

Spatial Distribution of *Tibraca limbativentris* (Heteroptera: Pentatomidae) in Babassou Palms

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Abstract

The babassou plant (*Attalea speciosa* Mart. Ex. Spreng, Arecaceae) is an important palm tree in the state of Maranhão, northeastern Brazil. This plant is the main arboreal component in extensive geographical areas including agricultural areas. However, limited research studies exist on its role as an alternative pest host in this region. This study investigated the occurrence of *Tibraca limbativentris* Stal (1860) in young babassou palm trees, the effect of abiotic factors (temperature, solar radiation and rainfall) on the number of *T. limbativentris* adults and postures, and this insect's spatial arrangement during the rice crop off-season. The research team inspected young babassou plants on a monthly basis in 2012 and 2013 to collect and quantify postures and adults. They collected a total of 1418 live adults, 13 dead and ten postures of *T. limbativentris*. There was a significant difference between the first and the other collections of live adults carried out in 2012 and 2013. Abiotic factors including rainfall, temperature and solar radiation, had no influence on the number of adults (alive and dead) and postures. The semivariogram adjusted to the Gaussian model showed that in 2013, the spatial distribution of living adults, that had an aggregate pattern, was highly dependent on the season. However, in 2012 there was a pure nugget effect. These results imply that young babassou plants are alternative *T. limbativentris* hosts.

Keywords: *Attalea speciosa*, geostatistics, kriging, spatial arrangement, stink bug

1. Introduction

The northern region of Maranhão, northeastern Brazil, has extensive babassou palm trees (*Attalea speciosa* Mart. Ex. Spreng, Arecaceae). These trees constantly transform during rice crop implantation periods. The area's farmers practice a cultivation system that combines subsistence agriculture, artisanal fishing and extraction. This system uses fire to clean and fertilize the soil by leaving the residual ash from burning the fallow bushes on the ground. Such techniques have made the state of Maranhão the largest rice producer in the northeast Brazilian region. Furthermore, this state ranks second among states with the most extensive

rice plantations in the country (CONAB, 2019).

The phytophagous bugs are pests of economic importance to rice farmers. This fact is mainly true for the thatched bugs, the hornbills, *Tibraca limbativentris* Stal, 1860 (Heteroptera: Pentatomidae) that are the main pests in South America (Panizzi, 2015). This pentatomid contributes to up to 90% of farmer's productivity losses (Souza *et al.*, 2008). The pest's adults and nymphs feed on the plant's vegetative and reproductive phases resulting in the symptoms of a dead heart and a white panicle, respectively (Botton *et al.*, 1996). Therefore, the bug causes the most damage in the rice crop's reproductive phase (Krinski & Foerster, 2017). The bug is also known as "cangapara" in the state of Maranhão. This bug is found in almost all the state's municipalities that grow upland rice.

Due to these bugs' polyphagy, they seek alternative plant hosts to feed, oviposition and develop their offspring (Panizzi, 1991); thus, they hibernate in adjacent crop remains or alternative host plants waiting for the next rice crop. A behavior confirmed by Pasini *et al.* (2018) who demonstrated the root bug in clumps of foxtail grass, *Andropogon bicornis* L and *A. lateralis* (Poaceae) in the rice crop's off-season period. According to Engel *et al.* (2019), these alternative resource sources help bugs survive unfavorable periods.

Because they are highly resistant to fire, babassou plants are the dominant species in Maranhão's cultivation areas after a rice harvest (Mitja *et al.*, 2018). Therefore, the babassou palm may be a potential shelter for *T. limbativentris* in the off-rice season.

Advances in integrated pest management have permitted study of the spatial distribution of some bug species in agricultural areas to construct infestation maps for targeted and precise application of population reduction measures. For instance, the spatial distribution of *T. limbativentris* adults and nymphs in irrigated rice fields depends on the crop's phenological stage (Costa *et al.*, 2019; Pasini *et al.*, 2020; Pasini *et al.*, 2021). Engel *et al.* (2021), point out that the spatial distribution study in alternative hosts helps in pest permanent monitoring and anticipating possible outbreaks.

