



# Morphological Diversity and Phytogeographic Patterns of *Chrysophyllum albidum* (Sapotaceae) in Benin

Blaise Alowanou-Kélé<sup>a,b\*</sup>, Antoine Abel Missihoun<sup>a,b</sup>,  
Relique Ignace Agbo<sup>a,b</sup>, Paulin Sedah<sup>a,b</sup>,  
Eben-Ezer Ewédjè<sup>c</sup>, Hounnankpon Yédomonhan<sup>d</sup>  
and Clément Agbangla<sup>a,b</sup>

<sup>a</sup> *Laboratoire de Génétique Moléculaire et d'Analyse des Génomes, Faculté des Sciences et Techniques, Université d'Abomey-Calavi, 01 BP 526, Cotonou, Bénin.*

<sup>b</sup> *Laboratoire de Génétique et des Biotechnologies, Université d'Abomey-Calavi, 01 BP 526, Cotonou, Bénin.*

<sup>c</sup> *Laboratoire de Botanique, d'Ecologie Végétale Appliquée et de Génétique Forestière, Ecole Nationale Supérieure des Biosciences et Biotechnologies Appliquées de Dassa (ENSBBA-Dassa), Université Nationale des Sciences, Technologies, Ingénierie et Mathématiques d'Abomey, UNSTIM-Abomey, Bénin.*

<sup>d</sup> *Laboratoire de Botanique et d'Ecologie végétale, Faculté des Sciences et Techniques, Université d'Abomey-Calavi, 01 BP 4521 Cotonou, Bénin.*

## **Authors' contributions**

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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\*Corresponding author: E-mail: [alowanoukelblaise@gmail.com](mailto:alowanoukelblaise@gmail.com);

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## ABSTRACT

*Chrysophyllum albidum* is an agroforestry tree that provides enormous goods and services to local populations in West Africa. The unbridled use of organs the specy, causes its vulnerability, even its disappearance in certain regions, in Benin. The present study aims to evaluate the morphological diversity of populations of *C. albidum* in Benin, in order to differentiate individuals of the specy and target interesting morphotypes for its conservation. Nine (9) variables were used to evaluation of the phenotypic diversity of sixty (60) fruiting trees of the specy, selected in four (04) phytodistricts of Benin. To determine the inter and intra-population variability of the specy, the descriptive statistic was carried out on the quantitative morphology variables of trees by population, and for all populations. The recorded morphological variables were subjected to ANOVA to test the variability of morphological descriptors within phytodistricts and between soil type levels. An Ascending Hierarchical Classification was performed to identify the different morphotypes of the specy. The results obtained reveal significant variability in certain morphological descriptors used, depending on the phytodistricts and soil groups. We observe depending on soil types, seven significant morphological descriptors, with a significance rate of 77.78% (higher) compared to five significant morphological descriptors for the phytodistricts, with a significance rate of 55.56% (lower). So, in Benin, soil types discriminate *C. albidum*, much more than phytodistricts. The descriptors based on the fruits and the leaves of trees of the specy are more discriminants than those the trunk and crown. Three (03) morphotypes of *C. albidum* were obtained in Benin. *Chrysophyllum albidum*'s plants of the phytodistricts Coastal and Plateau belong to the same phenotypic class while the trees of the phytodistricts Pobè and Valley of Ouémé each have a morphotype of the specy. Consisting of relatively short trees bearing longer and wider leaves and fruits, the morphotype of *C. albidum* from the phytodistrict Valley of Ouémé is better indicated for future selections. These various data found must be further supplemented by the molecular genetics characterization, for confirm genetic diversity of the species and support its reproduction programs.

**Keywords:** Benin; *Chrysophyllum albidum*; Ecological zones; Morphological variability; West Africa.

## 1. INTRODUCTION

Food security remains a major existential concern in this world exposed to the harmful effects of climate change and growing population (Kanazoe, 2017). To survive in the face of climate change which has profoundly reduced agricultural yields (Brou et al., 2005), rural communities particularly use to the plant genetic resources of fruit trees (Mbaye, 2011). These resources are increasingly essential in the areas of food security and development sustainable economy (FAO, 1996). *Chrysophyllum albidum*, one of the woody plants whose genetic resources have proven value for human well-being, are essential in West Africa (Houessou et al., 2012; Alowanou-Kélé et al., 2023). Almost all organs of *C. albidum* are exploited by the local populations of Benin. Its wood is used as energy wood and lumber, its fruits constitute a food very appreciated by its consumers, the bark, the roots and the leaves of trees of the species are used in the herbal medicine (Houessou et al., 2012). Aging, urbanization and the method of harvesting organs from *C. albidum* plants constitute the major factors in its disappearance in Benin (Alowanou-Kélé et al., 2023). It is therefore

necessary to develop adequate strategies to conservation of the species, to prevent this disappearance (Agbo et al., 2018). Sustainable management and conservation of forest species requires the analysis of variability morphology of their plant material, to differentiate individuals, in order to identify the elite morphotypes to reproduce (Kouyaté and Van Damme, 2002; Houèchégnon, 2016; Koffi et al., 2023; Bolamba et al., 2024). Among the numerous scientific studies carried out on the morphological variability of woody species useful to populations, we can cite among others, the work by Kouyaté (2005) and Agbo et al. (2018) on *Detarium microcarpum*, Fandohan et al. (2011) on *Tamarindus indica*, Gbèmavo et al. (2015) on *Jatropha curcas* Linn, Ewédjè et al. (2012) on *Pentadesma butyracea*, Ammari et al. (2016) on *Celtis australis*, Sourou Kuiga (2017) on *Haematostaphis barteri*. In each of these studies, the parameters morphological discriminants were identified and used to characterize the different morphotypes found.

From the results from research work on the phenotypic diversity of *C. albidum* in Benin, it appears that there is great variability at the level

of several morphological descriptors of the organs of the species (Dadégnon et al., 2014; Loughégnon et al., 2016). However, these various works have unfortunately not taken into account the edaphic data, although the quality of the soil is essential for the good conservation of agroforestry species (Kouyaté, 2005). Fertile or suitable soil allows the growth of plants, to prevent desertification and land degradation (FAO, 2015). In consequence, the identification of soil types favorable to plant species with multiple uses like *C. albidum*, can ensure food security, and allow the ecosystem to fulfill its fundamental functions.

The primary objective of this study is to assess the morphological diversity of *C. albidum* in Benin. Specifically, it involved: (i) describe the morphological variability of *C. albidum*, (ii) analyze the influence of phytodistricts and soil types on this morphological variability, and (iii) to characterize the morphotypes of the species in Benin.

## 2. MATERIALS AND METHODS

### 2.1. Study Zone

This study was conducted in four (4) phytodistricts of Benin, each characterized by distinct biophysical and climatic conditions (Table 1). These are the phytodistricts Coastal, Plateau, Pobè and Valley of Ouémé from the Guineo-Congolese zone, where *Chrysophyllum albidum* plants are present (Fig. 1).

