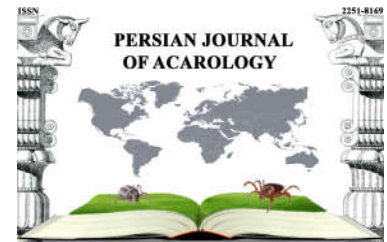




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## Article

# Effect of initial infestation on population fluctuation and spatial distribution of *Panonychus citri* (Acari: Tetranychidae) on Thomson navel orange in Ghaemshahr, Iran

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### ABSTRACT

Citrus red mite (CRM), *Panonychus citri* (McGregor) (Acari: Tetranychidae) is one of the important citrus pests in different parts of the world including northern Iran. Population fluctuation and spatial distribution pattern of this pest was studied in Ghaemshahr, northern Iran during 2016–2017 in different initial infestation treatments (paired-treatment and multiple-treatment experiments) that had been designed for crop loss assessment caused by CRM. Taylor's Power Law and Iwao's Patchiness Regression methods were used to determine the spatial distribution pattern of CRM. The results showed that the highest population density of the pest was during summer of 2016 and 2017 with an average of 127.3 and 91.15 CRM per leaf, respectively, and the population declined in the fall with an average of near zero mites per leaf. The spatial distribution pattern of CRM in both years and both methods was aggregated with an exception in which it was random. It could be concluded that initial infestation with different densities of the pest affected the population fluctuation of the pest during the growing season and somewhat the spatial distribution pattern of CRM.

**KEY WORDS:** Citrus red mite; Mazandaran Province; population fluctuation; spatial distribution pattern; Thomson navel orange.

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## INTRODUCTION

The citrus red mite (CRM), *Panonychus citri* (McGregor) (Acari: Tetranychidae) is a serious pest of citrus plants in many parts of the world (Jeppson *et al.* 1975; Jamieson *et al.* 2005; Childers *et al.* 2007) including northern Iran. Although different species of citrus plants are major hosts of CRM, the life cycle of the pest can be completed on other hosts such as rose, apple, pear, peach, plum, and several evergreen ornamentals (Bolland *et al.* 1998). On citrus, the mites feed primarily on the upper surface of mature leaves, fruit and young branches, where they produce grayish or silvery spots (stippling) (Prischmann *et al.* 2005). Under severe infestation, the mites can cause heavy leaf abscission, twig and branch dieback and fruit drop, especially when accompanied by other stressful factors such as dry season and drought (Jeppson *et al.* 1975). CRM has a short development time ranging from 9 to 52 days, depending on the temperature. As a result, the pest can produce up to 19

annual generations, the majority of which occur during the spring-summer period (Faraji 1992). Besides short generation time, high reproductive potential, and resistance development to convenient pesticides (Fernandez *et al.* 1997; Devine *et al.* 2001; Stump and Nauen 2001), the emergence of CRM as an economically important pest is largely attributed to the disruption caused in the orchard ecosystem, mainly by the application of broad-spectrum pesticides against other pests, leading to decrease in populations of natural enemies (Kasap 2005).

Analysis of spatial distribution patterns and population dynamics of pests and their natural enemies is crucial for designing efficient and cost-effective sampling plans for population studies (Deligeorgidis *et al.* 2002). Apart from this, field analysis of spatial distribution and population fluctuations of pests provide basic and useful information for development of appropriate measures for sustainable management of the pest (Pedigo 2002). For example, the efficiency of the two major families of predatory mites (*i.e.* Phytoseiidae and Stigmaeidae), which are widely used for biological control of spider mites, has been reported to vary depending on the host density.

The spatial distribution and population density of spider mites and their natural enemies has been shown to be affected by a variety of biotic and abiotic factors, including temperature, relative humidity, precipitation, host species/cultivar, and pesticides application (Jeppson 1963; Ikegami *et al.* 2000). Generally, high temperature (up to 40°C) and low relative humidity can accelerate the population growth of CRM (Swirski *et al.* 1986). However, temperatures higher than 40°C are likely to limit the population growth, a condition that is usually experienced during mid-summer (Kasap 2005). On the other hand, high relative humidity negatively affects the population density of CRM, probably due to increased abundance of natural enemies, especially entomopathogenic fungi. As a result, despite the fact that CRM is known to occur on host plants throughout the year under suitable climatic conditions (Faraji 1992; Futch 2011), one or two major population peaks, occurring at mid-spring to early summer and early- to mid-autumn, seem to be of higher importance in terms of pest outbreak (Faraji 1992; Kasap 2005; Futch 2011).

CRM occurs on citrus trees and some ornamental plants throughout the year in northern Iran, where it produces up to 19 generations per year (Faraji 1992). The shortest (9 days) and longest (50 days) development times of the pest occur during summer and winter months, respectively (Jeppson *et al.* 1975; Faraji 1992). Although several studies on the biology, chemical control and natural enemies of CRM have been conducted (Kasap 2005), little is known about its spatial distribution on citrus trees. Therefore, due to the economic importance of CRM, as well as the lack of information on its population changes and patterns of distribution on Thomson navel oranges in citrus areas of northern Iran, the present study aims to achieve the above knowledge and, ultimately, to monitor population changes of this pest in order to determine the best possible time to control it. Also, the findings from this study can be used in integrated pest management programs in citrus orchards.