Despite the potential economic damage caused by bugs, scarce information exists on its spatial distribution in alternative hosts. Therefore, this research aimed to describe the distribution of *T. limbativentris* in young babassou plants adjacent to rice growing areas in the northern region of the state of Maranhão. This study also investigated the influence of abiotic factors (temperature, solar radiation and rainfall) on the number of the pests' adult populations and spawnings and the insect's spatial distribution in the area inter-harvest period.

2. Material and Method

2.1 Study Area: Location and Characteristics

The research team conducted a study in the municipality of Matões do Norte (latitude 03°37'57" S; longitude 44°33'9" W), (05°42' S; 43°13' W), State of Maranhão, northeastern Brazil. They did the research in areas where family farmers cultivated upland rice intercropped with corn (*Zea mays* L.) and cassava (*Manihot esculenta* Crantz).

Thorntwaite's classification describes the region's climate as type (C₁SA' a'), sub-humid, mega-thermal, dry climate with a moderate water deficit in the summer (Geplan, 2002; Barros *et al.*, 2012).

2.2 Climatic Data

The study team obtained the average 30 days' temperature (°C), solar radiation (cal cm⁻² day) and rainfall (mm) from the Meteorological Laboratory of the Geoenvironmental Nucleus of the Maranhão State University (Figure 1).

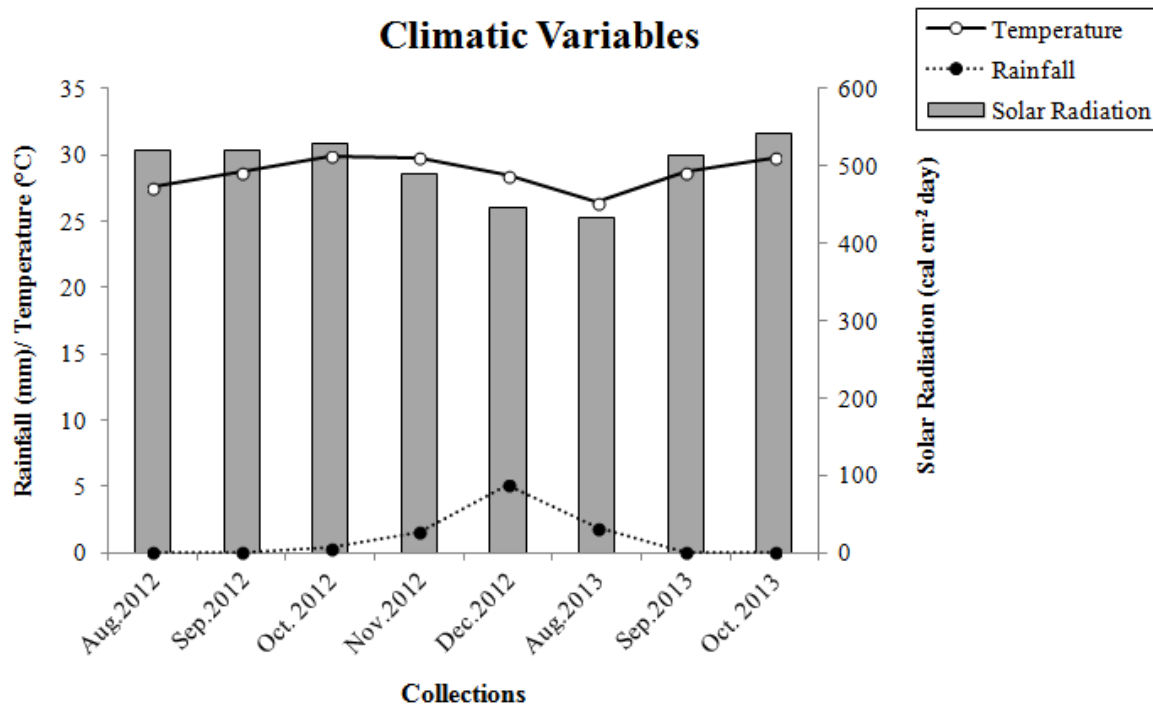


Figure 1. Average temperature (°C), solar radiation (cal cm⁻² day) and rainfall (mm) in 2012 and 2013, in the municipality of Matões do Norte, State of Maranhão, northeastern Brazil

2.3 Sampling of *T. limbativentris*

The team collected samples each month after the rice harvest from August to December 2012 and August to October 2013. Each year, they selected an area measuring approximately four hectares surrounded by young babassou palms as their study sample. The areas' predominant cultivation system was "slash and burn", where vegetation was cut, burnt to clean the site and the ash used as a soil fertilizer. This soil preparation generally occurred in November, followed by rice sowing in January to coincide with the beginning of the region's rainy season. Nevertheless, the areas were kept fallow for vegetation regeneration after a rice harvest.