### 2.2 Collection of Data

Following a spacing of at least 50 meters, sixty (60) fruiting trees of *Chrysophyllum albidum*, at a rate of fifteen (15) plants per phytodistrict, were selected and geo-referenced using a GPS (*Geographical Positioning System*). All of the individuals sampled in a phytodistrict was considered as a population at the same as those found on the same type of soil.

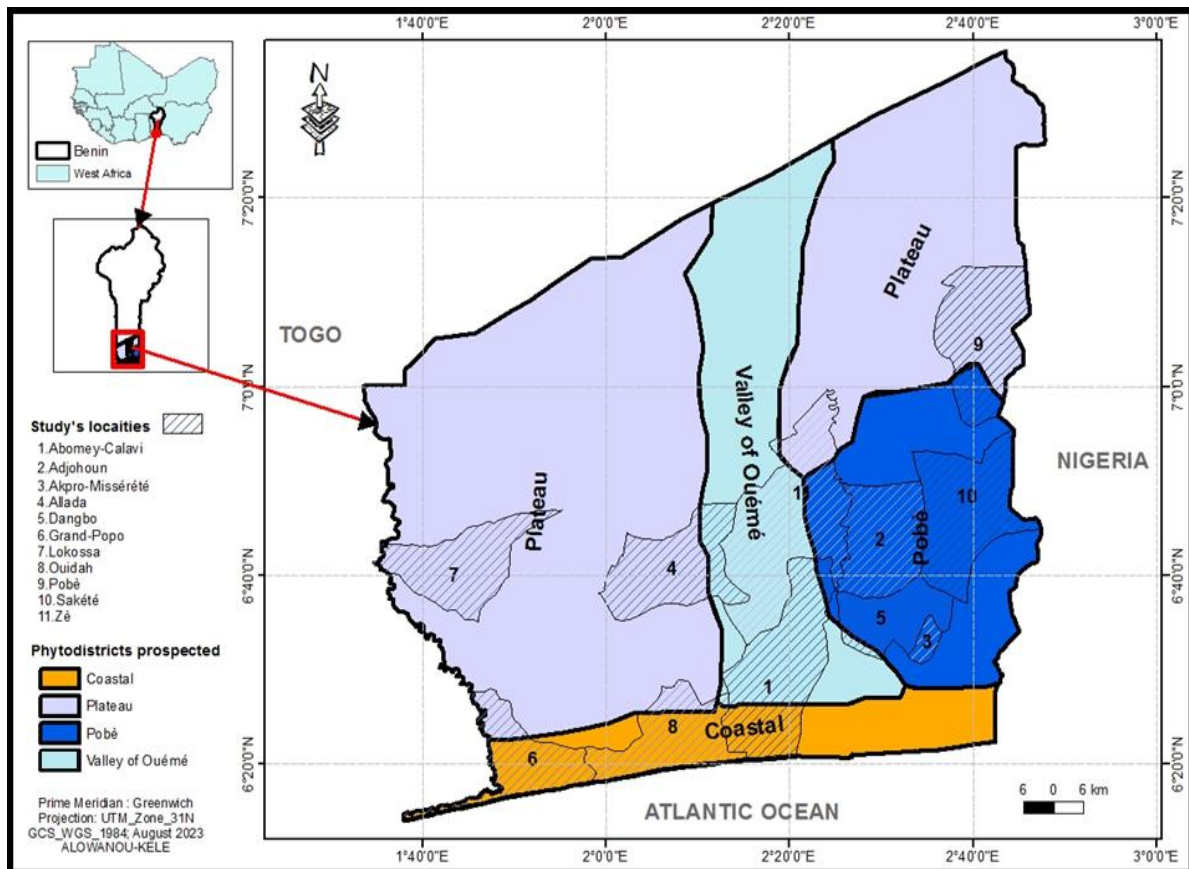


Fig. 1. Map of prospected localities according to the phytodistricts of the study area (Alowanou-Kélé, 2023)

**Table 1. Biophysical characteristics of the phytodistricts of the study area (Gbèmavo et al., 2015)**

<b>Phytodistricts of the area of study</b>	<b>Percentage corresponding to each of phytodistricts in the surface company of Benin</b>	<b>Diet rain</b>	<b>Rainfall</b>	<b>Main types of soil</b>	<b>Main training vegetables</b>
Coastal	1%	Bimodal	900 to 1300	Sandy + Hydromorphic & Halomorphic	Coastal forest and Mangrove
Plateau	7%		900 to 1100	ferralitic without concretions	Semi- deciduous forest
Pobè	2%		1200 to 1300		
Valley of Ouémé	2%		1100 to 1300	Soil hydromorphic	Swamp and Semi-deciduous Forest deciduous.

The morphological variability of *C. albidum* was evaluated using nine (09) descriptors inspired by the research work of several authors (Ouédraogo, 1995; Zitan, 1995; Agbo et al., 2018). These descriptors were measured on the trunk and crown, leaves and fruits of the trees retained. Morphological descriptors collected at the trunk and crown level are the diameter of the trunk at the height of a man's breast-breast (Dbh) expressed in centimeters (cm), the height of the first basal branching relative to the ground (Hpr) and the height of the plant (Hpl) each expressed in meter (m). The diameter of the trunk at the height of a man's breast has been measured using a tailor's meter, while the variables Hpr and Hpl were taken using a penta decameter. At the leaf level, the morphological descriptors identified are the leaf length (Lfe), leaflet length (Lfo) and width leaflets (lfo). The variables Lfe, Lfo and lfo expressed in centimeter (cm) were measured using a 90 cm graduated ruler. Morphological descriptors considered at the level of fruits are the mass of the fruits (mfr) expressed in grams (g) using a balance precision, the length of the fruits (Lfr) and the width of the fruits (lfr) expressed in centimeters (cm) using a graduated ruler. Furthermore, to measure morphological parameters relating to leaves and fruits, it was collected from each of the selected trees, five (5)

perfectly developed and unparasitized fresh leaves, and five (5) unparasitized fresh fruits.

