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Micorrizas em *Cynophalla flexuosa* e *Cratylia argentea*: Perspectivas Ecofisiológicas e Nutricionais

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A B S T R A C T

This research examines the impact of mycorrhizae on the eco-physiological and nutritional aspects of *Cynophalla flexuosa* (L.) and *Cratylia argentea* in saline soil environments. Beginning with the challenges in semiarid regions, particularly drought and soil salinization, it aims to understand mycorrhizae's role in plant adaptation and performance. Through a comprehensive literature review, the study explores plant-fungus interactions, emphasizing mycorrhizae's benefits in nutrient absorption and eco-physiological resilience. The findings suggest that mycorrhizae enhance plant adaptation to saline stress, aiding nutrient uptake and supporting plant survival in harsh conditions. This adaptation is crucial for food security and sustainable development in semiarid areas. The research highlights the importance of mycorrhizae in supporting biodiversity and agricultural productivity under saline stress, calling for further research and practical applications to maximize their potential in agriculture and natural resource management. The study can improve plant adaptation to environmental stress, optimize resource use, and promote sustainable agricultural practices.

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RESUME

Esta pesquisa examina o impacto das micorrizas nos aspectos ecofisiológicos e nutricionais de *Cynophalla flexuosa* (L.) e *Cratylia argentea* em ambientes de solo salino. A partir dos desafios das regiões semiáridas, particularmente a seca e a salinização do solo, o objetivo é entender o papel das micorrizas na adaptação e desempenho das plantas. Por meio de uma revisão abrangente da literatura, o estudo explora as interações planta-fungo, enfatizando os benefícios das micorrizas na absorção de nutrientes e na resiliência ecofisiológica. Os resultados sugerem que as micorrizas melhoram a adaptação das plantas ao estresse salino, auxiliando a absorção de nutrientes e apoiando a sobrevivência das plantas em condições adversas. Essa adaptação é crucial para a segurança alimentar e o desenvolvimento sustentável em áreas semiáridas. A pesquisa destaca a importância das micorrizas no apoio à biodiversidade e à produtividade agrícola sob estresse salino, ressaltando a necessidade de mais pesquisas e aplicações práticas para maximizar seu potencial na agricultura e no manejo de recursos naturais. O estudo pode melhorar a adaptação de plantas à estresse ambiental, otimizar o uso de recursos e promover práticas agrícolas sustentáveis.

Keywords:
Nutrição de Plantas,
Salinização do Solo,
Semiárido,
Plantas.

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Introduction

The semi-arid region is characterized by high variability in its natural conditions, such as topography, climate, soil structure, among others (Castro, 2012). According to Manavalan et al. (2019), drought is one of the main factors limiting plant biomass, as well as species distribution and biodiversity in ecosystems.

Moreover, soil salinization is a major environmental concern for biodiversity of both fauna and flora, as this soil condition reduces its physical, chemical, and biological properties, leading to a generalized reduction in vegetation at the base of the food chain (Cavalcante et al., 2010). The fact is that these environments end up accumulating salts, released from the parent material, irrigation, and improper use of agricultural fertilizers, with the predominance of the release of cations Ca^2, Mg^2, Na^2, and K and anions Cl, SO^2, HCO, and CO^2 in the soil (Ribeiro et al., 2009; Lima junior & Silva, 2010). Furthermore, the salinity in water is one of the limiting factors for plant survival, as it reduces osmotic and water potential, causing physiological disturbances due to poor availability of water and nutrients, making the search for alternatives to mitigate the effects of salts on plants a key factor (Freire & Nascimento, 2018; Alves et al., 2011; Farias et al., 2009).

The need to evaluate variables related to saline stress constitutes an effective criterion in the selection and identification of tolerant plants for deployment in saline environments (Chaum & Kirdmanee, 2009; Pandolfi et al., 2012). Consequently, the removal of salts from the soil by plants significantly contributes to the phytoremediation process, especially for species with forage potential, as their harvested parts do not return to the soil (Gharaibeth et al., 2011).

