



## Morphometric relationships for *Copaifera langsdorffii* (Desf.) Kuntze in northern region of Minas Gerais state, Brazil<sup>1</sup>

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**Abstract:** *Copaifera langsdorffii* specie occurs throughout Brazil and is of great economic importance, mainly due to its production of oil-resin used for various pharmacological purposes. The objective of this study was to analyze the morphometric relationships in *C. langsdorffii* stand in northern region of Minas Gerais state, Brazil. Twenty trees were randomly sampled and were measured: stem circumference at 1.3 m height, total height (Ht) and crown diameter (CD). Morphometric indices were estimated. Correlations between dendrometric and morphometric variables were obtained through the Pearson matrix. The morphometric relations of crown proportion (CP), crown area (CA), formal of crown (FC), degree of slenderness (DS), salience index (SI), coverage index (CI) and vital space (VS) presented values of 15.26%, 25.06 m<sup>2</sup>, 1.47, 16.35, 21.70, 0.47 and 7.01, respectively. Strong positive correlations were found in: diameter at breast height (DBH) in relation to CD and CA; Ht with crown proportion (CP) and DS; the formal of crown (FC) with the CI and VS, and between the CI and VS. The morphometric indices made it possible to understand the few magnitude of stand variation. The species can be characterized as facilitating management.

**Keywords:** Copaíba; morphometry; crown, height, development

## Relações morfométricas para *Copaifera langsdorffii* (Desf.) Kuntze na região norte de Minas Gerais, Brasil

**Resumo:** A espécie *Copaifera langsdorffii* ocorre em todo o território brasileiro e tem grande importância econômica devida, principalmente, à sua produção do óleo-resina utilizado para diversos fins farmacológicos. O objetivo deste estudo foi analisar as relações morfométricas em uma população de *C. langsdorffii* na região norte de Minas Gerais, Brasil. Foram amostradas 20 árvores ao caso, das quais se mensurou a: circunferência do fuste à altura de 1,3 m, a altura total (Ht) e o diâmetro da copa (CD). Foram estimados índices morfométricos. Correlações entre as variáveis dendrométricas e morfométricas foram obtidas através da matriz de Pearson. As relações morfométricas proporção de copa (CP), área da copa (CA), formal da copa (FC), grau de esbeltez (DS), índice de saliência (SI), índice de cobertura (CI) e espaço vital (VS) apresentaram valores de 15,26%, 25,06 m<sup>2</sup>, 1,47, 16,35, 21,70, 0,47 e 7,01, respectivamente. Correlações fortemente positivas foram encontradas em: diâmetro à altura do peito (DBH) em relação ao CD e CA; Ht com a proporção da copa (CP) e o DS; o formal da copa (FC) com o CI e o VS e entre o CI e o VS. Os índices morfométricos possibilitaram compreender pouca magnitude de variações na população. A espécie pode ser caracterizada como facilitadora ao manejo.

**Palavras – chave:** Copaíba; morfometria; copa; altura; desenvolvimento

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## Introduction

*Copaifera langsdorffii* (Desf.) Kuntze species belong to Fabaceae family, subfamily Caesalpinioideae. In Brazil, the common names are copaíba, copaibeira-de-minas, pau-do-óleo, cupiúva, and other. It has a mean height that varies from 15 to 20 meters, may measure 80 centimeters in diameter at breast height (MARTINS-DA-SILVA et al., 2008; PASA, DAVID and SÁNCHEZ, 2012).

With great ecological plasticity, the species can occur naturally in entire Brazilian territory, as in region of Minas Gerais state, Cerrado, Caatinga, Atlantic Forest, Riparian Forest formations and associated ecosystems (CARVALHO et al., 2009; MELO JUNIOR, CECCANTINI and BONA, 2011; COSTA et al., 2012b; NUNES et al., 2015; CARVALHO et al., 2018). According Orellana and Koehler (2008), although wood is the main economic resource derived from forests, some species have great importance for alternative products supply, as in the case of oil-resin, with wide range of medical applications (PIERI, MUSSI and MOREIRA, 2009; MUSSI et al., 2009; HECK, VIANA and VICENTINI, 2012).

