Ambiente (ISSN 1981-4127)
Vol. 18 nº 1. Jan/Abr 2025

# Biometric and morphological features of *Dimorphandra mollis Benth.* fruits and seeds from the Cerrado of Minas Gerais. | *Características biométricas e morfológicas de frutos e sementes de Dimorphandra mollis Benth. do cerrado de Minas Gerais*

DOI: 10.24979/ambiente.v18i1.1501

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**Abstract**: The fava-d'anta (*Dimorphandra mollis Benth.*) is a native species of the Brazilian Cerrado, valued for its economic and ecological importance, particularly due to its medicinal properties. This study aimed to determine whether the fruits and seeds of *D. mollis*, collected from different localities within the Cerrado biome of Minas Gerais, exhibit variations in their biometric and morphological characteristics. Fruits and seeds were collected from four locations and subjected to biometric and morphological analyses. Significant variation was observed among the locations for characteristics such as fruit weight, thousand-seed weight, number of seeds per fruit, and morphological traits. The dissimilarity dendrogram indicated similarities between populations from different locations. The results highlight the importance of location in the selection of matrices for determine the desired characteristics for various uses of *D. mollis* fruits and seeds.

**Keywords**: Seed and fruit quality; Fava-d'anta; Forest seeds, Morphometry.

**Resumo**: A fava-d'anta (*Dimorphandra mollis Benth.*) é uma espécie nativa do Cerrado brasileiro, valorizada por sua importância econômica e ecológica, devido à suas propriedades medicinais. Este estudo teve como objetivo investigar se frutos e sementes de *D. mollis*, coletados em diferentes localidades do Cerrado de Minas Gerais, alteram, sua biometria e morfologia. Frutos e sementes foram coletados em quatro localidades e submetidos a análises biométricas e morfológicas. Observou-se variação significativa entre as localidades para características como peso dos frutos, peso de mil sementes, número de sementes por fruto e características morfológicas. Por meio do dendrograma de dissimilaridade, foram identificadas semelhanças entre as populações das diferentes localidades. Os resultados destacam a relevância da localidade na seleção de matrizes na determinação das características desejadas para diferentes usos dos frutos e sementes de *D. mollis*.

**Palavras-chave**: Qualidade de frutos e sementes; Fava-d'anta; Sementes Florestais; Morfometria.

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## 7.1 Introduction

The fava-d'anta (*Dimorphandra mollis Benth.*) is a native species that hold a important role in the flora of the Brazilian Cerrado, due to its economic and ecological value (Costa *et al.*, 2021). It holds great importance to the local fauna, serving as a food source for macaws, toucans, agoutis and tapirs. It demonstrates resilience, thriving in low-fertility soils and acting as a pioneer plant in areas undergoing ecological succession (Filizola, 2013). As a member of the Fabaceae family, it is also a major source of rutin and quercetin (Costa *et al.*, 2016).

Rutin, extracted from the fruits of the *D. mollis*, has anti-inflammatory, antioxidant, and antitumor properties (Silva *et al.*, 2020). This versatile compound is widely used in the pharmaceutical and cosmetics industries. Between 2011 and 2023, Brazil exported approximately 1,819,882 kg of rutin and its derivatives, with an average value of US$ 27.37 per kg (Brasil, 2023).

Despite the importance of the species, vegetation changes and predatory extractivism have contributed to the progressive decline of several native plants, including *D. mollis* (Chaves; Usberti, 2003). In addition, silvicultural studies on *D. mollis*, particularly those focused on its propagation and seed quality, remain limited.

Morphometric analyses of fruits and seeds have proven useful in understanding species ecology and dispersal patterns (Patrício; Thunder, 2020), identifying species within the same genus (Battilani; Santiago; Dias 2011), and assessing genetic variability (Silva *et al.*, 2022). These analyses also aid in evaluating the relationships between fruit and seed traits, and the degree of interactions between these characteristics (Zuffo *et al.*, 2016).

