POPULATION STRUCTURE OF *Heteropsis* spp. Kunth (TITICA VINE) IN THE TAPAJÓS NATIONAL FOREST, PARÁ-BRAZIL

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ABSTRACT – The objective of the present study was to analyze the ecological aspects of Heteropsis spp. Kunth (titica vine) in an area maintained under forest management conditions. The study was carried out in the Tapajós National Forest, Pará state, Brazil, at Annual Production Unit 11. For the inventory of trees hosting titica vine, 206.25 hectares were covered. The parameters recorded were diameter at breast height – DBH (1.30 m above the soil), total height (Ht), regional name and geographical coordinates. The mature and immature aerial roots of titica vine were counted and the mass of mature roots with and without bark was collected and measured. The density of the host trees in different class centers of DBH and Ht was related. The ratio between the DBH and Ht of the host trees and the mass of mature root with bark of the titica vine was calculated. Spatial distribution was based on Ripley's K function. A total of 337 trees were inventoried as hosts, with average density of 1.65 trees.ha^{-1}, distributed in 88 species. Trees with DBH <30 cm were the ones that host most titica vines. Trees with 10 m ≤ Ht <15 m host more titica vines when compared to trees with Ht ≥ 25 m. Trees with higher DBH and Ht have the highest number of titica vine roots. The individuals of titica vine had 585 roots. ha^{-1}, leading to an average production of 2.1 kg.ha^{-1} of titica vine with bark, declining after processing to 0.6 kg. ha^{-1}. It was concluded that the titica vine has no preference for host tree species and that the spatial distribution tends to be aggregated.

Keywords: Hemiepiphyte; Extractivism; Spatial distribution

ESTRUTURA POPULACIONAL DE Heteropsis spp. Kunth (CIPÓ TITICA) NA FLORESTA NACIONAL DO TAPAJÓS, PARÁ-BRASIL

RESUMO – O presente estudo foi realizado com o objetivo de analisar os aspectos ecológicos de ***Heteropsis*** *spp. Kunth (cipó titica) em uma área mantida sob condição de manejo florestal. O estudo foi conduzido na Floresta Nacional do Tapajós, no estado do Pará, Brasil, na Unidade de Produção Anual 11. Para o inventário das árvores hospedeiras de cipó titica foram percorridas 206,25 ha. Os parâmetros registrados foram: diâmetro a 1,30 m do solo (DAP), altura total (Ht), nome regional e coordenadas geográficas. Foram contabilizadas as raízes aéreas maduras e imaturas do cipó titica e coletadas e mensuradas a massa das raízes maduras com e sem casca. Foi relacionada a densidade das árvores hospedeiras em diferentes centros de classes de DAP e Ht. Foi feita a relação do DAP e Ht das árvores hospedeiras com a massa das raízes maduras com casca do cipó titica. A distribuição espacial foi feita com base na função K de Ripley. Foram inventariadas 337 árvores como hospedeiras, com densidade média de 1,65 árv.ha^{-1}, distribuídas em 88 espécies. Árvores com DAP < 30 cm são as que hospedam mais plantas de cipó titica. Árvores com 10 m ≤ Ht < 15 m hospedam mais plantas de cipó titica, quando comparadas às árvores de Ht ≥ 25 m. Árvores com maior DAP e Ht são as que apresentam maior quantidade de raízes de cipó titica. Os indivíduos de cipó titica apresentaram 585 raízes.ha^{-1}, levando a uma produção média de 2,1 kg.ha^{-1} de cipó titica com casca, declinando após o beneficiamento para 0,6 kg.ha^{-1}. Concluiu-se que o cipó titica não tem preferência por espécie arbórea hospedeira e que a distribuição espacial tende a ser agregada.*

Palavras-Chave: Hemiepífita; Extrativismo; Distribuição espacial.

1. INTRODUCTION

Tropical forests have a large diversity of non-wood forest products (NWFPs) that can be of animal or plant origin (non-woody), which are found in native and planted forests and in agroecosystems (Wallace et al., 2005; Elias, 2016; Santos, 2016). Among the NWFPs found in these forests is the titica vine (*Heteropsis* spp. Kunth), which has resistant fiber and is easily worked and is used in artisanal crafts (baskets, domestic utensils and furniture, among others), and also as rope used for securing structures in building construction (Balcázar-Vargas et al., 2015).

