LUMEN ET VIRTUS

Genetic conservation of breeding populations: Literature review from the perspective of species of the Cerrado biome

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ABSTRACT

This work addresses the Genetic Conservation of Breeding Populations, focusing specifically on the species of the Cerrado biome. Using a qualitative approach and drawing on theoretical references, the research examined key concepts related to forest genetic conservation, genetic variability, conservation methods and the challenges faced in this context. The methodology employed involved a detailed bibliographic review and a critical analysis of the information collected in recent years. The efforts and cases of genetic conservation of some species of the cerrado were highlighted, despite the scarcity of studies in this field. The discussion raised the urgent need for more research and actions aimed at the conservation and improvement of the species of the cerrado biome, given their importance for biodiversity and their relevance for the maintenance of natural ecosystems. The study also addressed the advantages and disadvantages of different methods of genetic conservation, as well as future trends in this area. In short, the work offers a comprehensive view of the genetic conservation of cerrado species, highlighting the importance of their preservation for environmental sustainability and food security.

Keywords: Agroforestry, Biomarkers, Cerrado, Genetic Improvement.

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INTRODUCTION

Brazil is one of the world leaders in the biodiversity of tree species, standing out for its heritage of approximately 15 to 20% of all species in the world (BRASIL, 2022; ASSIS, DOBROVOLSKI AND BORGES, 2021).

However, as Peixoto and Vilella (2018) put it, in view of the socioeconomic and environmental challenges faced by Brazilian forest species, the use of biotechnology for the conservation and genetic improvement of tree species populations is indispensable and modern, as it contributes to the maintenance and improvement of species. Mainly, due to the fact that Brazil is a signatory to the Convention on Biological Diversity (CBD), in which it is responsible for preserving and sustainably using the genetic heritage of biological species existing in the national environment (SÁ AND NAVES, 2023; BALLESTEROS-MEJIA, LIMA AND COLLEVATTI, 2020).

Thus, the future of the populations of tree species in Brazilian biomes has been the object of study in the conservation of genetic resources, given the environmental, economic and social challenges, which directly influence the genetic conservation of the various species of the various Brazilian biomes, in particular, the cerrado (PEIXOTO and VILELLA, 2018; ASSIS, DOBROVOLSKI AND BORGES, 2021).

In this regard, according to the authors Assis, Dobrovolski and Borges (2021), the cerrado biome has suffered devastation with numerous socioeconomic and environmental factors, that is, climate change, expansion of livestock and agriculture, which puts native biodiversity at risk, especially endemic tree species, causing the risk of extinction, of decrease in the populations of forest species in this biome, which represents approximately 5% of the species in the world biome.

Given this scenario, it is questioned, as a result of the increase in deforestation in the Cerrado, a risk factor for the existence of native species, whether the forest diversity of the Cerrado has been prioritized by the genetic conservation of forest improvement populations?

The present study aims to carry out a literature review on the theoretical aspects regarding the genetic conservation of forest breeding populations, focusing on forest species of the cerrado biome.

Throughout the literature review, we seek to understand the theoretical aspects of genetic conservation, reviewing the current concepts. In addition, a theoretical overview will be carried out on breeding population, genetic variability, selective pressures and genetic drift, theoretical institutes used in genetic conservation. In addition, it will seek to understand the main methods used in genetic conservation, analyzing their advantages and disadvantages. Finally, to discuss the challenges and trends in genetic conservation, in an interdisciplinary way with the species of the cerrado biome.

MATERIAL AND METHODS

In the research on genetic conservation of forest breeding populations, with a focus on cerrado species, the methodological procedures were based on literature review, with a focus on bibliographic research, through relevant research in scientific articles, books, magazines, and academic websites (MATTAR AND RAMOS, 2021).

