Brazilian Journal of Biology®

ISSN 1519-6984 (Print)
ISSN 1678-4375 (Online)

Original Article

The monodominance of Acuri in Pantanal formations: allelochemical effects of its leaves and the presence of Acurizais

A monodominância do Acuri em formações do Pantanal: efeitos aleloquímicos de suas folhas e a presença de acurizais

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Abstract

The presence of monodominant vegetative formations almost exclusively composed of Acuri palm trees (*Attalea phalerata*) stands out in some regions of the Pantanal Sul-Mato-Grossense. These formations are generally associated with anthropic, edaphic and/or hydrological factors. However, little is known about the effect of allelopathy on the formation and maintenance of these areas. Herein, we investigated the chemical composition of *A. phalerata* aqueous leaf extract and the potential allelopathic effects on germination and growth of target *L. sativa*, *L. esculentum* and *S. obtusifolia* species. Thus, extracts at concentrations of 0, 2.5, 5, 10, 15, and 20% were used for germination and growth bioassays with a completely randomised design in a germination chamber and greenhouse. The results showed that the *A. phalerata* extracts negatively affected the germination speed index and mean germination time of the target species and positively affected seedling length under controlled conditions and were also stimulated in the greenhouse. Thus, the formation of Acurizals can be related to the presence of secondary metabolites in the leaves, in addition to other environmental factors.

Keywords: *Attalea phalerata*, allelopathy, secondary metabolites, phytohormones.

Resumo

No Pantanal Sul-Mato-Grossense se destaca, em determinadas regiões, a presença de formações vegetacionais monodominantes, compostas quase que exclusivamente por uma espécie de palmeira, o Acuri (*Attalea phalerata*). Normalmente estas formações estão associadas a fatores antrópicos, edáficos e/ou hidrológicos. Porém pouco se sabe sobre o efeito da alelopatia na formação e manutenção destas áreas. Desta maneira, objetivou-se estudar a composição química dos extratos aquosos das folhas de *A. phalerata* e seus possíveis efeitos alelopáticos na germinação e crescimento das espécies-alvo, alface, tomate e fedegoso. Para os bioensaios de germinação e crescimento, foram utilizados extratos nas concentrações de 0, 2,5, 5, 10, 15 e 20%, com delineamento inteiramente casualizado, em câmara de germinação e casa de vegetação. Os resultados demostraram que em condições controladas (câmara de germinação), os extratos de *A. phalerata* afetaram negativamente o índice de velocidade de germinação e o tempo médio de geminação das espécies-alvo e positivamente, o comprimento das plântulas, que também foram estimuladas em casa de vegetação, indicando a presença de fitormônios. Desta maneira, a formação de Acurizais pode estar relacionada à presença de metabolitos secundários nas folhas, além de outros fatores ambientais.

Palavras-chave: *Attalea phalerata*, alelopatia, metabólitos secundários, fitormônios.

1. Introduction

The Pantanal is a floodplain located in the extreme west of the state of Mato Grosso do Sul, in which seasonal changes associated with edaphic factors has resulted in a great heterogeneity of vegetation units which occupy different environments related to environmental conditions (Damasceno-Junior et al., 2021). This situation favors the permanence of many pioneer species due to their physiological and ecological strategies with high population density (Soares and Oliveira, 2009; Pott et al., 2011).

According to Soares and Oliveira (2009), there is a great diversity of monodominant formations in the region, being almost exclusively composed of one species and dominating large areas as a result of anthropic, edaphic and/or hydrological factors. Thus, the "*Acurizais*" stand

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Received: October 18, 2022 – Accepted: January 24, 2023

out among these formations composed of Acuri or Bacuri (*Attalea phalerata* Mart. ex Spreng.) pioneer palm trees, which occur in great abundance.

The palm tree is considered a key species because it retains part of the leaf petiole, offering different micro-habitats used by various plant and animal species (Santos et al., 2003), in addition to being an important source of resources for carpophagous communities, since it produces fruit throughout the year, especially in the dry season when the greatest scarcity of resources occurs (Reys et al., 2005). Acuri is also widely consumed by cattle (rich in crude protein - 10.5%) and is considered an invasive species in pastures (Lorenzi et al., 1996). This can occur after cutting native vegetation and fires, which facilitates the propagation of the species (Lorenzi et al., 1996; Rivaben et al., 2021).

