

## A COMPARATIVE MACROMORPHOLOGICAL AND ETHNOMEDICINAL ANALYSIS OF FIVE *Kalanchoe* Adans. TAXA FROM BANGLADESH

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### Abstract

The best-known species of the succulents family Crassulaceae in Bangladesh are *Kalanchoe blossfeldiana*, *Kalanchoe daigremontium*, *Kalanchoe heterophylla*, *Kalanchoe laciniata* and *Kalanchoe pinnata* during the period January, 2019 to March, 2020. But this is the first time that two new species named *K. delagoensis* and *K. gastonis-bonnierii* were reported from Bangladesh in this study. Viviparous plantlets formation along the leaf margin is the remarkable feature of these new two species along with formerly reported species *K. pinnata*. The abundance of *K. pinnata* among the five species of this genus was the highest (53%), while *K. gastonis-bonnierii* was the lowest (3%). The experimented five species were used to treat 9 human ailments named cough and cold, cuts and wounds, stomach disorder, kidney and gall bladder stones, jaundice, high blood pressure, skin burning, headache, and eye pain. The citation frequency of all the species except *K. laciniata* ranged from 2% to 100% in contrast to any ailment, while *K. blossfeldiana* and *K. pinnata* were frequently cited. Alike citation frequency the species *K. blossfeldiana* and *K. pinnata* along *K. gastonis-bonnierii* had the highest fidelity level, but *K. delagoensis* had the lowest fidelity level among the five species analyzed. Leaf juice and baked leaf are the common modes of administration. The most cited and high-fidelity species *K. blossfeldiana* and *K. pinnata* were top-ranked in DMR analysis. These two top-ranked species are under threat for several factors and need conservation strategies.

**Keywords:** Baked leaf, Ethnomedicinal, *Kalanchoe*, Leaf juice, Macroscopical

### Introduction

The Crassulaceae commonly known as succulents consist of approximately 1500 species belonging to 33 genera and distributed worldwide except in Australia, and Pacific Island (Allorge-Boiteau, 1996). Southern Africa is the suspected place of origin and the centers of diversification are Mexico, Micronesia, and the Mediterranean region along with the Himalayas (Ham and Hart, 1998).

This family raises the interest of research globally because it is the only family where Crassulacean acid metabolism (CAM) occurs in both aquatic and terrestrial

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representatives (Keeley, 1998; Keeley and Philip, 2003). They are known as wonders of nature due to their medicinal value. The best-known genus of this family is *Kalanchoe* Adans. comprising 144 species (Kubitzki, 2007) for they may have ethnomedicinal and beautification importance. For natural history, karyology, bioactive phytochemicals, eco-physiology, molecular biology and horticultural study of the genus *Kalanchoe* are suitable among crassulents (Osmond, 1978). Although Hooker (1886) documented eight genera including 40 species from the Indian subcontinent of which two species were explored from Bangladesh territory from the family Crassulaceae (Rahman and Rashid, 2012). Ahmed *et al.*, (2008) reported five species named *K. blossfeldiana*, *K. daigremontinum*, *K. heterophylla*, *K. laciniata* and *K. pinnata* from Bangladesh already.

Succulent and fleshy leaves, pendulous or erect flowers, and eight stamens inserted in the middle or at the base of the tubular corolla (Baldwin, 1938) are the typical features of all the members of this genus. But the taxonomical status of *Bryophyllum* and *Kitchingia* was not clear when the genus *Kalanchoe* was first published by Michel Adanson (1727-1806) (Dyer, 1952; Isley, 1994 and Staples, 2013). But in recent years with progress in molecular technology, the taxonomical status of *Kalanchoe* has been reanalyzed, and advancement has been made (Ham and Hart, 1998; Gehrig *et al.*, 2001; Gontcharova and Gontcharov, 2009; Laskar *et al.*, 2022; Smith and Figueiredo, 2018). However, *Kalanchoe* has diverged into three groups, i.e., *Kalanchoe*, *Bryophyllum*, and *Kitchingia* based on a few evolutionary studies (Gehrig *et al.*, 2001). The three-section (sect. *Kalanchoe*, sect. *Bryophyllum*, and sect. *Kitchingia*) view of *Kalanchoe* (Boiteau and Allorge-Boiteau, 1995) is instead famous and well-prevalent, participants of the species from those sections exhibit variations in flower morphology and geographical distribution. While the species of the sect. *Kalanchoe* generally tends to have erect flowers and connate stamens at the center of the tubular corolla, contributors of the sect. *Bryophyllum* usually bears bulbils along their leaf margins, pendent flowers, and inflated tube of fused sepals with basal position of stamens at the corolla tube. On the other hand, species of the sect. *Kitchingia* shares the constant flower morphology with the sect. *Bryophyllum* and therefore the same stamen position as the sect. *Kalanchoe*, with distinct spreading carpels of floral structure. A study of the comparative morphology may be enough in setting those species into proper taxonomical ranks because of the presence of similarities and variations both within and across sections.