In the same regard, Mattar and Ramos (2021) state that the literature review is a crucial step in scientific research, as it provides a more comprehensive and up-to-date analysis of existing knowledge on the respective topic. Therefore, in the last five years, the approaches and methods for conducting literature reviews have evolved, reflecting advances in information and communication technologies, as well as changes in the genetic conservation practices of native forest populations of the cerrado. In this study, the most relevant materials and methods used in recent literature reviews were addressed.

Corroborating, Marconi and Lakatos (2017) state that with the advancement of the internet, sources of information have become more accessible and diverse. In addition to traditional academic databases, such as Scopus, online platforms, institutional repositories, and academic social networks play a significant role in articles, theses, and other relevant documents.

In this sense, the search for the research was carried out through the digital platforms Portal periodicals of Capes, Google Scholar and others, as the search tools were aided with advances and access to the internet, such as Google Scholar, both were widely used to find scientific articles, while reference management tools, such as EndNote and Zotero, assist in the organization and selection of relevant materials (MATTAR AND RAMOS, 2021).

In summary, the material and methods of this literature review were based on the last five years, where they reflect an adaptation to emerging technologies, emphasizing the importance of a systematic approach, diversification of sources and efficient use of digital tools. This evolution continues to promote the quality and relevance of literature reviews as a basis for the advancement of scientific knowledge.

THEORETICAL ASPECTS OF GENETIC CONSERVATION

FOREST GENETIC CONSERVATION

Environmental changes resulting from natural phenomena, as well as anthropogenic actions, have caused concern among scientists and scholars about the preservation and conservation of the genetics of forest species. But what would Genetic Conservation be? In the words of Costa (2018), genetic conservation is the branch of science that produces knowledge with the objective of preserving species capable of genetic adaptation to environmental phenomena, with the use of systematized genetic methods and techniques, in order to minimize the possibility of extinction. This

is because species have genetic variability among populations and subpopulations (SILVA, et al., 2023).

In this sense, it is clear that forest genetic conservation aims to preserve the genetic material of species with potential for forest improvement and for the use of biotechnology, using existing conservation methods, whether in situ or *ex situ* (SILVA, et al., 2023).

For Sá and Naves (2023), genetic conservation is in its essence a global strategy and concern to ensure the conservation of the genetic bank of species, in order to preserve and maintain species lost in their natural habitats and centers of diversity.

In this way, genetic conservation is a salutary mechanism for the preservation of forest species, especially in the cerrado biome, which has been the target of anthropogenic actions that have put at risk the diversity of tree species essential for the life of diversity in this biome.

BREEDING POPULATIONS AND THEIR IMPORTANCE

The genetic conservation of populations is the scientific area that requires an object of research in a systematized way. In this regard, research on genetic conservation requires working with a base germplasm, with wide genetic variability, so it requires a breeding population (DE RESENDE AND ALVES, 2021).

According to the authors De Resende and Alves (2021), breeding population is the set of individuals, subpopulation, of a forest species that represents an effective number of individuals, so that they maintain the genetic variability of the original population, aiming at conservation and improvement (SALGOGRA AND CHAUHAN, 2023).

The breeding population is healthy, as it is through it that long-term improvement is sought, that is, over time there is a continuous increase in the presence of beneficial alleles, based on selective cycles, which can result in the gain and maintenance of the adequate population size (DE RESENDE AND ALVES, 2021).

GENETIC VARIABILITY, SELECTIVE PRESSURES, AND GENETIC DRIFT

The genetic variability of forest species plays a crucial role in adapting to and maintaining biological diversity, as well as being vital for the sustainability of ecosystems and human well-being. Therefore, their conservation is of paramount importance to ensure the resilience and health of forest ecosystems (JULLIEN et al., 2019). Also according to the author, gene flow is an evolutionary force that allows the exchange of alleles, thus increasing genetic diversity.

The reproductive system plays an important role in genetic diversity, as self-fertilization limits pollen and seed dispersal and the potential for recombination between alleles of different individuals, unlike crossbreeding. As a result, crossbred species are expected to preserve more

genetic diversity than autogamous species (JULLIEN et al., 2019; SALGOGRA AND CHAUHAN, 2023).

