

Genetic parameters and promising provenances and progenies for enhanced silvicultural traits in *Eremanthus erythropappus*

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Abstract

Eremanthus erythropappus, a species of economic importance for α -bisabolol production, has great potential for genetic improvement. However, limited knowledge on genetic parameters during the exploitation of commercial plantations hampers its progress. In this study, we estimated genetic parameters and correlations for silvicultural traits in a provenance and progenies test of *E. erythropappus* at 11 years of age, aiming to identify promising provenances and families. The experiment, conducted in Baependi, involved five provenances and 116 half-sib families in a complete randomized block design. Height (H), diameter at breast height (DBH), survival (SOB), and volume (Vol) were measured, and the REML/BLUP mixed model approach was used to estimate genetic parameters. Our results revealed significant genotype-level effects for all traits, except H at the provenance level. Narrow sense heritability ranged from 0.05 (SOB) to 0.17 (DBH), suggesting a substantial influence of environmental factors. Genotypic variation surpassed that of provenances, and positive phenotypic and genotypic correlations between growth traits were observed, ranging from moderate to strong. Notably, the provenances Itabirito and Delfim Moreira exhibited outstanding performance in terms of DBH and Vol. Furthermore, families 4, 6, 37, 118, and 124 emerged as top contenders for H, DBH, and Vol. Despite low heritability, selection strategies within and between provenances and families for silvicultural traits are viable. Importantly, high phenotypic and genotypic correlations allow for indirect selection, thus streamlining assessment efforts. These findings advance our understanding of genetic parameters providing valuable insights for the genetic improvement of *E. erythropappus*, fostering its sustainable utilization in various industries.

INTRODUCTION

Eremanthus erythropappus (DC.) MacLeish is a species belonging to the Asteraceae family that is naturally distributed in the southeastern Central Plateau of Brazil, encompassing the states of Goiás, Distrito Federal, Minas Gerais, São Paulo, Rio de Janeiro, and Espírito Santo (Araújo et al. 2018). It is found in a variety of habitats, ranging from forest communities to open fields such as Cerrado, rupestrian fields, and high-altitude fields, where it often forms nearly pure stands referred to as "candeais" in Portuguese (Araújo et al. 2018). The species is commonly exploited in rural communities, primarily for fence posts, due to its natural occurrence in Cerrado areas and high population density. However, commercial exploitation mainly focuses on the extraction of essential oil, which contains the active ingredient α -bisabolol and is widely used in the medical and cosmetic industries (Donadelli 2012).

Although most exploitation of *E. erythropappus* follows sustainable management plans (Araújo et al. 2018), there are limited commercial plantations typically associated with oil processing companies (Donadelli 2012). Since *E. erythropappus* is a Brazilian-native species with little domestication, plantation cultivation relies on seedlings with heterogeneity in growth and production. Consequently, there is a need for research on the genetic improvement of *E. erythropappus* to enhance its productive potential, given the commercial demand for increased uniformity and larger yields.

In genetic improvement programs for native forest species, a successful strategy has been to emulate the approach used for the genus *Eucalyptus*. Kageyama and Vencovsky (1983) outlined this approach, which begins with the identification of promising species, followed by progeny testing and ultimately focusing on selected progenies and cloning.

E. erythropappus is known for its high α -bisabolol production and exhibits significant genetic diversity among natural populations (Padua et al. 2021). Genetic variability has also been observed in progeny tests for initial growth up to 30 months (Avelar et al. 2021). However, limited information is available on different provenances at age crop exploitation, especially at 11 years.

In this context, the present study aims to (I) estimate the genetic parameters for growth traits of *E. erythropappus* at age crop exploitation; (II) examine the correlations among the growth traits themselves and with environmental variables from provenances; and (III) identify the most promising progenies for further development.

