IMPACTO CIENTÍFICO
EDITORA

SPATIAL DISTRIBUITION OF ANTICARSIA GEMMATALIS HÜBNER, 1818 (LEPIDOPTERA: EREBIDAE) IN SOYBEAN USING GEOSTATISTICS

DISTRIBUIÇÃO ESPACIAL DE ANTICARSIA GEMMATALIS HÜBNER, 1818 (LEPIDOPTERA: EREBIDAE) EM SOJA UTILIZANDO GEOESTATÍSTICA

DISTRIBUCIÓN ESPACIAL DE ANTICARSIA GEMMATALIS HÜBNER, 1818 (LEPIDOPTERA: EREBIDAE) EN SOJA MEDIANTE GEOESTADÍSTICA

10.56238/edimpacto2025.092-005

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ABSTRACT
Soybeans are one of the most important crops in Brazil, accounting for an estimated planted area of around 47.61 million hectares in 2024/2025. Among the pests affecting this crop, the velvetbean caterpillar, *Anticarsia gemmatalis* Hübner, 1818 (Lepidoptera: Erebidae), stands out due to its potential to cause up to 100% defoliation. This study aimed to evaluate the spatial distribution of the velvetbean caterpillar using geostatistical methods. The experiment was conducted with the soybean cultivar M 7908 RR1 during the 2014/2015 growing season in an 8,000 m² area, divided into 80 plots of 100 m² each. In each sampling unit (100 m²), five points were randomly selected, and the number of small, medium, and large caterpillars was counted. The semivariogram models fitted to the data demonstrated that the pest occurs in an aggregated pattern in the field, with a spatial dependence range varying from 7 to 55.42 meters.

Keywords: Velvetbean Caterpillar. Aggregation. Semivariogram. Pest Insects.

RESUMO
A soja é uma das culturas mais relevantes do Brasil, sendo responsável em 2024/2025, por uma área plantada estimada em cerca de 47,61 milhões de hectares. Entre as pragas mais importantes da cultura está a lagarta-da-soja, *Anticarsia gemmatalis* Hübner, 1818 (Lepidoptera: Erebidae), responsável por até 100% de desfolha. Este trabalho teve como objetivo avaliar a distribuição espacial da lagarta-da-soja utilizando geoestatística. O experimento, conduzido com a cultivar de soja M 7908 RR1, foi realizado durante a safra agrícola 2014/2015 na Fazenda de Ensino, Pesquisa e Extensão da Faculdade de Ciências Agrárias e Veterinárias, UNESP - Campus de Jaboticabal, SP, em uma área de 8.000 m2, dividida em 80 parcelas de 100 m2. Em cada unidade amostral (100 m2 de área) foram examinados ao acaso cinco pontos amostrais e avaliados o número de lagartas pequenas, médias e grandes por meio da técnica de batida de pano. Os modelos de semivariogramas ajustados demonstraram que a praga ocorre de maneira agregada no campo, com alcance da dependência espacial variando de 7 á 55,42 metros.

Palavras-chave: Lagarta-Da-Soja. Agregação. Semivariograma. Insetos-Praga.

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RESUMEN

La soja es uno de los cultivos más importantes de Brasil, representando una superficie plantada estimada en alrededor de 47,61 millones de hectáreas en 2024/2025. Entre las plagas más importantes de la soja en Brasil se encuentra la oruga del frijol terciopelo, *Anticarsia gemmatalis* (Lepidoptera: Erebidae), que causa hasta el 100% de defoliación de las plantas. Este estudio tuvo como objetivo evaluar la distribución espacial de la oruga del frijol terciopelo utilizando geoestadística. El experimento se realizó con los cultivares M 7908 RR1 durante la temporada 2014/2015 en un área de 8.000 m², divididos en 80 parcelas de 100 m² cada una. En cada unidad de muestreo (100 m²) se seleccionaron al azar cinco puntos y se contó el número de orugas pequeñas, medianas y grandes. Se ajustó un modelo de semivariograma a los datos y mostró que la plaga se presenta en un patrón agregado en el campo, con un rango de dependencia espacial de 7 a 55,42 metros.

Palabras clave: Oruga del Frijol Terciopelo. Agregación. Semivariograma. Insectos Plaga.

