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Assessment of Seed Diversity of Pata-de-Vaca (*Bauhinia forficata* Link)

Avaliação da Diversidade de Sementes de Pata-de-vaca (*Bauhinia forficata* Link)

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Abstract

The Bauhinia genus, popularly known as pata-de-vaca, is home to species of great ornamental and ecological value, with great potential for use in landscaping, urban afforestation, and ecological restoration projects. The objective of this study was to evaluate the diversity of *Bauhinia forficata* seeds based on seeds' morphological descriptors. The pods were collected in the city of Sud Mennucci - SP, where the Atlantic Forest biome predominates. The evaluation of the collected material was conducted at the State University of Mato Grosso do Sul (UEMS). The pods were evaluated for length (PL) and number of seeds per pod (NSP). Subsequently, the seeds were extracted from the pods and divided into five groups. In the seeds, the following descriptors were evaluated: seed thickness (ST), seed diameter (SD), average seed weight (ASW) and total seed weight (TSW) in each group. As a result, it was obtained that with the exception of the descriptor ST, the rest showed that there are statistical differences between the groups ($p < 0.05$). The variability of the descriptors showed values of 12 to 19.3 cm for PL; from 2 to 5 pods for NSP; from 0.9 to 1.6 cm for SD; 0.43 to 0.54 g for ASW and from 7.39 to 9.23 g for TSW. Correlation analyses were performed and showed significant correlations only between ASW and TSW ($r = 0.93$). The pata-de-vaca demonstrates a notable phenotypic variability, resulting from the complex interaction of environmental and genotypic factors of the species.

Keywords: Trees. Correlation. Descriptors. Variability.

Resumo

O gênero Bauhinia, popularmente conhecido como pata-de-vaca, abriga espécies de grande valor ornamental e ecológico**,** com grande potencial para uso em paisagismo, arborização urbana e projetos de restauração ecológica. O objetivo do trabalho foi avaliar a diversidade de sementes de *Bauhinia forficata* Link a partir de descritores morfológicos de sementes. A coleta das vagens ocorreu na cidade de Sud Mennucci - SP, onde predomina o bioma da Mata Atlântica. A avaliação do material coletado foi conduzida na Universidade Estadual do Mato Grosso do Sul (UEMS). As vagens foram avaliadas quanto comprimento (CVa) e número de sementes por vagens (NSV). Posteriormente as sementes foram extraídas das vagens e divididas em cinco grupos. Nas sementes foram avaliados os descritores: espessura das sementes (ES), diâmetro das sementes (DS), peso médio das sementes (PMS) e peso total das sementes (PTS) em cada grupo. Como resultado foi obtido que com a exceção do descritor ES o restante mostrou que existem diferencias estatísticas entre os grupos ($p<0.05$). A variabilidade dos descritores mostro valores de 12 a 19.3 cm para CVa; de 2 a 5 vagens para NSV; de 0.9 a 1.6 cm para DS; 0.43 a 0.54 g para PMS e de 7.39 a 9.23 g para PTS. Análises de correlação foram feitos e evidenciaram correlações significativas apenas entre PMS e PTS ($r = 0.93$). A pata-de-vaca demonstra uma notável variabilidade fenotípica, resultado da interação complexa de fatores ambientais e genotípicos da espécie.

Palavras-chave: Árvores. Correlação. Descritores. Variabilidade.

1 Introduction

Trees represent the lungs of the world and play an important role in mitigating the damage that climate change causes to the environment. The demand for seeds of native forest species is associated with ecosystem conservation and the production of seedlings intended for forest restoration, recovery of degraded areas, and the use of wood or by-products derived from these plants (Gomes *et al*., 2019).

The genus *Bauhinia*, belonging to the family Fabaceae, subfamily Caesalpinioideae, comprises more than 200 known species, most of which are originally found on the Asian continent. However, some species originate from other regions, as it is the case in the Atlantic Forest in Brazil, where *B. forficata* and *B. longifolia* can be found (Oliveira *et al*., 2001).