Heterozygosity is one of the parameters of genetic diversity. While gene flow increases genetic diversity by allowing the exchange of alleles between populations (SMITH et al., 2020), self-fertilization can lead to the loss of genetic variability over time, as there is no mixing of genes between different individuals. This makes populations more susceptible to disease, environmental stresses, and changing environmental conditions. In addition, it can lead to the accumulation of deleterious mutations and the expression of harmful recessive traits.

Furthermore, with regard to selective pressures and genetic drift, it is verified that they result from genetic mutation and recombination among members of a population, which results in the acquisition or suppression of characteristics that lead the species to adapt to ecological conditions and to survive environmental changes. Thus, genetic drift can occur due to the reduction or disappearance of existing genetic material in individuals that cease to exist (SMITH et al., 2020; SALGOGRA AND CHAUHAN, 2023).

Therefore, such concepts should be used in the analysis of genetic alterations of forest species existing in the Cerrado, since with the fragmentation of the biome, many rare alleles existing in certain individuals may cease to exist, compromising the conservation of native species of the Cerrado.

METHODS OF GENETIC CONSERVATION

TRADITIONAL METHODS OF GENETIC CONSERVATION

The conservation of the genetic diversity of plants and animals is a key aspect to ensure the resilience and sustainability of ecosystems over time. In this regard, over the years, a number of traditional methods have been developed to preserve this genetic diversity, ranging from seed storage to the protection of natural habitats (SALGOGRA AND CHAUHAN, 2023). This article explores some of these methods and their importance in maintaining biodiversity and providing valuable genetic resources for various areas, such as agriculture, medicine, and scientific research.

Among the methods discussed are seed and germplasm banks, *ex situ collections*, creation of natural reserves, genetic improvement programs, and *in situ* conservation (MOLONEY et al. 2023). Understanding and applying these strategies play a crucial role in preserving biological diversity and ensuring a sustainable future for generations to come.

The seed bank under the tree canopy was made up of diversified species of life form and dispersal syndrome, being determinant for successional dynamics (MORAES et al. 2020). In addition, it is considered the set of all viable seeds in the soil and can be composed of seeds of

species present in the local vegetation, as well as species that are present in neighboring areas, which arrive through seed rain (CAPELLESSO et al. 2015, OLIVEIRA et al. 2018).

The conservation situation of the species applies due to climate change and anthropogenic actions that have been causing strong genetic erosion of the species in their dispersion zones, which justifies the prospection and collection of germplasm for the introduction of new accessions in germplasm banks and the establishment of work collections (CORADIN et al. 2022). Ex *situ* conservation is a biodiversity preservation strategy that involves maintaining and caring for living organisms outside their natural habitats. This approach is essential to protect endangered species, as well as to preserve the genetic diversity of plants and animals (DINIZ-FILHO, 2020).

Thus, the conservation of plant variability in *ex situ* conservation chambers thus acquires relevance not only as a basis for breeding programs, which seek high performance and greater productivity, but also constitutes a matter of food security and ensuring the continuous use of the most important plant species for human consumption (SANTONIERI et al. 2016; SALGOGRA AND CHAUHAN, 2023).

The idea of nature conservation, for the creation of nature reserves, has required thinking about the maintenance of natural areas with little or no anthropogenic alteration (BRANDÃO et al. 2021). One of the alternatives for conservation was the creation of Conservation Units (UC), or legally protected territorial areas, in order to safeguard biodiversity and natural resources (GALVÃO, 2018).

The importance of nature conservation through the creation of nature reserves and Conservation Units (CUs), as strategies to protect and propagate biodiversity, conserving genetic material and natural resources. It is critical to recognize that maintaining areas with little or no human interference is crucial to preserving healthy and functional ecosystems. The UCs play a crucial role in protecting flora and fauna, as well as promoting awareness about the importance of environmental conservation. However, it is important not only to establish these protected areas, but also to ensure effective and sustainable management to ensure their long-term effectiveness (BALLESTEROS-MEJIA, LIMA AND COLLEVATTI, 2020).