1 INTRODUCTION

Soybean is a crucial oilseed crop globally, valued for its high oil content and extensive use in human and animal consumption (Costa, 1996). However, soybean production is significantly impacted by various pests, necessitating effective pest management strategies. The severity of these pest-related issues has escalated with the expansion of soybean cultivation areas (Antúnez et al., 2016). Pest damage to soybean can directly and indirectly reduce productivity by diminishing photosynthetic area and transmitting pathogenic agents (Ribeiro & Costa, 2000; Hartman et al., 2015a).

Soybean-feeding pests encompass insects from numerous orders, causing damage at all plant developmental stages (Hartman et al., 2015b). Among these, defoliating caterpillars are particularly significant. The velvetbean caterpillar, Anticarsia gemmatalis Hübner, 1818 (Lepidoptera: Erebidae), the soybean looper (Chrysodeixis (= Pseudoplusia) includens) (Walker, [1858]) (Pinto, Parra & Oliveira, 2008), and species from the genus Spodoptera (Lepidoptera: Noctuidae) (Moscardi et al., 2012) are prominent pests that substantially reduce soybean yields. The velvetbean caterpillar is prevalent in tropical and subtropical soybean-producing regions, primarily across the Americas (Praça et al., 2006). In Brazil, it is predominantly found in the South-Central region (Silva, 2010), where it preferentially feeds on legumes (Panizzi et al., 2004). The primary losses inflicted by this caterpillar result from defoliation, and high population densities can lead to widespread damage across entire fields (Reisig & Herbert, 2014).

The population dynamics of the velvetbean caterpillar are influenced not only by geographical region but also by seasonal weather patterns (Corrêa et al., 1977; Antúnez et al., 2016). Consequently, temperature and rainfall can significantly impact pest occurrence and population levels in a given area. Meteorological factors also play a role in the natural development of entomopathogenic fungi, which are crucial in regulating velvetbean caterpillar populations (Soza-Gómez et al., 2010).

Understanding the spatial distribution of pests in agricultural fields is vital for developing effective and efficient pest sampling designs, which are essential for implementing Integrated Pest Management (IPM) programs (Pimentel et al., 2016). Geostatistics offers a method to characterize spatial distribution by utilizing pest population data and locations to map their distribution across the field (Rijal, Brewster & Bergh, 2014). The fundamental tool in geostatistics is the semivariogram, which describes and quantifies the spatial variation of these phenomena (Huijbregts, 1975) and analyzes the degree of spatial dependence among samples. Varella & Sena (2008) and Frank et al. (2011) have underscored the utility of semivariograms in determining spatial variation in plants, pests, and soil, based on the premise that differences in variable values between two sample plots are dependent on the distance separating them.

The rapid and extensive damage caused by defoliating pests in soybean necessitates quick and efficient sampling to detect and quantify pest populations. This step is critical for successful pest management. The collected sample must accurately reflect the characteristics of the population's distribution in space and time (Young & Young, 1998). Adhering to this principle, it is imperative to establish a sampling plan that precisely and reliably estimates the population and spatial distribution of a pest, thereby minimizing errors associated with inappropriate control recommendations. The objectives of this research were, firstly, to investigate the population fluctuations and spatial distribution of the velvetbean caterpillar in soybean crops using geostatistical methods and, secondly, to propose sampling protocols based on this distribution to guide pest management actions.

2 METHODOLOGY

The experiment was carried out in a soybean crop during the 2014/2015 growing season at Fazenda de Ensino, Pesquisa e Extensão (FEPE) (Faculdade de Ciências Agrárias e Veterinárias, FCAV/ UNESP, Jaboticabal, Brazil). The experiment area was located at 21º 14’ 05’’ S and 48º 17’ 09” W, elevation 615 m. The climate region classification according to Koppen-Geiger is Cwa, characterized by hot, wet summers and cold, dry winters (Peel, Finlayson & McMahon, 2007).

The experiment area was planted to the soybean cultivar M 7908 RR. Sowing was in November 2014 using a no tillage system, with 0.45 m spacing between rows. The samplings of populations of velvetbean caterpillars were performed in an area of 8,000 m² sub-divided into 80 plots, each of 100 m², which were considered the sample plots. Fertilization and liming were applied following the recommendation for the region (Miranda et al, 1998). No pesticides were sprayed during the sampling period.

To estimate the number of individual velvetbean caterpillars in the area, we performed the sampling weekly using the beating cloth technique (length 1 m and width 0.5 m) (Boyer & Dumas, 1963). We evaluated a 2 m length of a row (approximately 30 plants) at each of five points in each sampling unit (100 m²) and performed the cloth beating during the soybean vegetative and reproductive stages (stages V8 to R8). The caterpillars captured were counted and classified according to size: small caterpillars (≤1 cm), medium caterpillars (1.5 to 2.5 cm) and large caterpillars (>2.5 cm).