### 2.3 Data Analysis

The soil groups considered in this study (Fig. 2) were identified using the projection of the geographical coordinates of the plants of *Chrysophyllum albidum* on the base Harmonized World Soil Database (HWSD) version 1.21 (FAO/IIASA/ISRIC/ISS-CAS/JRC, 2012). Quantitative morphological data measured on the trunk and crown, leaves and fruits of the selected trees, were used to calculate the mean, standard error and coefficient of variation, in order to evaluate the inter- and intra-population variability of the species. An analysis of the components of the variance was carried out on all the morphological descriptors considered in the four (4) populations of *C. albidum*, in order to study the part of the overall variability linked to individuals of the species, soil types and phytodistricts. From the coefficient of variation whose scale of interpretation was proposed by Ouédraogo (1995) and adopted by certain authors (Kouyaté et al., 2011; Sourou Kuiga, 2017; Agbo et al., 2018), the classification of variability was carried out the one hand, within and between the phytodistricts of origin of

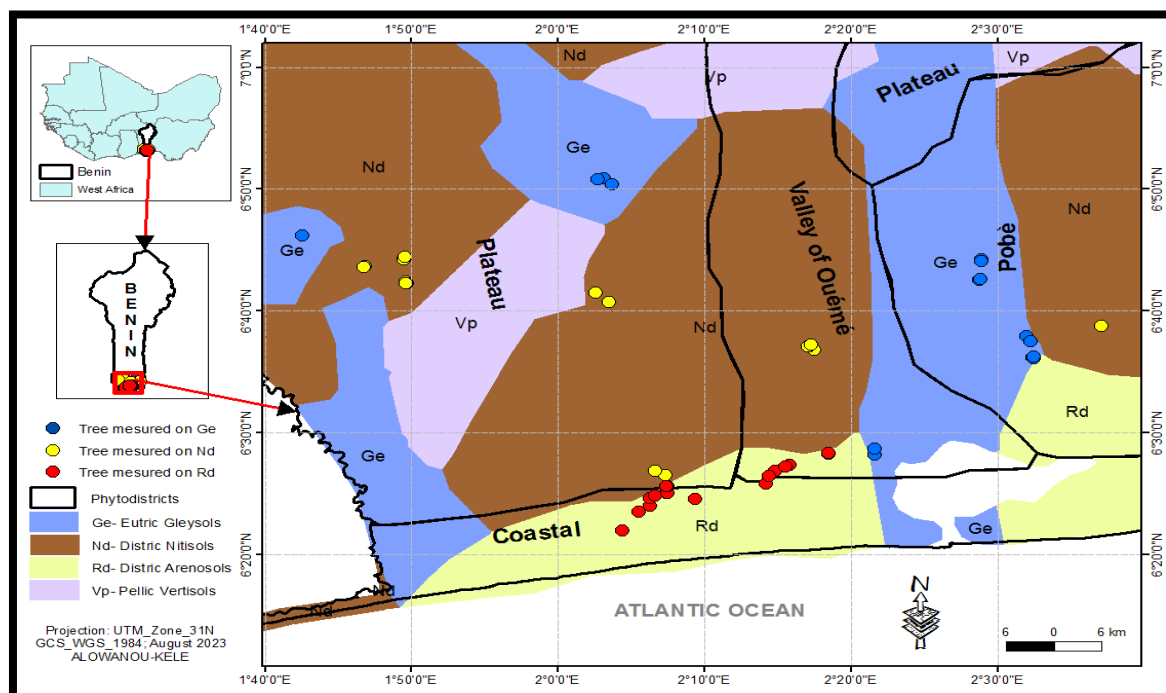


Fig. 2. Identification map of the soil groups hosting the sampled *Chrysophyllum albidum* plants (Alowanou-Kélé, 2023)

*C. albidum*, then on the other hand, within and between soil groups. According to this scale, the variation can be low (CV = 0 - 10%), medium (CV = 10 -15%), quite significant (CV = 15 - 44%) or even very important (CV > 44%). To test the variation of morphological descriptors within phytodistricts and across level of soil types, the recorded morphological variables were subjected to an Analysis of Variance (ANOVA). Likewise, all the morphological descriptors used were subjected to Ward's Ascending Hierarchical Classification (Euclidean distances on the averages of the characters studied), to identify the different morphotypes of the specy in Benin. All these analyzes were carried out with the statistical software R version 4.2.0 (R. Core Team, 2022).

### 3. RESULTS

#### 3.1 Variability of Morphological Descriptors of *Chrysothamnus albidum*

In Benin, the plants of *C. albidum* are found in the Guineo-Congolese, more precisely in the phytodistricts Coastal, Plateau, Pobè and Valley of Ouémé. Tables 2 and 3 presents respectively according to phytodistricts and soil types, variations of nine (9) descriptors quantitative morphological measured on the trunk and crown, leaves and fruits of *C. albidum* trees sampled.

##### 3.1.1 Descriptors of the trunk and crown of *C. albidum* trees

The height of the feet (Hpl) of *C. albidum* inventoried varied from 8 to 33 m with a average of 20.07 ( $\pm$  6.62) m. The height of the first basal branching relative to the ground (Hpr) is between 1.4 and 15 m with an average of 3.56 ( $\pm$  3.22) m. However, alone the average Hpr of the plants of the specy located in the phytodistrict Pobè is less than that given by all the individuals of *C. albidum* considered (Fig. 3). The diameter of the trunk at the height of a man' breast-breast (Dbh) varied from 20 to 136.5 cm with an average of 53.54 ( $\pm$  26.84) cm, slightly exceeded by the average Dbh of the specy' feet found in the phytodistricts Plateau and Pobè (Fig. 4). Intra-phytodistrict variability of the height of *C. albidum* plants was quite significant (15% < CV < 44%) in all the four (04) phytodistricts. Intra-phytodistrict variability of the height of the first basal branching in relation to the ground of the feet of the specy is very important (CV > 44%) in all the

phytogeographical districts covered. The intra-phytodistrict variability of the diameter of the trunk at the height of a man' breast-breast of the *C. albidum* plants, is quite important (15% < CV < 44%) in the Coastal district and very important in the others phytogeographic districts (CV > 44%) of the study environment.

The intra-type of soil variability of *C. albidum* plant height is quite significant (15% < CV < 44%) regardless of the soil group where the plants are found the specy. The intra-type of soil variation in the height of the first basal branching relative to the ground of the specy is quite important (15% < CV < 44%) on the Gleysols soil group, and is very significant (CV > 44%) on Nitisols and Arenosols. Intra-type of soil variability of diameter of the trunk at the height of a man' breast-breast of *C. albidum* plants, is quite significant (15% < CV < 44%) on the Arenosols type of soils, and very important (CV > 44%) on the Gleysols and Nitisols.

##### 3.1.2 Leafs descriptors of *C. albidum* plants

The specy *C. albidum* has leaves whose length (Lfe) is between 29 and 70 cm with an average of 44.68 ( $\pm$  10.16) cm, relatively lower than the averages of Lfe of plants of the specy in the Pobè and Valley of Ouémé districts (Fig. 5). There leaflet length (Lfo) varied from 14.73 to 33.93 cm with a mean of 22.39 ( $\pm$  3.47) cm. Leaflet width (lfo) is between 5 and 11.16 cm with an average of 8.03 ( $\pm$  1.23) cm. There intra-phytodistrict variability in *C. albidum* leaf length was quite significant (15% < CV < 44%) in all phytodistricts in the study area. Variability within phytodistricts leaflet length was quite significant in the Plateau (15% < CV < 44%), and moderately low (10% < CV < 15%) in the phytodistricts Coastal, Pobè and Valley of Ouémé. Intra-phytodistrict variability in leaflet width is low in the Plateau (0% < CV < 10%), moderately low in the Valley of Ouémé (10% < CV < 15%), and quite significant in the others districts of the study environment (15% < CV < 44%).