## MATERIALS AND METHODS

### *Study location*

This study was conducted in the Horticultural Research Station located at Ghaemshahr, (Mazandaran Province, northern Iran) during the growing seasons of 2016 and 2017. Initially, 30 Thomson navel orange trees upon Citrange rootstock were selected. Each selected tree was about 6–7 years old and about 2–2.5 meters tall. In addition, one tree was appointed as marginal.

### *Sampling program*

In this study, a sampling unit was one orange leaf which was randomly picked from middle height of the tree. All samplings were performed weekly from 27<sup>th</sup> May to 4<sup>th</sup> November 2016 and from 18<sup>th</sup> May to 6<sup>th</sup> November 2017, during mid-morning hours (9:00–11:00 AM).

In order to determine the reliable sample size, an initial sampling was performed with an equal number of 20 orange leaves per treatment on 18<sup>th</sup> May, 2016. The relative variation (RV) was then calculated to compare the efficiency of various sampling methods using the following formula (Hillhouse and Pitre 1974):

$$RV = \left( \frac{SE}{m} \right) 100$$

Where *SE* is the standard error of the mean and *m* is the mean of primary sampling data (Hillhouse and Pitre 1974).

The reliable number of leaves (sample size) sampled on each sampling date was calculated using the following formula (Southwood and Henderson 2000):

$$N = \left( \frac{ts}{dm} \right)^2$$

Where *N*, *t*, *s*, *d*, and *m* are the sample size, *t*-student, standard deviation, range of accuracy, and mean of primary sampling data, respectively (Ghaderi *et al.* 2018). In this study, the acceptable value for RV was considered as 25% (Jarosik *et al.* 2003; Darbemamieh *et al.* 2011). This means that the number of sampled leaves should be increased if the predicted RV is higher than 25%. According to this procedure, a total of 20 leaves per tree were selected as a reliable sample size. After sampling, the leaves were separately placed in plastic bags and transferred to the laboratory. In the laboratory and under a stereo-microscope (Olympus SZ40, Japan), the number of different developmental stages of CRM on either lower or upper surfaces of the leaves was counted.

#### *Experimental design*

To examine the effect of initial infestation on population fluctuation and spatial distribution of CRM on Thomson navel orange, the paired-treatment and multiple-treatment experiments were applied. These experiments had been designed for crop loss assessment and economic injury level determination of CRM on Thomson navel orange (Unpublished data).

#### *Multiple-treatment test*

Initially, 5 trees of 6-year-old Thomson navel orange from the Citrange rootstock were selected as five treatments in four replicates. To perform the experiment, five trees were selected as treatments which included treatment 1, with single artificial infestation, treatment 2 with double infestation, treatment 3 with three cases of infestation, treatment 4 with four artificial infestations and control treatment without artificial CRM infestation, respectively. The infestation operation of the treatments was carried out for four weeks in April, 2016. For this purpose, the CRM infested twigs were cut from the infested orchards and placed on the four directions of trees or selected treatments (North, South, West and East). In order to obtain different densities from the population of CRM, every week, one treatment was removed from the infestation operation. Finally, in the fourth week, only treatment 4 was infested. Also, in case of observation of infestation of CRM in the control treatment, controlling operation was carried out using Fenpyroximate acaricide.

#### *Paired-treatment test*

In this experimental method, 10 Thomson-6-year-old Juniper orange trees were selected from citrus rootstocks, in most of the two treatments. In the control treatment, trees were protected from

infestation using Fenpyroximate acaricide. However, other treatment trees were exposed to natural populations of CRM.

#### *Spatial distribution pattern*

Based on the results of the sampling, spatial distribution pattern of CRM was determined by the regression techniques of Taylor's Power Law and Iwao's Patchiness Regression (Taylor 1961; Iwao 1977; Southwood and Henderson 2000).

#### **Taylor's power law**

To determine the spatial distribution pattern of CRM on Thomson navel orange, the data of different stages of CRM in multi-treatment and pair-treatment experiments were analyzed separately for each date, and the log of its variance ( $s^2$ ) and mean ( $m$ ) were calculated. Then, the following linear regression equation was used to calculate the numerical values of intercept ( $a$ ) and slope ( $b$ ) (Taylor *et al.* 1961).

$$\text{Log } s^2 = \log a + b \log m$$

$m$  = Data average per sampling

$s^2$  = Variance average per sampling

$b$  = Slope of the regression line

$a$  = The intersection of the regression line with Y axis

Variance and mean of each sampling date were calculated during the agricultural seasons and after logging, the linear regression relationship was obtained using Minitab 17 software.

In this method, if the slope of the regression line ( $b$ ) is greater than 1 ( $b > 1$ ), the spatial distribution is of the aggregated type, and if it is equal to or smaller than 1, then the distribution is of the Random and Regular types, respectively. After determining the value of  $b$ , the goodness of fit test  $b = 1$  was used for statistical proving.

$$t_c = \frac{|b-1|}{SEb}$$

$t_c$  = ( $t_{calculated}$ )

$b$  = Slope of the regression line

$SEb$  = Standard error of  $b$

The null hypothesis states that the distribution of data is Random (ie,  $b = 1$ ), but must be statistically tested. Therefore, in the next step, the  $t_{table}$  (with  $df = n-2$  and confidence level of 95%) was compared with  $t_{calculated}$ . If the value of  $t_{calculated}$  is smaller than  $t_{table}$ , the null hypothesis (random distribution of data) is accepted. This means that  $b$  is equal to 1 and the spatial distribution is random. Otherwise, if  $b > 1$ , then it is an aggregated distribution and if  $b < 1$ , the distribution will be regular (Holt *et al.* 2002).