The samplings were performed during morning hours when insect numbers are highest and influence caterpillar mobility. To relate to caterpillar counts, meteorological data (temperature (C°) (higher, mean and lowest) and rainfall (mm)) were obtained from the Estação Agroclimatológica at FCAV/UNESP, Jaboticabal. To evaluate the temperature effects we used the weekly means, while for rainfall we used the cumulative total for the week prior to the sample collection.

The basic descriptive statistics for these data were obtained using Microsoft Excel®. The coefficient of variation (CV, the percentage variation in mean) was used to compare the variability between samples. It is dimensionless and can be used to directly compare the uniformity within the samples. Pattern analysis in the samples was performed using R (R Core Team, 2016). The semivariograms obtained were adjusted to a model of spatial dependence using the geoR library version 1.7-5.2 (Ribeiro et al, 2016). Subsequent to obtaining the degrees of spatial dependence [$SDD = C_0/(C_0 + C_1)$] the data were classified according to the intervals proposed by Zimback (2001), which considers the strength of spatial dependence as follows: strong spatial dependence ($SDD < 0.25$), moderate ($0.25 \leq SDD \leq 0.75$) and weak ($SDD > 0.75$). Furthermore, we prepared krigagem maps to present the spatial distribution of the velvetbean caterpillars in the area sampled (Vieira et al, 1981).

3 RESULTS AND DISCUSSIONS

In the first sampling of caterpillars of A. gemmatalis at 45 days after emergence (DAE) of the soybean seedlings, we obtained 6.24 larvae per beating cloth. The larvae population decreased to 1.73 at 65 DAE, which was likely due to seedling senescence. Franco et al, (2014) suggested that absence of food sources could directly affect insect populations in the soybean habitat. We observed that samples performed at 88 DAE were further decreased in numbers of velevetmoth caterpillars. At approximately 88 DAE, the soybean crop was in the final phase of its lifecycle and food source limitations could negatively impact the insect population, including those of the velvetbean caterpillar (Figure 1 and 2). Furthermore, abiotic factors, particularly temperature and relative humidity fluctuations can affect the pest population (Antunes et al, 2016). Sujji et al, (2002) demonstrated that populations of A. gemmatalis had highest populations during periods of lowest rainfall, when it was irregularly distributed during the year, as we observed in the current study (Figure 1).

The number of individuals at 71 DAE (2.92 larvae per beating cloth) and 80 DAE (3.12 larvae per beating cloth) was similar and were sampled during a period of no rainfall with a mean temperature >25 °C (Figure 2). Thus, the weather conditions may have influenced on the changes in populations of A. gemmatalis collected, as the conditions were most likely too dry for population reduction of velvetbean caterpillar to occur naturally through infection with entomopathogenic fungus. Praça et al. (2006) and Sosa-Gómez et al, (2010) demonstrated that low humidity can affect the entomopathogenic fungus Nomuraea rileyi (Farlow) Samson, an important biocontrol agent used to manage velvetbean in the field. Panizzi & Silva (2009) and Gutierrez (2009) also described abiotic factors that negatively impacted occurrence of Baculovirus anticarsia in the field, which is also an important biocontrol agent of velvetbean caterpillars.

The CV values obtained from the different samples of velvetbean caterpillars in this study was variable. For example, it ranged from 11.19 % and 174.01% for small caterpillars at 51 DAE and 100 DAE, respectively (Table 1). The highest CV values generally reflect a relationship between low incidence of the caterpillar in some samples having the lowest means and highest variances. The semivariogram model parameters showed pure nugget effects in the four samples at 56, 71, 80 and 94 DAE (Table 1). These values are indicative of an aggregated pattern, and generally follow a negative binomial probability distribution (Souza et al, 2016; Maldonado et al., 2016). Stürner et al., (2013) also noted that the tendency for the CV to decline as the population became more homogeneous in the field. Additionally, the abiotic factors already mentioned can influence the populations of a pest in some samples plots, together with micro-habitat characteristics and the presence of natural enemies in the field. Foerster, Marchioro & Foerster (2014) described the importance of parasitoids of Trichogramma (Hymenoptera: Trichogrammatidae) in controlling populations of A. gemmatalis by parasitizing eggs and first and second instar caterpillars.