The selected young babassou plants (called *pindovas*), measuring 60 cm in height and 52 cm in diameter, were the most vigorous plants located equidistantly (approximately 5m apart) within the rice planting area.

The team randomly selected *pindovas*' sampling points following a zigzag pattern covering the entire area related to the rice clump studied.

The team marked 64 and 49 *pindovas* in 2012 and 49 in 2013. They meticulously inspected *pindovas* leaves and trunk for the presence and collection of live and dead adult bugs, and *T. limbativentris* postures

2.4 Georeferencing of Sampled Plants

The study used a Garmin MAP 76CSX GPS (Global Positioning System) device to georeference the selected babassou plants for *T. limbativentris* sampling. The device used the flat coordinates of the Universal Transverse Mercator System (UTM) to identify the palm trees' location and facilitate repeated sampling from the same plants.

2.5 Statistical Analysis

First, the Shapiro-Wilks normality test was used to describe data collected on adult bugs (living and dead) and postures. Then, since data was non-normal, the Kruskal-Wallis non-parametric test, $p < 0.05$ (Statsoft Inc, 2011), was used to identify statistical differences between the number of adults (living and dead) and collected postures.

Subsequently, the number of live and dead adults and postures were transformed into their square roots (\sqrt{x}) and tested using the T-test at the level of 5% probability in the BioEstat 5.0 program (Ayres *et al.*, 2007). Finally, Pearson's linear correlation was used to describe the relationship between abiotic factors (temperature, solar radiation and rainfall) and the number of adults (living and dead) and postures.

2.6 Geostatistical Analysis

A Geostatistical analysis was used to construct semivariograms and verify spatial dependence between samples. According to Cambardella *et al.* (1994), the $[(C_0 / C_1 + C_0) \times 100]$ model's degree of spatial dependence is considered strong if this ratio is $\leq 25\%$, moderate if it is between 25 and 75%, and weak when the ratio is $> 75\%$. Subsequently, the variograms were constructed using the model with the best determination coefficient.

2.7 Preparation of Spatial Distribution Maps

The study developed spatial distribution maps using all the annual data on live adult bugs. The data obtained were imported into SAS version 8.2 (SAS Institute, 2001) for analysis then, crossed and interpolated. In addition, bug infestation maps were generated using the G.S. + program (Gamma Design Software, 2000).

3. Results and Discussion

A total of 1418 live adults, 13 dead and 10 postures of *T. limbativentris* were collected in 2012 and 2013. The high number of live individuals collected from the *pindovas* suggests the presence of a surviving *T. limbativentris* population large enough to infest the same rice fields the following year. Bugs infest rice plants within 20 or more days of emergence and begin oviposition ten days later (Ferreira, 1998), with the possibility of reproducing up to three

generations in a rice crop (Pasini *et al.*, 2018).

On the one hand, the 2012 results concerning 1304 live adults, 5 dead and 9 postures indicate that a farmer should use preventive measures, such as resistant cultivars or trap plants, to minimize the damage of *T. limbativentris* if he or she intends to reuse the area to plant rice.

On the other hand, the 2013 results had fewer collections (114 live adults, 8 dead and 1 posture) as the fallow period was not maintained because farmers needed to prepare the area for the next planting. The presence of postures in the two years suggests that palm trees are a refuge for *T. limbativentris* adults that preserve its population. Based on research by Fuentes-Rodríguez *et al.* (2019), the fact that *T. limbativentris* nymphs do not dwell in alternative hosts implies that the pest needs a rice plant to reproduce

The team observed a significant difference in the number of living adults in the first and the other collections in 2012 and 2013 (Figure 2). The first collection of each year had a higher average number of living adults but similar numbers of dead adults and postures to the collections made the rest of each year (Figure 2).

