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Genetic diversity of accessions of *Lippia alba* cultivated in Cruz das Almas, Bahia

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Abstract: The composition of the essential oil of *Lippia alba* shows quantitative and qualitative variation, allowing the component's separation into chemotypes. From this perspective, this study aimed to morphologically and chemically characterize *Lippia alba* accessions from the Germplasm Bank of the Center of Agricultural, Environmental, and Biological Sciences of Universidade Federal do Recôncavo da Bahia to deepen the knowledge about the genetic variability of the species. A cluster analysis was performed considering quantitative and qualitative descriptors simultaneously, according to Gower's algorithm. The genetic distance matrix was obtained by the UPGMA method, and the correlation coefficient was calculated. Two dissimilarity groups were formed (CCC: 0.9610**). The main dissimilarities were: Group 01: five to seven ligulate flowers, lilac-colored flower petals, lower values of height of the largest branch, leaf length, middle leaf lamina width, diameter of the central disk of the inflorescence, and higher values of essential oil content. Carvone and germacrene D were the major chemical constituents of this group; Group 02 the main dissimilarities were: eight to 11 ligulate flowers, light lilac colored flower petals, higher values of height of the largest branch, leaf length, middle leaf lamina width, diameter of the central disk of the inflorescence, and lower values of essential oil content. Geranial and neral were the major chemical constituents in this group. The highest essential oil contents were observed in accessions L05 (Group 1) and L06 (Group 2). The quantitative and qualitative morphological descriptors used in the study showed the existence of genetic diversity among the accessions evaluated.

Keywords: Chemotypes, Cidreira, Verbenaceae.

Diversidade genética de acessos de *Lippia alba* cultivados em Cruz das Almas, Bahia

Resumo: A composição do óleo essencial da *Lippia alba* apresenta variação quantitativa e qualitativa, levando à separação em quimiotipos. Objetivou-se com este trabalho, caracterizar morfologicamente e quimicamente acessos de *Lippia alba* do Banco de Gemoplasma do Centro de Ciências Agrárias, Ambientais e Biológicas da Universidade Federal do Recôncavo da Bahia, para aprofundar o conhecimento da variabilidade genética da espécie. Foi realizada análise de agrupamento, considerando descritores quantitativos e qualitativos simultaneamente, segundo o algoritmo de Gower. A matriz de distância genética foi obtida pelo método UPGMA e calculou-se o coeficiente de correlação cofenético. Formou-se dois grupos de dissimilaridade (CCC: 0,9610**). As principais dissimilaridades foram: Grupo 01: cinco a sete flores liguladas, pétalas das flores de coloração lilás; menores valores de altura do maior ramo, comprimento foliar, largura do limbo foliar no meio e de diâmetro do disco central da inflorescência, e; maiores valores de teor de óleo essencial. A carvona e germacreno D foram os constituintes químicos majoritários deste grupo; Grupo 02: oito a onze flores liguladas, pétalas das flores de coloração lilás claro; maiores valores de altura do maior ramo, comprimento foliar, largura do limbo foliar no meio e diâmetro do disco central da inflorescência, e; menores valores de teor de óleo essencial, tendo como constituintes químicos majoritários o geranial e neral. Os maiores teores de óleo essencial foram observados para os acessos L05 (Grupo1) e L06 (Grupo 2). Os descritores morfológicos quantitativos e qualitativos utilizados no estudo evidenciaram a existência de diversidade genética entre os acessos avaliados.

Palavras chave: Quimiotipos, Cidreira, Verbenaceae.

Introduction

The species *Lippia alba* (Mill.) N.E.Br. ex Britton & P.Wilson occurs in Central and South America and is present in almost all of Brazil, where it is commonly used as a medicinal plant due to its carminative, sedative, anticoagulant, and analgesic properties (Pereira-de-Morais et al., 2019 & Leite et al., 2023). The species also has fungicidal, antimicrobial, and antiparasitic activity against various microorganisms provided by its essential oils (Santos et al., 2016, Tomazoni et al., 2016, Baldissera et al., 2017 & Santos et al., 2023).

Most studies with *Lippia alba* have focused on the chemical composition of the essential oil of this species, which show wide chemical variability. Jannuzzi et al. (2010) reported that, due to the lack of a defined standard for differentiating chemotypes in this species, most authors have based their studies on the relationship between the major components of essential oils. In this scenario, the production and chemical composition of essential oils are affected by the genotype and the interactions involving the environment, soil conditions, harvest period, climate, plant part, and genetic variability regarding chemical composition (Sá et al., 2022). Several chemotypes have already been detected based on the main chemical components found in the essential oil of *Lippia alba* (Hennebelle et al., 2008, Jannuzzi et al., 2010 & Blank et al., 2015).