We obtained results by theorical models of experimental semivariograms and observed the nugget pure effect to four samples of small size caterpillars collected in 56, 71, 80 and 94 days after emergency of seedling. In these samples does not detected spatial dependence that can be relationship with lowest infestation of pest. Vieira et al, (1981) related that when the semivariogram showing the nugget pure effect occur no spatial dependence and the pest spatial distribution is random way. The lowest level of infestation probably is relationship with three main factors: available and quality of food and local microclimate conditions that influence in the pest development. Furthermore, the interspecific competition can result in the reduction of pest population (Fonseca et al, 2014).

The other samples of velevetbean caterpillar were best described by the spherical, exponential or Gaussian models with values ranging between 7 and 55.42. Thus, we observed that the behavior of the velvetbean caterpillar is to aggregate, which explains the spatial dependence. In the samples of small caterpillars at 71 DAE, and those of the sum of small, medium and large velvetbean caterpillars at 106 DAE the populations were close to zero or zero, making it impossible to assess spatial dependence (Table 2). Stürmer et al. (2012) and Stürmer et al. (2013) have previously described and discussed the variations in sample sizes used to evaluate population density of caterpillars in a soybean crop.

Spatial dependence (SDD) was moderate to major for those samples falling in the interval of 0.25 to 0.75, except for two samples: the 45 DAE sample for medium and large caterpillars had strong SDD (0.21) and the 88 DAE foe small velvetbean caterpillars had weak SDD (0.79) (Table 2). The heat maps based on the semmivariograms show the aggregation according to patches size (Figures 3 and 4). The whitish patches in the maps are caused by small aggregations that indicate infestation of A. gemmatalis populations in the field. The observed dispersion can be due to the insects mobility searching for food, and by those locations with most available and better quality food; also habitat characteristics as described by Stürmer et al. (2013) will influence the observed distributions. Thus, these factors play major roles in the distribution of velvetbean caterpillars.

4 CONCLUSION

We conclude that the velvetbean caterpillar behavior is to aggregate in the field and this is reflected in the evident spatial dependence. The resulting aggregation could be variable, and the degree of spatial dependence was moderate in some cases. This suggests the influence of environmental factors, primarily rainfall that influence the occurrence and distribution of the pest in the field. We conclude that any sampling protocol for the velvetbean caterpillar should be timed prior to the peak in population of the pest.

ACKNOWLEDGEMENTS

I thank the Coordination of Improvement of Higher Education Personnel (CAPES) for the scholarship during the development of the project.

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ATTACHMENT

Table 1

Descriptive statistics for populations of Anticarsia gemmatalis with dates converted by [y = ln (x+1)] in a soybean crop in Jaboticabal, Brazil, 2015

Size	Descriptive statistics	Sample									
		Days after Emergence									
		45	51	56	65	71	80	88	94	100	106
Small	Mean (± SE)	2,43 ± 0,08	2,13 ± 0,08	1,24 ± 0,07	1,16 ± 0,07	-	2,07 ± 0,05	1,10 ± 0,06	0,52 ± 0,06	0,20 ± 0,04	-
	Stand. Dev.	0,70	0,73	0,61	0,70	-	0,47	0,54	0,51	0,36	-
	Variance	0,49	0,54	0,37	0,50	-	0,22	0,29	0,26	0,13	-
	Kurtosis	6,45	3,96	3,07	2,11	-	3,63	2,76	1,90	3,14	-
	Asymmetry	-1,39	-0,99	-0,75	-0,57	-	-0,60	-0,52	-1,39	1,32	-
	CV (%)	28,65	34,68	48,18	60,88	-	22,22	49,27	28,65	174,06	-
Medium + Large	Mean (± SE)	2,85 ± 0,07	3,06 ± 0,04	2,59 ± 0,07	1,83 ± 0,04	2,32 ± 0,04	2,08 ± 0,05	1,93 ± 0,04	1,03 ± 0,07	0,30 ± 0,05	-
	Stand. Dev.	0,64	0,34	0,62	0,40	0,37	0,43	0,38	0,60	0,43	-
	Variance	0,41	0,12	0,38	0,16	0,11	0,19	0,15	0,36	0,19	-
	Kurtosis	14,97	5,04	12,10	2,80	4,74	10,15	3,35	2,28	2,89	-
	Asymmetry	-3,20	-1,03	-2,69	-0,36	-0,78	1,37	-0,80	-0,47	1,07	-
	CV (%)	22,59	11,19	23,87	21,65	14,47	20,81	20,01	57,78	146,01	-

Stand. Dev. – Standard Deviation; SE – mean Standard Error; CV (%) - coefficient of variation.