The titica vine is found in Brazil, the Guianas, Peru, Venezuela and Colombia. In Brazil it is found predominantly in the Amazon basin and the Atlantic rain forest, and the state with the greatest predominance of this species is Amapá, followed by Pará, Amazonas and Rondônia (Bentes-Gama et al., 2007; Soares et al., 2009).

Products made from the titica vine are found in open-air markets in the North region and are used in the furniture industry to make rustic items in the South and Southeast regions of Brazil (Elias, 2016; Santos, 2016). There is a significant market demand for this raw material which could compromise the abundance of this species in native forests.

According to the red list of species threatened with extinction, elaborated by the National Center for the Conservation of Flora, the titica vine is in a state of vulnerability because there has been a reduction in its populations due to extractivism. For example, in areas that are more easily accessible there has been a reduction in the quantity of roots available for harvest. As a consequence, harvesters have begun harvesting these roots in areas that are farther away and of more difficult access, and in these more distant areas harvesters have shown less preoccupation with collecting only mature roots and now collect even the roots of young individuals (CNCFlora, 2012).

Some sustainable use federal conservation units define the titica vine as a protected species, as in the Adolpho Ducke Forest Reserve in the state of Amazonas, and the Alto Juruá Extractivist Reserve in Acre, with the objective of guaranteeing the perpetuation of the species (CNCFlora, 2012). However, in the Tapajós National Forest (FLONA Tapajós) in the state of Pará, studies on this species are still incipient, and more information on the ecology of this species and its establishment on host trees is needed to define management and conservation parameters in natural environments (Bentes-Gama et al., 2007; Costa et al., 2019).

It is important to emphasize that in the state of Pará there is no specific legislation for the management of the titica vine, and this makes this species even more susceptible to predatory actions, in contrast to the states of Amapá and Amazonas, which have laws that regulate activities using the titica vine in order to minimize the impacts on its natural populations (Amapá, 2001; 2002; 2009; Amazonas, 2008; Santos et al., 2018).

In this context, the focus of this study was the following scientific question: how does the titica vine respond to forest management activities? The hypothesis that was tested was that the titica vine has no preference for the species of tree is uses as a host and does not present a defined pattern of spatial distribution. This hypothesis is justified based on the vast number of species that serve as support for the titica vine and on observations by extractivists that there does not appear to be a pattern in its spatial distribution (Ferreira and Bentes-Gama, 2005; Bentes-Gama et al., 2010). Therefore, this study was conducted with the objective of analyzing the ecological aspects of the titica vine in an area subjected to forest management.

2. MATERIAL AND METHODS

2.1. Study area

This study was conducted in an area of forest management (AMF) that is administered by the mixed cooperative of the FLONA Tapajós (COOMFLONA), in the FLONA Tapajós at km 117 (03º 20’ 57.54” S and 55º 01’ 50.62” W) along the BR 163 highway (Santarém-Cuiabá). The FLONA Tapajós is a federal sustainable use Conservation Unit (CU) located in the western region of the state of Pará and which contains all or part of the municipalities of Belterra, Rurópolis and Placas, with an area of approximately 527,000 hectares and contains 25 communities (ICMBio, 2016).

The climate in the FLONA Tapajós is classified as Am in the Köppen Geiger system, which is tropical humid with annual temperature variation of less than 5ºC, and average annual temperature of 25.5ºC, average air relative humidity of 88% and average annual rainfall of 1,820 mm (IBAMA, 2004). The predominant soil is a yellow dystrophic Oxisol with widely varying textures including some large areas with very sandy soil, generally very deep, acidic, and friable (Espírito Santo et al., 2005). The vegetation is classified as dense ombrophilous forest with predominance of large trees and an abundance of woody vines, palms, and epiphytes (IBGE, 2012).

2.2. Data collection

Data were collected in two work units (UTs; numbers 3 and 15), of the Annual Production Unit (UPA 11), which was managed in 2016. At each locale, leaf and fruit samples from the titica vine were collected, and exsiccatae were made and these were deposited in the herbarium of the Federal Rural University of Amazonia (UFRA).