Despite being relatively easy to assess, morphometric traits of fruits and seeds of tropical tree species often exhibit significant variability (Roveri; Paula, 2017). This variability may occur due to genetic factors and environmental conditions (Bezerra *et al.*, 2022; Freire *et al.*, 2015).

Morphometric information hold a important role in seed technology, silvicultural production and ecological restoration of degraded areas (Ferreira; Barretto, 2015). Previous research on the biometrics and morphology of *D. mollis* fruits and seeds has employed different approaches to identify correlations between morphological traits of these structures and other factors. For example, research has examined the relationship between fruit biometric characteristics and collection time and their impact on rutin yield (Costa *et al.*, 2022). In addition, studies have investigated how the dimensions of fruits and seeds relate to the surrounding environment (Costa *et al.*, 2021; Santos *et al.*, 2020).

Further studies covering dimensional and morphological traits of fruits and seeds from different localities are important for identifying patterns and variations within *D. mollis* populations, promoting a better understanding of the ecology of the species. Therefore, this study aimed to determine whether the fruits and seeds of *D. mollis*, collected from

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different localities within the Cerrado biome of Minas Gerais, exhibit variations in their biometric and morphological characteristics.

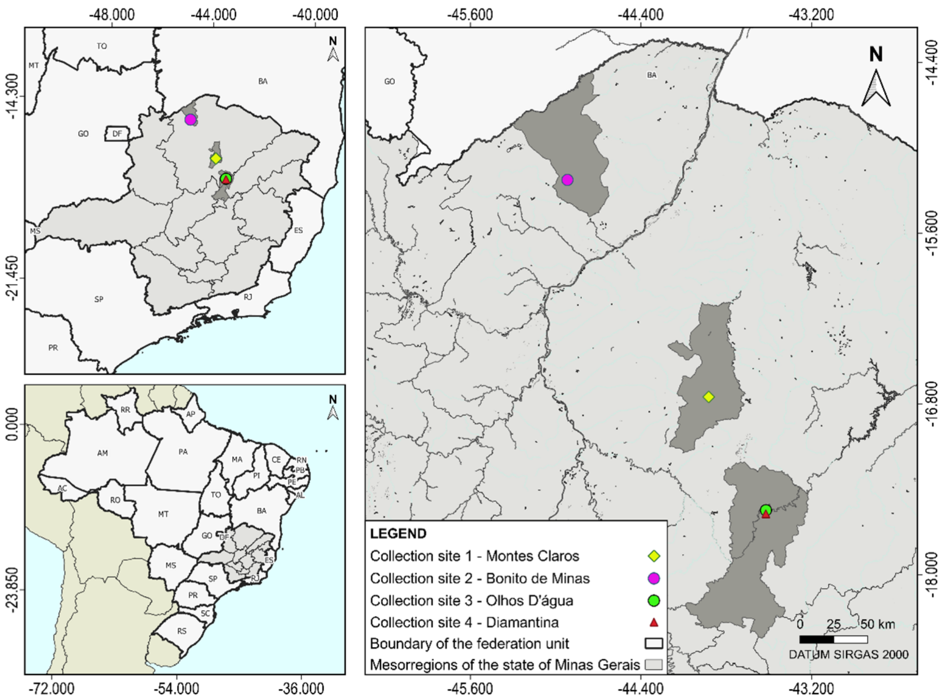
## 7.2 Material and Methods

### 7.2.1 Collection of the material and location of the experiment

Ripe fruits of Dimorphandra mollis, collected in August 2022, with deep brown color, were obtained from natural populations in the Cerrado biome. The collection was conducted from different mother trees until a total of 100 fruits per locality was reached. These populations were located in Montes Claros, Bonito de Minas, Olhos d'água, and Diamantina, in the state of Minas Gerais (Figure 7.1).

After collection, the fruits were placed in polyethylene bags and taken to the Laboratory of Medicinal and Aromatic Plants of the Institute of Agrarian Sciences at the Federal University of Minas Gerais (ICA-UFMG), for biometric analysis. The species was identified by means of comparison with sample of deposited plant in the "Herbário Norte Mineiro-MCCA", registry number: MCCA 3037.