However, despite the importance of studies on the chemical composition of essential oils, morphological variables can provide a more comprehensive analysis of genetic diversity within and between species. Furthermore, morphological characterization is important for conserving and maintaining germplasm banks and providing additional knowledge to genetic improvement programs. Despite this importance, little research has focused on the morphological components of *Lippia alba*. Studies on *Lippia alba* accessions carried out at the Germplasm Bank of Federal University of Sergipe showed that the use of morphological characterization is capable of differentiating and identifying the most promising accessions through descriptors such as branch length, canopy diameter, color of stems, leaves, and petals, growth habit, leaf length and width, and length/width ratio, in addition to essential oil content and yield (Jannuzzi et al., 2010, Camêlo et al., 2011 & Jezler et al., 2013).

Therefore, these studies may help select promising accessions for cultivation due to their superior traits, especially with regard to oil content and chemical composition. Such research is also crucial to understanding the adaptations present in various plant parts. From this perspective, the present study aimed to characterize the genetic diversity of accessions through morphological descriptors and chemical analyses in the essential oil of *Lippia alba* cultivated in the municipality of Cruz das Almas, Bahia.

Material and methods

The experiment was conducted in an experimental field at the Center of Agricultural, Environmental, and Biological Sciences [CCAAB] of Universidade Federal do Recôncavo da Bahia [UFRB], located in the municipality of Cruz das Almas, Bahia (12°40'0" S, 39°06'0" W), at an elevation of 200 m above sea level.

For the implementation of the Germplasm Bank of CCAAB/UFRB, cuttings were collected from different *Lippia alba* accessions obtained from mother plants in 13 locations of Cruz das Almas. The exsiccates of these accessions are deposited at the Recôncavo da Bahia Herbarium [HURB] (Table 1). The most vigorous branches were cut from the mother plants and, in the nursery, cuttings approximately 15 cm-long containing three axillary buds each were produced. The cuttings were inserted into the substrate (washed sand + Vivatto® in a 2:1 proportion) to a sufficient depth to cover the first bud.

Table 1 – Identification and origin of the 13 accessions of *Lippia alba* (Mill.) N.E.Br. ex Britton & P.Wilson cultivated in the Germplasm Bank of the Center of Agricultural, Environmental, and Biological Sciences (CCAAB) of UFRB (Universidade Federal do Recôncavo da Bahia), Cruz das Almas, Bahia, Brazil.

Accession	HURB (voucher)	Origin	Latitude	Longitude
L01	8793	Araçá, Cruz das Almas, Bahia	-12.7311	-39.1274
L02	8794	Araçá, Cruz das Almas, Bahia	-12.7311	-39.1275
L03	8795	Araçá, Cruz das Almas, Bahia	-12.7346	-39.1354
L04	8796	Araçá, Cruz das Almas, Bahia	-12.7354	-39.1342
L05	8797	Araçá, Cruz das Almas, Bahia	-12.7322	-39.1247
L06	8798	Araçá, Cruz das Almas, Bahia	-12.7359	-39.1293
L07	8799	Araçá, Cruz das Almas, Bahia	-12.7338	-39.1358
L08	8800	Suzana, Cruz das Almas, Bahia	-12.6771	-39.0974
L09	8801	Downtown, Cruz das Almas, Bahia	-12.6775	-39.0995
L10	8802	Ana Lúcia, Cruz das Almas, Bahia	-12.6635	-39.1034
L11	8803	Ana Lúcia, Cruz das Almas, Bahia	-12.6634	-39.1042
L12	8804	Ana Lúcia, Cruz das Almas, Bahia	-12.6648	-39.1036
L13	8805	Sapucaia, Cruz das Almas, Bahia	-12.6576	-39.0817

HURB = Recôncavo da Bahia Herbarium.
Source: Research data.

The saplings were propagated through cuttings and were planted at a 0.50 x 1.00 m spacing. Chemical correction in the soil of the experimental area was performed according to the results of the chemical analysis presented in Table 2, three months prior to transplantation. This correction consisted of applying lime (1.0 t ha^{-1}) and base fertilization with 50 kg ha^{-1} of P_2O_5 (single superphosphate) and 60 kg ha^{-1} of K_2O (potassium chloride). Irrigation was performed through sprinkling using Santeno® hoses twice a day

Table 2 – Soil chemical analysis in the experimental area located in the municipality of Cruz das Almas, Bahia, Brazil.

