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Article

Weed Vegetation Structure in an Area of Organic Acerola Cultivation, Parnaíba, Piauí, Brazil

Estrutura da Vegetação de Plantas Daninhas no Cultivo Orgânico de Acerola, Parnaíba-PI

SOUSA, P.H.S.[1]
MENDES, M.R.A.[1]*
VAL, A.D.B.[1]
TEIXEIRA, M.C.S.A.[1]

ABSTRACT - This study aimed to identify and quantify the weed species in an area of organic acerola cultivation in the Distrito de Irrigação dos Tabuleiros Litorâneos do Piauí (DITALPI) in Parnaíba, Piauí, Brazil. Phytosociological sampling was completed in the rainy season, before the farmers adopted management techniques for the plants. Thirty plots of 0.25 m^2 were sampled. The plots were located between crop rows, which consisted of herbaceous-subshrub plants. The absolute and relative covers and the absolute and relative frequencies of each species were calculated based on the occurrence and cover of each species. In total, 25 species comprising 13 families were registered, among which the Poaceae family that presented the largest number of species. *Commelina benghalensis* occurred the most frequently overall. Shannon's diversity index (H') and evenness were calculated as 2.30 nats ind^{-1} and 0.69, respectively. Five species accounted for 79.33% of absolute cover at DITALPI. The species were distributed heterogeneously within the field, and *Commelina benghalensis*, *Urochloa plantaginea*, *Panicum maximum*, *Amaranthus spinosus*, *Cynodon* sp., and *Cyperus aggregatus* were the species most likely to infest the acerola crop. As DITALPI is an area of organic cultivation, understanding these species is essential to help farmers select the best form of control.

Keywords: phytosociological survey, *Malpighia emarginata*, plot sampling method, organic agriculture.

*RESUMO - O objetivo deste estudo foi identificar e quantificar as espécies daninhas em uma área de cultivo de acerola orgânica no Distrito de Irrigação dos Tabuleiros Litorâneos (DITALPI), município de Parnaíba-PI. A amostragem fitossociológica ocorreu no pico da estação chuvosa, antes da adoção das técnicas de manejo dessas plantas pelos agricultores. Foram amostradas 30 parcelas de 0,25 m^2, instaladas nas entrelinhas da cultura, que incluíram as plantas do estrato herbáceo-subarbustivo. Foram calculadas, com base na ocorrência e cobertura de cada espécie, a cobertura absoluta e relativa e a frequência absoluta e relativa. Ao final do trabalho, registraram-se 25 espécies, distribuídas em 13 famílias, entre as quais Poaceae foi a mais significativa. **Commelina benghalensis** destacou-se com maior frequência. O índice de diversidade de Shannon (H') e a equabilidade representaram, respectivamente, 2,30 nats ind^{-1} e 0,69. Cinco espécies responderam por 79,33% da cobertura absoluta no DITALPI. As espécies apresentaram padrão heterogêneo na distribuição no campo, e as de maior poder de infestação na cultura da acerola foram **Commelina benghalensis**, **Urochloa plantaginea**, **Panicum maximum**, **Amaranthus spinosus**, **Cynodon** sp. e **Cyperus aggregatus**. Por se tratar de uma área de cultivo orgânico, o conhecimento destas espécies é essencial para a escolha da melhor forma de controle por parte dos agricultores.*

Palavras-chave: levantamento fitossociológico, *Malpighia emarginata*, método de parcelas, agricultura orgânica.

*** Corresponding author:**
<maurarejane@phb.uespi.br>

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[1] Universidade Estadual do Piauí, Parnaíba-PI, Brasil.

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INTRODUCTION

The occurrence of uncultivated species is common in agricultural areas, and these species compete for resources with crops (Brighenti and Oliveira, 2011). The literature refers to these species as “invasive” plants or “weeds.” However, according to Pitelli (2015), in ecological terms, they may be referred to as a “weed community”, which is defined as a set of weed populations in areas of interest to humans. Some of these species may be advantageous for crops, as they improve soil quality by assisting in nutrient cycling and by depositing organic matter (Gliessman, 2005). Proper management of these uncultivated species has been the subject of discussion, and successful control is essential to increase the production and sustainability of the system (Silva et al., 2006).

In organic crops weed management, no pesticides, chemical fertilizers, or other toxic or synthetic substances are used, thereby preventing food and environmental contamination (Araújo and Carvalho, 2014). This type of production system is gaining increasing prominence in food production and supply and preservation of natural resources, as it minimizes soil degradation and mitigates declines in insect pollinator populations.

