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Composição Polifenólica e Potencial Alelopático de *Senna cearensis* Afr. Fern. (Fabaceae)

Polyphenolic Composition and Allelopathic Potential of *Senna cearensis* Afr. Fern. (Fabaceae)

Composición Polifenólica y Potencial Alelopático de *Senna cearensis* Afr. Helecho. (Fabaceae)

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Resumo

Os compostos químicos do metabolismo secundário de uma planta, denominados aleloquímicos, podem interferir na germinação e/ou desenvolvimento de outras espécies vegetais, um fenômeno conhecido como alelopatia. O objetivo deste estudo foi analisar o potencial alelopático do *Senna cearensis* Afr. Fern. extrato aquoso em várias concentrações, coletado de uma área da Chapada do Araripe durante duas estações diferentes (seca e chuvosa), em sementes e mudas de *Lactuca sativa* L. e *Cenchrus echinatus* L., além de analisar a prospecção fitoquímica do extrato. Os bioensaios foram conduzidos em câmara de germinação a 25°C com fotoperíodo de 12 h e consistiram em quatro tratamentos (extrato a 12,5%, 25%, 50% e 100%) e um grupo controle (água destilada). As variáveis analisadas foram: germinação das sementes, índice de velocidade de germinação, comprimento das radículas e comprimento das mudas de caulícula. As médias de cada variável foram submetidas a uma análise de variância e comparadas pelo teste de Tukey (p <0,05), através do

ASSISTAT. A prospecção quantitativa do extrato foi realizada utilizando HPLC-DAD. Os extratos reduziram a germinação das sementes de *L. sativa*, porém não afetaram as sementes de *C. echinatus*. Os extratos causaram redução na taxa de germinação e apresentaram efeitos inibitórios no desenvolvimento de plântulas para ambas as espécies receptoras. A quercitrina foi o principal composto nos dois extratos. A atividade alelopática do extrato aquoso de folhas de *S. cearensis* coletado durante os períodos seco ou chuvoso pode ser uma alternativa viável para o controle de plantas daninhas. Mais estudos abordando o fracionamento para separação e o possível isolamento de substâncias responsáveis pela atividade alelopática observada são necessários.

Palavras-chave: Alelopatia; Germinação; Sazonalidade; CLAE.

Abstract

Chemical compounds from the secondary metabolism of a plant, termed as allelochemicals, may interfere with the germination and/or development of other plant species, a phenomenon known as allelopathy. The aim of this study was to analyze the allelopathic potential of the *Senna cearensis* Afr. Fern. aqueous extract at various concentrations, collected from an area in the Chapada do Araripe during two different seasons (dry and rainy), on *Lactuca sativa* L. and *Cenchrus echinatus* L. seeds and seedlings, in addition to analysing the extract's phytochemical prospection. The bioassays were conducted in a germination chamber at 25 °C with a 12h photoperiod and consisted of four treatments (extract at 12.5%, 25%, 50% and 100%) and a control group (distilled water). The variables analyzed were: seed germination, germination speed index, radicle length and caulicle seedling length. The means from each variable were submitted to an analysis of variance and compared using Tukey's test ($p<0.05$), through the ASSISTAT. Quantitative prospection of the extract was performed using HPLC-DAD. The extracts reduced *L. sativa* seed germination, however it did not affect *C. echinatus* seeds. The extracts caused a reduction in germination rate and presented inhibitory effects on seedling development for both receptor species. Quercitrin was the major compound in both extracts. The allelopathic activity of the *S. cearensis* aqueous leaf extract collected during dry or rainy periods may be a viable alternative for weed control. Further studies addressing fractionation for separation and the possible isolation of substances responsible for the observed allelopathic activity are necessary.

Keywords: Allelopathy; Germination; Seasonality; HPLC-DAD.

Resumen

Los compuestos químicos del metabolismo secundario de una planta, llamados aleloquímicos, pueden interferir con la germinación y/o desarrollo de otras especies de plantas, un fenómeno conocido como alelopatía. El objetivo de este estudio fue analizar el potencial alelopático de *Senna cearensis* Afr. Helecho. extracto acuoso en varias concentraciones, recolectado de un área de Chapada do Araripe durante dos estaciones diferentes (seco y lluvioso), de semillas y plántulas de *Lactuca sativa* L. y *Cenchrus echinatus* L., además de analizar la prospección fitoquímica del extracto. Los bioensayos se realizaron en una cámara de germinación a 25 °C con un fotoperíodo de 12 horas y consistieron en cuatro tratamientos (12.5%, 25%, 50% y 100% de extracto) y un grupo de control (agua destilada). Las variables analizadas fueron: germinación de semillas, índice de velocidad de germinación, longitud de raíz y longitud de plántulas de tallo. Las medias de cada variable se sometieron a un análisis de varianza y se compararon usando la prueba de Tukey (p <0.05), usando ASSISTAT. La prospección cuantitativa del extracto se realizó usando HPLC-DAD. Los extractos redujeron la germinación de las semillas de *L. sativa*, pero no afectaron las semillas de *C. echinatus*. Los extractos causaron una reducción en la tasa de germinación y mostraron efectos inhibitorios sobre el desarrollo de las plántulas para ambas especies receptoras. La quercitrina fue el compuesto principal en ambos extractos. La actividad alelopática del extracto acuoso de las hojas de *S. cearensis* recolectadas durante los períodos secos o lluviosos puede ser una alternativa viable para el control de malezas. Se necesitan más estudios que aborden el fraccionamiento para la separación y el posible aislamiento de las sustancias responsables de la actividad alelopática observada.

