Ensaios e Ciência
ISSN 1415-6938 e ISSN 2178-695X

DOI: 10.17921/1415-6938.2025v29n3p694-701

Allelopathic Potential of the Invasive Exotic Species *Cryptostegia madagascariensis* Bojer on the Germination of Native Cactus Caatinga Species

Potencial Alelopático da Espécie Exótica Invasora *Cryptostegia madagascariensis* Bojer Sobre a Germinação de Espécies Nativas de Cactáceas da Caatinga

Receveid: February 4, 2025
Accepted: July 22, 2025

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Abstract

Allelopathy is considered a competitive mechanism. Thus, this study aimed to evaluate the allelopathic effect of *C. madagascariensis* on the germination of *Xiquexique gounellei* and *Pilosocereus catingicola*. Initially, *C. madagascariensis* leaves were dried, ground, and used to prepare extracts at concentrations of 0%, 5%, 10%, 15%, and 20%. The experiment followed a completely randomized design (CRD) with four replications of 25 seeds for each native species. Germination was monitored daily. Based on the collected data, germination percentage, germination time, emergence speed index, and uniformity coefficient were calculated and subjected to analysis of variance followed by Tukey's mean test ($p \leq 0.05$). The extracts of *C. madagascariensis* affected the germination percentage of *X. gounellei* and *P. catingicola* from a concentration of 10%. The emergence speed index of *X. gounellei* and *P. catingicola* seeds was influenced at concentrations of 5% and 10%, respectively. *X. gounellei* exhibited a reduced uniformity coefficient at 20%, whereas

P. catingicola seeds remained unaffected, as did the germination time of both species. These findings demonstrate that *C. madagascariensis* leaves contain allelochemicals capable of impacting the native species germination. Therefore, the removal of this invasive exotic species is essential to mitigate its ecological damage to the Caatinga biome.

Keywords: Biological Invasion. Allelopathy. Chemical Compounds.

Resumo

A alelopatia é considerada um mecanismo competitivo. Dessa forma objetivou-se avaliar o efeito alelopático de *C. madagascariensis* sobre a germinação de *Xiquexique gounellei* e *Pilosocereus catingicola*. Inicialmente folhas de *C. madagascariensis* foram secas, trituradas e utilizadas para preparar os extratos nas concentrações de 0%, 5%, 10%, 15% e 20%. O delineamento experimental foi o inteiramente casualizado (DIC) com quatro repetições de 25 sementes de cada espécie nativa. O experimento foi avaliado diariamente. Com os dados foi calculada a porcentagem de germinação, o tempo, o índice de velocidade de emergência e o coeficiente de uniformidade que foram submetidos à análise de variância seguida de teste de média de Tukey ($p \leq 0,05$). Os extratos de *C. madagascariensis* interferiram na porcentagem de germinação de *X. gounellei* e *P. catingicola* desde a concentração de 10%. O índice de velocidade de emergência das sementes de *X. gounellei* e de *P. catingicola* foram afetadas a partir da concentração de 5% e 10%, respectivamente. *X. gounellei* teve o coeficiente de uniformidade reduzido na concentração de 20%, já as sementes de *P. catingicola* não foram afetadas, assim como o tempo de germinação de ambas as espécies. Esses resultados demonstram que as folhas de *C. madagascariensis* possuem aleloquímicos capazes de afetar a germinação de espécies nativas. Sendo assim, é imprescindível a remoção dessa espécie exótica invasora, a fim de reduzir os danos ecológicos ocasionados por ela na Caatinga.

Palavras-chave: Invasão Biológica. Alelopatia. Compostos Químicos.

1 Introduction

The introduction of species outside their native range, whether intentional or accidental, can trigger Biological Invasion (BI) processes (Gentili *et al*., 2021; Lockwood; Howarth; Purcell, 2001). This occurs when the introduced species is capable of adapting to the biotic and abiotic conditions of the new environment, allowing it to reproduce and spread to new areas, causing negative impacts (Blackburn *et al*., 2011; Moro *et al*., 2012; Roy *et al*., 2023). Among the ecological impacts, biodiversity loss (Dechoum *et al*., 2024) and changes in the hydrological cycle and nutrient cycling (Ziller, 2016) stand out.

