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Allelopathy of *Dahlstedtia araripensis* on *Calotropis procera* and *Zea mays*

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Abstract

Studies related to the allelopathic properties of plants have aroused great interest, since species that have compounds with allelopathic activity can be used as bioherbicides in the control of weeds. In this way, the aim of this study was to evaluate the allelopathic action of *Dahlstedtia araripensis* on the germination and growth of *Calotropis procera* and *Zea mays*. The bioassays were prepared using two 50 g portions of leaves, stem bark and *D. araripensis* roots, and each part of the plant received a hot treatment (1 L of distilled water at 100 °C) and one part cold (1 L of distilled water at 25 °C). The experimental design consisted of six treatments and the control group. The variables analyzed were: Index of Emergency Speed (IES), germinability, length and occurrence of necrotic radicles. The results indicated that the extracts interfered negatively on the germinability of the seeds, mainly on those of *C. procera*, since all extracts significantly inhibited its germination. In the seeds of *C. procera* and *Z. mays* there was delay in IES. The results indicated that the cold and hot extracts of the distinct parts of *D. araripensis* affected the development of the seedlings, besides promoting root necrosis. The observed effects may be due to the presence of secondary metabolites detected in the different extracts of *D. araripensis*. However, further research is required to prove the performance of such compounds, as well as their isolation, for future use asnatural herbicides.

Keywords: allelochemicals, angelim, ciumeira, corn, fabaceae, *Lonchocarpus araripensis*

1. Introduction

Plants produce through their secondary metabolism, chemical substances called allelochemicals, which, when liberated in sufficient quantities in the environment, may interfere positively or negatively in the process of germination and development of other species that are around them, such phenomena is called allelopathy (Almeida, Zucoloto, Zetun, Coelho, & Sobreir, 2008). These allelochemicals are distributed in different concentrations in the different tissues of the plant, also varying throughout their life cycle (Goldfarb, Pimentel, & Pimentel, 2009). These substances are liberated from the various parts of the plant to the environment, either directly or indirectly, through volatilization, leaching, root exudation or decomposition of dead tissues (Gurevitch, Scheiner, & Fox, 2009; Silva, Medeiros Filho, Duarte, & Moreira, 2014).

The allelochemicals may interfere in certain pathways of the metabolism of the recipient species, causing effects that include delay or inhibition of seed germination, growth and development of young plants, as well as induction of seedling growth abnormality (Moraes et al., 2014; Bezerra et al., 2018). These effects being capable of influencing natural or managed ecosystems, such as agricultural systems (Manoel, Doiche, Ferrari, & Ferreira, 2009; Brito, 2010).

Allelopathic studies are of great importance because they enable a better understanding of the chemical and biological interactions between plants and the mechanisms of action of various substances (Macias, Molinillo,

Varela, & Galindo, 2007; Kremer, 2017). In addition to allowing the understanding of the many causes of failure of the cultivars that did not obtain the expected performance, since for both agricultural and forest management, previous occupation may exert influence on the species that will be cultivated or will settle in the environment (Silva, 2012).

Studies related to the allelopathic properties of native species have called attention, both because they are related to interactions between organisms in native vegetation, and in agricultural production (Souza Filho & Alves, 2002; Ferreira, 2004). Besides, plants holding compounds with allelopathic activity can be used as efficient natural herbicides, contributing to the reduction of costs in agricultural production and the impact caused by the increasing use of pesticides, also making it possible to select plants to control weeds (Tokura & Nóbrega, 2006).

In this way, the study of the allelopathic action of native species becomes necessary. The example of *Dahlstedtia araripensis* (Benth.) M.J. Silva & A.M.G. Azevedo, a Fabaceae that presents a rich potential of secondary compounds, especially flavonoids (Campos, 2008; Lima, Ferreira, Monte, & Braz-Filho, 2014; Almeida et al., 2015). Phytochemical studies with *D. araripensis* have also shown the occurrence of important activities for some of its compounds, such as antioxidant, gastroprotective, antinociceptive and anti-inflammatory activity (Campos, 2008; Rodrigues, 2012; Amorim, 2013; Pires et al., 2016).

Considering the importance of the knowledge about the biological activities of the allelochemicals of *D. araripensis* and their use in agricultural systems for suppression of weeds. The present work aimed to identify the possible allelopathic effects of *D. araripensis* on germination and initial development of seedlings of *Calotropis procera* (Aiton) W.T. Aiton, a invasive species of pasture, and *Zea mays* L., a species considered as a bioindicator in allelopathy tests, as well as to raise the classes of secondary metabolites present in said extracts that can act as potential allelochemicals.

