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Spatial Distribution of Nymphs of *Triozoida limbata* Enderlein, 1918 (Hemiptera: Triozidae) in Guava Orchards

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Abstract

Triozoida limbata is considered one of the leading pests of guava crop in Brazil. Its nymphs are responsible for sucking leaf borders, causing curling and drying of the leaves, and leaving them with a necrotic appearance. Knowledge of the spatial distribution of nymphs of *T. limbata* is essential for improving sampling and control techniques. The objective of this study was to perform probabilistic analyses of patterns of spatial distribution of nymphs of *T. limbata* in guava orchards. The study was conducted in four guava orchards in Ivinhema, Mato Grosso do Sul, Brazil. Samplings were performed every 15 days, from April 2012 to March 2014. To obtain the nymph counts, a sampling area was demarcated in each orchard, comprising 50 sampling units. In each unit, a sample was taken randomly from a shoot of 10 cm to 15 cm in length at the median height of the central plant. Dispersion rates were calculated (variance/mean ratio, Morisita index, and Exponent k of Negative Binomial Distribution) and the data obtained in the field were adjusted to the theoretical frequency distributions (Poisson and Negative Binomial). Following the analyses, we concluded that nymphs of *T. limbata* in the studied populations were randomly organized in the four areas that were evaluated, and the sampling data have been adjusted to the Poisson distribution model.

Keywords: damage, horticulture, *Psidium guajava* L., random, spatial arrangement

1. Introduction

During its development, guava is attacked by various pest insects that cause different types of damage (Sá, 2011). These insects represent the main obstacles to cultivate guava because they reduce the yield and quality of fruits (Yana et al., 2010; Ndankeu et al., 2011). The species *Triozoida limbata* Enderlein, 1918 (Hemiptera: Triozidae) is considered as one of the leading crop pests in Brazil (Colombi & Galli, 2009).

Adults of *T. limbata* have transparent wings without stigmata, displaying radial wing nervures, and the middle and first cubital nervures emerge from a single point. They are greenish in color and measure around 2.0 mm to 2.4 mm in length (Taylor et al., 2010). Eggs are laid on branches, shoots, and new leaves. Later in the laboratory, we found that 19 to 92 eggs were laid per female with an egg incubation period of 7 days to 9 days and a nymphal stage between 29 days and 35 days.

Nymphs, which are responsible for the damage of guava plants, are flattened in shape with a pinkish color, and are covered by a whitish, waxy excretion. As they suck the sap at the edges of the leaves, they inject toxins (Munyaneza et al., 2010), making leaves curl and become dry, and causing the appearance of necrosis (Dalberto et al., 2004; Yana et al., 2010; Ndankeu et al., 2011).

The control of *T. limbata* is based on the application of insecticides but there is not much concern about the population density and economic losses (Hassani et al., 2009). Furthermore, the knowledge of spatial distribution of the insect is not taken into account, a factor that is of vital importance for establishing the best sampling criteria and determining the most appropriate moment to apply pest control.

To determine the pattern of spatial arrangement of a given species, it is necessary to have data on the number of individuals. For this purpose, the ecosystem in question needs to enable the performance of samplings (Fernandes et al., 2003). These samplings, according to L. J. Young and J. H. Young (1998), can be used to draw inferences about either the form of distribution of the population sampled or the characteristics of this distribution. To describe the distribution patterns of a population, aggregation indices and frequency distributions are used.

There is a need to understand the behavioral patterns of spatial distribution of the population of *T. limbata*, so that better strategies can be proposed for their management. This research therefore aims to perform probabilistic analyses of patterns of spatial distribution of nymphs of *T. limbata* in guava orchards.

2. Material and Methods

Samplings were performed from April 2012 to March of 2014 in four commercial guava orchards, Pedro Sato cultivar, in the municipality of Ivinhema - MS, Brazil, at the following locations: area 1, Gleba Piravevê, with a total of 550 plants: 22º16′32″S and 53º48′59″W at an altitude of 339 m; area 2, located in Gleba Vitória, with 300 plants: 22º 20′51″S and 53º47′59″W at an altitude of 377 m; area 3, in Gleba Azul, with 2,800 plants: 22º16′22″S and 53º54′07″W at an altitude of 400 m; and area 4, in Gleba Ouro verde, with an orchard comprising 300 plants: 22º17′34″S and 53º56′15″W at a latitude of 377 m. Plants were seven and a half years old at the beginning of the sampling period and were planted with a spacing of 5 m × 7 m between plants; the irrigation used was by micro-aspersion. Insecticides were applied only when the average infestations reached 30 % of the leaves with the presence of nymphs of *T. limbata* (Pazini & Galli, 2011).

The soil in the region is classified as dystrophic Red Latosol, which comprises 70% sand and 18% clay. According to the Köppen classification, the climate is Aw, which is characterized as a rainy tropical climate with dry winters. Guava, Pedro Sato cultivar, comprising plants propagated by seeds, probably Red Ogawa no. 1, in Nova Iguaçu, Rio de Janeiro, Brazil. Its main features are as follows: vigorous plants with relatively high yields; slightly oval fruits, good appearance (reaching 400 g in shavings of the branches); rough outer skin; pinkish, thick, firm pulp, pleasant flavor, and few seeds (Pommer et al., 2006).

The evaluation of nymphs in each area comprised 50 sampling units. In each unit, one shoot from 10 cm and 15 cm in length was sampled, which was randomly taken from the median height of the central plant in each plot where the number of nymphs was counted every 15 days.

For data analysis, the square root transformation of x + 0.5 was used (Zucareli et al., 2009). The mean ($\hat{m}$) and variance (S^2) in the number of nymphs of *T. limbata* were obtained on each sampling date, taking the relationship between these values as an indicator of spatial distribution (Elliott, 1979). The dispersion indices, described below, were calculated for each of the samplings performed.

Variance/mean ratio (I): values equal to the unit indicate random spatial distribution; values lower than the unit indicate uniform distribution, and values greater than the unit represent aggregate distribution (Rabinovich, 1980). Spatial randomness can be tested by the chi-square test with n-1 degrees of freedom, $\chi 2 = (n - 1)\ S^2/m$ (Elliott, 1979).