Palabras clave: Alelopatía; Germinación; Estacionalidad; HPLC-DAD.

1. Introduction

Throughout evolution, plants have developed a defense mechanisms using the production of chemicals from secondary metabolism. Due to their sessile nature, plants need these substances to protect themselves against herbivore attacks, pathogens and competition with other plants and microorganisms (Silva et al., 2019).

Allelopathy is a phenomenon involving the action certain plants exert on others, favoring or harming their development through the release of chemical substances (allelochemicals) into the environment, produced from the plant's secondary metabolism (Bezerra et al., 2018). The production of these metabolites is strongly influenced by

environmental factors such as: temperature, humidity, radiation and seasonal variation (Macêdo et al., 2020).

The allelopathic activity of plants play an important role in natural ecosystems and agrosystems, as it may influence the structure, composition and dynamics of plant communities (Rodrigues et al., 2020). The substitution of environmentally harmful compounds for plant extracts can diminish environmental impact, maintaining biological balance, thus preserving the environment (Bezerra et al., 2019).

Senna cearensis Afr. Fern. belonging to the Fabaceae family, popularly known as "flor-de-besouro", is a plant native to Northeast Brazil. The allelopathic activity of certain species from the *Senna* genus have already been reported in the literature, for example, a study by Peres et al. (2010) observed the inhibitory allelopathic activity of *Senna occidentalis* and *Senna obtusifolia*, as well as in Rodrigues et al. (2010) using the *Senna alata* leaf extract, thus demonstrating a possible allelopathic potential for the genus.

With this in mind, the objective of this study was to analyze the allelopathic potential of the *S. cearensis* extract at different concentrations from leaves collected during two seasons (dry and rainy) on *Lactuca sativa* L. (lettuce) and *Cenchrus echinatus* L. (burrow) seed germination and the development, in addition to analyzing the chemical prospection of the potential allelochemicals responsible for the observed allelopathic activities.

2. Methodology

2.1 Plant material collection

Leaves from several *Senna cearensis* Afr. Fern. specimens were collected from an area in the Araripe National Forest at the geographic coordinates 07° 18' 04.4" S and 039° 33' 02.9" W at an altitude of 935 m in the morning. Two collections were performed, one in the dry season (September/2014) and the other in the rainy season (March/2015).

The collection of the botanical material was authorized by the Biodiversity Authorization and Information System (SISBIO) of the Ministry of the Environment (MMA), Chico Mendes Institute of Biodiversity Conservation (ICMBio) under registration number: 44506-1, issued on the 06 of June 2014.

The identification of the botanical material was carried out, based on literature specialized and compared to material existing in the collection Herbarium Caririense Dárdano

de Andrade-Lima (HCDAL) and subsequently incorporated into the collection of the said herbarium under registration number 12.159.

2.2 Extract acquisition

To obtain the brute aqueous extract (EAB), 100 g of fresh leaves were ground in an industrial blender with 500 mL of distilled water. The extract was then filtered and centrifuged at 3000 rpm for 10 minutes. The residue was discarded and the supernatant considered as the brute aqueous extract (100%) was diluted in distilled water to obtain 50%, 25% and 12.5% v/v concentrations (Silva et al., 2019).

2.3 Physical-chemical characteristics of the extracts

The pH of all aqueous extract concentrations from the leaves collected during the dry and rainy periods were measured using a PZL 1000 Osmometer, with the aid of a pH meter and osmotic potential. The osmotic potential measurements from the different concentrations were obtained in mOsm/kg and converted to osmotic pressure (MPa) using the equation:

$$\pi = - W \times 0.00832 \times Tabs$$

Where: π = Osmotic Pressure in MPa; W = Osmotic Potential in Osm/kg; Tabs - Absolute temperature, expressed in degrees Kelvin.

2.4 Germination bioassays

The germination assays were carried out in Petri dishes containing two sterile filter paper sheets, moistened with 3 mL of the extracts according to their respective concentrations (12.5%, 25%, 50% and 100%) and the distilled water (0%) control group. The experimental design was completely randomized, with five treatments and five replicates, each using 20 seeds of the respective recipient *Lactuca sativa* L. (lettuce) and *Cenchrus echinatus* L. (sandbur) species, totaling 100 seeds per treatment. The bioassays were conducted in a Biochemical Oxygen Demand (BOD) germination chamber regulated at 25 °C with a photoperiod of 12 hours (Silva et al., 2018).

