

Ocorrência e distribuição espacial da *Helicoverpa armigera* (Hübner, 1808) (Lepidoptera: Noctuidae) na paisagem agrícola de Santa Catarina, Brasil

Occurrence and spatial distribution of Helicoverpa armigera (Hübner, 1808) (Lepidoptera: Noctuidae) in agricultural landscapes of Santa Catarina, Brazil

Presencia y distribución espacial de Helicoverpa armigera (Hübner, 1808) (Lepidoptera: Noctuidae) en el paisaje agrícola de Santa Catarina, Brasil

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Resumo: *Helicoverpa armigera* (Hübner, 1808) (Lepidoptera: Noctuidae) é uma praga polífaga de importância econômica para diversos cultivos, amplamente distribuída na Ásia, África, Oceania e, mais recentemente, no continente americano. Foi registrada no Brasil, em 2013, embora estudos posteriores comprovem que a introdução tenha ocorrido antes de 2008. No presente estudo, reportamos a ocorrência e a distribuição espacial de *H. armigera*, relacionando a presença da espécie a diferentes regiões e paisagens agrícolas do território catarinense, além de registrar as plantas hospedeiras associadas. Armadilhas de feromônio sexual capturaram 1761 mariposas, e *H. armigera* apresentou o maior número de capturas em relação a *H. zea*. Em lavouras de soja, tomate e fumo, foram coletadas larvas que, após a emergência de adultos, foram identificadas como predominantes da espécie *H. armigera*. A ocorrência de *H. armigera* foi confirmada em 59 municípios de 91 amostrados no território catarinense, a maioria deles pertencente à região Oeste. Os locais com maior número de capturas corresponderam àqueles com áreas de plantio de soja acima de quatro mil hectares, e também houve correlação entre a abrangência de lavouras diversas e o número de capturas. O estudo associou a importância da paisagem agrícola para a *H. armigera* e foi o primeiro a registrar a espécie em fumo no Brasil.

Palavras-chave: espécie invasora; paisagem agrícola; planta hospedeira; *Heliothinae*.

Abstract: *Helicoverpa armigera* (Hübner, 1808) (Lepidoptera: Noctuidae) is a polyphagous pest of economic importance for several crops, widely distributed in Asia, Africa, Oceania, and, more recently, in the American continent, being recorded in Brazil since 2013; however, subsequent studies indicate that its introduction occurred before 2008. In the present study, we report the occurrence and spatial distribution of *H. armigera*, documenting its presence across different regions and agricultural landscapes of Santa Catarina State, Brazil, and recording associated host plants. Pheromone traps captured 1761 male moths, among which *H. armigera* was in a higher number of captures compared to *H. zea*. Larvae were recorded in the soybean, tomato, and tobacco crops. The occurrence of *H. armigera* was confirmed in 59 municipalities out of 91 sampled in the territory of Santa Catarina, most of which belong to the Western region, which has the largest planted area of grains in the state. Soybean fields with areas greater than 4000 ha had the highest abundance of *H. armigera*. The results show the importance of the agricultural landscape to *H. armigera* occurrence, and this study is the first to record the species in tobacco in Brazil.

Keywords: invasive species; pest; host plant; Heliothinae.

Resumen: *Helicoverpa armigera* (Hübner, 1808) (Lepidoptera: Noctuidae) es una plaga polífaga de importancia económica para diversos cultivos, ampliamente distribuida en Asia, África, Oceanía y, más recientemente, en América. Se registró en Brasil en 2013, aunque estudios posteriores demuestran que su introducción ocurrió antes de 2008. En este estudio se reportan la presencia y la distribución espacial de *H. armigera*, se relacionan sus registros en diferentes regiones y paisajes agrícolas del territorio de Santa Catarina y se registran las plantas hospedantes asociadas. Las trampas de feromonas sexuales capturaron 1761 polillas, y *H. armigera* registró un mayor número de capturas que *H. zea*. En campos de soja, tomate y tabaco, se recolectaron larvas que, tras emerger como adultos, se identificaron como pertenecientes predominantemente a la especie *H. armigera*. La presencia de *H. armigera* se confirmó en 59 de los 91 municipios muestreados en el estado de Santa Catarina, la mayoría de los cuales pertenecen a la región occidental. Las localidades con mayor número de capturas fueron aquellas con áreas de cultivo de soja superiores a 4 mil hectáreas; también se observó una correlación entre la diversidad de cultivos y el número de capturas. El estudio asocia la importancia del paisaje agrícola para *H. armigera* y, además, constituye el primero en registrar la especie en tabaco en Brasil.

Palabras-clave: especies invasoras; paisaje agrícola; planta hospedante; Heliothinae.

1 INTRODUCTION

The subfamily Heliothinae (Lepidoptera: Noctuidae) includes around 400 species, and the genus *Helicoverpa* is considered one of the most important agricultural pests. *Helicoverpa* species have a high capacity for survival across various agroecosystems, and their larvae feed on reproductive structures, causing economic damage to several crops (Mitter; Poole; Matthews, 1993; Mitchell; Mitter; Regier, 2006; Cho *et al.*, 2008; Zahiri *et al.*, 2013). Hardwick (1965) described 18 species in the genus *Helicoverpa*, including *Helicoverpa armigera*, historically known as the “Old World bollworm” and originally endemic to Europe, Asia, Africa, and Oceania. Three of them are already present in Brazil: *H. zea* (Boddie, 1850), *H. gelotopoeon* (Dyar, 1921) (southern region), and *H. armigera* (Hübner, 1808) (Specht *et al.*, 2005, 2013; Czepak; Albernaz, 2013; Sosa-Gómez *et al.*, 2015). *H. armigera* has been recorded infesting plants of at least 68 different families (Cunningham; Zalucki, 2014), which include several cultivated species important to the Brazilian agribusinesses, characterized by extensive monocultures. In 2013, when it was officially reported in the country (Czepak; Albernaz, 2013), *H. armigera* resulted in significant yield losses, with outbreaks, particularly affecting crops of *Gossypium hirsutum* (L.) (cotton), *Glycine max* (L.) (soybean), *Zea mays* (L.) (corn), and *Solanum esculentum* (Mill) (tomato) (Pratissoli *et al.*, 2015; Specht *et al.*, 2021). However, in Santa Catarina, southern Brazil, no reports of the species’ presence were available until the beginning of 2013, when the present study was initiated. In addition, it raised many questions about how the composition of the agricultural landscape could influence and determine the occurrence, host plants, and spatial distribution of that pest. The need to know the parameters of occurrence and distribution of *H. armigera* in Santa Catarina is due to the importance of this State in the Brazilian agricultural scenario, with emphasis on the production of soybeans,