#### *Iwao's patchiness regression*

The relationship between the mean crowding index ( $m^*$ ) and the average population of red citrus ( $m$ ) is obtained using the following equation (Iwao 1977).

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

$m$  = Data average per sampling date

$m^*$  = Lloyd's mean crowding index in the data average per sampling date

The value of  $m^*$  is obtained by using the following equation (Lloyd 1967).

$$m^* = m + \left( \frac{s^2}{m} - 1 \right)$$

In this method, the data of different stages of CRM measured on each sampling date are calculated separately for  $m$  and  $m^*$  and the value of  $\beta$ , the slope of the regression line is obtained.

In this method, if  $\beta > 1$ , then it is an aggregated distribution and if  $\beta < 1$ , the distribution is regular and if  $\beta = 1$ , the distribution will be random. In this method, the goodness of fit test  $\beta = 1$  is similar to Taylor's method.

It should be noted that in using the regression method, there must be at least averages and variances in the three dates or sampling blocks. On the other hand, regression between mean number log and log of variance should also be statistically significant.

## RESULTS

### Sample size

The results of the initial sampling and the number of samples related to each of the research methods are shown in Table 1. In both experiments conducted in 2017, the RV value was acceptable. The RV was 19.86% in the initial sampling in the multi-treatment experiment, and 16.58% in the paired-treatment experiment, which is within an acceptable range (Table 1). Therefore, according to the results, to study the changes in the population of CRM on Thomson navel orange trees, 20 leaf samples from each tree will be sufficient.

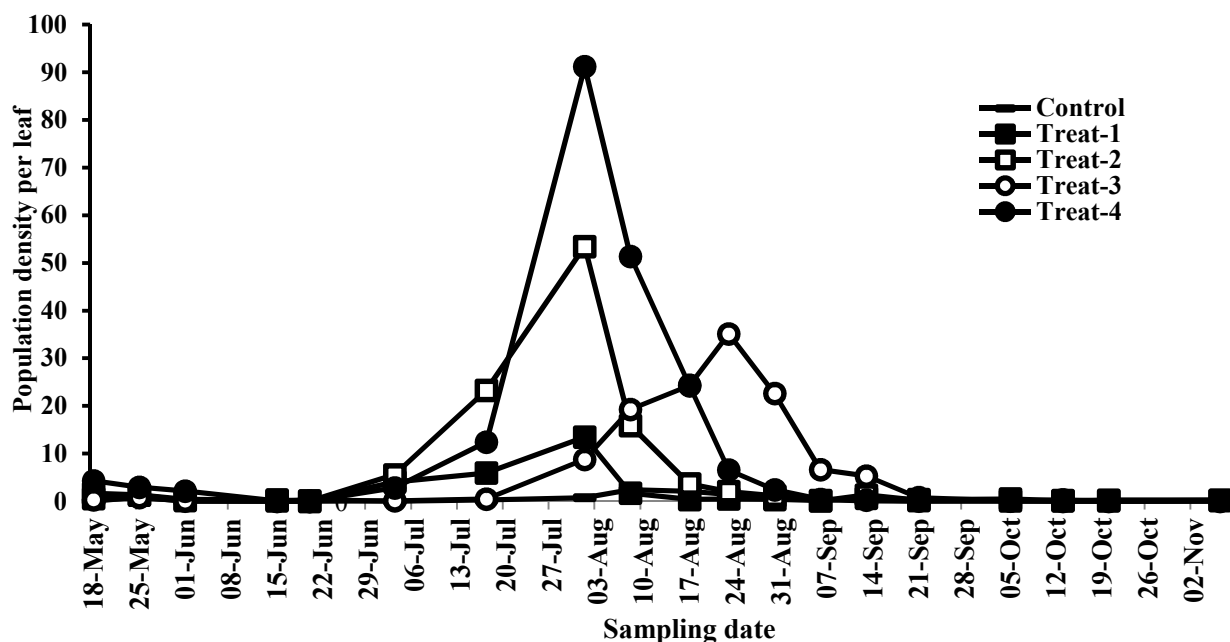
**Table 1.** Sample size of *Panonychus citri* on Thompson navel orange in multi-treatment and paired-treatment experiment in 2016.

Treatment	m	SD	t-table	D	N	RV	Sample size
Multi- treatment	1.430	2.900	1.980	0.25	100	19.86	247.4
Paired- treatment	1.655	3.906	1.960	0.25	200	16.58	338.6

**m** = Mean population densit per leaf in primary sampling, **SD** = Standard deviation, **N** = Number of sampling units in primary sampling, **RV** = Relative variation, **D** = Maximum acceptable variation.

### Population fluctuation of CRM in multi-treatment experiments in 2016

The results of population fluctuation of total population of CRM in multi-treatment method in 2016 are shown in Figure 1. The results showed that the population of CRM at different life stages in the first three months of the year (spring season) and from the beginning of the fall until harvesting was less than 5 mites per leaf. However, as the summer commenced, there was an upward trend and the increase continued by the end of the season, with the highest population density of the pest being recorded during the summer. According to the results of CRM population data on the sampling dates, the highest population density of CRM was observed on July 17<sup>th</sup>, 2016 in treatment 1, on August 1<sup>th</sup>, 2016 in treatment 2, on August 23<sup>rd</sup>, 2016 in treatment 3 and on August 1<sup>st</sup>, 2016 in treatment 4, and the number of CRM was  $5.95 \pm 2.35$ ,  $53.45 \pm 7.96$ ,  $35.10 \pm 10.20$  and  $91.2 \pm 14.6$  per leaf, respectively. Therefore, the pest population at different life stages peaked in the months of July and August, and this number didn't recur until the end of the sampling. Also, the results showed that the average population of the pest gradually subsided from the end of September and reached the lowest number per leaf. In this case, after September 21<sup>st</sup>, 2016 the population of CRM was decreased (Fig. 1).