The development of Brazilian agribusiness has brought major transformations and advances in the productive and technological structure, promoting a process of innovation in part of the country (OLIVEIRA; RODRIGUES, 2020; SANTOS et al., 2017). For example, the improvement of cashew (A. *occidentale* L.) solved the case of plant height and productivity, short stature helps in orchard management: pruning, pest control and harvesting, generating a substantial increase in nut production in CE, PI and RN (QUEIROZ et al., 2012). Overall, genetic improvement plays a crucial role in promoting food security, adapting to environmental changes, and sustaining agriculture, ensuring that plants can thrive and provide food.

In situ *conservation, on the other hand*, refers to the conservation of species and habitats in their natural environment, that is, where they are found in nature (ESLABÃO et al., 2022). This term is often used in contrast to "*ex situ* conservation," which involves removing specimens from their natural environment to be kept and protected in controlled facilities such as a zoo, botanical gardens, or germplasm banks. The *in situ conservation method* aims to protect entire ecosystems, wild populations, and natural habitats, ensuring that they continue to exist in their original environment. This can involve a variety of strategies, such as the creation and management of protected areas, the implementation of regulations to protect endangered species and their habitats, the sustainable management of natural resources, and the involvement of local communities in conservation.

It is clear that traditional methods are viable means to be applied in the genetic conservation of the populations of the Brazilian cerrado, as a way to ensure preservation. However, it is observed that other methods are currently being applied in the conservation of forest species.

MODERN TECHNIQUE METHODS: GERMPLASM BANKS, *IN SITU, EX SITU AND ON FARM CONSERVATION*

The genetic conservation of forest species has sought, through scientific studies, methods that ensure the existence of species, in view of natural phenomena and anthropogenic actions that threaten the existence of species in the Brazilian environment, including the Cerrado biome (SALGOGRA AND CHAUHAN, 2023). In this sense, some methods stand out in the process of species conservation.

According to Moloney et al (2023), the germplasm bank is a technique within the *ex situ method*, in which organic specimens are kept and conserved in an artificial environment, but under the control and supervision of man, seeking in this process to control the humidity of the environment and its temperature, giving greater viability to the seeds, for a long period. Through the germplasm bank, scholars have access to the genetic variety of several species, being able to conserve their hereditary set or carry out research on genetic modification and improvement, in order to make them more resistant to environmental changes. (SALGOGRA AND CHAUHAN, 2023)

Regarding the *in situ* conservation method, according to Moloney (2023) it can be said that it is the form of genetic conservation of certain tree species in their natural habitat, so that the conservation of the genetic chain is conserved naturally, in an environment that provides contact with land, water, and existing biological diversity (SALGOGRA AND CHAUHAN, 2023).

In this way, *in situ* conservation is carried out through protection strategies and policies, among which are legally protected areas, that is, Conservation Units, as provided for in the Law of the National System of Conservation Units - SNUC (HOBAN, et al., 2020).

Last but not least, there is the on-farm method, which according to Salgogra and Chauhan (2023) is the traditional method in which farmers or producers conserve species or seeds on their properties, it has a unique role in species conservation, since they conserve and maintain species in their habitat and in contact with biodiversity. *On-farm* conservation helps in the genetic conservation of species, contributing to the preservation of species, and contributing to the genetic perpetuation of species and ensuring a natural heritage for future generations.

CHALLENGES AND TRENDS IN THE GENETIC CONSERVATION OF THE SPECIES OF THE SCRUBLAND

STUDIES WITH NATIVE SPECIES OF THE CERRADO

The genetic conservation of forest species is one of the alternatives to try to minimize the loss of hereditary content of tree species (LEMES, DE ANDRADE AND LOYOLA, 2020). However, in the Cerrado, with the advance of agriculture and livestock, society demands sustainable development, which makes it difficult to introduce more effective environmental policies in the economic system, because it is not enough just to create legislation, because without public policies of applicability, as well as the lack of projects from the private sector for the preservation of species, the problem of population fragmentation and genetic loss tends to increase (COSTA AND MELO, 2020).