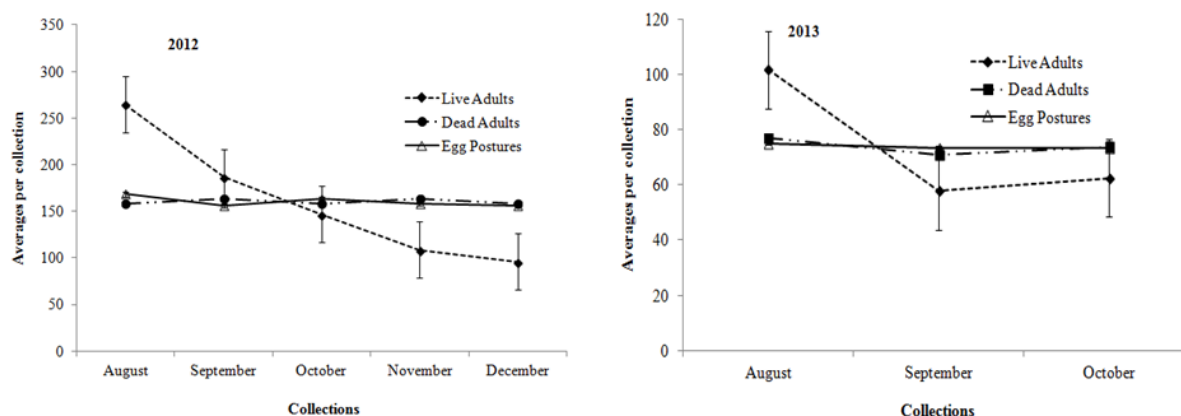


Figure 2. The average number of adults (alive and dead) and postures of *Tibraca limbativentris* collected in young babassou plants during the rice crop off-season in the municipality of Matões do Norte, State of Maranhão, northeastern Brazil in 2012 and 2013

Therefore, it is possible to infer that young babassou plants present microclimatic conditions that favor the survival of the *T. limbativentris* population. According to Klein *et al.* (2013), a protected environment is a better shelter since it provides more stable microclimates than the open environments.

The rainfall, temperature and solar radiation did not influence the number of adults (alive and dead) and postures collected between August and December 2012, and August and October 2013 (Table 1).

The absence of a correlation or presence of low correlation between climatic factors and pest populations may indicate that these abiotic factors did not affect the area's *T. limbativentris* population. However, the number of *T. limbativentris* adults and postures in each collection was insufficient to illustrate the influence of abiotic factors on this insect-pest's population.

Table 1. Pearson correlation coefficients showing the relationship between the number of adults (alive and dead) and postures of *Tibraca limbativentris* collected from young babassou plants during the rice inter-harvest period in the municipality of Matões do Norte, State of Maranhão, northeastern Brazil in 2012 and 2013

| Climatic data | Biological material | Pearson Correlation Index |
|--------------------|---------------------|---------------------------|
| Temperature | Live adults | -0.76 ^{ns} |
| | Dead adults | 0.03 ^{ns} |
| | Postures | -0.31 ^{ns} |
| Rainfall | Live adults | -0.54 ^{ns} |
| | Dead adults | -0.45 ^{ns} |
| | Postures | -0.53 ^{ns} |
| Solar Radiation | Live adults | 0.50 ^{ns} |
| | Dead adults | 0.27 ^{ns} |
| | Postures | 0.57 ^{ns} |

^{ns}Non-significant according to Pearson's correlation coefficients (r) tested by the T test at a 5% probability level.

Based on the above parameters, nugget effect, level and range for the period correspondent to the year 2012, there was a random pest distribution in the babassou young plants (Table 2). Thus, the appropriate model to describe the spatial behavior of adults of *T. limbativentris* was a pure nugget effect (Figure 3A).

A different research study conducted in irrigated rice fields substantiated the same distribution of adults and nymphs as *T. limbativentris* (Alves *et al.*, 2016). This pure nugget effect in insect collections is due to sampling error or spatial dependence; however, this usually occurs on a smaller scale than the one we adopted (Liebhold *et al.*, 1993). Thus, there was a random distribution of live adult bugs; alternatively, or that the distance between the sampling points in the area was too great to identify a dependent spatial distribution. This distance could be attributed to the disposition of the young babassou plants in the area.

