



Research article

Vegetative morphological study of selected species of genera *Kalanchoe* Adans. and *Bryophyllum* Salisb. (subfamily Kalanchoideae) from South Western Nigeria

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Abstract: A qualitative and quantitative morphological study of the three species of *Bryophyllum* and two *Kalanchoe* species in the subfamily Kalanchoideae was carried out to find out characters that may be useful in the identification, classification and also to solve some taxonomic problems within the subfamily Kalanchoideae. Vegetative parts from the various species were collected and subjected to morphological studies. Both qualitative and quantitative characters were recorded. Quantitative data were subjected to the least significance difference test (LSD), single linkage cluster analysis (SLCA) and principal components analysis (PCA). Unifying and diagnostic characters that are of taxonomic importance were recorded. The unifying characters propose that two genera in the Subfamily Kalanchoideae should be merged into a genus *Kalanchoe* with sections or subgenera under it.

Keywords: Simple leaf - Ornamentals - Leaf base - Leaf apex.

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INTRODUCTION

Crassulaceae is also referred to as the stone crop family. It is a family of dicots with 34–35 genera with about 1400 species. They are common herbs, sometimes subshrubs or shrubs. They globally spread majorly in the Northern hemisphere and Southern Africa (Xu & Deng 2017). The family Crassulaceae has three subfamilies Crassuloideae, Kalanchoideae and Sempervivoideae (Stojanović *et al.* 2015). Walters (2011) mentioned the genera *Bryophyllum* and *Kalanchoe* as one of the genera in the family Crassulaceae in Southern Africa. The genus *Kalanchoe* consist of about 125 species (Passero *et al.* 2013).

Various authors have emphasized the use of morphological characters in taxonomy (Adedeji & Illoh 2005). Crouch *et al.* (2016) distinguished a new species in South Africa called *Kalanchoe winteri* Gideon F. Sm., N.R. Crouch & Mich. Walters from *Kalanchoe luciae* Raym.-Hamet and *Kalanchoe thyrsoflora* Harv. using some important morphological characters. Santiago *et al.* (2019) also distinguished a new species *Pachyphytum viscidum* J. Reyes & L.E. Cruz-López in Mexico from *Pachyphytum hookeri* (Salm-Dyck) A. Berger which was morphologically similar using morphological characters. Lu *et al.* (2019) proposed two new *Sedum* species in Taiwan based on morphological evidence *i.e.*, *Sedum kwanwuense* H.W. Lin, J.C. Wang & C.T. Lu and *Sedum taiwanalpinum* H.W. Lin, J.C. Wang & C.T. Lu. Thiede & Eggl (2007) mentioned the genera *Pachyphytum* and *Sedum* as one of the genera in the Subfamily Sempervivoideae of the family Crassulaceae.

The present study is aimed at describing the qualitative and quantitative morphological characters of the five species of the genera *Kalanchoe* and *Bryophyllum* and also to solve some taxonomic problems in the subfamily Kalanchoideae. The taxonomy of the subfamily Kalanchoideae have been debated by various authors. Some say that the genera *Kalanchoe* and *Bryophyllum* should be distinguished as separate within the subfamily Kalanchoideae (Zepkova 1976, 1977, 1980, Takhtajan 1966, 1987, Vinogradov *et al.* 1976, 1978) while the other authors say that the genera *Kalanchoe* and *Bryophyllum* should be combined into one genus *Kalanchoe* with sections or subgenera (Jacobsen 1981, Descoings 2003, Descoings 2006, Chernetsky 2011). The study

proposes that the two genera should be merged.

