Morphometric data of *Colophospermum mopane* leaves in the Limpopo Province of South Africa

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**Abstract**

*Colophospermum mopane* (J. Kirk ex Benth.) J. Kirk ex J. Léonard occurs over a very large region of southern Africa, occupying varying habitats that could account for ecotypic speciation. This investigation statistically analysed the variations in the architecture of the leaflets of *C. mopane* from the Limpopo Province of South Africa, with the purpose of ascertaining whether natural variability can act as a source of information for investigating ecotypic variation. Leaf morphometric traits, such as leaflet area, length, width, perimeter, pulvinus angle and the acuteness of the apex, were digitally measured and statistically compared for intra- and inter-population variability. Data indicate that the intra-population variation is 35.33% (statistical similarity: 64.67%), while the inter-population (*n* = 5) variation is 46.67% (statistical similarity: 53.33%).

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Specifications table

| Subject          | Biology |
|------------------|---------|
| Specific subject area | Biodiversity, Botany |
| Type of data     | Table, Graph, Figure |
| How data were acquired | Mopane leaves were collected from randomly selected trees and morphometrically analysed for 10 characters via SigmaScan Pro version 5 (Build number 3981). |
| Data format      | Raw and Analyzed |
| Parameters for data collection | To investigate the intra-population variation in leaves of C. mopane six sites were identified. Four trees were identified per site, which were distanced at least 20 m from one another – to eliminate the mother-daughter phenomena, and 10 unpredicted leaves were randomly taken from each tree. To investigate the inter-population variation in C. mopane, three additional sites were used that were 20 kms apart from one another. Again 4 trees were identified per site, which were distanced at least 20 m from one another, and 10 sun-exposed, unbroken and unpredicted leaves taken from each tree. |
| Description of data collection | The following digitised measurements were taken using computer software: area (mm²), shape factor, length (mm), width (mm), feret diameter (mm), perimeter (mm), vertical - (mm), horizontal - (mm) and diagonal perimeter (mm), length/width ratio, angle of pulvinus attachment of leaflets (degrees), and acuteness of leaflet apex angle (degrees). |
| Data source location | Institution: University of Limpopo |
|                  | City/Town/Region: Limpopo Province |
|                  | Country: South Africa |
|                  | Latitude and longitude (and GPS coordinates) for collected samples/data: site 1: S 22° 17’ 33.1”, E 29° 55’ 34.6” |
|                  | site 2: S 22° 16’ 20.0”, E 29° 55’ 57.8” |
|                  | site 3: S 22° 16’ 19.9”, E 29° 55’ 16.1” |
|                  | site 4: S 22° 15’ 17.0”, E 29° 55’ 06.9” |
|                  | site 5: S 22° 15’ 04.3”, E 29° 54’ 08.0” |
|                  | site 6: S 22° 16’ 48.3”, E 29° 54’ 22.7”. |
|                  | Musina Nature Reserve: S 22° 22’ 09.8”, E 30° 01’ 55.2” |
|                  | Doreen: S 22° 29’ 22.3”, E 29° 59’ 10.4” |
|                  | Mopane: S 22° 38’ 27.5”, E 29° 55’ 09.2” |
| Data accessibility | All data associated with this article are hosted within the article, and as a supplementary file. |

Value of the Data

This data presents information on the leaf variation of Colophospermum mopane from different locations of the Limpopo Province, South Africa, which falls within the Zambian mopane woodland ecoregion, that can be used to assist in identifying ecotypes of this species.

The dataset will be of value to taxonomists to assist them in the narrower (sensu stricto) classification of variation observed within this widely distributed species in Southern Africa. The use of morphometrics in establishing parameters in leaves for classification purposes is novel, and might be of benefit to other large distribution taxa.

1. Data

1.1. Messina experimental farm

The digitised measurements of the 15 investigated characters for C. mopane are summarised in Table 1 for all 240 trees. From the data it is clear that large variations are apparent with regard to surface area, with little variation in the shape factor and length:width ratio of leaflets.