The intra-soil type variability of leaflet length (Lfo) and width of leaflets (lfo) is average (10% < CV < 15%) in *C. albidum* plants whatever the type of soil that shelters them. On the other hand, with regard to the length of the leaves (Lfe), this variation is quite significant (15% < CV < 44%) on each of the soil types in presence.

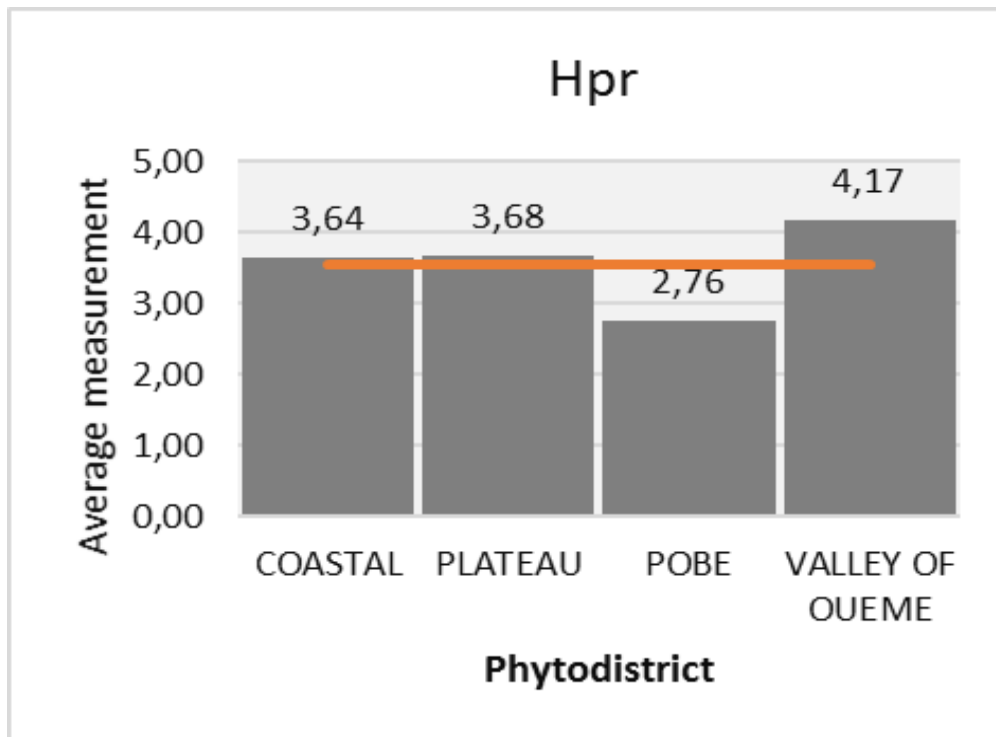


Fig. 3. Height of the first basal branching (Hpr) relative to the ground of *Chrysophyllum albidum* plants, depending on the phytodistricts

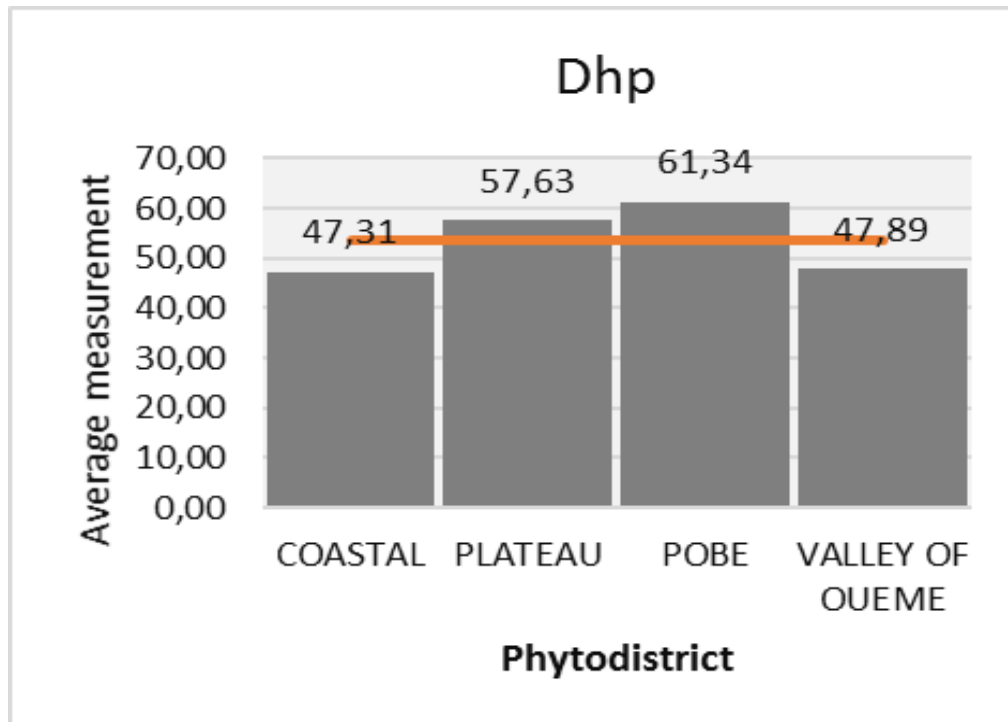


Fig. 4. Trunk diameter at height man's chest (Dhp) of the feet of *Chrysophyllum albidum*, depending on the phytodistricts