Germination readings were carried out at 24-hour intervals for five days (*C. echinatus*) and seven days (*L. sativa*), considering seeds with 2 mm or more of radicular protrusion as germinated. The germinability (G) of the seeds was calculated according to Labouriau and Valadares (1976), using the formula:

$$G = (N/A) \times 100 (2)$$

Where N is the total number of seeds germinated and A the number of seeds placed for germination. The germination speed index (IVG) was determined by summing the ratio between the number of seeds germinated on day i (ni) and the number of days (i) (Fernandes et al., 2007).

2.5 Development bioassay

In the developmental bioassay, size standardization was carried out for seedlings to be exposed to the extracts (Moraes et al., 2014). Seeds pre-germinated with distilled water were use for this purpose. After 48 hours, the seedlings were transferred to Petri dishes lined with two sheets of filter paper, moistened with the extracts and distilled water (control group). The methodology and treatments were the same as those used in the germination assays. After five days (*C. echinatus*) and seven days (*L. sativa*) of growth, the length of the radicles and caulicles were evaluated with the aid of a millimeter ruler.

2.6 Quantification of Compounds by HPLC-DAD

Senna cearensis extracts at 10 mg/mL was injected onto reversed phase Phenomenex C_{18} column (4.6 mm x 250 mm) packed with 5 µm diameter particles. The mobile phases were 0.5% (v/v) aqueous acetic acid (solvent A) and 1% (v/v) formic acid in acetonitrile (solvent B). The binary elution system was as follows: 2% B at initial 5 min to wash the column, a linear gradient was 8% B (25 min), 12% B (45 min), 24% B (60 min). After 80 min, the organic phase concentration was brought back to 2% (B) and lasted 6 min for column equilibration. Flow rate of 0.6 mL/min and injection volume 50 µl (Boligon et al., 2015). The wavelengths used were 254 nm for gallic acid and ellagic acid; 280 nm for catechin; 327 for chlorogenic acid and caffeic acid; and 356 nm rutin, quercitrin, luteolin and apigenin. The extract and mobile phase were filtered through 0.45 µm membrane filter (Millipore) and then degassed by ultrasonic bath prior to use. Stock solutions of standards references were prepared in the HPLC mobile phase at a concentration range of 0.020 – 0.500 mg/mL.

Chromatography peaks were confirmed by comparing its retention time with those of reference standards and by DAD spectra (200 to 700 nm). All chromatography operations were carried out at ambient temperature and in triplicate. Calibration curve for gallic acid: Y = 11457x + 1264.1 (r = 0.9995); catechin: Y = 10945x + 1370.3 (r = 0.9998); caffeic acid: Y = 12492x + 1178.9 (r = 0.9999); chlorogenic acid: Y = 11254x + 1265.1 (r = 0.9997); ellagic acid: Y = 10833x + 1379.6 (r = 0.9999); rutin: Y = 14058x + 1284.7 (r = 0.9996); quercitrin: Y = 13027x + 1375.4 (r = 0.9995); luteolin: Y = 12463x + 1197.2 (r = 0.9997) and apigenin: Y = 11973x + 1425.6 (r = 0.9999).

The limit of detection (LOD) and limit of quantification (LOQ) were calculated based on the standard deviation of the responses and the slope using three independent analytical curves. LOD and LOQ were calculated as 3.3 and 10 σ/S, respectively, where σ is the standard deviation of the response and S is the slope of the calibration curve (Khaliq et al., 2015; Bezerra et al., 2017).

2.7 Statistical analysis

Data were submitted to an analysis of variance (ANOVA) and the means of the analyzed variables were compared by Tukey's test at 5% probability, through the ASSISTAT version 7.7 beta program. Differences between groups of HPLC were assessed by an analysis of variance model and Tukey's test. The level of significance for the analyses was set to $p < 0.05$. These analyses were performed by using the free software R version 3.1.1.

3. Results and Discussion

3.1 Physico-chemical characteristics of extracts

Verification of the pH and osmotic potential of an extract prior to performing bioassays are necessary when the extract's constitution, with respect to the presence of sugars, amino acids, organic acids and other molecules, is unknown since extreme pH and osmotic potential values can negatively act upon seeds and/or seedlings and mask the allelopathic effect (Ferreira & Áquila, 2000).

The pH values from the *Senna cearensis* aqueous leaf extracts collected during the two seasons (dry and rainy) varied from 5.4 to 6.4 while the osmotic potential of the extracts

ranged from -0.03 to -0.1 MPa. (Table 1). These values fall within the limit tolerated by most vascular plants (Bezerra et al., 2018).

According to Gatti, et al., (2004) the osmotic potential should not exceed -0.2 MPa in allelopathic assays, with the *Senna cearensis* extract osmotic potential values being within the recommended range. Therefore, these interference factors may be ruled out in the initial *Cenchrus echinatus* and *Lactuca sativa* seedling development in the present study.