MATERIALS AND METHOD

The species used for this study are *Kalanchoe crenata* (Andr.) Haw, *Kalanchoe lanceolata* (Forsk.) Pers, *Bryophyllum pinnatum* (Lam.) Oken, *Bryophyllum delagoense* (Eckl. & Zeyh.) Schinz and *Bryophyllum houghtonii* (D.B Ward) P.I.Forst. These species were collected from various locations in Obafemi Awolowo University, Ile ife, Nigeria with GPS location N 07° 31.252', E 04° 31.307'. Qualitative morphological characters were carried out by direct observation while the quantitative morphological characters were either measured or counted. Data generated were subjected to Fisher's Least Significant Difference (LSD) Test for mean separation as well as Single Linkage Cluster Analysis (SLCA) (Fig. 1) and Principal Components Analysis (PCA) (Fig. 2)

RESULTS

Findings of qualitative morphological study were utilised to identify the morphological similarity between the selected species through Single Linkage Cluster Analysis (SLCA) applying Fisher's Least Significant Difference (LSD), which indicates that both the *Kalanchoe* species are more similar/close to each other in comparison with the three species of *Bryophyllum* selected in the present study (Fig. 1). Positioning of both the *Kalanchoe* species in the same group, while the *Bryophyllum* species in different group in the Principal Components Analysis (PCA) plot also supports the outcomes of cluster analysis (Fig. 2).

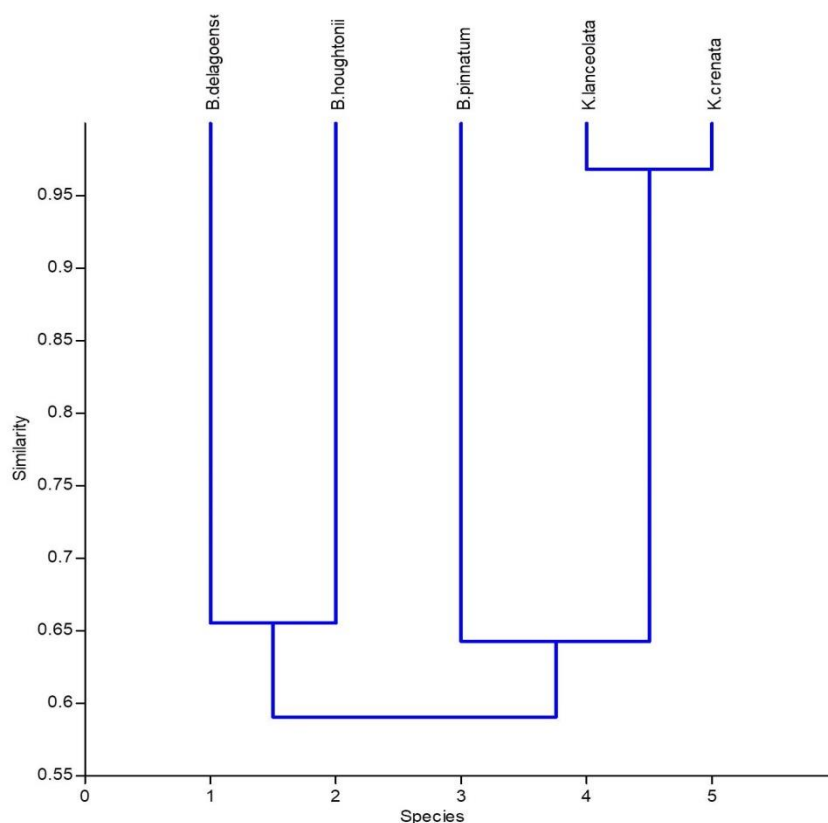


Figure 1. Dendrogram of the vegetative attributes of the species studied.

Kalanchoe crenata (Andr.) Haw

[Fig. 3A–B]

Leaf and Petiole: Simple leaf with young branches arising from the same node/axil; Opposite in arrangement.

Leaf shape was ovate with crenate margin, leaf base was rounded, apex acute. Length and breadth of the leaf ranged from 8.00–14.00 cm and 5.50–10.00 cm respectively. Leaf colour was green but when kept under shade conditions, leaves took red or purple colouration. Petiole was green in colour, conspicuous and clasping the stem; 1.50–3.50 cm long.

Stem: Green, glabrous, fleshy (robust), erect and caulescent.

Habitat and Habit: Ornamentals cultivated in gardens. An evergreen fleshy and erect perennial herb.