Native plants with forage potential exhibit a great biological diversity and are an important nutritional food source in the semi-arid region, leading to studies on their nutritional aspects. Additionally, their xerophytic character grants them adaptations to survive prolonged drought periods (Cassuce, 2012; Lacerda et al., 2015). Among the conditions imposed by the environment, the colonization of native plants with Arbuscular Mycorrhizal Fungi (AMF) has shown promising results in the establishment and performance of species in salt-affected areas (Lucio et al., 2013). ´ Despite the Caatinga vegetation presenting a wide variety of native species with forage potential, their utilization has been employed without adequate knowledge of their productive potential and with almost no environmental control techniques, indicating a need for further research in this area (Lacerda et al., 2015).

The efficiency of AMF varies, with each host species having a degree of dependency. Therefore, it is recommended to study different AMF under various soil conditions to select efficient species for plant development and nutritional benefit (Balota et al., 2011).

Given these conditions, the use of AMF has been an alternative in minimizing the effects of saline stress on plants and the presence of toxic forms of salts or nutrients in the soil, with favorable responses in eco-physiological aspects (Lucio et al., 2013). According to Dodd and P´erez-Alfocea (2012), in saline soils, the use of AMF in root colonization improves nutrient absorption, translocation, and nutritional efficiency, as well as soil structure, favoring plant growth. Despite the contributions of AMF to plant colonization and establishment under saline stress conditions, there are few reports in the literature, presenting highly varied results (Lucio et al., 2013).

This study aims to provide a comprehensive perspective on the influence of fungi on the eco-physiological and nutritional aspects of *Cynophalla flexuosa* (L.) and *Cratylia* argentea under soil salinization conditions.

Methodology

To identify relevant studies on the influence of mycorrhizae on the eco-physiological and nutritional aspects of *Cynophalla flexuosa* (L.) and *Cratylia argentea*, major scientific research platforms were used, including PubMed, Web of Science, Scopus, and Google Scholar. These platforms were selected due to their comprehensive coverage and diversity of academic sources, allowing for an extensive and thorough search of the available literature on the topic.

The keywords used in the search were selected based on terms relevant to the topic of interest. The main keywords included "mycorrhizae," "*Cynophalla flexuosa*," "*Cratylia argentea*," "eco-physiology," "plant nutrition," "plant-fungus interaction," "soil salinization," and "forage potential." Combining these keywords allowed for a broad and specific search of the literature related to the influence of mycorrhizae on these two plant species, considering both eco-physiological and nutritional aspects.

The inclusion criteria for selecting studies were established to ensure the relevance and quality of the reviewed articles. Studies specifically addressing the interaction between mycorrhizae and the species of interest, concerning eco-physiological and nutritional aspects, were considered. Peer-reviewed journal articles, dissertations, theses, and books that provided pertinent information within the scope of the study were included.

This literature review aims to provide a comprehensive and up-to-date analysis of the influence of mycorrhizae on the eco-physiological and nutritional aspects of *Cynophalla flexuosa* (L.) and *Cratylia argentea*. The rationale for conducting this review lies in the importance of these two plant species in various contexts, such as agriculture, ecosystem restoration, and recovery of degraded areas. Understanding how mycorrhizae influence the performance of these plants can provide valuable insights for optimizing their cultivation and use in sustainable soil management practices.

Furthermore, the significance of this study lies in its contribution to advancing knowledge about the interaction between mycorrhizae and forage potential species, particularly concerning their eco-physiology and nutrition. Additionally, the innovation of this study is in its integrated approach to different information sources and the synthesis of available evidence in the scientific literature, providing a holistic and updated view of the topic.

Development

Importance of Mycorrhizae in Plant Nutrition and Eco-physiology

Mycorrhizae are symbiotic associations between soil fungi and plant roots, classified into different types based on their structure and root colonization forms. The main types of mycorrhizae include arbuscular mycorrhizae, ectomycorrhizae, and endomycorrhizae, each with specific plant-fungal interaction characteristics. This diversity allows effective plant adaptation to environmental and soil conditions (Bisca et al., 2023; Pereira et al., 2021).

