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Spatial Distribution for Corn Root Worm *Diabrotica speciosa* (Coleoptera: Chrysomelidae) on Maize Crops

Distribuição Espacial do Besouro-da-Raiz-do-Milho *Diabrotica speciosa* (Coleoptera: Chrysomelidae) em Cultivos de Milho

Distribución Espacial del Escarabajo de la Raíz del Maíz *Diabrotica speciosa* (Coleoptera: Chrysomelidae) en Cultivos de Maíz

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Abstract
To develop a sequential sampling plan based on the guidelines of Integrated Pest Management (IPM), it is important to know the spatial distribution of the pest in question. The corn rootworm *Diabrotica speciosa* (Germar) (Coleoptera: Chrysomelidae) is a significant pest in the field corn (*Zea mays* L.) Brazil. The objective of the present study was to collect data on the distribution model of the adults of *D. speciosa* in the Bt and non-Bt maizefields. Samples were collected in six field trials of 250 m^2 each, during 2012 and 2013. Each field was divided into 100 plots, each measuring 25m^2 (5 ×5m) in area. The sampling unit for all the samples involved five randomly selected plants that were tested in each plot, a total 500 of plants per field. The number of adults of *D. speciosa*, was counted weekly, for a total of between five and seven samples per field. The dispersion index (variance / mean; Morisita index and the exponent of the negative binomial K) and chi-square fit of the values observed and expected for the theoretical

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frequency distribution (Poisson, negative binomial and binomial positive), showed that regardless of the cultivar, the adults of *D. speciosa* showed an aggregated distribution pattern, adjusting to the negative binomial model.

Keywords: Probability distribution; Negative binomial; Sampling; Bt maize; Dispersion pattern.

Resumo

Para desenvolver um plano de amostragem sequencial com base nas diretrizes do Manejo Integrado de Pragas (MIP), é importante conhecer a distribuição espacial da praga em questão. O besouro-da-raiz-do-milho *Diabrotica speciosa* (Germar) (Coleoptera: Chrysomelidae) é uma praga significativa nas lavouras de milho (*Zea mays* L.) no Brasil. O objetivo do presente estudo foi coletar dados sobre o modelo de distribuição dos adultos de *D. speciosa* em campos de milho Bt e não-Bt. As amostras foram coletadas em seis áreas experimentais de 250 m² cada, durante os anos de 2012 e 2013. Cada área foi dividida em 100 parcelas, cada uma com 25 m² (5 × 5 m). A unidade amostral consistiu em cinco plantas selecionadas aleatoriamente em cada parcela, totalizando 500 plantas por campo. O número de adultos de *D. speciosa* foi contado semanalmente, totalizando entre cinco e sete amostragens por campo. O índice de dispersão (variância/média; índice de Morisita e o expoente da binomial negativa K) e o teste do qui-quadrado entre os valores observados e esperados para as distribuições teóricas (Poisson, binomial negativa e binomial positiva) mostraram que, independentemente da cultivar, os adultos de *D. speciosa* apresentaram um padrão de distribuição agregada, ajustando-se ao modelo binomial negativo.

Palavras-chave: Distribuição de probabilidade; Binomial negativa; Amostragem; Milho Bt; Padrão de dispersão.

Resumen

Para desarrollar un plan de muestreo secuencial basado en las directrices del Manejo Integrado de Plagas (MIP), es importante conocer la distribución espacial de la plaga en cuestión. El escarabajo de la raíz del maíz *Diabrotica speciosa* (Germar) (Coleoptera: Chrysomelidae) es una plaga significativa en los cultivos de maíz (*Zea m*ays L.) en Brasil. El objetivo del presente estudio fue recopilar datos sobre el modelo de distribución de los adultos de *D. speciosa* en campos de maíz Bt y no-Bt. Las muestras se recolectaron en seis áreas experimentales de 250 m² cada una, durante los años 2012 y 2013. Cada área se dividió en 100 parcelas de 25 m² (5 × 5 m). La unidad de muestreo consistió en cinco plantas seleccionadas al azar en cada parcela, totalizando 500 plantas por campo. El número de adultos de *D. speciosa* se contó semanalmente, totalizando entre cinco y siete muestreos por campo. El índice de dispersión (varianza/media; índice de Morisita y el exponente de la binomial negativa K) y la prueba de ji-cuadrado entre los valores observados y esperados para las distribuciones teóricas (Poisson, binomial negativa y binomial positiva) mostraron que, independientemente del cultivar, los adultos de *D. speciosa* presentaron un patrón de distribución agregada, ajustándose al modelo binomial negativo.

