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

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Abstract
The aim of this study was to carry out probabilistic analyses of the spatial distribution patterns of adults of *Triozoida limbata* Enderlein, 1918 (Hemiptera: Triozidae) in guava orchards. This study was conducted in four guava orchards in Ivinhema, Mato Grosso do Sul, Brazil. The samplings were conducted every fortnight from April 2012 to March 2014. A sampling area was set up for adult samples, and it consisted of 24 sampling units or plots with 15 plants in each (3 rows × 5 plants). A double-sided adhesive yellow trap was installed, 23 cm in length and 11 cm in width, around the central plant of each sampling unit, approximately 1.5 m from the ground. The dispersion rates (variance/mean ratio, Morisita index and Exponent k of the Negative Binomial Distribution) and the theoretical frequency distributions (Poisson and Negative Binomial) were calculated. Following the analyses, it can be concluded that the adults of *T. limbata* of the populations studied are randomly distributed in the four areas evaluated, with the sampling data fitting the Poisson distribution model.

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

1. Introduction
Cultivation of guava is hindered by the presence of pest insects that cause different types of damage to the plants. One such insect is *Triozoida limbata* Enderlein, 1918 (Hemiptera: Triozidae), which is currently considered as one of the main guava crop pests in Brazil (Colombi & Galli, 2009). During the development of the plant, the young leaves are attacked by this insect (Sá, 2011), which sucks the sap from leaf edges and injects toxins in them (Munyaneza et al., 2010), causing the leaves to curl and wither, giving them the appearance of necrosis and limiting the production and quality of the fruits (Yana et al., 2010; Ndankeu et al., 2011).

The management of *T. limbata* is based on the use of chemical insecticides but with little regard to the population density and economic losses (Hassani et al., 2009). Furthermore, knowledge of the special distribution of the insect is not taken into account, a factor that is essential for establishing the best sampling criteria and determining the most appropriate moment to apply the pest control. To determine the pattern of spatial arrangement of a given species, it is necessary to collect data on the number of individuals. For this, the ecosystem in question needs to allow for sampling to be conducted (Fernandes et al., 2003). These samplings can be used to draw inferences about the form of distribution of the population sampled or about the characteristics of this distribution for which the indices of aggregation and frequency distribution are used (L. J. Young & J. H. Young, 1998).

Based on these facts, there is a need to understand the behavioral patterns of the spatial distribution of the population of *T. limbata*, to allow proposing a sampling program that seeks to minimize the use of chemical insecticides. Therefore, this study aims to perform probabilistic analyses of the patterns of the spatial distribution of adults 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: 22°16'32"S and 53°48'59"W at an altitude of 339 m; area 2, located in Gleba Vitória, with 300 plants: 22°20'51"S and 53°48'59"W at an altitude of 377 m; area 3, in Gleba Azul, with 2,800 plants:
22°16′22″S and 53°54′07″W at an altitude of 400 m; and area 4, in Gleba Ouro verde, with an orchard comprising 300 plants: 22°17′34″S and 53°56′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-asperion. The soil in the region is classified as dystrophic Red Latosol, which comprises 70% sand and 18% clay.

Each area consisted of 24 sampling units or parcels containing 15 plants each (3 rows × 5 plants). A double-sided adhesive yellow trap was installed, 23 cm in length and 11 cm in width, around the central plant of each sampling unit, approximately 1.5 m from the ground. The traps were changed every fortnight when they were taken to the laboratory to count the number of adult individuals. For data analysis, the square root transformation of \( x + 0.5 \) was used (Zucarelly et al., 2009). The mean (\( \bar{m} \)) and variance (\( S^2 \)) in the number of adults 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 (\( I_M \)): this index is relatively independent of the average and number of samples. Thus, when \( I_M = 1 \), the distribution is random; when \( I_M > 1 \), the distribution is of the contagious type, and when \( I_M < 1 \), 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: 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 (\( \bar{m} \)) 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 & 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

In each area, 48 samplings were conducted. A total of 34,436 adults of \( T. \) limbata were captured in the traps. In the 2 years in which the populations of this insect were sampled, population peaks occurred between October and November in areas 1 and 4. In areas 2 and 3, the highest populations were recorded between April and May. The high number of individuals sampled in the orchards may have been because of the presence of young guava leaves during the sampling period, providing ideal conditions for the multiplication of \( T. \) limbata (Melo, 2009).

The insect peak occurrences matched the intense presence of young leaves. It was observed that the values of variance were below the mean in thirty-three samplings performed in area 1 (Table 1); in forty-two of the samplings in area 2 (Table 2); in twenty-seven samplings in area 3 (Table 3); and thirty-four samplings in area 4 (Table 4). The variance/mean ratio was significantly equal to the unit in forty-three samplings in area 1 (Table 1); forty-four samplings in area 2 (Table 2); thirty-nine samplings in area 3 (Table 3); and forty-four samplings in area 4 (Table 4).