Table 1. pH values and osmotic potential from *Senna cearensis* aqueous leaf extracts collected during two annual seasons (dry and rainy).

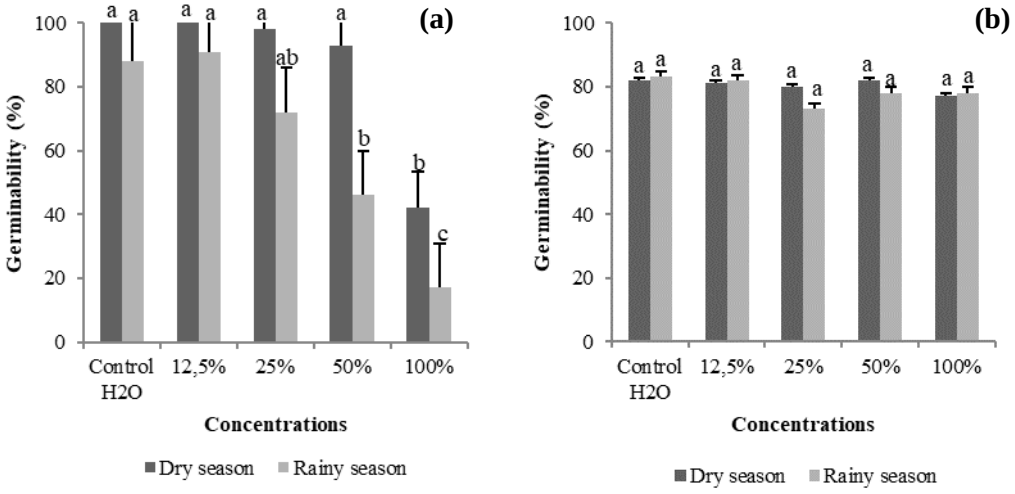
Concentrations	Dry season		Rainy season	
	pH	Osmotic Potential (- MPa)	pH	Osmotic Potential (- MPa)
Control H_2O	7.1	0	7.1	0
12.5%	6.1	0.03	5.6	-0.03
25%	6.4	0.05	5.7	-0.05
50%	5.7	0.08	5.4	-0.07
100%	5.7	0.1	5.5	-0.1

Source: Authors.

3.2 Germination bioassays

The aqueous extract produced from *Senna cearensis* leaves collected in the dry season inhibited *Lactuca sativa* seed germination (Figure 1a) at the 100% concentration, while the extract produced from leaves collected in the rainy season affected seed germination from the 25% concentration, with a significant linear *L. sativa* seed germination inhibition, with the inhibitory effect increasing according with the increase in extract concentration (Figure 1a).

Figure 1. Germination of (a) *Lactuca sativa* and (b) *Cenchrus echinatus* seeds treated with the *Senna cearensis* aqueous leaf extract collected during two seasons (dry and rainy). Averages followed by the same letter do not differ statistically from each other using Tukey's test ($p<0.05$).



Source: Authors.

These results confirm the *Senna cearensis* aqueous leaf extract possesses chemical compounds, which affect physiological processes in *Lactuca sativa* seeds. According to Azambuja et al., (2010), the phytotoxic effect demonstrated by a reduction in seed germinability evidenced the mobilization of nutrient reserves was probably, directly affected, influencing the epicotyl-radicle axis emission. *L. sativa* germination inhibition has also been report by Peres et al. (2010) using the *Senna obtusifolia* leaf extract, corroborating with the data obtained in this study.

In the environment, germination inhibition of seeds chemically sensitive to allelototoxic substances, released by individuals of their own species (autotoxicity) or not, may result in a decrease in density of their individuals, which in the medium and long term can lead to local extinction of the species, with implications for local biodiversity (Huang et al., 2019).

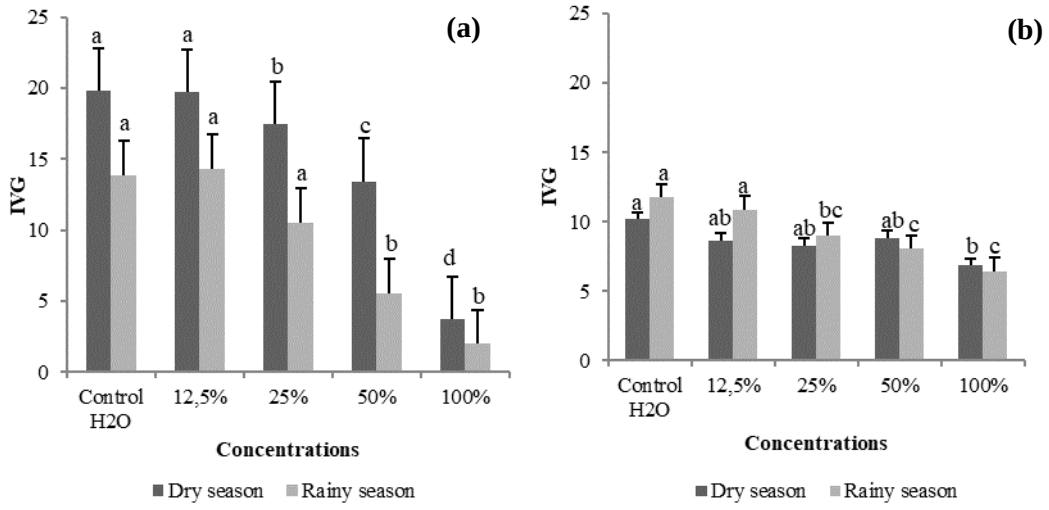
With respect to the seed germinability effects of the aqueous extracts (dry and rainy season) on *Cenchrus echinatus* (Figure 1b), none of the tested concentrations (12.5%, 25%, 50% and 100%) showed significant results when compared to the control group. This may be justified by the fact that *C. echinatus* is a weed species and, therefore, throughout its