**Figure 1.** Population fluctuation of *Panonychus citri* on Thomson navel orange in a multi-treatment experiment in 2016.

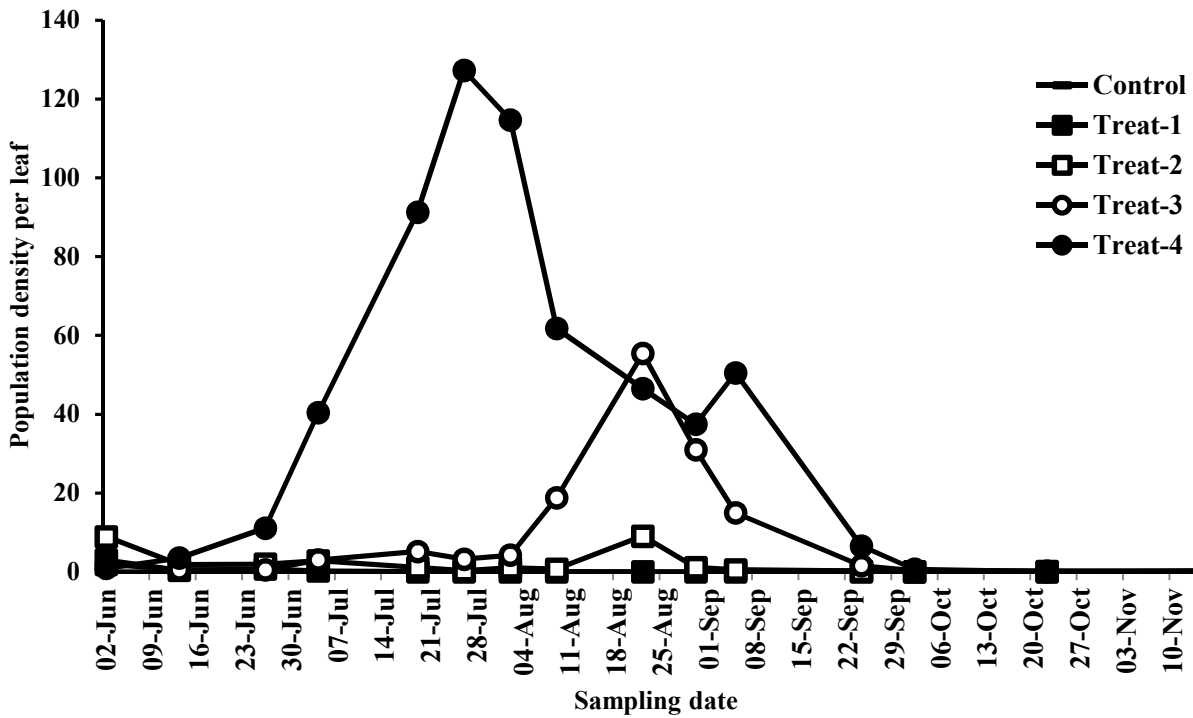
Control treatment = average number of 0.48 mite per leaf; Treatment 1 = average number of 1.12 mites per leaf, Treatment 2 = average number of 1.23 mites per leaf, Treatment 3 = average number of 6.36 mites per leaf, Treatment 4 = average number of 10.59 mites per leaf.

#### *Population fluctuation of CRM in multi-treatment experiment in 2017*

The results of population fluctuation of different life stages of CRM in multi-treatment method in 2017 are shown in Figure 2. The results showed that CRM population increased from the outset of the summer and this upward trend continued by the end of the summer, with the highest population density of the pests recorded in the summer. According to the results obtained from the population data of different life stages of CRM on the sampling dates, the highest population of CRM was observed on 22 August 2017 in treatment 2, on 22 August 2017 in treatment 3 and on July 26<sup>th</sup>, 2017 in treatment 4 and the population of different life stages of CRM were recorded as  $9.05 \pm 8.53$ ,  $55.4 \pm 14.2$  and  $127.3 \pm 18.5$  per leaf, respectively. Therefore, the population of different life stages of the pest peaked in late June and also in the months of July and August, and this number did not reoccur until the end of the sampling. In addition, the results showed that the mean of the population of the pest gradually subsided from the end of September and reached the lowest number of the pest per leaf (Fig. 2).