As of the late 1980s, the Brazilian state of Piauí has had a pole for irrigated agriculture. Although not exclusively organic, its main crop, acerola (*Malpighia emarginata* DC.), is organically cultivated. The state is home to the Distrito de Irrigação dos Tabuleiros Litorâneos do Piauí (DITALPI), a Federal Government project, which was granted an initial area of 2.500 ha for development (Brito et al., 2017). The second stage of the project is currently in progress and involves expanding the area used for irrigated agricultural production (Brito et al., 2017).

Acerola (*Malpighia emarginata* DC.) is a shrub native to the Caribbean Islands, Central America, and northern South America, which belongs to the Malpighiaceae family. Brazil is one of the few countries that cultivates the crop commercially (Ritzinger and Ritzinger, 2011). In commercial plantations, plant spacing depends on the management system adopted (mechanized or not), the shape of the cultivar (oblate or spheroid), and the fertility of the soil, and most spacings vary between 4.0 × 3.0 m and 6.0 × 4.0 m (Ritzinger and Ritzinger, 2011). Weeds emerge in the spaces between plants on the same row as well as between the rows.

A floristic survey is an initial step that can be taken to understand the vegetation in a certain area (Martins, 1990). According to Oliveira and Freitas (2008), the first steps in proper field management involve weed identification and knowledge of the vegetation structure.

The analysis of vegetation structure, also known as phytosociology, can be conceptualized as a method of recognizing and defining plant communities, and it is particularly concerned with the structural characteristics, classification, and distribution of these communities (Felfili and Rezende, 2003). Information provided by phytosociological parameters is vital when deciding upon a management strategy. In agricultural environments where conditions for infestation vary greatly, ecological knowledge of these plants can be extremely important (Oliveira and Freitas, 2008) for successful production. This is because variables such as leaf characteristics, form of reproduction, and phonological cycle are crucial in the planning and implementation of management strategies.

Due to the fact that weed flora occur in commercial crop plantations and can cause yield losses in production due to competition for resources, knowing which species occur and how they are organized in communities allows farmers to successfully choose the most appropriate management system. When the ecological characteristics of a species are known, it is possible to choose the ideal form of management and the ideal period of control. Thus, this study aimed to identify the weed species and describe the vegetation structure in an area of organic acerola cultivation in the municipality of Parnaíba, Piauí, Brazil.

MATERIALS AND METHODS

This study was conducted in a lot used for commercial cultivation of organic acerola (*Malpighia emarginata* D.C.) at DITALPI in Parnaíba, Piauí, Brazil. The lot measured 0.5 ha in area, with within-row plant spacing of 4 m and between-row spacing of 5 m. The municipality is located in the far north of Piauí, between the geographic coordinates of 02º54'17"S and 41º46'36"W, at an altitude of 5 m (Aguiar and Gomes, 2004). The region is characterized as having an average annual precipitation of 1,200 mm, is situated in the maritime equatorial region, and experiences maximum and minimum temperatures of 32º and 20º, respectively.

Vegetation from the herbaceous and subshrub habits was sampled at the peak of the rainy season (April 2017), before farmers adopted weed management techniques. The sample units were plots of 0.25 m^2 (0.5 × 0.5 m). Initially, the spaces between crop rows were stratified (beginning, middle, and end), and two samples between each row were subsequently selected, giving a total of 30 sample units.

The respective cover-abundance for each species was estimated using the Braun-Blanquet and Domin scale (Mueller-Dombois and Ellenberg, 2002). This entailed using five scales which expressed the degree of the species' presence and absence in the classes. The Braun-Blanquet and Domin scale is a procedure that estimates the visual cover of vegetation. Cover is defined as the perpendicular projection of the aerial parts of a particular individual in the soil, and it is estimated as a percentage ranging from 0% to 100%.

The plants in the sample were collected and initially identified by consulting the available specialized literature, and samples were then compared with previously collected specimens. Finally, taxonomy specialists made and/or confirmed the identifications. The species were classified into families based on the Angiosperm Phylogeny Group IV system (2016). Scientific names and synonyms were verified and corrected the according to the MOBOT virtual database, available at Tropicos (2019).