2. Material and Methods

2.1 Collection and Identification of Botanical Material

The botanical material of the donor species (*D. araripensis*) was collected in the Chapada of Araripe in Caatinga vegetation (Seasonally Dry Tropical Forest located in Northeast Brazil) in October 2017, in Moreilândia city, PE, Brazil (07º30′58.9″ S, 39°29′07.9″ W) (Figure 1). Leaves, stem barks and roots were collected in 50 L plastic bags, which were sealed and taken, for the preparation of the experiments. At the time, we were also collected flowering branches for the preparation of specimen, which was incorporated into the collection of the Herbarium Caririense Dárdano de Andrade-Lima-HCDAL of Regional University of Cariri-URCA under the voucher 13.256.

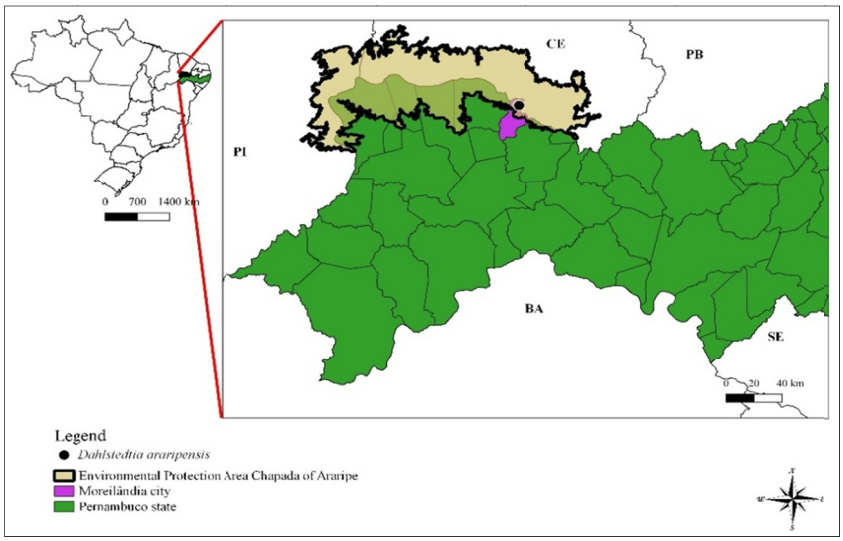

Figure 1. Place of specimen collection

2.2 Donor Species

Dahlstedtia araripensis is found mainly in the Northeast of Brazil, and its distribution extends to the Brazilian Midwest to the Bolivian dry forests, with records of occurrence in areas of caatinga, cerrado and seasonal

forests. It is popularly known in Brazil for angelim, ponytail, or jasmine, and is found from the coastal regions, sandy soils, rocky, low and humid lands, to plains and hills (Fernandes, 1964; Silva, 2010). Morphologically *D. araripensis* is a tree up to 12 meters high (Figure 2a), with glabrescent to pubescent branches with tricomes rustic or hyaline adpresses when young, leaves 7-9 foliolate opposing, apposing towards the apex and puberulos in both (Figure 2b), panicle-type inflorescence with purple petals (Figure 2a), sericeous calyx with short lacinii (0.5 mm length), sparsely pubescent stamens, and samarid fruit with the elliptical shape (Figure 2b) (São-Mateus, Cardoso, Jardim, & Queiroz, 2013; Córdula, Morim, & Alves, 2014).

Figure 2. General aspects of *Dahlstedtia araripensis* (Benth.) M.J. Silva & A.M.G. Azevedo in the municipality of Moreilândia - PE, Brazil, in: (A) Habitat and habit; (B) Individual in the flowering period; (C) Flowers and inflorescence of the species; (D) Fruits. Source: Sousa, J. F. O. (2018)

2.3 Recipients Species

Were used as recipients species, *Calotropis procera* (Apocynaceae), collected in empty lots near Regional University of Cariri (07º14′22.211″ S, 39°24′57.908″ W) and *Zea mays* cultivar Al Bandeirante p20 (Poaceae) from the local shops.

Calotropis procera is a shrub popularly knownin Brazil as “ciumeira” or “silk flower”, native to the arid regions of tropical Africa, Asia and common in the Middle East (Lottermoser, 2011; Lázaro et al., 2012). Considered as a ruderal species, *C. procera* possesses the ability to settle in degraded and nutrient-poor soils, such as sites surrounding roads, pastures and abandoned areas. It also has high potential for invasion of untouched areas, besides being a species of difficult eradication (Barbosa et al., 2013).