Kalanchoe lanceolata (Forsk.) Pers

[Fig. 3C–D]

Leaf and Petiole: Leaves simple and opposite in arrangement. Leaf shape was ovate with crenate margin. Leaf base acute, apex acute. Length of leaf ranged from 13.0–25.4 cm and breadth of leaf ranged from 5.10–11.60

cm. Leaves were thick and fleshy, green with violet or brownish-green markings on both the adaxial and abaxial surfaces. Whitish deposits or powder was also present on both surfaces. New plantlets were observed growing on the margin of the leaves. Petiole was light green, short, clasping the stem, 1.50–5.50 cm in length.

Stem: Light brown, erect, caulescent. They were short and glabrous.

Habitat and Habit: Ornamental plant cultivated or commonly found in gardens. A perennial or biennial glabrous herb.

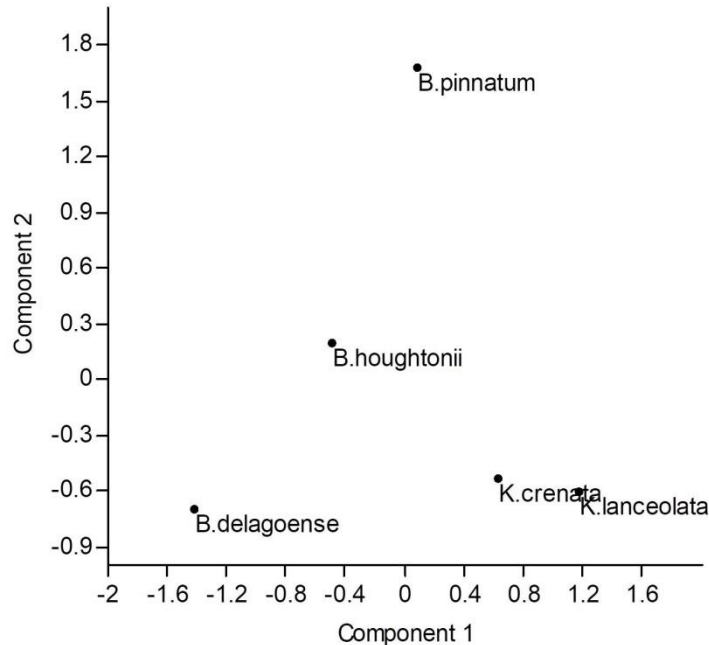


Figure 2. Principal Components Analysis that showed the relationship of the *Bryophyllum* and *Kalanchoe* species based on vegetative morphological characters for components 1 and 2.

***Bryophyllum pinnatum* (Lam.) Oken**

[Fig. 4A–D]

Leaf and Petiole: Lower leaves simple, upper leaves trifoliate, quadra or penta-foliate compound, opposite (decussate) in arrangement. Leaf shape was ovate with crenate margins. Leaf base was mostly rounded, occasionally oblique, apex was obtuse. Length of leaflets of compound leaves ranged from 5.20–12.60 cm while their breadth ranged from 3.10–7.40 cm; length of simple leaves ranged from 10.20–15.40 cm, breadth of simple leaves ranged from 6.30–10.40 cm. New plantlets were attached to the margins of the leaf. Leaf colour was green. Petiole had purple colouration on the upper side and green on the lower side. Petiole was long and swollen at the base, 5.5–12.5 cm long.

Stem: Grey in colour with purplish colouration at the upper part, erect and caulescent.

Habitat and Habit: Ornamental plants commonly cultivated in gardens. An erect, perennial succulent herb.

***Bryophyllum delagoense* (Eckl. & Zeyh.) Schinz**

[Fig. 4E–F]

Leaf and Petiole: Simple, alternate in arrangement. Leaf shape was narrowly oblong/acicular with entire margin.

Leaf base was acute, apex acute. Leaf consisted of new plantlets arising from the apex. Leaves were gray-green with green or reddish brown spots. Leaf length ranged from 5.5–7.4 cm and breadth from 0.3–0.5 cm. They were apetiolate.

Stem: Grey, glabrous, erect and caulescent. Shape was terete, 35.5–36.0 cm in length.