A factor not yet correlated with its predominance are allelopathic relationships, which constitute important ecological processes that influence the composition, structure and dynamics of plant communities (Macias et al., 2003). Plants interfere in the development of other species in different ways through releasing secondary metabolites, reducing or eliminating competition for resources, or even inducing the growth of other plants in processes which involve alterations in photosynthetic mechanisms and/or alterations in specific enzymatic processes, among other forms of action (Fujii and Hiradate, 2007).

The type of interference of secondary metabolites depends on the target species, phenological phase or its concentration, in addition to environmental factors (Gobbo-Neto and Lopes, 2007). Resistance or tolerance to these substances is specific and linked to the phytotoxic potential of metabolites released into the environment, with less or more sensitive species. Lettuce (*Lactuca sativa* L.) and tomato (*Lycopersicum esculentum* Mill.) are known to be sensitive to the action of a variety of phytoconstituents, including phenolic and nitrogenous compounds, which together with their germination uniformity makes these species suitable for allelopathic evaluation through bioassays (Ferreira and Aquila, 2000). Another species with potential for use in tests is the herb popularly known as coffee senna (*Senna obtusifolia* (L.) Irwin & Barneby – Fabaceae), an invasive species of pastures and wastelands.

Considering that the *A. phalerata* palm is an important resource for traditional communities (Negrelle, 2015) and livestock management (Lorenzi et al., 1996) in the Pantanal, in addition to representatives of the Arecaceae family having constituents with allelopathic activity (Lewis and Zona, 2000), this study aimed to evaluate the phytotoxic potential of *Attalea phalerata* leaf aqueous extract and powder in target species by determining the classes of secondary metabolites present in order to assist in the understanding of the formation of Acurizals.

2. Methodological Procedures

2.1. Collection area

The *A. phalerata* leaves were randomly collected from 20 matrices (riparian forest) in March and April 2019, in Acurizais in the Pantanal of Miranda, located in the extreme south of the Pantanal region (Figure 1), Mato Grosso do Sul (MS). The material was packed in sterile polyethylene bags and transported to the Interdisciplinary Laboratory for Research in Environmental and Biodiversity Systems (LabPSAB), Universidade Anhanguera-Uniderp, in Campo Grande - MS, where an exsiccate was herborized and deposited in the institution's herbarium under number 7841.

2.2. Extract preparation

After cutting up the botanical material into fragments with pruning shears, it was dried at room temperature (27 ± 2 °C) and crushed in an industrial mill (1,725 rpm, 20 mesh). The 20% extract was obtained by adding 200 g L^{-1} of powder to 1,000 mL of distilled water and then extraction was performed in an ultrasound bath (Ultrasonic Cleaner®) for 60 minutes, followed by static maceration for 24 hours in a refrigerator. This procedure was repeated, and after 24 hours the extract was filtered through a glass funnel with cotton and stored in a volumetric flask (1 L), following procedures adapted from Oliveira et al. (2013).

The extract was initially subjected to pH (pH DM-20, Digimed), electrical conductivity (EC DM3, Digimed) and concentration of soluble solids analyses using a digital refractometer (RTD-45, Refractometer), with results expressed in degrees Brix corrected to 20 °C.

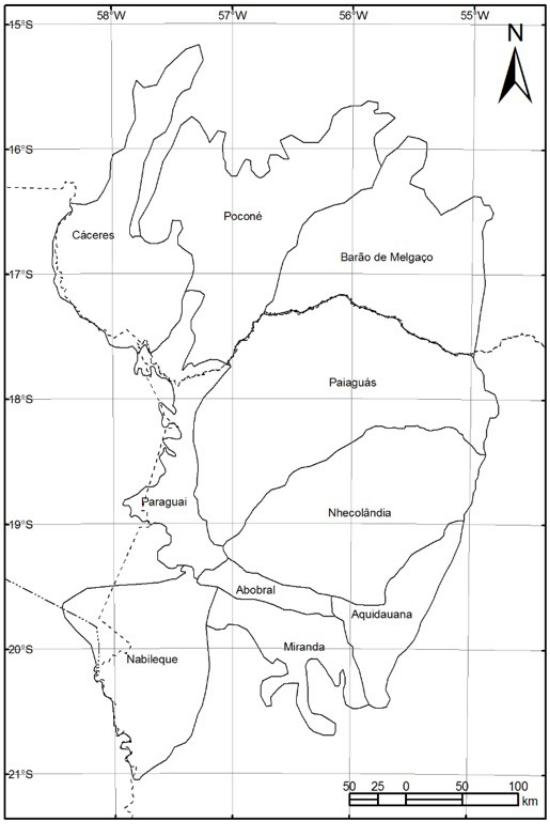

Figure 1. Delimitation of the sub-regions of the Brazilian Pantanal, Brazil.