Zea mays popularly known as corn, is a plant grown on almost all farms. It is considered one of the oldest cultivars and one of the most studied vegetables, with a wide distribution worldwide, being considered the second cereal of major importance in Brazil. Economically, it is important for its wide and diversified use in

human and animal food and in the high technology industry (Simoneto & Cruz-Silva, 2010; B. E. C. Silva, & M. R. J. Silva, 2017).

2.4 Preparation of Bioassays

For the preparation of the extracts by hot and cold immersion, 100 g of each part of *D. araripensis* were crushed in isolation, which were subdivided into half parts (50 g) for each organ. Each part of the plant received a hot treatment (1 L of distilled water at 100 °C) and cold (1 L of distilled water at room temperature). The extraction period was 30 minutes, and after that time, each content was submitted to grinding in a domestic blender for 3 min. Then, each extract was filtered with the aid of a glass funnel and cotton, for retention of all the fibrous material (Leandro et al., 2019).

2.5 Treatments

The bioassay consisted of six treatments: hot leaf infusion extract (EQF 100 °C), extract by cold infusion of leaves (EFF 25 °C), extract by hot infusion of bark (EQC 100 °C), extract by cold infusion of bark (EFC 25 °C), extract by hot root infusion (EQR 100 °C), extract by cold infusion of roots (EFR 25 °C) and a control group (distilled water) (Silva et al., 2018).

Each treatment consisted of four replicates with 25 seeds of both species, per treatment. The experiments were conducted in greenhouse (shading rate of 70%), in plastic trays containing 100 cells. As a substrate was used river washed sand, duly sterilized. The seeds were distributed one in each cell.

The volume of extract added in each cell corresponded to 60% of the field capacity of the substrate (Brasil, 2009). In this way, 5 mL of the corresponding extract was added to each cell, just as the control group was moistened with equal amounts of distilled water. The experiment was evaluated for a period of seven days for both species, and water was added whenever necessary.

2.6 Analyzed Variables

2.6.1 Percentage of Germination

The percentage of germination (PG) was determined at the end of the seven days of experiment. According to the following formula:

$$PG = N/Nt \times 100 \quad (1)$$

Where, N-refers to the total number of seeds sprouted at the end of the experiment and Nt refers to the total number of seeds sown.

2.6.2 Emergency Speed Index (ESI)

The germination was evaluated every 24 hours for seven days, counting the number of seeds germinated in each experimental plot. From this record the Emergency Speed Index (ESI) was obtained, which was calculated according to Maguire (1962) by the formula:

$$ESI = E1/N1 + E2/N2 + ... + En/Nn \quad (2)$$

where, E1, E2 and En refers to the number of normal seedlings computed in the first, second and last count, and N1, N2 and Nn refers to the number of days of sowing at the first, second and last count.

2.6.3 Length of Seedlings

Seven days after sowing, five seedlings of *C. procera* and *Z. mays* were randomly selected in each repetition, which were subjected to measurement of roots and shoots length using a millimeter ruler. Results were expressed in centimeters.

2.7 Physicochemical Analyzes of Extracts

The extracts corresponding to each treatment were submitted to pH and Osmotic Potential (OP), using pH (Tecnal) and Osmometer (PZL-1000), respectively. The osmolality data were obtained in mOsm/kg and converted to osmotic pressure (MPa), according to the equation proposed by Larcher (2004):

$$\pi = -W \times 0.00832 \times Tabs \quad (3)$$

where, π = Osmotic Pressure in MPa; W = Osmotic Pressure in Osm/kg; Tabs = Absolute temperature, expressed in degrees Kelvin.

2.8 Phytochemical Characterization

For the determination of secondary metabolites, lyophilized aqueous extracts were used for each treatment. The assays were carried out according to the method proposed by Matos (2009) aiming to identify the classes of

secondary metabolites present in the extracts, through color change and/or precipitate formation through cascades of chemical reactions after the addition of specific reagents.

2.9 Statistical Analysis

For the statistical analysis of the data, the program GraphPadPrism version 6.0 was used, with analysis of variance (ANOVA) of One-way and comparison of the means through the Tukey test at 5% of probability.

3. Results and Discussion

3.1 Physico-chemical Parameters

It was found that the values of pH and osmotic potential of the extracts of the different treatments varied between 6.0 to 6.8 and -0.02 MPa to -0.04 MPa, respectively (Table 2). These parameters are in accordance with acceptable standards for seedling germination and development in allelopathy experiments (Macias, Gallindo, & Molinillo, 2000).