According to Medeiros et al (2022), it is verified that the conservation study focused on the cerrado and its species were developed by a few groups, restricting it to *the cerrado stricto sensu* and riparian forests. In addition, it points out that plant species of the cerrado biome in conservation and restoration projects are neglected, being disregarded the original characteristics, growth, in short, there is no systematized method to evaluate results.

Corroborating Ballesteros-Mejia, Lima and Collevatti (2020) state that the Brazilian cerrado biome, due to inadequate land use, presents a depression of habitat fragmentation, reaching 39% of its cover, due to the growth of agriculture and livestock. Thus, this can cause the genetic loss of several species useful for conservation and genetic improvement. Therefore, the lack of scientific studies of the genetics and ecology of the cerrado strengthens the evidence to describe patterns in the study of the genetic diversity of the cerrado.

Furthermore, despite the little study on the genetic conservation of species in the cerrado, the university has stood out in research on the genetic conservation of species in this Brazilian biome, which despite being the second largest Brazilian biome, is threatened by the advances of human anthropic actions. (ASSIS, DOBROVOLSKI AND BORGES, 2021).

Among the few studies on the genetic conservation of cerrado species, Chave (2018) states that research carried out by the Federal University of Goiás stands out, for the formation of genetic

banks, aiming at the improvement and genetic preservation of species such as: Baru, Cagaita and Jatobá-do-Cerrado.

In addition, studies have been developed with the aim of conserving and improving Cerrado species, since the genetic variability of the Cerrado species is essential for survival and adaptation to environmental and socioeconomic changes that threaten the biome (RIBEIRO AND RODRIGUES, 2006; COLLI, VIEIRA AND DIANESE, 2020). Among the studies, the following stand out: Study with Araticum (*Anmona crassiflora* Mart.*)* which was developed with a view to its conservation and improvement, as it has potential for ornamentation and medicinal value. Another species studied is the Baru *(Ipteryx alta* Vog.*)* that has been researched because it has its value in food and in the pharmaceutical industry. Another species studied is the Cajuí (*Anacardium* spp.), a fruit widely used in the feeding of the species of the cerrado and the population, with enormous industrial potential. (GOMES et al, 2021). Cagaita (*E. Dysenterica*) was studied due to its genetic population structure, as well as its potential in agricultural production. The Ipê-Roxo (*Tabebuia Impetiginosa*) had a study for genomic analysis aiming at preservation and sustainable management. The Cerrado Jatobá (H. stigonocarpa) was studied due to its food potential and the quality of its wood, which provides important information for conservation programs. Jenipapo (*G. americana*) was studied for analysis of heterozygosity levels and the reproductive process. The Pequi (*Caryicar brasiliense* Camb.*)* was studied with a view to its genetic improvement due to being an important fruit tree in the diet (RIBEIRO AND RODRIGUES, 2006).

NEW TECHNOLOGIES FOR GENETIC CONSERVATION

In the country, about 50% of family farming establishments are concentrated in the Northeast, with the vast majority located in the region with a semi-arid climate; the remaining percentage corresponds to 19% in the South, 16% in the Southeast, 10% in the North, and 5% in the Midwest (MASSRUHÁ et al. 2020). According to Silva et al. (2019), the agricultural sector in the Northeast does not behave in a homogeneous way, that is, farmers located in the semi-arid region are faced with different geographical, cultural, and socioeconomic conditions, which must be taken into account regarding the productivity characteristics of each species and its technological efficiency.

The adaptability of common bean genotypes, for example, is specific to each region, brings a series of benefits to the farmer, since not all cultivars respond well, in all regions, due to local environmental conditions, such as temperature, humidity and especially the photoperiod, which interfere in the development of the crop, significantly reducing its productivity (HIOLANDA et al. 2018).