**Figure 7.1:** Location map of the fruit collection area of *Dimorphandra mollis Benth.*




**Source:** Authors (2024).

### 7.2.2 Biometric and morphometric characterization of fruits and seeds

For biometric analysis, only fruits and seeds exhibiting good formation, free from mechanical damage or signs of predation, were selected. From each locality, 100 fruits and

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100 seeds were randomly chosen. Subsequently, length, width and thickness were measured with the aid of a digital caliper (accuracy of 0.01 mm).

Fruit weight was measured using a precision analytical balance. To ascertain the number of seeds per fruit, fruits were dissected. The total number of seeds, the number of intact seeds and the number of seeds damaged by insects within the fruits were then counted.

The values obtained from the measurements of the orthogonal axes of the fruits and seeds were used to calculate the Volume Index (7.1). Seed shape was determined based on the H Coefficient (7.2) and J Coefficient (7.3) (Imidra, 2016; Vieira *et al.*, 2008); where "a,b,c" refer to the values of length, width and thickness of the seeds, respectively.

$$IV = a \times b \times c \tag{7.1}$$

$$H = \frac{b}{c} \tag{7.2}$$

$$J = \frac{a}{b} \tag{7.3}$$

To determine the weight of 1,000 seeds (7.4), eight subsamples of 100 seeds were weighed on a precision scale, following the guidelines for seed analysis established by Brasil (2009).

$$(PSM) = \frac{\text{sample weight} \cdot 1000}{n^{\circ} \text{ total seeds}} \tag{7.4}$$

### 7.2.3 Design and Statistical Analysis

The data for the described parameters were submitted to statistical analysis using a completely randomized design. This design included four treatments (localities) with four replicates each, containing 25 fruits and seeds per replicate. The same design was employed for the statistical analysis of one thousand seed weight, adhering to the previously mentioned guidelines for the number of replicates established by Brasil (2009).

The Shapiro-Wilk test was performed to assess data normality. Analysis of variance (ANOVA) was performed, and the means were then compared using the Scott-Knott grouping test, when significant differences were detected. All tests were conducted at a significance level of 5% using the ExpDes.pt package in RStudio software version 4.4.0 (R Core Team, 2024).

Principal component analysis (PCA) was employed to investigate the relationships among the localities and the biometric and morphological data of the fruits and seeds (Table 7.3). The data underwent normalization, followed by the calculation of the covariance matrix and the creation of a biplot.

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A dendrogram was constructed using the Mojena's criterion (1977), which is a procedure based on the relative size of the fusion levels (distances) in the dendrogram. The dendrogram was constructed from a dissimilarity matrix, generated using the mean Euclidean distance between four populations of *D. mollis*.

For the clustering strategy, the UPGMA (Unweighted Pair Group Method with Arithmetic Mean) method was used. This matrix was based on biometric and morphological characteristics of the fruits and seeds of the species.

The cophenetic correlation coefficient, calculated using the Mantel test, is a method to assess how well a dendrogram represents the original distances or similarities between pairs of observations.

For both analyses, the MultivariateAnalysis, ggplot2, FactoMiner, Factoextra, and missMDA packages, were used in RStudio software version 4.4.0 (R Core Team, 2024).

**Board 7.2:** Biometric and morphological data of the fruits and seeds used in the principal component analysis and dendogram.

| Category | Acronym | Variable | Unit |
|---|---|---|---|
| Fruit | CF | Fruit Length | mm |
| Fruit | LF | Fruit Width | mm |
| Fruit | EF | Fruit Thickness | mm |
| Fruit | PF | Average fruit weight | g |
| Fruit | IVF | Fruit Volume Index | $cm^3$ |
| Fruit | NSTF | Number of total seeds per fruit | - |
| Fruit | NSIF | Number of intact seeds per fruit | - |
| Fruit | NSDF | Number of damaged seeds per fruit | - |
| Seed | CS | Seed Length | mm |
| Seed | LS | Seed Width | mm |
| Seed | ES | Seed thickness | mm |
| Seed | IVS | Seed Volume Index | $cm^3$ |
| Seed | CJS | J Coefficient | - |
| Seed | CHS | H Coefficient | - |
| Seed | PSM | Weight of a Thousand Seeds | g |

**Source:** Authors (2024).

## 7.3 Results and Discussion

The analysis of the fruits and seeds of Dimorphandra mollis revealed significant variation in weight, indicating differences in this characteristic across localities (Table 7.3).