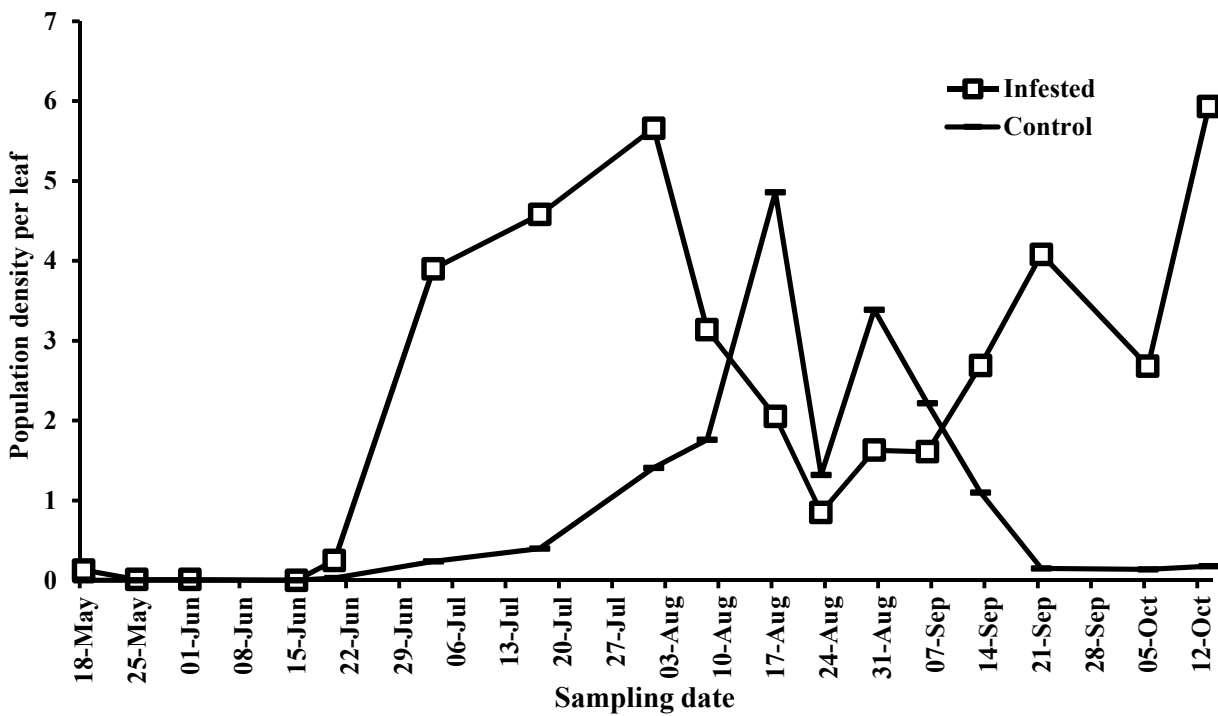
#### *Population fluctuation of CRM in paired-treatment experiment in 2016*

The results of population fluctuation of CRM in the paired-treatment experiment in 2016 are shown in Figure 3. Examining the changes in the population of CRM during the spring and summer showed that the highest population density of the pest belonged to the infested treatment with an average of  $5.66 \pm 0.83$  mites of different life stages per leaf on 18 August 2016. Furthermore, the results showed that the population of the pest in the infested treatment was less than three mites per leaf until 19 July 2016 and then gradually increased. This upward trend of population of CRM continued until 18 August 2016 and eventually dropped on 6 September 2016. However, on 13 October 2016 and 6 November 2016, there were two population peaks of the pest ( $4.08 \pm 0.7$  and  $5.93 \pm 0.88$  mites of different life stages, respectively). In the control treatment, population of the pest peaked at the highest level of  $4.86 \pm 1.45$  mites per leaf (Fig. 3).



**Figure 2.** Population fluctuation of *Panonychus citri* on Thomson navel orange in a multi-treatment experiment in in 2016.

Control treatment = average number of 0.2 mite per leaf, Treatment 1 = average number of 0.3 mite per leaf, Treatment 2 = average number of 2.01 mites per leaf, Treatment 3 = average number of 9.42 mites per leaf, Treatment 4 = average number of 39.56 mites per leaf.