2.3. Phytochemical prospection, chromatographic profiling and UV-visible spectrophotometric analysis

Analyses were performed in triplicate and wet through precipitation reactions and/or colour change (Table 1), with reading based on Fontoura et al. (2015). The results were classified as negative (-), partial (±), weakly positive (+), moderately moderate (++), moderate (+++) and high intensity (+++), with a score of 0, 10, 25, 50, 75 and 100%, respectively (score = sum of points obtained in the evaluation of precipitation and colour intensity). The exception to this procedure was the analysis of saponins (afrosymmetric index), which was determined using 1 g of dry plant powder with cold extraction, and 1 g with hot extraction, with energetic agitation in both (Schenkel et al., 2010).

The major constituents in the extract (200 g L^{-1}) was confirmed by Thin Layer Chromatography (TLC) on aluminum chromatoplates (Merck GF_{254}). Moreover, quercetin (flavonoid), gallic acid (phenol) and 1,2 benzopyrone (coumarin) were used as standards (Sigma®). Cholesterol was used as the steroid skeleton. All standards were used in 1% ethanolic solution.

The bands in the eluent systems were visualised by ultraviolet radiation (UV) at 254 and 365 nm (VILBER LOURMA®, VOO-6168). The specific revealers for each class were: flavonoids, NP-PEG, following the methodology described in Wagner and Bladt (2009), and steroids, SPF 15% ($FeCl_3 \cdot 6H_2O$) (Lin et al., 2009). The retention factor (Rf - distance that a liquid compound travels on a chromatography plate) of the characteristic bands of each standard and sample was calculated to show the chemical groups.

The second extract characterization method was scanning performed by spectroscopy in the UV-visible spectrum (FEMTO®, 800XI) in the region from 190 to 750 nm in quartz cuvettes. The analyses were performed with three replications and the absorption bands were compared with the literature (Workman Junior, 2000).

2.4. Allelopathic bioassays

The extract (5 mL) was tested at concentrations of 2.5, 5.0, 10.0, 15.0, and 20.0% in *L. sativa*, *L. esculentum*, and *S. obtusifolia* (overcoming dormancy by immersion in sulphuric acid for 20 min, followed by washing in running water for

Table 1. Analysis methods of secondary metabolite classes based on Matos (2009) and Simões et al. (2016).

Constituents	Analysis method			
Phenolic compounds	$FeCl_3$ 2% solution (Colour changes)			
	Lead acetate 10% solution (Precipitate formation)			
	Copper acetate 4% solution (Precipitate formation)			
Tannins	2% gelatin solution in physiological solution Albuminous solution			
Flavonoids	Cyanide reaction, Shinoda reaction or hydrogenation. Reaction with concentrated sulphuric acid. Confirmatory: Wilson's citroboric reaction			
Anthocyanins	Colour table			
	pH 2 - 3	Neutral pH	pH 8 - 9	pH 11
Anthocyanin and anthocyanidins	Red	No noticeable colour changes	Lilac	Purple blue
Flavones, flavonoids and xanthones	No noticeable colour changes	No noticeable colour changes	No noticeable colour changes	Yellow
Chalcones and aurones	Red	No noticeable colour changes	No noticeable colour changes	Purple-red
Flavonols	No noticeable colour changes	No noticeable colour changes	No noticeable colour changes	Red-orange
Free coumarins	10% NaOH solution or 20% KOH solution with UV light test			
Anthraquinone	Borntrager reaction			
Anthraquinone glycosides	Borntrager reaction with previous hydrolysis			
Steroids	Liebermann-Burchard test			
Triterpenes	Liebermann-Burchard and Salkowski test			
Alkaloids	Reagent: Dragendorff, Hager, Mayer and Bertrand; Reinecke's salt			
Cyanogenic heterosides	Guignard technique (sodium picrate)			
Cardiotonic heterosides	Pesez reaction; Keller-Killiani test; Baljet reaction; Raymond reaction			
Reducing sugar	Test: Molisch, Barfoed, Seliwanoffs and Fehling; Benedict reagent			

three min), in addition to the control (distilled water). The seeds were distributed on two sheets of Germitest® paper in transparent plastic boxes (11 x 11 x 3.5 cm) sealed with film paper, with four replications with 25 of *Lactuca sativa* seeds of the "maravilha quatro estações" variety, *Lycopersicum esculentum* of the "Santa Clara" variety (obtained in a commercial establishment), and *Senna obtusifolia* (collected in pasture areas).