The UT 3 has a size of 1,000 m x 1,000 m with clay soil and had 2,204.37 m³ of wood harvested. The UT 15 has a size of 1,000 m x 1,250 m with sandy soil and had 1,578.50 m³ of wood harvested. Each UT is divided into quadrants of 250 m x 250 m, and these are the sampling units.

For the inventory of host trees of the titica vine we sampled 14 quadrants in UT 3 (87.5 ha) and 19 quadrants in UT 15 (118.75 ha), totaling 33 quadrants which covered 206.25 ha of sampled area.

The parameters recorded in the inventory of trees that are hosts to titica vine and that had diameter at breast height (DBH) ≥ 10 cm at 1.3 m above the soil surface were DBH, total height (Ht), regional name and geographic coordinates (latitude and longitude).

Aerial roots were quantified in two groups: mature with brown bark and that did not break easily, and immature with green bark and that were easily broken. Immature roots are generally not collected for artisan crafts because of a lack of rigidness, so these roots were not collected in this study. Mature roots were collected for each host and weighed (kg) using a digital hook balance, and this was done in the forest so that the mass of the roots was not influenced by loss of humidity.

2.3. Characterization of host species and production of titica vine

Trees hosting titica vine were identified by regional name in the field by an experienced parabotanist that also participates in the annual inventory done by COOMFLONA. The taxonomic classification system adopted was the *Angiosperm Phylogeny Group* - APG IV (APG, 2016). The authors of the species were confirmed by consulting the site Flora do Brasil (JBRJ, 2019). All host trees were counted and grouped according to their botanical families.

In order to test whether titica vine displays a preference for a specific range of host tree diameters and heights, the density of individuals in different classes of diameter and height were used to establish a relationship. (Bentes-Gama et al., 2010).

To determine if diameter and height of host trees influence the production of titica vine, 15 trees of different sizes of height and diameter were selected in each DBH and height class, and these were classified in small, medium, and large size classes (Table 1).

2.4. Spatial distribution

The spatial distribution of titica vine was analyzed by applying the Ripley K function, an efficient statistical tool in population ecology studies that simultaneously takes into account different scales and distances, and also includes the isotropic border principle (Ripley, 1981; Silva, 2015).

By conducting 99 Monte Carlo simulations the confidence envelopes were defined with a probability of 99%, and this process indicates the acceptance of the hypothesis of a random spatial pattern. The extreme limits of the envelopes are represented by the

Table 1 – Size classes of host trees selected for the calculation of the ratio between the dendrometric variables and biomass production of *Heteropsis* spp. Kunth (titica vine), Tapajós, National Forest, Pará.
Tabela 1 – *Classes de tamanho das árvores hospedeiras selecionadas para fazer a relação das variáveis dendrométricas com a produção de massa de Heteropsis spp. Kunth (cipó titica), Floresta Nacional do Tapajós, Pará.*

Size	DBH (cm)	Total height (m)
Small	10 cm ≤ DBH< 40 cm	5 m ≤ Ht < 15 m
Medium	40 cm ≤ DBH< 70 cm	15 m ≤ Ht < 25 m
Large	DBH≥ 70 cm	Ht ≥ 25 m

amplitude of the K values that result from simulations for each distance (S). In order to simplify the analysis, the K values were transformed into L^ (S), in which the axes of the abscissas correspond to the distances, and the ordinates the transformed values of the function K (Ripley, 1979).

The null hypothesis of the Ripley K function is that of Completely Random Spatial (CRS) distribution. In the case that this hypothesis is refuted then there are two options: aggregation or uniformity, when the values fall outside of the limit of the envelopes. The limits of the confidence envelope are identified by the pointed lines, with one positive and the other negative. The K value is identified by the continuous line, and when it falls above the upper line of the confidence envelope this indicates an aggregated distribution; when it is in the interior of the envelope this signifies a random pattern, and when it is below the lower line this indicates a uniform distribution (Vieira, 2015).

2.5. Data analysis

The data were compiled using the program Excel for Windows 2013, and statistical analyses were done using R version 3.1.2 (R Development Core Team, 2014), with the univariate K function estimated using the *Splancs* package (Rowlingson and Diggle, 2014).