Habitat and Habit: They were weed that grew on rocky crevices or slopes and also in sandy soil. An erect, succulent biennial or semi-perennial herb

***Bryophyllum houghtonii* (D.B Ward) P.I. Forst**

[Fig. 4G–H]

Leaf and Petiole: Simple, opposite in arrangement, leaf shape was deltoid with serrate margins. Leaf base was acute, apex is acuminate. Leaf consisted of small teeth along their margins which produce plantlets. Leaves were green in colour. Leaf length ranged from 8.6–11.6 cm while leaf breadth ranged from 1.1–2.1 cm. Petiole is Grey, mottled and borne on rounded stalks (Sub-cylindrical petioles). Petiole sometimes produced root. Petiole length ranged from 2.8–4.9 cm.

Stem: Grey, glabrous, erect and caulescent, flesh.

Habitat and Habit: Weed that grew in rocky crevices, fence lines. An erect fleshy perennial herb.



Figure 3. Morphology of the species of *Kalanchoe* studied: **A**, Leaf arrangement and habit of *Kalanchoe crenata* (Andr.) Haw; **B**, Simple leaves with young branches arising from the same node/axil on a robust stem; **C**, Leaf arrangement and habit of *Kalanchoe lanceolata* (Forsk.) Pers; **D**, Simple leaves showing new plantlets arising from the apex.

DISCUSSION

Hutchinson & Dalziel (1952) used morphological features to characterize species in the family Crassulaceae. García-Ruiz & Costea (2014) described a new species, *Echeveria marianae* I. García & Costea (Crassulaceae) in Jalisco, Mexico and distinguished the species by the colour and shapes of the leaves and the shape of the petal. Perez-Calix & Torres-Colin (2018) identified a new species *Pachyphytum rogeliocardenasii* E. Pérez-Calix & R. Torres. (Crassulaceae) in Mexico and distinguished the species from *Pachyphytum garciae* Pérez-Calix & Glass using the length and breadth of the leaf and other floral characters. Zhang *et al.* (2019) identified a new species *Sedum lipingense* R.B. Zhang, D.Tan & R.X. Wei in China based on evidences from morphology and molecular study. All of the species studied were erect, succulent herbs, this is in consonant with the description of family Crassulaceae made by Thiede & Egli (2007), in which members of the family have been described as herbs or shrubs with succulent leaves and sometimes succulent stems. Chernetsky (2012) also recorded succulent leaves as a common feature of the genus *Kalanchoe*.

The two species of *Kalanchoe* in this study and *Bryophyllum pinnatum* are usually cultivated as ornamentals while the other two *Bryophyllum* species, *Bryophyllum delagoense* and *Bryophyllum houghtonii*, were observed growing on rocky crevices. These two species are also good ornamental plants with unique features when domesticated. Costa (2008) and Milad (2014) underscored the ornamental value of members of family Crassulaceae and their importance in horticulture.

Simple leaf type is a unifying character across the species studied although *Bryophyllum pinnatum* has both simple and compound leaves. *Bryophyllum pinnatum* is pinnately compound with 3-5 leaflets. This can be used to delimit the species as it separates *Bryophyllum pinnatum* from the other two *Bryophyllum* species and the *Kalanchoe* species. Thiede & Egli (2007) made a similar observation of simple and rarely compound leaves in the family Crassulaceae. Also, Jain *et al.* (2008) and Walters (2011) observed simple and compound leaves in *Bryophyllum pinnatum*.