Palabras clave: Distribución de probabilidad; Binomial negativa; Muestreo; Maíz Bt; Patrón de dispersión.

1. Introduction

Knowledge regarding the spatial distribution of insects not only serves the purposes of ecological and behavioral studies but is also useful as a tactic to control insect populations considered pest (Toninato et al., 2024). Initially, the area under study should be divided into several units or quadrants (grids) of the same size, and subsequently the area occupation model should be described for the individuals in the population as a distribution of their frequencies observed in each quadrant (Kuno, 1991).

The spatial patterns of the organisms in the field are distinguishable into three patterns, viz., aggregated, uniform or random (Silva et al., 2025). Categorizing the distribution of an organism into one of these three categories can be achieved through the dispersion indexes and the theoretical distribution of their frequencies (Chen and Shen, 2024). Although the aggregation and dispersion indexes do not mathematically describe the distribution of the population studied (Elliot, 1971), they provide data for an approximation to reality. It is important to note that knowing the distribution of the frequencies (which mathematically describe the spatial distribution of the pest) is vital to determine the adequate sampling criteria, statistical analyses, and decision to employ control measures (Ruesink, 1980; Taylor, 1984).

The genus *Diabrotica* Chevrolat is an important group of pests occurring in the Americas, damaging different cultivars. In the corn fields, the northern corn root worm *D. barberi* Smith & Lawrence has been a significant pest, difficult to control in the U.S. Corn Belt (Pereira et al., 2023). Even in this region, the costs of handling and the loss of cultivation due to the western corn rootworm *Diabrotica virgifera virgifera* LeConte amount to $1 billion annually (Roeder et al., 2025; Rashev et al., 2024; Smith et al., 2023).

In Brazil, the corn rootworm *Diabrotica speciosa* (Germar) causes problems mainly in soy, beans and potatoes. Its presence in *Zea mays* L. (Poacecae), besides causing significant losses in production due to the larvae boring tunnels in the stem, produce the bend of the first internode, while the adults feed on the aerial plant parts. The injuries caused to the young maize plant leaves are similar to those produced by the fall armyworm, *Spodoptera frugiperda* Smith (Revista Cultivar, 2025; Maguintontz, 2025; Menezes-Netto et al. 2012).

The present management methods of *D. speciosa* in corn, high light the application of insecticide eats so wing and seed treatment; however, the latter is often not efficient due to its low dose and short residual effect (Rodrigues, 2024). The alternative to applying insecticides use the genetically modified insect-resistant Bt maize. Marketing the Bt had commenced in 2008, and currently about 20% is being used, with their rate of production showing an increase every year. Bt maize MON (88017) off resistance to the larvae of *D. speciosa* due to Cry3 Bb1protein (Vidal et al., 2024; Marini et al., 2023). However, the technology is more commercialized in Brazil and does not management the pest, which makes conventional control methods indispensable (Costa et al., 2021).

Although this technology is increasingly being adopted by the farmers, leading to the reduced use of insecticides (Lorente et al., 2025; Seixas et al., 2022), it is not known with certainty whether the Bt protein of the modified crops affects the populations of several organisms in the agroecosystems. For this reason, studies that aim at detecting alterations in the spatial distribution of the target and non-target insect populations in response to Bt crops are highly desirable (He et al., 2025; Legan et al., 2024; Zhang et al., 2024).