Due to its economic importance, *Copaifera* species have been subject to strong anthropic pressure for oil-resin extract, even though the mode is most sustainable currently (PIERI, MUSSI and MOREIRA, 2009; MEDEIROS et al., 2018). The conservation methods and more comprehensive studies are important for more detailed information, for provides a better economic exploitation form for the species.

The dasonomic studies are morphometric relationships that can provide predictive information of silvicultural and stand management interest (ORELLANA and KOEHLER, 2008). Degree of slenderness (DS), salience index (SI), coverage index (CI), crown proportion (CP) and the formal of crown (FC) as important morphometric indices to estimate, e.g., competition degree, stability and productivity of the stand (SANTOS et al., 2015b; DIONÍSIO et al., 2018).

The DS is an index for trees architecture

understands, defining the tendency of height growth in relation to diameter at breast height, and its competition stability (DURLO and DENARDI, 1998). The SI expresses how many times the crown diameter is greater than the DBH (diameter at breast height); the CI predicts the behavior of community in an upright position and level of occupation and light interception (DURLO and DENARDI, 1998).

Canopy morphometry studies through the crown area (CA), formal of crown (FC) and crown proportion (CP), associated the crown diameter and length to other variables in the same stand (FIGUEIREDO et al., 2014). Because it is a vital organ, normally correlated to its growth in diameter (SILVEIRA et al., 2015) and height (SANTOS et al., 2015a), these indices (e.g. CA, FC and CP) are more indicative of competition effect.

The occupation degree of each tree, in particular crown projection area, is determined by the CA index, where the increase is greater for trees with superior sociological position. The FC is more related to tree photosynthetic productivity (ASSMANN, 1970). When FC value is lower, greater is the influence of neighboring trees on canopy lateral expansion; the CP is an index that estimates photosynthetic potential of the tree, which, sensitive to competition effects, makes the crown length shorter, correlating strongly with growth (CUNHA and FINGER, 2012).

The vital space (VS) is an index that allows the growth return, even when the crowns compete again as soon as the air space closes, starting the differentiation of sociological classes according to competition between trees, compromising the growth of those who are not in the upper class (DURLO, 2001). It is also understood that the probability of a neighboring tree becoming a competitor increases with the increase of its size, represented by total height and proximity of objective-tree, causing a greater competition (CUNHA and FINGER, 2012). The objective of this research is to analyze morphometric indices for *Copaifera langsdorffii* (Desf.) Kuntze stand in northern region of Minas Gerais state, Brazil.



## Material and methods

### Study area characterization

The study was carried out in the northern region of Minas Gerais state, Brazil, between Salinas and Novorizonte counties, in a strip of area with transition vegetation from the Cerrado stricto sensu and Seasonal Deciduous and Semideciduous forest, with predominant Cerrado vegetation on Ferralsol (USDA, 2014), that correspond to “Latosolo” (CORREIA et al., 2007) in Brazilian System of Soil Classification (EMBRAPA, 2018). The coordinates of the study area are Lat.: 781901.786363 and Long.: 822218.821789. The climate of the region is Tropical Semi-Arid of Bsw type, according to the Köppen classification, with mean annual pluviometric precipitation of 880 mm and mean air temperature of 28 °C year<sup>-1</sup>.

### Data collection and analysis

A sample of 20 trees was randomly selected from *C. langsdorffii* stand, having as inclusion criteria those with a diameter at breast height (DBH)  $\geq 20$  cm from these trees. The dendrometric variables of circumference at breast height (CBH) were measured at 1.30 m at soil level later converted into diameter at breast height (DBH). The total height (Ht) and stem height (Hs), up to the incidence of the first branch, were measured with a clinometer (Abney level).

The crown diameter (CD) of the trees was measured with a graduated measuring band, taking one measurement per tree. The crown length (CL) was obtained by difference in total height minus stem height (Ht-Hs). The morphometric indices of crown proportion (CP), degree of slenderness (DS), salience index (SI), coverage index (CI), formal of crown (FC) and vital space (VS), were calculated in an Excel® Windows 2010 spreadsheet. Equations to calculate

dendrometric variables (morphometric indices) and measurement scheme in the tree showed in Table 1.

To verify the relationship between morphometric and dendrometric variables, Pearson's correlation matrix at 5% probability was calculated using an Excel® Windows 2010 spreadsheet.