corn and tomatoes, in addition to *Nicotiana tabacum* (L.) (tobacco), *Phaseolus vulgaris* (L.) (common bean) and *Triticum aestivum* (L.) (wheat), which are likewise reported as host plants of this pest (Cunningham; Zalucki, 2014).

The correct identification of the pest and its spatial distribution in association with landscape composition is essential for establishing effective Integrated Pest Management (IPM) programs (Zhou *et al.*, 2024). Given its high polyphagy and mobility, continuous monitoring is fundamental for defining control strategies (Specht *et al.*, 2021; Cordeiro *et al.*, 2020). In 2013, following the initial detection of the pest in Brazil, several states declared a phytosanitary emergency to authorize the importation and emergency use of the insecticide based on emamectin benzoate, which was then unapproved in Brazil. However, in Santa Catarina, a systematic survey of its occurrence and spatial distribution across the agricultural landscape enabled precise characterization of infestation levels at the time. This technical-scientific assessment provided the Plant Health Protection Department of Santa Catarina (*Companhia Integrada de Desenvolvimento Agrícola de Santa Catarina* – CIDASC) with the necessary data to justify the decision not to declare a state of emergency, as the actual field situation didn't meet the criteria for such an administrative measure. Today, this historical record remains crucial, as systematic data collection and continuous surveillance allow the Plant Health Protection Department to update regional occurrence databases and establish technical criteria for pest management (Specht *et al.*, 2021). This approach supports the official validation of control methods and the rational use of inputs, ensuring that phytosanitary interventions are based on real-time field occurrence rather than emergency responses, preventing economic losses and preserving the sustainability of agroecosystems.

Pest management depends on the correct identification, based on male and female genitalia characters and molecular tools, to accurately identify adult males collected with pheromone traps, because various species are attracted to the same sex pheromone compounds. In addition, their incursion and distribution depend on the presence of host plants and on how they are adapted to the agricultural landscape, a dynamic further intensified by abiotic factors, altitude, and climatic conditions. Several studies have linked pest abundance with agricultural landscape structure and a high proportion of non-crop habitats, comparing polyculture and monoculture systems (Estrada-Carmona *et al.*, 2022; Poveda *et al.*, 2025; Yang *et al.*, 2025). Some factors increase and decrease the population of the species, resulting from the higher proportion of natural enemies or increased availability of host plants, which can also be involved in the management of resistance to *Bacillus thuringiensis* (Bt) technology and insecticides (Lu; Baker, 2013; Yang *et al.*, 2013; Tsafack *et al.*, 2013; Balzan; Bocci; Moonen, 2016; Rusch *et al.*, 2016; Baker; Tann, 2017a, 2017b; Downes *et al.*, 2017; Parry *et al.*, 2017).

Therefore, the objective of the present study was to identify species of the genus *Helicoverpa*, their occurrence, dispersion, and host plant records of *H. armigera* during 2013-2016 in Santa Catarina State, and to examine the relationship between species and the agricultural landscape composition.

2 MATERIAL AND METHODS

The present study was carried out in agricultural farms in the State of Santa Catarina (SC), southern Brazil, characterized by smallholder farmers of horticultural crops, corn, rice, and tobacco, larger soybean farmers, and extensive forests of *Pinus* and *Eucalyptus*. The predominant climate condition is mesothermal humid subtropical. Corn and soybeans are mostly grown in the Midwest and West regions of SC, with sowings from October to December and harvests from January to March. Tomatoes are planted in the municipality of Caçador (Midwest); however, they are also cultivated in the municipalities of Bom Retiro (Highlands) and Santo Amaro da Imperatriz (East coast), with harvest beginning in January. The other horticulture crops are grown year-round in municipalities near the East coastal region.

The occurrence of *Helicoverpa armigera* was recorded through the collection of larvae on host plants and the collection of moths using pheromone traps [active ingredient Z-11-hexadecenal at 1.49g/kg, Bio *Helicoverpa*® or a mixture of (Z)-11-hexadecenyl acetate and (Z)-9-hexadecenyl acetate at 1.425g/kg (Iscalure *Armigera*®)]. Larval sampling was conducted in commercial tomato and soybean crops under a conventional production system.

In tomato, phytosanitary inspections were conducted in two plots located in different tomato crops in the municipality of Caçador, Santa Catarina State, Brazil, on January 28 and February 10 and 18, 2014. Sampling was

performed at fixed observation points, totaling 40 points spaced 15 meters apart. At each point, the central plant and two adjacent plants were visually inspected. The observation was between 10:00 a.m and 2:00 p.m.