One of the mechanisms used by invasive alien species during the BI process is allelopathy. According to Ferguson, Rathinasabapathi, and Chase (2013), allelochemicals can inhibit or reduce germination and affect the growth of other species. As such, many non-native species are potentially allelopathic (Araújo *et al*., 2013; Costalonga; Batitucci, 2020; Hierro; Callaway, 2003; Santos *et al*., 2023), including *Hyparrhenia rufa* (Nees) Stapf (Santos *et al*., 2023), *Artocarpus heterophyllus* Lam.

(Costalonga; Batitucci, 2020), *Cenchrus ciliaris* L. (Araújo *et al*., 2013), and *Leucaena leucocephala* (Lam.) (Mauli *et al*., 2009; Ribeiro *et al*., 2019).

One invasive alien species that has been causing negative impacts on the caatinga native vegetation is *Cryptostegia madagascariensis* Bojer (commonly known as "unha-do-cão") (Sousa; Andrade; Xavier, 2016; Souza *et al*., 2017a). Native to Madagascar, it can reduce the natural biodiversity of the invaded environment (National Database of Invasive Alien Species; Horus Institute for Environmental Development and Conservation, 2024).

In light of the above, the objective of the present study was to evaluate the allelopathic potential of the invasive alien species *Cryptostegia madagascariensis* on the germination of native Cactaceae Caatinga species: *Xiquexique gounellei* (F.A.C. Weber) Lavor & Calvente subsp. *gounellei* and *Pilosocereus catingicola* subsp. *salvadorensis* (Werderm.) Zappi.

2 Material and Methods

The biological materials (leaves of the invasive alien species and seeds of the native species) used in the experiments were collected in Canindé de São Francisco, SE, Brazil (9°33'13.4"S, 37°41'13.5"W). The collected leaves of *Cryptostegia madagascariensis* were dried at an average temperature of 50 °C in a forced-air oven. Subsequently, they were ground and used to prepare aqueous extracts at concentrations of 5%, 10%, 15%, and 20%, in addition to the control (deionized water), and then stored in containers wrapped in aluminum foil.

After 24 hours of storage, the experiments were set up at the Laboratory of Ecology and Biodiversity Conservation (LECoB) at Universidade Federal de Sergipe, Professor Alberto Carvalho Campus, Itabaiana, Sergipe. A completely randomized design (CRD) was used, with four replicates of 25 seeds for each treatment. Seeds of *Xiquexique gounellei* were used in one experiment, and seeds of *Pilosocereus catingicola* in another. The seeds were placed in acrylic boxes lined with two germitest papers, moistened with the respective extracts or water (control).

After setting up the experiment, each acrylic box was weighed, and every three days the water lost due to evaporation was replenished. The bioassay was kept on the laboratory bench. During the experimental period, the average temperature was 22 ± 1 °C, and the average relative humidity was 74 ± 6%.

Daily readings were taken until the experiment stabilized (five consecutive days without new changes). Based on the collected data, the following parameters were calculated: germination

percentage (%G), angular coefficient of uniformity (ACU), mean germination time (MGT), and germination speed index (GSI). These variables were subjected to analysis of variance (ANOVA), followed by Tukey's test for mean comparison ($p \leq 0.05$) (Tukey, 1959). Statistical analyses were performed using SISVAR software version 5.6 (Ferreira, 2011).

To assess the osmotic effect on the results, the pH and electrical conductivity of the extracts were measured (Table 1). The calculations were based on the table by Villela, Doni Filho, and Sequeira (1991), and were used for preparing the PEG (polyethylene glycol 6000) solution. Subsequently, new bioassays were assembled using the same methodological procedures described above.

Table 1 – pH, electrical conductivity, and osmotic potential values of leave extracts of *Cryptostegia madagascariensis* Bojer

Concentrations (%)	pH	Electrical Conductivity (mS cm^{-1})	Osmotic Potential (MPa)
5%	5.37	7.42	0.0003
10%	5.44	13.85	0.0005
15%	5.33	19.42	0.0007
20%	5.42	23.95	0.0009

Source: research data.

3 Results and Discussion

The aqueous extracts of *C. madagascariensis* affected the germination percentage of *X. gounellei* ($F = 45.462$; $p \leq 0.01$) and *P. catingicola* ($F = 5.107$; $p < 0.01$) starting at the 10% concentration. The germination speed index of *X. gounellei* seeds was affected ($F = 95.687$; $p \leq 0.01$) from the 5% concentration onward, and that of *P. catingicola* ($F = 45.501$; $p \leq 0.01$) from the 10% concentration. The angular coefficient of uniformity of *X. gounellei* ($F = 6.473$; $p < 0.01$) was only affected at the 20% concentration, where total inhibition occurred; however, it was not affected in *P. catingicola* ($F = 0.515$; $p > 0.7257$). For both species, the mean germination time showed no significant changes (*X. gounellei* – $F = 1.761$; $p > 0.1893$; *P. catingicola* – $F = 1.325$; $p > 0.206$) (Table 2).