## Results

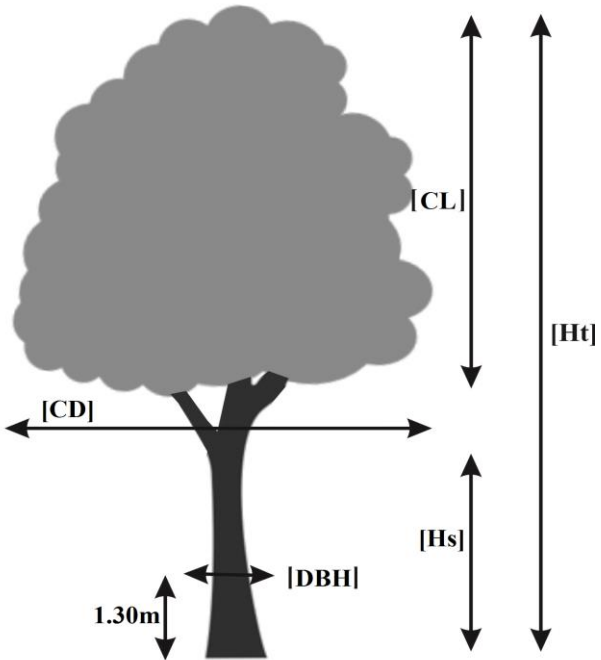
The mean values for dendrometric variables in *Copaifera langsdorffii* stand are: 10.1 m of total tree height (Ht); 5.9 m of stem height (Hs); 31.2 cm diameter at breast height (DBH); 9.35 m of crown diameter (CD); and 4.15 m of crown length (CL) (Table 2).

The crown area (CA), crown proportion (CP) and formal of canopy (FC), with values of 72 m<sup>2</sup>, 41.8% and 2.47 respectively, infer that the *C. langsdorffii* occurrence is in condition favorable on canopy space. This occurs because, in addition to existence of expressive canopy area, the crown proportion showed a trend of similarity between canopy height and total tree height and formal of crown (FC). That is, the crowns are, on mean, 2.5 times greater than their height, which made the *C. langsdorffii* trees to have more width than the crown length, consequently reaching a greater contact area in canopy space.

The degree of slenderness (DS), ranging from 16 to 50, explained the satisfactory condition of tree stability, indicating low competition. The salience index (SI) showed that crown diameter is, on average, 30.5 times greater than diameter at breast height. For mean coverage index (CI) of 1.0, it is understood that trees have same proportion of height and crown diameter, that is, trees of equal width and height. The variable vital space (VS) of *C. langsdorffii* crown (14.76 value) showed that there is enough space for its full development.

**Table 1.** Schematic of dendrometric measurements of a tree and equations of morphometric indices evaluated for *Copaifera langsdoffii* (Desf.) Kuntze in northern region of Minas Gerais state, Brazil.

**Tabela 1.** Esquema de medições dendrométricas de uma árvore e equações de índices morfométricos avaliados para a *Copaifera langsdoffii* (Desf.) Kuntze na região norte de Minas Gerais, Brasil.

Equations	Schemes
$CA = CD^2 \times \frac{\pi}{4}$ $CL = Ht - Hs$ $CP = \frac{CL}{DBH} \times 100$ $FC = \frac{CD}{CL}$ $DS = \frac{Ht}{DBH}$ $SI = \frac{CD}{DBH}$ $CI = \frac{CD}{Ht}$ $VS = CI \times Htdom$	

Where: CA = crown area (m<sup>2</sup>); CD = crown diameter (m);  $\pi$  = pi constant (3.141592); CL = crown length (m); Ht = total tree height (m); Hs = stem height up to the first branch incidence (m); CP = crown proportion (%); DBH = diameter at breast height measured at 1.30 m from the soil level (cm); FC = formal of crown; DS = degree of slenderness; SI = salience index; CI = coverage index; VS = vital space; Htdom = total dominant height (m).

**Table 2.** Variables and morphometric indices of *Copaifera langsdoffii* (Desf.) Kuntze stand in northern region of Minas Gerais state, Brazil.

**Tabela 2.** Variáveis e índices morfométricos de uma população de *Copaifera langsdoffii* (Desf.) Kuntze na região norte de Minas Gerais, Brasil.