Fruits and seeds collected from Montes Claros stood out for exhibiting significantly higher average weight, both for individual fruits (20.23 g) and for the weight of one thousand seeds (209.75 g). In contrast, the collection carried out in Diamantina yielded fruits with the lowest average weight (14.80 g), and the sample from Bonito de Minas showed the lowest weight of one thousand seeds (180.75 g) compared to the other areas analyzed.

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**Table 7.3:** Average values fruit weight and weight of thousand seeds (PSM) of *Dimorphandra mollis Benth.* from four localities.

| Localities | Average fruit Weight (g) | PSM (g) |
|---|---|---|
| Bonito de Minas | 18.18 b | 180.75 b |
| Montes Claros | 20.23 a | 209.75 a |
| Olhos d'água | 17.41 b | 211.50 a |
| Diamantina | 14.80 c | 227.00 a |

Averages followed by equal lowercase letters in the column belong to the same grouping according to the Scott-Knott test at the 5% significance level.
**Source:** Authors (2024).

The observed variations in fruit and thousand-seed weights can be attributed to the influence of environmental factors during flowering and development, as well as to the presence of genetic variability among the studied areas (Nogueira *et al.*, 2023).

Following Brasil (2009), seeds were categorized as small seeds (weight of thousand seeds [PSM]) less than 200 g) and large seeds (PSM greater than 200 g). The lots from Montes Claros, Olhos d'água and Diamantina were classified as large-seeded, while the seeds from Bonito de Minas were classified as small-seeded.

Regarding fruit-characterization based on the number of seeds, significant variation was observed among the localities (Table 7.4). The highest values for the total number of seeds per fruit were obtained (17 and 16, respectively) for the lots of Bonito de Minas and Montes Claros.

**Table 7.4:** Average values and standard deviation of total, intact, and malformed seeds per fruit of *Dimorphandra mollis Benth.* from different localities.

| Localities | Total Number of Seeds per Fruit | Number of Intact Seeds per Fruit | Number of Malformed Seeds per Fruit |
|---|---|---|---|
| Bonito de Minas | 17 ± 0.29 a | 8 ± 0.41a | 9 ± 0.29 a |
| Montes Claros | 16 ± 0.29 a | 6 ± 0.41 b | 10 ± 0.50 a |
| Olhos d'água | 9 ± 0.75 b | 6 ± 0.25 b | 3 ± 0.50 b |
| Diamantina | 8 ± 0.85b | 3 ± 0.41 c | 5 ± 0.48 b |

Averages followed by equal lowercase letters in the column belong to the same grouping according to the Scott-Knott test at the 5% significance level.
**Source:** Authors (2024).

Studies have shown a negative correlation between the number of seeds and seed mass in forest species. For example, Janzen (1982) observed that pods containing 1 to 5 seeds had a mass up to 3.0 times greater than those containing 7 to 16 seeds. This trend was also evident in the seeds from Bonito de Minas, which, despite registering the highest numbers of seeds per fruit, had significantly lower thousand-seed weight (180.75 g).

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The extractive activity of the *D. mollis* involves the collection of immature fruits directly from the plant (Filizola, 2013). In this study, the proportion of malformed seeds per fruit varied significantly among the localities, ranging from 33.33% to 62.50%. Comparatively, a study conducted by Freitas *et al.* (2009), in Papagaios and Paraopeba, both cities in the state of Minas Gerais, Brazil, found approximately 70.7% of malformed seeds. These results, from both studies, correspond to ripe fruits collected from the soil. This suggests that *D. mollis* fruits remaining in the field may have more than half of their seeds unviable, potentially contributing to a decline in the natural population over time.