Table 2. Physicochemical values of the hot and cold extracts of different organs of *D. araripensis* used in the germination bioassays of *C. procera* and *Z. mays*

Treatment	pH	Osmolarity (MPa)
EFF	6.29	-0.029
EQF	6.42	-0.040
EFC	6.26	-0.027
EQC	6.05	-0.024
EFR	6.64	-0.036
EQR	6.82	-0.036

Note. EFF: Cold Leaf Extract; EQF: Hot Leaf Extract; EFC: Cold Peel Extract; EQC: Hot Peel Extract; EFR: Cold Root Extract; EQR: Hot Root Extract.

For allelopathy tests, it is important that the osmolarity levels are as near as possible to 0 MPa, as the solute level in the solution may negatively affect seed germinability (Góis, Torres, & Pereira, 2008). High levels of osmolarity can exert an osmotic pressure between the solution and the seeds, as a consequence, the water will not penetrate them, leading to the inhibition or retardation of germination (Ortiz, Gomes, Urbano, & Strapasson, 2014). Kappes, Andrade, Haga, Ferreira, and Arf (2010) observed that potentials above -0.3 MPa affect seed germination and vigor of *Z. mays*. Leal, Meiado, Lopes, and Leal (2013) found that saline stress negatively influenced the germinability of *C. procera* and completely inhibiting when the seeds were submitted to a concentration equal to or greater than -0.8 MPa.

In germination tests it is recommended that the pH values of the extracts are in the range of 6.0 to 7.5 as this is the ideal pH range for seed germination and observation of allelopathic effects (Larcher, 2004; Brasil, 2009). Therefore, the pH values obtained in this study are close to neutrality, so as not to interfere in the germination process, since both germination and seedling development can be negatively affected in conditions where the medium is extremely acidic or highly alkaline (Yamashita, Guimarães, Silva, Carvalho, & Camargo, 2009; Pacheco et al., 2017).

3.2 Percentage of Germination

The extracts of *D. araripensis* interfered negatively in the germination of *C. procera*, since on the 7th day the control group presented 78±2.3% of germinated seeds, whereas for the seeds submitted to *D. araripensis* extracts the highest germination percentage was 38±16.8%, verified in the seeds submitted to the cold extract of the roots (Figure 3). It was observed that cold (24±13.4%) and hot (17±8.8%) extracts of the stem bark and warm root extract (18±9.5%) interfered negatively more significant in the germinability of *C. procera* (Figure 3).

Similar results were obtained by Leandro et al. (2019) when analyzing the allelopathic effect of cold and hot extracts of the aerial parts and roots of *Libidibia ferrea* (Mart. ex Tul.) L.P. Queiroz (Fabaceae) on the germination and development of *C. procera*, where they observed the inhibition of the germination of the recipient species in all treatments tested.

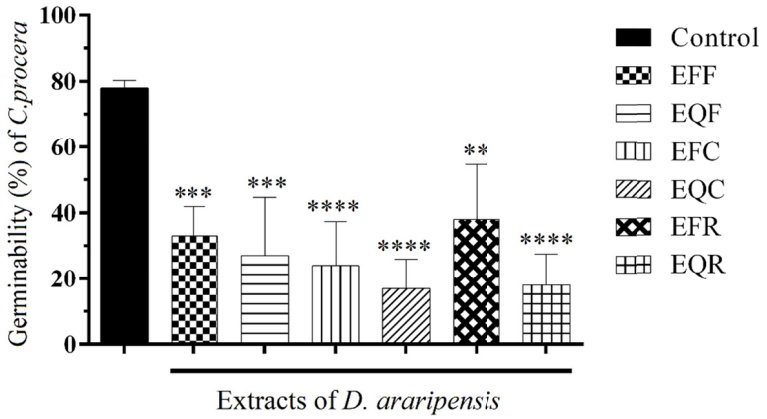

Figure 3. Percentage of germination of seeds of *C. procera* submitted to extracts of *D. araripensis.* Analysis of variance (ANOVA) One-way. Mean (±standard deviation). *$p < 0.05$ compared to control. EFF: Cold Leaf Extract; EQF: Hot Leaf Extract; EFC: Cold Peel Extract; EQC: Hot Peel Extract; EFR: Cold Root Extract; EQR: Hot Root Extract

As for germination the seeds of *Z. mays*, the tests showed a decrease in the percentage of germination in all treatments, but only the seeds submitted to the cold extract of the leaves of *D. araripensis* (41±11.4%) presented a significant difference when compared to the control (90±5.1%) (Figure 4).