Morisita Index (I_δ): this index is relatively independent of the average and number of samples. Thus, when $I_\delta = 1$, the distribution is random; when $I_\delta > 1$, the distribution is of the contagious type, and when $I_\delta < 1$, this indicates a regular distribution (Morisita, 1962).

Exponent k of the negative binomial distribution (k): this is an appropriate dispersion index when the size and number of sampling units are the same in each sample. Often, this is influenced by the size of the sample units. This parameter is an inverse measure of the degree of aggregation, and in this case, negative values indicate a regular or uniform distribution; positive values, close to zero, indicate aggregate arrangement; and values greater than eight indicate a random distribution (Southwood, 1978; Elliot, 1979). On this aspect, Poole (1974) uses another interpretation: when $0 < k < 8$, the index indicates aggregate distribution, and when $0 > k > 8$, this indicates random distribution.

The theoretical frequency distributions used to evaluate the spatial distribution of the species observed in the field were also used. These distributions are presented below, according to L. J. Young and J. H. Young (1998): Poisson Distribution, also known as random distribution, is characterized by the variance that equals the mean ($S^2 = m$); Negative Binomial Distribution presents greater variance than the average, thereby indicating aggregate distribution, in addition to having two parameters as follows: the mean ($\hat{m}$) and parameter k (k > 0).

The chi-square adhesion test was performed to check the adjustments f of the data collected in the field regarding the theoretical frequency distributions. Therefore, we used the chi-squared adhesion test, which compares the total frequencies observed in the sample area with the expected frequencies, according to L. J. Young and J. H. Young (1998). These frequencies are defined by the product of the probabilities of each class and the total number of sampling units used. For this test, it was decided to establish a minimum expected frequency that equals the unit. Statistical analysis was performed using the chi-square test at the levels of 1% and 5%

probability.

3. Results and Discussion

Forty-eight samplings were performed in each field. A total of 30,973 nymphs of *T. limbata* were observed in guava leaves. During the two years of samplings, population peaks occurred between October and December in areas 1 and 4. In areas 2 and 3, the highest populations were recorded between March and May. The large number of individuals sampled in the orchards was probably due to the presence of young leaves of guava during the sampling period. This fact promoted ideal conditions for the multiplication of *T. limbata* (Melo, 2009) due to the scaled pruning method, which favors the production of guava fruits all year round (Hojo et al., 2007). The periods in which the peaks of occurrence of the insect were recorded happened simultaneously with the intense presence of the shoots.

It should be noted that the values of the variances were lower than the averages in thirty-six samplings performed in area 1 (Table 1), forty-six samplings in area 2 (Table 2), thirty-seven samplings in area 3 (Table 3), and forty-four samplings in area 4 (Table 4). The variance/mean ratios were significantly equal to the unit in forty-six samplings in area 1 (Table 1); the same occurred in forty-seven samplings in area 2 (Table 2), forty-six samplings in area 3 (Table 3), and forty-eight samplings in area 4 (Table 4).

The values of the Morisita Index found in these samples, and confirmed by the spatial randomness test, demonstrated that results were significantly equal to the unit in forty-two samplings in area 1 (Table 1), forty-seven samplings in area 2 (Table 2), forty-five samplings in area 3 (Table 3), and forty-eight samplings in area 4 (Table 4).

The values of the K parameter in area 1 were negative in thirty-six of the samplings, and positive and higher than 8 in 11 samplings (Table 1); in area 2, the values were negative in forty-six of the samplings (Table 2); in area 3, thirty-seven samplings had negative values and 10 were higher than 8 (Table 3); and in area 4, values in forty-four of the samplings were negative (Table 4).

Table 1. Statistical Analysis (means and variances) and dispersion index for nymphs of *Triozoida limbata* in guava orchard (area 1), in Ivinhema, Mato Grosso do Sul, Brazil, 2012/2014 (N = 50)

Index	Sampling date					
	10/04/12	25/04/12	10/05/12	25/05/12	09/06/12	24/06/12
$\widehat{m}$	2.840	2.680	3.260	5.120	3.540	6.880
S^2	2.137	1.896	4.278	7.781	4.539	5.985
I	0.753 ^{ns}	0.707 ^{ns}	1.312 ^{ns}	1.520 *	1.282 ^{ns}	0.870 ^{ns}
I_δ	0.914 ^{ns}	0.892 ^{ns}	1.094 ^{ns}	1.100 *	1.079 ^{ns}	0.981 ^{ns}
K	-11.475 ^{un}	-9.156 ^{un}	10.440 ^{al}	9.851 ^{al}	12.542 ^{al}	-52.906 ^{un}
X^2	36.873	34.657	64.301	74.469	62.831	42.628
	09/07/12	24/07/12	08/08/12	23/08/12	07/09/12	22/09/12
$\widehat{m}$	6.660	7.000	3.960	5.760	5.820	3.800
S^2	6.474	6.449	2.651	8.186	8.681	3.959
I	0.972 ^{ns}	0.921 ^{ns}	0.670 ^{ns}	1.421 ^{ns}	1.492 *	1.042 ^{ns}
I_δ	0.996 ^{ns}	0.989 ^{ns}	0.918 ^{ns}	1.072 *	1.083 *	1.011 ^{ns}
K	-238.314 ^{un}	-88.926 ^{un}	-11.984 ^{un}	13.675 ^{al}	11.838 ^{al}	90.713 ^{al}
X^2	47.631	45.143	32.808	69.639	73.089	51.053
	07/10/12	22/10/12	06/11/12	21/11/12	06/12/12	21/12/12
$\widehat{m}$	4.780	3.880	3.220	8.820	2.840	2.500
S^2	6.502	6.516	2.461	9.171	2.260	2.010
I	1.360 ^{ns}	1.679 *	0.764 ^{ns}	1.040 ^{ns}	0.796 ^{ns}	0.804 ^{ns}
I_δ	1.074 *	1.172 *	0.928 ^{ns}	1.004 ^{ns}	0.929 ^{ns}	0.923 ^{ns}