Based on the occurrence and cover of each species in the sample units, the following phytosociological parameters were calculated for each species according to Kent and Coker (1992) and adapted by Munhoz and Felfili (2006): absolute cover (CA), relative cover (CR), absolute frequency (FA), and relative frequency (FR). To determine these parameters, the following equations were used:

$$FAi = \left(\frac{ni}{n}\right) x\ 100$$

$$FRi = \left(\frac{FAi}{\sum FAi}\right) x\ 100$$

$$CAi = \sum PiA$$

$$CRi = \left(\frac{CAi}{\sum CAi}\right) x\ 100$$

where n_i = number of plots where species i occurred; n = total number of sample units; FAi = absolute frequency of species i; ΣFAi = sum of the absolute frequencies (FAs) of all species in the sample; ΣPiA = sum of the projection of species i in all sample units; and ΣCAi = sum of the covers of all species in the sample.

Shannon-Wiener diversity index at log base e (H') was used to assess species diversity, and Pielou's evenness index (J') (Kent and Coker, 1992) was also calculated, which applies the species' cover values as a measure of abundance.

A free ordination tool known non-metric multidimensional scaling (NMDS) was applied based on Bray-Curtis dissimilarity, and PC-ORD version 6.0 was used (Mccune and Mefford, 2011). According to Peck (2010), NMDS may be used to search for redundant patterns within almost all types of databases. In this study, the analysis was conducted using quantitative matrix.

RESULTS AND DISCUSSION

A total of 25 species were sampled, which were distributed across 22 genera and 13 families (Table 1). The number of species reported in this study was higher than those recorded in several studies conducted on other crops – organic or not – such as Moura Filho et al. (2015), Santos et al. (2015), and Sarmento et al. (2015), which registered 13, 16, and 12 to 17 species, respectively. Costa et al. (2014) reported fewer uncultivated species in winter crops under chemical

Table 1 - Species sampled at DITALPI, in the municipality of Parnaíba, Piauí, Brazil, in alphabetical order by family. Absolute Cover (CA), Relative Cover (CR), Absolute Frequency (FA), and Relative Frequency (FR) identified in an area of organic acerola cultivation

Family/Species	FA	FR (%)	CA	CR (%)
AMARANTHACEAE				
Alternanthera tenella Colla	10	1.82	0.65	1.65
Amaranthus spinosus L.	63.3	11.52	4.5	10.75
ASTERACEAE				
Emilia sonchifolia (L.) DC.	20	3.64	0.43	1.27
COMMELINACEAE				
Commelina benghalensis L.	93.33	17	8.67	20.72
CUCURBITACEAE				
Momordia charantia L.	3.33	0.61	0.1	2.39
CYPERACEAE				
Cyperus aggregatus (Willd.) Endl.	43.33	7.88	1.81	4.32
Cyperus chalaranthus J. Presl & C. Presl	3.33	0.61	0.03	0.07
Cyperus compressus L.	3.33	0.6	0.05	0.12
Cyperus rotundus L.	3.33	0.6	0.8	1.91
Kyllinga squamulata Vahl	6.67	1.21	0.15	0.36
EUPHORBIACEAE				
Chamaesyce hirta (L.) Millsp.	20	3.64	0.39	0.93
Croton hirtus L'Hér	3.33	0.61	0.05	0.12
FABACEAE				
Vígna sp.	6.67	1.21	0.12	0.29
LOGANIACEAE				
Spigelia anthelmia L	3.33	0.6	0.05	0.12
MALVACEAE				
Sida jussieana DC.	6.67	1.21	0.09	0.22
POACEAE				
Cenchrus echinatus L.	10	1.82	0.28	0.67
Cynodon sp.	3.33	0.61	0.15	0.36
Dactyloctenium aegyptium (L.) Willd	13.33	2.42	0.21	0.5
Digitaria sp.	33.33	6.06	3.42	8.17
Panicum maximum Jacq.	56.7	10.3	5.88	14.1
Paspulum maritimum Trind.	10	1.82	1.5	3.58
Urochloa plantaginea (Link) R. D. Webster	70	12.1	10.73	25.6
TALINACEAE				
Talinum triangulare (Jacq.) Wild	3.33	0.6	0.2	0.48
PHYLLANTHACEAE				
Phyllanthus niruri L.	53.33	9.7	1.01	2.41
TURNERACEAE				
Turnera subulata Sm.	3.33	0.6	0.2	0.48

management compared to crops under mechanical management (oat IPR 126, crambe FMS Brilhante, forage turnip common cultivar, and wheat BRS Tarumã) in Paraná. However, Batista et al. (2015) studied phytosociology in bean cultivars of different shapes (plants with raised or semi-prostrate stems) in northern Minas Gerais and observed that cultivar shape can also influence the number of weeds. The aforementioned authors reported a smaller number of weed species in the cultivar with a semi-prostrate stem, which is due to soil space closure caused by the crop's form of growth and the consequent decrease in available sunlight for weed species.