Mycorrhizae play a crucial role in plant nutrition and eco-physiology by establishing a mutualistic symbiosis with host roots. Through this symbiotic relationship, they supply essential nutrients such as phosphorus, nitrogen, potassium, and other mineral elements to plants in exchange for carbohydrates produced by photosynthesis. This exchange benefits both mycorrhizae and plants, enhancing nutrient absorption efficiency and improving plant development (Sampaio, 2021).

Mycorrhizal colonization occurs through complex mechanisms involving recognition between fungi and plant roots, followed by fungal penetration into the root cortex and the development of specialized structures like arbuscules and vesicles. These structures facilitate nutrient exchange between the symbiotic partners, promoting plant growth and health. The plant-fungal interaction in mycorrhizae is regulated by a variety of chemical and genetic signals that influence the specificity and efficiency of the symbiosis (Colodete et al., 2014; Silva, 2005).

In the semi-arid context, where soil conditions are often challenging due to low fertility and water availability, mycorrhizae play a crucial role in plant survival and productivity. These symbiotic organisms improve water and nutrient absorption by plants, allowing greater drought resistance and better adaptation to adverse environmental conditions (Costa, 2010; Moreira et al., 2019). Additionally, mycorrhizae can contribute to the recovery of degraded areas and the conservation of biodiversity in semi-arid regions (Silva, 2005).

In agriculture, the use of mycorrhizae is increasingly recognized as an effective strategy to enhance crop productivity sustainably. By reducing dependence on chemical fertilizers and improving nutrient use efficiency, mycorrhizae can help reduce the environmental impacts of agriculture and promote food security in vulnerable regions such as the semi-arid areas (Costa, 2010; Macedo et al., 2022).

Despite significant advances in understanding the mechanisms and importance of mycorrhizae, many challenges remain in research in this field. Issues related to mycorrhizal diversity, plant-fungal interactions, and the effects of mycorrhizae on soil microbial communities continue to be areas of interest and investigation. Deepening knowledge about mycorrhizae has the potential to open new perspectives for sustainable agriculture and ecosystem conservation in semi-arid environments and beyond (Pereira et al. 2021; Costa, 2010; Marques Cardozo Junior et al., 2023; Moreira et al., 2019; Macedo et al., 2022).

***Eco-physiology of** Cynophalla flexuosa (L.)* ***and** Cratylia argentea*

The eco-physiology of C*ynophalla flexuosa* (L.) and C*ratylia argentea* plays a fundamental role in understanding these species' adaptation to the environmental conditions of the semi-arid region. Studies in this area have significantly contributed to elucidating the physiological mechanisms underlying these plants' tolerance to water scarcity, high light intensity, and high temperatures typical of this ecosystem. Additionally, the eco-physiology of these species provides valuable insights for developing management and conservation strategies in semi-arid environments (Moreira et al., 1997; Macedo et al., 2022).

Understanding the eco-physiology of C*ynophalla flexuosa* (L.) and C*ratylia argentea* is essential for identifying adaptive traits that confer competitive advantages to these plants under environmental stress conditions (Colodete et al., 2014). Mechanisms such as water use efficiency, transpiration regulation, and photosynthesis capacity under high light conditions are key aspects that influence the survival and reproductive success of these species in the semi-arid region. Therefore, detailed study of these plants' eco-physiology is crucial for biodiversity conservation and promoting resilience in semi-arid ecosystems in the face of climate change (Macedo et al., 2022).

In the semi-arid context, where climatic conditions are often challenging and unpredictable, the eco-physiology of C*ynophalla flexuosa* (L.) and C*ratylia argentea* assumes even greater importance. These species, known for their adaptability to arid and semiarid environments, play a vital role in maintaining biodiversity and providing essential ecosystem services, such as soil erosion protection and hydrological cycle regulation (Figueiredo, 2016). Therefore, studying and understanding the eco-physiology of these species is fundamental for the sustainable management of natural resources and the conservation of native vegetation in semi-arid areas (Miguel et al., 2014; Gil, 2009).