K	13.271 al	5.711 ag	-13.657 un	221.618 al	-13.896 un	-12.760 un
X^2	66.649	82.289	37.447	50.950	38.986	39.400
	05/01/13	20/01/13	04/02/13	19/02/13	06/03/13	21/03/13
$\widehat{m}$	6.800	2.580	1.140	1.900	2.680	2.840
S^2	9.347	2.698	0.123	0.622	1.936	2.545
I	1.375 ns	1.046 ns	0.108 ns	0.328 ns	0.723 ns	0.896 ns
I_δ	1.054 *	1.017 ns	0.219 ns	0.649 ns	0.898 ns	0.964 ns
K	18.1551 al	56.626 al	-1.278 un	-2.826 un	-9.658 un	-27.369 un
X^2	67.353	51.233	5.281	16.053	35.403	43.915
	05/04/13	20/04/13	05/05/13	20/05/13	04/06/13	19/06/13
$\widehat{m}$	2.680	2.840	2.600	3.060	2.940	3.140
S^2	1.936	2.178	2.163	2.507	2.180	2.776
I	0.723 ns	0.767 ns	0.832 ns	0.819 ns	0.741 ns	0.884 ns
I_δ	0.898 ns	0.919 ns	0.936 ns	0.942 ns	0.913 ns	0.964 ns
K	-9.658 un	-12.183 un	-15.479 un	-16.918 un	-11.373 un	-27.081 un
X^2	35.403	37.577	40.769	40.137	36.333	43.318
	04/07/13	19/07/13	03/08/13	18/08/13	02/09/13	17/09/13
$\widehat{m}$	3.480	3.340	3.140	2.640	3.680	3.140
S^2	2.581	2.311	2.368	2.031	2.834	2.653
I	0.742 ns	0.692 ns	0.754 ns	0.769 ns	0.770 ns	0.845 ns
I_δ	0.927 ns	0.909 ns	0.923 ns	0.914 ns	0.938 ns	0.951 ns
K	-13.474 un	-10.837 un	-12.767 un	-11.445 un	-16.013 un	-20.265 un
X^2	36.345	33.898	36.949	37.697	37.739	41.408
	02/10/13	17/10/13	01/11/13	16/11/13	01/12/13	16/12/13
$\widehat{m}$	3.900	3.340	2.560	2.880	3.300	2.780
S^2	3.561	3.372	2.047	2.189	2.378	1.971
I	0.913 ns	1.010 ns	0.800 ns	0.760 ns	0.720 ns	0.709 ns
I_δ	0.978 ns	1.003 ns	0.923 ns	0.918 ns	0.916 ns	0.897 ns
K	-44.897 un	350.400 al	-12.784 un	-12.010 un	-11.806 un	-9.553 un
X^2	44.744	49.467	39.188	37.250	35.303	34.741
	31/12/13	15/01/14	30/01/14	14/02/14	01/03/14	16/03/14
$\widehat{m}$	1.020	1.080	1.020	1.000	1.000	1.000
S^2	0.020	0.075	0.020	0.000	0.000	0.000
I	0.020 ns	0.070 ns	0.020 ns	0.000 ns	0.000 ns	0.000 ns
I_δ	0.039 ns	0.140 ns	0.039 ns	0.000 ns	0.000 ns	0.000 ns
K	-1.040 un	-1.161 un	-1.040 un	-1.000 un	-1.000 un	-1.000 un
X^2	0.961	3.407	0.961	0.000	0.000	0.000

* Significant at 5% probability; ns Non-significant at 5% probability; AG aggregate; un uniform; al Random; $\widehat{m}$ -mean; S^2 - Variance; I - Mean-variance ratio; I_δ - Morisita index; K - Exponent of the negative binominal; X^2 - calculated chi-square.

Table 2. Statistical Analysis (means and variances) and dispersion index for nymphs of *Triozoida limbata* in guava orchard (area 2), in Ivinhema, Mato Grosso do Sul, Brazil, 2012/2014 (N = 50)

Index	Sampling date					
	10/04/12	25/04/12	10/05/12	25/05/12	09/06/12	24/06/12
$\widehat{m}$	4.900	4.500	12.260	3.060	2.460	2.460
S^2	4.459	3.888	11.380	2.874	2.131	1.968
I	0.910 ^{ns}	0.864 ^{ns}	0.928 ^{ns}	0.939 ^{ns}	0.866 ^{ns}	0.800 ^{ns}
I_δ	0.982 ^{ns}	0.970 ^{ns}	0.994 ^{ns}	0.980 ^{ns}	0.946 ^{ns}	0.920 ^{ns}
K	-54.467 ^{un}	-33.075 ^{un}	-170.804 ^{un}	-50.309 ^{un}	-18.395 ^{un}	-12.294 ^{un}
X^2	44.592	0.970	45.483	46.020	42.447	39.195
	09/07/12	24/07/12	08/08/12	23/08/12	07/09/12	22/09/12
$\widehat{m}$	2.560	2.720	2.280	1.220	2.580	1.500
S^2	2.211	2.532	1.838	0.175	2.044	0.418
I	0.864 ^{ns}	0.931 ^{ns}	0.806 ^{ns}	0.144 ^{ns}	0.792 ^{ns}	0.279 ^{ns}
I_δ	0.947 ^{ns}	0.975 ^{ns}	0.916 ^{ns}	0.301 ^{ns}	0.921 ^{ns}	0.523 ^{ns}
K	-18.757 ^{un}	-39.405 ^{un}	-11.771 ^{un}	-1.424 ^{un}	-12.430 ^{un}	-2.080 ^{un}
X^2	42.313	45.618	39.509	7.033	38.829	13.667
	07/10/12	22/10/12	06/11/12	21/11/12	06/12/12	21/12/12
$\widehat{m}$	2.440	2.860	2.500	1.840	3.100	3.120
S^2	1.925	2.123	1.888	0.464	2.704	2.720
I	0.789 ^{ns}	0.742 ^{ns}	0.755 ^{ns}	0.252 ^{ns}	0.872 ^{ns}	0.872 ^{ns}
I_δ	0.915 ^{ns}	0.911 ^{ns}	0.903 ^{ns}	0.597 ^{ns}	0.959 ^{ns}	0.959 ^{ns}
K	-11.558 ^{un}	-11.096 ^{un}	-10.208 ^{un}	-2.460 ^{un}	-24.273 ^{un}	-24.336 ^{un}
X^2	38.656	36.371	37.000	12.348	42.742	42.718
	05/01/13	20/01/13	04/02/13	19/02/13	06/03/13	21/03/13
$\widehat{m}$	3.140	2.760	7.000	2.540	4.360	2.560
S^2	2.735	3.043	12.612	2.172	3.133	1.925
I	0.871 ^{ns}	1.103 ^{ns}	1.802 *	0.855 ^{ns}	0.719 ^{ns}	0.752 ^{ns}
I_δ	0.959 ^{ns}	1.037 ^{ns}	1.113 *	0.944 ^{ns}	0.936 ^{ns}	0.904 ^{ns}
K	-24.351 ^{un}	26.892 ^{al}	8.731 ^{al}	-17.524 ^{un}	-15.494 ^{un}	-10.319 ^{un}
X^2	42.682	54.029	88.286	41.898	35.211	36.844
	05/04/13	20/04/13	05/05/13	20/05/13	04/06/13	19/06/13
$\widehat{m}$	7.940	7.260	6.860	6.480	6.140	5.660
S^2	5.935	4.890	4.286	3.642	6.123	3.902
I	0.747 ^{ns}	0.674 ^{ns}	0.625 ^{ns}	0.562 ^{ns}	0.997 ^{ns}	0.689 ^{ns}
I_δ	0.969 ^{ns}	0.956 ^{ns}	0.946 ^{ns}	0.934 ^{ns}	1.000 ^{ns}	0.946 ^{ns}
K	-31.445 ^{un}	-22.241 ^{un}	-18.284 ^{un}	-14.798 ^{un}	-2199.143 ^{un}	-18.227 ^{un}
X^2	36.627	33.006	30.615	27.543	48.863	33.784
	04/07/13	19/07/13	03/08/13	18/08/13	02/09/13	17/09/13
$\widehat{m}$	5.380	4.780	2.740	2.420	2.580	1.040
S^2	3.179	3.032	2.564	2.371	2.044	0.039
I	0.591 ^{ns}	0.634 ^{ns}	0.936 ^{ns}	0.980 ^{ns}	0.792 ^{ns}	0.038 ^{ns}