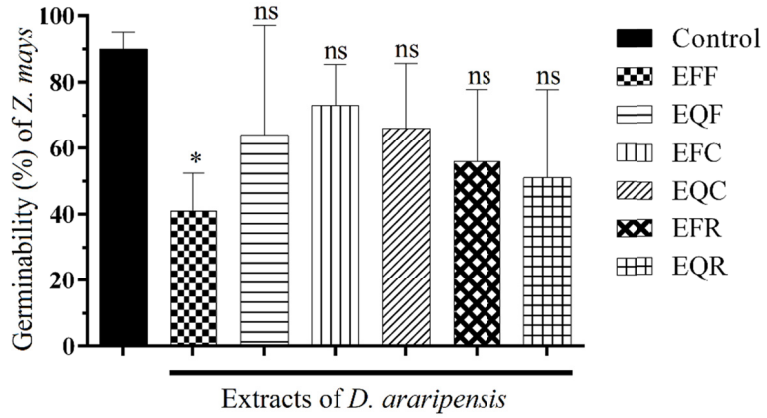

Figure 4. Percentage of germination of seeds of *Z. mays* submitted to extracts of *D. araripensis*. Analysis of variance (ANOVA) One-way. Mean (±standard deviation). *$p < 0.05$ compared to control. Analysis of variance (ANOVA) One-way. Mean (±standard deviation). ns: no statistical significance. *$p < 0.05$ compared to control. EFF: Cold Leaf Extract; EQF: Hot Leaf Extract; EFC: Cold Peel Extract; EQC: Hot Peel Extract; EFR: Cold Root Extract; EQR: Hot Root Extract

In studies carried out with extracts of *Mimosa tenuiflora* (Willd.) Poir. and *Amburana cearensis* (Allemão) A.C.Sm., inhibitory effects on the germination of *Z. mays* and other economically important species such as lettuce, sorghum and pigeon pea were also observed (Mano, 2006; Felix, 2012).

According to Ferreira (2004), the effects of the allelochemicals on the germination and/or development of the plant are secondary manifestations due to effects that occurred initially at the cellular and molecular level. The same authors also point out that changes in the germination pattern may result in effects on membrane permeability, DNA transcription and translation, in the operation of secondary messengers, respiration alteration, enzyme and receptor conformation, or the combination of these factors.

3.3 Emergency Speed Index (ESI)

The ESI of *C. procera* seeds was negatively affected in all treatments tested. It was verified that the seeds submitted to hot extracts of the stem bark (0.77±0.36) and hot extracts of roots (0.71±0.37) presented a lower emergency speed when compared to the control group (3.85±0.25) (Table 1).

According to Hoagland and Williams (2004), the delay in emergency speed is an indicator of the allelopathic effect on stretching and cell division. The same authors also observed that the delay can occur through the activation of mechanisms of cellular detoxification, so the time required for the activation of these mechanisms can lead to the retardation of germination. Changes in the speed of emergence can have serious ecological consequences, because seeds that germinate more slowly can give rise to small seedlings, thus increasing the probability of being attacked by microorganisms of the soil (Jefferson & Pennachio, 2003; Dadkhah & Asaadi, 2010; Oliveira, Coelho, Maia, Diógenes, & Medeiros Filho, 2012).

In the seeds of *Z. mays*, ESI delay was observed in all tested treatments, and this effect was more pronounced in the seeds submitted to the cold extract of the leaves and to the cold and hot extracts of the roots of *D. araripensis*, which differed statistically from the control group (4.61±0.22) (Table 1).

Table 1. Emergency Speed Index (ESI) of seeds of *Calotropis procera* (Aiton) W. T. Aiton and *Zea mays* L. submitted to extracts of *Dahlstedtia araripensis* (Benth.) M.J. Silva & A.M.G. Azevedo

Treatment	**ESI**	
	Calotropis procera	***Zea mays***
EFF	1.49±0.45b	1.65±0.55bc
EQF	1.42±0.75b	2.81±1.62ac
EFC	1.13±0.68b	3.42±0.77ac
EQC	0.77±0.36b	3.12±1.17ac
EFR	1.84±1.08b	2±0.82bc
EQR	0.71±0.37b	2.13±1.21bc
Control (H_2O)	3.85±0.25a	4.61±0.22a

Note. Means followed by the same column letter do not differ from each other at 5% probability, by the Tukey test. EFF: Cold Leaf Extract; EQF: Hot Leaf Extract; EFC: Cold Peel Extract; EQC: Hot Peel Extract; EFR: Cold Root Extract; EQR: Hot Root Extract.

Silva and Santos (2010) suggest that an extract of a certain plant organ can be more efficient in reducing the speed of emergency in comparison to another. This fact can be explained by the concentrations of the secondary metabolites present in the organ. These authors also indicate in their study with *Senna obtusifolia* (L.) H.S.Irwin & Barneby that the difference observed between leaf extracts in relation to stems and roots may be due not only to the concentration ofthe allelochemicals but, together or not with qualitative differences of such metabolites.