evolutionary process developed tolerance mechanisms against certain allelochemicals, thus facilitating its competitive and adaptive capacity.

Figure 2 shows extracts collected from both the dry and rainy seasons reduced the germination speed index (IVG) of seeds from the two recipient species. The extract collected in the dry season was observe to reduce the *C. echinatus* seed IVG from the lowest concentration (Figure 2b). Some authors affirm that allelochemicals often do not act on seed germination, rather they act on the IVG. The reduction of this variable indicates allelochemicals present in the extracts induce a loss of synchrony in the germination metabolic reactions (Leandro et al., 2019; Bezerra et al., 2019; Silva et al., 2019).

According to Azambuja et al. (2010), IVG reduction may represent inhibition of the unfolding speed and the translocation of endosperm nutritional components to the embryo. This factor may have an important ecological meaning, since plants, which germinate slowly may have a reduced size and as a consequence be more susceptible to external influences, possess lower chances of competing for resources and consequently find it more difficult to become established in the environment and complete its life cycle (Huang et al., 2013).

Figure 2. Germination speed index (IVG) of (a) *Lactuca sativa* and (b) *Cenchrus echinatus* seeds treated with the *Senna cearensis*aqueous leaf extract at various concentrations during two seasons (dry and rainy). Averages followed by the same letter do not differ statistically and by each other using Tukey's test ($p<0.05$).



Source: Authors.

3.3 Development bioassays

The data in Table 2 demonstrate *Lactuca sativa* radicle development of seedlings treated with the *Senna cearensis* aqueous leaf extract at different concentrations, collected during the dry and rainy seasons, were negatively affected, presenting a significant reduction at all concentrations.

L. sativa seedling caulicles exposed to the extract produced from leaves collected in the dry season were reduced at all tested concentrations, while caulicles exposed to the extract from leaves collected in the rainy season were reduce when from an extract concentration of 25%. Similar results were reported in the literature by Cândido et al. (2010b), when treating *L. sativa* seedlings with *Senna occidentalis* extracts.

Inhibitory effects were also observe regarding the radicular length of *Cenchrus echinatus* seedlings exposed to both *S. cearensis* extracts (dry and rainy season) at all tested concentrations, demonstrating a strong dose-dependent relationship for the extract concentrations. However, the caulicular growth in these seedlings was not affect by these extracts at any of the tested concentrations (Table 2).

The inhibitory effect of *S. cearensis* leaves collected during both seasons (dry and rainy) was greater with respect to radicular growth than caulicular growth of *C. echinatus* seedlings. These results corroborate with Chung et al. (2001), who demonstrated the roots are more sensitive to allelochemicals than other seedling structures due to their direct and prolonged contact with the allelochemicals.

Table 2. Mean *Lactuca sativa* and *Cenchrus echinatus* radicular (CR) and caulicular (CC) in cm measurement of seeds treated with the *Senna cearensis* aqueous leaf extract at various concentrations collected during two seasons (dry and rainy).