Among the biometric parameters of the fruits, significant statistical differences were observed only for mean fruit volume, length and width index (Table 7.5). Fruits collected in Bonito de Minas displayed the highest average length (129.48mm). However, the Montes Claros (27.86 mm) and Olhos d'água (27.39 mm) lots exhibited the highest average width.

**Table 7.5:** Average values and standard deviation of length, width, thickness and volume index (IV) of fruits and seeds of *Dimorphandra mollis Benth.* from different localities.

| Localities | Length (mm) | | Width (mm) | | Thickness (mm) | | IV (cm³) | |
|---|---|---|---|---|---|---|---|---|
| | Fruit | Seed | Fruit | Seed | Fruit | Seed | Fruit | Seed |
| Bonito de Minas | 129.48 ± 0.71 a | 11.26 ± 0.40 a | 25.17 ± 0.34 b | 5.46 ± 0.11 b | 9.88 ± 0.18 a | 3.76 ± 0.13 b | 32.85 ± 1.05 b | 0.24 ± 0.02 a |
| Montes Claros | 118.71 ± 3.79 b | 11.06 ± 0.33 a | 27.86 ± 0.60 a | 5.65 ± 0.08 b | 10.88 ± 0.21 a | 4.12 ± 0.04 a | 36.99 ± 2.08 a | 0.26 ± 0.01 a |
| Olhos d'água | 101.18 ± 2.73 c | 11.24 ± 0.07 a | 27.39 ± 0.37 a | 5.75 ± 0.04 b | 10.95 ± 0.27 a | 4.04 ± 0.03 a | 30.48 ± 1.98 b | 0.26 ± 0.01 a |
| Diamantina | 102.73 ± 2.14 c | 10.95 ± 0.25 a | 26.13 ± 0.76 b | 6.27 ± 0.09 a | 10.60 ± 0.39 a | 4.20 ± 0.09 a | 29.63 ± 1.59 b | 0.29 ± 0.01 a |

Averages followed by equal lowercase letters in the column belong to the same grouping according to the Scott-Knott test at the 5% significance level.
**Source:** Authors (2024).

For the biometric parameters of the seeds, significant statistical differences were found only for the mean width and thickness. The Diamantina lot presented the highest mean width (6.27 mm) compared to the other locations. No significant statistical difference was observed in thickness among the Montes Claros, Olhos d'água and Diamantina lots. However, the Bonito de Minas lot had the lowest mean thickness (3.76 mm).

Regarding the volume index, the Montes Claros lot showed higher fruit volume. No significant statistical differences were observed in the seed volume index among the collection sites.

When analyzing the seed morphology, it was observed that the seeds of the Montes Claros, Olhos d'água and Diamantina lots were oblong and semi-filled (Table 7.6). In contrast, the seeds from Bonito de Minas differed in format, being oblong and flattened seeds.

The PCA, illustrating the variation among different localities based on the biometric and morphological characteristics of the fruits and seeds of *D. mollis*, is presented in Figure 7.7. The first two principal components accounted for 73.4% of the total variation in the dataset.

DOI: 10.24979/ambiente.v18i1.1501

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**Table 7.6:** Characteristics of the shape of *Dimorphandra mollis Benth.* seeds from different localities.

| Localities | Coefficients | | Shape |
|---|---|---|---|
| | J | H | |
| Bonito de Minas | 2.08 | 0.70 | oblong and flattened |
| Montes Claros | 2.00 | 0.74 | oblong and semi-full |
| Olhos d'água | 1.94 | 0.71 | oblong and semi-full |
| Diamantina | 1.76 | 0.67 | oblong and semi-full |

**Source:** Authors (2024).

The first dimension (Dim1) accounts for 47,4% of the total variance in the data, while the second dimension (Dim2) contributes 26% (Figure 7.7). The observations, representing four distinct localities, are clearly distinct in the PCA space, indicating significant variations in the original variables, and distinct patterns of variation among them.