Thus, a change in the spatial distribution of a particular pest as a direct consequence of the genetically modified crop will result in a different sequential sampling influencing, for example, the number of sampling units and thus the feasibility of the decision. Therefore, we evaluated the spatial distribution of *Diabrotica speciosa* (Coleoptera: Chrysomelidae) present in the Bt maize crop and compared it with the population present in the non-Bt maize fields.

2. Methodology

This study was conducted in the autumn-winter season, between 2012 and 2013, in six maize fields (two in Dourados and one in Maracajú in 2012; and two in Maracajú and one in Dourados in 2013) located in the south of Mato Grosso do Sul state, Brazil. The fields were planted with Bt transgenic maize (DKB 390 VTPRO) expressing the Cry1A.105 + Cry2Ab2 toxins and non-Bt maize DKB 177. No insecticides were applied during the study. Each field was divided into 100 plots, each measuring 25 m^2 (5 × 5 m) area. The sampling unit for all the samples involved 05 randomly selected plants that were tested in each plot, 500 plants in total per field. We counted the total number of adults of *D. speciosa*, weekly, for a total of between five and seven samples per field.

Statistical analyses to determine the spatial distribution pattern of the insect took into consideration the means of the number of individuals found in the plots in the four working areas, and the following dispersion indices were used for this purpose:

Variance/Mean Ratio Index: This ratio (*I*) is an index which measures the deviation of a random data arrangement. For this index, values equal to 1 indicate random or chance spatial arrangement, values lower than 1 indicate regular or uniform spatial arrangement, and values significantly greater than 1 show aggregated or contagious distribution (Rabinovich 1980). Limitations of this index, according to (Southwood 1966), lie in the influence of the sampling unit size as well as on the number of individuals observed, being extremely affected by the provisions of the infection. This index is estimated by:

$$I = \frac{s^2}{m}$$

where: s^2 = sample variance and m = sample mean. The test of non-randomness consists of rejecting the randomness if:

$\chi^2 = I.\,(\text{N-1}) \geq \chi^2_{(\text{n-1df})}$

where: N = sample size; χ^2= calculated chi-squared; χ^2= tabulated chi-squared.

Morisita index: The Morisita Index (I_δ) is relatively independent of the mean and the number of the samples. When I_δ= 1 the distribution is random and when I_δ> 1 the distribution is contagious, whereas I_δ<1 indicates the regular distribution (Silveira Neto et al. 1976). The limitation of the Morisita Index lies in the fact that it is overly influenced by sample size (N), where, for safe use, the number of sampling units must be the same for all the fields being compared. It is expressed as:

$$I_\delta = N \frac{(\sum_{i=1}^{N} x_i^2 - \sum_{i=1}^{N} x_i)}{(\sum_{i=1}^{N} x_i)^2 - \sum_{i=1}^{N} x_i}$$

where: N = sample size and x_i = number of insects in the i-th sampling unit. The randomness test is calculated by:

$$\chi^2_\delta = I_\delta(\sum_{i=0}^{n} x_i - 1) + N - \sum_{i=0}^{n} x_i$$

$I\delta$ = value of the Morisita index; N = sample size; x_i = number of insects in the i-th sample unit. When $\chi^2_\delta \geq \chi^2_{(N-1\text{df},\alpha=0.005)}$, the randomness is rejected.

Exponent K of the Negative Binomial Distribution: Exponent K is a suitable dispersion index when the size and numbers of the sample units are the same in each sample, often being influenced by the sampling unit size. This parameter is an inverse measure of the degree of aggregation; in this case, the negative values indicate a normal or uniform distribution, the positive values close to zero indicate an aggregated arrangement and the higher values, up to 8, indicate a random distribution (Southwood 1966, Elliot 1971). Regarding this aspect, Poole (1974) proposed a different interpretation, where when 0<K<8 the index indicates an aggregated distribution, and when 0 <K> 8 it points to random distribution. It is calculated by employing the following expression:

$$k = \frac{m^2}{(s^2 - m)}$$

where; m^2 = sample average; s^2 = sample variance.