3. RESULTS

3.1. Characterization of host species and production of titica vine

The species of the genus *Heteropsis* identified in the study area, popularly denominated as titica vine, were *Heteropsis flexuosa* (Kunth) G.S.Buting and *Heteropsis steyermarkii* G.S.Buting. Exsiccates of these species are deposited in the UFRA herbarium under numbers 3,284 and 3,285, respectively.

A total of 337 trees hosting the titica vine were identified and measured, with a density of 0.2 to 3.8 trees.ha^{-1} (average of 1.65 trees.ha^{-1}), distributed in 88 species belonging to 35 families.

The botanical families that were most prevalent as hosts for the titica vine were Fabaceae, Lecythidaceae, Sapotaceae, Burseraceae, Lauraceae and Moraceae, corresponding to 73% of the total.

The host species that had the greatest quantity (kg) of mature roots of titica vine were *Pouteria cladantha* Sandwith (3,368 kg.ha^{-1}), *Chamaecrista scleroxylon* (Ducke) H.S.Irwin & Barneby (3,354 kg.ha^{-1}), *Eschweilera* sp. Mart. ex DC. (3,244 kg.ha^{-1}) and *Lecythis lurida* (Miers) S.A.Mori (3,087 kg.ha^{-1}).

Titica vine was found on trees that ranged in diameter from 10.19 cm to 189.39 cm. However, as shown in Figure 1, smaller diameter trees (DBH < 30 cm) host more titica vines than do larger diameter trees (DBH ≥ 65 cm).

With respect to host tree height and titica vine presence, there was a relationship with trees between 7 m to 35 m. Figure 2 shows that trees between 10 m ≤ Ht < 15 m host more titica vines when compared to trees with Ht ≥ 25 m.

Figure 3 shows that larger trees (DBH ≥ 70 cm and Ht ≥ 25 m) are those that have a greater quantity of titica vine roots (kg) when compared to smaller trees (DBH ≥ 10 cm and Ht ≥ 5 m).

The sampled titica vine in this study had a total of 585 roots.ha^{-1}, and average production of 2.1 kg.ha^{-1} titica vine with bark. After loss of humidity and removal of the bark production declined to 0.6 kg.ha^{-1} with respect to the mass of mature roots that were collected.

3.2. Spatial distribution

In Figure 4 the results for the analysis of spatial distribution are shown for the two sampled production

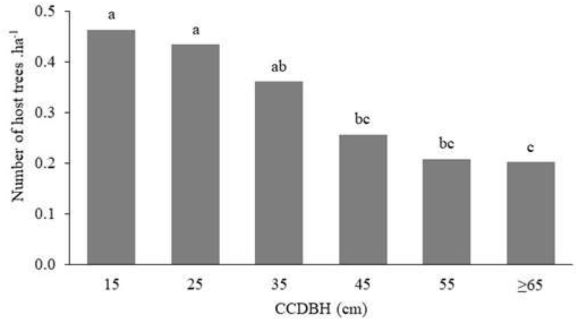

Figure 1 – Density of *Heteropsis* spp. Kunth (titica vine) host trees by DBH Class Center (CCDBH), Tapajós National Forest, Pará. Averages followed by the same letter are not different according to the Kruskal-Wallis test at 95% probability (*p-value* = 9.9488 x 10^{-8}).

Figura 1 – *Densidade de árvores hospedeiras de Heteropsis spp. Kunth (cipó titica) por Centro de Classe de DAP (CCDAP), Floresta Nacional do Tapajós, Pará. Médias seguidas pela mesma letra não diferem entre si, de acordo com o Teste de Kruskal-Wallis a 95% de probabilidade (p-valor = 9,9488 x 10^{-8}).*

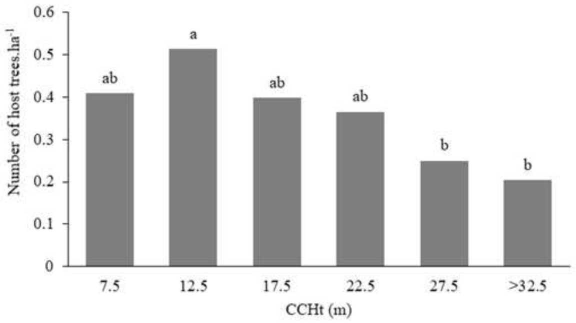

Figure 2 – Density of *Heteropsis* spp. Kunth (titica vine) host trees by Height Class Center (CCHt), Tapajós National Forest, Pará. Averages followed by the same letter are not different according to the Kruskal-Wallis test at 95% probability (*p - value* = 0.0059).