MATERIALS AND METHODS

The progeny experiment was established in January 2005 in the rural area of Baependi, Minas Gerais, Brazil (21°57'52.35 "S; 44°45'45.88 "W). The region has a Cwb (high altitude tropical) climate with hot and humid summers and cold and dry winters, with a mean annual temperature of 18.5°C and rainfall of 1400 mm. Open-pollinated seeds were collected from five locations (Delfim Moreira, Baependi, Carrancas, Itabirito, and Morro do Pilar), and within each source, 20 to 24 progenies were collected, totaling 116 progenies (Table 1 and Fig. 1).

Table 1
Geographical coordinates, altitude, climate, average annual temperature, and the number of progenies of each *Eremanthus erythropappus* provenance

Provenance	Progenies*	Latitude	Longitude	Altitude (m)	Climate	T (°C)**
Delfim Moreira	24 (26–50)	-22,50392438	-45,27919975	1200	Cwb	17,0
Baependi	24 (51–75)	-21,79987416	-44,89627636	893	Cwb	18,5
Carrancas	24 (76–100)	-21,48346426	-44,64443417	1052	Cwa	20,7
Itabirito	24 (101–125)	-20,24505001	-43,80469534	848	Cwa	17,4
Morro do Pilar	20 (1–25)	-19,21642284	-43,37687709	760	Cwb	22,0

* Total number of progenies and individual number of each progeny within the provenance; ** average annual temperature.

The test of progenies was implemented in a randomized complete block design, with seven replicates and linear plots of six plants. The area was prepared by tillage at a depth of 30 cm, with planting at a spacing of 2.5 m x 2.0 m and planting fertilization of 150 g of NPK (08:28:16) per plant. Throughout the experimental period, control of leaf-cutting ants and fire prevention measures were carried out.

At eleven years after planting, survival (SOB) and height (H) were evaluated using a graduated ruler (m), and diameter at breast height (DBH-cm) with the circumference measured with a tape measure was recorded and later converted to diameter. Then, individual volume (Vol) was estimated according to the model of Schumacher and Hall (Eq. 1) parameterized for this data set, using only the main stem.

$$\ln (Vol) = -8,78608 + 1,83257\ln (DBH) + 0,47149\ln (H) \text{ (Eq. 1)}$$

$$R^2 (\%) = 77,6; S_{xy} (m^3) = 0,0007;$$

where Vol = individual volume (m³), DBH = diameter at breast height (cm), H = height (m), R² (%) = regression coefficient of the model, and S_{xy} (m³) = standard deviation of the error.

To estimate the variance components and predict genetic values, the maximum likelihood residual and best linear unbiased predictor (REML/BLUP) procedure was used. For this, the statistical model $y = Xr + Za + Wp + Ts + e$ was used, where y is the vector of data, r is the vector of repetition effects (assumed as fixed) added to the general average, a is the vector of individual additive genetic effects (assumed as random), p is the vector of plot effects (assumed as random), s is the vector of population or provenance effects (random) and e is the vector of errors or residues (random). The capital letters X, Z, W, and T represent the incidence matrices for these effects.

The significance of the random effects of genotypes, plots, and provenances (populations) was tested by the likelihood ratio test (LRT) at 1% error probability in a deviance analysis for each trait. Pearson correlation analysis was performed with phenotypic means and environmental variables for each origin. Genotypic means and genetic and phenotypic correlations were obtained by models 5 and 120 of the SELEGEN REML/BLUP software (Resende 2016).

The coincidence index (CI) was used to evaluate the selection efficiency of progenies across traits for the following selection scenarios and selection intensities: 10 best progenies (8.62%), 20 best progenies (17.24%), 30 best progenies (25.86%), 40 best progenies (34.48%), and 50 best progenies (43.10%). The 116 progenies were used for the calculation, applying the formula of Hamblin and Zimmermann (1986) as follows:

$$CI = \frac{A-C}{M-C} \text{ (Eq. 2)}$$

where C is the number of selected superior progenies due to chance. It is assumed that the number of selected superior progenies, a proportion equal to the selection intensity, coincides by chance. A is the number of selected superior progenies common to the different traits. M is the number of superior progenies selected for one of the characteristics.

RESULTS

The effects of genotypes were significant by the likelihood ratio test for all variables analyzed (Table 2). The effect of provenance was not statistically significant only when the H of *E. erythropappus* plants was evaluated.