Variables and morphometric indices	Minimum	Mean <sup>1</sup>	Maximum	CV (%)
Ht (m)	4.67	10.10	14.92	27.81
Hs (m)	2.28	5.94	10.24	35.30
DBH (cm)	22.92	31.20	53.48	28.51
CD (m)	5.65	9.35	15.75	25.18
CL (m)	1.84	4.15	7.02	33.22
CP (%)	15.26	41.84	55.30	22.90
CA (m <sup>2</sup> )	25.06	72.71	194.73	53.54
FC	1.47	2.47	6.08	42.75
DS	16.35	33.81	50.74	31.09
SI	21.70	30.52	40.62	16.38
CI	0.47	0.99	2.03	35.99
VS	7.01	14.76	30.29	36.56

<sup>1</sup>Sample universe = 20 trees of *Copaifera langsdoffii*; Where: Ht = total tree height; Hs = stem height; DBH = diameter at breast height; CD = crown diameter; CL = crown length; CP = crown proportion; CA = crown area; FC = formal of crown; DS = degree of slenderness; SI = salience index; CI = coverage index; VS = vital space; CV = coefficient of variation.

Correlations between dendrometric and morphometric variables were strongly positive (greater than 69%) for the diameter at breast height (DBH) with crown diameter (CD) and the crown area (CA). The same occurs between the total height (Ht) with crown length (CL), and the degree of slenderness (DS); between the formal of canopy (FC) with the coverage index (CI) and the vital space (VS). In addition to the coverage index (CI) with the vital space (VS) (Table 3).

The strong positive correlations explained the direct and dependent relations of some structures development of *C. langsdorffii* trees. This result can be observed through the indices, such as, for example, DBH being favorable to higher CA index, in a proportionally direct way. Already, the strong negative correlations, both of total height and DS with CI and VS and between CL and FC, made it understand an inverse and independent proportionality for behavior between these indexes.

**Table 3.** Pearson correlation matrix ( $p \leq 0.05$ ) between dendrometric variables and morphometric indices of *Copaifera langsdorffii* (Desf.) Kuntze trees in northern region of Minas Gerais state, Brazil.

**Tabela 3.** Matriz de correlação de Pearson ( $p \leq 0,05$ ) entre as variáveis dendrométricas e índices morfométricos de árvores de *Copaifera langsdorffii* (Desf.) Kuntze na região norte de Minas Gerais, Brasil.

	DBH	Ht	CD	CL	CP	CA	DS	SI	CI	FC	VS
<b>DBH</b>	1										
<b>Ht</b>	0.296689	1									
<b>CD</b>	0.825541	0.177557	1								
<b>CL</b>	0.475206	0.695249	0.459347	1							
<b>PC</b>	0.198787	-0.27222	0.28003	0.485265	1						
<b>CA</b>	0.834223	0.187759	0.987348	0.447854	0.258714	1					
<b>DS</b>	-0.5104	0.652272	-0.47418	0.217535	-0.44073	-0.46575	1				
<b>SI</b>	-0.41593	-0.24377	0.150281	-0.05852	0.169939	0.096143	0.124602	1			
<b>CI</b>	0.291943	-0.72305	0.495183	-0.34221	0.325264	0.478165	-0.86592	0.255276	1		
<b>FC</b>	0.152175	-0.47171	0.29501	-0.65811	-0.40295	0.285952	-0.50594	0.139489	0.716556	1	
<b>VS</b>	0.300909	-0.71213	0.503026	-0.33326	0.32679	0.484628	-0.86557	0.252961	0.998435	0.71546	1

Where: DBH = diameter at breast height; Ht = total tree height; CD = crown diameter; CL = crown length; CP = crown proportion; CA = crown area; DS = degree of slenderness; SI = salience index; CI = coverage index; FC = formal of crown; VS = vital space.

## Discussion

The morphometric variables of *Cordia trichotoma* (Vell.) Arrab. Ex Steud trees cultivated in Santa Maria municipality, Rio Grande do Sul state, Brazil, found by Roman, Bressan and Durlo (2009) was a low values for formal of crown (0.57), crown area (14.70 m<sup>2</sup>) and a higher crown proportion (54.50%) with in relation this study with *C. langsdorffii*. Selle and Vuaden (2010) observed higher CP values

only in individuals with a diameter at breast height (DBH) at 35 and 40 cm. Similarly, the FC, even though it is a relationship between the crown diameter (CD) and crown length (CL), was proportional to DBH growth and the height crown development of *Cedrela fissilis* Vell trees with 10 cm to 40 cm of DBH, occurring in central region of Rio Grande do Sul state, Brazil.