***Nutrition of** Cynophalla flexuosa (L.)* ***and** Cratylia argentea*

Understanding the specific nutritional requirements of plants, including essential macronutrients and micronutrients, plays a critical role in optimizing the growth and development of C*ynophalla flexuosa* (L.) and C*ratylia argentea*. These species exhibit distinct nutritional demands, reflecting their ecological and physiological adaptive strategies. Detailed knowledge of these plants' specific nutritional requirements is essential for proper soil nutrient management and developing fertilization strategies that enhance their productivity and resilience in semi-arid environments (Santos et al., 2023; Costa et al., 2024).

The presence of mycorrhizae in the roots of C*ynophalla flexuosa* (L.) and C*ratylia argentea* can also influence the availability of micronutrients such as iron, zinc, and manganese, which play essential roles in various plant physiological processes. Mycorrhizal colonization can increase the absorption and mobility of these micronutrients in the soil, contributing to plant health and development under nutritional stress conditions. Therefore, understanding the role of mycorrhizae in nutrient absorption and availability is crucial for maximizing the productive potential and sustainability of these species in semi-arid environments (Lima, 2020; Santos et al., 2023).

Influence of *Mycorrhizae* **on** *Cynophalla flexuosa (L.)* **and** *Cratylia argentea*

The influence of mycorrhizae on C*ynophalla flexuosa* (L.) and C*ratylia argentea* is significant, as these plants rely heavily on this symbiosis for efficient nutrient absorption and increased resistance to environmental stresses. The presence of mycorrhizae in these species' roots contributes to greater availability of essential nutrients, such as phosphorus and nitrogen, which are often limiting in semi-arid soils. Additionally, mycorrhizae play a crucial role in improving the plants' ability to cope with adverse conditions such as drought and salinity, thus promoting their survival and growth in these areas (Lima, 2020; Santos & Silva, 2024).

Moreover, the symbiosis with mycorrhizae can positively affect other aspects of the physiology and development of C*ynophalla flexuosa* (L.) and C*ratylia argentea,* including oxidative stress response, water balance regulation, and pathogen resistance. This plant-fungal interaction not only improves plant health and vitality but can also have beneficial effects on agricultural product quality, such as high-quality forage production in agro-pastoral systems. Thus, the influence of mycorrhizae on these species stands out as an essential component for sustainability and productivity in semi-arid environments (Costa et al., 2024; Santos et al., 2023; Lima, 2020).

Future Perspectives and Practical Applications

The study of mycorrhizae in C*ynophalla flexuosa* (L.) and C*ratylia argentea* opens doors to a range of future perspectives and practical applications that could benefit agriculture and conservation in semi-arid environments. One such perspective is ongoing research into the molecular mechanisms underlying plant-fungal interactions, aiming to better understand the processes involved in symbiosis and identify potential targets for genetic manipulation of plants to enhance their nutrient absorption efficiency (Mattar et al., 2022; Camara et al., 2024; Valles-De La Mora et al., 2017).

Furthermore, developing technologies and management practices that promote mycorrhizal colonization in C*ynophalla flexuosa* (L.) and C*ratylia argentea* could represent a valuable practical application. This may include selecting cultivars with higher mycorrhizal affinity, using specific mycorrhizal inoculants, and implementing soil management systems that favor the development and activity of mycorrhizae (Teixeira et al., 2023).

Another promising perspective is the use of mycorrhizae as bioindicators of soil health and environmental quality in agricultural systems and conservation areas. Monitoring mycorrhizal colonization can provide important information about soil fertility, microbial biodiversity, and plant responses to different management practices, thus contributing to evidence-based decision-making in agriculture and ecosystem management (Antoniolli & Kaminski, 1991).