The values of the Morisita Index found in this study and confirmed by the spatial randomness test demonstrate that the results were significantly equal to the unit in forty-three samplings in area 1 (Table 1); forty-four samplings in area 2 (Table 2); thirty-nine samplings in area 3 (Table 3); and forty-three samplings in area 4 (Table 4).

The values of the \( K \) parameter in area 1 were negative in thirty-three samplings, positive and lower than eight in thirteen samplings, and higher than eight in two samplings (Table 1); in area 2, the values were negative in forty-two
samples and positive and lower than 8 in six samplings (Table 2); for area 3 it was found that in twenty-seven samplings, the values were negative and in 16 they were positive and lower than 8 and in five samplings, the values were higher than eight (Table 3); in area 4 it was observed that the values were negative in thirty-four of the samplings, positive and lower than eight in 13 samplings, and in only one samplings, the value was higher than eight (Table 4). The three spatial distribution indices used in this research indicate that the spatial arrangement of adults of *T. limbata* is random in the four areas studied.

Table 1. Statistical analysis (means and variances) and dispersion index for adults of *Triozoida limbata* in guava orchard (area 1), in Ivinhema, Mato Grosso do Sul, Brazil, 2012/2014 (N = 24)

| Index | 10/04/12 | 25/04/12 | 10/05/12 | 25/05/12 | 09/06/12 | 24/06/12 |
|-------|----------|----------|----------|----------|----------|----------|
| $\bar{m}$ | 10.667 | 10.125 | 12.125 | 19.583 | 9.458 | 8.375 |
| $S^2$ | 6.928 | 5.418 | 21.158 | 15.297 | 4.955 | 4.418 |
| $I$ | 0.649 | 0.535 | 1.745 | 0.781 | 0.524 | 0.528 |
| $I_0$ | 0.968 | 0.956 | 1.059 | 0.989 | 0.952 | 0.946 |
| $K$ | -2.853 | -2.151 | 1.342 | -4.569 | -2.100 | -2.117 |
| $X^2$ | 14.938 | 12.309 | 40.134 | 17.966 | 12.048 | 12.134 |

| Index | 09/07/12 | 24/07/12 | 08/08/12 | 23/08/12 | 07/09/12 | 22/09/12 |
|-------|----------|----------|----------|----------|----------|----------|
| $\bar{m}$ | 8.208 | 9.125 | 5.792 | 5.538 | 16.708 | 9.500 |
| $S^2$ | 4.259 | 34.114 | 5.042 | 4.949 | 43.172 | 23.652 |
| $I$ | 0.519 | 3.739 | 0.871 | 0.886 | 2.584 | 2.490 |
| $I_0$ | 0.944 | 1.289 | 0.978 | 0.980 | 1.091 | 1.151 |
| $K$ | -2.078 | 0.365 | -7.722 | -8.806 | 0.631 | 0.671 |
| $X^2$ | 11.934 | 85.986 | 20.022 | 20.388 | 59.429 | 57.263 |

| Index | 07/10/12 | 22/10/12 | 06/11/12 | 21/11/12 | 06/12/12 | 21/12/12 |
|-------|----------|----------|----------|----------|----------|----------|
| $\bar{m}$ | 9.667 | 24.042 | 9.167 | 18.500 | 17.125 | 5.792 |
| $S^2$ | 24.754 | 5.042 | 11.884 | 15.217 | 15.505 | 4.085 |
| $I$ | 2.561 | 0.714 | 1.296 | 0.823 | 0.905 | 0.705 |
| $I_0$ | 1.155 | 0.989 | 1.031 | 0.991 | 0.995 | 0.951 |
| $K$ | 0.641 | -3.500 | 3.373 | -5.636 | -10.574 | -3.394 |
| $X^2$ | 58.897 | 85.986 | 20.022 | 20.388 | 59.429 | 57.263 |

| Index | 05/01/13 | 20/01/13 | 04/02/13 | 19/02/13 | 06/03/13 | 21/03/13 |
|-------|----------|----------|----------|----------|----------|----------|
| $\bar{m}$ | 14.417 | 13.458 | 7.708 | 6.917 | 6.830 | 6.042 |
| $S^2$ | 14.254 | 14.955 | 4.216 | 8.949 | 8.341 | 6.998 |
| $I$ | 0.989 | 1.111 | 0.547 | 1.294 | 1.267 | 1.158 |
| $I_0$ | 0.999 | 1.008 | 0.943 | 1.041 | 1.039 | 1.025 |
| $K$ | -88.422 | 8.949 | -2.207 | 3.403 | 3.746 | 6.316 |
| $X^2$ | 22.740 | 25.557 | 12.578 | 29.759 | 29.139 | 26.641 |