Table 2. Semivariogram models showing the spatial distribution of *Tibraca limbativentris* live adults o collected from babassou young plants during the rice crop off-season in the municipality of Matões do Norte, State of Maranhão, northeastern Brazil in 2012 and 2013

| Years | Semivariogram Parameters | | | GDE | R ² | Model |
|-------|--------------------------|--------|-------|-------|----------------|--------------------|
| | Co | Co+C | A | | | |
| 2012 | - | - | - | - | - | Pure Nugget Effect |
| 2013 | 0.0001 | 0.2252 | 29.45 | 0.044 | 0.666 | Gaussian |

Co: Nugget effect; Co+C: Level; A: Range; GDE: Degree of spatial dependence; Determination coefficient: R²

The distribution of bugs in 2013 was adjusted to the Gaussian model (Figure 3B), due to the great continuity of the variables, that is, values found very close to semivariance (Table 2). Similarly, Pazini *et al.* (2015) found that this model was the best that was adjusted in most *T. limbativentris* collections in irrigated rice.

In 2013, the semivariance initially increased as the distance between the sampling points increased until a point where the semivariance reached a plateau (Figure 3B). However, the semivariance for the year 2012 remained constant throughout the sampling distances (Figure 3A). As for the adjustment's efficiency, the Gaussian model obtained an R² = 0.67; this figure indicates a good adjustment based on Silva *et al.* (2015). The number of adult live wire bugs collected in 2013 had a range of 29.45 m. This parameter represents the limit of dependence on the sampled points.

Based on the criterion by Cambardella *et al.* (1994), the 2013 samples portrayed strong spatial dependence, because it was $\leq 25\%$, indicating that the number of individuals depends on their position in the area.