I_δ	0.925 [ns]	0.925 [ns]	0.977 [ns]	0.992 [ns]	0.921 [ns]	0.075 [ns]
K	-13.152 [un]	-13.073 [un]	-42.578 [un]	-119.568 [un]	-12.430 [un]	-1.081 [un]
X^2	28.955	31.084	45.847	48.008	38.829	1.846
	02/10/13	17/10/13	01/11/13	16/11/13	01/12/13	16/12/13
$\widehat{m}$	1.020	1.020	1.040	1.020	1.040	1.060
S^2	0.020	0.020	0.039	0.020	0.039	0.058
I	0.020 [ns]	0.020 [ns]	0.038 [ns]	0.020 [ns]	0.038 [ns]	0.054 [ns]
I_δ	0.039 [ns]	0.039 [ns]	0.075 [ns]	0.039 [ns]	0.075 [ns]	0.109 [ns]
K	-1.040 [un]	-1.040 [un]	-1.081 [un]	-1.040 [un]	-1.081 [un]	-1.121 [un]
X^2	0.961	0.961	1.846	0.961	1.846	2.660
	31/12/13	15/01/14	30/01/14	14/02/14	01/03/14	16/03/14
$\widehat{m}$	1.120	1.100	2.440	2.500	2.700	2.380
S^2	0.108	0.092	1.802	1.847	2.010	1.955
I	0.096 [ns]	0.083 [ns]	0.739 [ns]	0.739 [ns]	0.745 [ns]	0.821 [ns]
I_δ	0.195 [ns]	0.168 [ns]	0.894 [ns]	0.897 [ns]	0.907 [ns]	0.926 [ns]
K	-1.239 [un]	-1.200 [un]	-9.338 [un]	-9.570 [un]	-10.568 [un]	-13.318 [un]
X^2	4.714	4.091	36.197	36.200	36.481	40.244

* Significant at 5% probability; [ns] Non-significant at 5% probability; [un] uniform; [al] Random; $\widehat{m}$ - mean; S^2 - Variance; I - Mean-variance ratio; I_δ - Morisita index; K - Exponent of the negative binominal; X^2 - calculated chi-square.

Table 3. Statistical Analysis (means and variances) and dispersion index for nymphs of *Triozoida limbata* in guava orchard (area 3), in Ivinhema, Mato Grosso do Sul, Brazil, 2012/2014 (N = 50)

Index	Sampling date					
	10/04/12	25/04/12	10/05/12	25/05/12	09/06/12	24/06/12
$\widehat{m}$	3.480	8.560	3.500	5.840	5.460	3.700
S^2	2.989	7.598	2.418	6.953	6.947	4.663
I	0.859 [ns]	0.888 [ns]	0.691 [ns]	1.191 [ns]	1.272 [ns]	1.260 [ns]
I_δ	0.960 [ns]	0.987 [ns]	0.913 [ns]	1.032 [ns]	1.049 [ns]	1.069 [ns]
K	-24.684 [un]	-76.197 [un]	-11.325 [un]	30.630 [al]	20.043 [al]	14.212 [al]
X^2	42.092	43.495	33.857	58.342	62.348	61.757
	09/07/12	24/07/12	08/08/12	23/08/12	07/09/12	22/09/12
$\widehat{m}$	4.020	4.020	2.400	3.060	2.900	2.580
S^2	7.612	5.408	2.000	2.017	2.418	1.800
I	1.893 *	1.345 [ns]	0.833 [ns]	0.659 [ns]	0.834 [ns]	0.698 [ns]
I_δ	1.219 *	1.085 [ns]	0.931 [ns]	0.890 [ns]	0.943 [ns]	0.884 [ns]
K	4.499 [al]	11.645 [al]	-14.400 [un]	-8.975 [un]	-17.461 [un]	-8.529 [un]
X^2	92.781	65.915	40.833	32.294	40.862	34.178
	07/10/12	22/10/12	06/11/12	21/11/12	06/12/12	21/12/12
$\widehat{m}$	2.900	3.440	2.880	1.920	2.700	2.960
S^2	2.255	2.456	2.230	1.993	3.031	3.182
I	0.778 [ns]	0.714 [ns]	0.774 [ns]	1.038 [ns]	1.122 [ns]	1.075 [ns]