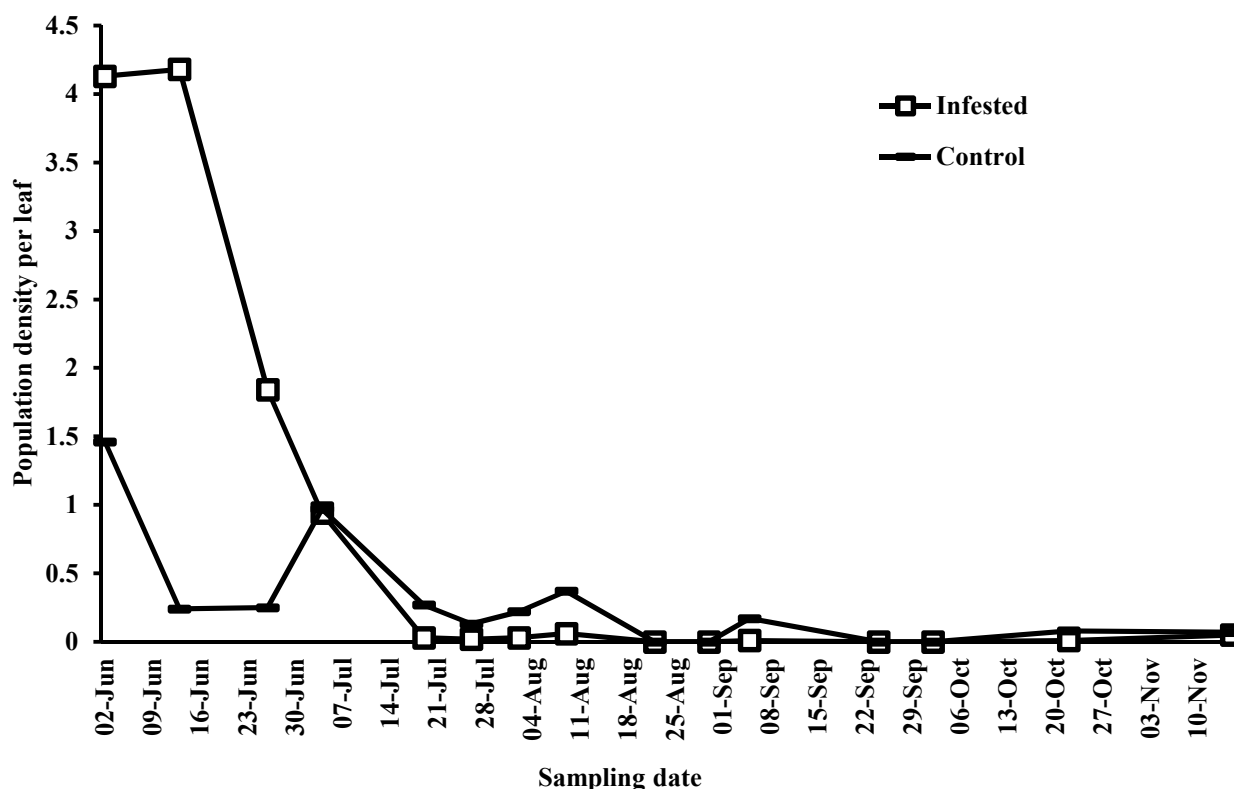


**Figure 3.** Population fluctuation of *Panonychus citri* on Thomson navel orange in a paired-treatment experiment in in 2016.

Infested treatment = average number of 2.26 mites per leaf, Control treatment = average number of 1.01 mites per leaf.

### Population fluctuation of CRM in paired-treatment experiment in 2017

The results of population fluctuation of CRM in the paired-treatment experiment in 2017 are shown in Figure 4. Examination of the changes in the population of CRM on different sampling dates showed that after the sampling began, the population density of the pest gradually decreased, so that at the last sampling date, the population measured in the treatments was near to zero. Therefore, according to the results obtained in this research, the pest had a population peak at the beginning of the sampling and this population peak did not reoccur during the sampling (Fig. 4).



**Figure 4.** Population fluctuation of *Panonychus citri* on Thomson navel orange in a paired-treatment experiment in 2017.

Infested treatment = average number of 0.79 mite per leaf, Control treatment = average number of 0.59 mite per leaf.

### Spatial distribution pattern

The results of Taylor's power law (Table 2) and Iwao's patchiness regression (Table 3) analyses in the multi-treatment experiment during 2016 and 2017 showed that there was a significant relationship between mean log and variance of population density in all experimental treatments. In Taylor's method, the coefficient  $b$  in all treatments was greater than 1 ( $b > 1$ ) and the distribution pattern was aggregated. In general, the results showed that different treatments did not play a significant role in the distribution pattern of the pest.

In Iwao's method, the coefficient  $b$  in all treatments was greater than 1 ( $\beta > 1$ ) except in the treatment 4, so that in treatment 4, the value of the coefficient  $\beta$  was equal to 1 ( $\beta = 1$ ). Therefore, the distribution pattern of this pest in the treatment 4 was random, with an average of  $10.59 \pm 1.09$  and  $39.56 \pm 1.59$  mites per leaf in 2016 and 2017, respectively. In other experimental treatments, the  $\beta$  coefficient was larger than 1 ( $\beta > 1$ ) and the pattern of spatial distribution was aggregated.



The results of determining the spatial distribution using Taylor and Iwao methods in paired-treatment experiment during 2016 and 2017 (Table 4) indicated an aggregated spatial distribution pattern with some exceptions (Taylor, control, 2017 and Iwao, control, 2017) that the pattern was random (see Table 4 for details).

**Table 2.** Regression analysis (Taylor's power law) in determining spatial distribution pattern of *Panonychus citri* on Thompson navel orange in multi-treatment experiment in 2016–2017.

Treatment	$a$	$b$	$r^2$	$t_{cal}$	$t_{tab}$	$P$ -value	Distribution
<b>Taylor-2016</b>							
Control (0.48 per leaf)	- 0.01356	1.5494	0.911	4.8320	2.110	< 0.0001	Aggregated
Treatment 1 (1.12 per leaf)	- 0.1392	1.8102	0.821	4.0877	2.110	< 0.0001	Aggregated
Treatment 2 (1.23 per leaf)	- 0.05435	1.42058	0.959	6.0611	2.110	< 0.0001	Aggregated
Treatment 3 (6.34 per leaf)	- 0.11499	1.77653	0.964	9.6331	2.110	< 0.0001	Aggregated
Treatment 4 (10. 59 per leaf)	- 0.00452	1.32878	0.956	4.8773	2.110	< 0.0001	Aggregated
<b>Taylor-2017</b>							
Control* (0.02 per leaf)	-	-	-	-	-	-	-
Treatment 1 (0.30 per leaf)	- 0.0276	1.4928	0.956	5.7526	2.160	< 0.0001	Aggregated
Treatment 2 (2.01 per leaf)	0.4407	1.8795	0.972	10.2927	2.160	< 0.0001	Aggregated
Treatment 3 (9.42 per leaf)	0.1878	1.7554	0.968	8.8928	2.160	< 0.0001	Aggregated
Treatment 4 (39.52 per leaf)	0.006	1.628	0.937	56.0714	2.160	< 0.0001	Aggregated

Control\* = The treatment had less than 3 dates of infestation

**Table 3.** Regression analysis (Iwao's patchiness) in determining spatial distribution pattern of *Panonychus citri* on Thompson navel orange in multi-treatment experiment in 2016-2017.