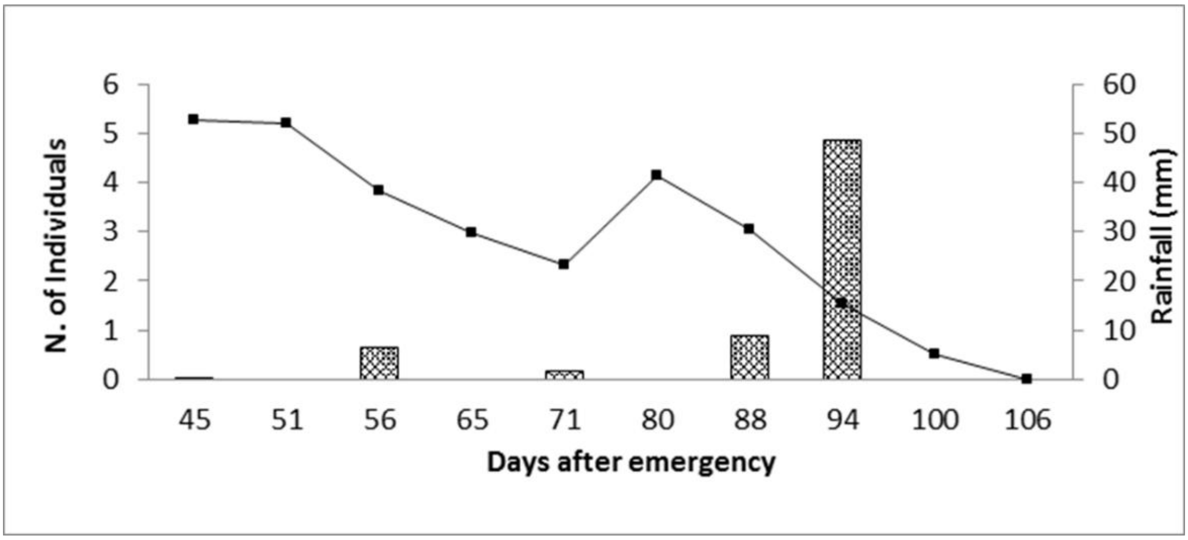
Table 2

Models and parameters of the semiological tests for Anticarsia gemmatalis species in soybean, Jaboticabal - SP, 2015.

Size	Parameters	Sample									
		Days after Emergence									
		45	51	56	65	71	80	88	94	100	106
	Model	Gaussian	Spherical	Pure nugget effect	Exponential	Pure nugget effect	Gaussian	Spherical	Pure nugget effect	Exponential	Pure nugget effect
Small	C_0	0,26	0,22	0,41	0,33	-	0,22	0,25	0,25	0,09	-
	C_0+C_1	0,63	0,59	0,41	0,52	-	0,22	0,32	0,25	0,14	-
	a	23,36	33,87	0,00	40,34	-	0,00	26,68	0,00	55,42	-
	R^2	0,73	0,61	-0,02	0,84	-	-0,04	0,22	-0,03	0,80	-
	SDL	0,41	0,37	0,00	0,65	-	0,00	0,79	0,00	0,65	-
Medium + Large	C_0	0,12	0,00	0,19	0,15	0,11	0,18	16,00	0,17	0,11	-
	C_0+C_1	0,58	0,12	0,52	0,15	0,11	0,18	0,16	0,37	0,19	-
	a	21,78	6,00	22,90	0,00	0,00	0,00	0,00	34,98	10,43	-
	R^2	0,82	0,46	0,89	-0,004	-0,003	-3,24	-0,01	0,61	0,24	-
	SDL	0,21	0,00	0,37	0,00	0,00	0,00	0,00	0,46	0,58	-