3.4 Growth of the Stem

As can be observed in Figure 5, the extracts of *D. araripensis* interfered negatively in the development of the *C. procera* seedlings, and this effect was significant when compared to the control (2.12±0.1 mm) in the seedlings submitted to the hot extract (0.85±0.3 mm) and cold (1.26±0.04 mm) of the roots and the hot extract of the stem bark (1.24±0.4 mm) of the said species.

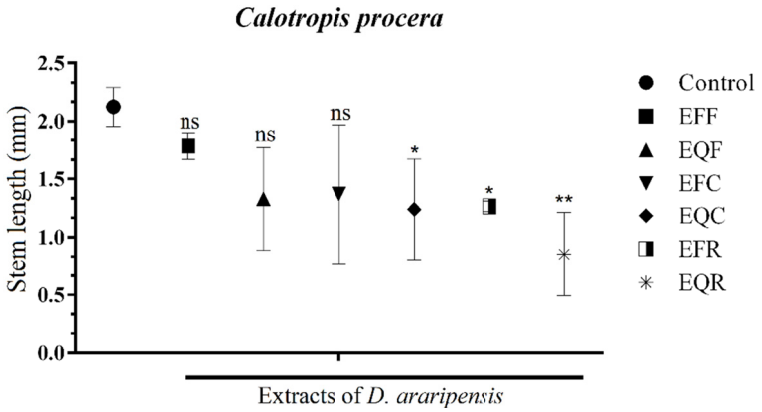

Figure 5. Growth of the stem of *C. procera* submitted to extracts of *D. araripensis*. Analysis of variance (ANOVA) One-way. Mean (± standard deviation). ns: no statistical significance. *$p < 0.05$ compared to control. EFF: Cold Leaf Extract; EQF: Hot Leaf Extract; EFC: Cold Peel Extract; EQC: Hot Peel Extract; EFR: Cold Root Extract; EQR: Hot Root Extract

Oliveira, Soares, and Isaias (2008) analyzed the allelopathic effects of aqueous extracts of healthy leaflets and branches of *Dahlstedtia muehlbergiana* (Hassl.) M. J. Silva and A. M. G. Azevedo observed, among other alterations, a marked decrease in the stem length of *Lactuta sativa* L., attributing this alteration to the presence of substances derived from the secondary metabolism of *D. muehlbergiana*.

Tests carried out with *Z. mays* seeds showed a significant decrease in thestem length of the seedlings subjected to cold leaf extract (0.91±0.4 mm) and to warm root extract (1.02±0.4 mm) of the study specie, when compared to the control group (1.87±0.3 mm) (Figure 6).

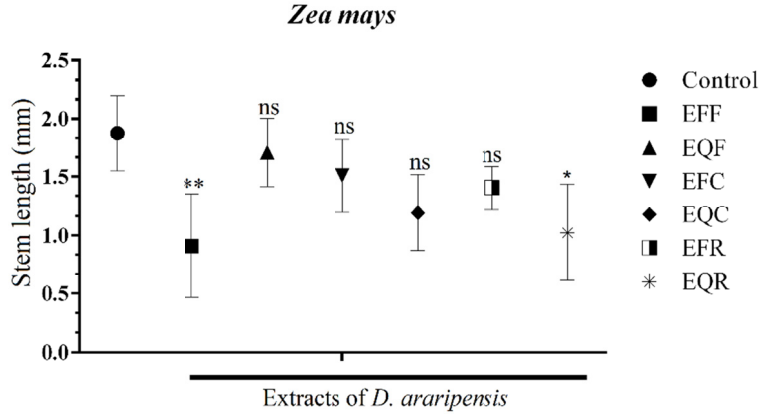

Figure 6. Growth of the stem of *Z. mays* submitted to extracts of *D. araripensis*. Analysis of variance (ANOVA) One-way. Mean (±standard deviation). ns: no statistical significance. *$p < 0.05$ compared to control. EFF: Cold Leaf Extract; EQF: Hot Leaf Extract; EFC: Cold Peel Extract; EQC: Hot Peel Extract; EFR: Cold Root Extract; EQR: Hot Root Extract

It was observed that the extracts of the distinct parts of *D. araripensis* interfered negatively on the development of the stem of the recipient species, also verifying that this effect occurred more sharply or not depending on the extract and the test species. This observation reinforces the thesis of Prati and Bossdorf (2004), stating that allelopathy is a type of species-specific relationship, that is, different species may respond differently to the presence of a same allelochemicals (Ferreira & Aquila, 2000; Navas & Pereira, 2016).