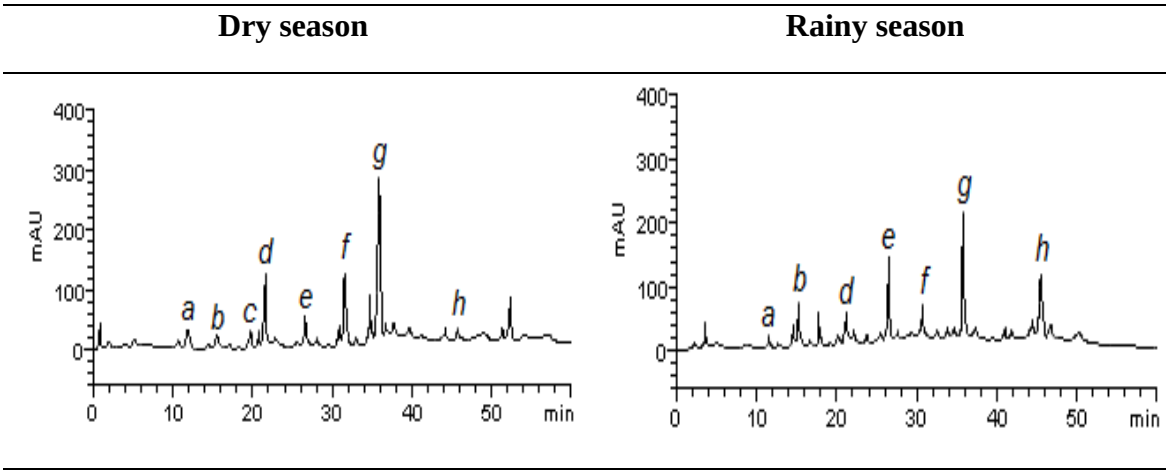
	Lactuca sativa				***Cenchrus echinatus***			
	Dry season		**Rainy season**		**Dry season**		**Rainy season**	
Concentrations	**CR**	**CC**	**CR**	**CC**	**CR**	**CC**	**CR**	**CC**
Control H_2O	2.12 a	2.72 a	2.28 a	3.82 a	9.24 a	0.72 a	8.78 a	0.71 a
12.5%	2.48 a	1.78 b	2.54 a	3.62 a	7.56 b	0.76 a	5.76 b	0.73 a
25%	1.14 b	2.02 b	1.95 b	3.34 ab	3.98 c	0.72 a	5.40 b	0.80 a
50%	0.52 c	1.87 b	0.98 c	3.03 bc	2.01 d	0.68 a	3.16 c	0.73 a
100%	0.50 c	1.78 b	0.79 c	2.68 c	1.90 d	0.68 a	2.28 c	0.76 a
CV%	19.94	8.57	11.87	7.79	16.0	9.36	13.94	6.78

Legend: CV% – variation coefficient. Averages followed by the same letter in the columns do not differ statistically from each other by Tukey's test ($p<0.05$). Source: Authors

3.4 Compound quantification by HPLC-DAD

HPLC quantitative analysis of the *Senna cearensis* aqueous leaf extract collected during the dry and rainy season revealed the presence of gallic acid (retention time - t_R = 11.89 min; peak *a*), catechin (t_R = 14.93 min; peak *b*); chlorogenic acid (t_R = 19.80 min, pico *c*), caffeic acid (t_R = 21.07 min, peak *d*), ellagic acid (t_R = 26.15 min, peak *e*), rutin (t_R = 30.45 min; peak *f*), quercitrin (t_R = 35.96 min, peak *g*) and luteolin (t_R = 45.61 min, peak *h*) (Fig 3 and Tab 3). Calibration curve for gallic acid: Y = 11457x + 1264.1 (r = 0.9995); catechin: Y = 10945x + 1370.3 (r = 0.9999); caffeic acid: Y = 12492x + 1178.9 (r = 0.9999); chlorogenic acid: Y = 11254x + 1265.1 (r = 0.9997); ellagic acid: Y = 110833x + 1379.6 (r = 0.9999); rutin: Y = 14058x + 1284.7 (r = 0.9996); and quercitrin: Y = 13027x + 1375.4 (r = 0.9995); luteolin: Y = 12463x + 1197.2 (r = 0.9997).

Figure 3. High performance liquid chromatography (HPLC) profile of the *Senna cearensis* aqueous leaf extract collected during the dry and rainy season. Gallic acid (peak *a*), catechin (peak *b*), chlorogenic acid (peak *c*), caffeic acid (peak *d*), ellagic acid (peak *e*), rutin (peak *f*), quercitrin (peak *g*), and luteolin (peak *h*).



Source: Authors.

Quercitrin and caffeic acid were the compounds identified in greater amounts in the *Senna cerensis* aqueous leaf extract collected in the dry season. In the rainy season quercitrin and luteolin were the major extract compounds.

The compounds found in the extracts, such as phenolic acids and flavonoids, are widely distributed in plant tissues and are often associated with the allelopathic phenomena. Phenolic acids are reported as being responsible for the reduction of micro- and macronutrient absorption in several species (Cândido et al., 2010a). Flavonoids also indirectly interfere with nutrient uptake in plants (Santos & Rezende, 2008).

Table 3. Chemical composition of the *Senna cearensis* aqueous leaf extract collected during the dry and rainy season.