The plastic boxes containing the seeds were kept in a germination chamber (four fluorescent lamps - 20 W ± 660 lux), constant temperature of 20 °C (*L. sativa* – optimal temperature) and 25 °C (*L. esculentum* and *S. obtusifolia* – optimal temperature), with a photoperiod of 12 h. The observations were performed every 24 hours for a period of seven days. Seeds that presented 2 mm of primary root protrusion were considered germinated, according to Oliveira et al. (2014a, b).

Extracts (10 ml) were used at the same concentrations of the germination bioassays on two Germitest® paper sheets in plastic boxes sealed with film paper, with four replications of 10 pre-germinated seeds (2 mm of root) per treatment to evaluate the seedling growth. Distilled water was used as a negative control in germination chambers (same germination temperatures). Seedling evaluations were performed after 10 days measuring from the meristematic apex of the root system to the apex of the aerial system (mm) with a digital calliper, according to Oliveira et al. (2014a, b).

The bioassays in the greenhouse were carried out in 128-cell expanded polystyrene trays using substrates obtained by mixing dry *A. phalerata* leaf powder with vermiculite at concentrations of 2.5, 5.0, 10.0 and, 20.0%. After homogenization, the material was moistened with distilled water and transferred to the trays and left to rest for one day, considering only the vermiculite substrate as a control. Then for sowing in the cells, 60 seeds of each species were used per treatment, one seed per cell. The shoot emergence process was observed daily for 10 days, then the seedlings were removed from the trays after this period and measured again using the same procedure mentioned above (Oliveira et al., 2014a, b).

The germination (Borghetti and Ferreira, 2004) and vigor percentages were evaluated by being indirectly measured by the mean germination time in days (MGT), quantifying germination from the kinetic point of view (Labouriau and Agudo, 1987) and by the germination speed index (GSI) (Maguire, 1962). The GSI percentage (Borghetti and Ferreira, 2004) and emergence speed index (ESI) were evaluated in the greenhouse (Maguire, 1962).

The statistical design was completely randomised and the results were analysed using the Bioestat 5.0 program. The data of the evaluated characteristics were submitted to analysis of variance (data subjected to the tests of normality and homogeneity of variances) and the means were compared when there was significance using the Tukey's test at 5% ($p < 0.05$).

3. Results

3.1. Phytochemistry

The analysis of the extract indicated a predominance of the steroid group, followed by chemical groups of high polarity such as phenolic compounds and saponins; those with lower scores included: tannins, flavonoids, coumarins and cardiotonic heterosides (Figure 2). The aphrosimetric index confirmed the presence of saponins, with the maximum absorption band $\lambda_{máx.MeOH}$ at 180 nm (A) (Figure 2) also being indicative of the steroid ring present in the group.

The major constituents confirmed by TLC revealed the presence of a major band with an Rf of 0.52, which presented a colour reaction for steroids with a similar Rf value to the cholesterol standard (Rf = 0.52), with a Dichloromethane: Acetate eluent of Ethyl: Methanol (7:4:0.5 v/v/v). A second band with an Rf of 0.84 (Chloroform: Methanol, 7.5:2.5 v/v) showed a colour reaction for flavonoids. The presence of coumarins was also evidenced, however different from the standard used (1,2 benzopyrone).