OM ($g\ dm^{-3}$)	pH (in water)	P ($mg\ dm^{-3}$)	K	Ca + Mg	Ca	Mg	Al	H + Al	CEC	V (%)
			$Cmol_c\ dm^{-3}$							
12.00	5.10	12.40	0.24	2.90	2.00	0.90	0.10	1.80	4.94	63.56

OM = Organic matter; CEC = Cation exchange capacity.
Source: Research data.

Morphological Characterization

All 13 accessions were characterized using 10 morphological descriptors, oil content, and chemical constituents. The quantitative and qualitative descriptors used in the characterization are described in Table 3.

The following descriptive statistics were calculated for the morphological quantitative descriptors: mean, standard deviation, minimum and maximum values, coefficient of variation, and Shapiro-Wilk normality test. The analyses were performed using the *Statistical Analysis System* (SAS, 2006).

Table 3 – Quantitative and qualitative descriptors used to characterize the accessions of *Lippia alba* (Mill.) N.E.Br. ex Britton & P.Wilson cultivated in the municipality of Cruz das Almas, Bahia, Brazil.

Quantitative morphological descriptors	
Height of the longest branch	Measurement of the three longest branches – expressed in meters
Leaf length	Measurement of five leaves from the fifth node – expressed in meters
Middle leaf blade width	Measurement of five leaves from the fifth node – expressed in meters
Diameter of the central disc of the inflorescence	Measurement of five inflorescences – expressed in meters
Quantitative descriptors of the essential oil	
Oil content	Expressed in %
Chemical constituents	Expressed in %
Qualitative morphological descriptors	
Number of ligulate flowers	1 = 5 to 7 ligulate flowers; 2 = 8 to 11 ligulate flowers
Leaf texture	1 = rough; 2 = smooth
Leaf color	1 = light green; 2 = dark green
Stem color	1 = brown; 2 = purplish
Color of flower petals	1 = lilac; 2 = pale lilac
Growth habit	1 = upright plant; no branches touching the ground; 2 = plant with 25% of branches touching the ground; 3 = plant with 50% of branches touching the ground; 4 = plant with 75% of branches touching the ground; 5 = plant with 100% of branches touching the ground.

Source: Research data.

Determination of essential oil content

The material was sampled 90 days after transplantation, from 8 and 9 A.M., by cutting the shoot part of the plant 10 cm above the ground. The leaves were dried in a forced-circulation oven at 45 ± 2 ºC for one week.

Oil extraction was performed by hydrodistillation. The dry material was ground up in an electric mill, and 1.0 g was used for determining the moisture content, which was performed in triplicate using a moisture analyzer (Series ID Version 1.8 Marte ®).

Samples weighing from 13 to 68 g (depending on the dry weight variation of each accession) were added to a 2-liter flask containing a sufficient volume of distilled water to cover the plant material completely, and the hydrodistillation process was started. This procedure was performed using a graduated Clevenger apparatus coupled to the 2-L flask, which was heated using an electric heating mantle with a thermostat. Extraction was performed for three hours, counted from the condensation of the first drop. The extracted oil volume was verified in the graduated column of the Clevenger apparatus. Anhydrous sodium sulfate was added to the oil removed from the apparatus to prevent losses due to hydrolysis during storage. Next, using a Pasteur pipette, the oil was placed in a 2 mL flask, which was labeled and stored in a commercial freezer at -11 ºC until the chemical analysis was performed.

The oil content was calculated on a moisture-free basis, corresponding to the volume (mL) of essential oil in relation to the dry mass according to the following equation (Santos et al., 2004):

$$To = \frac{Vo}{Bm - \left(\frac{Bm \times U}{100}\right)} \times 100$$

Where: To: oil content; Vo: extracted oil volume; Bm: shoot biomass; (Bm x U): biomass moisture; Bm – (Bm x U): dry biomass content.

Identification of the chemical composition of the essential oil

The analysis of the chemical composition of the essential oil of *L. alba* accessions was

performed at the Department of Organic and Inorganic Chemistry of the Federal University of Ceará, in Fortaleza. The arithmetic indexes of the components of the essential oil were identified and determined using a gas chromatograph (Shimadzu CG-2010) coupled to a mass spectrometer (Shimadzu CG/MS-QP 2010) equipped with an automatic injector and a RtX-5ms column (30 m x 0.25 mm; film thickness 0.25 µm). The procedure was performed at oven temperatures increasing from 60 °C to 240 °C at 3 °C/min, followed by 240 °C for 20 min; injector temperature: 220 °C; helium carrier gas: 1 mL/min; split ratio: 1:10; interface temperature: 240 °C; temperature of the ionization source: 240 °C; ionization energy: 70 eV; and ionization current: 0.7 kV.