Commonly known as “pata-de-vaca” or “cow’s hoof,” the name is particularly appropriate because the leaves of these plants consist of two leaflets joined at the base (Marchiori, 1995); “forficata” refers to the leaf shape, which resembles a cow’s hoof. The genus *Bauhinia* has spread worldwide due to its desirable landscape characteristics, such as medium size (up to 10 meters in height), large leaves, moderately wide crown, and visually appealing flowers, making it an excellent option for urban afforestation.

This species shows wide potential for use in agroforestry systems, recovery of degraded areas, environmental programs, and is also an excellent choice for landscaping and urban afforestation in parks, squares, streets, and avenues, contributing to natural green spaces (Garcia Seifert; Chassot, 2021). Its wood is moderately heavy, suitable for light construction, tool handles, paper production, firewood, or charcoal. Its leaves can also be used for animal feed or as ground cover (Vieira *et al*., 2016).

In traditional medicine, the leaves of *pata-de-vaca* are commonly used for their antidiabetic and diuretic properties, usually consumed as infusions or tea. They are also used in the treatment of urinary tract infections, cholesterol reduction, cystitis, intestinal parasitosis, and elephantiasis, placing the plant on the list of medicinal plants of interest to the Brazilian Unified Health System (SUS) (Celedonio *et al*., 2023).

Native species are also exploited as medicinal plants, such as *B. forficata*, whose leaves and flowers are used to control diabetes (Oliveira *et al*., 2001; Gazzola *et al*., 2023), as hypoglycemic agents (De Pontes *et al*., 2017), for flavonoid extraction (Pizzolatti *et al*., 2003; Sellaoui *et al*., 2023), among other uses. These species have also been widely used in forest regeneration projects (Marangon *et al*., 2008; Trentin *et al*., 2018; Gazzola *et al*., 2023), with *B. forficata* being particularly used because it is a pioneer species.

Fruits should be collected when they change color from green to grayish-brown. It is important to monitor physiological maturation to avoid losing seeds (Gazzola *et al*., 2023). Since dehiscence is explosive, seeds are dispersed over long distances once the fruits reach the ideal stage of ripeness. With simple finger pressure, the pod opens, and seeds can be manually extracted. Another method is to place harvested fruits in the sun until they open and release the seeds (Carvalho; Carvalho, 2003).

The seeds of this species exhibit orthodox behavior in storage, maintaining viability for more than one year in both uncontrolled environments and cold chambers (Verteiro *et al*., 2022). However, *pata-de-vaca* seeds begin to lose their germinative power 180 days after harvest (Carvalho; Carvalho, 2003).

Descriptors are characteristics that allow the comparison of plant attributes and their organs (seeds, flowers, stems, pods, hypocotyls, etc.), helping to differentiate individuals within the same species (Zuffo *et al*., 2022; Aguilera *et al*., 2023; Melo *et al*., 2024). In germplasm banks, such descriptors include morphological and agronomic traits of great relevance to breeders, which can be measured on quantitative or qualitative scales (Figás *et al*., 2018; Aguilera *et al*., 2019; Sampaio *et al*., 2023). Seeds of forest species represent important material for conservation, and their characterization is necessary to obtain uniform seedlings with normal development (Zuffo *et al*., 2021).

Biometric studies of plants are essential to guide the improvement of plant species and provide information to distinguish species within the same genus (Aguilera *et al*., 2019). These analyses allow to understand the species' phylogeny and evolution through morphological characteristics of fruits, seeds, seedlings, and young plants. Although several studies address the chemical composition and medicinal uses of *Bauhinia forficata* L., biometric research involving fruits and seeds, germination, storage, and ecology remains scarce (Vieira *et al.,* 2016).

The objective of this study was to evaluate the diversity of *Bauhinia forficata* L. seeds through seeds' morphological descriptors.

2 Material and Methods

The pods of *Bauhinia forficata* L. were collected in the rural area of the municipality of Sud Mennucci, São Paulo, Brazil. The municipality is located within the Atlantic Forest biome, which, according to Cardoso (2016), is the third largest biome in Brazil, characterized by a predominantly humid tropical climate and composed of diverse ecosystems where the Atlantic Forest predominates.