The maximum absorption bands ($\lambda_{máx.MeOH}$) at 260 (B), 330 (C) and 390 nm (D) in the UV-visible spectrum (Figure 1) are indicative of the presence of phenolic compounds and

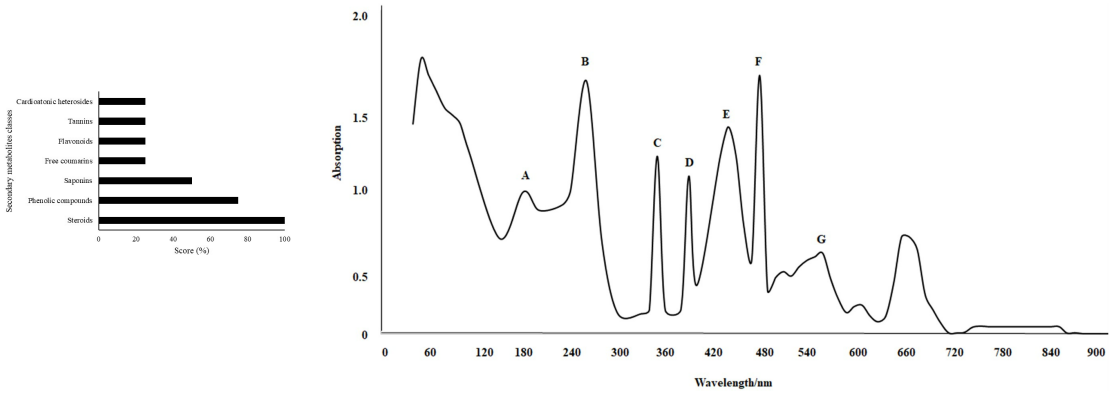

Figure 2. Score of secondary metabolite classes of the aqueous extract (20%) obtained from *Attalea phalerata* leaves. UV-visible spectrum with the maximum absorption bands ($\lambda_{max.MeOH}$) from the extract of *Attalea phalerata* leaves collected in the Pantanal de Miranda, Mato Grosso do Sul, Brazil.

flavonoids, which was observed by means of total phenols, 83.5 ± 0.03 mg of gallic acid equivalents/g and, flavonoids, 69.4 ± 0.02 mg of quercetin equivalents/g.

Moreover, slightly acidic values were found (6.1) regarding the pH of the extract, the electrical conductivity was low (4.8 ± 0.2 µS cm^{-1}), and the presence of soluble solids was not detected (zero).

3.2. Germination

The results showed that *L. sativa*, *L. esculentum* and *S. obtusifolia* seeds did not suffer negative interference from any of the extract concentrations in a germination chamber. However, the GSI of *L. sativa*, *L. esculentum* and *S. obtusifolia* were negatively affected from the concentration of 5% and MGT starting from 10% (Table 2).

Emergence and the emergence speed index did not suffer a negative effect of *A. phalerata* leaf powder on the target species in the greenhouse (Table 3).

In relation to the length of seedlings kept in a germination chamber, *L. sativa* and *L. esculentum* and *S. obtusifolia* were positively influenced from the concentration of 2.5% of the extract, significantly differing from the control, although the increase in the extract concentration resulted in a lower growth rate. On the other hand, the seedlings of *S. obtusifolia* were positively affected only in the highest concentration (20%) (Table 4).

In the greenhouse (Table 3), the result was similar to that found in the germination chambers, with the growth process being positively influenced for all species, with an increase in size from the concentration of 2.5% of the powder associated with vermiculite. However, higher powder concentrations did not result in better growth.

4. Discussion

4.1. Phytochemistry

The analysis of the leaves indicated a predominance of the steroid group, followed by chemical groups of high polarity such as phenolic compounds and saponins, with their maximum absorption bands indicating their presence (Zuanazzi and Montanha, 2010). Phenolic derivatives (tannins, flavonoids and coumarins) and cardiotonic glycosides were found less frequently. The other investigated classes were not evidenced.

Silva (2007) reports that flavonoids with different structures were found in 16 species of the genus *Attalea*, which is the only genus that contains apigenin as one of the major constituents. This metabolite is considered a phytoestrogen, which is a natural estrogen present in plants that primarily acts at the membrane level but not in the nucleus, more specifically where the receptor proteins are located.

Table 2. Germination (G %), germination speed index (GSI) and mean germination time (MGT) of *L. sativa* (lettuce), *L. esculentum* (tomato) and *S. obtusifolia* (coffee senna) seeds submitted to aqueous extracts from *Attalea phalerata* leaves, germination chamber.