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

Poisson distribution, also termed random distribution, is characterized by presenting variance equal to the mean (Southwood 1966).

$$P(x = x) = \frac{e^{-m} m^x}{x!}$$

where: x= classes 0,1,2,3...; e= base of the natural log (e= 2.718282...); $P(x=x)$ = probability of encountering x individuals in the sample; m= sample mean.

Positive Binomial Distribution: Describes a uniform distribution with variance lower than the mean.

$$P(0) = q^k$$

$$P(x) = \frac{p}{q} \cdot \frac{(\mathrm{k} - x + 1)}{x} \cdot P(x - 1)$$

where: x= classes 0,1,2,3...,k; $P(x)$ = probability of encountering x individuals in the sample; k = unit sample size; $p = \frac{m}{k}$ and $q = 1 - p$.

Negative Binomial Distribution: This shows greater variance than the mean, thereby indicating an aggregated distribution. It has two parameters: the mean (m) and the parameter K (K>0).

$$P(x = x) = \binom{K + x - 1}{K - 1} \left(\frac{K}{m + K}\right)^{K} \left(\frac{m}{m + K}\right)^{m}$$

where: for x = 0,1,2,3…

Chi-squared test: To verify the fitness test of the data collected to the theoretical distributions of frequency, the chi-squared test for adherence was used to compare the total frequencies observed in the sample 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 sampling units used. In the present study, it was selected to fix a minimum expected frequency equal to 1, due to the number of minimum classes necessary to find the degree of freedom.

$$\chi^2 = \sum_{i=0}^{n} \frac{(FO_i - FE_i)^2}{FE_i}$$

where n_c= number of frequency distribution classes; FO_i = the frequency observed in the i-th class; FE_i = frequency expected in the i-th class.

$\chi^2 \geq \chi^2_{(nc-np1df,\alpha=0.005)}$,

where: χ^2= calculated chi-squared; χ^2= tabulated chi-squared; nc= number of frequency distribution classes; np= number of estimated parameters in the sample.

3. Results and Discussion

Results:

Considering the results of the index variance / mean, the valuesabove unity were observed to be predominant in relation to the values equal to unity for both the Bt and non-Bt cultivars (Tables 1 and 2). The results for values above unit were also observed to calculate the Morisita index, i.e. most of the data distribution resulted in an aggregate for the adults of *D. Speciosa,* regardless of the cultivar studied (Tables 1 and 2). No difference was observed in the cultivar values of the exponent K of the negative binomial distribution, or most of the data was positive, not exceeding 8, which characterized aggregation of the population (Tables 1 and 2).

The test adjustment frequencies observed the numerical classes of the adult *D. speciosa* in the fields of Bt and non-Bt corn and the chi-square values were evaluated for each theoretical distribution. Thus, the positive binomial distribution did not show a good fit to the data with the standard uniform distribution and, therefore, only a sampling Bt corn was set to this model (Tables 3 and 4). About the Poisson distribution, there were sampling date adjustments with this model (random) distribution, although still insufficient for completion of the outcome. These results were founding both cultivars (Tables 3 and 4).

The data collected in the field being tested using the negative binomial distribution showed a good fit to this distribution model. As each cultivar contained 29 samples,17:20 non-significant values were observed in total. This refers to the values that did not rule out the possibility of aggregation in non-Bt and Bt, respectively. Thus, the *D. speciosa* adults, exhibit clustered distribution in both Bt maize, as in conventional maize.

Table 1. Statistics {mean (ṁ) and variance (S^2)} for adults of *Diabrotica speciosa* per sample unit and the dispersion index {variance/mean (*I*); Morisita (I_δ) exponent K (*k*)} and Chi-Square calculated (χ^2) on Maize DKB 350PRO.