***Figura 2** – Densidade de árvores hospedeiras de Heteropsis spp. Kunth (cipó titica) por Centro de Classe de Altura (CCHt), Floresta Nacional do Tapajós, Pará. Médias seguidas pela mesma letra não diferem entre si, de acordo com o Teste de Kruskal-Wallis a 95% de probabilidade (p-valor = 0,0059).*

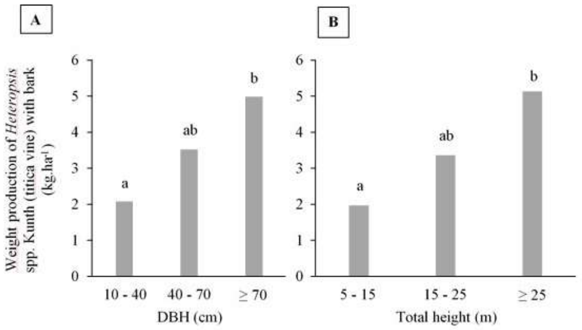

Figure 3 – Ratio of biomass production of *Heteropsis* spp. Kunth (titica vine) with bark (kg.ha^{-1}), with host tree size, taking into account DBH and total height, Tapajós National Forest, Pará. A: Averages followed by the same letter are not different according to the Tukey Test at 95% probability (*p-value* = <0.01). B: Averages followed by the same letter are not different according to the Kruskal-Wallis test at 95% probability *(p-value* = <0.0001).

***Figura 3** – Relação da produção de massa de Heteropsis spp. Kunth (cipó titica) com casca (kg.ha-1), com porte das árvores hospedeiras, levando em consideração DAP e altura total, Floresta Nacional do Tapajós, Pará. Em que A: Médias seguidas pela mesma letra não diferem entre si, de acordo com o Teste Tukey a 95% de probabilidade (p-valor = < 0,01). B: Médias seguidas pela mesma letra não diferem entre si, de acordo com o Teste de Kruskal-Wallis a 95% de probabilidade (p-valor = < 0,0001).*

units. The first graph shows the results for UT 3 wherein titica vine presented an aggregated spatial distribution although at points 150 m and 450 m there is a small tendency toward randomness. In UT 15 the spatial distribution was aggregated up to 350 m, and from this point onward it was random.

The soil at UT 3 was clayey, but at UT 15 it was sandy, therefore, further studies including soil analyses are needed in order to determine if this variable influences the distribution of the titica vine.

The aggregate distribution dominated the spatial arrangement of titica vine at these research sites, and the mode of seed dispersion is indicative of this behavior.

4. DISCUSSION

4.1. Characterization of host species and production of titica vine

The species *Heteropsis flexuosa* (Kunth) G.S.Buting and *Heteropsis steyermarkii* G.S.Buting are among the most common in the Amazon of the genus *Heteropsis*, however, *H. flexuosa* has a tendency to occupy clay soils while *H. steyermarkii* is more prevalent on sandy soils (Morais, 2008).

In the sites evaluated in the present study there was a low occurrence of titica vine when compared to other sites where similar inventories have been done (Hoffman, 1997; Plowden et al., 2003; Bentes-Gamaet al., 2013; Klauberg et al., 2016). For large areas, similar to those in the present study, there is a reduction in the density of hosts of titica vine, as observed in the Jaú National Park in the state of Amazonas where only 1 to 5 trees.ha^{-1} that are hosts of titica vine were found (Durigan, 1998).

With respect to the botanical families that are most represented for trees that are hosts of titica vine, Canalez (2009) affirms that the Araceae family in terra *firme* forest is most frequently represented by tree species in the families Myristicaceae, Lecytidaceae and Sapatoceae. However, the last two families mentioned above are predominant in the sites of the present study. The family Lecytidaceae was the one that had the largest number of hosts for *Heteropsis* in the Ducke Reserve in the State of Amazonas (Morais, 2008).