%	G (%)			GSI			MGT (days)		
	Lettuce	Tomato	Coffee senna	Lettuce	Tomato	Coffee senna	Lettuce	Tomato	Coffee senna
0	99 a	100 a	96 a	23.0 a	7.7 a	23.2 a	1.2 a	3.3 a	1.1 a
2.5	98 a	98 a	97 a	22.9 a	7.4 a	21.7 a	1.2 a	3.4 a	1.2 a
5	97 a	94 a	96 a	20.0 b	6.3 b	19.2 b	1.4 a	3.6 a	1.3 a
10	99 a	94 a	94 a	17.5 b	6.4 b	16.7cd	1.8 b	4.2 b	1.8 b
15	98 a	93 a	94 a	13.0 c	6.5 b	14.2 d	2.2 b	4.1 b	1.8 b
20	93 a	99 a	94 a	7.6 d	6.3 b	11.4 e	3.2 c	4.4 b	1.9 b

Averages followed by the same letter in the column do not differ significantly by the Tukey's test ($p < 0.05$).

Table 3. Emergence (%), emergence speed index (ESI) and size of *L. sativa* (lettuce), *L. esculentum* (tomato) and *S. obtusifolia* (coffee senna) seedlings (seedl) grown in substrate containing *Attalea phalerata* leaf powder, greenhouse.

%	Emergence (%)			ESI (days)			Seedlings (mm)		
	Lettuce	Tomato	Coffee senna	Lettuce	Tomato	Coffee senna	Lettuce	Tomato	Coffee senna
0	96.9 a	100 a	93.7 a	3.7 a	2.6 a	8.6 a	56.2 b	57.2 b	92.3 b
2.5	94.6 a	98.5 a	92.1 a	4.0 a	2.5 a	8.7 a	65.9 a	67.7 a	102.3 a
5	93.7 a	96.9 a	90.6 a	4.2 a	2.7 a	8.9 a	66.6 a	66.6 a	104.4 a
10	95.3 a	87.9 a	90.6 a	3.8 a	2.4 a	9.3 a	66.0 a	66.0 a	102.6 a
20	96.9 a	89.1 a	95.3 a	4.4 a	2.4 a	8.5 a	65.6 a	65.8 a	103.8 a

Averages followed by the same letter in the column do not differ significantly by the Tukey test ($p < 0.05$).

Table 4. Seedling lengths of *L. sativa* (lettuce), *L. esculentum* (tomato) and *S. obtusifolia* (coffee senna) submitted to aqueous extracts from *Attalea phalerata* leaves, germination chamber.

Concentrations (%)	Lettuce	Tomato	Coffee senna
0	18.1 d	65.9 e	49.4 b
2.5	61.2 a	156.8 a	46.2 b
5	58.3 a	152.6 a	47.7 b
10	47.0 b	120.9 b	46.2 b
15	42.7 b	90.3 c	48.1 b
20	26.1 c	79.5 d	59.8 a

Averages followed by the same letter in the column do not differ significantly by the Tukey's test ($p < 0.05$).

Regarding the results found, only saponins and flavonoids are cited for other species of Arecaceae (Silva, 2007), and constituting knowledge gaps. *Acurizais* are abundant in the Pantanal and the fruits are an energy source for the animals, and so are the predominant structure investigated (Negrelle, 2015). However, despite the leaves being used in folk medicine (Pott and Pott, 1994; Negrelle, 2015), its phytochemical data are still incipient, which highlights the importance of this sorting and the potential of the leaves to be explored.

Among the classes of secondary metabolites found are phenolic compounds (simple phenols and flavonoids to complex structures such as tannins), considered potent inhibitors of germination and possible interference with shoot growth and root elongation (Weir et al., 2004; Fujii and Hiradate, 2007). The same authors describe that this class has the ability to decrease the elongation and elasticity of the cell wall and lignin formation, contributes to reduce roots, and also blocks the mitochondrial respiration of plants.

Other known germination and growth inhibitors present, such as coumarins, act by decreasing water entry into the cell, among other actions (Macias et al., 2003). Saponins are divided into two groups, steroids and triterpenoids, and can interact with cell membranes which modifies their permeability, in addition to being able to cause other types of damage, including in the photosynthetic process (Weir et al., 2004). The value regarding the presence of saponins found can be considered moderate compared to the results found by Oliveira et al. (2014b) for aqueous extract of *Palicourea rigida* Kunth. (Rubiaceae) (index of 1250), a species of occurrence in the Pantanal region, whose extracts negatively affected the development of *L. sativa* seedlings, which was also observed for *A. phalerata*.