According to the ANOVA data, significant differences exist between all 10 investigated characters (Table 2). The shape factor and horizontal perimeter differs the most among the investigated
Table 1
Measurements of leaflets of C. mopane.

| Character                 | Mean±Std. Dev.          |
|---------------------------|-------------------------|
| Area                      | 3064.6 ± 1599.34 mm²    |
| Shape factor              | 0.59 ± 0.07             |
| Width                     | 39.29 ± 9.55 mm         |
| Length                    | 99.62 ± 22.89 mm        |
| Feret diameter            | 56.88 ± 13.92 mm        |
| Perimeter                 | 22.85 ± 8.22 mm         |
| Diagonal perimeter        | 102.24±13.43 mm         |
| Acuteness:width ratio     | 1:2.28±0.20             |
| Pulvinus shallowness      | 53.75±11.43             |
| Stomata number            | 1:16.55±18.60           |
| Stoma aperture length     | 14.90±4.48 μm           |
| Stomatal distances        | 29.40±4.56 μm           |
|                           | 56.00±14.69 μm          |

Table 2
Statistically significant differences between the leaflets of six sites, consisting of five C. mopane trees each, at the Messina Experimental Farm.

|                  | Site 1vs | Site 2vs | Site 3vs | Site 4vs | Site 5vs | *Total/% out of 15: |
|------------------|----------|----------|----------|----------|----------|--------------------|
|                  | 2 3 4 5 6| 3 4 5 6  | 4 5 6    | 5 6      | 6        |                    |
| Area             | S S S S S| D D D S S| S S S S S| S S S S S| 4 (27)   |                    |
| Shape factor     | D D D D D| S S S S S| D D D D D| S S S S S| 11 (73)  |                    |
| Length           | D D D D D| S S S S S| D D D D D| S S S S S| 4 (27)   |                    |
| Width            | S S S S S| D D D S S| S S S S S| D D D S S| 3 (20)   |                    |
| Feret diameter   | S D S S S| D D D S S| D D D D D| S S S S S| 6 (40)   |                    |
| Perimeter        | S S S S S| D D D S S| S S S S S| S S S S D| 3 (20)   |                    |
| Diagonal perimeter| S S D D S| D D S S S| S S S D S| S S S S D| 10 (67)  |                    |
| Horizontal perimeter| D D D D D| S S S S S| D D D D D| D D D S D| 7 (7)    |                    |
| Vertical perimeter| S S S S S| D D D S S| S S S S S| S S S S D| 1 (7)    |                    |
| Length:Width ratio| S S D S D| D D S S D| D D D S D| S S S S D| 13 (8)   |                    |
| *Total out of 10:| 3 2 3 2 4| 7 6 6 1 2| 1 2 1 6 1| 5 4      | 63 (Y/150(Z) |

D=significant difference (the mean difference is significant at the 0.05 level), S = not significant.
* Total number of comparative differences of ten characteristics of six sites.
** Total number and percentage occurrences of characteristics found to be comparatively different between six sites. (Y) = actual number of differences between six sites. (Z) = possible maximum number of differences between six sites. (Y) and (Z) to be used to calculate the percentage differences/similarities.

characters, scoring 11 (73% difference) and 10 (67% difference) out of a possible 15 occurrences (last vertical column, Table 2). The vertical perimeter varies the least among the significant different characters, scoring only a 7% difference (last vertical column, Table 2). In total the intrapopulation difference is 35.33% (63 out of a potential maximum of 150 occurrences).

1.2. Four populations in the Limpopo Province

According to the ANOVA data, significant differences exist between all 10 investigated characters (Table 3). The shape factor and vertical perimeter differs the most among the investigated characters, scoring four (67% difference) out of a possible 6 occurrences (last vertical column, Table 3). The area, width, feret diameter and horizontal perimeter vary the least among the significant different characters, scoring only a 33% difference (last vertical column, Table 3).

The 10 analysed characters illustrate 28 differences, out of a possible 60, between the four populations, translating into a 46.67% variation concerning the leaves of C. mopane (Table 3).
Table 3
Statistically significant differences between the leaflets of four populations of C. mopane in the Limpopo Province.

|                  | MNRs              | Doreenvs | Mopanevs | Mopanevs | Mopanevs | ▲▲ Total % out of 6: |
|------------------|-------------------|----------|-----------|-----------|-----------|----------------------|
|                  | Doreen | Mopane | MEF      | Doreen  | Mopane  | MEF      | MEF      |        |
| Area             | D      | S      | D        | S        | S        | S        | 2        | (33)   |
| Shape factor     | S      | D      | D        | D        | D        | S        | 4        | (67)   |
| Length           | S      | D      | D        | S        | S        | D        | 3        | (50)   |
| Width            | D      | S      | D        | S        | S        | S        | 2        | (33)   |
| Feret diameter   | D      | S      | D        | S        | S        | S        | 2        | (33)   |
| Perimeter        | S      | D      | D        | S        | D        | S        | 3        | (50)   |
| Diagonal perimeter | D     | D      | D        | S        | S        | S        | 3        | (50)   |
| Horizontal perimeter | S   | S      | D        | D        | S        | D        | 2        | (33)   |
| Vertical perimeter | S   | D      | D        | D        | S        | D        | 4        | (67)   |
| L:W ratio        | S      | D      | S        | D        | D        | S        | 3        | (50)   |
| ▲▲ Total out of 10: | 4     | 6      | 9        | 3        | 4        | 2        | 28°       | 60°    |

D=significant difference (the mean difference is significant at the 0.05 level), S=not significant.