The overlap between the variable "thousand-seed weight" and the observation of "Olhos d'água" indicates that this variable is informative for observation. This suggests that the weight of 1,000 seeds contributes significantly to the position of this observation in the Principal Component space. In addition, in the locality "Olhos d'água", the highest estimates were observed for the index of seed volume, seed thickness, fruit thickness and fruit width.

In the "Montes Claros" observation, the highest estimates for both Dim1 and Dim2 were highlighted, indicating higher values for seed H coefficient, fruit volume index, average fruit weight, number of damaged seeds per fruit, and seed length.

It is observed that the locality of Bonito de Minas presented low estimates in both Principal Components, which suggests a high estimate for fruit length and the number of intact seeds per fruit. In addition, these two variables demonstrate a strong positive correlation. The locality of Diamantina registered a significantly high score in Dim1, which indicates greater seed width.

Most of the variables showed a moderate positive relationship, indicating a reasonable association. However, "fruit length" and "number of intact seeds per fruit" showed a association, while "fruit length" and "fruit width and thickness" showed a negative relationship, although less intense.

The same pattern of moderate negative relationship between seed length and seed width and thickness variables was identified, indicating a consistent relationship between these variables in both fruits and seeds. The cophenetic correlation was calculated as K = 0.85.

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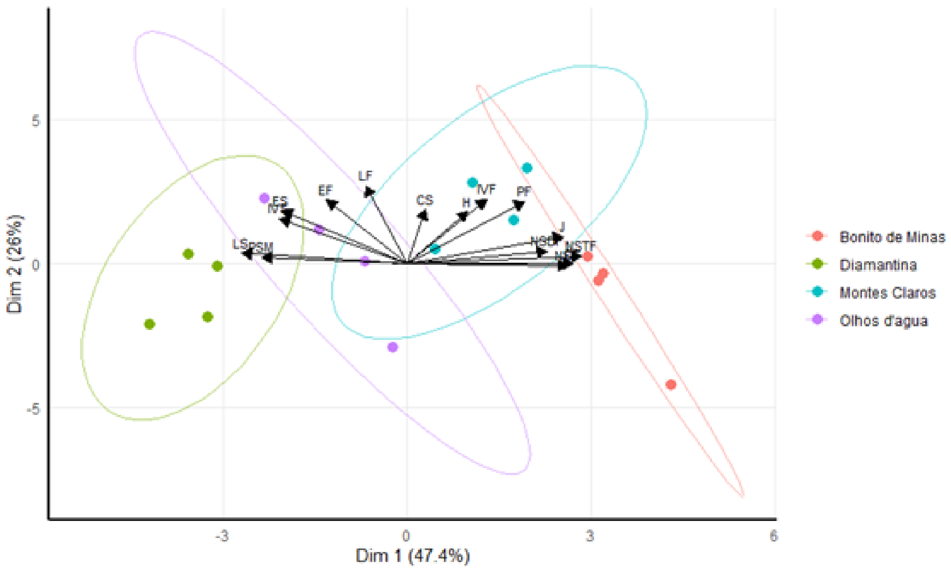
**Figure 7.7:** Bi-plot graph obtained from principal component analysis (PCA) of biometric and morphological variables of fruits and seeds of *Dimorphandra mollis Benth.* collected in 4 localities.




CF (Fruit Length); LF (Fruit Width); EF (Fruit Thickness); PF (Average fruit weight); IVF (Fruit Volume Index); NSTF (Number of total seeds per fruit); NSIF (Number of intact seeds per fruit); NSDF (Number of damaged seeds per fruit); CS (Seed Length); LS (Seed Width); ES (Seed thickness); IVS (Seed Volume Index); CJS (J Coefficient); CHS (H Coefficient); PSM (Weight of a Thousand Seeds).
**Source:** Authors (2024).

However, it is important to note that the cophenetic correlation of K = 0.85 was not considered statistically significant by the Mantel test. This means that the relationships observed in the dendrogram may not be statistically conclusive.