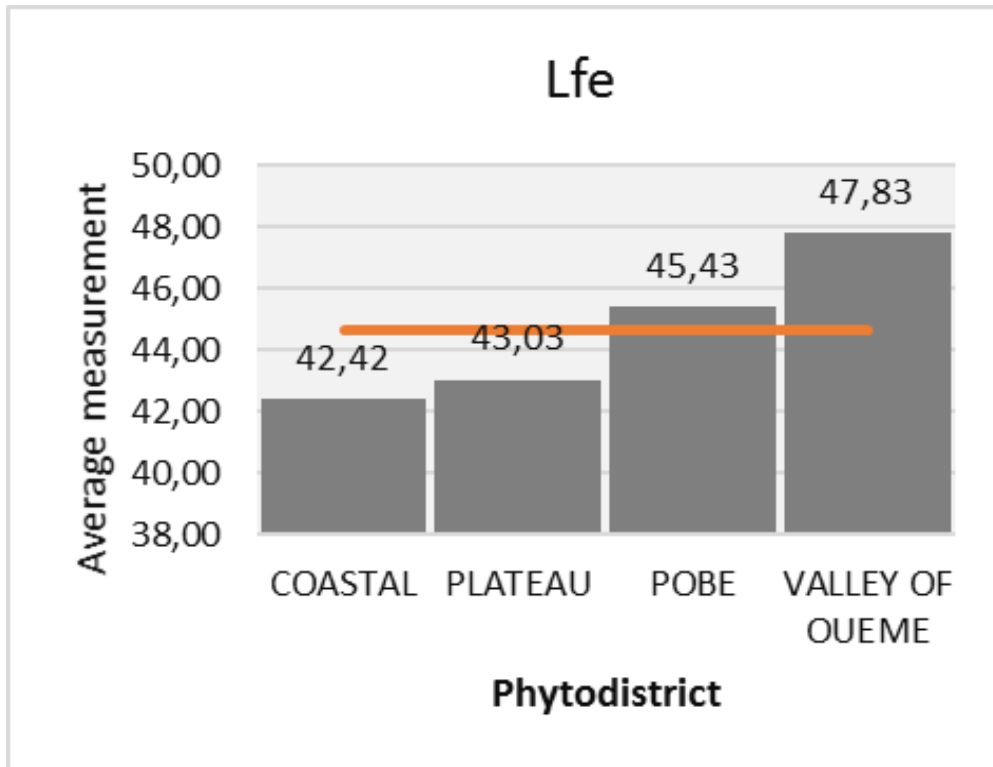


Fig. 5. Leaf length (Lfe) of feet of *Chrysophyllum albidum*, depending on the phytodistricts

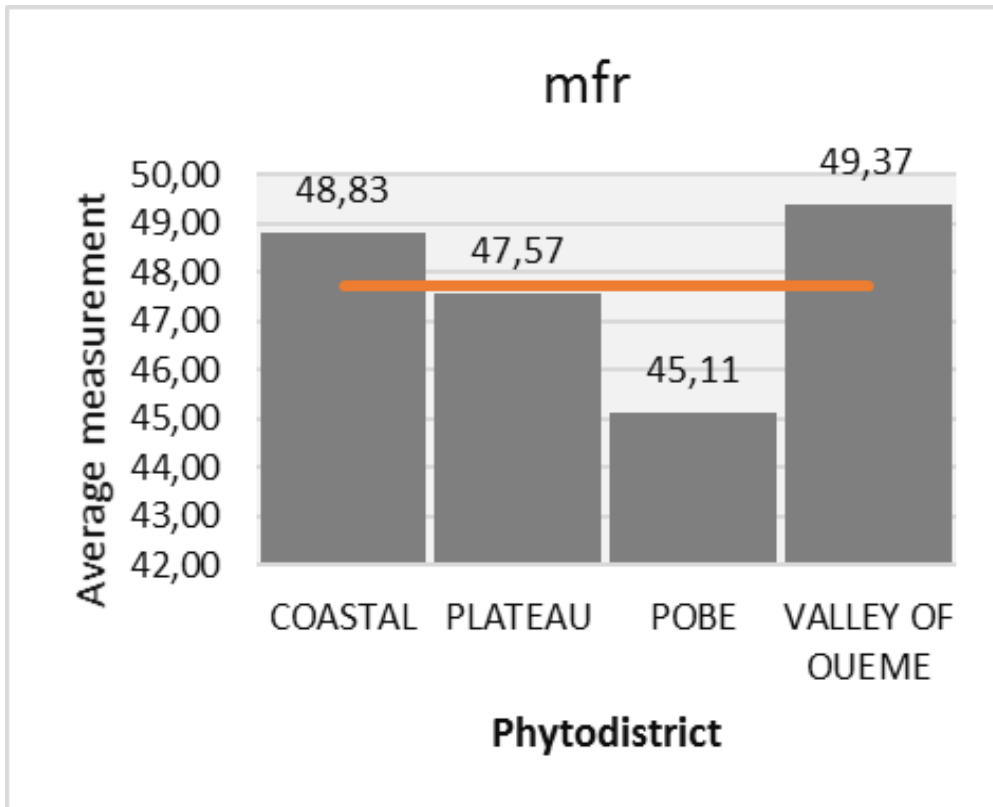


Fig. 6. Fruit mass (mfr) of trees of *Chrysophyllum albidum*, depending on the phytodistricts

### 3.1.3 Fruit descriptors of *C. albidum* plants

The fruits of *C. albidum* have a length (Lfr) between 3.3 cm and 5.5 cm with an average of 4.61 ( $\pm$  0.63) cm, lower than those the Lfr of the plants of the specy in the phytodistricts Coastal and Valley of Ouémé. Its width (lfr) varied from 2.3 to 4.6 cm with an average of 3.65 ( $\pm$  0.64) cm, higher than those the lfr of the plants of the specy *C. albidum* in the phytodistricts Coastal, Plateau and Pobè. The fruits mass (mfr) of *C. albidum* in the study environment is between 23 g and 54 g with an average of 47.72 ( $\pm$ 7.22) g, lower than those of the mfr of the specy located in the phytodistricts Coastal and Ouémé Valley (Fig. 6). Intra-phytodistrict variability in *C. albidum* fruit length is moderately low (10% < CV < 15%) in the phytodistricts Coastal, Pobè and Valley of Ouémé. The variation in fruit width is moderately low (10% < CV < 15%) within the populations of *C. albidum* sheltering the phytodistricts Pobè and Valley of Ouémé, and quite significant (15% < CV < 44%) in the phytodistricts Coastal and Plateau. The intra-phytodistrict variability of *C. albidum* fruit mass is moderately low (10% < CV < 15%) in the phytodistricts Plateau, and quite significant (15% < CV < 44%) in the phytodistricts Coastal, Pobè and Valley of Ouémé.

The intra-type of soil variability of fruit length of *C. albidum* plants is medium (10% < CV < 15%) on Gleysols, Nitisols and Arenosols. Intra-type of soil variability of width fruit of plants of the species is average (10% < CV < 15%) on Gleysols, and quite significant (15% < CV < 44%) on Nitisols and Arenosols. Furthermore, the

variation of the fruit mass of individuals of the species is low (0% < CV < 10%) on Nitisols, average (10% < CV < 15%) on Regosols, and quite significant (15% < CV < 44%) on Gleysols.

### 3.2 Impacts of Phytodistricts and Soil Types on *Chrysophyllum albidum* Variability

Leaflet length (Lfo), leaflet width (lfo) and fruit width (lfr) are the morphological descriptors of *C. albidum* that showed highly significant differences significant between phytogeographic districts (Table 2) at the 1% threshold ( $P < 0.01$ ) according to the Student-Newman-Keuls test. Plant height of *C. albidum* (Hpl) and fruit length (Lfr) of trees of the species, showed inter-phytodistrict differences significant at the 5% level ( $P < 0.05$ ) according to the Student-Newman-Keuls test. In function phytogeographic districts, the morphological variables which best discriminate the populations of *C. albidum*, are leaflet length, leaflet width and width fruits. The leaf of *C. albidum* plants that was found in the phytodistrict Valley of Ouémé is on average longer and wider than those of the leaves of the feet which were found in the others phytodistricts (Fig. 7). The fruits of plants of *C. albidum* which were measured in the phytodistrict Valley of Ouémé are in average longer and wider than those of the feet sampled in the others phytodistricts (Fig. 7). Furthermore, the feet of the tree, found in the phytodistrict Pobè, are on average larger in size than those of others phytodistricts (Fig. 7).