Pod collections were carried out between August and October 2023, with selection based primarily on the brown coloration of mature pods. After collection, the pods were identified, stored in plastic bags, and transported to the municipality of Cassilândia, Mato Grosso do Sul, where they were sent to the Agronomy Laboratory of the Universidade Estadual do Mato Grosso do Sul (UEMS), Cassilândia campus.

The pods were measured using a millimeter ruler to evaluate length (CVa, cm) and the number of seeds per pod (NSV, unit). Subsequently, the seeds were extracted from the pods and divided into five groups: groups 1, 2, and 3 consisted of 18 seeds each, while groups 4 and 5 contained 17 seeds each.

The groups were individually weighed on a precision scale to determine the weight of each group and the mean seed weight (PM, g). Seed thickness (ES, mm) and diameter (DS, cm) were also measured using a caliper.

The collected data were subjected to analysis of variance, and the means were compared using Tukey's test at 5% probability, with the aid of Rbio software, version 166 for Windows (Bhering, 2017). Pearson's correlations were established among all the descriptors employed to better understand the relationships between them.

3 Results and Discussion

The ANOVA results are exhibited in Table 1. For most descriptors, highly significant differences ($p < 0.001$) were observed among the seed groups of *Bauhinia forficata* L., with the exception of seed thickness (ES), which showed no significant variation. This descriptor (ES) displayed the highest coefficient of variation (28.75%), while the other evaluated descriptors presented adequate values below 10%.

According to the data exhibited in Figure 1B, groups 1 and 2 resulted in the highest number of seeds per pod, with 4.5 seeds each. Group 3 exhibited the lowest number of seeds per pod, averaging 2.5 seeds, showing the weakest performance among the analyzed groups. For the descriptor seed thickness (Figure 1C), no statistical differences were observed among the groups by Tukey's test at 5%. Values for this descriptor ranged from 0.3 to 3.03 mm (Table 1).

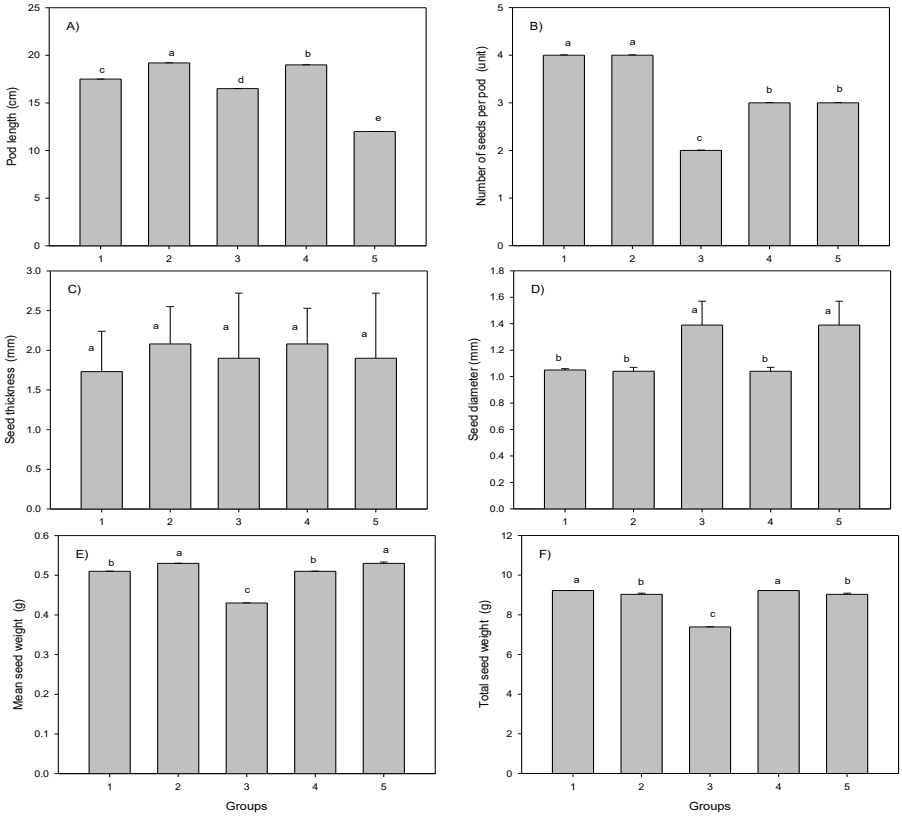
Table 1 - Summary of ANOVA obtained for descriptors comparing five groups of *Bauhinia forficata* L. seeds collected in São Paulo, 2024