In the present study the relationship between the host species that had the greatest number of productive titica vines was highlighted because commercialization of raw material depends on the quantity of fiber that is collected (Ferreira and Bentes-Gama, 2005). In general, studies have reported this relationship as the percentage of association of this hemiepiphyte

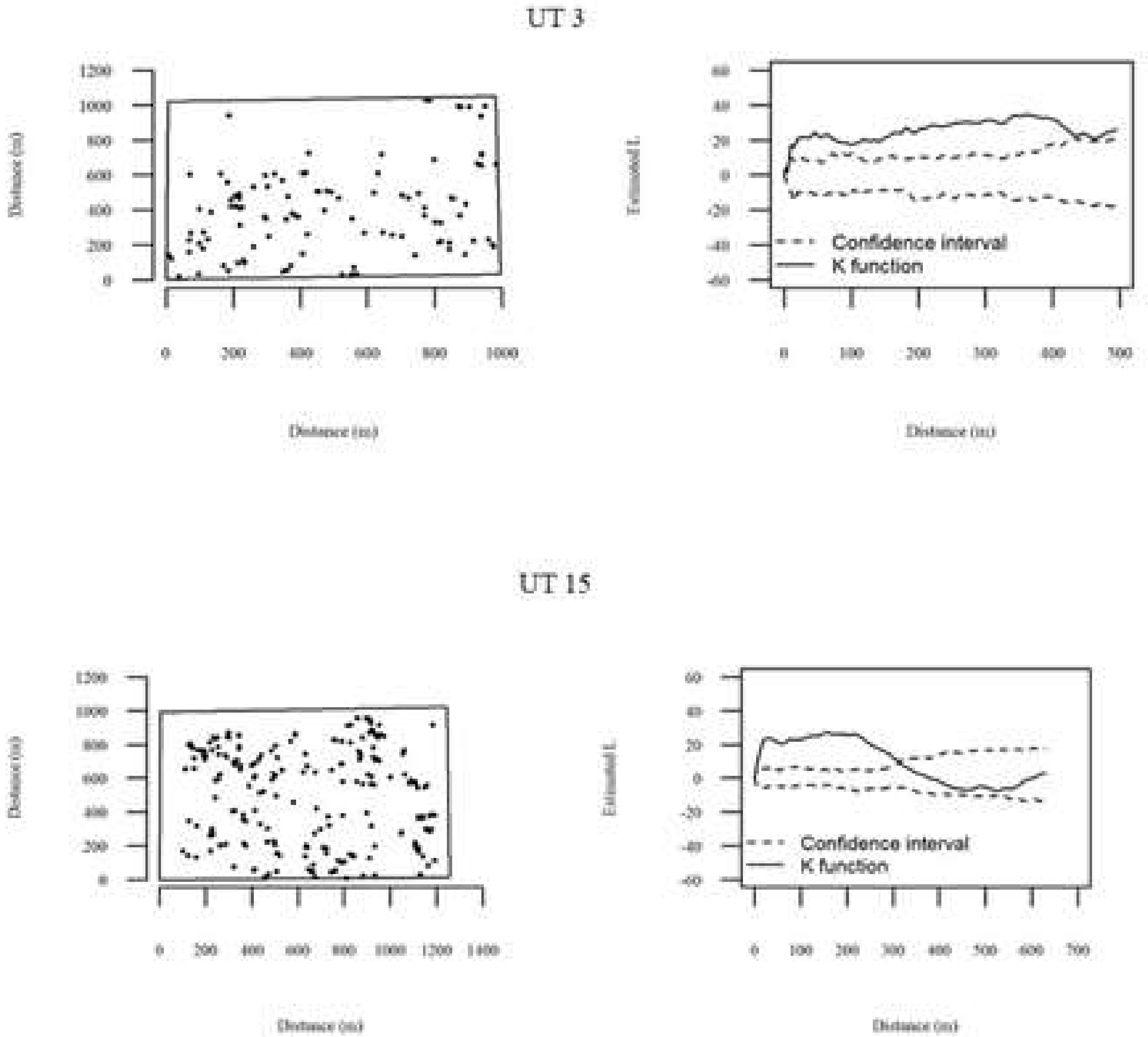

Figure 4 – Spatial distribution pattern of *Heteropsis* spp. Kunth (titica vine) in the Work Units (UT 3 and 15) of UPA 11, Tapajós National Forest, Pará.
Figura 4 *– Padrão de distribuição espacial de Heteropsis spp. Kunth (cipó titica) nas Unidades de Trabalho (UT 3 e 15) da UPA 11, Floresta Nacional do Tapajós, Pará.*