Total number of comparative differences of ten characteristics of four populations.

Total number and percentage occurrences of characteristics found to be comparatively different between four populations.

\( (Y) = \text{actual number of differences between four populations.} \)

\( (Z) = \text{possible maximum number of differences between five trees.} \)

\( (Y) \) and \( (Z) \) to be used to calculate the percentage differences/similarities.

The largest difference was found between MEF and MNR, scoring nine (90%) out of a possible 10 differences. The two populations that differs the least are those from the MEF and Mopane, scoring only a 20% difference.

2. Experimental design, materials, and methods

2.1. Study area

The study area is situated in the summer rainfall region of South Africa, with a typical long term (31 years: 1961–1990) annual rainfall of 339 mm [1]. Mean daily maximum and minimum temperatures range from 32.8 to 20.4 °C in summer and 24.8 to 6.7 °C in winter. Air temperatures of below 0 °C are rare, but frost rarely occurs due to low humidity of the area [2]. The area is situated in the Colophospermum-Combretum-Commiphora plant community and illustrates considerable variation in the vegetation diversity and structure [3].

2.2. Collection of leaf material

To investigate the intra-population variation in leaves of C. mopane, the Messina Experimental Farm (MEF), Limpopo Province of South Africa (MEF: 22° 12’ and 22° 17’ S and 29° 50’ and 29° 57’ E) was selected, consisting of six populations separated by at least 5 kms (site 1: S 22° 17’ 33.1”, E 29° 55’ 34.6”, site 2: S 22° 16’ 20.0”, E 29° 55’ 57.8”, site 3: S 22° 16’ 19.9”, E 29° 55’ 16.1”, site 4: S 22° 15’ 17.0”, E 29° 55’ 06.9”, site 5: S 22° 15’ 04.3”, E 29° 54’ 08.0”, site 6: S 22° 16’ 48.3”, E 29° 54’ 22.7”). At each of these six sites 4 trees were identified, which were distanced at least 20 m from one another – to eliminate the mother-daughter phenomena, and 10 unpredated leaves were randomly taken from each tree, resulting in a total of 240 leaves (Table 1). 15 characters were used for descriptive analysis, while 10 characters (Table 2) were used for Analysis of Variance (ANOVA), to determine the degree of similarities/differences via a matrix.

To investigate the inter-population variation in C. mopane, three additional sites (Musina Nature Reserve [MNR]: S 22° 22° 09.8”, E 30° 01’ 55.2”, Doreen: S 22° 29’ 22.3”, E 29° 59’ 10.4”, town of Mopane: S 22° 38’ 27.5”, E 29° 55’ 09.2”) were used that were 20 kms apart from one
another. Again 4 trees were identified per site, which were distanced at least 20 m from one another, and 10 sun-exposed, unbroken and unpredicted leaves taken from each tree, resulting in a total of 40 leaves per site. Thus in total 360 (MEF = 240 + MNR = 40 + Doreen = 40 + town of Mopane = 40) leaves were used to investigate the inter-population variation. Ten characters (Table 3) were used for this analysis.

The two large outer leaflets of a leaf were separated from one another, and the third atrophied middle leaflet and petiole removed. As no statistical significant difference exists between the left and right leaflet [4], only one leaflet was digitised with a scanner to enable software utilization.

2.3. Characters investigated

The following digitised measurements were taken using computer software as described in Section 2.4: area (mm²), shape factor, length (mm), width (mm), feret diameter (mm), perimeter (mm), vertical - (mm), horizontal - (mm) and diagonal perimeter (mm), length/width ratio, angle of pulvinus attachment of leaflets (degrees), and acuteness of leaflet apex angle (degrees).

2.3.1. Description of measurement attributes

Area: This measurement sums the number of pixels defining an object. If a calibration has been performed, the area is given in the units’ specified (mm²) in the calibration.