Treatment	$\alpha$	$\beta$	$r^2$	$t_{cal}$	$t_{tab}$	$P$ -value	Distribution
<b>Iwao-2016</b>							
Control (0.48 per leaf)	-0.0755	1.7805	0.766	3.3890	2.110	<0.0001	Aggregated
Treatment 1 (1.12 per leaf)	-1.2341	2.2780	0.944	9.7856	2.110	<0.0001	Aggregated
Treatment 2 (1.23 per leaf)	0.1862	1.06103	0.988	2.1976	2.110	<0.0001	Aggregated
Treatment 3 (6.34 per leaf)	-0.7965	1.55873	0.983	11.7109	2.110	<0.0001	Aggregated
Treatment 4 (10. 59 per leaf).	0.4729	1.02841	0.995	1.7344	2.110	<0.0001	Random
<b>Iwao-2017</b>							
Control* (0.02 per leaf)	-	-	-	-	-	-	-
Treatment 1 (0.30 per leaf)	0.262	1.416	0.888	3.1044	2.160	<0.0001	Aggregated
Treatment 2 (2.01 per leaf)	0.053	3.332	0.744	4.5193	2.160	<0.0001	Aggregated
Treatment 3 (9.42 per leaf)	2.933	1.521	0.834	2.8944	2.160	<0.0001	Aggregated
Treatment 4 (39.52 per leaf).	8.016	1.101	0.924	1.1995	2.160	<0.0001	Random

Control\* = The treatment had less than 3 dates of infestation

## DISCUSSION

Most polyphagous mites associated with different agricultural crops throughout the world belong to the family Tetranychidae (Sedaratian *et al.* 2011), therefore, study on their population dynamics and control measures is vital. Examining the population density of CRM on Thomson navel orange in

paired-treatment and multi-treatment experiments showed that CRM density at the beginning of the spring played a pivotal role in causing damages. Our observations during sampling dates indicated the presence and activity of some predators like *Transeius wainsteini* (Gomelauri) (Phytoseiidae), *Allothrombium pulvinum* Ewing (Trombidiidae), *Tyodus spathulatus* Odmemans (Tydeidae), *Pronematus sextoni* Baker (Lolinidae) and *Scolothrips longicornis* Priesner (Thripidae). Studies by Fadamiro *et al.* (2013) on three species of the predatory mites of Phytoseiidae family including *Galendromus occidentalis* (Nesbitt), *Phytoseiulus persimilis* Athias-Henriot and *Neoseiulus californicus* (McGregor) as natural enemies of *Panonychus citri* in southern Alabama showed that all the three phytoseiid species were effective in reducing *P. citri* density on citrus trees. However, the initial density of these natural enemies was a major factor in their performance.

**Table 4.** Regression analysis (Taylor's power law and Iwao's patchiness) in determining spatial distribution pattern of *Panonychus citri* on Thompson navel orange in paired-treatment experiment in 2016-2017.

Treatments	<i>a</i>	<i>b</i>	<i>r</i> <sup>2</sup>	<i>t</i> <sub>cal</sub>	<i>t</i> <sub>tab</sub>	<i>P</i>	Distribution
<b>Taylor-2016</b>							
Infested (2.26 per leaf)	- 0.05411	1.8568	0.940	7.3168	2.131	< 0.0001	Aggregated
Control (1.01 per leaf)	- 0.07759	2.1218	0.943	8.5895	2.131	< 0.0001	Aggregated
<b>Taylor-2017</b>							
Infested (0.79 per leaf)	- 0.0016	1.883	0.978	11.5879	2.160	< 0.0001	Aggregated
Control (0.59 per leaf)	0.2322	1.276	0.814	1.7037	2.160	< 0.0001	Random
<b>Iwao- 2016</b>							
Infested (2.26 per leaf)	- 0.3967	2.0136	0.904	6.1880	2.131	< 0.0001	Aggregated
Control (1.01 per leaf)	- 0.6408	3.0272	0.927	9.5803	2.131	< 0.0001	Aggregated
<b>Iwao-2017</b>							
Infested (0.79 per leaf)	0.5734	1.851	0.894	5.0058	2.160	< 0.0001	Aggregated
Control (0.59 per leaf)	0.512	1.453	0.363	0.9340	2.160	0.01	Random

The results of population changes at different stages of the pest on the sampling dates in the multi-treatment and paired-treatment sampling methods showed that the population peak of CRM (over 5 different life stages) occurred in the summer and often during the months of July to September. The average population density of the pest in the treatments was also different. The results also showed that the population of CRM at different life stages reached the lowest point in the spring and autumn so that at some sampling dates in autumn, the population of the pest might be zero.

According to Futch (2011) in the California region in the USA, CRM is found at any time of the year, and its population peak occurs in July and August. Other research has shown that CRM individuals are found in the spring and autumn seasons too (Griffiths and Thompson 1957). The abundance of CRM and their natural enemies in Indonesia showed that the population peak of CRM generally occurs in May and June (Retno *et al.* 2011).