In soybean crops, field inspections were conducted in a single area located in the municipality of Campos Novos, Santa Catarina State, Brazil, on January 17 and 27, and February 11 and 19, 2014. At that site, 25 fixed observation points were sampled within a demarcated area of 1 m², spaced 15m apart, and manually collected. Additionally, larvae were sporadically collected from tomato and tobacco plants through visual inspection in crops surrounding the pheromone traps, in the municipalities of Santo Amaro da Imperatriz and Donna Emma, Santa Catarina State, Brazil, respectively. All collected larvae were kept in laboratory conditions and fed a natural diet until adult emergence. The moths of the genus *Helicoverpa* were submitted to morphological analysis, in which their genitalia were examined to confirm species, as described by Pogue (2004) and Specht *et al.* (2013).

From the total number of morphologically identified specimens, 100 were submitted to molecular confirmation for PCR-RFLP. The DNA was extracted from the thoracic tissue or legs of preserved moths (95% ethanol) using an adapted 2% CTAB protocol (Boiteux *et al.*, 1999). Partial sequences of the mitochondrial genes Cytochrome Oxidase I (COI) and Cytochrome B (CytB) were amplified for PCR using the primer pair: LCO 1490-J-1514 (5'-GGTCAACAAATCATAAAGATATTGG-3') and HCO 2198-N2175 (5'-TAAACTTCAGGGTGACCAAAAAATCA-3') CytB-10933 (5'-TAGGATATGTTTTACCTTGAGGAC-3') and CytB-11388 (5'-TCCTCCTAATTATTAGGAATTG-3'), respectively. PCR reactions (25 µL) were carried out in a thermocycler (Applied Biosystems) under the following cycling conditions: initial denaturation at 94°C for 2 min; 35 cycles of 94°C for 1min, 48°C for 1min, and 72°C for 1.5 min; and a final extension at 72°C for 5 min. Amplicons were verified by 1,5% agarose gel electrophoresis. In the PCR-RFLP technique used for species differentiation, a 10 µL aliquot of the PCR product was digested with restriction enzymes *HphI* for the COI gene or *BstZ17I* for the CytB gene, in a final volume of 25 µL. Samples were incubated for 6 h at 37 °C, followed by thermal inactivation at 65 °C for 30 min. The restriction fragments were separated by electrophoresis at a constant voltage of 80V on a 3.0% agarose gel, stained, and visualized under UV light using a gel documentation system.

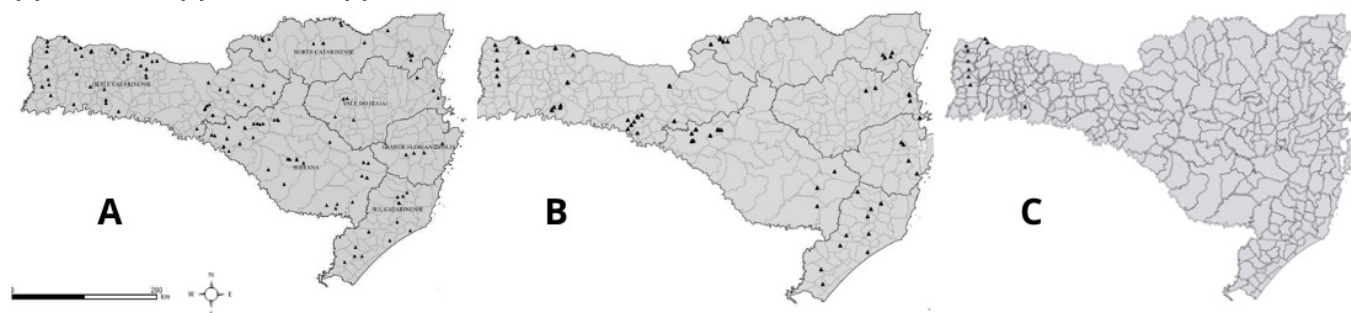
The distribution of the species in the State of Santa Catarina was determined through the capture of adults in pheromone traps and the collection of larvae from tomato, tobacco, and soybean crops. The monitoring was done in three periods: the first one from November 2013 to March 2014, near bean, maize, soybean, tomato, and tobacco crops; the second from September 2014 to March 2015, with inspections beginning while winter crops (wheat and oats) were still present; and the third between October 2015 and September 2016, near fields of the previously mentioned host plants.

The sampling grid was monitored over three distinct periods during the study. In the first period (2013/2014 season), 214 traps were installed across 121 sites. This was followed by a reduction in sampling effort, with 93 traps installed in the second period and 10 traps in the final period. In total, the survey covered 185 sites across 91 municipalities. The traps were distributed across the West, Midwest, Mountain (Serra), South, and North Plateau regions of the state of Santa Catarina, Brazil (Figure 1). To ensure a comprehensive and standardized coverage of the state's territory, the monitoring network was managed through 19 regional administrative units of the Plant Health Protection Department of Santa Catarina (*Companhia Integrada de Desenvolvimento Agrícola de Santa Catarina – CIDASC*). Agronomists from the Plant Health Protection Department were responsible for installing two traps per site at selected crop locations within their respective jurisdictions. Although the specific installation site varied across all periods, consistent data collection was maintained; technicians provided georeferenced coordinates, identified the host plants present at each farm, and checked the traps every two weeks.

The relationship between abiotic factors and the spatial dynamics of *H. armigera*, data on relative humidity, wind speed, average, minimum, and maximum temperatures, as well as precipitation, were obtained from Centro de Informações de Recursos Ambientais e de Hidrometeorologia de Santa Catarina (Ciram)/Empresa de Pesquisa Agropecuária e Extensão Rural de Santa Catarina (Epagri). These data were collected at meteorological stations in Caçador, Chapecó, Florianópolis, São Miguel do Oeste, Campos Novos, Criciúma, and Canoinhas. Traps were stratified into classes ranging from 6 meters to 1384 meters above sea level.