FV*	CVa (cm)	NSV (unit)	ES (mm)	DS (cm)	PMS (g)	PTS (g)
Groups	***	***	NS	***	***	***
CV (%)	2.15	7.27	28.75	9.16	0.37	0.36
Minimum	12	2	0.3	0.9	0.43	7.39
Maximum	19.3	5	3.03	1.6	0.54	9.23
Mean	16.89	3.7	1.90	1.16	0.50	8.78

*FV: source of variation; CV: coefficient of variation; CVa: pod length; NSV: number of seeds per pod; ES: seed thickness; DS: seed diameter; PMS: mean seed weight; PTS: total seed weight per group. *** and NS indicate significant differences at 0.01% and no significant differences, respectively, by the F-test of ANOVA.
Source: research data.

As shown in Figure 1A, all groups differed, with group 2 presenting the highest pod length values (19.2 cm). Conversely, group 5 showed the lowest mean values for this variable (12 cm). Pod length values ranged from 12 to 19.3 cm (Table 1), highlighting the variation of this trait in the species. The results shown in Figure 1D indicate that groups 3 and 5 exhibited the best performance for seed diameter, standing out from the other groups, which did not show significant differences by Tukey's test at 5%. Data for this descriptor varied between 0.9 mm and 1.6 mm (Table 1).

Figure 1 - Evaluation of pod length (A), number of seeds per pod (B), seed thickness (C), seed diameter (D), mean seed weight (E), and total seed weight (F) of *Bauhinia forficata* L. (pata-de-vaca). Each bar represents the mean of 17 values. Different letters indicate significant differences at the 5% level by Tukey's test



Source: research data.

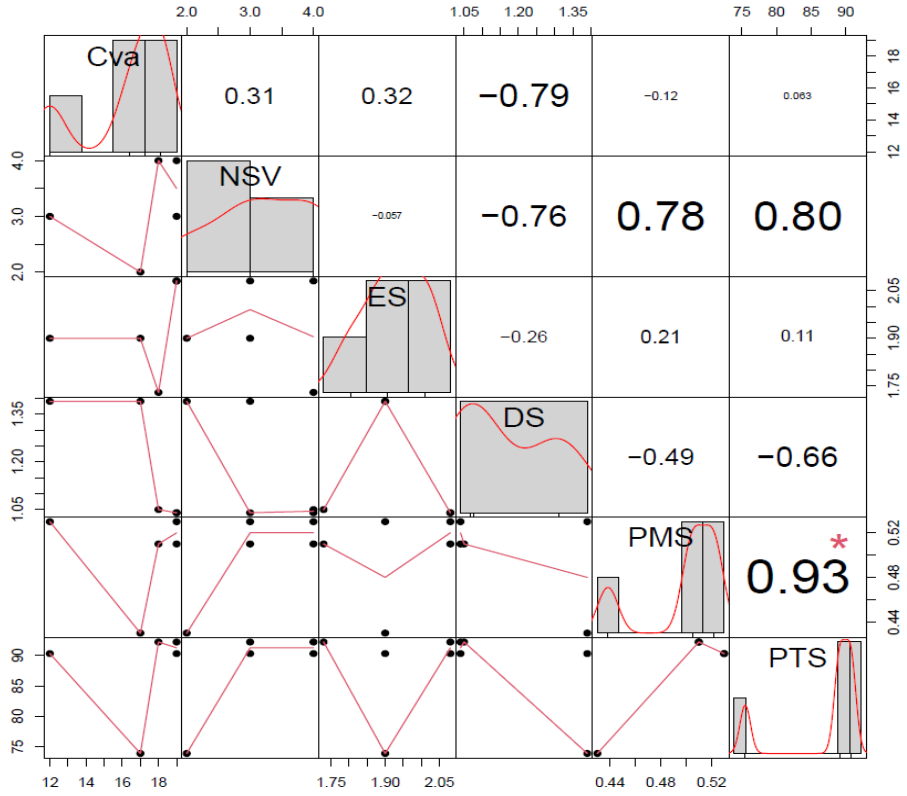
As illustrated in Figure 1E, the highest mean seed weight was observed in groups 2 and 5, both with 0.53 g, outperforming the other groups. On the other hand, group 3 showed the lowest mean seed weight

(0.43 g). Values for this variable ranged from 0.43 to 0.54 g (Table 1).