The present study found that the Poaceae and Cyperaceae families were the most abundant, with seven and five species, respectively. Their representatives contributed to the largest number of monocotyledons in the area (13 species) and accounted for 59.76% of the total relative cover.

In general, these families have been well-represented in studies investigating weeds in various crops (Oliveira and Freitas, 2008; Santos et al., 2017).

The species with the highest relative cover values were *Urochloa plantaginea*, *Commelina benghalensis*, *Cynodon* sp., *Panicum maximum*, and *Amaranthus spinosus* (Table 1). *Urochloa plantaginea* is considered one of the most damaging invasive species in the Poaceae family due to its efficient environmental occupation and easy proliferation and growth, and its presence can cause agricultural damage due to competition with crops (Batista et al., 2016). The species has already been cited by Costa et al. (2014) as one of the most common grasses in south and southeastern Brazil.

Commelina benghalensis is remarkably resistant to glyphosate use in chemical management, possibly due to the unregulated use of herbicides, which leads to the selection of more tolerant plants over time. Its resistance may also be due to the low efficiency of the mechanical methods used for its control, and to its rapid reproduction, which may be vegetative or by seeds (Concenço et al., 2013; Santos et al., 2001). There have been reports in the literature of the species in the states of Bahia (Silva et al., 2006), Rio Grande do Norte (Moura Filho et al., 2015), Minas Gerais (Sarmento et al., 2015), Goiás (Santos et al., 2017), Rio de Janeiro (Oliveira and Freitas, 2008), and Paraná (Costa et al., 2014), among others. Therefore, it is commonly reported in studies carried out in different regions of Brazil.

Species such as *Amaranthus spinosus* and *Panicum maximum* also achieved significant cover values within the studied area. The *Amaranthus* genus is difficult to manage because of the large number of seeds it produces and its longevity and viability in the soil, in addition to its quick development and short life cycle (Carvalho, 2013; Batista et al., 2016). The presence of *Panicum maximum* in arable areas can incur management costs given the difficulty of eliminating the propagules of the species that remain in the soil and can resist burning, allowing successive invasion cycles (Oliveira and Freitas, 2008). The species is also responsible for extracting large amounts of nutrients from the soil, making it an important competitor for crops.

In general, the same species accounted for the highest frequencies of occurrence in the study area. *Commelina benghalensis* had the highest frequency (Table 1), and *Cyperus aggregatus* had the fifth highest frequency (7.88%). The *Cyperus* genus was also significant in presenting the largest number of species (four in total). According to Carvalho (2013), species of this genus can reproduce both asexually and sexually, which makes them difficult to manage, especially when it comes to asexual reproduction, since the propagules remain in the soil even after the aerial parts of the plants are removed. In areas with coffee plantations in Vitória da Conquista, Bahia, Silva et al. (2006) reported a high frequency of *Panicum maximum* and *Commelina benghalensis* plants in both full sunlight and in the shade.

Shannon's diversity index (H') and Pielou's evenness were calculated to be 2.30 nats ind^{-1} and 0.69, respectively. The values for H were similar to those reported in the literature by Concenço et al. (2013) and Mata et al. (2016) for corn and rice crops, respectively, and are considered average for Shannon's diversity index, which ranges from zero to five (Kent and Coker, 1992).

We observed heterogeneity in the distribution of some species within the area, such as *Commelina benghalensis*, *Amaranthus spinosus*, and *Cyperus aggregatus*. Other species were concentrated in specific regions of the plantation. We found species such as *Turnera subulata* and *Momordia charantia* only in the border zone, and some species of the *Cyperus* genus were only observed in the center of the plantation (*Cyperus chalaranthus*, *Cyperus compressus*, and *Cyperus rotundus*). The *Cyperus* genus is associated with humid areas (Gil and Bove, 2004), and it is possible that its distribution concentrated towards the center of the study area may be due to greater water availability in this region through the irrigation of acerola. This distribution of the species' occurrence and abundance determined plot distribution (Figure 1).