Table 2

Analysis of deviance (ANADEV) for height, diameter at breast height (DBH), volume, and survival of progenies of *Eremanthus erythropappus* at 11 years of age in Baependi, MG

Models	Height		DBH		Volume		Survival	
	DEV	LRT	DEV	LRT	DEV	LRT	DEV	LRT
Complete	1760		5750.25		-37484.99		-3663.93	
(-) genotypes	1765	5.02*	5766.05	15.8*	-37476.07	8.92*	-3659.87	4.06*
(-) plot	2910	1150*	5990.93	240.68*	-37212.21	272.78*	-3424.18	239.75*
(-) provenance	1763	2.67	5755.62	5.37*	-37480.13	4.86*	-3623.28	40.65*

DEV - Deviance, LRT - Likelihood ratio test, with distribution with 1 degree of freedom; *significant at 1% probability level by chi-square test; (-) model without the said effect.

The estimated genetic parameters are shown in Table 3. Among the parameters, it is remarkable that the variation in the coefficients of heritability in the restricted sense (h^2_r) ranged from 0.05 for survival to 0.17 for DBH. The higher expression of the genetic coefficient of variation of the progenies ($CV_{gP}\%$) and the lower value of the genotypic coefficient of variation of the provenances ($CV_{gp}\%$) are also noteworthy.

Table 3
Estimates of genetic parameters for height (m), diameter at breast height (DBH-cm), Vol (m³) and survival (%) of the progenies of *Eremanthus erythropappus* at 11 years in Baependi, MG

Parameters	Height	DBH	Volume	Survival
σ^2_a	0.123	0.359	0.000002	0.010
σ^2_{parc}	0.432	0.448	0.000003	0.032
σ^2_{proc}	0.009	0.024	0.000000	0.008
σ^2_e	0.309	1.186	0.000008	0.141
σ^2_f	0.873	2.018	0.000013	0.191
h^2_r	0.141	0.178	0.132	0.055
c^2_{parc}	0.495	0.222	0.247	0.165
c^2_{proc}	0.010	0.012	0.011	0.044
CVgi%	8.226	13.921	25.449	13.838
CVgp%	4.113	6.960	12.724	6.919
CVe%	16.559	19.296	42.311	32.157
CVr	0.496	0.721	0.430	0.601
Overall average	4.26 m	4.31 cm	0.005 m ³	74%

σ^2_a – additive genetic variance; σ^2_{parc} – environmental variance between plots; σ^2_{proc} – genetic variance between provenances; σ^2_e – residual variance; σ^2_f – individual phenotypic variance; h^2_r – individual heritability in the restricted sense; c^2_{parc} – c coefficient of determination of plot effects; c^2_{proc} – coefficient of determination of the effects of provenance; CVgi% - coefficient of individual additive genetic variation; CVgp% - coefficient of genotypic variation between populations; CVe% - coefficient of residual variation; CVr – coefficient of relative variation.

The phenotypic and genotypic correlations were positive among the growth variables (H, DBH, and Vol). There was a high positive correlation between the DBH and Vol variables for both phenotypic (0.96) and genotypic (0.98) traits. Moderate correlations were observed between H and DBH, 0.70 and 0.71 for phenotypic and genotypic correlations, respectively. The phenotypic and genotypic correlations between H and Vol were coincident for both, with 0.72 being considered moderate.

Among the provenances, the best performance for growth in DBH and Vol was the Itabirito origin, which presented the highest genotypic effects for these characteristics (Table 4). The provenances of

Carrancas and Baependi showed negative genotypic effects for DBH and Vol but showed the highest survival values.