In addition to flavonoids, steroids and cardiotonic heterosides comprise chemical messengers capable of transmitting cellular information and coordinating cellular growth and reproduction responses, thereby positively or negatively affecting plant development (Weir et al., 2004; Javid et al., 2011).

The phytochemical analysis also indicated that the values found in relation to the pH of the extract were slightly acidic (6.1), the electrical conductivity was low (4.8 ± 0.2 µS cm^{-1}) and the presence of soluble solids was not detected (zero).

According to Laynez-Garsaball and Mendez-Natera (2006), pH values of 6.0 and 7.5 are considered ideal for the germination of most plant species. Conductivity values lower than 200 µS cm^{-1} do not cause deleterious effects on germination or growth due to the small amount of electrolytes. Another important parameter to be considered is the presence of reducing sugars (Oliveira et al., 2014a), which was not detected, and therefore this group did not interfere in the germination or growth processes. In the end, it can be said that these parameters did not affect the germination or growth processes of the seedlings.

4.2. Germination and seedling formation

The results found for the germination chamber and greenhouse indicated that the extracts used and/or the addition of leaf powder did not affect the germination or emergence of the target species, despite the presence of several compounds which have inhibitory action, such as phenolic compounds (simple phenols, flavonoids and tannins, for example), which are potent germination inhibitors with action on growth (Weir et al., 2004; Fujii and Hiradate, 2007). Coumarins (Macias et al., 2003), saponins (Weir et al., 2004) and cardiotonic heterosides (Weir et al., 2004; Javid et al., 2011) are also considered as germination inhibitors. However, their action depends on the balance between metabolites and its effects in dilution processes may be different (Zhou and Yu, 2006), which may have affected their action.

However, the effects of extracts are generally insignificant on the germination kinetics, with little or no difference in relation to the control. On the other hand, it is more common for vigour to be altered, changing the germination speed and synchrony (Ferreira and Aquila, 2000); this situation was observed in this work, as seeds in the germination chamber took longer to germinate.

Thus, it can be seen that there was no effect of the extracts on the number of germinated seeds under the conditions evaluated in the germination chamber and in the greenhouse, but the germination vigour was negatively affected in the germination chamber for the three target species. According to Gusman et al. (2014), the effects of secondary metabolites may be different in a greenhouse or in nature from those found in laboratory biotests, and is a factor related to variable environmental conditions, such as temperature and solar radiation, altering the structure chemistry of compounds. In addition, Nóbrega et al. (2009) describe that cell membranes may break and chemical substances may be released during the germination and growth processes of plants, which may affect the chemical structure of the substrate.

According to the species studied, the results may be similar to those found for *A. phalerata*. This situation was reported by Oliveira et al. (2014b) in work with *L. sativa* seeds and extracts of *P. rigida* with similar results to those found for *A. phalerata*, in which germination was not affected, although the seeds had lost vigour. On the other hand, plant extracts can also affect germination, as occurred with the extract obtained from *Vochysia divergens* Pohl (Vochysiaceae) when evaluated on *L. sativa* and *L. esculentum* (Oliveira et al., 2013).

In addition to germination vigour, Ferreira and Aquila (2000) describe that the size of seedlings subjected to extracts and/or substrates with the presence of secondary compounds can be strongly affected, with this situation being observed in the results of *A. phalerata*. The results for the species indicated that the seedling growth was stimulated, but not its inhibition, with the lower extract concentration positively affecting *L. sativa* and *L. esculentum* in the germination chamber, although the increase in the extract concentration resulted in a lower benefit for growth. *Senna obtusifolia* seedlings were affected to a lesser extent by the extracts, since only the highest concentration had a positive effect, providing greater seedling growth.

The results in the greenhouse were similar, with leaf powder inducing greater growth of the target species, although the increase in powder concentration did not result in greater or lesser growth, as observed in the germination chamber. Temperature variations and the presence of ultraviolet radiation can affect the structure of metabolites, and the physiology of plants belonging to different families can also result in different behaviour in relation to the target species (Rizzi et al., 2016).