Figure 1

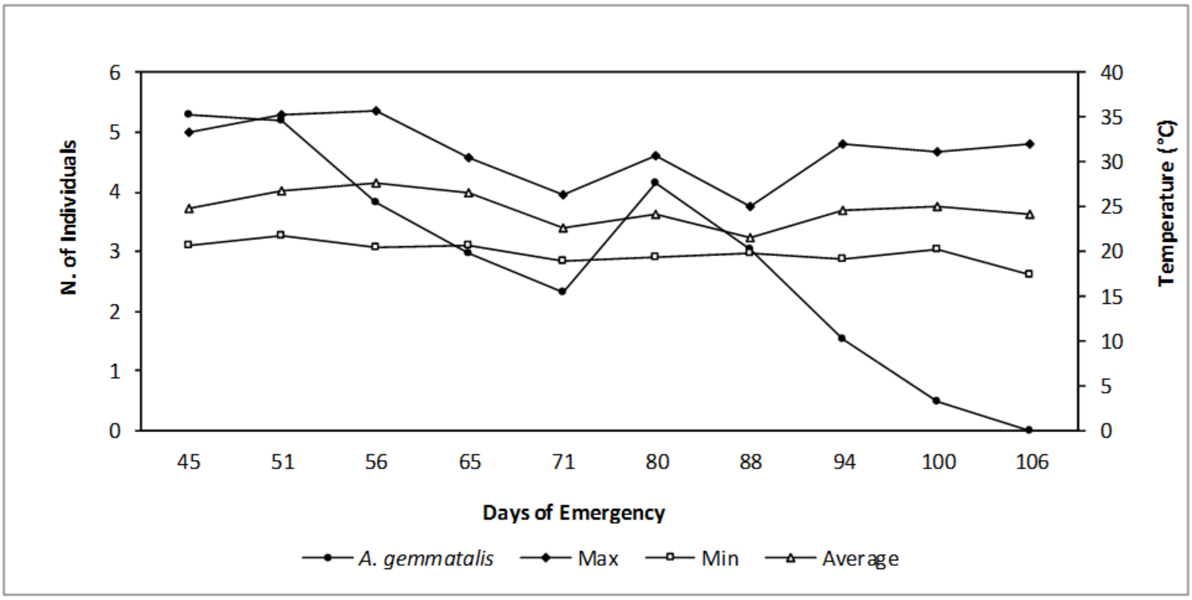
Population density of caterpillars of Anticarsia gemmatalis according to days after emergence and rainfall average in soybean crops iin Jaboticabal, Brazil. The bars represent rainfall average and the line the population curve for A. gemmatalis.



Source: Prepared by the authors themselves.

Figure 2

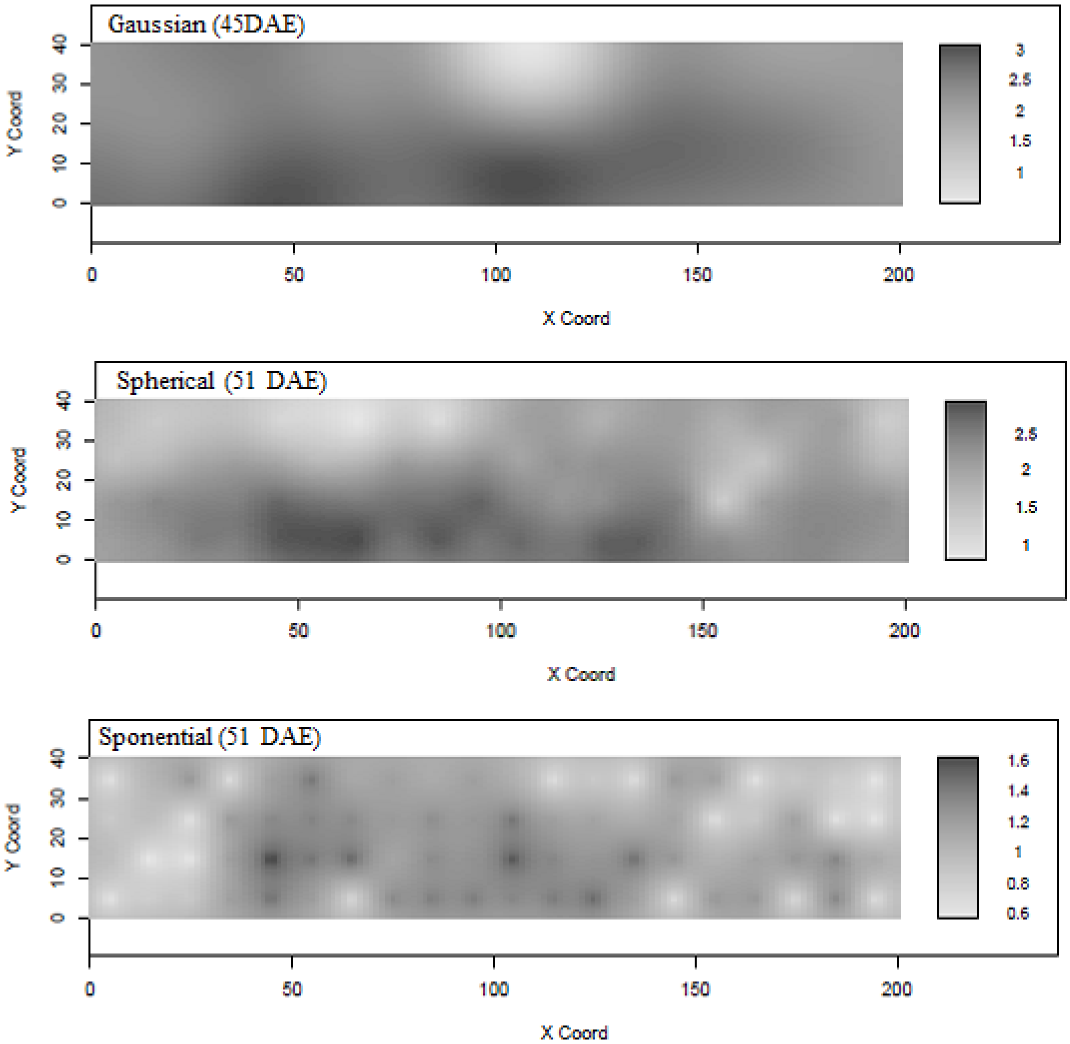
Population density of caterpillars of Anticarsia gemmatalis based on sample time – Days After Emergency (DAE) and mean temperature in soybean crops in Jaboticabal, Brazil