Compounds	Dry season	Rainy season	LOD	LOQ
	mg/g	mg/g	µg/mL	µg/mL
Gallic acid	1.41 ± 0.02 a	0.85 ± 0.03 a	0.012	0.039
Catechin	1.39 ± 0.01 a	3.15 ± 0.01 b	0.025	0.083
Chlorogenic acid	1.35 ± 0.03 a	-	0.017	0.056
Caffeic acid	6.52 ± 0.02 b	2.76 ± 0.04 b	0.008	0.027
Ellagic acid	2.93 ± 0.04 c	6.08 ± 0.03 c	0.023	0.079
Rutin	6.27 ± 0.01 b	2.70 ± 0.02 b	0.021	0.069
Quercitrin	13.08 ± 0.02 d	8.93 ± 0.02 d	0.009	0.030
Luteolin	0.83 ± 0.01 e	6.11 ± 0.01 c	0.028	0.092

Legend: Results are expressed as mean ± standard deviation (SD) of three mean determinations. Means followed by different letters differ by Tukey's test at $p<0.05$. LOD: limit of detection and LOQ: limit of quantification. Source: Authors

Caffeic acid can interfere with the balance between stimulatory and inhibitory substances during seed germination, as well as pose an obstacle for gas diffusion in moistened seeds. For Basile et al. (2003), flavonoids, such as quercitrin (major compound in both extracts), affect membrane permeability influencing radicular cell turgidity thus affecting germination.

It is noteworthy the *Senna cearensis* allelopathic effect can not be solely attributed to the compound found at the greatest quantity (quercitrin), since in plant communities, interferences attributed to allelopathic actions result not from the action of a single, but of different allelochemicals (Rezende et al., 2011), released in the environment by plants at different concentrations, quantities and times.

4. Conclusion

The results demonstrate that the leaves of *Senna cearensis* presented inhibitory allelopathic effects on the target species. Further studies are needed, such as fractionation for

separation and the possible isolation of substances responsible for the observed allelopathic activity.

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References

Azambuja, N., Hoffmann, C. E. F., Neves, L. A. S. & Goulart, E. P. L. (2010). Potencial alelopático de *Plectranthus barbatus* Andrews na germinação de sementes de *Lactuca sativa* L. e de *Bidens pilosa* L. *Revista de Ciências Agroveterinárias*, 9(1), 66-73.

Basile, A., Sorbo, S., Lopez-Saez, J. A. & Cobianchi, R. C. (2003). Effects of seven pure flavonoids from mosses on germination and growth of *Tortula muralis* HEDW. (Bryophyta) and *Raphanus sativus* L.(Magnoliophyta). *Phytochemistry*, 62(7), 1145-1151.

Bezerra, J. W. A., Costa, A. R., da Silva, M. A. P., Rocha, M. I., Boligon, A. A., da Rocha, J. B. T., Barros, L. M. & Kamdem, J. P. (2017). Chemical composition and toxicological evaluation of *Hyptis suaveolens* (L.) Poiteau (LAMIACEAE) in *Drosophila melanogaster* and *Artemia salina*. *South African Journal of Botany*, 113(s/n), 437-442.

Bezerra, J. W. A., Santos, M. A. F., Meiado, M. V., Linhares, K. V., Boligon, A. A., Leandro, C. S. & Silva, M. A. P. (2018). Allelopathy of aromatic species on the germination of *Cereus jamacaru* DC. subsp. *jamacaru* (Cactaceae). *Journal Agricultual of Science*, 10(11), 337-348.

Bezerra, J. W. A., Leandro, C. S., Rodrigues, M. D. P., Silva, A. K. F., Linhares, K. V., Silva, V. B., Bezerra, J. S., Souza, M. A. & Silva, M. A. P. (2019). Allelopathic Activity of Cactus Used in the Foraging in the Brazilian Semi-arid. *Journal of Agricultural Science*, 11(13), 206-212.

Boligon, A. A., Piana, M., Kubiça, T. F., Mario, D. N., Dalmolin, T. V., Bonez, P. C. & Athayde, M. L. (2015). HPLC analysis and antimicrobial, antimycobacterial and antiviral activities of *Tabernaemontana catharinensis* A. DC. *Journal of Applied Biomedicine,* 13(1), 7-18.

Cândido, A. C. S., Dias, A. C. R., Serra, A. P., Christoffoleti, P. J., Scalon, S. D. P. Q. & Peres, M. T. L. P. (2010a). Potencial alelopático de lixiviados das folhas de plantas invasoras pelo método sanduiche. *Revista Brasileira de Biociências,* 8(3), 268-272.

Cândido, A. C. S., Schmidt, V., Laura, V. A., Faccenda, O., Hess, S. C., Simionatto, E. & Peres, M. T. L. P. (2010b). Potencial alelopático da parte aérea de *Senna occidentalis* (L.) Link (Fabaceae, Caesalpinioideae): bioensaios em laboratório. *Acta Botânica Brasílica, 24*(1), 235-242.

Chung, I. M., Ahn, J. K. & Yun, S. J. (2001). Assessment of allelopathic potential of barnyard grass (*Echinochloa crus-galli*) on rice (*Oryza sativa* L.) cultivars. *Crop Protection,* 20(10), 921-928.

Fernandes, L. D. A. V., de Miranda, D. L. C., & Sanquetta, C. R. (2007). Potencial alelopático de *Merostachys multiramea* Hackel sobre a germinação de *Araucaria angustifolia* (Bert.) Kuntze. *Revista Acadêmica de Curitiba,* 5(2), 139-146.