A gas chromatograph (Shimadzu CG-2010) with a flame ionization detector and an RtX-5 capillary column (30 m x 0.25 mm; film thickness 0.25 µm) was used to quantify the essential oil components at oven temperatures increasing from 60 °C to 240 °C at 3 °C/min), followed by 240 °C for 20 min; injector temperature: 220 °C; helium carrier gas: 1 mL/min; split ratio: 1:10; and detector temperature: 240 °C. Each chromatogram peak was identified according to its mass spectrum by comparing it with the equipment's library (Wiley Nist 08) and with data available in the literature (Adams, 2007) and injections of authentic standards.

Cluster analysis

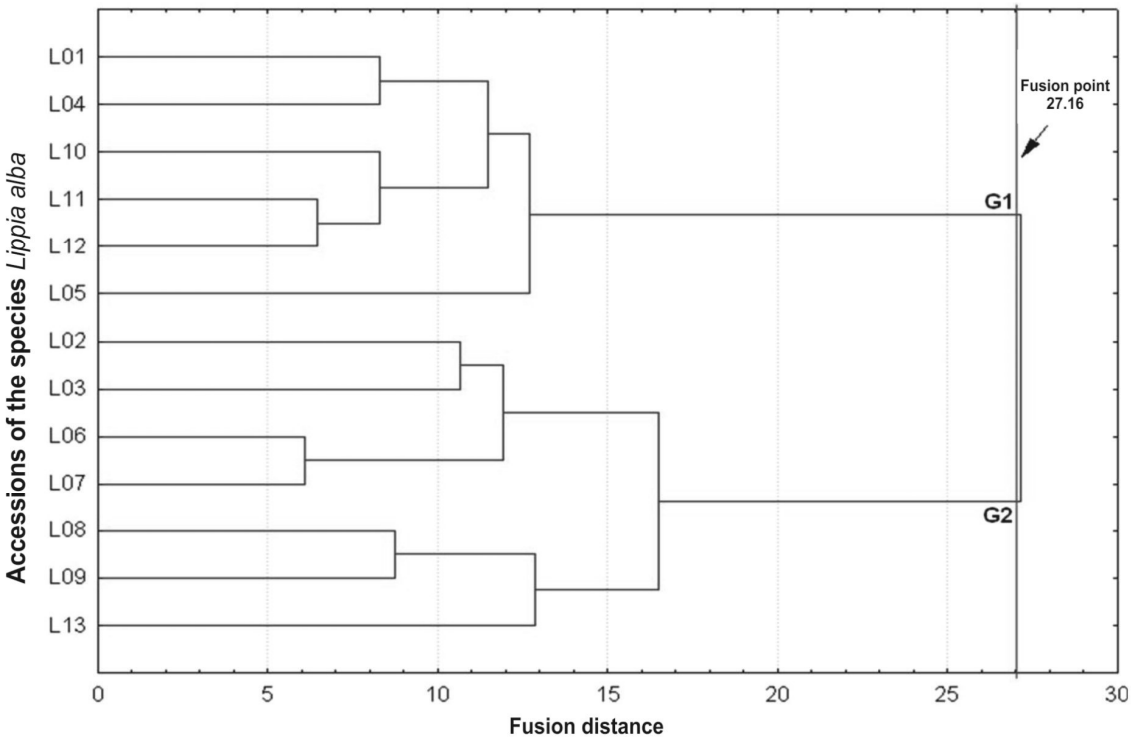
A cluster analysis was performed by taking quantitative and qualitative descriptors into consideration simultaneously, in accordance with Gower's algorithm (Gower, 1971). Hierarchical clusters from the genetic distance matrix were obtained through the UPGMA method (Unweighted Pair Group Method with Arithmetic Mean) (Sneath & Sokal, 1973). The fusion point criterion was used to determine the number of groups. Cluster validation was determined through the cophenetic correlation coefficient (Sokal & Rohlf, 1962). The genetic distance matrix using Gower's algorithm and the cophenetic correlation coefficient were obtained through the Genes software (Cruz, 2008). The dendrogram was obtained using the *Statistica software* Version 7.1 (Statsoft, 2005).