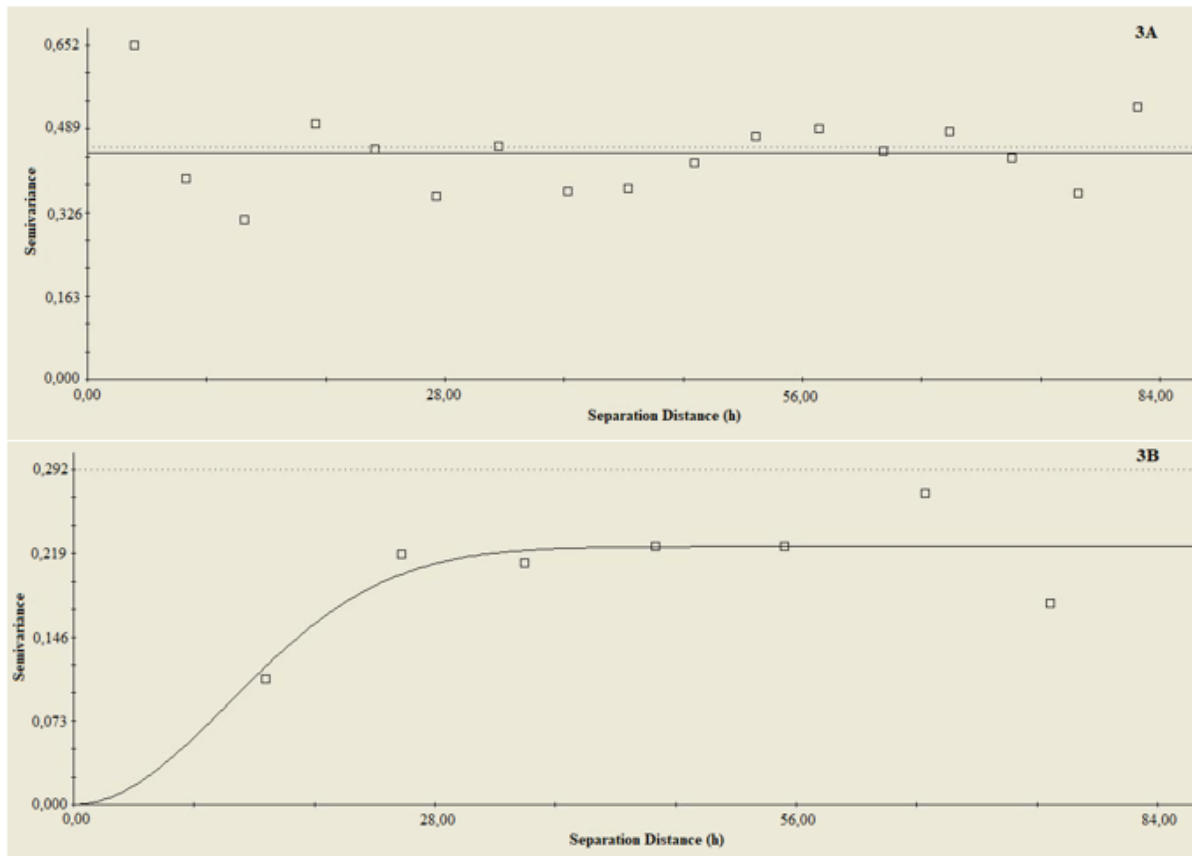


Figure 3. Semivariograms of the distribution of live adults of *Tibraca limbativentris* in young babassou plants during the rice inter-harvest period in the municipality of Matões do Norte, State of Maranhão, northeastern Brazil, in 2012 (3A) and 2013 (3B)

The kriging map was generated for the year 2013 only. This map shows that the spatial distribution of *T. limbativentris* was aggregated, with a concentration of specimens in the young babassou plants located at the area's edge (Figure 4). When assessing the spatial distribution of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) and *Pectinophora gossypiella* (Saunders) (Lepidoptera: Gelechiidae), Milonas *et al.* (2016) reported that these pests' spatial distribution depends on the area's availability and distribution of hosts. Following this study, Martins *et al.* (2020) mentioned that it is possible to expand the study of insect behavior in the field from their study of the spatial distribution of *Neomegalotomus parvus* (Hemiptera: Alydidae).

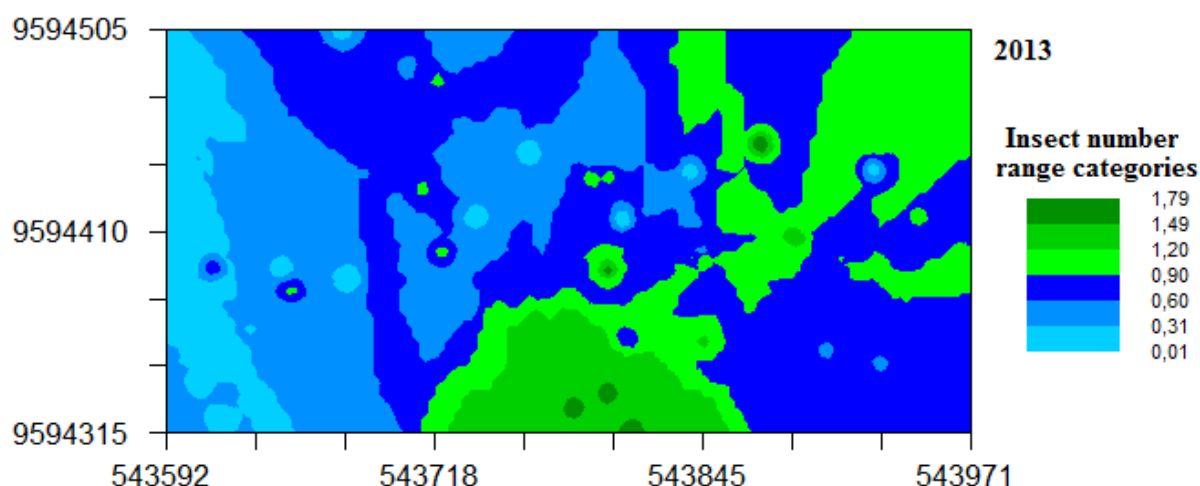


Figure 4. The Spatial distribution of *Tibraca limbativentris* adult population collected from young babassou plants during the rice crop off-season in the municipality of Matões do Norte, State of Maranhão, northeastern Brazil, in 2013

Young babassou plants are widely distributed on the edges and within rice-growing areas. Consequently, these plants play an essential role in *T. limbativentris* survival during the rice crop off-season. Therefore, program managers can focus appropriate strategies on young babassou plants to manage and control *T. limbativentris* to reduce this pest's incidence in the new rice planning season.

4. Conclusions

The young babassou plants serve as a refuge for *Tibraca limbativentris* in the rice crop off-season. This shelter implies that abiotic factors, such as temperature, humidity and precipitation, have no impact on the study area's insect population. Furthermore, aggregates of fully-grown *T. limbativentris* are spatially distributed in this alternative host and form ridges at the area's edge. Such a location favors sampling plans for the management and control of this pest that economically influences rice crop production.

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