| Index | 05/04/13 | 20/04/13 | 05/05/13 | 20/05/13 | 04/06/13 | 19/06/13 |
|-------|----------|----------|----------|----------|----------|----------|
| $\bar{m}$ | 12.667 | 10.167 | 9.667 | 8.417 | 7.000 | 9.625 |
| $S^2$ | 13.536 | 8.232 | 9.362 | 9.819 | 8.000 | 11.201 |
| $I$ | 1.069 | 0.810 | 0.969 | 1.167 | 1.143 | 1.164 |
| $I_0$ | 1.005 | 0.982 | 0.997 | 1.019 | 1.020 | 1.016 |
| $K$ | 14.567 | -5.255 | -31.762 | 6.003 | 7.000 | 6.107 |
| $X^2$ | 24.579 | 18.623 | 22.276 | 26.832 | 26.286 | 26.766 |
Note. * Significant at 5% probability; ns Non-significant at 5% probability; AG aggregate; un uniform; al Random; \( \bar{m} \) -mean; \( S^2 \) - Variance; \( I \) - Mean-variance ratio; \( I_6 \) - Morisita index; \( K \) - Exponent of the negative binominal; \( X^2 \) - calculated chi-square.

Table 2. Statistical analysis (means and variances) and dispersion index for adults of *Triozoida limbata* in guava orchard (area 2), in Ivinhema, Mato Grosso do Sul, Brazil, 2012/2014 (N = 24)

| Index | 04/07/13 | 19/07/13 | 03/08/13 | 18/08/13 | 02/09/13 | 17/09/13 |
|-------|----------|----------|----------|----------|----------|----------|
| \( \bar{m} \) | 7.833 | 6.208 | 6.875 | 6.167 | 11.542 | 8.042 |
| \( S^2 \) | 4.667 | 6.172 | 4.462 | 4.232 | 16.172 | 5.520 |
| \( I \) | 0.596<sup>ns</sup> | 0.994<sup>ns</sup> | 0.649<sup>ns</sup> | 0.686<sup>ns</sup> | 1.401<sup>ns</sup> | 0.686<sup>ns</sup> |
| \( I_6 \) | 0.950<sup>ns</sup> | 0.999<sup>ns</sup> | 0.951<sup>ns</sup> | 0.951<sup>ns</sup> | 1.033<sup>ns</sup> | 0.962<sup>ns</sup> |
| \( K \) | -2.474<sup>un</sup> | -171.350<sup>un</sup> | -2.849<sup>un</sup> | -3.187<sup>un</sup> | 2.493<sup>ag</sup> | -3.189<sup>un</sup> |
| \( X^2 \) | 13.702 | 22.866 | 14.927 | 15.784 | 32.227 | 15.788 |

| Index | 02/10/13 | 17/10/13 | 01/11/13 | 16/11/13 | 01/12/13 | 16/12/13 |
|-------|----------|----------|----------|----------|----------|----------|
| \( \bar{m} \) | 6.958 | 7.500 | 6.625 | 7.292 | 5.500 | 6.708 |
| \( S^2 \) | 3.955 | 4.435 | 3.636 | 4.042 | 3.565 | 3.781 |
| \( I \) | 0.568<sup>ns</sup> | 0.591<sup>ns</sup> | 0.549<sup>ns</sup> | 0.554<sup>ns</sup> | 0.648<sup>ns</sup> | 0.564<sup>ns</sup> |
| \( I_6 \) | 0.940<sup>ns</sup> | 0.947<sup>ns</sup> | 0.934<sup>ns</sup> | 0.941<sup>ns</sup> | 0.938<sup>ns</sup> | 0.937<sup>ns</sup> |
| \( K \) | -2.317<sup>un</sup> | -2.447<sup>un</sup> | -2.216<sup>un</sup> | -2.44<sup>un</sup> | -2.843<sup>un</sup> | -2.291<sup>un</sup> |
| \( X^2 \) | 13.072 | 13.600 | 12.623 | 12.749 | 14.909 | 12.963 |

| Index | 31/12/13 | 15/01/14 | 30/01/14 | 14/02/14 | 01/03/14 | 16/03/14 |
|-------|----------|----------|----------|----------|----------|----------|
| \( \bar{m} \) | 5.458 | 6.542 | 9.250 | 8.458 | 7.083 | 7.083 |
| \( S^2 \) | 3.389 | 3.911 | 8.370 | 4.520 | 4.428 | 3.993 |
| \( I \) | 0.621<sup>ns</sup> | 0.598<sup>ns</sup> | 0.905<sup>ns</sup> | 0.534<sup>ns</sup> | 0.625<sup>ns</sup> | 0.564<sup>ns</sup> |
| \( I_6 \) | 0.933<sup>un</sup> | 0.941<sup>un</sup> | 0.990<sup>ns</sup> | 0.947<sup>ns</sup> | 0.949<sup>ns</sup> | 0.941<sup>ns</sup> |
| \( K \) | -2.638<sup>un</sup> | -2.487<sup>un</sup> | -10.506<sup>un</sup> | -2.148<sup>un</sup> | -2.676<sup>un</sup> | -2.292<sup>un</sup> |
| \( X^2 \) | 14.282 | 13.752 | 20.811 | 12.291 | 14.376 | 12.965 |