I_δ	0.924 [ns]	0.918 [ns]	0.923 [ns]	1.020 [ns]	1.045 [ns]	1.025 [ns]
K	-13.041 [un]	-12.020 [un]	-12.765 [un]	50.176 [al]	22.050 [al]	39.459 [al]
X^2	38.103	34.977	37.944	50.875	55.000	52.676
	05/01/13	20/01/13	04/02/13	19/02/13	06/03/13	21/03/13
$\widehat{m}$	2.440	4.740	4.480	6.600	3.380	3.680
S^2	1.843	6.768	6.051	13.796	2.404	2.426
I	0.755 [ns]	1.428 [ns]	1.351 [ns]	2.090 *	0.711 [ns]	0.659 [ns]
I_δ	0.901 [ns]	1.089 *	1.077 [ns]	1.162 *	0.916 [ns]	0.909 [ns]
K	-9.977 [un]	11.080 [al]	12.779 [al]	6.053 [ag]	-11.701 [un]	-10.800 [un]
X^2	37.016	69.962	66.179	102.424	34.846	32.304
	05/04/13	20/04/13	05/05/13	20/05/13	04/06/13	19/06/13
$\widehat{m}$	2.740	2.780	2.820	3.220	2.760	2.600
S^2	2.074	1.971	2.028	2.665	2.268	1.918
I	0.757 [ns]	0.709 [ns]	0.719 [ns]	0.828 [ns]	0.822 [ns]	0.738 [ns]
I_δ	0.912 [ns]	0.897 [ns]	0.902 [ns]	0.947 [ns]	0.936 [ns]	0.900 [ns]
K	-11.271 [un]	-9.553 [un]	-10.043 [un]	-18.678 [un]	-15.475 [un]	-9.917 [un]
X^2	37.088	34.741	35.241	40.553	40.261	36.154
	04/07/13	19/07/13	03/08/13	18/08/13	02/09/13	17/09/13
$\widehat{m}$	3.100	3.260	3.080	2.960	2.880	2.720
S^2	2.500	2.400	2.238	2.202	2.393	2.287
I	0.806 [ns]	0.736 [ns]	0.727 [ns]	0.744 [ns]	0.831 [ns]	0.841 [ns]
I_δ	0.938 [ns]	0.920 [ns]	0.912 [ns]	0.915 [ns]	0.942 [ns]	0.942 [ns]
K	-16.017 [un]	-12.364 [un]	-11.271 [un]	-11.566 [un]	-17.048 [un]	-17.100 [un]
X^2	39.516	36.080	35.610	36.459	40.722	41.206
	02/10/13	17/10/13	01/11/13	16/11/13	01/12/13	16/12/13
$\widehat{m}$	2.920	2.820	3.080	3.060	2.520	2.340
S^2	2.238	2.110	2.524	2.302	1.969	1.862
I	0.767 [ns]	0.748 [ns]	0.820 [ns]	0.752 [ns]	0.781 [ns]	0.796 [ns]
I_δ	0.921 [ns]	0.912 [ns]	0.942 [ns]	0.920 [ns]	0.914 [ns]	0.914 [ns]
K	-12.509 [un]	-11.197 [un]	-17.064 [un]	-12.360 [un]	-11.525 [un]	-11.446 [un]
X^2	37.562	36.660	40.156	36.869	38.286	38.983
	31/12/13	15/01/14	30/01/14	14/02/14	01/03/14	16/03/14
$\widehat{m}$	2.500	2.560	2.720	2.460	3.340	2.540
S^2	2.092	1.884	2.165	1.927	2.556	2.049
I	0.837 [ns]	0.736 [ns]	0.796 [ns]	0.783 [ns]	0.765 [ns]	0.807 [ns]
I_δ	0.935 [ns]	0.898 [ns]	0.926 [ns]	0.913 [ns]	0.931 [ns]	0.925 [ns]
K	-15.313 [un]	-9.696 [un]	-13.328 [un]	-11.353 [un]	-14.220 [un]	-13.150 [un]
X^2	41.000	36.063	39.000	38.382	37.491	39.535

* Significant at 5% probability; [ns] Non-significant at 5% probability; [AG] aggregate; [un] uniform; [al] Random; $\widehat{m}$ - mean; S^2 - Variance; I - Mean-variance ratio; I_δ - Morisita index; K - Exponent of the negative binominal; X^2 - calculated chi-square.

Table 4. Statistical Analysis (means and variances) and dispersion index for nymphs of *Triozoida limbata* in guava orchard (area 4), in Ivinhema, Mato Grosso do Sul, Brazil, 2012/2014 (N = 50)