Table 4
Estimates of genotypic effects (g), genetic value (u + g), genetic gain, and new mean with selection of *Eremanthus erythropappus* strains for diameter at breast height (DBH), Vol and survival at 11 years in Baependi, MG

(DBH) (cm)	Rank	Provenances	g	u + g	Gain	New mean
	1	Itabirito	0.146	4.453	0.146	4.453
	2	Delfim Moreira	0.065	4.371	0.105	4.412
	3	Morro do Pilar	0.062	4.369	0.091	4.398
	4	Carrancas	-0.086	4.221	0.047	4.354
	5	Baependi	-0.186	4.121	0.000	4.307
Volume (m ³)	Rank	Provenances	g	u + g	Gain	New mean
	1	Itabirito	0.0003	0.0054	0.0003	0.0054
	2	Morro do Pilar	0.0002	0.0053	0.0003	0.0054
	3	Delfim Moreira	0.0001	0.0051	0.0002	0.0053
	4	Carrancas	-0.0002	0.0048	0.0001	0.0052
	5	Baependi	-0.0004	0.0047	0.0000	0.0051
Survival (%)	Rank	Provenances	g	u + g	Gain	New mean
	1	Carrancas	6.6%	80.4%	6.6%	80.4%
	2	Baependi	6.2%	80.1%	6.4%	80.2%
	3	Itabirito	1.9%	75.7%	4.9%	78.7%
	4	Delfim Moreira	0.5%	74.3%	3.8%	77.6%
	5	Morro do Pilar	-15.2%	58.6%	0.0%	73.8%

The environmental variables of the original regions of the progenies and the silvicultural aspects observed in the plantation in Baependi show a moderate correlation between latitude and performance in H, Vol, and survival (Table 5).

Table 5
Person's correlation between the genetic value for height, diameter at breast height (DBH), Vol and survival and the environmental variables of *Eremanthus erythropappus* branches at 11 years in Baependi, MG

Environmental characteristics	Height	DBH	Volume	Survival
Latitude*	-0.70	-0.45	-0.65	0.74
Longitude*	-0.71	-0.49	-0.68	0.70
Altitude (m)	-0.43	-0.09	-0.36	0.50
Average annual temperature (°C)	0.08	-0.20	-0.06	-0.54
* The latitude and longitude moduli were used for the correlation calculations				

For survival, the correlation was positive, differing from the negative correlation observed for H and Vol associated with latitude and longitude. DBH showed a weak correlation among all the variables analyzed, with no correlation with altitude. There were no correlations for mean annual temperature (°C) with H and Vol of *E. erythropappus*.

Analyzing the progenies, more than half of the progenies of *Eremanthus erythropappus* presented negative BLUP for H, DBH, and Vol (Fig. 2). For survival, there was a higher number of good families within the analyzed progenies.

There is a high coincidence among the best progenies for H, DBH and Vol, highlighting the progenies 4, 6, 37, 118 and 124, which appeared among the ten best progenies for all the characteristics mentioned (Table 6). The pattern of coincidence continues between these characteristics if there is the selection of a greater number of progenies selected (Table 7), highlighting the total coincidence between the 20 best progenies for DBH and Vol. Survival seems to be uncorrelated with the growth characteristics because there is no coincidence among the ten progenies selected (Table 6), and there is a negative coefficient of coincidence in the different intensities of selection (Table 7).

Table 6
Ranking of the ten best *Eremanthus erythropappus* progenies for height, diameter at breast height (DBH), volume and survival at 11 years and their respective gains from selection in Baependi, MG

Rank	Progenies			
	Height	DBH	Volume	Survival
1	4	37	7	76
2	6	109	109	81
3	37	118	37	53
4	8	14	118	95
5	11	124	101	63
6	118	6	124	74
7	57	7	6	97
8	124	4	4	92
9	17	36	14	93
10	3	115	3	112
Gain (%)	9.24	17.50	33.33	14.54

In bold, the families coinciding for the characteristics of height, DBH and volume.

Table 7
Coincidence index in the selection of *Eremanthus erythropappus* progenies for the combinations of height (H), diameter at breast height (DBH), volume (Vol) and survival (Sur) at different selection intensities at 11 years in Baependi, MG

Number of selected	Selection Intensity	Number of randomly selected (C)	Coincidence index (%)					
			DBH-H	DBH-Sur	DBH-Vol	H-Sur	H-Vol	Sor-Vol
10	8.62	0.74	46.0	-8.0	78.4	-8.0	56.8	-8.0
20	17.24	2.97	53.0	-17.4	100.0	-11.6	53.0	-17.4
30	25.86	6.68	52.8	-24.4	82.8	-11.5	52.8	-20.1
40	34.48	11.88	64.4	-13.8	92.9	-6.7	64.4	-10.2
50	43.1	18.57	71.4	-1.8	90.5	-1.8	74.5	-8.2

DISCUSSION

Genetic parameters

The selection of superior genotypes within populations is supported by the sufficient variability of H, DBH, Vol, and survival inferred by the significance of the effects of genotypes by the likelihood ratio test (Table 2). There is no possibility of plant H gains via the selection of provenances because there was no notable effect of this trait among the *E. erythropappus* progenies (Table 2).

Within the estimates of phenotypic variation ($\sigma^2_{\hat{p}}$), the greatest influence of environmental variances (σ^2_{parc} and σ^2_e) and a smaller contribution of genetic variance (σ^2_a and σ^2_{proc}) were observed for all traits analyzed (Table 3). The greater influence of environmental variances was emphasized when observing the plot determination coefficients (c^2_{parc}), which refer to the variation within the blocks. Values of c^2_{parc} above 10% are not recommended (Resende 2002). In the situation where it exceeds 10%, it is suggested to reduce the number of plants in the plot and increase the number of repetitions in the experiment (Kubota et al. 2015), thus reducing the within-plot effect and increasing the repetition and environmental control within the repetition. This same scenario was observed in another progeny test of *E. erythropappus* with six plants per plot (Avelar et al. 2021), indicating that reducing the number of plants in the plot and increasing the number of blocks is important for breeding programs of the species.

Within the estimates of the components of genetic variance, there was a greater contribution of the additive genetic variance (σ^2_a) than of the genetic variance between provenances (σ^2_{proc}) for all traits (Table 3). Similar behavior to that of *Toona ciliata* progenies was demonstrated by Santos et al. (2021). Due to a low expression of σ^2_{proc} , there was a low coefficient of determination of the effects of provenances (c^2_{proc}), all lower than 4.5%, similar to those found in *Eucalyptus urophylla* provenances in tests in Brazil (Hodge and Dvorak, 2015). These values indicate that although there is variation among provenances, it is modest compared to variation among individuals.

The relationship of CVgi% being twice as high as CVgp% was also observed by Santos et al. (2021) in *T. ciliata* provenances. Although populations are more homogeneous for growth traits than the variation between individuals, it is still possible to make gains in selecting for these traits in conjunction with selection between families and individuals.

Heritability estimation is highly influenced by the homogeneity of the experimental environment (White et al. 2007). Therefore, the heritabilities for *E. erythropappus* were low due to the high values of environmental variance obtained in the test. Similar heritability was obtained for the H of *E. erythropappus* at different ages, ranging from 0.08 to 0.18 (Avelar et al. 2021). In *T. ciliata*, higher heritability estimates were obtained for H (0.30) and DBH (0.15), but with a reduction in values with planting age due to environmental factors, such as intraspecific competition (Santos et al. 2021).

The heritabilities for the characteristics of commercial interest in forest species usually vary between 0.10 and 0.30, and only traits related to wood quality reach heritabilities greater than 0.40, as reported by White et al. (2007). The same authors emphasize that heritability in the narrow sense, estimated from a

single test and in a single location, is usually overestimated due to not considering the effect of the genotype– environment interaction.

The higher magnitudes of the coefficient of variation (CVe%) may be associated with the differential response of genotypes to stressors such as aluminum toxicity, low soil fertility, water deficit, high temperatures, pest attacks, and fires that may occur throughout cultivation (Santos et al. 2021). In field experiments, high values of CVe% are expected, with those between 10% and 20% being considered adequate (Pimentel-Gomes 2009). Under these conditions, the CVe% for H and DBH can be considered adequate, and the high values of CVe% for Vol may be associated with its indirect estimation, accumulating the residues of the variables that are part of its calculation.

The values of the relative coefficient of variation were all less than 1 due to the greater magnitude of CVe% compared to CVgi%, indicating a greater variation due to the environment than the estimated variation due to the genetic component. This scenario seems to be commonly found in genetic experiments with native Brazilian species, as observed in *Tachigali vulgaris* (Cruz et al. 2020), *Dipteryx alata* (Andrade et al. 2020) and *Erythropappus* (Avelar et al. 2021). This scenario is not the most favorable for selection (Massaro et al. 2010); however, Resende and Duarte (2007) state that although CVr is below 1, high accuracy and precision can be achieved if the number of repetitions is higher than five. Therefore, even with the low values of the relative coefficient of variation, it is still possible to perform selection with good accuracy due to the use of seven blocks in the experimental design.

As reported, *E. erythropappus* has slow growth and is subject to intense environmental variation due to factors inherent to its cultivation, such as the high demand and duration of measures to control weed competition, or even due to the lack of appropriate protocols for its silviculture, such as the lack of information about soil correction and fertilization protocols. These factors affect the quality of the genetic parameter estimates for the species, as reported by Avelar et al. (2021) and observed in this work. Changes in the design of genetic tests with the species should be considered, such as reducing the number of plants per plot and increasing the number of repetitions, adjustments that could reduce c^2_{parc} and CVe% and increase the precision of heritability estimates.

The fact that all phenotypic and genotypic correlations were positive and moderate (over 0.70) to strong (over 0.96) is beneficial for the improvement program of the species since there is the possibility of gains with indirect selection. The high phenotypic and genotypic correlations can be explained by gene linkage or pleiotropy (Falconer and Mackay, 1996).

Provenance and environmental variables

Higher survival values were found in the Carrancas and Baependi varieties, indicating that they have interesting alleles of adaptability to the soil and climate factors of the planting region. Importantly, the lower survival of plants from the Morro do Pilar provenance may have masked its growth values since competition within and between plots dictates the growth of individuals, so the DBH and the individual Vol of the Morro do Pilar provenance plants may be overestimated.

The moderate correlations between latitude and longitude with H and survival variables may indicate clinal variation (Table 5), that is, a continuous genetic gradient associated with environmental variation. However, it is necessary to test more provenances to obtain a more comprehensive distribution pattern. This behavior shows that natural selection events provided the maintenance of individuals better adapted to the environmental gradient, being a selection pressure that continuously caused changes in allele frequencies, mainly on loci that control traits aimed at adaptation (White et al. 2007).

Studies of population behavior and environmental variables are important tools to guide the prospection of seed collection, the indication of planting locations, and, above all, studies on the effects of climate change. *Eucalyptus tereticornis* progenies, for example, showed a high correlation between growth variables and mean annual temperature (Booth 2019), drawing attention to future selections within the species under a scenario of increasing mean annual temperature due to the effects of climate change. In this scenario, although of moderate magnitude, there is a negative correlation (-0.54) between *E. erythropappus* survival and increasing mean annual temperature, and there may be damage to the conservation and production of this species due to the progressive increase in this environmental characteristic.

These observations corroborate the simulations of Carvalho et al. (2019) in a study that showed that the precipitation of the wettest quarter, the temperature of the coldest quarter, and the average annual temperature were the variables that most influenced the ecological niche models for the conservation of *E. erythropappus*. The same authors also reinforce that altitude is an important variable in the conservation of the species, as populations of *E. erythropappus* are more likely to be found at higher altitudes, which corroborates the positive correlation (0.5) of this environmental characteristic with survival (Table 5).

Breeding considerations

Significant genetic parameters were identified that bring relevant advances for the management of the breeding program of *E. erythropappus*. The analysis of the different provenances concerning growth and adaptation traits revealed low genetic variability, indicating a preference for progeny selection strategies.

Among progenies, there is an opportunity to exploit the benefits from selection for growth traits. However, due to the reduced proportion of progenies with favorable genotypic values for H and Vol (Fig. 2), it is necessary to carefully select these traits. Importantly, the establishment of plantations in Baependi is favored since most of the progenies (66%) present good genetic values for survival at the site.

The positive and high correlation between the variables of growth and production with the DBH, as evidenced by the high rate of coincidence of the direct selection of DBH with the characteristics H and Vol (Table 7), is explained by the strong phenotypic and genotypic correlation between these characteristics (Table 4). This favorable scenario makes it possible to implement the breeding program of *E. erythropappus* efficiently since the direct selection of DBH, a trait that is easy to measure, would

result in indirect gains in H and Vol. Indirect selection would save time and resources during evaluations without causing losses in the gains obtained through selection.

CONCLUSION

The progenies of *E. erythropappus* showed genetic diversity favorable for selection in volume, DBH, Vol, and survival. However, the parameters of heritability were low. Little genetic variation is contained among the provenances, with more present within the progenies.

The Itabirito and Delfim Moreira progenies stood out in DBH and volume, while the Carrancas and Baependi progenies stood out in survival. The progenies 4, 6, 37, 118, and 124 were among the ten best for H, DBH, and Vol of *E. erythropappus* when evaluated at 11 years of age.

Declarations

Author contributions: Conceptualization: Rodolfo Soares de Almeida, Lucas Amaral de Melo; Methodology: Rodolfo Soares de Almeida, Lucas Amaral de Melo; Formal Analysis: Rodolfo Soares de Almeida; Heloisa Guimaraes Santos, Lavínia Barbosa Oliveira, Adelson Lemes da Silva Júnior; Visualization: Fernanda Leite Cunha, Ernani Lopes Possato; Writing – original draft: Rodolfo Soares de Almeida; Writing – review & editing: All Authors.

Interests: The authors have no relevant financial or non-financial interests to disclose.

Data availability All the data used in this study are freely available from the corresponding Author under request.