For the species *Carapa guianensis* Aubl., *Bertholletia excelsa* Humb. & Bonpl., *Tabebuia*

*avellanadae* Lorentz ex Griseb and *Hymenaea courbaril* L, with 13.5 cm of mean DBH and 11.5 m of mean total height, the crown morphology showed higher CP than *C. langsdorffii*, with emphasis on species *B. excelsa* with higher CP (72.7%), although low FC (0.86) compared to *C. langsdorffii* (TONINI and ARCO-VERDE, 2005). This conformation demonstrates a greater investment in total height (Ht) than crown diameter (CD).

The quality of *C. langsdorffii*, in having a leafy crown, can be explained by high size and diameter class of selected individuals, with crowns reaching the upper canopy and being mostly shading free. This is also related to fact that CI has same proportion of height and crown diameter, as well as the dominant height being above of average trees. In this aspect, the growth of trees is expressed by the stability and vitality, among other factors (WEBER et al., 2018).

When *Ocotea wild* Vattimo-Gil was a cultivated in Serra Geral region of southern Brazil, Costa et al. (2012a) observed a high degree of slenderness (SD) in individuals of smaller DBH and with intense competition. The degree of slenderness decrease in individual who reach larger dimension surviving the competition for canopy occupation. In Roman, Bressan and Durlo (2009) study with *C. trichotoma* trees, DS (84.30) and SI (24.70) values were found to be higher than *C. langsdorffii* and lower in CI (0.31). In Tonini and Arco-Verde (2005) study, the species showed higher values of DS and CI than that of *C. langsdorffii*, with the exception of *B. excelsa*, with higher SI (50.00) and lower CI (0.61).

For the specie *Ocotea porosa* Nees & Mart. cultivated in Rio Negro municipality, Paraná state, Brazil, Santos et al. (2015b) found a SI value of 21; practically equal to SI (0.22) observed by Selle and Vuaden (2010) among individuals of *C. fissilis*. For DS and CI, Selle and Vuaden (2010) found significant values in smaller individuals with shorter heights, increasing DS and CI according DBH and heights increase. Orellana and Koehler (2008)

studying the morphometric relationships of *Ocotea odorifera* (Vell.) Rohwer stand in Fazenda Rio Grande municipality, Paraná state, Brazil, observed positive correlations between DBH and Ht, CD, CL, SI, CA and DS. There were also positive correlations between total height (Ht) with CD and CL.

In a study with *Cedrela odorata* L. trees in the Amazon region, Brazil, few competitions was estimated for some small individuals, with DBH less than 20 cm (CUNHA and FINGER, 2012). And, considering that light is the most important growth factor, the authors mentioned above pointed out those small trees, with same diameter received different luminous intensity, which probably resulted in different levels of growth reduction. Otherwise, in large trees with DBH greater than 70 cm, the result followed expectations.

Boivin et al. (2010) reported an increase in predictive power of growth model when including, in competition calculation, the shading of objective-tree caused by neighboring tree competing. This improvement may be associated with the fact that result of interaction (competition) determines the canopy size of each individual tree, which reflects in light interception, photosynthetic capacity, growth and survival (THORPE et al., 2010).

The diameter at breast height (DBH) and crown area (CA) are positive and strongly correlated, indicating the particular need of individuals to invest in diametric growth to support the canopy weight in large individuals, when submitted of strong winds which impacting the forest ecosystem. The correlation between coverage index (CI) with formal of crown (FC) and vital space (VS), justified the necessary condition of greater space for better photosynthetic gain and satisfactory species development. However, correlations found between dendrometric variables and morphometric indices may possibly suffer from the effect of extrinsic influences on trees, such as mainly competition for light or nutrients between individuals of the same or different species in a community.



## Conclusions

*Copaifera langsdorffii* specie was able to obtain a greater amount of light per crown area, in addition to strong growth stability. The morphometric indices made it possible to understand the small magnitude of variations for *C. langsdorffii* stand, which morphometrically can be characterized as facilitating management. The indexes can assist in obtaining the most appropriate management methods for species in commercial plantations, when this is intended to silviculture increase of this specie in region.

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