Results and discussion

The cluster analysis was performed with 56 descriptors (four quantitative morphological descriptors, six qualitative morphological descriptors, the essential oil content, and 45 chemical constituents). The clustering of accessions by the UPGMA method allowed the formation of two dissimilarity groups (Group 01 and Group 2), highlighting the presence of genetic diversity among the accessions evaluated (Figure 1). The cophenetic correlation coefficient was 0.9610**, being significant at 1% probability by the t-test. As suggested by Bussab, Miazaki and Andrade (1990), the cluster analysis is acceptable if it produces a cophenetic correlation coefficient starting at 0.80. The melting point value that defined the number of groups was 27.16. Group 01 (G1) was formed by accessions L01, L04, L05, L10, L11, and L12, and Group 02 (G2) was formed by accessions L02, L03, L06, L07, L08, L09, and L13 (Figure 1).

The predominant qualitative traits in the *Lippia alba* accessions of Group 01 were brown stem, light green leaves, leaf texture varying between rough and soft, five to seven ligulate flowers, and lilac flower petals (Table 4). As for the growth habit, the accessions had 50% to 100% of the branches touching the ground. For the quantitative traits, the accessions showed lower values for height of the largest branch, leaf length, middle leaf lamina width, and diameter of the central disk of the inflorescence. However, they showed the highest values of essential oil content, with accession L05 standing out (1.40%).

Figure 1 – Dissimilarity dendrogram based on 50 quantitative descriptors and six qualitative descriptors evaluated in relation to 13 accessions of the species *Lippia alba* (Mill.) N.E.Br. ex Britton & P.Wilson cultivated in the municipality of Cruz das Almas, Bahia, Brazil.



Source: Research data.

Table 4 – Characteristics of quantitative and qualitative descriptors, according to the groups formed in the cluster analysis for the accessions of *Lippia alba* (Mill.) N.E.Br. ex Britton & P.Wilson cultivated in the municipality of Cruz das Almas, Bahia, Brazil.

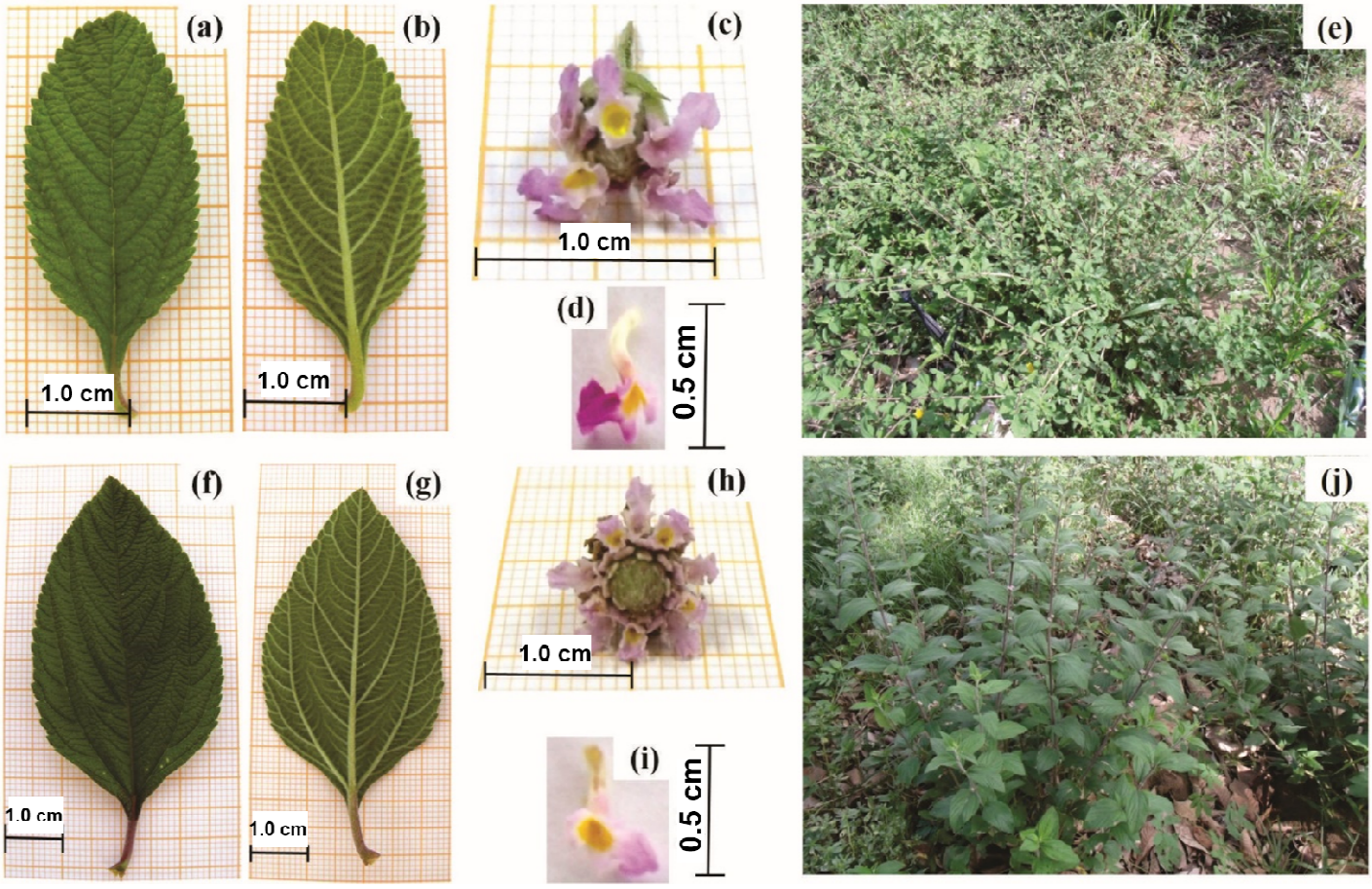
Accession	Height of the longest branch	Leaf length	Middle leaf blade width	Diameter of the central disc of the inflorescence	EOC	GH	Number of ligulate flowers	Color of flower petals	Leaf texture	Leaf color	Stem color
			cm		%						
GROUP 1											
L01	102.0	4.0	2.0	0.40	1.24	4	5 to 7	Lilac	Rough	Light green	Brown
L04	101.0	4.0	2.0	0.40	1.10	5			Rough		
L05	93.0	4.0	2.0	0.40	1.40	4			Rough		
L10	92.0	4.0	2.0	0.38	0.83	3			Rough		
L12	95.0	5.0	2.0	0.40	0.87	3			Smooth		
L11	97.0	4.0	2.0	0.38	1.09	3			Smooth		
GROUP 2											
L02	100.0	9.0	4.0	0.68	0.48	1	8 to 11	Pale lilac	Smooth	Dark green	Brown
L07	102.0	9.0	4.0	0.73	0.35	1			Smooth		Brown
L03	106.0	9.0	4.0	0.63	0.39	1			Smooth		Brown
L06	101.0	10.0	4.0	0.65	0.30	1			Smooth		Brown
L08	105.0	9.0	3.0	0.68	0.35	1			Rough		Purplish
L09	111.0	7.0	3.0	0.60	0.38	1			Rough		Purplish
L13	103.0	6.0	3.0	0.58	0.39	1			Smooth		Purplish