Thus, all types of plants must be subjected to experiments in crop fields in different regions, in order to identify which are the most suitable and which have the best yield in each location.

Several breeders have adopted molecular marker tools to assist in breeding work, especially for germplasm characterization, assisted selection, identification of accessions with tolerance to biotic and abiotic stresses, in which the results have been a major contributor to the advancement of breeding work on various crops (SANTOS et al. 2013). For Leal et al. (2010), the molecular markers RAPD and SSR are among the most used to determine genetic divergence.

The technique of random amplified DNA polymorphism (RAPD) is low-cost and easy to perform, where it consists of arbitrary primers and does not depend on the previous sequencing of the genome of the species in which it will be applied (DUTRA FILHO et al., 2013). Thus, we realize that the main advantage of this technique is the speed and ease of execution in obtaining the results. For Dutra et al. (2013), the EST'S SSR primers are a functional class of molecular markers based on simple repeated sequences. They are linked to *loci* that determine characteristics of interest, have a co-dominant character, and can differentiate homozygous from heterozygotes, forming highly polymorphic genetic loci (FERREIRA; GRATTAPAGLIA, 1998).

However, the joint use of these two types of markers, each amplifying specific regions in terms of their potential, will contribute to greater genome coverage and also to greater consistency in the results related to interpopulation genetic similarity or divergence (Dutra et al. 2013).

Technology plays a key role in genetic conservation for several reasons. Firstly, it allows for the efficient and long-term storage of genetic material in germplasm banks, preserving genetic diversity and ensuring future food security and biodiversity. In addition, the technology facilitates the selection of desirable traits in plants and animals through the identification and use of genetic markers, accelerating genetic improvement programs and adapting varieties to adverse environmental conditions. Assisted reproductive technologies are essential to conserve and genetically propagate animals and plants of high genetic value or threatened with extinction, contributing to the conservation of species at risk and the recovery of wild populations. To this end, gene editing techniques offer new possibilities, allowing the precise modification of genetic material to correct genetic defects, develop resistance to pests and diseases, or adapt organisms to climate change. Finally, bioinformatics tools and DNA sequencing technologies allow for detailed monitoring of genetic diversity, which is essential to understand the genetic structure of populations and guide conservation strategies (SALGOGRA AND CHAUHAR, 2023).

While genetic enhancement techniques offer numerous advantages, it is important to recognize that they also have significant disadvantages, such as the potential loss of genetic diversity and the homogenization of populations, which can increase vulnerability to pests and diseases (SALGOGRA AND CHAUHAN, 2023).

FINAL CONSIDERATIONS

It is concluded that the genetic conservation of breeding populations is crucial to ensure the genetic diversity and resilience of agricultural and forest crops in the face of environmental challenges, pests and diseases.

In addition, it was found that by preserving and protecting plant varieties adapted to different climatic conditions and environments, we can maintain food security and promote long-term agricultural and forestry sustainability. In addition, genetic conservation is essential to enable future breeding programs, providing a reservoir of valuable genes for the creation of new varieties with desirable traits such as disease resistance, tolerance to environmental stresses, and increased productivity.

Furthermore, it was found that the genetic conservation of forest species in the cerrado has not been a priority for the study of conservation in Brazil, even in the face of 39% of this biome having been consumed by anthropic action, with irreparable forest genetic losses.

Thus, it was clear that specific studies were carried out on some native species of the cerrado. Universities that have led research in the conservation of species in the biome have stood out.

Therefore, the study demonstrated the urgent need for more research and actions aimed at the conservation and improvement of species in the cerrado biome, given their importance for biodiversity and their relevance for the maintenance of natural ecosystems.

Additionally, investing in the genetic conservation of breeding populations is critical to ensuring global food security and promoting agricultural sustainability in an ever-changing world.

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