In the fields nearest to each trap, the crops grown were recorded. Data on soybean area for municipalities were provided by the Agricultural Observation and Monitoring System in Brazil (SOMABrasil) and sorted into two groups: the

Figure 1 – Map with georeferenced points representing the distribution of traps in Santa Catarina during cycles of the 2013-2014 (A); 2014-2015 (B); 2015-2016 (C)



Source: Prepared by the authors (2026).

first one with areas smaller than 4000 hectares and the other with areas above this value. The degree of association with the abundance of moths caught in the pheromone traps and the size of soybean fields was analyzed by the Student's t-test. Based on Google Earth imagery, crops within a 500m radius were demarcated as polygons, and area (ha) was calculated using Earth Point. The correlation with *H. armigera* abundance was analyzed using Spearman's coefficient.

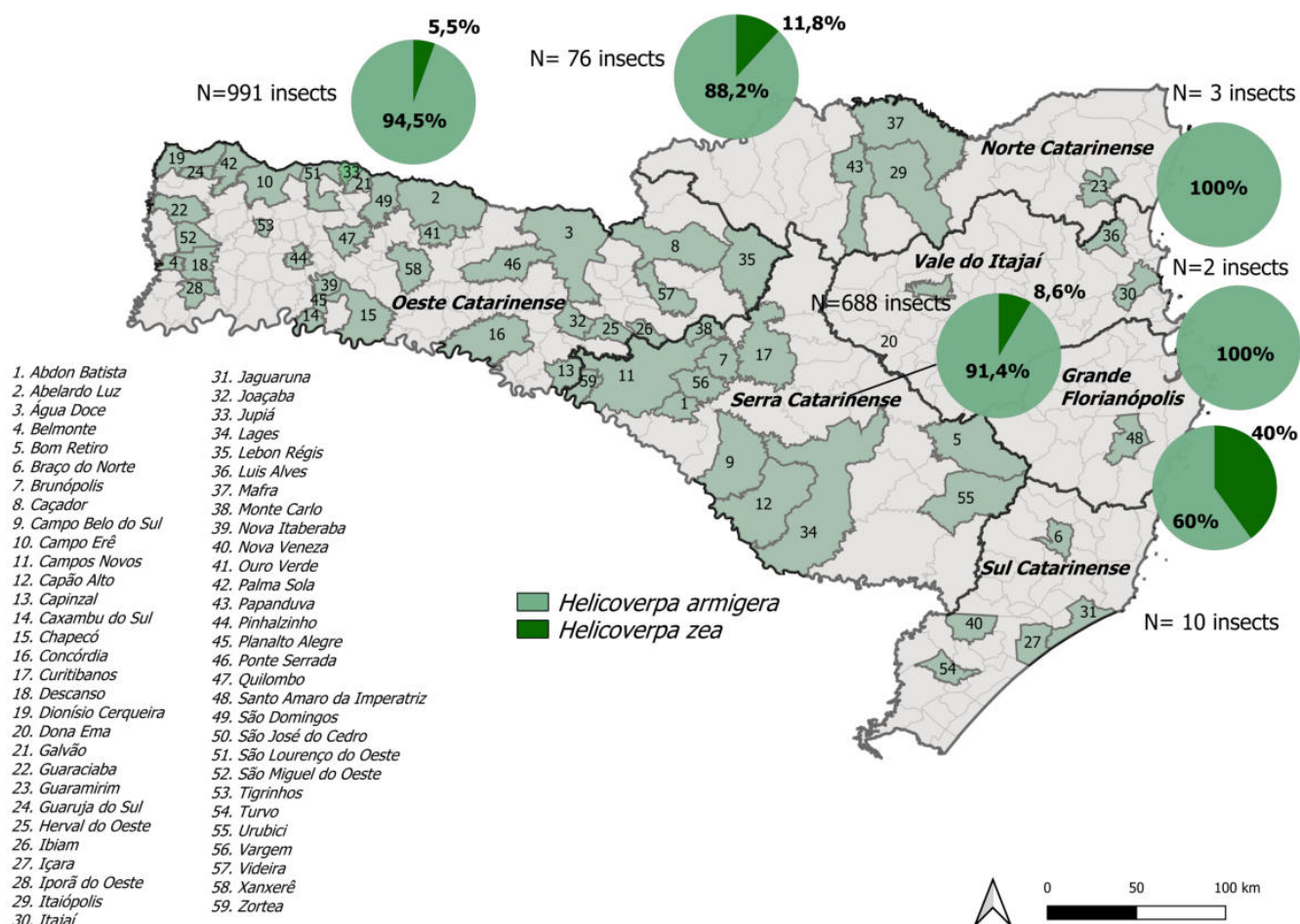
To evaluate the abundance (moths/trap) related to spatial distribution, the following analyses were performed: Cluster analysis using the Global Moran's Index (*I*) to determine whether the distribution of *H. armigera* was aggregated or random, and LISA (Local Indicator of Spatial Association) analysis to map hotspots. For these procedures, data from the first sampling period (2013/2014) were used. Additionally, altimetric stratification was analyzed to evaluate the influence of relief by comparing the mean captures across different altitudes using Analysis of Variance (ANOVA).

3 RESULTS AND DISCUSSION

The adopted methodology enabled us to identify 1761 adult males collected in pheromone-baited traps and 75 larvae in soybean, tomato, and tobacco crops. A total of 75 caterpillars were recorded across farms with fixed observation points. In tomato crops, 24 larvae of the genus *Helicoverpa* were collected, with a population density of up to three caterpillars occurring at the same sampling point. All specimens collected were identified as *H. armigera*. In soybean crops, 50 *Helicoverpa* larvae were collected across three evaluations, averaging 0.5 per sampling point, with a maximum of four caterpillars per evaluation point. It should be noted that the collection of *H. armigera* in tobacco was conducted solely to identify its occurrence; therefore, no density assessment was performed.