Index	Sampling date					
	10/04/12	25/04/12	10/05/12	25/05/12	09/06/12	24/06/12
$\widehat{m}$	3.020	4.060	3.840	4.260	2.940	2.520
S^2	2.306	3.731	3.280	2.890	2.629	1.847
I	0.763 ns	0.919 ns	0.854 ns	0.678 ns	0.894 ns	0.733 ns
I_δ	0.923 ns	0.980 ns	0.963 ns	0.926 ns	0.964 ns	0.895 ns
K	-12.769 un	-50.105 un	-26.331 un	-13.248 un	-27.791 un	-9.429 un
X^2	37.411	45.030	41.854	33.244	43.816	35.905
	09/07/12	24/07/12	08/08/12	23/08/12	07/09/12	22/09/12
$\widehat{m}$	2.580	2.820	2.500	2.720	3.460	2.340
S^2	1.922	2.804	1.847	1.961	4.049	1.943
I	0.745 ns	0.994 ns	0.739 ns	0.721 ns	1.170 ns	0.830 ns
I_δ	0.902 ns	0.9980 ns	0.897 ns	0.899 ns	1.049 ns	0.928 ns
K	-10.117 un	-487.085 un	-9.570 un	-9.7452 un	20.312 al	-13.802 un
X^2	36.504	48.716	36.200	35.324	57.347	40.692
	07/10/12	22/10/12	06/11/12	21/11/12	06/12/12	21/12/12
$\widehat{m}$	2.820	2.880	3.580	3.200	4.580	2.740
S^2	2.110	2.189	2.575	3.510	4.820	2.156
I	0.748 ns	0.760 ns	0.719 ns	1.097 ns	1.052 ns	0.787 ns
I_δ	0.912 ns	0.918 ns	0.923 ns	1.030 ns	1.011 ns	0.923 ns
K	-11.197 un	-12.010 un	-12.754 un	33.011 al	87.402 al	-12.845 un
X^2	36.660	37.250	35.246	53.750	51.568	38.547
	05/01/13	20/01/13	04/02/13	19/02/13	06/03/13	21/03/13
$\widehat{m}$	2.720	2.880	2.440	3.020	3.000	2.860
S^2	1.920	2.679	2.129	2.796	2.531	2.409
I	0.706 ns	0.930 ns	0.873 ns	0.926 ns	0.844 ns	0.842 ns
I_δ	0.893 ns	0.976 ns	0.948 ns	0.976 ns	0.949 ns	0.946 ns
K	-9.248 un	-41.303 un	-19.142 un	-40.627 un	-19.174 un	-18.119 un
X^2	34.588	45.583	42.754	45.358	41.333	41.266
	05/04/13	20/04/13	05/05/13	20/05/13	04/06/13	19/06/13
$\widehat{m}$	3.080	1.840	2.720	2.400	2.800	2.720
S^2	2.238	0.586	1.879	1.755	2.000	1.920
I	0.727 ns	0.319 ns	0.691 ns	0.731 ns	0.714 ns	0.706 ns
I_δ	0.912 ns	0.633 ns	0.888 ns	0.889 ns	0.899 ns	0.893 ns
K	-11.271 un	-2.700 un	-8.799 un	-8.932 un	-9.800 un	-9.248 un
X^2	35.610	15.609	33.853	35.833	35.000	34.588
	04/07/13	19/07/13	03/08/13	18/08/13	02/09/13	17/09/13
$\widehat{m}$	2.820	2.520	2.900	2.760	2.640	2.620
S^2	2.151	2.051	2.255	2.309	1.868	1.832
I	0.763 ns	0.814 ns	0.778 ns	0.836 ns	0.707 ns	0.699 ns

I_δ	0.917 ns	0.927 ns	0.924 ns	0.942 ns	0.891 ns	0.887 ns
K	-11.880 un	-13.529 un	-13.041 un	-16.874 un	-9.025 un	-8.714 un
X^2	37.369	39.873	38.103	40.986	34.667	34.267
	02/10/13	17/10/13	01/11/13	16/11/13	01/12/13	16/12/13
$\widehat{m}$	2.760	2.720	2.480	2.660	2.620	3.360
S^2	2.104	2.981	1.847	2.392	1.873	2.602
I	0.762 ns	1.096 ns	0.745 ns	0.899 ns	0.715 ns	0.775 ns
I_δ	0.915 ns	1.035 ns	0.898 ns	0.963 ns	0.893 ns	0.934 ns
K	-11.621 un	28.322 al	-9.709 un	-26.426 un	-9.190 un	-14.903 un
X^2	37.362	53.706	36.484	44.068	35.031	37.952
	31/12/13	15/01/14	30/01/14	14/02/14	01/03/14	16/03/14
$\widehat{m}$	2.880	2.940	2.420	2.620	2.820	2.840
S^2	2.230	2.425	2.330	2.281	2.477	2.219
I	0.774 ns	0.825 ns	0.963 ns	0.871 ns	0.878 ns	0.781 ns
I_δ	0.923 ns	0.941 ns	0.985 ns	0.951 ns	0.957 ns	0.924 ns
K	-12.765 un	-16.780 un	-65.219 un	-20.262 un	-23.195 un	-12.983 un
X^2	37.944	40.415	47.182	42.664	43.043	38.282

[ns] Non-significant at 5% probability; [un] uniform; [al] Random; $\widehat{m}$ - mean; S^2 - Variance; I - Mean-variance ratio; I_δ - Morisita index; K - Exponent of the negative binominal; X^2 - calculated chi-square.

The three indices of spatial distribution used in this research indicated that the spatial arrangement of the nymphs of *T. limbata* was random in both areas studied. This is in contrast with the results found for the guava orchard of the Paluma cultivar, in which the pattern of distribution was aggregate (Marcelino, 2013).

Regarding the test of frequency adjustment of numerical classes of the nymphs of *T. limbata* observed in area 1, the values of the chi-square test were not significant for Poisson distribution in forty samplings, indicating that the distribution is random. For negative binomial distribution, all forty-one samplings presented significant chi-square values, indicating that the distribution was not aggregate. We also found that, in thirty-two samples in area 2, the chi-square values were not significant for Poisson distribution, but in sixteen samplings, values were significant. All thirty-six samplings tested for negative binomial distribution were significant, indicating that the distribution was not contagious (Table 5).

Table 5. Chi-square adhesion test of the expected frequencies of Poisson and Negative Binomial (Bn) distributions, spatial arrangement for nymphs of *Triozoida limbata,* in Ivinhema, Mato Grosso do Sul, Brazil, (areas 1 and 2), 2012/2014

