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Spatial distribution of *Bemisia tuberculata* (Hemiptera: Aleyrodidae) on cassava crop in Brazil

Distribución espacial de *Bemisia tuberculata* (Hemiptera: Aleyrodidae) en el cultivo de yuca en Brasil

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Abstract: To determine an adequate sampling plan, according to the guidelines of Integrated Pest Management (IPM), it is important to understand the spatial distribution of the pest in question. The objective of this work was to develop a distribution model for *Bemisia tuberculata* adults on cassava crops. Sampling was performed in a commercial field of 2,500 m^2, divided into 100 plots, where the numbers of individuals on the apical leaves were counted. No insecticides were applied during the study. Fifteen samples were taken weekly from January to April 2012. In general, the aggregation indices (variance/mean; Morisita index and k exponent) and frequency indices showed that the spatial distribution model that best represents this pest population was aggregated or contagious.

Key words: Negative binomial. Distribution. Whitefly. Sampling.

Resumen: En la definición de un adecuado plan de muestreo, siguiendo las directrices del Manejo Integrado de Plagas (MIP), es importante conocer el comportamiento de distribución espacial de la plaga en cuestión. Así, el objetivo de este trabajo fue generar información sobre el modelo de distribución de adultos de *Bemisia tuberculata* en cultivo de yuca. Fueron realizados muestreos en un cultivo comercial de 2.500 m^2, dividido en 100 parcelas, donde fueron contados los números de individuos en las hojas apicales. Ninguna aplicación de insecticida fue realizada durante el muestreo. Se realizaron quince muestreos semanales desde enero hasta abril de 2012. De manera general, los índices de agregación (varianza/media; Índice de Morisita y exponente k) e índices de frecuencia, permiten concluir que el modelo de distribución espacial que representa la población de esta plaga fue el agregado o contagioso.

Palabras clave: Binomial negativa. Distribución. Mosca-blanca. Muestreo.

Introduction

The Cassava (*Manihot esculenta* Crantz) is one of the most important crops with respect to socioeconomics and human consumption (FAO 2008). The plant is considered the main carbohydrate source for more than 925 million people in 105 countries across tropical and subtropical regions (FAO 2010, 2011). Not only is a food source, cassava is also a raw material for the chemical, paper and biofuels industries (Felipe *et al*. 2010). Cultivated in all Brazilian states, national cassava production in 2011 was estimated at 27.1 million tons, an increase of 9.1% compared to 2010 (IBGE 2011).

Brazilian cassava crops are subject to pest attacks, which are generally cyclical and may not occur each year (Farias *et al.* 2000; Espinel *et al*. 2009; Bellon *et al*. 2012). These attacks reduce the production and commercialization of cassava and its derivatives (Silva *et al*. 2007). Among the main pests, the whitefly, *Bemisia tuberculata* Bondar, 1923 (Hemiptera: Aleyrodidae), is a vector of virus known as frogskin disease (Angel *et al.* 1990). Damage caused by *B. tuberculata* can result in losses between 5% to 80% (Schimitt 2002; Bellotti *et al*. 2007; Sagrilo *et al*. 2010).

Direct injuries are caused by sucking of sap, potentially causing decreased plant vigor, defoliation, wilting, chlorotic spots and premature leaf fall. Indirect damage is also caused by the growth of sooty mold on the honeydew, which acts to reduce photosynthesis (Pietrowski *et al*. 2010).

Studies on the distribution frequency of different insect species in different cultures are important for acquiring knowledge on spatial distribution of these individuals, adopting appropriate sampling criteria to estimate population parameters and facilitate the control of the pest (Barbosa 1992).

Utilization of a sampling model for assessing pest population is fast, reliable and less costly according to the philosophy of Integrated Pest Management (IPM), and is very important for sustainable food production (Hodgson *et al*. 2004). Therefore, to establish a reliable sampling plan it is necessary to know the spatial distribution of pest species in the crop (Giles *et al*. 2000).

Spatial dispersion of a population usually follows one of three in accordance with one of the tree models: aggregated (or contagious), random (or by chance) or uniform (or regular) (Barbosa 1992; Young and Young 1998). To determine the spatial distribution pattern of a given species it is necessary to obtain data on the count of individuals in the ecosystem to be considered. It is fundamental that the ecosystem in question allows for sampling (Fernandes *et al*. 2003).

These samples, according to Young and Young (1998), can be used to infer the form of distribution of the population sampled or the characteristics of the distribution. For the description of population distribution forms, the aggregation indices and frequency distributions were used.

Initially the area under study should be divided into study several units or quadrants (grids) of the same size and subsequently describe the area occupation model for individuals in the population as a distribution of frequencies of individuals observed in each quadrant (Kuno 1991).