EOC: Essential oil content; GH: Growth habit (1: erect plant, no branches touching the ground no solo; 2: plant with 25% of branches touching the ground; 3 = plant with 50% of branches touching the ground; 4 = plant with 75% of branches touching the ground; 5 = plant with 100% of branches touching the ground).
Source: Research data.

The accessions clustered in Group 02 were characterized by brown to purplish stems, dark green leaves, leaf texture ranging from soft to rough, eight to 11 ligulate flowers, and light lilac flower petals (Table 4). They also showed the highest values for the height of the largest branch, leaf length, middle leaf lamina width, and diameter of the central disk of the inflorescence, in addition to the lowest values of essential oil content. These accessions showed an erect growth habit. The lowest essential oil content in this group was obtained by accession L06 (0.30%).

The accessions that obtained one of the greatest dissimilarities by the cluster analysis (Group 01: L05 and Group 02: L06) were selected to make a board demonstrating the main morphological traits of the two groups formed by cluster analysis (**Figure 2**). The quantitative and qualitative morphological descriptors used in this study demonstrated the existence of genetic diversity among the accessions evaluated, confirming the existence of phenotypic variability.

Figure 2 – *Lippia alba* (Mill.) N.E.Br. ex Britton & P. Wilson, accessions L05 (Group 01) and L06 (Group 02) cultivated in the municipality of Cruz das Almas. Accession L05: a – leaf (adaxial); b - leaf (abaxial); c - inflorescences; d - perianth; e – whole plant; Accession L06: f = leaf (adaxial); g – leaf (abaxial); h – inflorescences; i – perianth; j – whole plant. Cruz das Almas, Bahia, Brazil.



Source: Research data.