Sampling date	Area 1				Area 2			
	Poisson		Bn		Poisson		Bn	
	X^2	DF (nc-2)	X^2	DF (nc-3)	X^2	DF (nc-2)	X^2	DF (nc-3)
10/04/12	7.210 ^{ns}	5	378.308 *	4	6.177 ^{ns}	8	2523.623 *	8
25/04/12	7.202 ^{ns}	5	3374.213 *	1	6.348 ^{ns}	7	2082.656 *	7
10/05/12	15.499 ^{ns}	8	240.971 *	6	13.272 ^{ns}	14	10883.626 *	19
25/05/12	15.896 ^{ns}	9	4093.879 *	11	13.311 ^{ns}	7	1655.738 *	6
09/06/12	15.453 ^{ns}	8	2443.138 *	8	10.310 ^{ns}	5	943.610 *	4
24/06/12	4.742 ^{ns}	9	3611.833 *	10	11.452 ^{ns}	6	1643.483 *	5
09/07/12	10.062 ^{ns}	10	4852.907 *	11	10.598 ^{ns}	6	1335.673 *	5
24/07/12	17.774 ^{ns}	11	5584.338 *	13	11.954 ^{ns}	6	1305.088 *	5
08/08/12	7.323 ^{ns}	6	1099.699 *	6	10.242 ^{ns}	5	385.508 *	4
23/08/12	16.696 ^{ns}	10	3491.862 *	10	39.228 ^{ns}	1	-	-
07/09/12	18.826 ^{ns}	11	4095.147 *	11	5.942 ^{ns}	5	698.281 *	4
22/09/12	6.744 ^{ns}	8	2023.486 *	7	22.548 *	2	1.511 ^{ns}	1
07/10/12	16.404 ^{ns}	9	3501.294 *	10	10.272 ^{ns}	5	385.020 *	4
22/10/12	16.155 ^{ns}	9	3475.152 *	10	6.860 ^{ns}	5	97.068 *	4
06/11/12	4.938 ^{ns}	5	207.158 *	2	9.211 ^{ns}	4	3072.193 *	3
21/11/12	7.421 ^{ns}	11	8878.718 *	17	19.811 *	2	-	-
06/12/12	7.515 ^{ns}	5	868.501 *	4	8.033 ^{ns}	7	2559.688 *	8
21/12/12	10.330 ^{ns}	5	742.606 *	4	29.284 *	6	1262.915 *	5
05/01/13	15.537 ^{ns}	11	6234.389 *	14	12.682 ^{ns}	7	1649.486 *	6
20/01/13	13.245 ^{ns}	7	1622.610 *	6	40.463 *	7	1236.693 *	5
04/02/13	50.755 *	1	-	-	20.119 ^{ns}	13	6196.112 *	14
19/02/13	13.049 *	2	21093.672 *	1	26.240 *	6	1345.818 *	5
06/03/13	9.047 ^{ns}	4	5367.791 *	3	6.294 ^{ns}	7	2184.423 *	7
21/03/13	6.101 ^{ns}	6	1270.469 *	5	12.312 ^{ns}	7	343.656 *	5
05/04/13	7.519 ^{ns}	4	5367.976 *	3	9.612 ^{ns}	10	4289.781 *	11
20/04/13	4.632 ^{ns}	6	1636.208 *	3	15.404 ^{ns}	8	3160.597 *	8
05/05/13	9.130 ^{ns}	5	918.402 *	4	14.311 ^{ns}	8	3227.736 *	8
20/05/13	11.840 ^{ns}	6	1344.263 *	5	13.933 ^{ns}	7	1189.850 *	5
04/06/13	11.320 ^{ns}	6	1967.140 *	5	13.258 ^{ns}	10	4183.093 *	11
19/06/13	10.171 ^{ns}	5	1247.967 *	5	14.576^{ns}	9	4263.374 *	11
04/07/13	7.692 ^{ns}	3	799.455 *	3	22.240 *	7	4355.904 *	7
19/07/13	3.785 ^{ns}	6	3111.196 *	5	4.542 ^{ns}	6	1009.070 *	5
03/08/13	12.544 ^{ns}	6	1550.115 *	5	6.448 ^{ns}	6	1665.146 *	6
18/08/13	10.850 ^{ns}	5	374.228 *	4	19.140 *	6	1285.863 *	5
02/09/13	11.970 ^{ns}	7	2153.918 *	6	7.322 ^{ns}	5	698.035 *	4
17/09/13	7.228 ^{ns}	6	1312.430 *	5	71.384 *	1	-	-

02/10/13	13.343 ^{ns}	7	2069.202 *	7	76.463 *	1	-	-
17/10/13	11.581 ^{ns}	6	1247.103 *	5	76.463 *	1	-	-
01/11/13	8.280 ^{ns}	6	1544.826 *	5	71.384 *	1	-	-
16/11/13	11.944 ^{ns}	6	1681.976 *	5	76.463 *	1	-	-
01/12/13	9.245 ^{ns}	5	382.281 *	4	71.384 *	1	-	-
16/12/13	7.720 ^{ns}	4	6461.637 *	3	66.643 *	1	-	-
31/12/13	76.463 *	1	-	-	54.293 *	1	-	-
15/01/14	62.224 *	1	-	-	58.112 *	1	-	-
30/01/14	76.463 *	1	-	-	8.444 ^{ns}	4	7841.148 *	2
14/02/14	72.702 ^{i}	0	-	-	8.705 ^{ns}	4	5771.259 *	3
01/03/14	72.702 ^{i}	0	-	-	6.643 ^{ns}	6	2756.223*	5
16/03/14	72.702 ^{i}	0	-	-	8.898 ^{ns}	5	790.810 *	4

* Significant at 5% probability; ^{ns} Non-significant; ^{i} insufficient of classes; X^2 - chi-square value calculated; DF - degree of freedom; nc - number of classes observed at field.

Considering adjustments of the frequencies for areas 3 and 4, forty-seven samplings were not significant for Poisson distribution. For negative binomial distribution, forty-eight samplings were significant in area 3 and forty-seven samplings in area 4, indicating that the distribution was not aggregate (Table 6).

Table 6. Chi-square adhesion test of the expected frequencies of Poisson and Negative Binomial (Bn) distributions, spatial arrangement for nymphs of *Triozoida limbata,* in Ivinhema, Mato Grosso do Sul, Brazil, (areas 3 and 4), 2012/2014