The potential of mycorrhizae as biocontrol agents for soil pathogens also deserves attention as an area of research and practical application. Through resource competition and the production of antifungal metabolites, mycorrhizae can contribute to the suppression of plant diseases caused by pathogenic fungi, thereby reducing dependence on agrochemicals and promoting crop health (Bonfante, 2010; Bucking et al., 2016; Oldroyd et al., 2009; Folli-Pereira et al., 2012).

Finally, spreading knowledge about the importance of mycorrhizae and their practical applications among farmers, rural extension workers, and decision-makers is essential to ensure the effective adoption of these technologies and management practices. Investments in education and training can help raise awareness about the benefits of mycorrhizae and encourage their integration into agricultural and conservation systems, thereby contributing to the sustainability and resilience of semi-arid agroecosystems and beyond (Ribeiro, 2019; Berude et al., 2015).

Influence of *Mycorrhizae* ***on*** *Cynophalla flexuosa (L.)* ***and*** *Cratylia argentea* ***under Soil Salinization***

Soil salinization is a growing challenge for agriculture in many regions around the world, negatively affecting crop productivity and the sustainability of agricultural systems. C*ynophalla flexuosa* (L.) and C*ratylia argentea* are two plant species that have shown potential for tolerance to soil salinity. However, understanding the underlying mechanisms of this tolerance and strategies to improve these plants' adaptation to saline environments is crucial for maximizing their agricultural potential. In this context, arbuscular mycorrhizal fungi (AMF) emerge as key components in mitigating the adverse effects of soil salinity on these plant species (Castro & Santos, 2020).

Recent studies have highlighted the crucial role of AMF in promoting salinity tolerance in host plants such as C*ynophalla flexuosa* (L.) and C*ratylia argentea*. These symbiotic microorganisms establish a mutualistic association with plant roots, enhancing their ability to absorb water and nutrients from the soil. Under saline conditions, AMF play a fundamental role in regulating the plant's water balance, reducing osmotic stress, and improving water use efficiency (Leal et al., 2021).

Moreover, mycorrhizal symbiosis induces biochemical and physiological responses in the associated plants, including increased antioxidant activity and the accumulation of osmoprotective solutes. These biochemical mechanisms help plants cope with oxidative damage and ionic imbalances caused by salt stress, contributing to the maintenance of cellular integrity and physiological function.

Considering these benefits, deliberate inoculation of C*ynophalla flexuosa* (L.) and C*ratylia argentea* with AMF can be a promising strategy to enhance soil salinity tolerance in agricultural cropping systems. The use of AMF as biocontrol agents for salinity can not only increase crop productivity but also contribute to environmental sustainability and the resilience of agricultural systems in the face of climate change and soil degradation (Folli-Pereira et al., 2012).

Conclusion

This study provided a comprehensive perspective on the influence of mycorrhizae on the eco-physiological and nutritional aspects of C*ynophalla flexuosa* (L.) and C*ratylia argentea* under soil salinization conditions. The literature review highlighted the importance of mycorrhizae in promoting the survival and performance of these plant species in semi-arid environments, particularly in response to saline stress.

The analysis of the reviewed studies revealed that mycorrhizae play a crucial role in improving nutrient absorption by plants, enhancing their resistance to osmotic stress, and improving their water use efficiency. Additionally, mycorrhizal symbiosis induces biochemical and physiological responses in host plants, such as activation of antioxidant mechanisms and accumulation of osmoprotective solutes, which help mitigate the adverse effects of soil salinity.

Future perspectives and practical applications emphasize the importance of continuing to investigate the molecular mechanisms underlying plant-fungal interactions, as well as developing technologies and management practices that promote mycorrhizal colonization in C*ynophalla flexuosa* (L.) and C*ratylia argentea*. These strategies have the potential to improve agricultural productivity, promote biodiversity conservation, and contribute to the sustainability of agricultural systems in semi-arid environments.

In summary, this study reinforces the importance of mycorrhizae as key agents in plant adaptation to saline stress conditions and highlights their potential to contribute to food security, natural resource conservation, and sustainable development in semiarid regions and beyond.

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