with the host tree. In a study done by Bentes-Gama et al. (2010), the most frequent host species of titica vine were *Eschweilera coriacea* (DC.) S.A.Mori, *Protium* sp. Burm f., *Licania membranacea* Sagot ex Laness., *Annona exsucca* DC. e *Pouteria bilocularis* (H.K.A.Winkl.) Baehni, because these were the most frequent species found at this site (Vieira et al., 2002).

For the relationship between the titica vine and tree diameter, Morais (2008), found a positive relationship between individuals of the genus *Heteropsis* and host tree diameter; however, this author also observed that in spite of the fact that *Heteropsis* spp. colonized trees from all diameter classes, they were more frequent on trees with DBH > 30 cm. Similar results were reported by Knab-Vispo et al. (2003), but in contrast Plowden et al. (2003), reported that most individuals were associated with host trees of DBH < 10 cm.

The analysis of host tree height showed that the development of titica vine is facilitated on trees of intermediate height (Knab-Vispo et al., 2003; Bentes-

Gama et al., 2013). For example, five species of the genus *Heteropsis* were shown to occupy principally the understorey (0 - 5 m height) and below the canopy (5 - 10 m height) in a *terra firme* forest (Morais, 2008).

The production of titica vine was greatest on trees with a larger surface area for fixation. Bálcázar-Vargas et al. (2015) affirm that the height of the host species is a good indicator for growth of feeder roots of adult individuals of titica vine and that the higher it climbs in the tree the greater the possibility of survival, number of leaves, branches, and roots.

Similar results for titica vine production to those of the present study were related by Plowden et al. (2003) in their study done in the eastern Brazilian Amazon wherein they reported 544 roots.ha^{-1}. Klauberg (2014), in spite of having observed a high density of titica vine in Paragominas-PA, found results that were inferior to those of the present study reporting only 62 roots.ha^{-1}.

4.2. Spatial distribution

The spatial distribution of a forest population can be represented in three ways: random – when the position of an individual is not influenced by other individuals, and therefore it is possible to find any individual at any point in the area; aggregated – individuals tend to occur in groups, therefore their presence is influenced by other individuals in the area; and regular – distance is equivalent between individuals and the presence of one precludes the presence of the other (Odum, 1986; Vieira, 2015).

The differences in spatial distribution observed in the two areas possibly occurred due to a greater number of host trees in UT 15 (n = 225), and that this UT has a larger area than UT 3. Another factor that could have cause the titica vine to display two types of spatial distribution is that it shows no preference for a specific host species and that there is a large range of host species with distinct forms and distributions in the area (Knab-Vispo et al., 2003).

Silva (2015), affirm that the pattern of spatial distribution of a population can be affected by factors that are intrinsic to a species, such as aspects of reproduction, and social and coactive habits, and also extrinsic factors such as external environmental variables of wind, light intensity and soil conditions. According to Antonini and Nunes-Freitas (2004), species whose seed is dispersed by animals are generally present in an aggregated form in forests, and in this case the titica vine is dispersed by birds and monkeys (Morais, 2008).

Collectors that extract titica vine in the state of Amapá relate that there is no pattern of spatial distribution because in some areas individuals are widely dispersed, while in others they are highly concentrated (Ferreira and Bentes-Gama, 2005). This information comes from empirical knowledge of traditional populations and has great value as a complement to scientific knowledge, however more ecological studies are needed on the spatial distribution of Heteropsis spp in order to aid in management activities.

5. CONCLUSION

The hypothesis that Heteropsis spp. (titica vine) does not have a preference for specific species of host trees was affirmed, however the frequency of titica vine is greater on smaller trees, and vine production is greater for taller trees with larger diameter. Furthermore, this study showed that the spatial distribution of titica vine tends to be aggregated.

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