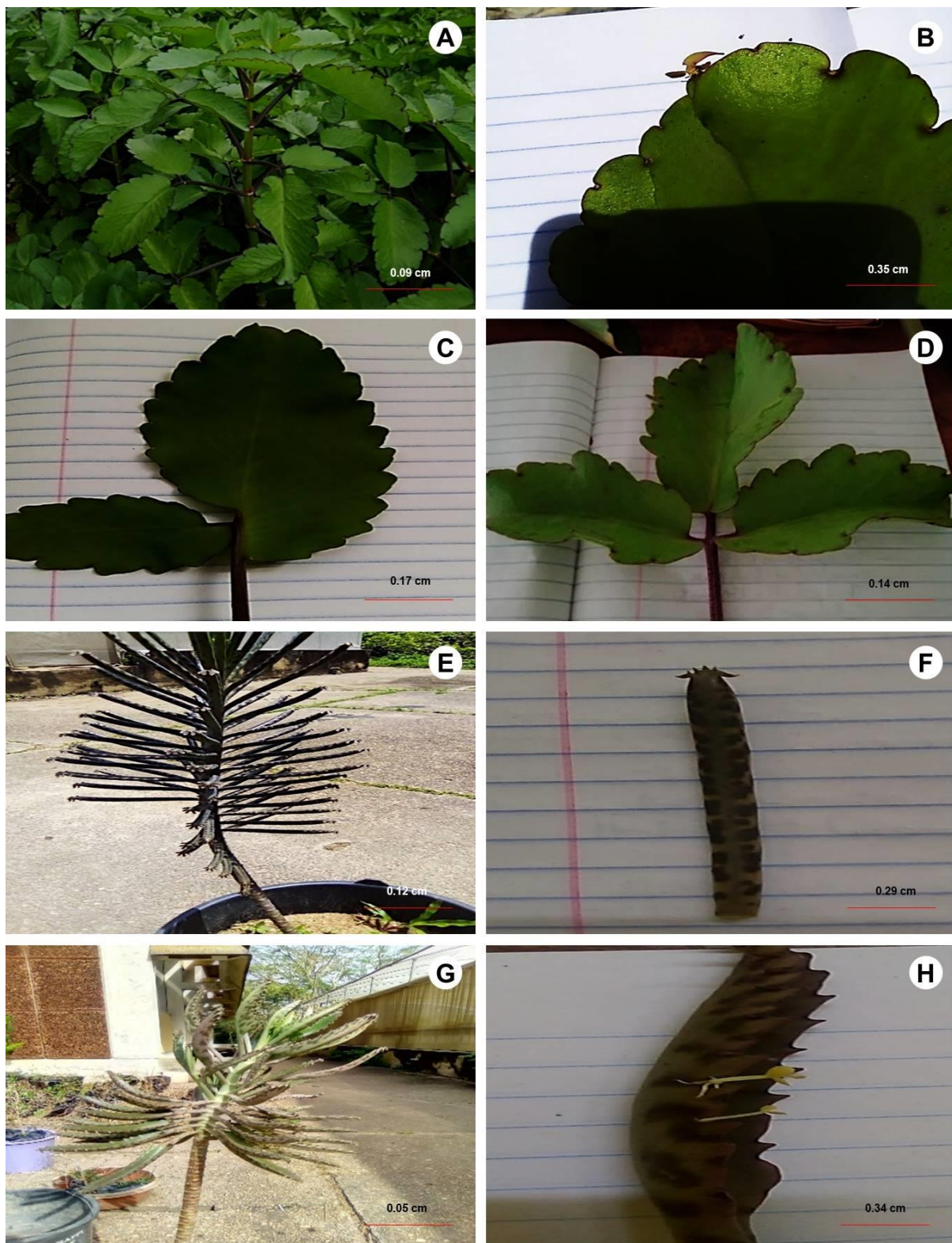


Figure 4. Morphology of *Bryophyllum* species: **A**, Leaf arrangement and habit of *Bryophyllum pinnatum* (Lam.) Oken; **B**, New plantlets arising from the leaves of *Bryophyllum pinnatum*; **C**, Bifoliate leaves of *Bryophyllum pinnatum*; **D**, Trifoliate leaves of *Bryophyllum pinnatum*; **E**, Leaf arrangement and habit of *Bryophyllum delagoense* (Eckl. & Zeyh.) Schinz; **F**, Leaf of *Bryophyllum delagoense*; **G**, Leaf arrangement and Habit of *Bryophyllum houghtonii*; **H**, New plantlet arising from the margins of the leaf of *Bryophyllum houghtonii*.