Morphological analysis of male genitalia and molecular confirmation via PCR-RFLP in a subsample of 100 specimens revealed that the captures consisted of *H. armigera* and *H. zea*. No occurrences of *H. gelotopoeon* were recorded in the sampled areas. Morphological and molecular identifications were fully congruent for *H. armigera*. Conversely, for *H. zea*, three samples showed discrepancies between morphological and molecular methods; however, only seven samples of this species were analyzed by PCR-RFLP, yielding 85% convergence. Notably, in this study, the amplified region of the *CytB* gene produced two novel bands between 200 bp and 300 bp when digested with *HphI* enzyme, whereas no cleavage occurred with *BstZ171I*. Of the total samples, 89.2% matched *H. armigera*, the most abundant species across all monitored regions and widely distributed throughout the Santa Catarina territory (Figure 2). Using light traps, another study also indicated that *H. armigera* was more abundant than *H. zea*. This result suggests that the invasive species (*H. armigera*) dominated agricultural niches, which is correlated with the excessive use of insecticides and the succession of crops in extensive agricultural areas featuring the same host plant species (Specht *et al.*, 2021).

Figure 2 – Abundance of *Helicoverpa armigera* and *Helicoverpa zea*, captured for pheromone traps in different regions of Santa Catarina State, Brazil, in the period from 2013 to 2015



Source: Prepared by the authors (2026).

Note: The numbers indicate the municipalities, and the circles indicate the proportions of *Helicoverpa* species.

The presence of *H. armigera* was confirmed in 59 of the 91 sampled municipalities, with the highest frequency, regardless of the host plants present at the collecting site. Often, *H. armigera* and *H. zea* were simultaneously captured in the same trap, but without any specimens of *H. gelatopoeon*. Among the municipalities in which the presence of *H. armigera* was determined, 61% belonged to the West and Midwest regions. In these two State regions, pest detection occurred in at least 74% of the monitored municipalities, as verified by the capture in pheromone-baited traps or by collecting larvae directly from host plants. In the northern part of the State, only one municipality (Guaramirim) was monitored, resulting in no catches in the first period and two species captured in 2014-2015. These results indicate the presence of *H. armigera* at elevations ranging from 9 to 1324m above sea level, in different host plants, with catches occurring from September (early Spring) in wheat crops (*Triticum aestivum*), until March in soybean crops (Fall season) (Table 1).

The analysis of spatial dynamics and cluster indicated that the distribution of *H. armigera* in Santa Catarina did not occur randomly, but rather through a significant aggregated pattern. The global Moran's index (*I*) was 0.32, with a Z-score of 4.85 ($p < 0.001$), indicating a moderate positive spatial dependence. The local indicators of spatial analysis (LISA) showed the formation of consolidated hotspots (high-high clusters) in Campos Novos, Xanxerê, Chapecô, and São Miguel do Oeste (Figure 3). Coldspots (low-low clusters) were mapped in the Planalto Norte, where population pressure remained low throughout the harvest season.

Table 1 – Geographic distribution and host plants of *Helicoverpa armigera* in Santa Catarina, Brazil

Municipality	MASL (m)	Stage collected	Collection/host plant	Monitoring period
Abdon Batista	758	Adult	Pheromone traps in soybean crop	January to March 2014; November-March 2014-2015
Abelardo Luz	958	Adult	Pheromone traps in soybean crop	January to March – 2015
Água Doce	1324	Adult	Pheromone traps near soybean, corn and bean crops	January to March 2014; November-March 2014-2015
Belmonte	549	Adult	Pheromone traps in soybean crop	January 2014
Bom Retiro	910	Adult	Pheromone traps in soybean crop	January to March 2014; November-March 2014-2015
Braço do Norte	267	Adult	Pheromone traps in tobacco crop	January to March 2014; November-March 2014-2015
Brunópolis	986	Adult	Pheromone traps in soybean and wheat crops	January to March 2014; November-March 2014-2015; September to December 2015
Caçador	940	Larva	Tomato	January to March 2014
Campo Belo do Sul	995	Adult	Pheromone traps in soybean crop	January to March 2014; November-March 2014-2015
Campo Erê	879	Adult	Pheromone traps near soybean and wheat crops	January to March 2014; November-March 2014-2015; September-October 2015-2016
Campos Novos	985	Adult/ Larva	Soybean	January to March 2014; September-March 2014-2015; September to December 2015
Capão Alto	1033	Adult	Pheromone traps in soybean crop	December-2013 the Alexss-2014
Capinzal	480	Adult	Pheromone traps in soybean crop	November-March 2013-2014; November-March 2014-2015
Caxambu do Sul	529	Adult	Pheromone traps in soybean crop	October-March 2014-2015
Chapecó	705	Adult	Pheromone traps near soybean, wheat and tobacco crops	November-March 2013-2014; November-March 2014-2015; September and October 2015-2016
Concórdia	620	Adult	Pheromone traps in maize crop	November-March 2013-2014; November-March 2014-2015
Curitibanos	989	Adult	Pheromone traps in soybean and corn crops	November-March 2013-2014
Descanso	651	Adult	Pheromone traps in soybean and corn crops	November-March 2013-2014; November-March 2014-2015
Dionísio Cerqueira	751	Adult	Pheromone traps near soybean and wheat crops	November-March 2013-2014; September-March 2014-2015

Table 1 – Geographic distribution and host plants of *Helicoverpa armigera* in Santa Catarina, Brazil