Source: Prepared by the authors themselves.

Figura 3

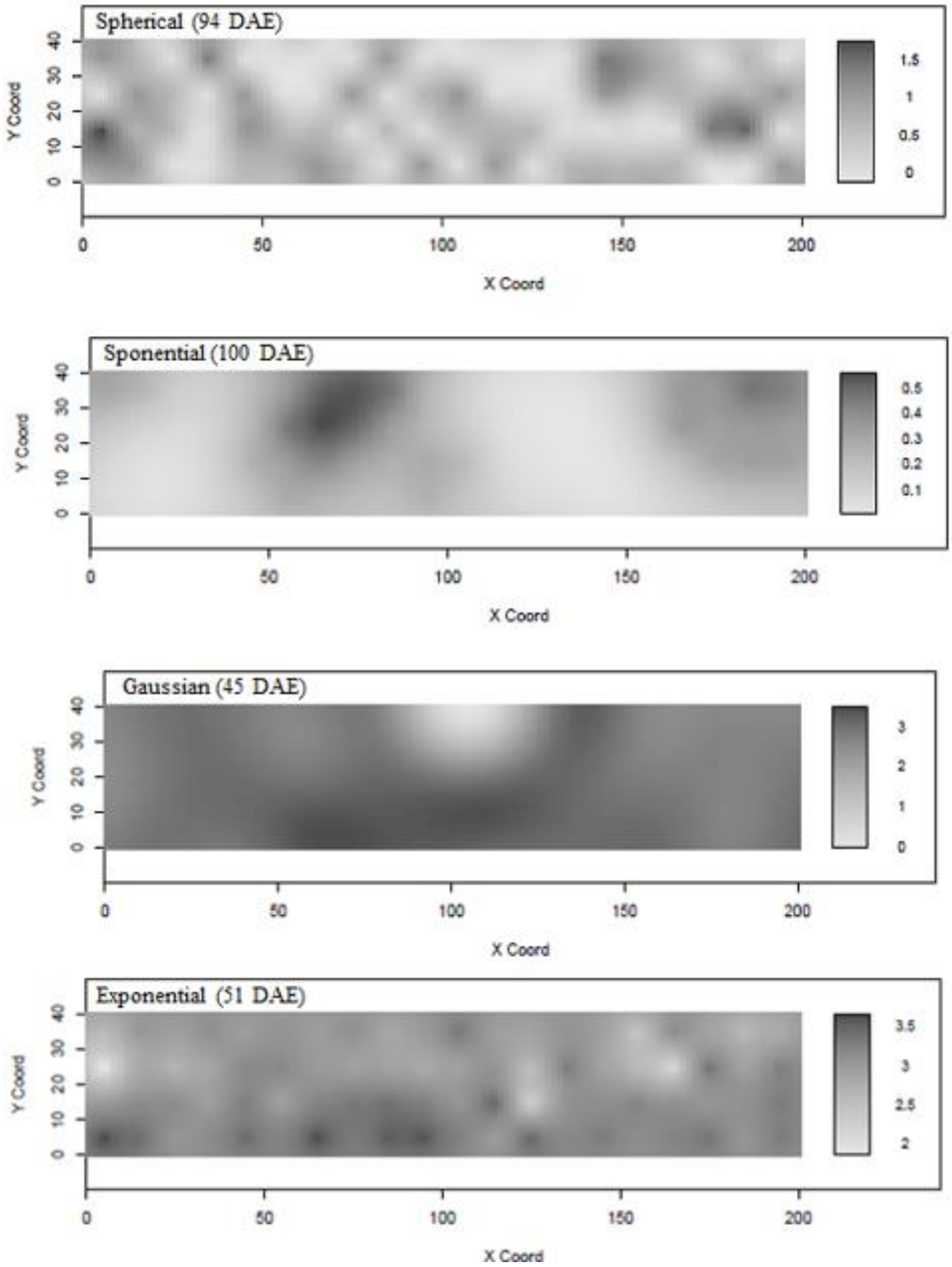
Krigagem maps showing the spatial distribution of Anticarsia gemmatalis small caterpillars in soybean