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Based on these facts, the objective of this study was to evaluate the spatial distribution of adults of *B. tuberculata* in the cassava crop, seeking to devise a sampling plan that may be adopted by farmers.

Material and methods

Description of the sampling area. The experiment was conducted during the first crop cycle of 2012 in a commercial production area, located in the municipality of Ivinhema, Mato Grosso do Sul, Brazil. The sampled area consisted of 2,500 m^2, located at 22º20'57"S 53º54'37"W and elevation of 423 m.

Spacing of the plants was 0.90 m between rows and 0.45 m between plants of the "fécula-branca" variety. This variety is included in the group of those most tolerant to *B. tubercula* (Sagrilo *et al*. 2010). The cuttings were planted on August 28th, 2011; fertilizer was applied at a rate of 290 kg ha^{-1} (N-P_2O_5-K_2O; 00-30-10 formulation) and in the area used there was no trace of chemical treatment for pest control.

Sampling. The sampling was organized as follows: one area was demarcated in the sampling area. It was divided into 100 plots of 25 m^2 (5 m x 5 m). In each plot, there were evaluated five randomly chosen plants, totaling 500 plants in field. For sampling of whitefly adults, visual observations were made in the morning by slightly turning the leaves to the side (Tonhasca Jr *et al*. 1994).

The complete sampling period lasted from January 7th, 2012 to April 14th, 2012; totaling 15 samples according to occurrence of the whitefly in the crop. This period ranges from the beginning of colonization of the pest until completion of the its first cycle in the crop.

Statistical analysis. The statistical analyses used for determining the spatial distribution pattern of the insect consider the mean of *B. tuberculata* adults found in the quadrants of the area under study. For this purpose the following parameters were used:

Dispersion indexes

Variance/Mean ratio: this ratio (I) is an index that measures the deviation of a random data arrangement. For this index values equal to one indicate random or by chance spatial distribution, whereas smaller values indicate that the unit presents regular or uniform spatial distribution and values significantly greater than 1 indicate aggregated or contagious distribution (Rabinovich 1980).

Morisita index: the Morisita index ($I\delta$) is relatively independent on the mean and number of samples. Thus, when $I\delta = 1$ the distribution is random; when $I\delta > 1$ the distribution is contagious and when $I\delta < 1$ the distribution is regular (Silveira Neto *et al*. 1976).

Exponent k of the negative binomial distribution: the exponent k is a suitable dispersion index when the size and numbers of sample units are the same in each sample, since this is frequently influenced by the size of the sampling units. This parameter is an inverse measure of the degree of aggregation, where in this case negative values indicate a normal or uniform distribution, positive values near zero indicate an aggregated dispersion and values greater than eight indicated a random dispersion (Elliot 1977; Southwood 1978). Regarding this aspect, Poole (1974) used another interpretation when $0 < k < 8$, the aggregated distribution index and $0 > k > 8$ indicated random distribution.

Theoretical frequency distribution. The theoretical frequency distributions used to assess spatial distribution of the species observed are as follows, according to Young and Young (1998).

Poisson distribution: also known as random distribution, characterized by presenting a variance equal to the mean ($S^2 = \dot{m}$).

Negative Binomial Distribution: presents a variance greater than the mean, thereby indicating an aggregated distribution and it also has two parameters: the mean ($\dot{m}$) and the parameter k ($k > 0$).

Chi-square adherence test: The chi-square adherence test was used to compare the total frequency observed in the sampling area with the expected frequencies, according to Young and Young (1998), where these frequencies are defined by the product of the probabilities for each class and the total number of sample units utilized. For this test, it was opted to fix an expected frequency equal to one.

Results and discussion

The presence of *B. tuberculata* adults was observed in all samples collected, since sampling dates coincided with the occurrence period of the pest in cassava (Gomez *et al*. 2005). The population peak of *B. tuberculata* occurred on January 21st, 2012 and the average number of adults observed per plot was 24.39 (Table 1).

Results of the aggregation indices indicated variance/mean and Morisita values significantly greater than one. For these indexes the pest dispersion presented an aggregated pattern. In the Morisita index it was observed that in all evaluations of this study the values were higher than one with significance level of 1% probability and values resulting from the exponent k ranged from 0.372 to 4.638. i.e., positive values less than eight (Table 1).

The aggregation indexes showed that all evaluations performed for the *B. tuberculata* adults presented aggregated dispersion of individuals in the population studied. However, in studies with the whitefly, considering the presence and absence of the pest rather than the population, was found that the spatial distribution of *Bemisia tabaci* Gennadius in bean plants presented a regular dispersion (Pereira *et al*. 2004). Considering the whitefly population in cotton (Naranjo and Flint 1995; Rodrigues *et al*. 2010) and melon (Tonhasca Jr *et al*. 1994; Gould and Naranjo 1999) it found that *B. tabaci* showed an aggregated distribution in the field.