All the species studied have opposite leaf arrangement except *Bryophyllum delagoense* which has alternate leaf arrangement. This distinguishes it from the other two *Bryophyllum* and *Kalanchoe* species. Walters (2011) made a similar observation of opposite or alternate leaf arrangement in members of the family Crassulaceae. Narrowly oblong leaf shape, lack of petiole and presence of entire margin are also diagnostic characteristics for *Bryophyllum delagoense* as this was the only species with such features among the species in this study. On the

other hand, deltoid leaf shape and serrate margin can be used to delimit *Bryophyllum houghtonii* from the other species of *Bryophyllum* and *Kalanchoe* in which ovate leaf shape and crenate margin were observed. This agrees with the findings of Walters (2011) and Chen *et al.* (2018) who described *Bryophyllum delagoense* as seemingly sessile and with narrowly oblong leaf shape and *Bryophyllum houghtonii* with serrate margin.

Leaf base has been used by various researchers in the delimitation of species. An example of such is the work of Adedeji & Illoh (2005) in which leaf base was used to separate some *Hibiscus* species. *Bryophyllum pinnatum* was observed to sometimes express oblique leaf base as against acute and rounded leaf base in other species studied. This unique feature can be used to delimit *Bryophyllum pinnatum* from other species especially *Kalanchoe crenata* which is morphologically similar to it. Leaf apex can also be employed in the separation of the species in this study. Leaf apices of *Kalanchoe crenata*, *Kalanchoe lanceolata* and *Bryophyllum delagoense* are generally acute. Obtuse apex was observed in *Bryophyllum pinnatum* and acuminate apex in *Bryophyllum houghtonii*. Inyama *et al.* (2015) distinguished *Chrysophyllum cainito* L. from *Chrysophyllum albidum* G. Don. and *Chrysophyllum subnudum* Baker using the leaf apex along with leaf base. Akinsulire *et al.* (2018) also used leaf apex as a classificatory character in some species of genus *Combretum*.

The color of the petiole, as well as its presence or absence, are critical in identifying the species in this study. All the species have petiole except *Bryophyllum delagoense* which is apetiolate. This separates it from other species. Petiole colour of the species of genera *Kalanchoe* and *Bryophyllum* varies. *Kalanchoe crenata* is green in colour, *Kalanchoe lanceolata* is light green in colour, *Bryophyllum pinnatum* is purple on adaxial and green on abaxial while *Bryophyllum houghtonii* is grey. Ezebara *et al.* (2015) stated that petiole colour alongside other characters can be used to differentiate *Xanthosoma sagittifolium* from *Colocasia esculenta* (L.) Schott.

Walters (2011) observed that certain species in the genus *Bryophyllum* produce plantlets on the margins or leaf apex, or on their inflorescence. The leaves of all the species studied produced plantlets along either the margin as was observed in *Bryophyllum pinnatum*, *Bryophyllum houghtonii* and *Kalanchoe lanceolata* or leaf apex as observed in *Bryophyllum delagoense*. The only species that did not produce plantlets is *Kalanchoe crenata*. Another interesting observation is that the petiole of *Bryophyllum houghtonii* produces roots when detached from its leaf. This can be used to delimit the species.

Based on the morphological characters of the vegetative parts alone, the species clustered into two main groups. In the first main cluster, *Bryophyllum delagoense* and *Bryophyllum houghtonii* were grouped together at a similarity index of 65%. In the second main cluster, *Bryophyllum pinnatum* was singled out while *Kalanchoe lanceolata* and *Kalanchoe crenata* were grouped together at 97% similarity index.

From the Principal Components Analysis of the vegetative morphological characters of *Bryophyllum* and *Kalanchoe* species, Based on Component one, the leaf length, leaf breadth, ratio of the leaf length and petiole length as well as the ratio of the leaf breadth and petiole length accounted for the differences observed among the species. Only petiole length is responsible for the variance found among the species, according to Component two.

CONCLUSION

The unifying and diagnostic characteristics are useful for the classification, standardization and identification of the *Bryophyllum* and *Kalanchoe* species studied. The five species studied have unifying features such as succulent herbs, habitats, simple leaf type, suggesting that the five species may be grouped in a genus *Kalanchoe*.

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