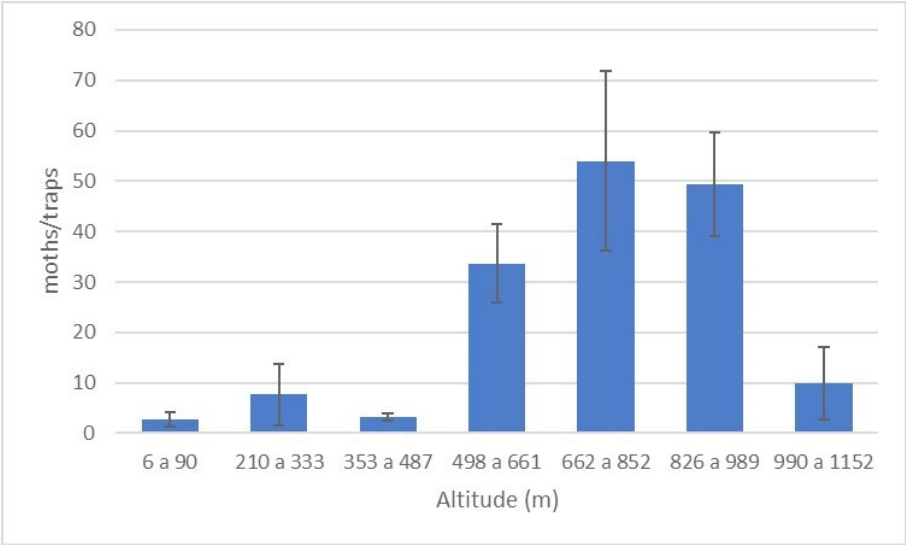
Municipality	MASL (m)	Stage collected	Collection/host plant	Monitoring period
Dona Ema	552	Larva	Tobacco	January 2014
Galvão	698	Adult	Pheromone traps near soybean and wheat crops	November-March 2013-2014; September-March 2014-2015
Guaraciaba	662	Adult	Pheromone traps in soybean crop	December-2013 to March 2014; November-March 2014-2015
Guaramirim	60	Adult	Pheromone in maize crop	February-2015
Guarujá do Sul	695	Adult	Pheromone traps in soybean crop	December-2013 to March 2014; November-March 2014-2015
Herval do Oeste	520	Adult	Pheromone traps in corn and wheat crops	October-March 2014-2015
Ibiam	951	Adult	Pheromone traps in soybean crop	October-March 2014-2015
Içara	21	Adult	Pheromone traps near corn and tobacco crops	November-March 2013-2014; November-March 2014-2015
Iporã do Oeste	553	Adult	Pheromone traps in maize crop	November-March 2013-2014
Itaiópolis	803	Adult	Pheromone traps in soybean and wheat crops	November-March 2013-2014; October-March 2014-2015
Itajaí	9	Adult	Pheromone traps near vegetable species	December-2013 to March 2014; December-March 2014-2015
Jaguaruna	45	Adult	Pheromone traps in corn and tobacco crops	October-March 2013-2014; December-March 2014-2015
Joaçaba	522	Adult	Pheromone traps in soybean crop	November-March 2013-2014
Jupia	817	Adult	Pheromone traps in soybean crop	December-March 2013-2014
Lages	897	Adult	Pheromone traps in soybean crop	December-March 2013-2014
Lebon Régis	1134	Adult	Pheromone traps in soybean and tomato crops	November-March 2013-2014
Luis Alves	231	Larva	Tobacco	November - 2013 to March - 2014
Mafrá	873	Adult	Pheromone traps in soybean and wheat crops	November-March 2013-2014; October-March 2014-2015
Monte Carlo	979	Adult	Pheromone traps in wheat crop	October-March 2014-2015
Nova Itaberaba	333	Adult	Pheromone traps in bean crop	October - 2013 o March - 2014
Nova Veneza	95	Adult	Pheromone traps in maize crop	September-March 2013-2014; November-March 2014-2015

Table 1 – Geographic distribution and host plants of *Helicoverpa armigera* in Santa Catarina, Brazil

Municipality	MASL (m)	Stage collected	Collection/host plant	Monitoring period
Ouro Verde	808	Adult	Pheromone traps in soybean crop	November-March 2013-2014
Palma Sola	698	Adult	Pheromone traps in soybean, maize and wheat crops	November-March 2013-2014; September-March 2014-2015
Papanduva	796	Adult	Pheromone traps near soybean crop	November-March 2013-2014
Pinhalzinho	528	Adult	Pheromone traps in soybean and corn crops	October - 2013 to March - 2014
Planalto Alegre	529	Adult	Pheromone traps in soybean crop	October-March 2014-2015
Ponte Serrada	1067	Adult	Pheromone traps in soybean crop	November - 2014 to March - 2015
Quilombo	503	Adult	Pheromone traps in soybean crop	November - 2014 to March - 2015
Santo Amaro da Imperatriz	11	Adult/ Larva	Tomato	January-March 2013-2014
São Domingos	765	Adult	Pheromone traps in soybean crop	November-March 2013-2014
São José do Cedro	896	Adult	Pheromone traps in soybean crop	November-March 2013-2014
São Lourenço do Oeste	684	Adult	Pheromone traps in soybean crop	December-2013 to March 2014; September-March 2014-2015
São Miguel do Oeste	636	Adult	Pheromone traps near soybean and wheat crops	November - 2014 to March - 2015
Tigrinhos	637	Adult	Pheromone traps in soybean and corn crops	November-March 2013-2014
Turvo	43	Adult	Pheromone traps in maize crop	November-March 2013-2014
Urubici	940	Adult	Pheromone traps in maize crop	December-March 2013-2014
Vargem	949	Adult	Pheromone traps in soybean crop	January to March 2014; October-March 2014-2015
Videira		Larva	Tomato	January to March 2014
Xanxerê	678	Adult	Pheromone traps in soybean crop	November to March 2013-2014; October-March 2014-2015
Zortea	770	Adult	Pheromone traps in soybean and wheat crops	January to March 2014

Source: Prepared by the authors (2026).