The Indian subcontinent has nine species (Singh *et al.*, 2011) of which six are introduced and naturalized, while three are endemic and poorly documented. As no recent complete monograph is available for the genus *Kalanchoe*, reliable species determination in the genus is confused and greatly in need of revision (Descoings, 2003). Moreover, uncertainty remains, and more work needs to be done to fully elucidate the taxonomical properties and the phylogenetic history of *Kalanchoe*. No comparative morphological and ethnobotanical study among these five *Kalanchoe* found in Bangladesh has been conducted. So the present study intends to explore the comparative habitat, macroscopic

morphological profiling, and ethnobotanical information about different ailments. So that the disputed taxonomic status of species and disputed interspecific relationships can be resolved.

## Materials and Methods

### Plant specimen collection, preservation and conservation

Plant specimens of five *Kalanchoe* Adans. species viz., *K. blossfeldiana*, *K. delagoensis*, *K. gastonis-bonnieri*, *K. laciniata*, and *K. pinnata* were collected from different districts of Bangladesh (Table 1 and Fig. 1A-E) and critically studied along with identification with the help of a comprehensive literature review on the genus from January, 2019. A number of different samples were selected for this investigation. *Kalanchoe* species were collected from home gardens, nurseries, and abandoned areas of Barishal and Khulna divisions. Identifications were confirmed by consulting standard relevant literature (Hooker, 1886 and Eggle, 2003) and experts. Specimens belonging to these five species are housed at the net house of the University of Barishal. The updated nomenclature of the species is confirmed by consulting the Encyclopedia of Flora and Fauna of Bangladesh (Ahmed *et al.*, 2008), and the nomenclatural databases of The Plant List (2013), TROPICOS (2017) and Flora of Bangladesh (2020). A voucher specimen has been preserved at the Department of Botany and germplasm have been conserved at the net house of the University of Barishal respectively. Several additional localities for all of the five species examined have been identified in different regions of Bangladesh, where collections were made and photographs were taken with the digital camera.

### Ethnomedicinal data collection

The ethnomedicinal information was gathered through semi-structured interviews, key informant discussions, and informal conversations with all social classes of people from the Barishal and Bagerhat of Khulna division from both sexes including traditional herbal medicinal practitioners, farmers, small shopkeepers, street hawkers, students from Department of Botany of the University of Barishal. A total of 72 informants were interviewed among which 56 were male and the remaining 16 were female. The voucher specimen was shown to every informant and they were asked about the ethnobotanical information, availability, and mode of administration regarding each species. Then the data collected from the survey was compiled through an Excel spreadsheet (2007) and summarized following graphical and statistical analysis.