| Index | 09/07/12 | 24/07/12 | 08/08/12 | 23/08/12 | 07/09/12 | 22/09/12 |
|-------|----------|----------|----------|----------|----------|----------|
| \( \bar{m} \) | 6.833 | 5.292 | 3.792 | 4.708 | 4.542 | 4.792 |
| \( S^2 \) | 4.058 | 3.607 | 2.694 | 3.607 | 3.129 | 3.042 |
| \( I \) | 0.594<sup>ns</sup> | 0.682<sup>ns</sup> | 0.710<sup>ns</sup> | 0.766<sup>ns</sup> | 0.689<sup>ns</sup> | 0.635<sup>ns</sup> |
| \( I_6 \) | 0.943<sup>ns</sup> | 0.942<sup>ns</sup> | 0.926<sup>ns</sup> | 0.952<sup>ns</sup> | 0.934<sup>ns</sup> | 0.926<sup>ns</sup> |
| \( K \) | -2.462<sup>ns</sup> | -3.141<sup>un</sup> | -3.454<sup>un</sup> | -4.275<sup>un</sup> | -3.214<sup>un</sup> | -2.738<sup>un</sup> |
| \( X^2 \) | 13.659 | 15.677 | 16.341 | 17.619 | 15.844 | 14.600 |

| Index | 07/10/12 | 22/10/12 | 06/11/12 | 21/11/12 | 06/12/12 | 21/12/12 |
|-------|----------|----------|----------|----------|----------|----------|
| \( \bar{m} \) | 3.500 | 7.917 | 8.917 | 10.958 | 8.833 | 11.083 |
| \( S^2 \) | 2.522 | 9.993 | 7.384 | 32.911 | 30.319 | 32.601 |
| Date       | $\bar{m}$ | $S^2$ | $I$   | $I_0$   | $K$      | $X^2$ | $\overline{m}$ | $S^2$ | $I$   | $I_0$   | $K$      | $X^2$ | $\overline{m}$ | $S^2$ | $I$   | $I_0$   | $K$      | $X^2$ | $\overline{m}$ | $S^2$ | $I$   | $I_0$   | $K$      | $X^2$ | $\overline{m}$ | $S^2$ | $I$   | $I_0$   | $K$      | $X^2$ | $\overline{m}$ | $S^2$ | $I$   | $I_0$   | $K$      | $X^2$ | $\overline{m}$ | $S^2$ | $I$   | $I_0$   | $K$      | $X^2$ |
|------------|-----------|-------|-------|---------|---------|-------|----------------|-------|-------|---------|---------|-------|----------------|-------|-------|---------|---------|-------|----------------|-------|-------|---------|---------|-------|----------------|-------|-------|---------|---------|-------|----------------|-------|-------|---------|---------|-------|----------------|-------|-------|---------|---------|-------|
| 05/01/13   | 19.125    | 14.667| 19.000| 4.083   | 4.292   | 3.708 | 10.723         | 3.536 | 14.000| 2.862   | 2.998   | 5.259 | 0.561          | 0.241 | 0.737| 0.701   | 0.699   | 1.418 | 0.976          | 0.950 | 0.987| 0.929   | 0.932   | 1.109 | 12.895         | 5.545 | 16.947| 16.122  | 16.068  | 32.618 | 15.833         | 12.333| 10.417| 9.958   | 9.708   | 12.083 |
| 04/04/13   | 13.383    | 12.333| 10.417| 9.958   | 9.708   | 12.083 | 10.723         | 3.536 | 14.000| 2.862   | 2.998   | 5.259 | 0.561          | 0.241 | 0.737| 0.701   | 0.699   | 1.418 | 0.976          | 0.950 | 0.987| 0.929   | 0.932   | 1.109 | 14.988         | 20.865| 22.448| 14.556  | 16.991  | 18.028 | 10.375         | 10.542| 9.542 | 8.125   | 7.125   | 6.917  |
| 02/10/13   | 6.375     | 6.667 | 6.250 | 5.250   | 5.542   | 5.542 | 6.592          | 5.563 | 5.303| 4.897   | 5.071   | 4.428 | 0.652          | 0.907 | 0.976| 0.633   | 0.739   | 0.784 | 0.976          | 0.993 | 0.998| 0.965   | 0.974   | 0.983 | -2.743          | -1.772| -4.167| -2.724  | -3.828   | -4.626 | -14.614         | 12.138| 12.782| 13.862  | 16.368  | 14.723 |
| 31/12/13   | 5.625     | 3.542 | 3.750 | 3.875   | 3.750   | 3.917 | 5.114          | 4.754 | 1.587| 1.413   | 1.998   | 2.259 | 0.802          | 0.713 | 0.254| 0.269   | 0.361   | 0.408 | 0.970          | 0.958 | 0.885| 0.866   | 0.889   | 0.897 | -5.056          | -3.485| -1.340| -1.368  | -1.564   | -1.688 | -18.451         | 16.400| 5.840 | 6.190   | 8.293   | 9.376  |