Table 2 – Mean and standard deviation of germination percentage (G, %), mean germination time (MGT), germination speed index (GSI), and angular coefficient of uniformity (ACU) of *Xiquexique gounellei* (F.A.C. Weber) Lavor & Calvente subsp. *gounellei* and *Pilosocereus catingicola* subsp. *salvadorensis* (Werderm.) Zappi, subjected to aqueous leaf extracts of *Cryptostegia madagascariensis* Bojer

Concentrations	G(%)	MGT	GSI	ACU
Xiquexique gounellei				
0%	75±6.83c	7.21±0.88a	3.0±0.40c	0.13±0.05b
5%	47±13.21c	8.95±0.58a	1.49±0.38b	0.09±0.01 ba
10%	18±5.16b	11.31±2.15a	0.43±0.08a	0.12±0.04b
15%	4±5.65a	5.33±6.18a	0.09±0.13a	0.03±0.07ba
20%	1±2a	3.75±7.5a	0.01±0.03a	0±0a
Pilosocereus catingicola				
0%	93±1.91b	4.30±0.43a	6.22±0.17b	0.78±0.27a
5%	95±1.91b	5.36±0.16a	4.85±0.22b	0.28±0.03a
10%	78±18.07ba	9.87±1.11a	1.64±0.75a	2.04±1.91a
15%	23±18.06a	8.46±4.89a	0.34±0.27a	1.07±0.70a
20%	31±16.36 ba	12.65±4.23a	0.46±0.24a	0.64±0.32a

Means followed by the same letters do not differ from each other according to Tukey's test ($p \leq 0.05$).
Source: research data.

Statistical analyses showed that *C. madagascariensis* affects the germination of *Xiquexique gounellei* and *Pilosocereus catingicola* seeds (Table 2). A study conducted with the species *Lactuca sativa* L. (Araújo *et al*., 2017) presented similar results. However, the study conducted with *Libidibia ferrea* (Mart. ex Tul.) L.P. Queiroz and *Mimosa caesalpiniifolia* Benth. showed different outcomes from those observed in the present work (Araújo *et al*., 2017). Seifu *et al*. (2023) observed allelopathic effects in the congener *Cryptostegia grandiflora* R.Br. on the cultivated species *Linum usitatissimum* L. and the wild species *Guizotia abyssinica* Cass.

The leaves of *C. madagascariensis* contain quercetin 3-O-gal-1,6-rhm and caffeic acid hexose (Araújo, 2017). According to Santos *et al*. (2011), these compounds are considered allelopathic substances, since quercetin belongs to the flavonoid group and caffeic acid to the phenolic acid group. Therefore, these substances may be related to the results obtained in this study.

The Novel Weapons Hypothesis proposes that exotic species possess allelopathic, defensive, and/or antimicrobial compounds to which native organisms are not adapted (Callaway; Aschehoug,

2000). These compounds exert strong inhibitory effects on native plants or soil microbes (Mallik; Pellissier, 2000), giving invasive alien species a competitive advantage in the invaded ecosystems (Callaway *et al*., 2008; Kim; Eun, 2011). The results of the present study support this hypothesis and show that allelochemical compounds are possibly an important factor in the invasion of *C. madagascariensis* in the Caatinga.

Furthermore, other studies, such as that of Araújo *et al*. (2017), which evaluated the effect of *C. madagascariensis* on lettuce seed germination, also highlight allelopathy as a key mechanism that enhances the species invasiveness by reducing the seed bank diversity (Sousa *et al*., 2017b) and altering factors such as soil nutrients and the growth of other species (Souza *et al*., 2016). In addition, the species also affects multiple environmental factors, such as light availability, leading to reduced species richness and impacting the natural regeneration process (Sousa; Andrade; Xavier, 2016; Barbosa *et al*., 2019).

4 Conclusion

The invasive alien species *Cryptostegia madagascariensis* has varying inhibitory effects on the germination of *Xiquexique gounellei* and *Pilosocereus catingicola*, with more pronounced effects on *X. gounellei*. Allelopathy may be one of the mechanisms responsible for the success of this allochthonous species in the Caatinga biome.

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