Sampling date	Area 3				Area 4			
	Poisson		Bn		Poisson		Bn	
	X^2	DF (nc-2)	X^2	DF (nc-3)	X^2	DF (nc-2)	X^2	DF (nc-3)
10/04/12	6.520 ^{ns}	7	1661.443 *	6	11.456 ^{ns}	7	2237.595 *	7
25/04/12	18.141 ^{ns}	11	6355.919 *	14	7.477 ^{ns}	7	2062.243 *	7
10/05/12	12.950 ^{ns}	7	1003.630 *	6	10.309 ^{ns}	8	2076.470 *	7
25/05/12	18.446 ^{ns}	11	4797.295 *	12	5.699 ^{ns}	6	1524.442 *	6
09/06/12	16.183 ^{ns}	10	4783.458 *	12	13.947 ^{ns}	7	2032.698 *	7
24/06/12	13.477 ^{ns}	7	1563.932 *	6	8.467 ^{ns}	4	6892.334 *	3
09/07/12	11.686 ^{ns}	8	5439.167 *	13	8.581 ^{ns}	4	3297.221 *	3
24/07/12	16.279 ^{ns}	9	2431.250 *	8	10.679 ^{ns}	7	1633.014 *	6
08/08/12	9.072 ^{ns}	6	1436.840 *	5	9.304 ^{ns}	4	5771.067 *	3
23/08/12	9.281 ^{ns}	4	25056.732 *	3	7.703 ^{ns}	4	4928.765 *	3
07/09/12	10.729 ^{ns}	5	943.709 *	4	11.452 ^{ns}	7	1579.241 *	6
22/09/12	8.724 ^{ns}	4	36288.768 *	3	11.385 ^{ns}	6	1481.883 *	5
07/10/12	6.430 ^{ns}	5	799.198 *	4	5.239 ^{ns}	5	197.113 *	4
22/10/12	8.140 ^{ns}	5	421.603 *	4	4.415 ^{ns}	6	1683.111 *	5
06/11/12	7.896 ^{ns}	5	763.303 *	4	5.744 ^{ns}	5	644.513 *	4
21/11/12	32.221 *	5	284.814 *	1	10.469 ^{ns}	6	1226.190 *	5
06/12/12	13.650 ^{ns}	7	1598.586 *	6	14.817 ^{ns}	8	2996.997 *	9

21/12/12	13.577 ns	7	1606.544 *	6	5.339 ns	6	1525.075 *	5
05/01/13	7.358 ns	5	4653.618 *	3	8.571 ns	4	9666.293 *	3
20/01/13	15.756 ns	10	3493.493 *	10	8.506 ns	6	1292.287 *	5
04/02/13	7.006 ns	8	2941.664 *	9	10.767 ns	5	944.865 *	4
19/02/13	22.249 ns	13	5427.198 *	13	7.709 ns	6	1285.986 *	5
06/03/13	6.794 ns	5	262.095 *	4	4.472 ns	6	1327.025 *	5
21/03/13	4.227 ns	6	4711.235 *	5	8.653 ns	6	1333.294 *	5
05/04/13	8.782 ns	5	267.049 *	4	4.041 ns	5	134.385 *	4
20/04/13	8.396 ns	4	6461.584 *	3	13.379 *	2	-	-
05/05/13	8.696 ns	4	3767.426 *	3	8.850 ns	4	22202.383 *	3
20/05/13	8.297 ns	7	1709.985 *	6	9.060 ns	4	14984.102 *	3
04/06/13	7.277 ns	5	921.996 *	4	8.994 ns	4	4823.654 *	3
19/06/13	8.859 ns	4	3968.711 *	3	12.276 ns	6	9666.144 *	3
04/07/13	4.946 ns	5	1361.909 *	5	4.300 ns	5	561.593 *	4
19/07/13	3.303 ns	6	1651.657 *	5	8.121 ns	6	1474.980 *	5
03/08/13	4.696 ns	5	134.519 *	4	8.437 ns	6	1501.986 *	5
18/08/13	8.336 ns	5	397.481 *	4	10.527 ns	5	938.324 *	4
02/09/13	10.320 ns	5	938.888 *	4	7.917 ns	4	13334.736 *	3
17/09/13	9.790 ns	5	938.293 *	4	7.543 ns	4	24357.434 *	3
02/10/13	9.384 ns	5	717.158 *	4	6.333 ns	5	462.652 *	4
17/10/13	8.556 ns	5	196.911 *	4	12.252 ns	6	1234.195 *	5
01/11/13	9.857 ns	5	939.603 *	4	8.917 ns	4	4930.936 *	3
16/11/13	9.478 ns	5	669.762 *	4	10.119 ns	6	1284.300 *	5
01/12/13	9.828 ns	5	396.885 *	4	9.307 ns	4	9993.327 *	3
16/12/13	10.174 ns	5	261.762 *	4	5.000 ns	6	878.942 *	5
31/12/13	10.008 ns	5	911.887 *	4	8.660 ns	6	1534.019 *	5
15/01/14	9.238 ns	4	4991.929 *	3	11.275 ns	6	1347.442 *	5
30/01/14	6.270 ns	5	827.104 *	4	11.484 ns	6	1291.968 *	5
14/02/14	8.633 ns	6	1984.314 *	5	10.766 ns	6	1319.584 *	5
01/03/14	5.101 ns	5	873.838 *	4	11.705 ns	6	1291.992 *	5
16/03/14	7.980 ns	5	798.360 *	4	10.343 ns	6	1508.077 *	5

* Significant at 5% probability; ns Non-significant; X^2 - chi-square value calculated; DF - degree of freedom; nc - number of classes observed at field.

Data obtained in 86.46% of samplings adjusted the Poisson distribution, indicating a random distribution model for nymphs of *T. limbata*. This contradicts the values of 86.36% of the samplings found by Marcelino (2013), which adjusted the negative binomial distribution. Similar results were also reported for another representative of the family Triozidae, *Bactericera cockerelli*, which is considered a pest of potato, bell pepper, and tomato (Prager et al., 2013, 2014).

The random distribution is considered the least common distribution of contagion in nature, occurring when members of the species are located, generally, in a homogenous environment, where an individual's position is independent of others' positions (Taylor, 1984). In this form of arrangement, the energy expenditure on reproduction is lower, as males can find females without having to extensively search in the area (Shea et al., 1993). In addition, the population gains greater genetic variability because insects that come into the crop can find reproductive partners more easily (Diekötter et al., 2008). Therefore, it would be difficult for the entire population to be affected (Courtney, 1986).

Taking into account that the damage is also distributed in a random manner, the applications of insecticides, either at the wrong time or in an uneven manner, could undermine the efficiency of the integrated pest control as various individuals in the population may not be reached. Under these circumstances, the surviving insects could remain in the crop with enough energy to reproduce and begin a new cycle of attack (Alves, 2012).

Information of the spatial arrangement of the nymphs of *T. limbata* is of vital importance to establish the best sampling criteria and determine the best moment to apply the pest control. Our results will contribute to the development of future sequential sampling plans for T. *limbata* in order to define the exact number of sampling units that should be used.

4. Conclusion

Nymphs of *Triozoida limbata* in the studied populations were randomly organized in the four areas that were evaluated, and the sampling data have been adjusted to the Poisson distribution model.

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