According to Almeida et al. (2008), all the organs of a plant have the potential to store allelochemicals, but the chemical nature and amount of these may vary with the age and organ of the plant. In this way, the species can present different allelopathic responses of compounds of different organs of the same plant (Oliveira et al., 2012).

3.5 Growth of the Root

The biometry of *C. procera* rootlets submitted to extracts of *D. araripensis* showed a decrease in the length of these structures in all treatments, but only the seedlings subjected to hot root extract (1.51±0.5 mm) showed a significant result when compared to control (3.89±0.2 mm) (Figure 7).

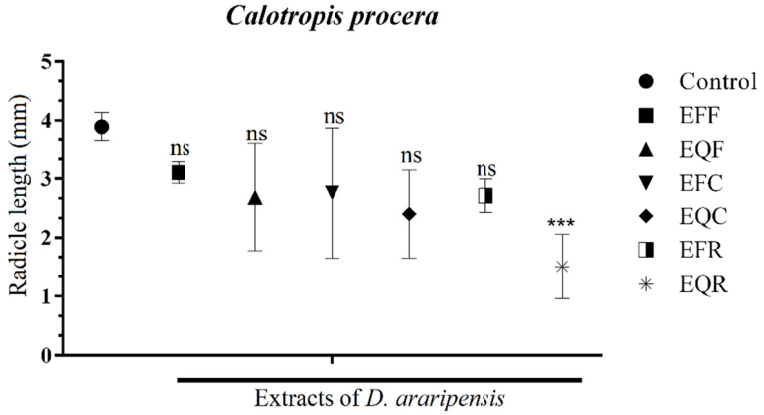

Figure 7. Growth of the root of *Z. mays* submitted to extracts of *D. araripensis.* Analysis of variance (ANOVA) One-way. Mean (±standard deviation). ns: no statistical significance. *$p < 0.05$ compared to control. EFF: Cold Leaf Extract; EQF: Hot Leaf Extract; EFC: Cold Peel Extract; EQC: Hot Peel Extract; EFR: Cold Root Extract; EQR: Hot Root Extract

In relation to the biometry of the rootlets of *Z. mays*, it was verified that the extracts of the donor species promoted a significant reduction in the length of said structure, and the cold extract of the roots (4.59±0.7 mm) was the only which did not present significant activity when compared to the treatment using only distilled water (6.67±0.8 mm) (Figure 8).

The inhibitory effect observed on primary root growth, reported frequently in the literature, is considered one of the characteristics that best indicates the phytotoxicity of plant extracts (Maraschin-Silva & Aquila, 2005; Suzuki, Zonetti, Ferrarese, & Ferrarese-Filho, 2008). Some authors suggest that the negative effect observed in the root occurs due to the more intimate contact of this organ with the substrate, and to the fact that it is responsible for absorbing the bioactive compounds present in the environment (Ferreira & Aquila, 2000; Turk & Tawaha, 2002; Rice, 2012).

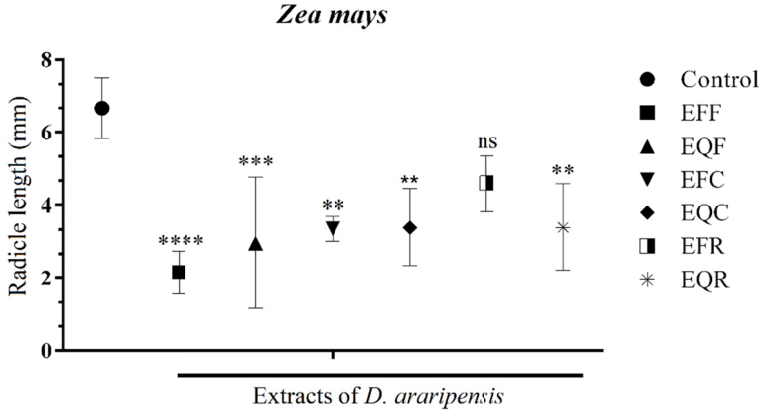

Figure 8. Growth of the root of *Z. mays* seedlings submitted to extracts of *D. araripensis.* Analysis of variance (ANOVA) One-way. Mean (±standard deviation). ns: no statistical significance. *$p < 0.05$ compared to control. EFF: Cold Leaf Extract; EQF: Hot Leaf Extract; EFC: Cold Peel Extract; EQC: Hot Peel Extract; EFR: Cold Root Extract; EQR: Hot Root Extract

The allelochemicals can affect certain enzymatic activities and depolarize rapidly the membranes of the root cells, which results in the increase in the permeability of the membranes, thus blocking the absorption of nutrients by the plants, which consequently leads to a reduction of root growth (Yu, Ye, Zhang, & Hu, 2003; Weir, Park, & Vivanco, 2004; Santos & Resende, 2008; Rice, 2012).