In the grouping of populations according to the Mojena criterion, all populations were united into a single cluster, with a cut-off point of 11.64. This indicates that, based on the dissimilarity of the characteristics analyzed, the four populations of *D. mollis* were considered similar enough to be grouped in a single cluster, suggesting great similarity between them in this context.

In the dendrogram, it is observed that the populations of "Diamantina" and "Olhos d'Água" are the closest to each other, since they were grouped at a lower height level, suggesting a greater similarity in their biometric and morphological characteristics. On the other hand, "Bonito de Minas" and "Diamantina" appear as more distant populations in the dendrogram, since their grouping occurred at a considerably higher height. This position suggests that these two populations are the most dissimilar in terms of the characteristics analyzed, standing out as the most distinct in the context of the analysis. This can be explained by the fact that the collection sites are more geographically distant, being present in two hydrographic basins, the São Francisco and the Jequitinhonha.

It can be observed, from the data obtained, the importance of the locality, especially for programs aimed at the selection of matrices, aiming at the desired purpose for the fruits

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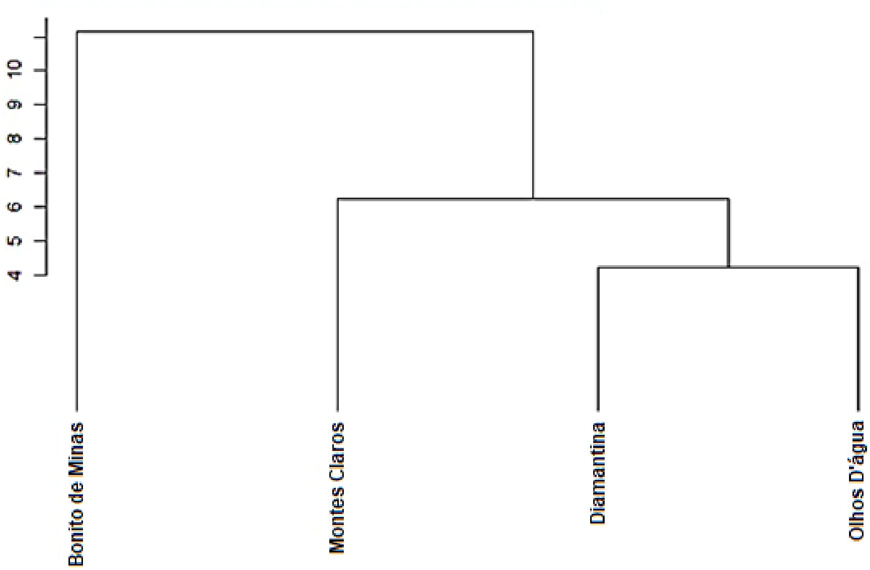
**Figure 7.8:** Dendrogram of the grouping of four populations of *Dimorphandra mollis Benth.* (based on biometric and morphological characteristics of fruits and seeds), obtained by the UPGMA method and using the mean Euclidean distance.




**Source:** Authors (2024).

and seeds. For the extraction of bioflavonoids from the fruits, it may be more interesting to propagate seeds from localities where the matrices are characterized by the production of larger fruits.

However, if the intention is to collect seeds for the production of seedlings or galactomannans, we notice that smaller fruits, and consequently with fewer seeds, have intact seeds and probably with greater viability. On the other hand, when compared to larger fruits, although they contain more malformed seeds, they require fewer fruits for processing, since the average number of intact seeds is still higher.

## 7.4 Conclusion

In conclusion, the dissimilarity dendrogram revealed significant similarities between populations from different localities. Depending on the intended use of the *D. mollis* fruits and seeds, it is possible to select specific characteristics by using the variables separately, considering the particularities of each locality. The fruits and seeds from Montes Claros stood out for having the highest average weight, both for individual fruits and for the weight of 1,000 seeds. Bonito de Minas and Montes Claros had the highest values for the number of seeds per fruit. These results suggest that the choice of locality holds a crucial role in selecting the desired characteristics, depending on the intended purpose.

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## Acknowledgments

This study was carried out with the support of the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brazil (CAPES) – Finance Code 001, and the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG).