REVISTA DELOS DESARROLLO LOCAL SOSTENIBLE

Selection and phenotypic divergence in pau de balsa of different origins

Seleção e divergência fenotípica em pau de balsa de diferentes origens

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ABSTRACT
Pau de balsa is a forest species that is native to the Amazon and stands out for its rapid growth, being an option for a productive and profitable activity. The objective of this study was to select phenotypically superior pau de balsa trees and verify the dissimilarity between them and their respective origins in order to identify individuals for wood production. Three distinct populations trees in plantations of pau de balsa implanted in January 2011 in the municipality of Guarantã do Norte, Mato Grosso, Brazil, were evaluated as to their characteristics of commercial importance. Among the trees evaluated, highlight the genotype A09 as a candidate for the matrix in breeding programs of the species due to its superiority in the characteristics of diameter at breast height and total height. Genotypes A09 and IF03 are the most genetically distant and S02 and S09 the most similar. The principal component analysis explained 81.24% of all the variance of the characteristics analyzed in the first two variables. With the results obtained, it was possible to identify the superior characteristics of the Ecuadorian genotypes A01, A09 and A14; the first two present good characteristics for wood production, and the third presents the lowest basic density of wood.

Keywords: commercial cultivation, dissimilarity, *Ochroma pyramidale*, wood production.

RESUMO
O pau de balsa é uma espécie florestal nativa da Amazônia, e destaca-se pelo rápido crescimento e, portanto, considerada como uma opção de atividade produtiva e rentável. Objetivou-se neste estudo selecionar árvores de pau de balsa superiores fenotipicamente e verificar a dissimilaridade entre elas e suas respectivas origens, afim de identificar indivíduos para a produção de madeira. Foram avaliadas as árvores de plantios de pau de balsa implantado em janeiro de 2011 no município de Guarantã do Norte, Mato Grosso, Brasil, em três populações distintas e avaliadas características de importância comercial. Entre as árvores avaliadas podemos destacar o genótipo

A09 como um candidato à matriz em programas de melhoramento da espécie, devido à superioridade nas características de diâmetro à altura do peito e altura total. Os genótipos A09 e IF03 são os mais distantes geneticamente e S02 e S09 os mais similares. A análise de componentes principais explicou 81,24% de toda a variância das características analisadas logo nas duas primeiras variáveis. Com os resultados obtidos foi possível selecionar os genótipos equatorianos A01, A09 e A14, os dois primeiros por apresentar boas características para a produção de madeira, e o terceiro por apresentar a menor densidade básica da madeira.

Palavras-chave: cultivo comercial, dissimilaridade, *Ochroma pyramidale*, produção de madeira.

1 INTRODUCTION

Pau de balsa (*Ochroma pyramidale*) is a species that is native to the Amazon and occurs in Brazil and also in neighboring countries such as Bolivia, Venezuela, Costa Rica, Ecuador and Paraguay (SERNA-MOSQUERA; TORRES-TORRES; ASPRILLA-PALACIOS, 2019; TITUANÃ; ZURITA, 2020). It is a woody tree species of a large size, which can reach dimensions close to 30 m in height in adulthood. Its trunk is straight, cylindrical, and the stem can reach up to 15 m in length (CARVALHO, 2010). The wood is of the light type with a basic density of 0.06 to 0.38 g cm^3 and is extremely valuable in applications that require light materials with good mechanical performance, which is consequently dependent on its density (CAÑADAS-LÓPEZ *et al*., 2019; ZEA-CAMAÑO *et al*., 2020).

Due to its advantageous rapid growth, pau de balsa stands out as a forest species that has a shorter response time when compared to other eucalyptus and teak species, and is therefore considered as a productive and profitable activity that can benefit small and medium producers (CRUZ *et al*., 2020; WEIRICH, 2008). The cultivation of pau de balsa for commercial purposes occupies large areas in Ecuador due to its diversity in use, making it the country with the highest production and trade of the species (GARCÍA *et al*., 2017). In Brazil, more specifically in Mato Grosso, the first plantations of pau de balsa were carried out speculatively, with materials from different sources and without the use of appropriate silvicultural practices, which resulted in planting areas with great variability in tree patterns in relation to the quality of the trunk and the density of the wood. This problem has generated great setbacks for the farmers, and thus requires the search for solutions to meet the demand of industries (BEHLING *et al*., 2019).

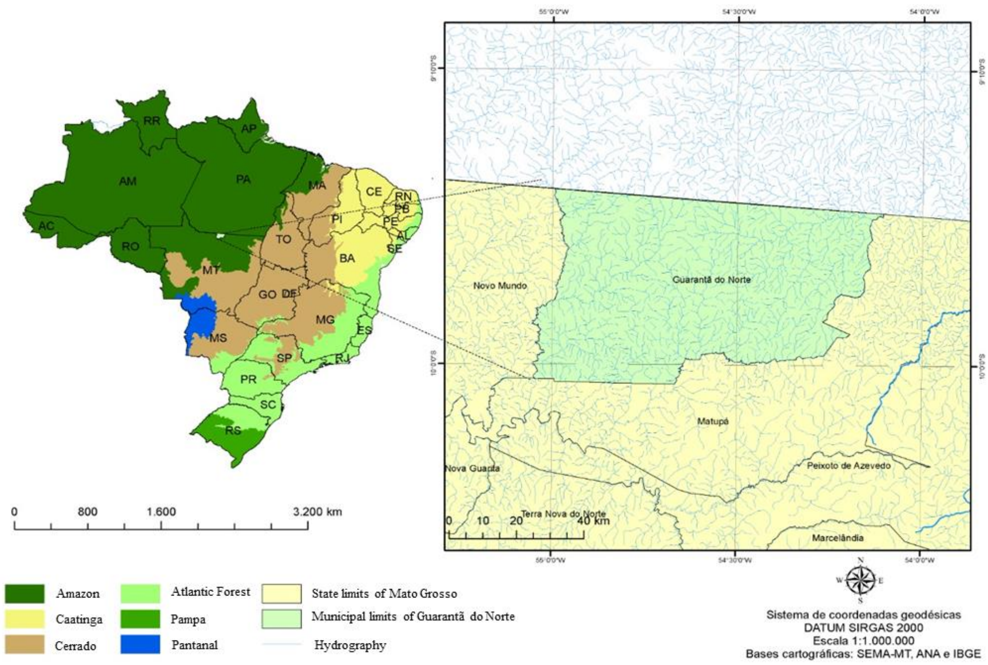
The selection of superior genotypes emerges as a great possibility for the advancement of the culture of pau de balsa in Brazil. Via the identification of desirable traits, genotype selection can be carried out and thus promote the development of genetically superior plants (PALUDETO *et al*., 2020). However, for this to occur, the variability of the populations must be verified, and the grouping of individuals must be established according to the determined methodology, aiming at their classification and kinship, in order to maximize the selection and genetic gain of the plantation (RESENDE, 2007).

Based on the above, the objective of this work was to select phenotypically superior pau de balsa trees and verify the dissimilarity between them and their respective origins, in order to identify individuals for wood production.

2 MATERIALS AND METHODS

The trees of pau de balsa plantations (*Ochroma pyramidale* Cav. ex Lam. Urb.) implemented in January 2011 in the municipality of Guarantã do Norte, Mato Grosso, were evaluated (Figure 1). The municipality has a tropical rainy climate (Aw according to the Köppen classification), average temperatures of 25 °C, average altitude of 345 m, with average annual precipitation 2,000 mm.

Figure 1. Location of the municipality of Guarantã do Norte (light green), Mato Grosso, Brazil, and Brazilian biomes.



Source: The authors.

The sampling of the individuals of pau de balsa was carried out in three distinct populations (Aliança, IFMT and Sinuelo), and involved approximately 8,500 trees in total, planted with spacing of 3x3, and using seeds from Ecuador and Brazil.

Of these, 70 trees were selected, 1 to 20 from the Aliança population (seeds from Ecuador), 21 to 45 from the IFMT area and 46 to 70 from the Sinuelo population (both with seeds from Brazil). The following nomenclatures were assigned: A, IF and S, for the Aliança, IFMT and Sinuelo populations, respectively. The areas where these populations are found have the following geographic distances: Aliança – IFMT (8.5 km); Aliança – Sinuelo (10 km); and IFMT – Sinuelo (4.5 km)

For the selection of the 70 trees, the following phenotypic characteristics were considered: Vigor – superiority in height and diameter, straightness of the trunk and absence of bifurcation, branching (angle, thickness, height, length and number of branches per whorl), conicity of the trunk, length of internodes, length of the second log, wood quality, sanitary aspects, and bark thickness. Subsequently, the 70 trees were evaluated for the following characteristics of commercial importance:

Total tree height (TH) – expressed in meters using a digital hypsometer (Vertex®).

Diameter at breast height (DBH) – expressed in centimeters, for which we initially collected circumference at breast height (CBH) with the help of tape measure, and which was later transformed using the Equation 1:

$$DBH = \frac{CBH}{\pi} \qquad (1)$$

Basic wood density (BWD) expressed in grams per cubic centimeter, which in turn was predicted with the help of a hardness meter and subsequently the values were substituted in Equation 2:

$$BWD = 0.3828 - 0.0477.Py \qquad (2)$$

The criterion of Singh 1981 was used to quantify the relative contribution of the characteristics evaluated in the genetic divergence and establish the ranking of the selected genotypes according to the characteristics that most contributed to genetic dissimilarity. Multivariate analysis was also performed by means of the principal components, as well as their two-dimensional dispersion of the scores and, later, the dissimilarity was calculated using the standardized Euclidean distance. The genotypes were grouped via the Tocher optimization method and UPGMA (Unweighted Pair Group Method using Arithmetic Averages). All analyses were performed with the help of the Genes program (CRUZ, 2016).

3 RESULTS AND DISCUSSION

The ranking of the 70 analyzed genotypes distributes them into three distinct characteristics of total height (TH), diameter at breast height (DBH), and basic wood density (BWD). We can observe that the first ten positions for TH are composed of genotypes from the Aliança population (seeds from Ecuador), in which there was the presence of more developed trees in relation to the others for the character in question (Table 1).

Table 1. Ranking of the 70 genotypes of pau de balsa from Guarantã do Norte, Mato Grosso.

Classification	Characteristics and genotypes evaluated						
	TH	DBH	BWD	Classification	TH	DBH	BWD
1st	A01	S11	A14	36th	S02	A12	IF12
2nd	A12	A09	A11	37th	S09	S20	S06
3rd	A20	S05	A02	38th	IF12	A15	S12
4th	A09	S10	IF05	39th	IF14	S08	S13
5th	A07	S13	S17	40th	IF05	S23	A04
6th	A08	S07	A17	41th	S23	A14	A20
7th	A14	A07	A06	42nd	IF17	A05	IF18
8th	A13	A13	A05	43rd	IF07	S15	IF21
9th	A10	S18	IF03	44th	IF24	IF10	S02
10th	A18	IF08	S05	45th	IF21	S22	S03
11th	A19	S24	A19	46th	S22	S06	S04
12th	S17	IF16	A01	47th	IF20	A19	S09
13th	A04	IF06	A13	48th	S19	IF07	S25
14th	A17	S25	A03	49th	IF23	IF12	A09
15th	A03	S21	IF09	50th	S07	IF17	IF10
16th	A06	A16	S07	51st	IF16	IF01	IF15
17th	S11	A08	S22	52nd	IF08	IF13	S15
18th	S04	S01	IF17	53rd	IF15	IF21	S24
19th	S24	A04	IF25	54th	IF25	IF20	IF16
20th	S01	S17	A18	55th	S03	A02	S10
21st	S20	S12	S18	56th	IF06	IF19	S16
22nd	S12	S09	A15	57th	IF22	A06	S20
23rd	S13	IF04	A16	58th	IF09	IF11	A12
24th	A05	S16	IF02	59th	IF18	IF05	A08

25th	A11	IF23	IF08	60th	S06	IF15	IF07
26th	S25	S02	IF23	61st	A02	IF18	IF19
27th	S16	A18	S21	62nd	IF19	A03	S23
28th	S21	A10	IF13	63rd	IF10	IF22	IF20
29th	IF13	A01	A07	64th	IF02	IF24	S14
30th	S15	S19	IF04	65th	IF01	A17	IF22
31st	S10	IF25	IF06	66th	S08	IF14	S08
32nd	S18	S03	A10	67th	IF04	IF09	S01
33rd	A15	A20	IF14	68th	IF03	IF02	S19
34th	A16	S14	S11	69th	S05	A11	IF24
35th	IF11	S04	IF01	70th	S14	IF03	IF11

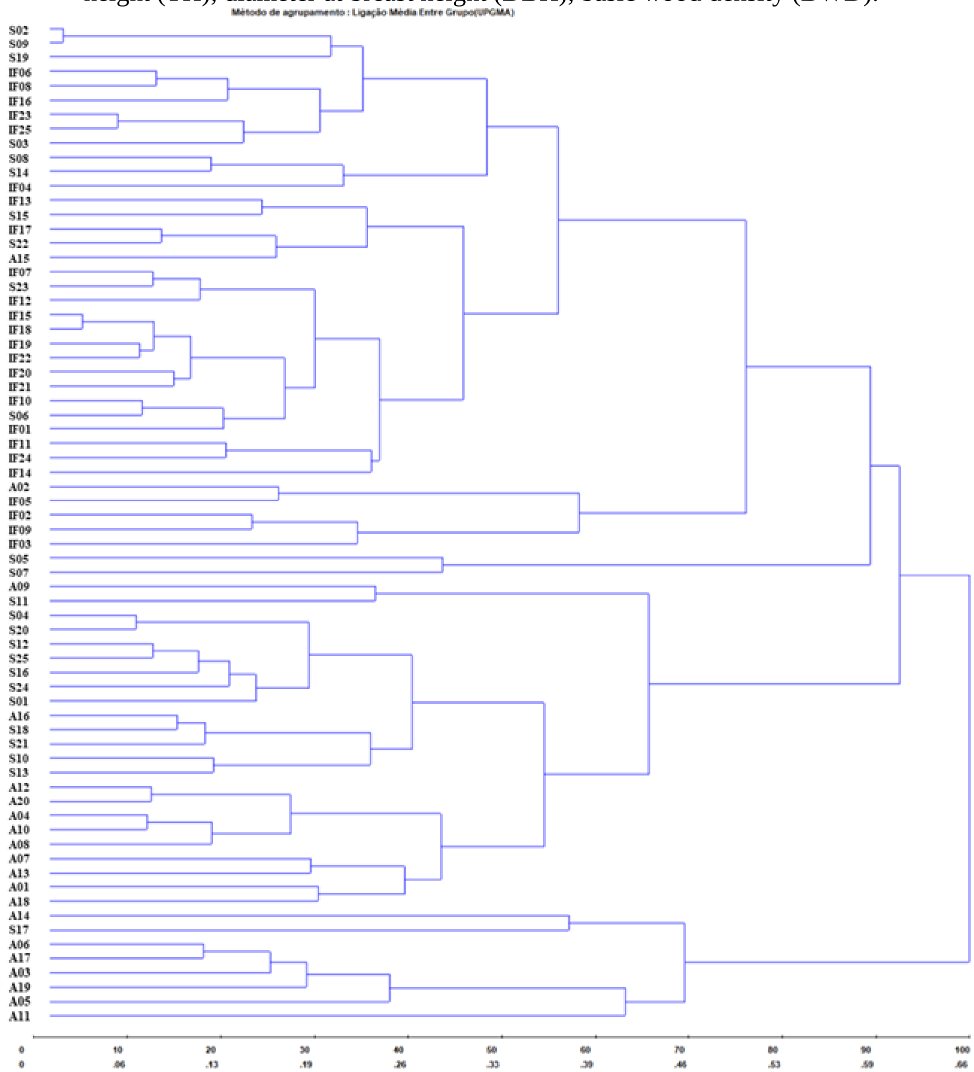
TH – Total height (m); DBH – diameter at breast height (cm); BWD – basic wood density (g cm^{-3}). Source: The authors.

For DBH, six of the top ten are representatives of the Sinuelo population (seeds from Brazil), for which the largest DBHs were observed together with the Aliança population. However, when we analyze the characteristic BWD, we can observe that the best individuals are in the Aliança population, which has the lowest values for BWD for the genotypes A14 and A11, with 0.197 and 0.209 g cm^{-3}, respectively. These results are corroborated by Oliveira *et al*. (2017) who observed densities of 0.195 and 0.239 g.cm^{-3} in the state of Mato Grosso. It is worth mentioning that, for the consumer market, pau de balsa must have a low density, ideally between 100 to 170 kg m^{-3} (FARIA, 2013).

Among the trees evaluated, we can highlight the A09 genotype as a candidate matrix in breeding programs of the species, due to the superiority in the characteristics of DBH and TH (Table 1). Once inserted in a breeding program, this genotype may be used to carry out crossbreeding with genotypes that present low wood density characteristics, and thus promote offspring with the desirable characteristics, i.e., with high DBH and TH and low BWD.

In the dendrogram of the genotypes evaluated, with the cophenetic coefficient adjusted to 1.0, we can observe the formation of several groups according to the proximity of the characteristics between them (Figure 2). It is noted that genotypes A11 and S02 appear at the ends. However, genotypes A09 and IF03 are the most distant with dii = 1.32, and the closest are genotypes S02 and S09 with dii = 0.02 (Figure 2). When the origin is observed, there is proximity between the genotypes of Brazilian origin (S02-S09), and the distance with the genotype of Ecuadorian origin (A09). Analyzing the possibility of selecting possible genotypes for insertion in pre-breeding programs, it is worth highlighting the genotypes A09 and IF03, since they have the greatest Euclidean distance between them, which indicates that the crossbreeding carried out between both can generate descendants with high heterotic variability of the characters of interest (SHIVANI; SREELAKSHMI, 2013), thus allowing the chance to select superior genotypes.

Figure 2. Dendrogram representing the dissimilarity of 70 pau de balsa genotypes obtained by Euclidean distance and grouped by the average linkage between groups (UPGMA) method, considering the characteristics of total height (TH), diameter at breast height (DBH), basic wood density (BWD).



Source: The authors.

Genotype A09 presented the fourth best mean for TH and the second best mean for DBH (Table 1). The genotype IF03 presented the ninth best mean for BWD, representing, therefore, the ninth lowest BWD, which are desirable characteristics for the improvement of the species.

After performing cluster optimization using Tocher's method, considering the characteristics of TH, DBH and BWD among the 70 genotypes evaluated, we can observe the distinction of nine groups, for which the genotypes are considered as similar within each group (Table 2).

Table 2. Grouping of the 70 pau de balsa genotypes, considering the characteristics of TH, DBH, BWD via the mean Euclidean distance and the Tocher optimization technique.

Group	Genotypes
I	S02 S09 S16 S12 S25 S21 A16 S24 S18 S13 S01 S04 S20 A04 S15 A10 A15 A08 A18 S10 A07 S23 IF13 IF12
II	IF15 IF18 IF19 IF22 IF20 IF21 IF07 S06 IF10 IF01 IF24 IF14 S08 IF17 S22 S03 IF02 IF09 IF11 S19 IF23 IF25 IF04 S14
III	A12 A20 A01 A19 A13
IV	IF06 IF08 IF16 S07 S05
V	A06 A17 A03 A05 IF05
VI	A09 S11
VII	A02 IF03
VIII	A14 S19
IX	A11

TH – Total height (m); DBH – diameter at breast height (cm); BWD – basic wood density ($g.cm^{-3}$). Source: The authors.

Groups I and II represent the largest groups among the others, presenting approximately 34% of each of the genotypes analyzed. While the other groups (III, IV and V) present approximately 7% each, and groups VI, VII and VIII present about 3% each and, finally, there is group IX with only one genotype. The grouping proposed by Tocher's method helps us in the selection of the superior genotypes present in each group, which makes it possible to perform the crossbreeding between them to obtain progenies that provide genetic gain for the species.

The percentage distribution of the eigenvalues associated with the principal components of the characteristics of TH, DBH and BWD, in which the first two main characteristics correspond to 43.22% and 38.02% respectively, explains 81.24% of all the variance of the characteristics under analysis (Table 3). In this way, the two-dimensional graphical representation of the scores of the principal components can be performed according to (CRUZ; REGAZZI, 2001), when the sum of the first two principal components accounts for more than 80% of the total variance.

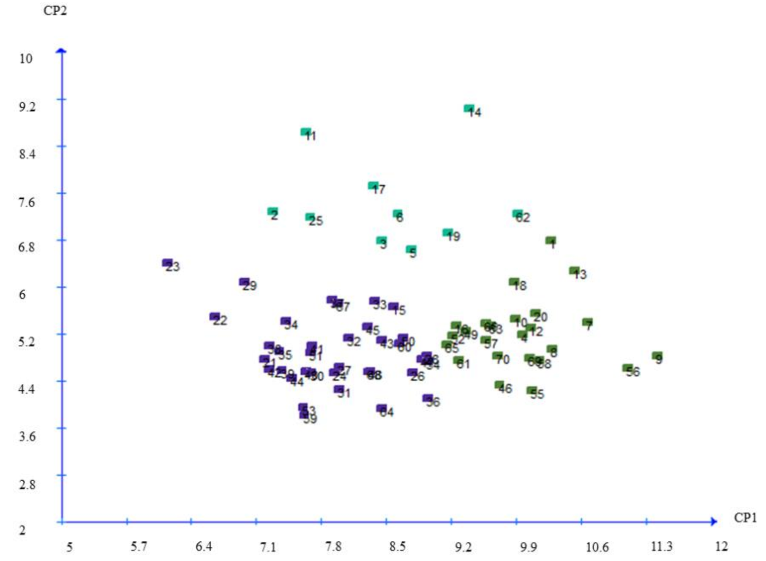
Table 3. Estimation of eigenvalues associated with the principal components of the characteristics TH, DBH, BWD, for the selection of pau de balsa genotypes.

Principal Component	Eigenvalues		
	Root	Root (%)	(%) Cumulative
PC1	1.30	43.22	43.22
PC2	1.14	38.02	81.24
PC3	0.56	18.75	100

TH – Total height (m); DBH – diameter at breast height (cm) BWD – basic wood density ($g.cm^{-3}$). Source: The authors.

In the two-dimensional dispersion of the scores, we can observe the distance between individuals 9 (A09) and 23 (IF03), as well as in the Euclidean distance, which presents the phenotypic variability between both (Figure 3). Considering the totality of the 70 genotypes, according to the dispersion of the scores of the main characteristics, the closest individuals were grouped, thus establishing three different groups. Although they initially had seed individuals from Brazil and Ecuador, the grouping of these individuals highlights a separate group formed by genotypes from Ecuador, with the exception of individual 62 (S17), which is the only genotype from Brazil in this group.

Figure 3. Two-dimensional dispersion of the scores of the principal characteristics PC1 and PC2 of 70 pau de balsa genotypes, considering TH, DBH and BWD. 1=A01; 2=A02; 3=A03; 4=A04; 5=A05; 6=A06; 7=A07; 8=A08; 9=A09; 10=A10; 11=A11; 12=A12; 13=A13; 14=A14; 15=A15; 16=A16; 17=A17; 18=A18; 19=A19; 20=A20; 21=IF01; 22=IF02; 23=IF03; 24=IF04; 25=IF05; 26=IF06; 27=IF07; 28=IF08; 29=IF09; 30=IF10; 31=IF11; 32=IF12; 33=IF13; 34=IF14; 35=IF15; 36=IF16; 37=IF17; 38=IF18; 39=IF19; 40=IF20; 41=IF21; 42=IF22; 43=IF23; 44=IF24; 45=IF25; 46=S01; 47=S02; 48=S03; 49=S04; 50=S05; 51=S06; 52=S07; 53=S08; 54=S09; 55=S10; 56=S11; 57=S12; 58=S13; 59=S14; 60=S15; 61=S16; 62=S17; 63=S18; 64=S19; 65=S20; 66=S21; 67=S22; 68=S23; 69=S24; 70=S25.



Source: The authors.

The DBH variable was the one that most contributed to the divergence between the 70 genotypes, with 58.34%, followed by the TH of the individuals with 40.86%, while BWD contributed only 0.8% to the divergence (Table 4). However, although its representativeness is low, it is still as important as the other characteristics, especially since we are dealing with pau de balsa.

Table 4. Relative contribution of characters to divergence – Singh (1981), with non-standard means of 70 pau de balsa genotypes.

Variable	S.j	Value (%)
HT	39,911.81	40.86
DBH	566,991.28	58.34
BWD	779.79	0.80

TH – total height (m); DBH – diameter at breast height (cm); BWD – basic wood density ($g.cm^{-3}$). Source: The authors.

In the selection of genotypes to be incorporated in genetic improvement programs, it is necessary to establish the desirable characteristics of the species in question, and determine the grouping model that best suits their needs (BERTAN *et al*., 2006). Thus, for the insertion of pau de balsa individuals in breeding programs, we must prioritize genotypes that stand out in wood production, with higher values of DBH and TH. However, we must pay attention to the characteristics of the wood, such as the basic density, and thus select individuals that meet the requirements of the market. In this sense, the genotypes A09 and A14 stand out, the first having good values for TH and DBH, and the second for TH and low basic wood density.

4 CONCLUSIONS

The genotypes evaluated in this research present genetic variability among themselves. The DBH variable is the one that most contributed to the genetic divergence between genotypes, followed by TH, while BWD had the lowest contribution.

Genotypes A09 and IF03 are the most genetically distant and S02 and S09 the most similar. The genotypes A01, A09 and A14, of Ecuadorian origin, stand out. The first two due to the characteristic production of wood, and the latter because it has a lower basic density of wood. Therefore, they can be indicated as candidates for the matrix in breeding programs of the species.

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REFERENCES

BEHLING, M. *et al*. Crescimento de pau-de-balsa sob diferentes níveis de adubação e espaçamento, em Guarantã do Norte, MT. *In*: AUSTECLÍNIO, L. F. N. (Ed.). **Primeiras contribuições para o desenvolvimento de uma Agropecuária Sustentável**. 1. ed. Brasília, DF: Embrapra Agrossilvipastoril, 2019. p. 442–453.

BERTAN, I. *et al*. Comparação de métodos de agrupamento na representação da distância morfológica entre genótipos de trigo. **Agrociência**, v. 12, n. 3, p. 279–286, 2006.

CAÑADAS-LÓPEZ, Á. *et al*. Growth and Yield Models for Balsa Wood Plantations in the Coastal Lowlands of Ecuador. **Forests**, v. 10, n. 9, p. 2–16, 2019.

CARVALHO, P. E. R. **Espécies arbóreas brasileiras**. 1. ed. Brasília: Embrapa Florestas, 2010.
CRUZ, C. D. Genes Software - extended and integrated with the R, Matlab and Selegen. **Acta Scientiarum**, v. 38, n. 4, p. 547–552, 2016.

CRUZ, C. D.; REGAZZI, A. J. **Modelos biométricos aplicados ao melhoramento**. 2. ed. Viçosa: UFV, 2001.

CRUZ, V. D. S. *et al*. Efeito da salinidade na germinação e desenvolvimento de plântulas de Ochroma pyramidale. **Nativa**, v. 8, n. 2, p. 239–245, 2020.

FARIA, G. **Informações obtidas em pesquisa poderão viabilizar mercado de pau de balsa**. Disponível em: https://www.embrapa.br/busca-de-noticias/-/noticia/1489283/informacoes-obtidas-em-pesquisa-poderao-viabilizar-mercado-de-pau-de-balsa#:~:text=em%20Mato%20Grosso.-,Sem%20materiais%20gen%C3%A9ticos%20selecionados%2C%20as%20%C3%A1rvores%20cultivadas%20no%20estado%20s%C3%A3o,m%C2%B3%20a%20170%20kg%2Fm%C2%B3. Acesso em: 10 nov. 2022.

GARCÍA, Y. *et al*. Quality indicators in Ochroma pyramidale seeds from three sites in the Ecuadorian Amazon for reforestation in degraded areas. *In*: Proceedings of MOL2NET, International Conference on Multidisciplinary Sciences, 3., 2017, Basel, Switzerland. **Anais** [...] Basel, Switzerland: MDPI, 2017. p. 1-3.

OLIVEIRA, W. C. *et al*. Propriedades da madeira de Ochroma pyramidale (cav. ex lamk) urban em duas idades. *In*: III CBCTEM Congresso Brasileiro de Ciência e Tecnologia da Madeira, 2017, Campinas. **Anais** [...] Campinas: Galoá, 2017. p. 1-10. Disponível em: https://proceedings.science/cbctem/papers/propriedades-da-madeira-de-ochroma-pyramidale--cav--ex-lamk--urban-em-duas-idades. Acesso em: 10 nov. 2022.

PALUDETO, J. G. Z. *et al*. Variabilidade genética em população base de Eucalyptus viminalis em idade juvenil. **Scientia Forestalis**, v. 48, n. 126, p. e3081, 2020.

RESENDE, M. D. V. **Matemática e estatística na análise de experimentos e no melhoramento genético**. 1. ed. Colombo: Embrapa Florestas, 2007.

SERNA-MOSQUERA, Y. B.; TORRES-TORRES, J. J.; ASPRILLA-PALACIOS, Y. Y. Durabilidad natural de la madera de Ochroma pyramidale Urb. en el municipio de Atrato, Colombia. **Entramado**, v. 16, n. 1, p. 192–202, 2019.

SHIVANI, D.; SREELAKSHMI, C. Genetic divergence studies in safflower (Carthamus tinctorius L.) germplasm lines. **Electronic Journal of Plant Breeding**, v. 4, n. 2, p. 1184–1187, 2013.

SINGH, D. The relative importance of characters affecting genetic divergence. **Indian Journal of Genetics and Plant Breeding**, v. 41, n. 2, p. 237–245, 1981.

TITUANÃ, T. W. F.; ZURITA, M. K. F. **Estudio del perfil fitoquímico y reológico de dos variedades de plantas mucilaginosas del cantón La Maná: Herrania balaensis y Ochroma pyramidale**. Carrera de ingeniería agroindustrial (Curso Técnico)—Latacunga - Ecuador: Universidad Técnica de Cotopaxi Facultad de Ciencias Agropecuarias Y Recursos Naturales, 2020.

WEIRICH, N. E. **Diretrizes técnicas para o cultivo do pau-de-balsa (Ochroma pyramidale) no Estado de Mato Grosso**. Disponível em: https://www.ruralcentro.com.br/analises/2085/diretrizes-tecnicas-para-o-cultivo-de-pau-de-balsa-no-estado-de-mato-grosso. Acesso em: 10 nov. 2022.

ZEA-CAMAÑO, J. D. *et al*. Improving the Modeling of the Height–Diameter Relationship of Tree Species with High Growth Variability: Robust Regression Analysis of Ochroma pyramidale (Balsa-Tree). **Forests**, v. 11, n. 3, p. 2–20, 2020.