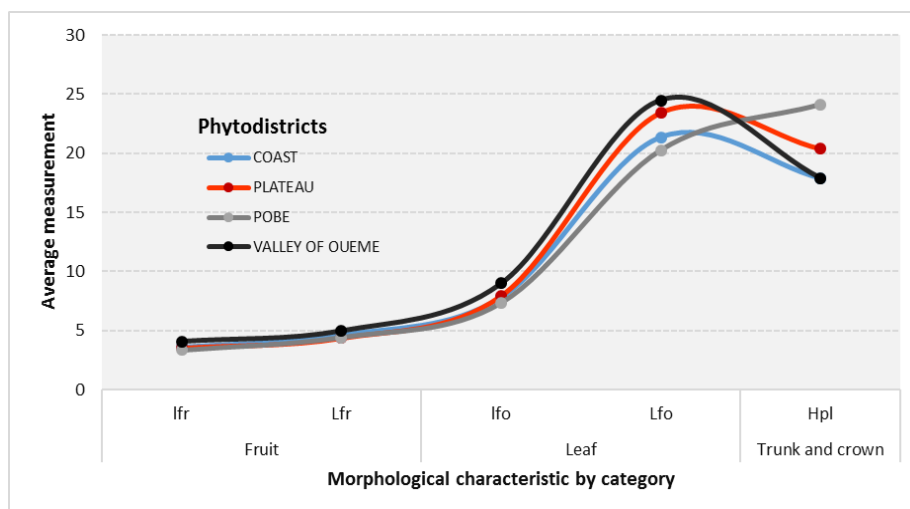


Fig. 7. Variation of the five (05) significant morphological descriptors (Hpl, Lfo, lfo, Lfr and lfr) of *Chrysophyllum albidum*, according to their averages and phytodistricts

**Table 2. Morphological description of quantitative variables of *Chrysophyllum albidum*, depending on the phytodistricts.**

Phytodistricts	Parameter	Hpl (m)	Hpr (m)	Dhp (cm)	Lfo (cm)	lfo (cm)	Lfe (cm)	Lfr (cm)	lfr (cm)	mfr (g)
Coastal	Average	17.87 b	3.64 a	47.31 a	21.36 bc	7.83 b	42.42 a	4.64 ab	3.61 ab	48.83 a
	SE	5.97	3.89	17.42	3.08	1.19	6.92	0.59	0.65	8.05
	CV (%)	33.44	106.85	36.81	14.43	15.16	16.31	12.74	18.07	16.49
Plateau	Average	20.4 ab	3.68 a	57.63 a	23.47 ab	7.96 ab	43.03 a	4.38 b	3.53 ab	47.57 a
	SE	5.64	2.69	31.2	3.59	0.77	9.66	0.68	0.68	6.33
	CV (%)	27.63	73.21	54.14	15.31	9.64	22.44	15.61	19.36	13.31
Pobè	Average	24.11 a	2.76 a	61.34 a	20.26 c	7.36 b	45.43 a	4.43 ab	3.35 b	45.11 a
	SE	6.77	2.32	28.59	2.92	1.21	13.59	0.53	0.42	6.77
	CV (%)	28.08	84.06	46.61	14.40	16.43	29.93	11.86	12.39	15.02
Valley of Ouémé	Average	17.88 b	4.17 a	47.89 a	24.49 a	8.99 a	47.83 a	4.99 a	4.09 a	49.37 a
	SE	6.59	3.85	27.97	2.81	1.17	9.47	0.56	0.59	7.58
	CV (%)	36.83	92.36	58.42	11.49	12.99	19.80	11.29	14.53	15.35
Probability		0.0259 *	0.692ns	0.386ns	0.00168 **	0.00146 **	0.456ns	0.0295 *	0.00917 **	0.383ns
Minimum population		8	1.4	20	14.73	5	29	3.3	2.3	23
Maximum population		33	15	136.5	33.93	11.16	70	5.5	4.6	54
Average population		20.07	3.56	53.54	22.39	8.03	44.68	4.61	3.65	47.72
SE population		6.62	3.22	26.84	3.47	1.23	10.16	0.63	0.64	7.22
CV (%)		32.99	90.42	50.13	15.50	15.27	22.75	13.59	17.62	15.14

CV: Coefficient of Variation; SE: Standard Error, \*: Significant at the 5% threshold; \*\*: Highly significant at the 1% level; \*\*\*: Very highly significant at the 0.1% level; ns: not significant.

**Table 3. Morphological description of the quantitative variables of *Chrysophyllum albidum*, according to soil types**

Soil types	Parameter	Hpl (m)	Hpr (m)	Dhp (cm)	Lfo (cm)	lfo (cm)	Lfe (cm)	Lfr (cm)	lfr (cm)	mfr (g)
Ge - Gleysols	Average	23.07 a	2.24 b	61.01 a	20.24 b	7.42 b	42.62 a	4.3 b	3.3 b	43.63 b
	SE	6.69	0.46	28.08	2.42	1.09	12.32	0.58	0.47	8.41
	CV (%)	29.01	20.41	46.02	11.94	14.68	28.91	13.58	14.15	19.28
Nd - Nitisols	Average	19.24 ab	5 a	50.82 a	24.5 a	8.54 a	45.74 a	4.71 ab	3.83 a	49.76 a
	SE	7.24	3.95	33.04	3.28	1.16	8.24	0.6	0.62	3.65
	CV (%)	37.61	79.05	65.02	13.39	13.54	18.01	12.65	16.20	7.33
Rd - Arenosols	Average	17.89 b	3.45 ab	48.8 a	22.44 ab	8.14 ab	45.68 a	4.83 a	3.82 a	49.77 a
	SE	4.87	3.52	16.32	3.36	1.21	9.71	0.6	0.7	7.18
	CV (%)	27.21	102.14	33.45	14.98	14.89	21.26	12.51	18.36	14.43
Probability		0.0339 *	0.0227 *	0.309ns	0.000231 ***	0.0112 *	0.548ns	0.0184 *	0.0104 *	0.0063 *
Minimum population		8	1.4	20	14.73	5	29	3.3	2.3	23
Maximum population		33	15	136.5	33.93	11.16	70	5.5	4.6	54

<b>Soil types</b>	<b>Parameter</b>	<b>Hpl (m)</b>	<b>Hpr (m)</b>	<b>Dhp (cm)</b>	<b>Lfo (cm)</b>	<b>lfo (cm)</b>	<b>Lfe (cm)</b>	<b>Lfr (cm)</b>	<b>lfr (cm)</b>	<b>mfr (g)</b>
Average population		20.07	3.56	53.54	22.39	8.03	44.68	4.61	3.65	47.72
SE population		6.62	3.22	26.84	3.47	1.23	10.16	0.63	0.64	7.22
CV (%)		32.99	90.42	50.13	15.50	15.27	22.75	13.59	17.62	15.14

CV: Coefficient of Variation; SE: Standard Error; \*: Significant at the 5% threshold; \*\*: Highly significant at the 1% level; \*\*\*: Very highly significant at the 0.1% level; ns: not significant.