Figure 3 – Cumulative mean of *Helicoverpa armigera* captures during the 2013/2014 harvest season in the state of Santa Catarina, Brazil. Vertical lines indicate the standard deviation



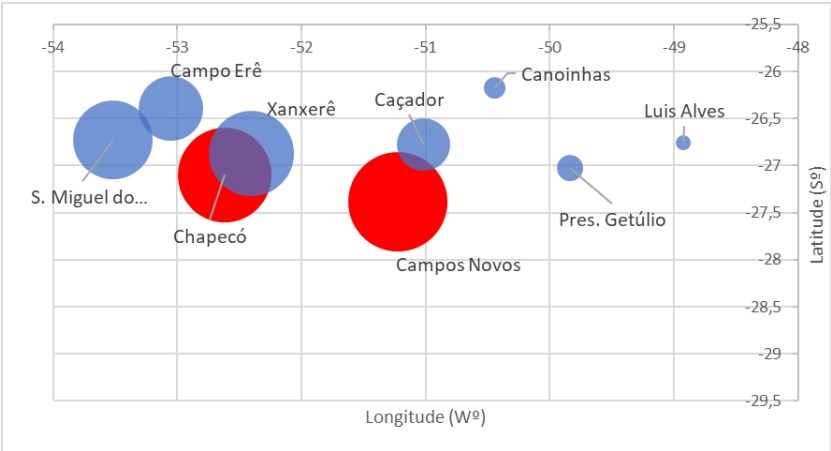
Source: Prepared by the authors (2026).

There was a direct correlation between altitude and capture intensity. The peak abundance occurred in the altitudinal range between 662 and 852m, with a mean of 54.0 ± 17.8 moths/trap, significantly higher than in areas below 200m above sea level ($2,67 \pm 1,41$) (Figure 4). The influence of altitude was due to temperature differences, which are decisive for *H. armigera* development, especially in relation to average minimum temperatures (Specht *et al.* 2021).

Although *H. armigera* has been officially reported in Brazil only in the year 2013, subsequent studies have shown that the species has been present since 2008 (Sosa-Gómez *et al.*, 2015), causing losses in cotton, soybeans, corn, and tomato crops since that year. Corroborating the great mobility of adults, the late identification of the pest in Brazil, and the multiple introductions (Tay *et al.*, 2017), the present study reported the official presence of *H. armigera* in Santa Catarina State, southern Brazil, in 2013.

However, the population of *H. armigera* in Santa Catarina landscapes must be largely connected to the migration process the species adopts to search for better conditions for the survival and development of its progeny. As an anchor for migrant moths, this territory provides host plants, phenological aspects, and the predominance of an agricultural landscape (Jallow *et al.*, 2004; Cunningham; West, 2008; Cunningham; Zalucki, 2014).

Figure 4 - Density and spatial distribution of *Helicoverpa armigera* in the state of Santa Catarina, Brazil



Note: The geographic coordinates delimit the spatial occurrence, and the bubble sizes represent the total number of adults captured per trap, indicating hotspots in the Western and Midwestern regions.

Source: Prepared by the authors (2026).

Corroborating with the conditions described above, the municipalities with planted area of up to 4000 hectares of soybean, predominantly located in the Midwest and West regions, were those with the highest number of captures of moths in the sex pheromone traps (average 54.2 moths per site) in comparison with the sites with smaller areas (average 9.7 moths per site), with significant difference between these two groups ($t = 2.41$; $df = 18$; $P < 0.05$). In addition, the Spearman's rank correlation coefficient ($r = 0.672$; $S = 9592.5$; $P < 0.001$) between the size of the farming area up to 500m away from the trap and the number of catches suggested an association between large-sized farms and the presence of *H. armigera*.

The influence of the agricultural landscape, as indicated by its association with pests, has also been reported by other authors, reinforcing the relevance of the results of the present study, conducted in Santa Catarina. Evaluating the effect of landscape on the abundance of *H. armigera* has been the goal of several studies, which showed that variations in pest population depend on the composition of the agricultural landscape or the presence of natural enemies (Tsafack *et al.*, 2013; Downes *et al.*, 2017). In addition, selecting a host plant for oviposition is an adaptive strategy that ensures reproductive benefits (Liu; Scheirs; Heckel, 2010). Thus, the greater proportion of soybean crops in the analyzed regions of Santa Catarina provides greater food availability, which explains the greater captures of moths in these environments. The municipality of Campos Novos, with more than 49 thousand hectares of soybean crop, recorded the highest captures in January and February, during the flowering period, which was attractive to *H. armigera* (Figure 2).

Moreover, Veres *et al.* (2013), in a review of various studies, found that landscapes are associated with pest abundance (61%). Similarly, the agricultural landscape was associated with a positive relationship between the proportion of cotton and the abundance of *H. armigera*, with higher infestation rates when the analyzed cotton crops were surrounded by more cotton fields (Tsafack *et al.*, 2013). More recently, Silva *et al.* (2020) reported initial signs of population differentiation associated with host plant types and showed that landscape composition and host plants influenced the evolutionary process of *Chrysodeixis includens*, a pest insect.