Ferreira, A. G. & Áquila, M. E. A. (2000). Alelopatia: uma área emergente da ecofisiologia. *Revista Brasileira de Fisiologia Vegetal,* 12(s/n),175-204.

Gatti, A. B., Perez, S. C. J. G. A. & Lima, M. I. S. (2004). Efeito alelopático de *Aristolochia esperanzae* O. Kuntze na germinação e no crescimento de *Lactuca sativa* L. e *Raphanus sativus* L. *Acta Botanica Brasilica,* 18(3), 459-472.

Huang, W., Hu, T., Chen, H., Wang, Q., Hu, H., Tu, L. & Jing, L. (2013). Impact of decomposing Cinnamomum septentrionale leaf litter on the growth of Eucalyptus grandis saplings. *Plant Physiology and Biochemistry,* 70(s/n), 411-417.

Huang, X., Chen, J., Liu, J., Li, J., Wu, M. & Tong, B. (2019). Autotoxicity Hinders the Natural Regeneration of *Cinnamomum migao* HW Li in Southwest China. *Forests*, 10(10), 919-936.

Khaliq, A., Sabir, S. M., Ahmed, S. D., Boligon, A. A., Athayde, M. L., Jabbar, A. J. & Khan, A. (2015). Antioxidant activities and phenolic composition of Olive (*Olea europaea*) leaves. *Journal of Applied Botany and Food Quality*, 88(1), 16-21.

Labouriau, L. G. & Valadares, M. B. (1976). On the germination of seeds of *Calotropis procera*. *Anais da Academia Brasileira de Ciências*, 48(s/n), 174-186.

Leandro, C. S., Bezerra, J. W. A., Rodrigues, M. D. P., Silva, A. K. F., Silva, D. L., Santos, M. A. F., Bezerra, J. S., Silva, M. A. P. (2019). Phenolic Composition and Allelopathy of *Libidibia ferrea* Mart. ex Tul. in Weeds. *Journal of Agricultural Science*, 11(2), 109-120.

Macêdo, D. G., de Almeida Souza, M. M., Morais-Braga, M. F. B., Coutinho, H. D. M., dos Santos, A. T. L., Machado, A. J. T., & Menezes, I. R. A. (2020). Seasonality influence on the chemical composition and antifungal activity of *Psidium myrtoides* O. Berg. South *African Journal of Botany*, 128(s/n), 9-17.

Moraes, L. P. S., Gualtieri, S. C. J., Lima, M. I. S., Gatti, A. B., Pereira, V. C. & Miranda, M. A. F. M. (2014). Efeitos alelopáticos de *Lafoensia glyptocarpa* Koehne sobre *Sesamum indicum* L. e sobre o crescimento de coleóptilos de *Triticum aestivum* L. *Iheringia. Série Botânica*, 69(1), 37-48.

Peres, M. T. L. P., Cândido, A. C. S., A. C. D., Bonilla, M. B., Faccenda, O., & Hess, S. C. (2010). Phytotoxic potential of *Senna occidentalis* and *Senna obtusifolia*. *Acta Scientiarum. Biological Sciences*, 32(3), 305-309.

Rezende, G. A. A., Terrones, M. G. H. & Rezende, D. M. L. C. (2011). Estudo do potencial alelopático do extrato metanólico de raiz e caule de *Caryocar brasiliense* Camb. (Pequi). *Bioscience Journal*, 27(3), 460-472.

Rodrigues, A. S., Bezerra, J. W. A., da Silva, V. B., Costa, A. R., Rodrigues, F. C., Linhares, K. V. & da Silva, M. A. P. (2020). Phytotoxic activity of *Guapira graciliflora* (Nyctaginaceae) on weeds. *Journal of Agricultural Studies*, 8(1), 287-301.

Rodrigues, I. M. C., Souza Filho, A. P. S., Ferreira, F. A. & Demuner, A. J. (2010). Prospecção química de compostos produzidos por *Senna alata* com atividade alelopática. *Planta Daninha*, 28(1), 1-12.

Santos, S. & Rezende, M. (2008). Avaliação do potencial herbicida de compostos secundários na germinação de sementes de plantas daninhas encontradas em pastagens. *Revista Analytica*, 2(32), 72-78.

Silva, D. L.; Santos, M. A. F.; Bezerra, J. W. A.; Leandro, C. S.; Rodrigues, M. D. P.; Boligon, A. A.; Silva, M. A. P. (2018). *Cordia oncocalyx* (Allemão) Baill. (Boraginaceae) Chemical Composition and Alelopathic Effect Against Weeds. *Journal of Agricultural Science*, 10(12), 262-271.

Silva, V. B., Bezerra, J. W., Cruz, M. F., Leandro, C. S., Sousa, J. F., & Santos, M. A. (2019). Allelopathy of *Dahlstedtia araripensis* on *Calotropis procera* and *Zea mays*. *Journal of Agricultural Science*, 11(14), 32-46.

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