One reason for the increase in the population of CRM is probably the favorable environmental conditions and good nutritional quality for this pest. However, the low or decreased population of CRM during the spring and autumn in the present study may be due to the appropriate temperature and conditions for activity of some predators such as *Transeius wainsteini* (Phytoseiidae) and *Scolothrips longicornis*. These predators are one of the most important CRM predators in the study area. Retno *et al.* (2011), Jamieson *et al.* (2008), Zhang (2003) and Childers (1994) have pointed to the positive and effective impact of these natural enemies on reducing the population of CRM. The study by van de Vrie *et al.* (1972) on the fluctuation of the population of the tetranychid mites showed that temperature, rainfall and natural enemies are the main determinants of CRM

population. The climatic factors affecting the population of the spider mites include temperature, relative humidity (Ikegami *et al.* 2000) and rainfall (Jeppson 1963).

A study on the population density of CRM in the Adana coastal region of Turkey showed that the pest has two population peaks at the time of the appearance of new leaves in the spring or early summer and the autumn. Also, the population of CRM is low in the middle of summer and during the winter (Kasap 2005). Researchers have shown that usually high temperature and low relative humidity can accelerate the growth of CRM population (Swirski *et al.* 1986). They also showed that high relative humidity increased the natural enemies in the various regions in the United States, and studies showed that the population of CRM usually drops in the summer probably due to high temperature which has damaging effects on this pest (Keetch 1971). High temperatures (above 40 °C) are likely to be important in limiting the population of the mites in the US. It should be noted that these effects may vary on citrus varieties (Hare 1988).

The results of research projects on changes in the population density of CRM on Thomson navel orange during the sampling period showed that in addition to environmental factors, other factors also were influential among which the use of chemical pesticides during the growing year was the most important. The study showed that the CRM population had a regular feeding activity on Thomson navel trees during the year and in the case of chemical applications against them, CRM or citrus pests experienced infestation fluctuations. During direct spraying on citrus pests, the natural enemies of CRM vanished and over time high densities of the population of CRM emerged. However, a number of species of predatory mites such as Phytoseiidae were reported to be resistant to chemical pesticides (Gerson *et al.* 2003). Generally, pesticides used to control citrus pests appear to negatively affect the population of CRM populations and its predators.

Although different initial population densities of CRM were placed on the trees at the beginning of the season, the studies showed that the spatial distribution pattern of this mite was aggregated. Ahmadi *et al.* (2005) reported that the spatial distribution pattern of two-spotted spider mite on four bean cultivars determined using the of mean-to-variance index method and Taylor's regression method was of aggregated. In a study by Liu *et al.* (2011), the spatial distribution pattern of two-spotted spider mite on apple was reported to be aggregated. Study of spatial distribution of *Panonychus ulmi* (Koch, 1836) in an apple orchard in Khoramdareh (Zanjan Province, Iran) during 2007 showed an aggregated spatial distribution in the prey and its predator (Rahmani *et al.* 2010).

Together, it could be concluded that initial infestation with different densities of the pest affected the population fluctuation of the pest during the growing season and somewhat the spatial distribution pattern of CRM.

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## تأثیر میزان آلودگی اولیه روی تغییرات جمعیت فصلی و الگوی پراکنش پهنه‌ای کنه قرمز مرکبات روی پرتقال تامسون ناول

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### چکیده

کنه قرمز مرکبات *Panonychus citri* (McGregor) (Acari: Tetranychidae) یکی از مهم‌ترین آفات مرکبات در جهان از جمله شمال ایران است. نوسانات جمعیت و الگوی پراکنندگی پهنه‌ای کنه قرمز مرکبات در منطقه قائم‌شهر طی سال‌های ۶-۱۳۹۵ با میزان آلودگی متفاوت در قالب آزمایش‌های زوج تیماری و چند تیماری مورد بررسی قرار گرفت. این آزمایش‌ها پیش‌تر برای تعیین میزان خسارت این آفت طراحی شده بود. در این پژوهش از روش‌های آزمایشی چند تیماری و زوج تیماری استفاده شد. برای تعیین الگوی پراکنندگی پهنه‌ای کنه قرمز مرکبات از دو روش رگرسیونی تیلور و آیوانو استفاده شد. بررسی روند نوسانات جمعیت در تاریخ‌های مختلف نمونه‌برداری در سال‌های ۱۳۹۵ و ۱۳۹۶ نشان داد که بیش‌ترین تراکم جمعیت آفت در طول تابستان اتفاق افتاده و به ترتیب به میزان ۱۲۷/۳ و ۹۱/۱۵ عدد کنه قرمز مرکبات در برگ بود. همچنین نتایج پژوهش نشان داد که جمعیت این آفت در فصل پاییز فروکش کرده و به پایین‌ترین میزان خود می‌رسد. الگوی پراکنندگی پهنه‌ای کنه قرمز مرکبات در همه تیمارها در هر دو سال و با استفاده از هر دو روش به صورت تجمعی و در موارد استثنایی از نوع تصادفی به دست آمد. می‌توان نتیجه‌گیری کرد که آلودگی نخستین کنه قرمز روی تغییرات انبوهی جمعیت و تا حدی الگوی پراکنندگی پهنه‌ای کنه قرمز مرکبات تأثیرگذار است.

**واژگان کلیدی:** کنه قرمز مرکبات؛ استان مازندران؛ نوسانات جمعیت؛ الگوی پراکنندگی پهنه‌ای، پرتقال تامسون ناول.

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