In the present study, beyond soybean (*Glycine max*), other plant species, such as tomato (*Solanum esculentum*) and tobacco (*Nicotiana tabacum*), also served as hosts of *H. armigera*, as evidenced by the presence of their larvae in reproductive structures and tomato fruits. This is the first report of *H. armigera* in tobacco in Brazil. Tomato fields in the municipality of Caçador (Midwest) with high infestation and damage were unsuitable for either consumption or marketing due to injuries caused by the pest. In the municipality of Campos Novos (Midwest), damage in soybeans was associated not only with *H. armigera*, but also with other species, such as *Anticarsia gemmatilis*, *Chrysodeixis includens*, and *Spodoptera spp.* In tobacco plants, larvae were collected on two farms located in different regions of the State, in the South and in the Vale do Itajaí, but no damage caused by *H. armigera* was observed.

In the municipality of Caçador, we observed a high incidence of *H. armigera* on tomato farms totaling 1378 hectares cultivated during 2013-2014, after soybean fields produced seeds (Cepa, 2016). Other studies do support the effect on the pest abundance in a crop if a susceptible crop has been previously grown nearby. For example, Tsafack *et al.* (2013) found a positive and significant relationship between the proportion of tomato crops and the abundance of *H. armigera* larvae before sowing cotton in a study conducted in the North of Benin, West Africa. The flowering of tomato plants can be attractive to the insects and decisive in the discrimination of the host plant, because the adult feeds on nectar (Cunningham; Zalucki; West, 1999; Jallow *et al.*, 2004; Cunningham; Zalucki, 2014; Liu; Scheirs; Heckel, 2010). The blooming season of tomato plants at sites assessed before soybean sowing is attractive to *H. armigera*. At these sites, damage was observed in tomatoes, but not in soybeans. Since the frequency of insecticide applications intensified after the outbreak, it may have disrupted the pest's life cycle, as farmers sprayed tomato plants every week afterward, possibly eliminating the source of infestation.

Even though *H. armigera* was the most frequent, regardless of crop present at the site or host plants; *H. zea* was often captured simultaneously in the same trap. This fact indicates the coexistence of the two species and the absence of differentiation in the sexual pheromone, thereby allowing interspecific mating and potentially leading to hybrid offspring. The identification of *Helicoverpa* species has been based on the differentiation of male genitalia using the "lock-and-key" structure, which prevents interspecific mating and distinguishes one species from another. However, this assumption has recently been questioned by Anderson *et al.* (2018), who identified individuals that originated from hybridization

between *H. armigera* and *H. zea*. According to the authors, the genetically analyzed hybrids were more similar to *H. armigera* than to *H. zea*, although these differences may not be apparent in the male genitalia for morphological species identification. In addition, hybrid individuals may exhibit greater environmental adaptation, necessitating changes in pest management strategies.

Factors inherent to the agricultural landscape, associated with abiotic factors, also influence a potential hybridization between *H. armigera* and *H. zea*. This process does not occur in a mosaic pattern, as crop succession—specifically maize and soybean—is a determining factor for introgression levels (Cordeiro *et al.*, 2020). Regardless of the hybridization process, pressure from *H. armigera* has decreased throughout the crop season. Even in the 2013/2014 crop season, when significant production losses were observed across various regions of the country, the species accounted for only 2.7% of the caterpillars in commercial soybean crops in Santa Catarina (Wille, 2016).

However, the presence of *H. armigera* in Santa Catarina should not be overlooked, as current management relies heavily on insecticides and *Bt* toxins. If these management practices are combined with new adapted populations originated from hybridization, the occurrence of new outbreaks cannot be ruled out. In fact, several *Bt* genes introduced in cropping transgenic varieties, including *Vip3Aa*, have been overcome by *H. armigera* populations in distinct countries (Downes *et al.*, 2010, 2017; Bachler *et al.*, 2025). In addition, populations of *H. armigera* exhibited resistance to several insecticides used tentatively for its control (Yang; Li; Wu, 2013). Later, a new study used a laboratory strain of *H. armigera* that is resistant to the phthalic acid diamide flubendiamide to demonstrate that the resistance inheritance pattern was due to an autosomal dominant trait (Abbade-Neto *et al.*, 2022). The authors also showed that heterozygotes between the susceptible and the laboratory strain resistant to the phthalic acid diamide flubendiamide showed high survival and no reduction in leaf consumption.

In this context, the influence of agricultural landscape composition on *Helicoverpa* species prevalence should be considered when defining pest management practices. Tsafack *et al.* (2016) suggested that the evaluation zone within a 500 m radius is essential for estimating the abundance of *H. armigera*. That advice was used in the present study, and correlation coefficients between the number of catches and the cultivation areas were estimated. However, additional studies are needed to better elucidate the degree of association between the abundance of *H. armigera* and other variables on pest population dynamics, especially those related to agricultural practices, such as the time of sowing, spraying with insecticides, and the presence of weeds, as well as frequency of weeding, which may alter the availability of host plants. Likewise, it is necessary to study the presence of natural enemies in the agricultural landscapes. Anyway, this is the first report to relate the pest's occurrence to the agricultural landscape over a period of three years, on a scale that covers various landscape features and crop species.

The continuous monitoring approach enabled us to assess the pest's population level and, thus, to argue against declaring a state of emergency in Santa Catarina. Consequently, the results of the present study supported the informed decision-making process of the Plant Health Protection Department (CIDASC), which did not authorize the use of emamectin benzoate insecticide formulations.

That strategy is consistent with United Nations Sustainable Development Goal 2, in which target 4 determines that by 2030, “ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality” (UN, 2015).

4 CONCLUSION

- *Helicoverpa armigera* was the most abundant species of the genus across all monitored regions from 2013 through 2016, and was widely distributed throughout the sampled territory of Santa Catarina State.
- In this study, *H. armigera* was reported to feed on soybean, tomato, and tobacco host plants.
- Agricultural landscape composition influences pest occurrence, dispersion, and records of host plants of *H. armigera*.

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