Morphological variations were also found in 72 *Lippia alba* accessions belonging to the Germplasm Bank of the Federal University of Sergipe. The accessions showed predominant brown stems and dark green leaves, green leaf veins and sepals, and light lilac petals. To a lesser extent, there are also plants with green stems and green leaves, green sepals and veins, and flowers with lilac petals. Variations in growth habit and

length of the largest branch among 38 accessions of *Lippia alba* were also pointed out by Jannuzzi et al. (2010). The authors suggested that the high phenotypic variability of the species demonstrates high genetic variability, a typical characteristic of plants not yet domesticated. This variability can allow the selection of promising accessions for cultivation and breeding programs as some of them have superior characteristics of interest.

A total of 45 compounds were identified in the essential oils of the 13 accessions of *L. alba*. For the accessions of Group 01, 36 chemical constituents were identified, whereas 40 chemical constituents were found in the accessions of Group 02, divided among monoterpenes, diterpenes, and sesquiterpenes (Table 5). The major components of Group 01 were carvone and germacrene D. Carvone has antitumor, antioxidant, relaxant, and bactericidal and fungicidal activity potential (Moro et al., 2017, Alasmari, Mehanna, 2019, Iraji et al., 2020 & Pombal et al., 2020). Studies have also demonstrated the effects of carvone on the central nervous system through its action on neurotransmission systems, modulating the pain response and brain excitability in the context of epilepsy and anxiety (Sousa et al., 2007). Germacrene D is detected by plant odor receptor neurons (similar to insect pheromone receptor neurons) of *Heliothis virescens*. The mechanism of this compound is still under investigation. However, studies suggest that it may act as a stimulant for feeding and oviposition or inhibiting these behaviors, thus indicating the importance of germacrene D as a chemical marker in interactions with host plants (Røstelien et al., 2000).

Geranial and neral were the major components of the accessions in Group 02. The presence of citral (geranial + neral) provides antibacterial and antifungal action. Previous studies have shown that citral has an inhibitory effect on the fungus *Aspergillus Niger* and can inhibit bacteria such as *Listeria monocytogenes* and *Salmonella enterica* Typhimurium (Prakash et al., 2020, Prakash & Vadivel, 2020). Studies have also shown that citral and the essential oil of *Lippia alba* also has acts against the replication of the yellow fever virus (Gómez, Stashenko & Ocazionez, 2013).

Variations in the composition and concentration of the major components of the essential oils of *Lippia alba* can also be observed in the literature. Carvone, (E)-caryophyllene, and limonene were described as the major components of the oil obtained from *Lippia alba* (Ermen et al., 2023), whereas geranial, limonene, and neral were described for the same species in studies evaluating the chemical composition performed by Santos et al., 2023.

The complex variation in the composition of the essential oils of the two groups of *Lippia alba* presented in this study is influenced by several interactions between the plant and the environment, e.g., the climate, the soil, insects for attraction or defense, and other plant species (Sá et al., 2022).

Table 5 - Chemical composition of the essential oil of *Lippia alba* (Mill.) N.E.Br. ex Britton & P.Wilson for the two groups formed by cluster analysis, cultivated in Cruz das Almas, Bahia, Brazil.