### Citation frequency of the medicinal plants (Cf%)

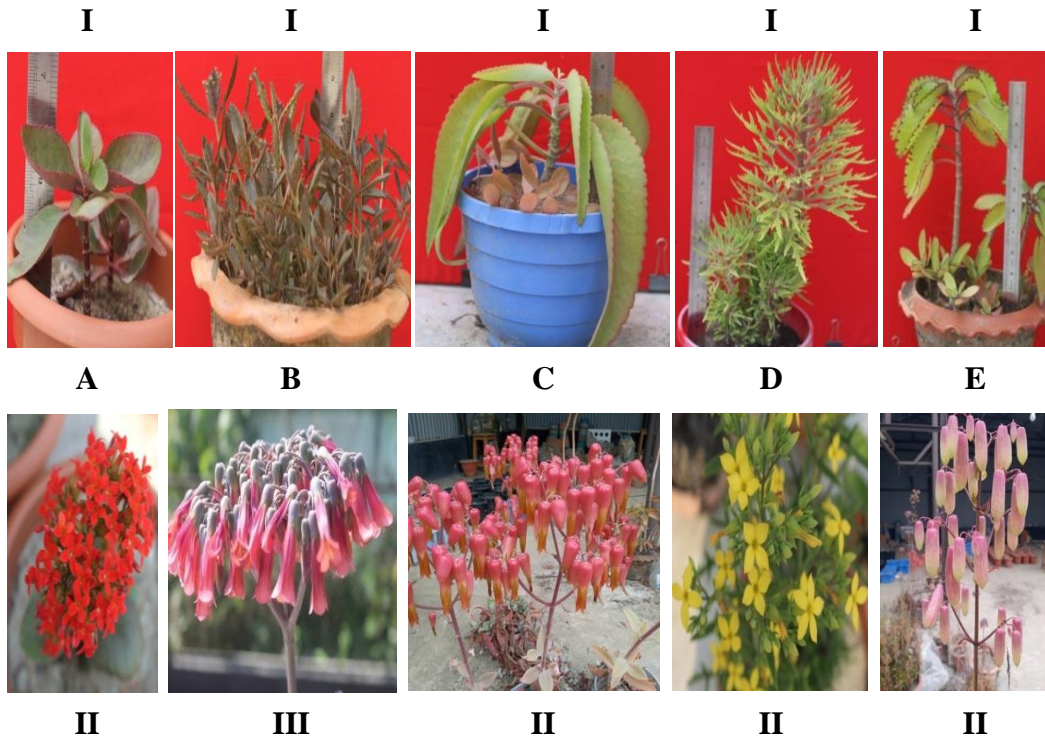
Citation frequency values are useful to conclude the most common medicinal plants. Citation frequency values of medicinal plants were estimated (Friedman *et al.*, 1986) using the formula:

$$\text{Citation frequency (Cf \%)} = \frac{n}{N} \times 100$$

Where n refers to the number of people interviewed citing species, N refers to the total number of people interviewed.

**Table 1.** List of collected *Kalanchoe* species

Sl. No.	Scientific name	Common name
1.	<i>Kalanchoeblossfeldiana</i> V. Poelln.	Florist's Kalanchoe
2.	<i>Kalanchoedelagoensis</i> Eckl. and Zeyh.	Chandelier plant
3.	<i>Kalanchoegastonis-bonnieri</i> Raym.-Hamet and H. Perrier	Donkey ear plant
4.	<i>Kalanchoelaciniata</i> (L.) DC.	Christmas tree plant
5.	<i>Kalanchoepinnata</i> (Lamk.) Pers.	Life plant



**Fig. 1.** Comparative vegetative (I) and inflorescence (II) morphology of five species of *Kalanchoe* taxa. A). *K. blossfeldiana*; B). *K. delagoensis*; C). *K. gastonis-bonnieri*; D). *K. laciniata* and E). *K. pinnata*.

**Fidelity level (Fl %)**

The Fidelity level value is useful for identifying the informants' most claimed species in use for treating certain ailments (Friedman *et al.*, 1986). The Fidelity level index was determined by the following formula:

$$\text{Fidelity level (Fl \%)} = \frac{N_p}{N} \times 100$$

Where  $N_p$  is the number of informants who claimed one species to treat a certain disease, and  $N$  is the number of informants who uses the species to treat any disease (Alexiades, 1996).

**Data matrix ranking (DMR)**

Data collected from the respondents were used for DMR analysis to compare the use diversity of given plant species. Selected informants were asked to assign use values in the following categories 5, 4, 3, 2, 1, and 0 for best, very good, good, less used, least used, and not used classes respectively for each species. The round value of average scores given to each species was summed up and ranked.

**Results and Discussion****Morphological investigation of *Kalanchoe* Adans.**

The members of the genus *Kalanchoe* are mostly succulent, fleshy, erect, and herbs. Phyllotaxy is the opposite decussate type, leaf simple. Inflorescence cymose, flowers paniculate, erect/pendent tetramerous, bisexual. Sepals and petals are united at the base to form calyx and corolla tubes respectively. Stamens were four/eight arranged in two series and carpel four. Fruit is many seeded follicles.

***Kalanchoe blossfeldiana* V. Poelln.****Vernacular Name: Lalpathorkuchi**

A succulent, erect, perennial herb. Stem round, glabrous, reddish-green. Leaves simple, opposites-decussate, petiolate, exstipulate, ovate, crenate, apex round. Inflorescence is a paniculate cyme. Flowers erect, pedicellate, bracteates, actinomorphic, bisexual, hypogynous. Calyx of four sepals, free reddish-green, persistent. Corolla of four, united at base to form a long tube, lobes four, spreading, red. Stamens eight in two series of four each. Carpels four, apocarpous, green, glabrous, each carpel with long style. Fruit follicle, seeds small (Fig. 1A). The partial persistent result was reported by Klein *et al.*, 2021. Flowering and fruiting-December-April. Habitat: Gardens under direct sunlight. Propagation: Stem and leaf cuttings.