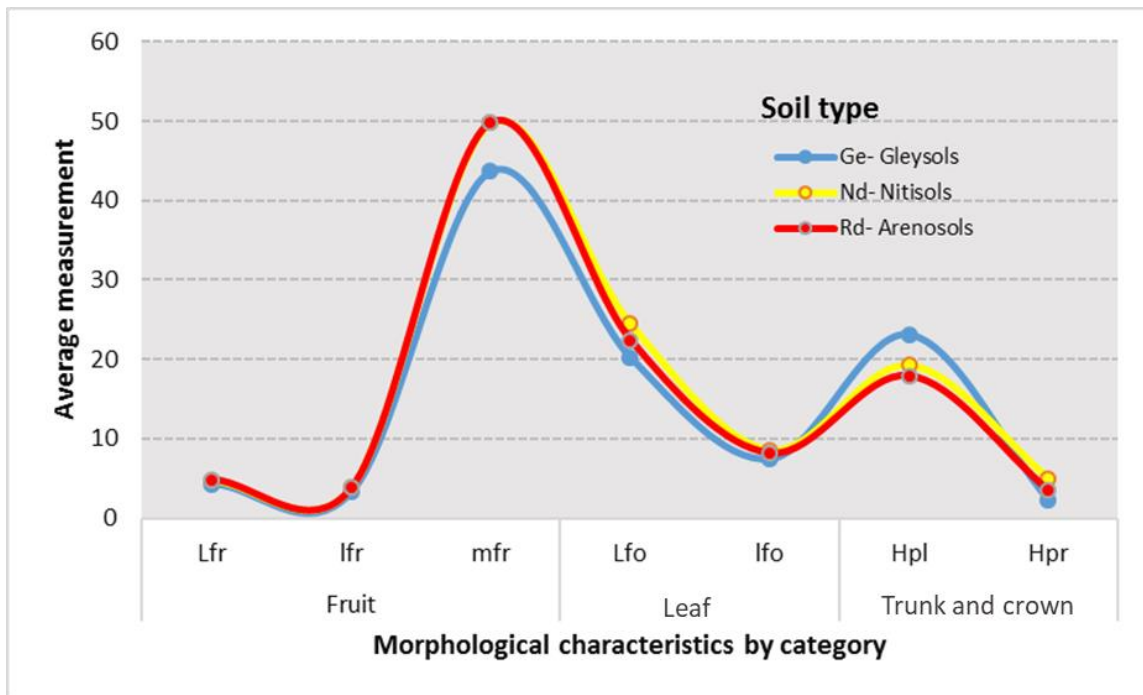


Fig. 8. Variation of the seven (07) significant morphological descriptors (Hpl, Hpr, Lfo, lfo, Lfr, lfr and mfr) of *Chrysophyllum albidum*, according to their averages and soil types

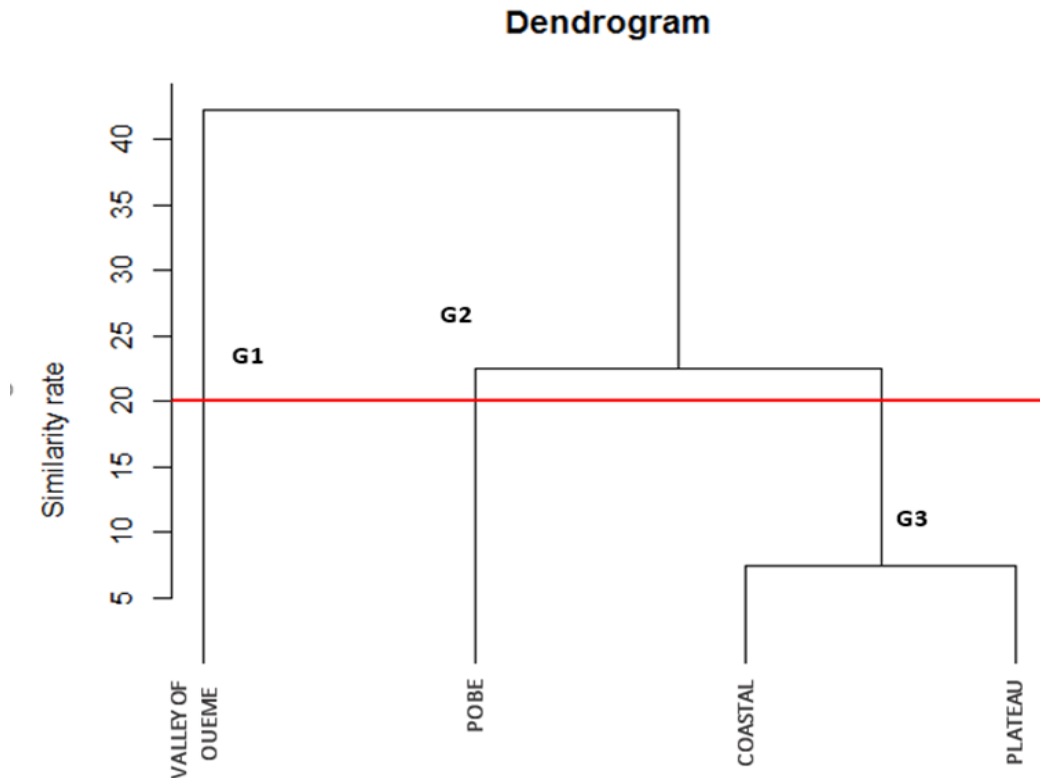


Fig. 9. *Chrysophyllum albidum* morphotypes from hierarchical classification ascending

Depending on the soil types, quantitative morphological variables such as the height of *C. albidum* plants (Hpl), the height of the first basal branching per relationship to the ground (Hpr), the width of the leaflets (lfo), the fruits length (Lfr) and the width of the fruits (lfr) showed significant inter-pedological differences (Table 3) at the threshold of 5% ( $P < 0.05$ ) according to the Student-Newman-Keuls test. On the other hand, the mass of the fruits of plants of the species (mfr) showed highly significant inter-pedological differences at the threshold of 1% ( $P < 0.01$ ), and the length of the leaflets (Lfo) of the trees of the species showed very highly significant differences between the soil types, at the threshold of 0.1% ( $P < 0.001$ ) according to the Student-Newman-Keuls test. Depending on the type pedological, the morphological variables which best discriminate the populations of *C. albidum*, are the length of the leaflets and the mass of the fruits of plants of the species. The feet of the tree which were found on the Gleysols, are on average larger in size than those occupying the other soil groups (Fig. 8). The fruits of the plants of *C. albidum* which have been found on the Arenosols, are on average longer, and weigh more than those of the feet which were found on other soil types (Fig. 8). However, these fruits of plants of the species are wider on Nitisols than on Gleysols and Arenosols. Furthermore, the leaflets of the leaves of the plants of *C. albidum* which were measured on the Nitisols are on average longer than those of the leaves of the feet which were found on the others soil types (Fig. 8).