In this sense, seedling growth induction is probably related to the balance of growth facilitators and inhibitors, and phytohormones overlap when there is greater dilution, leading to differentiated growth (Zhou and Yu, 2006). Gatti et al. (2004) report that the actions of secondary metabolites interfere with the physiological processes of the recipient plant and can inhibit or stimulate growth, since most allelochemicals, which are inhibitors at some concentrations, can also act as stimulants at other concentrations. Thus, the chemical balance of secondary compounds produced greater seedling growth, although the increase in the extract concentration and leaf powder may have altered this balance, leading to a restriction in the development of target species.

In turn, the chemical balance of growth facilitators and inhibitors favoured the facilitators, leading to greater plant development. It should be noted that the secondary metabolites that act as plant growth regulators, such as flavonoids and alkaloids, do not have their action modes fully elucidated, having different pathways, possibly with specific receptors for each species. It is recognised that plant regulators or bioregulators, such as steroids, can directly act on different cellular structures and cause physical, chemical and metabolic changes in them (Kalita and Milligan, 2010), and thereby interfere with plant growth.

Steroids are part of chemical messengers capable of transmitting cellular information and coordinating cellular growth and reproduction responses (Weir et al., 2004; Javid et al., 2011), being considered phytohormones (Javid et al., 2011). Linhares Neto et al. (2014) demonstrated this action, evaluating *Copaifera sabulicola* J.A.S. Costa & L.P. Queiroz extracts and obtaining stimulation in the growth of *L. esculentum* seedlings; their results were similar to those found in the present study, indicating that certain species can release phytohormones.

It is interesting to emphasise that inhibiting the development of competitors (in the ecological aspect) could be an efficient strategy for the dominance of certain species. For example, in studying the action of extracts of *Leucaena leucocephala* (Lam.) de Wit on *Desmodium purpureum* (Mill.) Fawc. & Rendle, *Bidens pilosa* L. and *Amaranthus hibridus* L. weeds, Pires et al. (2001) demonstrated this type of action, in which the employed extract concentrations were harmful to the development of the target species. On the other hand, if the release of phytohormones which accelerate growth occurs, it can also facilitate the colonization process and dominance of the area in ecological terms.

Taking into account that the species *Attalea phalerata* occurs in monodominant formations in extensive areas, the results found herein raise the hypothesis that, in addition to the species being benefited through anthropic action (fires and deforestation), allelopathic action occurs through the release of water-soluble phytohormones by their leaves, which then induce faster seedling growth, facilitating their own establishment.

However, it is possible to infer that further studies are necessary, aiming at evaluating the effects of *A. phalerata* leaf extract and powder on the seeds/seedlings themselves. Allelochemicals are generally fundamental for the germination process and to establish individuals, playing a significant role in the plant distribution pattern (Ferreira and Aquila, 2000). The literature presents results which indicate the stimulus of plant species growth due to the action of phytohormones (Sausen et al., 2009), as observed in the present study.

Pott and Pott (1994) and Lorenzi et al. (1996) describe that clear cutting and the occurrence of occasional fires are factors which provide high *A. phalerata* density due to the fact that the species is invasive to open areas. Thus, its growth in these areas produces dense shading, making it difficult for other species to establish (Rivaben et al., 2021), and which together with the production of phytohormones favours their development and the formation of denser *A. phalerata* populations.

In addition to these factors, Negrelle (2013) writes that *Attalea phalerata* communities may be dominated by younger categories of *A. phalerata*, which could be a consequence of growth induced by phytohormones, resulting in a large number of individuals with potential to be recruited when under favourable conditions.

5. Final Considerations

The results indicated that the extracts did not interfere with seed germination of the target species, while the vigour was negatively affected in the germination chamber, increasing the germination time. However, there was no effect on vigour in the greenhouse. The phytochemical analysis showed the presence of phytohormones in the extract, which may have induced seedling growth in the germination chamber and in the greenhouse, with results superior to the control. Thus, *A. phalerata* populations forming in the Pantanal may also be related to allelochemical processes of the species which, together with the dense shading produced by the *A. phalerata* leaves, would favor the formation of the Acurizais.

Acknowledgements

We give thanks to the Coordination of Superior Level Staff Improvement (CAPES) for granting the scholarship,

and for the financial support from the National Council for Scientific and Technological Development (CNPq), the Center for Research in the Pantanal (CPP), the Support Foundation for the Development of Education, Science and Technology of the State of Mato Grosso do Sul (FUNDETEC), the National Institute of Wetlands (INAU) and Universidade Anhanguera-Uniderp for funding the Interdisciplinary Research Group and Natural Products.

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