***Kalanchoe delagoensis* Eckl. and Zeyh.****Vernacular Name: Hazaripathorkuchi**

Succulent herbs, robust biennials or perennials, completely glabrous. Stems simple, erect, terete; Leaf ternate to apparently opposite or alternate, sessile, usually straight, erect to spreading, sub-cylindrical, grooved, reddish-green to grey-green with reddish-brown spots, tip with small teeth with numerous bulbils, base attenuate; Inflorescence compact many-flowered rounded thyrus, Pedicel slender; Flower pendent

bisexual, hypogynous, actinomorphic; calyx campanulate, reddish to green striped with red, tube, lobes triangular-lanceolate, very acute; corolla red, violet, pale orange to yellow suffused with red, tube funnel-shaped, lobes oblong-obovate, obtuse or truncate, spreading; Stamen inserted below the middle of the Corolla tube; Anther ovate; Carpel ovate-oblong; Style long; Fruits dry, indehiscent, papery follicles (Fig. 1B). Similar morphology was reported by Tian *et al.*, 2021. Flowering and fruiting: November-March. Habitat: Arid regions, grows on concrete as a weed. propagation: viviparous plantlet leaf margin.

***Kalanchoe gastonis-bonnieri* Raym.-Hamet and H. Perrier**

**Vernacular Name: Boro Pathorkuchi**

Perennials or sometimes biennials with basal Rosette; stems usually very short, glabrous; Leaf petiolate, very thick, fleshy, whitish-pruinose above, green with numerous irregular brownish-green spots, glabrous, petiole broad, amplexicaul, lamina ovate-lanceolate, folded lengthwise like a gutter, tip long-acute with bulbils, base cuneate, margins coarsely crenate; Inflorescence many-flowered corymb pedicellate; Flower pendent or spreading, actinomorphic, hypogynous, bisexual; Calyx glabrous, green with red or violet lines, tube cylindrical, lobes deltoid, acute; Corolla yellow-green with red or violet lines, finely glandular-hairy, tube cylindrical, lobes orbicular, acuminate; Stamens inserted towards the base of the Corolla tube, upper stamens slightly exerted; Anther reniform; Carpel long. Fruit follicles and seeds are small (Fig. 1C). These morphologies were partially supportive with results reported by Smith *et al.*, 2020. Flowering and fruiting-November-March Habitat: Arid regions, planted in gardens that receive direct sunshine. Propagation, viviparous plantlet in leaf margin at maturity.

***Kalanchoe laciniata* (L.) DC.**

**Vernacular Name: Himasagar**

An erect, rather robust herb. Stem round, glabrous, green. Leaves opposites-decussate, petiolate, exstipulate, twice/thrice forked, lacinate. Inflorescence is a paniculate cyme. Flowers erect, pedicellate, actinomorphic, bisexual, tetramerous. Calyx of 4 sepals, free, lanceolate, persistent. Corolla of four petals united to form a long tube, lobes four, spreading, yellow, and cruciform. Stamens four in two series of two each. Carpel four, apocarpous, green, glabrous, each carpel with moderately long style and capitate stigma. Fruit follicle, seeds small (Fig. 1D). The partially similar result was found in Deb and Dash, 2013. Flowering and fruiting: January-May Habitat: Gardens in arid condition as ornamental Propagation: Stem and petioles cuttings.

***Kalanchoe pinnata* (Lamk.) Pers.**

**Vernacular Name: Pathorkuchi**

A tall, erect, perennial herb. Stem round, glabrous, reddish. Leaves simple, opposites-decussate, foliate, fleshy, petiolate, ovate, elliptic, crenate, apex rounded to acute. Inflorescence is a very long paniculate cyme. Flowers are pendulous, pedicellate, actinomorphic, bisexual, and hypogynous. Calyx of 4 sepals, united at the base to form a tube, reddish, lobes four. The Corolla of four petals, united at the base to form a long tube exceeding the calyx tube, lobes four, red. Stamens eight in two series of four each.

Carpels four, apocarpous, each carpel with a short style and stigma. Fruit follicle, seeds small (Fig. 1E). This macroscopical finding is partially consistent with Shrutti *et al.*, (2018); Fernandes *et al.*, 2019. Flowering and fruiting: December-April. Habitat: Dry regions, also planted in gardens Propagation: New plantlet from leaf margin. From the observations, it can be demonstrated that all these species have a strong interrelationship among them with respect to leaf and floral morphology. However, there were some significant differences too. Chernetsky (2012) also reported that leaves of *Kalanchoe* sp. exhibit permanent species-specific macro-morphological traits.

