host plant resistance (Underwood et al, 2005) and plant

Tab. 3 Some statistical parameters and distribution index for mulberry thrips

Direction	Statistical Parameters	Lower Crown			Upper Crown		
		Adult	1 st	2 nd	Adult	1 st	2 nd
			Instar	Instar		Instar	Instar
Northern	Mean	1.600	25.22	4.367	1.978	2.522	0.222
	SE	0.218	4.630	1.054	0.332	0.364	0.070
	ID	2.680	76.49	22.87	5.010	4.733	2.000
	MI	2.045	3.961	5.967	3.017	2.470	5.684
	MSI	0.505	0.516	0.527	0.510	0.508	0.518
Southern	Mean	1.778	20.85	3.456	2.089	2.933	0.478
	SE	0.310	3.900	0.751	0.350	0.772	0.220
	ID	4.876	65.65	13.92	5.268	18.29	9.135
	MI	3.170	4.070	4.711	3.031	6.852	18.23
	MSI	0.511	0.516	0.520	0.511	0.532	0.593
Eastern	Mean	1.633	16.28	3.376	1.956	2.089	0.289
	SE	0.289	2.889	0.636	0.366	0.392	0.070
	ID	4.615	46.12	10.823	6.181	6.634	1.886
	MI	3.204	3.741	3.895	3.635	3.681	4.154
	MSI	0.511	0.515	0.516	0.514	0.514	0.512
Western	Mean	1.533	23.06	5.689	2.178	2.311	0.289
	SE	0.242	4.607	1.864	0.309	0.555	0.111
	ID	3.447	82.82	54.97	3.958	11.98	3.831
	MI	2.590	4.509	10.401	2.350	5.723	11.07
	MSI	0.508	0.520	0.553	0.507	0.525	0.551

SE: Standard Error; ID: Index of Distribution; MI: Morista’s Index of Distribution; MSI: Morista Standardized Index of Distribution

phenology (Pearsall and Myers, 2001; Faeth et al, 1981). These results indicate that the mulberry thrips is more abundant on KM variety and in 1st instar larva. *P. mori* is found mainly on the lower leaves of mulberry, which may avoid the influences of wind speeds and high temperature on the thrips. Also the thrips was more abundant on trees located in East, South and Northern parts of orchard. It suggests that the sampling should involve all the surface of orchards. The thrips distribution was not related to leaf direction in the tree.

This study provides the first experiment on the spatial distribution of *P. mori*. Our data indicate that mulberry thrips were spatially distributed on the trees. Also we found that *P. mori* populations were localized

in certain parts of the tree. The thrips is often recorded with high population densities in mulberry orchards in Iran and elsewhere (Cappellozza and Miotto, 1987; Etebari et al, 1999; Etebari atal, 2004; Jalali et al, 2001; Yin et al, 1994). Results in this paper can be used for the development of sampling protocols and also in the management of *P. mori* in orchards. Additional research is required in order to assess these variables for a wider range of cases, probably the effect of parasitism and predation on this thrips and finally to designate an action threshold for this pest in this region.

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