The results presented in Figure 1F indicate significant differences in total seed weight among treatments. Groups 1 and 4 presented the highest total seed weights, with 9.22 g each. Group 3 recorded the lowest total seed weight (7.39 g), demonstrating inferior performance for this descriptor. The values ranged between 7.39 and 9.23 g (Table 1).

Figure 2 shows Pearson's correlations established among all the descriptors evaluated in the five groups of pods and seeds of *Bauhinia forficata* L. High significant correlations ($p < 0.05$) were obtained between PMS and PTS ($r = 0.93$). However, high but non-significant positive correlations were found between NSV and PMS ($r = 0.78$) and NSV and PTS ($r = 0.80$). Strong negative non-significant correlations were found between CVa and DS ($r = –0.79$), NSV and DS ($r = –0.76$), and DS and PTS ($r = –0.66$) (Figure 2).

Figure 2 - Pearson's correlations obtained by evaluating pod length (CVa), number of seeds per pod (NSV), seed thickness (ES), seed diameter (DS), mean seed weight (PMS), and total seed weight (PTS) of *Bauhinia forficata* L. (pata-de-vaca). * indicates significant differences at 5% by Student's *t*-test



Source: research data.

Bauhinia forficata L. is one of the tree species found in the Atlantic Forest, the third largest biome in Brazil, encompassing different ecosystems and harboring 2.7% of all the plant species in the world (about 20,000 species). With a humid tropical climate, this biome plays a fundamental role in regulating water flow, soil fertility, and climate balance (Cardoso, 2016).

According to Vieira *et al.* (2016), pod length in *Bauhinia forficata* is an important characteristic because it is related to seed production, influencing viability and germination success. This analysis can optimize cultivation and propagation techniques. Comparing with the results obtained in Figure 1A, it is evident that all groups differed, indicating that pod length in this species shows high diversity. The same author also highlights that the number of seeds is directly related to propagation capacity, and pods may contain varying seed numbers, which may explain the low correlation observed between CVa and NSV (r = 0.31) (Figure 2).

Studies show that *Bauhinia forficata* (pata-de-vaca) is a species that stands out for its properties and ecological adaptability. However, seed thickness is of great importance for germination potential and storage. In the present study, ES showed low correlations with most descriptors (Figure 2), as well as low variation (Figure 1). Studies have shown that this species does not have significant seed coat impermeability, which is important for seed conservation under natural conditions, although some heat treatments may be necessary to overcome possible dormancy. Thickness is associated with the ability to retain moisture, viability, and quality for planting (Da Costa Silva *et al*., 2003; Lopes; Barbosa; Capucho, 2007; Meira *et al*., 2025). As shown in Figure 1C, the five evaluated groups did not differ significantly, suggesting that this descriptor is stable with little variation.

Seed weight is directly related to germination potential, reserve accumulation, and seed production. However, this weight may vary since it is linked to nutrient reserves, which favor initial seedling development (Da Costa Silva *et al*., 2003). This fact can be observed in Figures 1E and 1F, where seed weight varied among the different groups formed. The variation among all the variables may be related to climatic conditions, management, genetic factors, dormancy, dispersal, and resource availability (Vieira *et al*., 2012). Duarte (2012) found that the use of a substrate composed of organic matter + subsoil for seed quality traits had a beneficial effect on plants, reflecting higher moisture levels, nutrient supply, and favorable conditions for germination, development, and seedling growth.

4 Conclusion

The species Pata-de-vaca (*Bauhinia forficata* L.) exhibits remarkable phenotypic variability for most of the seed descriptors evaluated (CVa, NSV, DS, PMS, and PTS), which results from the complex interaction of environmental factors and the plant's own response. Understanding this diversity is essential for developing more efficient strategies in seedling production programs, ecological restoration, and

biodiversity conservation.

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