In the present study, it was found that for the length of the *Z. mays* radicle and for the other variables, the cold extract of the leaves of *D. araripensis* caused a more pronounced inhibitory effect on the recipient species compared to the other treatments. This shows the need to test different forms of preparation for the same plant, since, depending on the type of treatment used to extract the compounds, the results generated may be different, which provides more information on the performance of its secondary metabolites (Costalonga, 2009).

3.6 Phytochemical Analysis

The phytochemical analysis of the extracts of *D. araripensis* revealed the presence of condensed tannins and several constituents belonging to the flavonoid group in all extracts of the aerial parts and roots of the species (Table 3).

Among the phenolic compounds belonging to the class of flavonoids, the phytochemical prospection of extracts revealed the presence of catechins, chalcones, aurones, flavones, flavonols, xanthones, flavonones, flavononols and leucoanthocyanidins (Table 3).

Table 3. Class of secondary metabolites found in the extracts of *D. araripensis* used in the germination bioassays of *C. procera* and *Z. mays*

Class	**Treatment**					
	EFF	**EQF**	**EFC**	**EQC**	**EFR**	**EQR**
Alkaloids	-	-	-	-	-	-
Anthocyanins and Anthocyanidins	-	-	-	-	-	-
Catechins	+	+	+	+	+	+
Chalcones and Auronas	+	+	+	+	+	+
Phenols	-	-	-	-	-	-
Flavones, flavonols and xanthones	+	+	+	+	+	+
Flavonones	+	+	+	+	+	+
Flavononols	+	+	+	+	+	+
Leucoantocianidines	+	+	+	+	+	+
Condensed Tannins	+	+	+	+	+	+
Hydrolysabletannins	-	-	-	-	-	-

Note. (+): present; (-) absent. EFF: Cold Leaf Extract; EQF: Hot Leaf Extract; EFC: Cold Peel Extract; EQC: Hot Peel Extract; EFR: Cold Root Extract; EQR: Hot Root Extract.

Studies on the phytochemical prospection of plant extracts of *D. araripensis* showed the presence of flavonoid substances (chalcones, flavones and flavanones) from researches with different parts of the plant (Lima, 2007; Almeida et al., 2015), corroborating with the results found in this study.

Bibliographical research on chemical constituents already isolated from species of the genus *Dahlstedtia*, showed that flavonoids are among the compounds found in greater profusion, especially chalcones, flavones and flavanones (Magalhães, Tozzi, Magalhães, Blanco, & Soriano, 2004; Lima, 2007; Lima et al., 2009), and these compounds are characterized by the presence of prenylated groups, which are indicators of the evolution of these species (Garcez, Scramin, Nascimento, & Mors, 1988). According to Simões et al. (2010), flavonoids represent one of the most important and diverse groups among the secondary metabolites present in plants, since it plays a fundamental role in the protection of the plant in response to microbial attack and against ultraviolet irradiation, protecting the underlying photosynthetic tissues from damage (Harborne & Williams, 2000; Lattanzio, Kroon, Quideau, & Treutter, 2008; Ignat, Volf, & Popa, 2011).

Flavonoids may interfere with pollen tube growth, influence plant development, control auxin transport, and have allelopathic effects, being able to inhibit seed germination and plant growth (Shimoji & Yamasaki, 2005; Peer & Murphy, 2007; Edwards et al., 2008; Agati & Tattini, 2010).

The tannins according to Monteiro, Albuquerque, Araújo, and Amorim (2005), are involved in the plant defense mechanism against attacks of fungi, viruses, bacteria and herbivores being the compounds with allelopathic properties more commonly found in plant extracts (Mendonça, 2008; Vaca-Sánchez, González-Rodríguez, Maldonado-López, Fernandes, & Cuevas-Reyes, 2017). The condensed tannins are composed of monomers known as flavonoids, and according to Rice (2012), may present allelopathic effects on seed germination and inhibition of seedling growth (Silva, 2007).

Based on the results described, it is probable that the secondary metabolites of *D. araripensis* may be responsible for their ability to inhibit seed germination and seedling development of the test species (*C. procera* and *Z. mays*), being able to be used as natural herbicides.

5. Conclusion

In reforestation programs, *D. araripensis* seeds should not be sown near maize plantations, since the allelochemicals released into the environment may negatively interfere with the crop. Therefore, research is needed on the isolation and purification of these compounds in order to identify the specific substances for the action detected in the tests, with a view to their future use as a bioherbicide.

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