### 3.3 Phytogeographic Patterns of *Chrysophyllum albidum*

Using the morphological descriptors of *C. albidum* considered, the Ascending Hierarchical Classification was carried out, and made it possible to highlight three (03) morphotypes at the 20% similarity threshold (Fig. 9).

Group G1 consists of *C. albidum* plants from the phytodistrict Valley of Ouémé. This morphotype is characterized by short trees, bearing fruits longer, wider, heavier, and with longer and wider leaves. The group G2 is made up of *C. albidum* plants from the Pobè phytodistrict. This morphotype is characterized by larger trees, developing less long and wider leaves, and bearing lighter fruits of average length and width. The G3 group contains the *C. albidum* plants from the Coastal and Plateau phytodistricts. This class phenotypic is characterized by moderately

tall individuals, presenting leaves moderately long and wide, bearing fruits of average mass, length and width.

## 4. DISCUSSION

### 4.1 Morphological Variability of *Chrysophyllum albidum*

*Chrysophyllum albidum* is a plant species that provides multiple goods and services to local populations (Houessou et al., 2012; Loubégnon et al., 2012). However, the importance of the resources of this species for the local populations of Benin makes it vulnerable and even contributes to its disappearance (Alowanou-Kélé et al., 2023). With an index of 2.67, *D. microcarpum* was also considered a very vulnerable species in the phytodistrict Zou, Benin (Agbo et al., 2017). The settings morphological plants of this very useful species in Benin vary as well depending on phytogeographic provenances as well as soil types. The trees of shorter *C. albidum* produced longer and wider fruits and leaves, as had reported the results of the work of Dadégnon et al. (2014). These small feet, mainly come from the phytodistrict Valley of Ouémé, and seem very interesting for breeding programs for elite morphotypes of the species for fruit production. Furthermore, in function of the phytogeographic districts of presence of individuals of *C. albidum*, the leaves of the species are made highly polymorphic at the threshold of 1% by the length of the leaflets and leaflet width; the fruits of the species are highly polymorphic at the threshold of 1%, and polymorphic at the threshold of 5% thanks respectively to their widths and their lengths; the trunk and crown of the species are polymorphic at the threshold of 5% thanks to the height of its plants. Depending on the soil groups serving as support for individuals of *C. albidum*, the trunk and crown are made polymorphic at the threshold of 5% by the height of the plants of the species and the height of the first basal branching relative to the ground; the leaves are made polymorphic at the threshold of 5% by the width of the leaflets, and very highly polymorphic at the threshold of 0.1% by leaflet length; the fruits are made polymorphic at the threshold of 5% by its length and width, and highly polymorphic at the threshold of 1% thanks to its mass. These variations observed at the level of certain morphological descriptors could be due to the characteristics of climatic and soil types, or to the reproductive biology of the plant (Agbo et al., 2018), or even genotypic factors (Sourou Kuiga, 2017). The relatively high

variability recorded in the fruits of *C. albidum*, agree well with those obtained by Lougbégnon et al. (2016) on the same species, Fandohan et al. (2010) on *Tamarindus indica* L., and Abasse et al. (2011) on *Balanites aegyptiaca*.

At the phytodistricts level, five (05) significant morphological descriptors have been identified, compared to seven (07) for soil types. Soil types therefore have a much greater influence on the variability of *C. albidum* plants in Benin. These results reinforce those revealed by the work of Agbo et al. (2018) where phytodistricts and soil groups equitably influence the variability of *D. microcarpum*. However, the variation in morphological descriptors remains much more significant in *C. albidum* than in *D. microcarpum*. This slight difference could be linked to the fact that *D. microcarpum* trees would have covered a larger part of the Beninese territory than *C. albidum*, and could thus allow a greater variation in climatic and edaphic conditions. The height of the first basal branching relative to the ground, the diameter of the trunk at height of a man's breast, the length of the leaf and the mass of the fruits, constitute the descriptors for which the *C. albidum* plants are morphologically similar, from phytodistrict to another. According to the work of Dadégnon et al. (2014), there is a large similarity between agro ecological zones, with regard to the total height of plants of *C. albidum* in Benin.

#### **4.2 Influence of Environmental Factor on the Growth and Survival of *Chrysophyllum albidum***

Ward's Ascending Hierarchical Classification indicates three (03) morphotypes or subpopulations of *C. albidum* in Benin. The plants of *C. albidum* from the phytodistricts Coastal and Plateau belong to the same phenotypic class, therefore are quite close morphologically from each other. The identified morphotypes present different characteristics, and depend on the districts Valley of Ouémé (G1), Pobè (G2) then Coastal and Plateau (G3). Despite the fact that all of these four (04) districts phytogeographical all belong to the Guineo-Congolese zone located between 6°25'N and 7°30'N, a difference is observed in these morphotypes. By deduction, from a sub-population of *C. albidum* to another, each phytodistrict presents characteristics that make it's specified. Morphological variabilities are then mainly based on environmental conditions and habitat (Assogbadjo et al., 2008). Larger trees found in the Pobè district, formed mainly of

ferrallitic soils without concretions (Gbèmavo et al., 2015), are due to the sufficient space available for the right development and survival of trees of the species in this phytodistrict. Furthermore, the analyzes carried out in the present study revealed a significant intra- and inter-pedological difference at the level of seven (7) morphological characters, then a significant intra- and inter-phytodistrict difference at the level of five (5), morphological characters. Consequently, soil types are essential in the morphological characterization of *C. albidum* to Benin. The Valley of Ouémé, with its numerous wetlands (Gbèmavo et al., 2015), constitutes one of the prediction territories of *C. albidum*, and is essential in the selection future of elite morphotypes for the sustainable management (Koffi et al., 2023; Bolamba et al., 2024) of genetic resources of *C. albidum*.

The multiple uses of *C. albidum* and the extensive urbanization in certain communes of Benin, dangerously threaten the survival and good development of the feet of the species, through the ever-increasing reduction of its populations in habitats natural, and the observation in certain phytodistricts of less giant trees of the species. Therefore, anthropogenic activities can negatively impact the presence of the species.

#### **5. CONCLUSION**

This study highlights the significant morphological variability of *C. albidum* in Benin, influenced by phytogeographic and pedological factors. The findings indicate that leaf and fruit characteristics exhibit greater polymorphism than trunk and crown attributes. Three distinct morphotypes of *C. albidum* were identified, each associated with specific phytogeographic structures. The morphotype found in the Valley of Ouémé, characterized by superior fruit quality, holds the greatest potential for future breeding and conservation initiatives.

#### **DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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