With respect to test results for removal of randomness from the Poisson chi-square, these were significant at 1% probability level for 14 samples, adjusting the randomness only on January 21st, 2012, i.e., adjusting to aggregation (Table 2).

Moreover, of all the 15 sampling events performed, ten samples adjusted to the negative binomial distribution model with non-significant chi-square value. The values were significant at 1% probability in only five samples (Jan 21st, 2012; Feb 18th, 2012; Feb 25th, 2012; Mar 3rd, 2012; Apr 14th, 2012).

Therefore, according to the results of the aggregation index and the frequency index, the aggregated distribution best defined *B. tuberculata* in cassava because the negative

Table 1. Statistics {(mean $\dot{m}$) and variance (S^2)} for adults *Bemisa tuberculata* (Hemiptera: Aleyrodidae) per sample unit and dispersion indexes {variance/mean (I); Morisita index ($I\delta$); k exponent (k)} and calculated chi-square (χ^2) in cassava. Ivinhema (MS), Brazil. 2012.

Sampling	$\dot{m}$	S^2	I	$I\delta$	k	χ^2
January/7/2012	8.09	52.305	6.465*	1.670*	1.480 ag	640.073
January/14/2012	4.76	11.356	2.386*	1.289*	3.435 ag	236.185
January/21/2012	24.39	253.149	10.379*	1.381*	2.600 ag	1.027,544
January/28/2012	19.68	164.402	8.354*	1.370*	2.676 ag	827.020
February/4/2012	23.21	139.359	6.004*	1.214*	4.638 ag	594.424
February/11/2012	13.77	86.623	6.291*	1.381*	2.603 ag	622.782
February/18/2012	8.3	92.717	11.171*	2.215*	0.816 ag	1.105,904
February/25/2012	11.6	188.485	16.249*	2.303*	0.761 ag	1.608,621
March/3/2012	18.28	915.840	50.101*	3.661*	0.372 ag	4.959,965
March/10/2012	16.1	408.778	25.390*	2.501*	0.660 ag	2.513,602
March/17/2012	7.71	66.774	8.661*	1.985*	1.006 ag	857.405
March/24/2012	15.29	200.814	13.134*	1.786*	1.260 ag	1.300,235
March/31/2012	8.2	73.131	8.918*	1.957*	1.036 ag	882.927
April/7/2012	18.59	311.234	16.742*	1.839*	1.181 ag	1.657,460
April/14/2012	14.43	353.7	24.511*	2.614*	0.613ag	2426.646

*Significant at the 5% level using the chi-square; ag aggregate.

binomial model was that which best fit to the data obtained in the field.

According to the advanced strategies of IPM, control of this pest in cassava should not rely solely on chemical insecticides, but adopt systems that emphasize the ecological management of populations of this arthropod. Thus, understanding the distribution of *B. tuberculata* in the crop may promote alterations in the sampling and pest control strategies, which may then contribute to phytosanitary management of this species in the culture.

Conclusion

B. tuberculata adults presented an aggregated spatial distribution throughout the occurrence period. This spatial distribution model requires a large number of units per area so that the data obtained during sampling does not underestimate or overestimate the number of insect pests in the area. Furthermore, it is suggested that insecticides and/or biopesticides be applied locally in order to reach the clusters of *B. tuberculata*.

Table 2. Chi-square test of adherence to adults of *Bemisa tuberculata* (Hemiptera: Aleyrodidae) (Poisson and negative binomial) in cassava. Ivinhema (MS), Brazil. 2012.

Sampling	Poisson		Negative Binomial	
	χ^2	GL (nc-2)	χ^2	GL (nc-3)
January/7/2012	1452.53**	13	19.88 ns	18
January/14/2012	77.75**	10	8.86 ns	11
January/21/2012	11.19 ns	7	61.60*	36
January/28/2012	29674.08**	5	9.90 ns	33
February/4/2012	9.00**	-1	6.42 ns	37
February/11/2012	9777.76**	19	6.07 ns	26
February/18/2012	633.08**	4	47.07*	18
February/25/2012	12313.29**	17	45.21*	21
March/3/2012	1885830.87**	24	81.94*	16
March/10/2012	381067.10**	21	34.04 ns	23
March/17/2012	1584.96**	13	7.93 ns	18
March/24/2012	21770.99**	21	13.88 ns	27
March/31/2012	3646.79**	13	5.66 ns	18
April/7/2012	3448441.47**	24	18.01 ns	29
April/14/2012	194307.24**	20	51.941*	22

[ns]no significant. [*]significant at 0.01%. [**]significant at 0.05%. χ^2 - chi-square value calculated. GL - degree of freedom.

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