Note. * Significant at 5% probability; ns Non-significant at 5% probability; AG aggregate; un uniform; $\bar{m}$ - mean; $S^2$ - Variance; $I$ - Mean-variance ratio; $I_0$ - Morisita index; $K$ - Exponent of the negative binomial; $X^2$ - calculated chi-square.
Table 3. Statistical analysis (means and variances) and dispersion index for adults of *Triozoida limbata* in guava orchard (area 3), in Ivinhema, Mato Grosso do Sul, Brazil, 2012/2014 (N = 24)

| Index | Sampling date |          |          |          |          |          |          |          |          |
|-------|---------------|----------|----------|----------|----------|----------|----------|----------|----------|
|       | 10/04/12      | 25/04/12 | 10/05/12 | 25/05/12 | 09/06/12 | 24/06/12 | 09/07/12 | 24/07/12 | 08/08/12 |
|       | 15/02/12      | 22/02/12 | 06/02/13 | 21/02/13 | 06/03/13 | 21/03/13 | 05/01/13 | 20/01/13 | 04/02/13 |
| μ̅    | 4.625         | 2.940    | 0.636    | 0.924    | -2.745   | 14.622   | 4.125    | 2.027    | 12.792   |
| S²    | 5.167         | 3.188    | 0.617    | 0.928    | -2.612   | 14.194   | 5.417    | 9.210    | 6.208    |
| I     | 3.417         | 3.906    | 1.143    | 1.041    | 6.9852   | 26.293   | 3.458    | 8.428    | 14.875   |
| I₀    | 3.417         | 3.906    | 1.143    | 1.041    | 6.9852   | 26.293   | 3.458    | 8.428    | 14.875   |
| K     | 1.037         | 1.075    | 1.105    | 1.030    | 1.168    | 26.012   | 1.137    | 1.030    | 1.001    |
| X²    | 2.875         | 3.906    | 1.143    | 1.041    | 6.9852   | 26.293   | 3.458    | 8.428    | 14.875   |
|       | 56.792        | 53.129   | 17.216   | 39.505   | 10.208   | 21.013   | 12.792   | 6.208    | 14.875   |
|       | 31.013        | 20.013   | 04.0213  | 19.0213  | 06.0313  | 21.0313  | 12.792   | 6.208    | 14.875   |
| μ̅    | 12.792        | 6.208    | 14.875   | 10.208   | 6.583    | 6.833    | 12.333   | 10.958   |
| S²    | 31.013        | 20.013   | 04.0213  | 19.0213  | 06.0313  | 21.0313  | 12.792   | 6.208    | 14.875   |
| I     | 56.792        | 53.129   | 17.216   | 39.505   | 10.208   | 21.013   | 12.792   | 6.208    | 14.875   |
| I₀    | 31.013        | 20.013   | 04.0213  | 19.0213  | 06.0313  | 21.0313  | 12.792   | 6.208    | 14.875   |
| K     | 12.792        | 6.208    | 14.875   | 10.208   | 6.583    | 6.833    | 12.333   | 10.958   |
| X²    | 31.013        | 20.013   | 04.0213  | 19.0213  | 06.0313  | 21.0313  | 12.792   | 6.208    | 14.875   |
| Index | 10/04/12 | 25/04/12 | 10/05/12 | 25/05/12 | 09/06/12 | 24/06/12 |
|-------|----------|----------|----------|----------|----------|----------|
| $\bar{m}$ | 9.458 | 8.917 | 11.833 | 11.292 | 9.500 | 9.333 |
| $S^2$ | 5.216 | 6.341 | 7.275 | 6.911 | 5.130 | 4.928 |
| $I$ | 0.551$^{ns}$ | 0.711$^{ns}$ | 0.615$^{ns}$ | 0.612$^{ns}$ | 0.540$^{ns}$ | 0.528$^{ns}$ |
| $I_0$ | 0.954$^{ns}$ | 0.969$^{ns}$ | 0.969$^{ns}$ | 0.967$^{ns}$ | 0.953$^{ns}$ | 0.951$^{ns}$ |
| $K$ | -2.229$^{un}$ | -3.461$^{un}$ | -2.596$^{un}$ | -2.578$^{un}$ | -2.174$^{un}$ | -2.118$^{un}$ |
| $X^2$ | 12.683 | 16.355 | 14.141 | 14.077 | 12.421 | 12.143 |

| Index | 09/07/12 | 24/07/12 | 08/08/12 | 23/08/12 | 07/09/12 | 22/09/12 |
|-------|----------|----------|----------|----------|----------|----------|
| $\bar{m}$ | 5.625 | 6.083 | 6.000 | 6.042 | 8.917 | 8.542 |
| $S^2$ | 3.027 | 3.384 | 3.652 | 3.259 | 12.428 | 10.433 |
| $I$ | 0.538$^{ns}$ | 0.556$^{ns}$ | 0.609$^{ns}$ | 0.539$^{ns}$ | 1.394$^{ns}$ | 1.221$^{ns}$ |
| $I_0$ | 0.921$^{ns}$ | 0.930$^{ns}$ | 0.937$^{ns}$ | 0.926$^{ns}$ | 1.043$^{ns}$ | 1.025$^{ns}$ |
| $K$ | -2.165$^{un}$ | -2.254$^{un}$ | -2.556$^{un}$ | -2.171$^{un}$ | 2.540$^{ag}$ | 4.516$^{ag}$ |
| $X^2$ | 12.378 | 12.795 | 14.000 | 12.407 | 32.056 | 28.093 |