Field	Index	Sampling period									
		2012					2013				
		7 D.A.E	14 D.A.E	21 D.A.E	28 D.A.E	35 D.A.E	7 D.A.E	14 D.A.E	21 D.A.E	28 D.A.E	35 D.A.E
I	$\dot{m}$	1,13	1,04	0,62	1,07	0,78	0,12	0,34	0,22	0,31	0,67
	S^2	1,71	1,41	0,76	1,43	1,06	0,20	0,46	0,25	0,45	1,01
	I	1,51*	1,35*	1,23^{ns}	1,34*	1,36*	1,73*	1,37*	1,15^{ns}	1,47*	1,50*
	I_δ	1,45*	1,34*	1,37^{ns}	1,32*	1,46*	7,57*	2,13*	1,73^{ns}	2,58*	1,76*
	k	2,20^{ag}	2,90^{ag}	2,68^{ag}	3,09^{ag}	2,15^{ag}	0,16^{ag}	0,89^{ag}	1,41^{ag}	0,64^{ag}	1,31^{ag}
	X^2	149,83	134,46	121,87	133,18	134,82	171,33	136,58	114,36	146,41	149,41
II	$\dot{m}$	1,03	0,9	0,51	0,45	1,08	0,09	0,23	0,04	0,09	0,15
	S^2	0,99	1,42	0,59	0,57	1,28	0,12	0,44	0,03	0,10	0,18
	I	0,96^{ns}	1,58*	1,16^{ns}	1,27^{ns}	1,19^{ns}	1,36*	1,91*	0,96^{ns}	1,14^{ns}	1,26^{ns}
	I_δ	0,97^{ns}	1,64*	1,33^{ns}	1,61*	1,17^{ns}	5,55*	5,13*	0	2,77^{ns}	2,85*
	k	-34,32^{un}	1,54^{ag}	3,02^{ag}	1,64^{ag}	5,64^{ag}	0,24^{ag}	0,25^{ag}	-1,32^{un}	0,62^{ag}	0,57^{ag}
	X^2	96,02	156,66	115,66	126,11	117,92	135,44	190,04	96	113,22	125
III	$\dot{m}$	0,85	0,61	0,54	0,47	-	0,3	0,12	0,1	0,21	0,14
	S^2	1,13	0,82	0,67	0,63	-	0,37	0,20	0,11	0,43	0,34
	I	1,33*	1,35*	1,25^{ns}	1,35*	-	1,24^{ns}	1,73*	1,11^{ns}	2,04*	2,45*
	I_δ	1,40*	1,58*	1,46*	1,75*	-	1,83*	7,57*	2,22^{ns}	6,19*	12,08*
	k	2,50^{ag}	1,72^{ag}	2,15^{ag}	1,33^{ag}	-	1,22^{ag}	0,16^{ag}	0,9^{ag}	0,20^{ag}	0,09^{ag}
	X^2	132,64	134,08	123,77	133,85	-	123,33	171,33	110	202,80	243,14

* = significant difference at (P> 0.05) for chi-square test; ag = aggregate; al = random; ns = not significant.

Table 2. Statistics {mean (ṁ) and variance (S^2)} for adults of *Diabrotica speciosa* per sample unit and the dispersion index {variance/mean (I); Morisita (I_δ) exponent K (k)} and Chi-Square calculated (χ^2) on Maize DKB.

Field	Index	Sampling period									
		2012					2013				
		7 D.A.E	14 D.A.E	21 D.A.E	28 D.A.E	35 D.A.E	7 D.A.E	14 D.A.E	21 D.A.E	28 D.A.E	35 D.A.E
I	ṁ	0,88	1,07	0,43	0,76	0,54	0,07	0,4	0,27	0,29	0,81
	S^2	1,13	1,01	0,44	0,81	0,71	0,10	0,86	0,46	0,57	1,04
	I	1,29^{ns}	0,94^{ns}	1,04^{ns}	1,06^{ns}	1,32*	1,51*	2,17*	1,71*	1,97*	1,28^{ns}
	I_δ	1,33*	0,95^{ns}	1,10^{ns}	1,08^{ns}	1,60*	9,52*	3,97*	3,70*	4,43*	1,35*
	k	3,01^{ag}	-20,91^{un}	9,43^{al}	11,43^{al}	1,66^{ag}	0,13^{ag}	0,34^{ag}	0,38^{ag}	0,29^{ag}	2,79^{ag}
	X^2	127,90	93,93	103,51	105,57	131,18	150,14	215	169,29	195,13	127,64
II	ṁ	1,04	0,6	0,14	0,6	0,7	0,1	0,07	0,08	0,03	0,12
	S^2	1,06	0,88	0,22	0,78	0,89	0,17	0,10	0,07	0,04	0,20
	I	1,02^{ns}	1,48*	1,59*	1,31*	1,27^{ns}	1,71*	1,51*	0,92^{ns}	1,65*	1,73*
	I_δ	1,02^{ns}	1,80*	5,49*	1,52*	1,40*	8,88*	9,52*	0	33,33*	7,57*
	k	37,18^{al}	1,24^{ag}	0,23^{ag}	1,91^{ag}	2,46^{ag}	0,13^{ag}	0,13^{ag}	-1,13^{un}	0,04^{ag}	0,16^{ag}
	X^2	101,76	146,66	157,42	130	127,14	170	150,14	92	163,66	171,33
III	ṁ	0,68	0,42	1,03	0,66	-	0,43	0,19	0,14	0,13	0,29
	S^2	0,84	0,52	1,24	0,89	-	0,71	0,27	0,22	0,13	0,47
	I	1,24^{ns}	1,25^{ns}	1,20^{ns}	1,35*	-	1,65*	1,45*	1,59*	1,03^{ns}	1,62*
	I_δ	1,36^{ns}	1,62*	1,19^{ns}	1,53*	-	2,54*	3,59*	5,49*	1,28^{ns}	3,20*
	k	2,78^{ag}	1,62^{ag}	5,01^{ag}	1,86^{ag}	-	0,65^{ag}	0,41^{ag}	0,23^{ag}	3,80^{ag}	0,46^{ag}
	X^2	123,17	124,66	119,33	134	-	163,97	144,15	157,42	102,38	160,65

* = significant difference at ($P > 0.05$) for chi-square test; ag = aggregate; al = random; ns = not significant.

Table 3. Chi-square test (χ^2) for *Diabrotica speciosa* (Coleoptera: Chrysomelidae) (Poisson, Negative Binomial and Positive Binomial) on Maize DKB 350PRO (Bt).

			Poisson		Negative Binomial		Positive Binomial	
Field		Sampling Period	$\chi2$	DF(nc-2)	$\chi2$	DF(nc-3)	$\chi2$	DF(nc-3)
I	2012	7 D.A.E	29,738**	3	19,12**	3	62,00**	2
		14 D.A.E	20,54**	3	14,24**	2	31,69**	1
		21 D.A.E	7,40^{ns}	2	1,47^{ns}	1	28,42**	1
		28 D.A.E	8,65^{ns}	3	4,10^{ns}	3	27,22**	1
		35 D.A.E	9,93**	2	5,72^{ns}	2	34,52**	1
	2013	7 D.A.E	7,87**	1	6,24^{ns}	1	8,00^{i}	-1
		14 D.A.E	3,51^{ns}	1	0,43^{ns}	1	26,56^{i}	0
		21 D.A.E	2,53^{ns}	1	0,50^{ns}	1	29,81^{i}	0
		28 D.A.E	2,50^{ns}	1	1,28^{ns}	1	30,45^{i}	0
		35 D.A.E	2,53^{ns}	2	1,00^{ns}	2	27,73**	1
II	2012	7 D.A.E	3,41^{ns}	3	3,49^{ns}	2	4,53*	1
		14 D.A.E	19,13**	3	13,61**	2	35,47**	1
		21 D.A.E	3,63^{ns}	2	1,98^{ns}	1	27,44^{i}	0
		28 D.A.E	8,65^{ns}	3	4,10^{ns}	3	27,22**	1
		35 D.A.E	17,09**	3	14,29**	2	35,99**	1
	2013	7 D.A.E	1,54^{i}	0	0,59^{i}	0	1,59^{i}	-1
		14 D.A.E	23,52**	1	6,12^{ns}	1	33,90^{i}	0
		21 D.A.E	0^{i}	0	0^{i}	-1	25,24^{i}	-1
		28 D.A.E	0,30^{i}	0	0,14^{i}	-1	27,28^{i}	0
		35 D.A.E	1,78^{i}	0	0,60^{i}	0	27,27^{i}	-1
II	2012	7 D.A.E	6,41^{ns}	2	2,91^{ns}	2	14,47**	1
		14 D.A.E	10,95**	2	2,51^{ns}	1	31,21**	1
		21 D.A.E	6,49^{ns}	2	2,80^{ns}	1	27,94**	1
		28 D.A.E	10,01**	2	0,70^{ns}	1	26,42**	0
		35 D.A.E	-	-	-	-	-	-
	2013	7 D.A.E	1,85^{ns}	1	0,11^{i}	0	2,96^{i}	0
		14 D.A.E	3,62^{i}	0	0,31^{i}	0	129,50^{i}	-1
		21 D.A.E	0,24^{i}	0	0,11^{i}	-1	26,34^{i}	-1
		28 D.A.E	3,80^{ns}	1	1,94^{ns}	1	28,07^{i}	0
		35 D.A.E	8,17^{i}	0	1,30^{i}	0	28,69^{i}	-1

** = significant difference at (P> 0.01) for chi-square test; ag = aggregate; al = random; ns = not significant; ^{i} = insufficient degrees of freedom

Table 4. Chi-square test (χ^2) for *Diabrotica speciosa* (Coleoptera: Chrysomelidae) (Poisson, Negative Binomial and Positive Binomial) on Maize DKB 177 (non-Bt).

			Poisson		Negative Binomial		Positive Binomial	
Field		Sampling Period	$\chi 2$	DF(nc-2)	$\chi 2$	DF(nc-3)	$\chi 2$	DF(nc-3)
I	2012	7 D.A.E	$2,71^{ns}$	3	$3,98^{ns}$	2	$2,99^{ns}$	1
		14 D.A.E	$3,01^{ns}$	3	$3,46^{ns}$	2	25,85**	1
		21 D.A.E	$0,15^{ns}$	1	$0,18^{ns}$	1	26,61**	0
		28 D.A.E	$1,44^{ns}$	2	$0,51^{ns}$	1	28,12**	1
		35 D.A.E	8,54*	2	$2,21^{ns}$	1	32,28**	1
	2013	7 D.A.E	$2,12^{i}$	0	$1,12^{ns}$	1	$2,16^{i}$	-1
		14 D.A.E	7,59**	1	$6,45^{ns}$	1	$31,06^{i}$	0
		21 D.A.E	$4,69^{ns}$	1	$4,31^{ns}$	1	$31,14^{i}$	0
		28 D.A.E	16,62**	1	$6,37^{ns}$	1	$33,98^{i}$	0
		35 D.A.E	$3,42^{ns}$	2	$1,58^{ns}$	2	35,35**	1
II	2012	7 D.A.E	$3,12^{ns}$	3	$3,02^{ns}$	2	5,72*	1
		14 D.A.E	$5,12^{ns}$	2	$3,11^{ns}$	2	29,52**	1
		21 D.A.E	$2,93^{i}$	0	$0,91^{i}$	0	28,14**	-1
		28 D.A.E	$1,44^{ns}$	2	$0,51^{ns}$	1	28,12**	1
		35 D.A.E	8,88*	2	$6,30^{ns}$	2	28,61**	1
	2013	7 D.A.E	$6,07^{i}$	0	$4,61^{i}$	0	$6,16^{i}$	0
		14 D.A.E	15,27**	1	$1,12^{i}$	-1	$26,29^{i}$	-1
		21 D.A.E	$0,01^{i}$	0	-	-	$26,36^{i}$	-1
		28 D.A.E	$1,30^{i}$	0	$0,72^{i}$	-1	$26,70^{i}$	-1
		35 D.A.E	$3,64^{i}$	0	$0,31^{i}$	0	$27,29^{i}$	-1
III	2012	7 D.A.E	$0,81^{ns}$	2	$0,75^{ns}$	1	$2,99^{ns}$	1
		14 D.A.E	$2,62^{ns}$	1	$0,40^{ns}$	1	27,42**	1
		21 D.A.E	$4,68^{ns}$	3	$3,54^{ns}$	2	29,33**	1
		28 D.A.E	$3,25^{ns}$	2	$0,71^{ns}$	2	29,49**	1
		35 D.A.E	-	-	-	-	-	-
	2013	7 D.A.E	$2,53^{ns}$	1	$3,46^{ns}$	1	$3,02^{i}$	0
		14 D.A.E	$3,45^{ns}$	1	$0,15^{i}$	0	$26,34^{i}$	0
		21 D.A.E	$2,92^{i}$	0	$0,21^{i}$	0	$26,13^{i}$	-1
		28 D.A.E	$0,11^{i}$	0	$0,08^{i}$	-1	$26,01^{i}$	-1
		35 D.A.E	$4,92^{ns}$	1	$1,00^{ns}$	1	$27,05^{i}$	0