**Table 2.** Macroscopic morphology of leaf and flower of five *Kalanchoe* spp.

Part	Character	<i>Kalanchoe blossfeldiana</i>	<i>Kalanchoe delagoensis</i>	<i>K. gastonis- bonnieri</i>	<i>Kalanchoe laciniata</i>	<i>Kalanchoe pinnata</i>
	Petiole	Visible	Mixed with leaf blade	Short, stout	Mixed with leaf blade	Long, violet
	Leaf blade	Ovate	Narrowly oblong	Ovate-lanceolate	Lanceolate	Ovate
	Phyllotaxy	Decussate	Decussate, whorled in sets	Opposite decussate	Opposite decussate	Opposite decussate
	Leaflets	No	No	No	No	Yes
Leaf	Leaflet margin	Crenate	Dentate	Tooth-like jagged at young, serrate at aged	Coarsely dentate	Dentate-crenate
	Leaf apex	Round	Tapered	Blunt	Blunt	Obtuse
	Leaf-borne plantlets	No	Yes	Yes	No	Yes
	Leaf color	Deep green	Reddish green with reddish brown spots	Light to bronze green, waxy white powder at young	Light green	Medium green
	Midrib	Obscure	Obscure	Prominent lower part	Obscure	Prominent lower part
	Inflorescence	Compact corymbose cyme	Corymbose cyme	Compact corymbose cyme	Corymbose cyme	Loose corymbose cyme
	Inflorescence position	Terminal, axillary at apex	Terminal	Terminal	Terminal, axillary at apex	Terminal
Flower	Flower	Erect	Hanging	Hanging	Erect	Hanging
	Calyx color	Dark green/red green	Pale green	Bright peach colored	Pale green	Reddish green
	Corolla color	Bright red	Orange to scarlet	Yellowish green, reddish yellow	Bright yellow	Yellowish green

But many members of this genus possess polymorphism, which made it essential to conduct micro-morphological analysis for better identification of *Kalanchoe* sp. Nevertheless, all the findings of our observations are compatible with the previous literature (Ahmed *et al.*, 2008; Eggli, 2003). So it can be concluded that all these five *Kalanchoe* sp. possess distinct vegetative and reproductive characteristics.

Based on Morphological characters a taxonomic key to the investigated species of *Kalanchoe* Adans. is depicted below:

- A. Leaf viviparous, large hanging flowers;
  - I). Leaf blade narrow, short petiole, small calyx, long corolla tube → *K. delagoensis*;
  - II). Broadleaf blade, long petiole, large calyx, short corolla tube;
    - a). Leaf simple, lanceolate; Calyx bright peach colored → *K. gastonis-bonnieri*;
    - b). Leaf pinnate, ovate; Calyx reddish green colored → *K. pinnata*;
- B). Leaf non-viviparous, small erect flowers;
  - I). Leaf blade coarsely dentate, corolla bright yellow → *K. laciniata*;
  - II). Leaf blade simple, ovate, corolla scarlet red → *K. blossfeldiana*.

The taxonomic key based on macroscopic characteristics is supportive of the taxonomic key morpho-anatomy-based systematic key proposed by Laskar *et al.*, 2022.

### Availability

Alike other plant species each species of *Kalanchoe* spp. has required a specific environmental condition. From the result, it was observed that *K. pinnata* has highest availability (53%) following *K. blossfeldiana*, *K. delagoensis*, *K. laciniata* (Fig. 2) respectively. The reason for this distributional variation of these *Kalanchoe* taxa may be habit and/or habitual variation among them. The availability of particular taxa in a specific region may affect ethnobotanical information among informants. In addition, sometimes due to consumption of specific taxa having medicinal potentiality may reduce the availability of that taxa. Moreover, urbanization, deforestation, exotic species plantation, and other anthropogenic practices may affect the availability of particular specimens. Moreover, both biotic and abiotic factors of an environment may affect the availability of a particular species.