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Figures

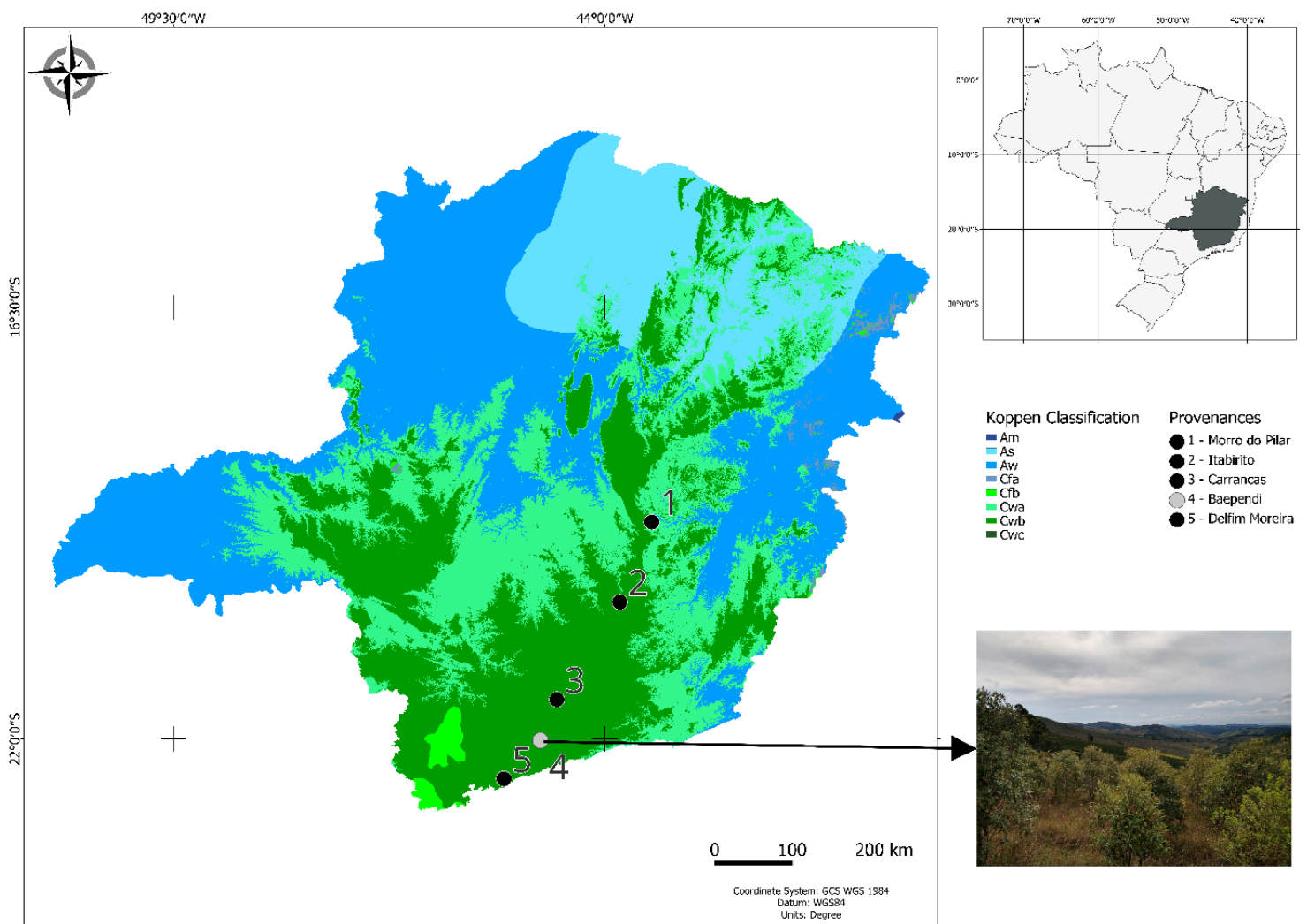


Figure 1

Map of the state of Minas Gerais and its climatic classification according to Koppen with the locations of the *Eremanthus erythropappus* provenances and the genetic test site in Baependi, MG, Brazil

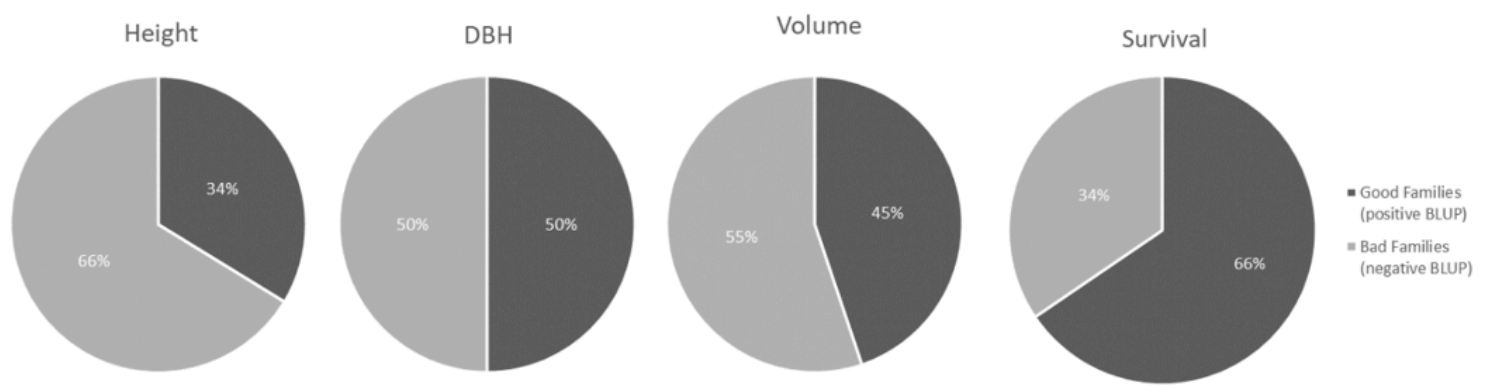


Figure 2

Percentage of good (BLUP positive - darker shades) and bad (BLUP negative - lighter shades) progenies of *Eremanthus erythropappus* for diameter at breast height (DBH), volume and survival at 11 years in Baependi, MG