Source: Prepared by the authors themselves.

Figura 4

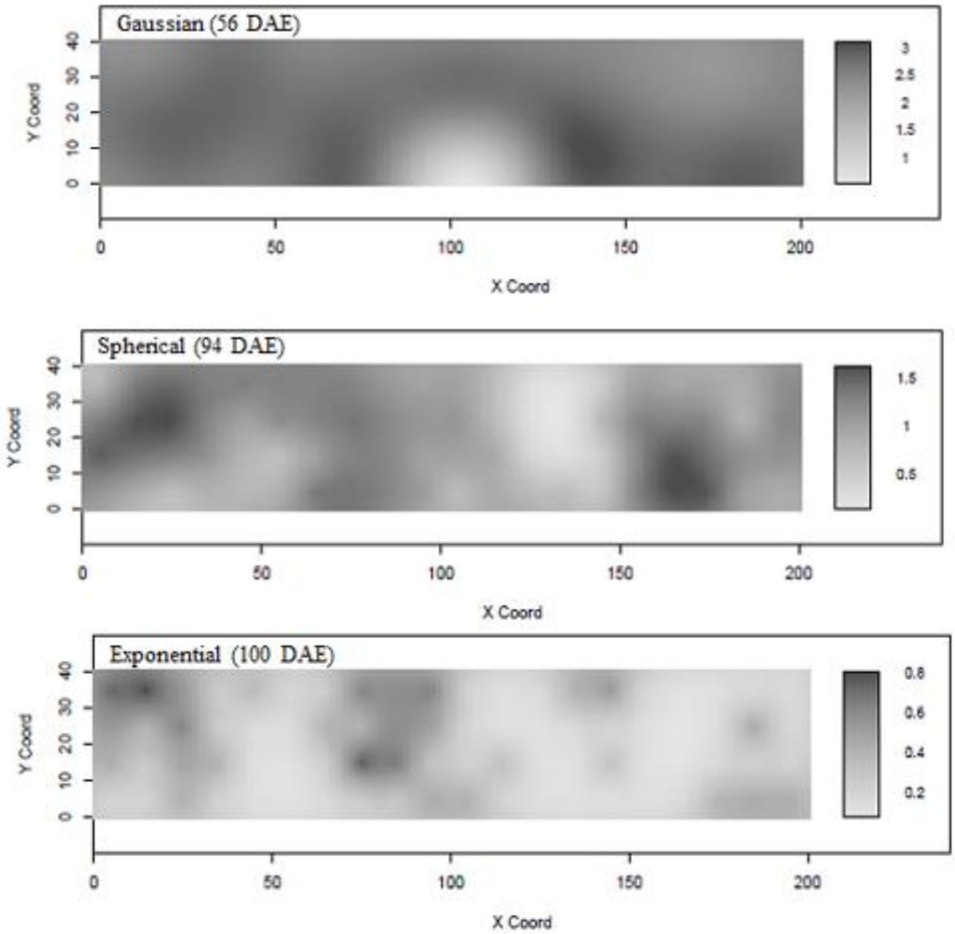
Krigagem maps showing the spatial distribution of Anticarsia gemmatalis small caterpillars in soybean



Source: Prepared by the authors themselves.

Figura 5

Krigagem maps showing the spatial distribution of medium and large caterpillars of Anticarsia gemmatalis in soybean



Source: Prepared by the authors themselves.