** = significant difference at (*P*> 0.01) for chi-square test; ag = aggregate; al = random; ns = not significant; ^{i} = insufficient degrees of freedom

Discussion:

The first step in developing a sampling plan for sequential decision making is the knowledge of the spatial distribution of the pest in question. This is an important element that influences the sample size and efficiency in deciding whether to control a given population or not, highly essential for Integrated Pest Management (IPM) (Melo et al., 2025; Toninato et al., 2024; Adeleye et al., 2024; Wu et al., 2023).

In the present study, the need to use both index and dispersion indices frequency arose, because it was not possible to complete the spatial distribution of any entity based on only a single probabilistic index, due to the limitations that each one may apply (Rabinovich 1980). Clearly, the spatial distribution of *Diabrotica speciosa* was presented through both the dispersion indexes; the indexes are often added in the two cultivars tested. A similar distribution was found for the eggs, larvae and adults of *D. virgifera* and *D. barber*i (Schumann and Vidal, 2012) and the eggs of *D. longicornis* (Foster et al., 1979).

The aggregation occurs due the fact that the populations of the individual stend to make density-dependent moves in areas where the population is more abundant (Taylor and Taylor 1977). In *D. speciosa* this aggregation is explained by the pheromone used by the females to attract the males for mating. As the samples in the present study focused on the morning times, and although the results indicated that sexual communication was concentrated at the end of the photophase and the beginning of the scotophase compared with the morning period, it is noteworthy that other fact or scan also influence the aggregated distribution of the adults of *D. speciosa* in maize (Cabrera Walsh et al., 2020).

The genetically-modified insect-resistant Bt is not an important factor in the spatial distribution of the pest, as verified by Rodrigues et al. (2010), who studied the spatial distribution of *Bemisia tabaci* (*Gennadius*) biotype B (Hemiptera: Aleyrodidae) in Bt and non-Bt cotton, and Paula-Moraes et al. (2011), as well as egg laying in *Striacosta albicosta* (Smith) (Lepidoptera: Noctuidae) in the maize cultivars of Bt and non-Bt corn expressing the Cry1F toxin. Therefore, a sequential plan of adults there may be conducted without discrimination to the cultivar, with all the means and variances used. This has been done by (Fernandes et al. 2011) to the assembly of sequential sampling plan for *Frankliniella schultzei* Trybom (Thysanoptera: Thripidae) in the cotton Bt and conventional types. Thus, the management of the adult *D. speciosa* in corn was observed, independent of the cultivar studied.

4. Conclusion

Once the distribution becomes clustered, we recommend the development of a sequential sampling plan based on the negative binomial model for management measures using insecticides. This technique is faster and more reliable than the conventional management measures.

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