From an ecological point of view, and because of their successive character, the presence of weeds in the environment may bring benefits to the soil's structure, microorganisms, and biodiversity, in addition to helping decrease soil temperature and improve soil organic matter content through decomposition (Brighenti and Oliveira, 2011). Nevertheless, the negative impacts of weeds on crop production cannot be disregarded. According to Brighenti and Oliveira (2011), the greatest damage caused by these plants is in agriculture.

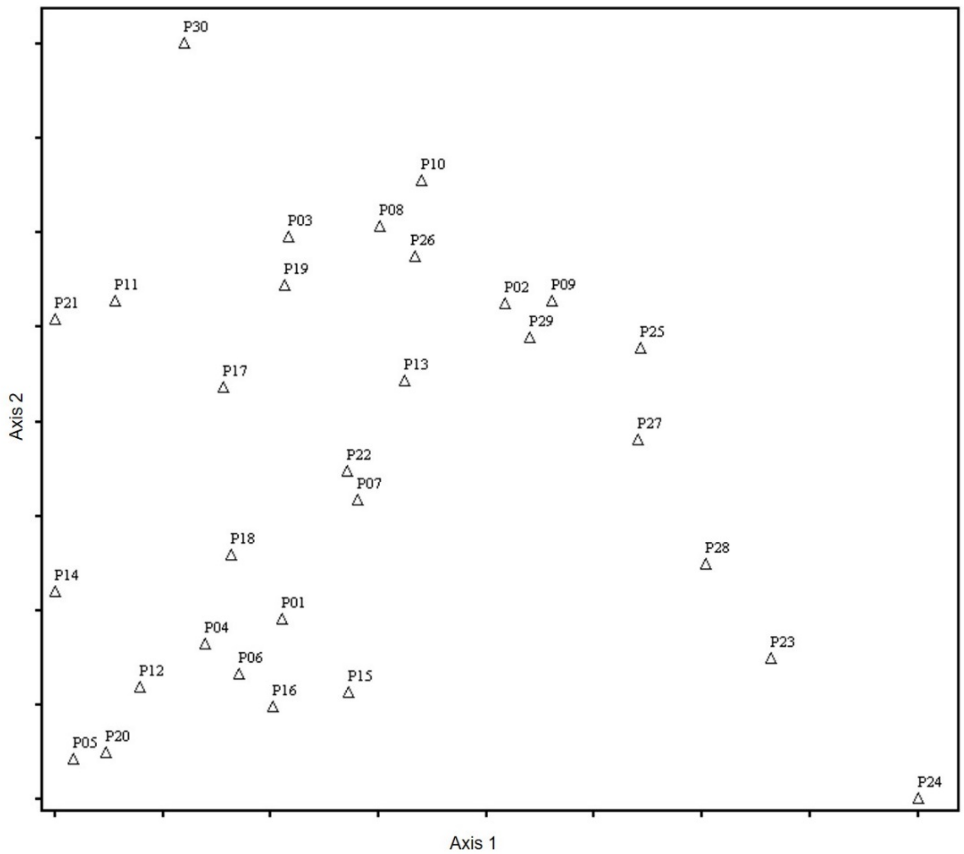

Figure 1 - Non-metric multidimensional scaling (NMDS) of the 30 plots (P) installed between rows of acerola shrubs in an area located in DITALPI, Parnaíba, Piauí, Brazil.

Weed control in acerola plantations may be carried out using manual, chemical, or mechanical methods (Ritzinger and Ritzinger, 2011). Regardless of the method chosen by the farmer, management is a very costly step in the production process. Although it is not possible to quantify the decline in acerola production due to the presence of these plants, even in the literature, the main problems caused by weeds come from the direct competition that they have with crops for soil resources and from their potential to act as hosts for pests and diseases. Both cases can interfere directly with fruit production or development.

Therefore, understanding the distribution patterns of weed species is important in informing the management strategies adopted by farmers, especially in areas with organic cultivation, where weed control is more complex because it does not involve the use of chemical pesticides, which is the most commonly employed method in commercial plantations. At DITALPI, the species with the high potential for infesting the acerola crop were *Commelina benghalensis*, *Urochloa plantaginea*, *Panicum maximum*, *Amaranthus spinosus*, *Cynodon* sp., and *Cyperus aggregatus*. All were efficient in environmental occupation, and some, like *Commelina benghalensis* and *Urochloa plantaginea*, have already been cited as herbicide-resistant. Knowledge of the autoecology of these species is essential to select the best forms of control, whether they are preventive, cultural, or mechanical.

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