| Index | 07/10/12 | 22/10/12 | 06/11/12 | 21/11/12 | 06/12/12 | 21/12/12 |
|-------|----------|----------|----------|----------|----------|----------|
| $\bar{m}$ | 6.667 | 6.417 | 17.208 | 16.417 | 10.667 | 10.167 |
| $S^2$ | 12.928 | 12.514 | 23.824 | 23.645 | 8.928 | 9.797 |
| $I$ | 1.939$^{*}$ | 1.950$^{*}$ | 1.384$^{ns}$ | 1.440$^{ns}$ | 0.837$^{ns}$ | 0.964$^{ns}$ |

**Note.** * Significant at 5% probability; $^{ns}$ Non-significant at 5% probability; $^{ag}$aggregate; $^{un}$uniform; $^{al}$ Random; $\bar{m}$ -mean; $S^2$ - Variance; $I$ - Mean-variance ratio; $I_0$ - Morisita index; $K$ - Exponent of the negative binominal; $X^2$ - calculated chi-square.

Table 4. Statistical analysis (means and variances) and dispersion index for adults of *Triozoida limbata* in guava orchard (area 4), in Ivinhema, Mato Grosso do Sul, Brazil, 2012/2014 (N = 24)
| Date       | $\bar{m}$  | $S^2$  | $I$     | $I_\delta$ | $K$      | $X^2$  |
|-----------|-----------|-------|--------|-----------|---------|-------|
|          | 5.583     | 10.080| 1.805  | 1.139     | 1.242   | 41.522|
| 05/01/13  | 5.417     | 9.471 | 1.748  | 1.133     | 1.336   | 40.215|
| 20/01/13  | 5.292     | 7.607 | 1.438  | 1.080     | 2.286   | 33.063|
| 04/02/13  | 4.875     | 7.071 | 1.450  | 1.089     | 2.220   | 16.476|
| 19/02/13  | 4.792     | 6.955 | 1.451  | 1.091     | 2.145   | 13.201|
| 06/03/13  | 4.792     | 5.824 | 1.126  | 1.043     | 4.640   | 27.957|
| 21/03/13  | 4.792     | 1.139 | 1.133  | 1.080     | 2.286   | 33.063|
| 05/04/13  | 5.583     | 9.391 | 1.565  | 1.091     | 1.769   | 36.000|
| 20/04/13  | 5.417     | 6.650 | 1.116  | 0.961     | 2.220   | 16.476|
| 05/05/13  | 5.292     | 4.514 | 0.763  | 0.948     | 0.356   | 13.201|
| 20/05/13  | 4.875     | 3.761 | 0.716  | 0.934     | 2.245   | 13.201|
| 04/06/13  | 4.792     | 3.563 | 0.574  | 0.939     | 0.256   | 13.201|
| 19/06/13  | 4.792     | 3.739 | 0.623  | 0.866     | 1.344   | 13.201|
| 05/07/13  | 5.583     | 3.449 | 1.565  | 0.932     | 2.447   | 13.600|
| 19/07/13  | 4.750     | 3.065 | 0.763  | 0.949     | -2.819  | 14.842|
| 03/08/13  | 6.000     | 4.087 | 0.681  | 0.962     | -3.136  | 15.667|
| 18/08/13  | 5.375     | 4.245 | 0.790  | 0.938     | -1.304  | 16.476|
| 02/09/13  | 5.542     | 3.563 | 0.645  | 0.938     | -2.401  | 16.476|
| 17/09/13  | 5.375     | 1.375 | 0.716  | 0.866     | -1.344  | 16.476|
| 04/10/13  | 5.042     | 3.781 | 0.681  | 0.962     | -2.819  | 14.842|
| 17/10/13  | 6.125     | 2.375 | 0.681  | 0.962     | -3.136  | 15.667|
| 01/11/13  | 5.542     | 1.998 | 0.594  | 0.938     | -7.55   | 16.476|
| 16/11/13  | 5.750     | 3.413 | 0.352  | 0.878     | -2.460  | 16.476|
| 01/12/13  | 5.417     | 1.906 | 0.352  | 0.878     | -1.543  | 16.476|
| 16/12/13  | 4.833     | 1.884 | 0.352  | 0.878     | -1.639  | 16.476|
| 31/12/13  | 6.042     | 0.626 | 0.594  | 0.390     | -2.672  | 14.393|
| 15/01/14  | 4.750     | 0.388 | 0.352  | 0.390     | -1.635  | 8.918 |
| 30/01/14  | 5.542     | 0.361 | 0.594  | 0.884     | -1.564  | 8.293 |
| 14/02/14  | 5.750     | 0.261 | 0.374  | 0.884     | -2.460  | 13.652|
| 01/03/14  | 5.417     | 0.261 | 0.278  | 0.884     | -1.543  | 8.092 |
| 16/03/14  | 4.833     | 2.196 | 0.278  | 0.896     | -1.639  | 8.966 |