Chemical compound	Group 01						Group 02						
	L01	L04	L05	L10	L11	L12	L02	L03	L06	L07	L08	L09	L13
1-Octen-3-ol	0.1	0.1	0.1	0.1	0.1	0.1	0.7	0.1	0.3	0.3	0.5	0.1	0.7
Bornyl acetate	0.3	0.1	0.1	0.4	0.1	0.1	-	-	-	-	-	-	-
Myrtenyl acetate	0.5	0.4	-	-	-	-	1.9	1.4	1.1	1.1	-	-	-
Trans-carvil Acetate	0.1	0.1	0.3	-	-	-	-	-	-	-	-	-	-
Allo-Aromadendrene	1.2	0.9	0.6	0.9	1.1	1.1	-	-	-	-	-	-	0.2
Aromadendrene	0.4	0.4	0.1	0.1	0.2	0.3	-	-	-	-	-	-	-
Bicyclogermacrene	1.7	0.9	0.8	0.6	1.0	0.9	-	-	-	-	-	-	-
Carvone	28.8	53.5	60.9	30.1	23.4	32.8	4.3	4.5	4.7	3.3	3.6	3.6	2.9
cis-Verbenol	0.4	1.0	1.1	0.1	0.1	0.1	-	-	0.5	0.1	-	0.1	2.6
E-Caryophyllene	1.0	0.9	0.6	2.0	4.4	1.5	5.1	6.4	5.1	7.3	3.2	6.6	5.8
E-Nerolidol	3.9	1.4	2.4	3.4	4.3	3.6	3.2	4.0	3.6	4.8	4.5	12.9	0.1
Spathulenol	0.6	0.3	0.4	0.7	0.6	0.5	2.2	1.0	1.3	1.6	-	1.0	1.1
E-β-Farnesene	0.6	0.5	0.4	0.8	1.3	0.9	0.5	0.4	0.4	0.7	0.7	2.1	-
Germacrene D	32.9	21.2	16.9	22.9	30.7	28.9	3.1	5.7	2.1	3.6	5.0	1.7	3.2
Germacrene D-4-ol	1.0	0.5	0.6	0.9	0.9	0.9	-	0.9	0.3	0.3	-	-	0.4
Limonene	0.8	0.6	0.7	0.6	1.0	1.2	0.1	0.1	0.1	0.1	0.1	0.1	0.6
Linalool	0.3	0.5	0.7	0.5	0.4	0.7	0.1	0.1	1.4	1.0	1.3	2.0	2.2
Myrcene	0.1	0.1	0.2	0.2	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Myrtenal	0.6	1.2	0.1	0.1	0.1	0.1	0.3	0.1	0.9	0.5	-	-	0.1
Piperitenone	0.5	1.5	1.3	0.9	0.2	0.4	-	-	-	-	-	-	0.3
Piperitone	0.4	0.6	0.7	0.3	0.2	0.3	-	-	-	-	-	-	0.2
Thymol	0.3	0.1	0.2	-	-	-	-	-	-	-	-	-	-
Viridiflorol	0.7	0.4	0.3	0.8	1.0	0.6	1.1	0.1	-	-	0.2	-	0.1
α-Bulnesene	0.7	0.4	0.3	0.5	0.7	0.7	0.3	0.4	0.9	1.3	0.6	1.1	0.6
α-Muurolene	0.3	0.3	0.2	0.2	0.5	0.4	0.3	0.6	-	-	-	-	0.1
α-pinene	0.1	0.1	1.7	-	-	-	-	-	-	-	-	-	-
β-Bourbonene	2.8	2.7	0.6	2.6	3.1	3.4	-	-	-	-	0.7	-	0.9
β-Cubebene	0.3	0.6	0.6	0.7	1.0	-	0.6	1.2	0.6	0.6	-	0.1	0.2
β-Elemene	1.1	0.4	0.4	0.7	0.7	-	1.0	1.8	0.9	1.4	0.9	1.1	0.9
β-Gurjunene	0.7	0.6	0.2	0.7	0.9	-	-	-	-	-	0.2	-	-
δ-Cadinene	0.7	0.4	0.0	0.7	0.7	-	0.3	0.5	-	-	-	-	0.3
6-Methyl-5-hepten-2-one	-	0.1	0.1	0.1	0.1	0.1	0.5	0.1	2.5	1.3	0.9	3.3	2.9
Geranyl acetate	-	-	-	-	-	-	2.3	2.7	2.0	2.8	0.6	0.7	0.7
Geranial	-	0.2	0.1	1.3	0.4	1.1	17.5	10.1	22.7	23.8	17.9	25.6	19.7
Geraniol	-	-	-	-	-	-	0.1	0.1	0.6	0.8	-	0.1	-
Neral	-	-	-	-	-	-	11.7	6.4	15.4	15.4	11.0	16.3	13.4
Caryophyllene oxide	-	-	-	-	-	-	5.1	4.8	3.3	2.6	3.8	4.4	2.0
p-Cymen	-	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.3	0.8	0.1	0.4	0.5
α-humulene	-	-	-	-	-	-	1.3	1.9	0.7	0.9	0.3	0.3	0.2
Citronellol	-	-	-	-	-	-	-	-	-	-	0.5	0.7	-
Phytol	-	1.0	1.2	8.0	5.6	4.1	2.3	1.7	1.3	1.3	1.5	1.1	-
Neryl acetate	-	-	-	-	-	-	1.6	0.8	1.2	-	-	0.5	0.7
Geranyl Isobutyrate	-	-	-	-	-	-	0.6	1.6	0.6	1.0	-	-	0.2
Carvone oxide	-	-	-	-	-	-	0.7	0.1	-	-	-	-	0.1
Nerol	-	-	-	-	-	-	-	-	-	-	-	-	0.8

(-): Not found.
Source: Research data.

Conclusion

The use of quantitative and qualitative morphological descriptors evidenced the existence of genetic diversity among *Lippia alba* accessions, demonstrating the phenotypic and chemical variability of the species. The groups formed by the cluster analysis showed variation in chemical composition that should be seen as a promising aspect for selection programs, genetic improvement, and use in the development of

pharmaceutical formulations with the essential oil of *L. alba*.

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