Feret diameter: This measurement calculates the diameter of a fictitious circular object that has the same area as the object being measured. It is often compared with the major and/or minor axis lengths of the measured object to determine how nearly circular the measured object is. The Feret diameter is calculated as:

\[ \text{Feret diameter} = \sqrt{\frac{4 \times \text{Area}}{\pi}} \]

Major axis length: The major axis is defined by searching all the border pixels of an object and choosing the two pixels that are the farthest apart, defined as (MajX1, MajY1) and (MajX2, MajY2). Note that the major and minor axes are not always entirely within the object (e.g. in a curved object). The Major Axis Length measurement finds the distance between the two points defining the major axis. It is calculated as:

\[ \text{Major Axis Length} = \sqrt{(\text{MajX2} - \text{MajX1})^2 + (\text{MajY2} - \text{MajY1})^2} \]

Minor axis length (width): Once a major axis is defined, the minor axis can be calculated. Minor axes are drawn between two pixels defining the longest line perpendicular to the major axis, defined as (MinX1, MinY1) and (MinX2, MinY2). The Minor Axis Length measurement measures the distance between the two endpoints of the minor axis. It is calculated as:

\[ \text{Minor Axis Length} = \sqrt{(\text{MinX2} - \text{MinX1})^2 + (\text{MinY2} - \text{MinY1})^2} \]

Perimeter: Due to the fact that the image's pixels are square, any object represented in a digital image is only an approximation of the actual object's dimensions. The Perimeter measurement attempts to account for this discrepancy by approximating the vertical, horizontal, and diagonal components of the object’s true perimeter. Perimeter is thus the sum of the horizontal, vertical, and diagonal perimeters.

Vertical perimeter: Vertical perimeter reports the sum of the distance of all vertical edge pixels. This measurement is reported in calibrated units (mm).

Horizontal perimeter: Horizontal perimeter reports the sum of the distance of all horizontal edge pixels. This measurement is reported in calibrated units (mm).

Diagonal perimeter: Diagonal perimeter reports the sum of the distance of all diagonal edge pixels. This measurement is reported in calibrated units (mm). A single unit of diagonal distance is calculated as:

\[ \text{Diagonal Perimeter} = \sqrt{dx^2 + dy^2} \]
dx is the width of one pixel on the X axis, and dy is the height of one pixel on the Y axis.

Shape factor: This measurement calculates how circular an object is. Shape factor is calculated as $\text{Shape Factor} = \frac{4\pi \times \text{Area}}{\text{Perimeter}^2}$.

A perfect circle has a shape factor of 1.00, and a line has a shape factor approaching zero. Theoretically, the shape factor should never be greater than 1.00, but due to the constraints of digital measurements this rule may be broken for very small objects. For reference, the shape factor for an equilateral triangle is about 0.61, for a square it is about 0.79 and for a pentagon it is about 0.86.

Pulvinus shallowness: This measurement calculates the shallowness/depth of the pulvinus taken from the upper most margin of the leaflet (Fig. 1). This was calculated by measuring the leaflet length (A) and the distance from the uppermost margin of the leaflet to the pulvinus (B) (Fig. 1). The leaflet length (A) was then divided by pulvinus distance from upper margin (B) to obtain a value (C). This calculation eliminates the influence of leaflet size.

Acuteness of leaflet apex angle: This measurement calculates the acuteness of leaflet apex angle in degrees (Fig. 2). This measurement was derived at with the use of Sigma Scan software, where one selects three points and the angle defined by the second point being the apex, is reported in degrees.

2.4. Software employed and measurements

The attributes of the leaflet were determined using SigmaScan Pro version 5 (Build number 3981). Differences and variations of the characters mentioned in Section 2.3 were statistically analysed using SPSS (Statistical Products & Service Solutions) version 21. Post hoc tests (Bonferroni) were run after ANOVA has been conducted. In this investigation, a 5% level of significance was used for all statistical tests.

2.5. Matrix comparisons

A matrix (i.e. Tables 2 and 3) was developed to indicate statistically significant intra- and inter-differences (D) as well as similarities (S) between C. mopane populations. The matrix also indicates the total number of characteristics against the potential maximum number of characteristics compared between the selected numbers of trees (columns). Rows of the matrix rep-
resent the total number of occurrences of characteristics as found to be comparatively different between the numbers of investigated trees.

**Declaration of Competing Interest**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**Supplementary materials**

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.dib.2020.106002.

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