Note. * Significant at 5% probability; ** Non-significant at 5% probability; *ag* aggregate; *un* uniform; *al* Random; $\bar{m}$ - mean; $S^2$ - Variance; $I$ - Mean-variance ratio; $I_\delta$ - Morisita index; $K$ - Exponent of the negative binominal; $X^2$ - calculated chi-square.
In relation to the tests on the frequency fits of numerical classes of adults of *T. limbata*, it was observed that in area 1, the values of the chi-squared test were not significant for Poisson’s Distribution in forty-three samplings, indicating that the distribution is random. For the Negative Binomial Distribution, only one sampling was not significant, indicating that the distribution is not aggregate. In area 2, the values of the chi-squared test were not significant for the Poisson distribution in forty-four samplings, suggesting a random distribution. For the Negative Binomial Distribution of the thirty-seven samplings tested, all were significant, indicating that the distribution is not contagious (Table 5).

Table 5. Chi-square adhesion test of the expected frequencies of Poisson and Negative Binomial (Bn) distributions, spatial arrangement for adults 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 | 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      | 11.472 $^{ns}$ | 9 | 2755.112 * | 9 | 17.394 $^{ns}$ | 10 | 8050.735 * | 21 |
| 25/04/12      | 10.219 $^{ns}$ | 9 | 2831.089 * | 8 | 18.826 $^{ns}$ | 11 | 4674.427 * | 18 |
| 10/05/12      | 22.190 $^{ns}$ | 13 | 6742.407 * | 21 | 8.747 $^{ns}$ | 8 | 1513.727 * | 13 |
| 25/05/12      | 11.443 $^{ns}$ | 13 | 8670.821 * | 25 | 11.033 $^{ns}$ | 6 | 1263.396 * | 6 |
| 09/06/12      | 14.823 $^{ns}$ | 8 | 2450.268 * | 7 | 6.610 $^{ns}$ | 7 | 1195.837 * | 4 |
| 24/06/12      | 12.772 $^{ns}$ | 7 | 1543.713 * | 7 | 4.389 $^{ns}$ | 6 | 619.090 * | 13 |
| 09/07/12      | 13.581 $^{ns}$ | 7 | 1130.893 * | 6 | 4.916 $^{ns}$ | 6 | 1221.341 * | 6 |
| 24/07/12      | 84.997 * | 15 | 6719.734 * | 22 | 5.004 $^{ns}$ | 5 | 806.056 * | 4 |
| 08/08/12      | 6.846 $^{ns}$ | 7 | 1737.431* | 10 | 3.719 $^{ns}$ | 4 | 318.984 * | 6 |
| 23/08/12      | 6.743 $^{ns}$ | 7 | 1212.895 * | 8 | 8.090 $^{ns}$ | 7 | 1014.485 * | 6 |
| 07/09/12      | 66.438 * | 19 | 9855.360 * | 27 | 3.996 $^{ns}$ | 6 | 1074.079 * | 5 |
| 22/09/12      | 77.192 * | 12 | 4653.970 * | 18 | 8.925 $^{ns}$ | 7 | 1302.389 * | 5 |
| 07/10/12      | 67.926 * | 12 | 3348.915 * | 15 | 3.582 $^{ns}$ | 4 | 289.581 * | 3 |
| 22/10/12      | 13.662 $^{ns}$ | 13 | 11449.129* | 27 | 9.074 $^{ns}$ | 10 | 4236.288 * | 17 |
| 06/11/12      | 35.187 * | 11 | 4692.617$^{ns}$ | 28 | 5.162 $^{ns}$ | 9 | 3064.622 * | 14 |
| 21/11/12      | 15.655 $^{ns}$ | 13 | 8657.539 * | 25 | 179.220 * | 13 | 11276.412 * | 20 |
| 06/12/12      | 21.555 $^{ns}$ | 14 | 7403.414 * | 22 | 117.820 * | 14 | 6166.715 * | 21 |
| 21/12/12      | 12.118 $^{ns}$ | 6 | 816.622 * | 4 | 24.261 * | 14 | 7903.094 * | 24 |
| 05/01/13      | 8.064 $^{ns}$ | 11 | 4726.785 * | 18 | 12.520 $^{ns}$ | 12 | 8792.618 * | 21 |
| 20/01/13      | 11.902 $^{ns}$ | 11 | 4249.202 * | 27 | 11.533 $^{ns}$ | 8 | - - |
| 04/02/13      | 8.459 $^{ns}$ | 8 | 1699.025 * | 7 | 20.461 $^{ns}$ | 12 | 8059.574 * | 22 |
| 19/02/13      | 15.824 $^{ns}$ | 9 | 1976.112 * | 11 | 6.601 $^{ns}$ | 6 | 1268.077 * | 8 |
| 06/03/13      | 15.272 $^{ns}$ | 9 | 1978.332 * | 11 | 9.256 $^{ns}$ | 5 | 738.327 * | 5 |
| 21/03/13      | 10.171 $^{ns}$ | 8 | 2088.123 * | 11 | 10.522 $^{ns}$ | 6 | 742.751 * | 6 |
| 05/04/13      | 16.229 $^{ns}$ | 9 | 2018.525 * | 15 | 87.255 * | 9 | 3508.782 * | 12 |
| 20/04/13      | 13.162 $^{ns}$ | 9 | 2700.215 * | 11 | 40.578 $^{ns}$ | 10 | 3432.244 * | 15 |
| 05/05/13      | 15.430 $^{ns}$ | 9 | 2667.821 * | 13 | 9.490 $^{ns}$ | 10 | 3420.996 * | 15 |
| 20/05/13      | 15.964 $^{ns}$ | 9 | 2643.507 * | 13 | 13.322 $^{ns}$ | 9 | 2765.014 * | 10 |
| 04/06/13      | 6.300 $^{ns}$ | 8 | 1988.411 * | 11 | 9.149 $^{ns}$ | 9 | 2722.400 * | 11 |
In relation to the fits of the frequencies in area 3, forty-two samplings were not significant for the Poisson distribution, while in area 4 this result was observed in forty-three samplings. For the Negative Binomial Distribution, all forty-one samplings tested in area 3 and thirty-seven in area 4 had significant chi-squared values, indicating that there was no fit to this type of distribution (Table 6).

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

| Sampling date | Poisson |         | Bn   |         | Poisson |         | Bn   |         |
|---------------|---------|---------|------|---------|---------|---------|------|---------|
|               | $X^2$   | DF (nc-2) | $X^2$ | DF (nc-2) | $X^2$   | DF (nc-2) | $X^2$ | DF (nc-2) |
| 10/04/12      | 17.307*ns  | 10 | 2685.075 * | 13 | 15.425*ns  | 8 | 2463.927 * | 9 |
| 25/04/12      | 13.900*ns  | 9 | 2451.802 * | 10 | 15.979*ns  | 9 | 2389.860 * | 9 |
| 10/05/12      | 472.643*  | 20 | 9847.830 * | 27 | 10.736*ns  | 10 | 3949.727 * | 12 |
| 25/05/12      | 16.643*ns  | 12 | 3355.921 * | 15 | 13.455*ns  | 10 | 3953.331 * | 12 |
| 09/06/12      | 12.477*ns  | 7 | 1202.290 * | 8 | 12.135*ns  | 7 | 2176.323 * | 8 |
| 24/06/12      | 11.725*ns  | 6 | 992.303 * | 7 | 13.814*ns  | 9 | 2455.624 * | 9 |
| 09/07/12      | 7.037*ns  | 7 | 1377.494 * | 6 | 11.458*ns  | 6 | 2733.861 * | 5 |
| 24/07/12      | 10.559*ns  | 6 | 1390.555 * | 5 | 2.950*ns  | 6 | 3876.036 * | 5 |
| 08/08/12      | 11.981*ns  | 6 | 1185.508 * | 8 | 4.584*ns  | 6 | 1225.478 * | 5 |
| 23/08/12      | 12.018*ns  | 6 | 962.765 * | 7 | 3.984*ns  | 7 | - | - |

*Note.* * Significant at 5% probability; ns Non-significant; † insufficient of classes; $X^2$- chi-square value calculated; DF - degree of freedom; nc-number of classes observed at field.
The data obtained in 89.58% of the samplings studied from the orchards fits the Poisson’s distribution, indicating a random model of distribution of the adults of *T. limbata*. In studies with adults of *Bactericera cockerelli*
(Hemiptera: Triozidae), it was found that in the green tomato crop, the spatial distribution was also random (Crespo-Herrera et al., 2012). The random distribution found in this work occurs when the environmental conditions are similar in any point of the area, and the presence of one organism does not interfere with the presence of another individual nearby, indicating the absence or reduced interaction among individuals, and between these and the environment (Begon et al., 1996). In this type of arrangement, the energy expenditure on reproduction is lower because the males can find females without having to extensively search the area (Shea et al., 1993). In addition, the population gains greater genetic variability because the insects that come into the crop can find reproductive partners more easily (Diekötter et al., 2008), and it would be difficult for the entire population to be affected (Courtney, 1986).

Considering that the damage is also distributed in a random manner, the applications of insecticides at the wrong time or in an uneven way could undermine the efficiency in the integrated pest control because various individuals in the population may not be reached. Thus, the surviving insects could remain in the crop with sufficient energy to reproduce and begin a new cycle of attack (Alves, 2012). Knowledge of the spatial arrangement of the adults of *T. limbata* is of vital importance for determining the best sampling criteria and deciding on the best moment to apply the pest control. Thus, the results of this research will contribute to the development of future sequential sampling plans for *T. limbata*, which is aimed at defining the exact number of samplings to be used.

4. Conclusion

The adults of *Triozoida limbata* of the populations are arranged randomly in the four areas evaluated, with the sampling data fitting the Poisson distribution model.

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