### Ethnobotanical data analysis

#### Ethnomedicinal information

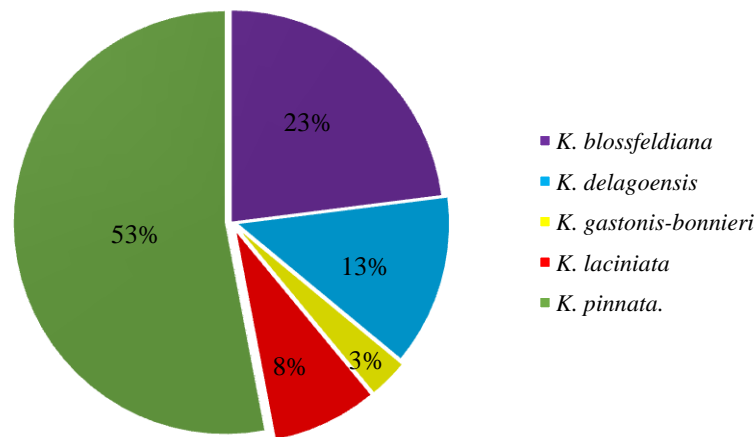
Ethnomedicinal information is respected by local people and students from the district Barishal and Bagerhat districts of the Khulna division. The documented five *Kalanchoe* Adans. species viz., *K. blossfeldiana*, *K. delagoensis*, *K. gastonis-bonnieri*, *K. laciniata*, and *K. pinnata* were used to treat 9 human ailments named cough and cold, cut and wounds, stomach disorder, kidney and gall bladder stone, jaundice, high blood pressure, skin burning, headache and eye pain. The collected ethnomedicinal information



regarding this genus was cross-checked with already published available literature and was found supportive of Costa *et al.*, (2008); Fernandes *et al.*, 2019; Shruti *et al.*, (2018); Ahmed *et al.*, (2008) and Khan *et al.*, (2015). The quantitative method was implemented to evaluate the relative importance of each species against each ailment. The results of the ethnomedicinal data supported that the alternative uses of different species against the same ailment depend on the availability of the species from locality to locality.

### Citation frequency

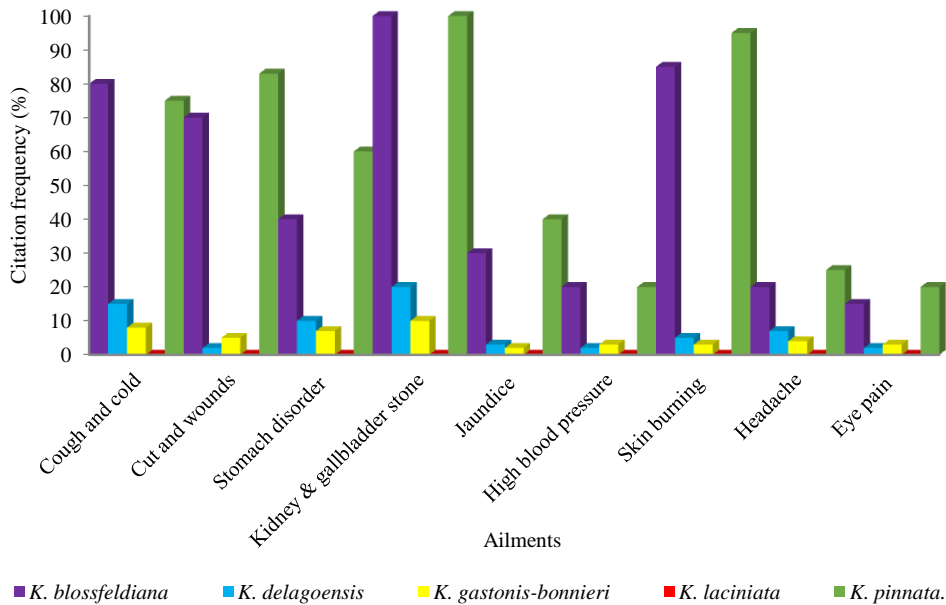
The citation frequency of each species except *K. laciniata* ranges from 0 to 100% in contrast to any ailment (Fig. 3). The species *K. blossfeldiana* and *K. pinnata* had highest citation frequency among the five species against all ailments. All the species except *K. laciniata* of *Kalanchoe* taxa had the highest citation frequency against kidney and gall bladder stone ailments among all other ailments. It was recorded that the rare species *K. gastonis-bonnierii* had citation frequency against all ailments categories though the value was more runt. The reason for this least citation frequency was suspected that the scarcity has limited their popularity among local people. The species *K. laciniata* had no citation frequency against all ailments and informants answered that though the species has been used for indoor ornamentation it is systematic



**Fig. 2.** Comparative availability of five species of *Kalanchoe* taxa.

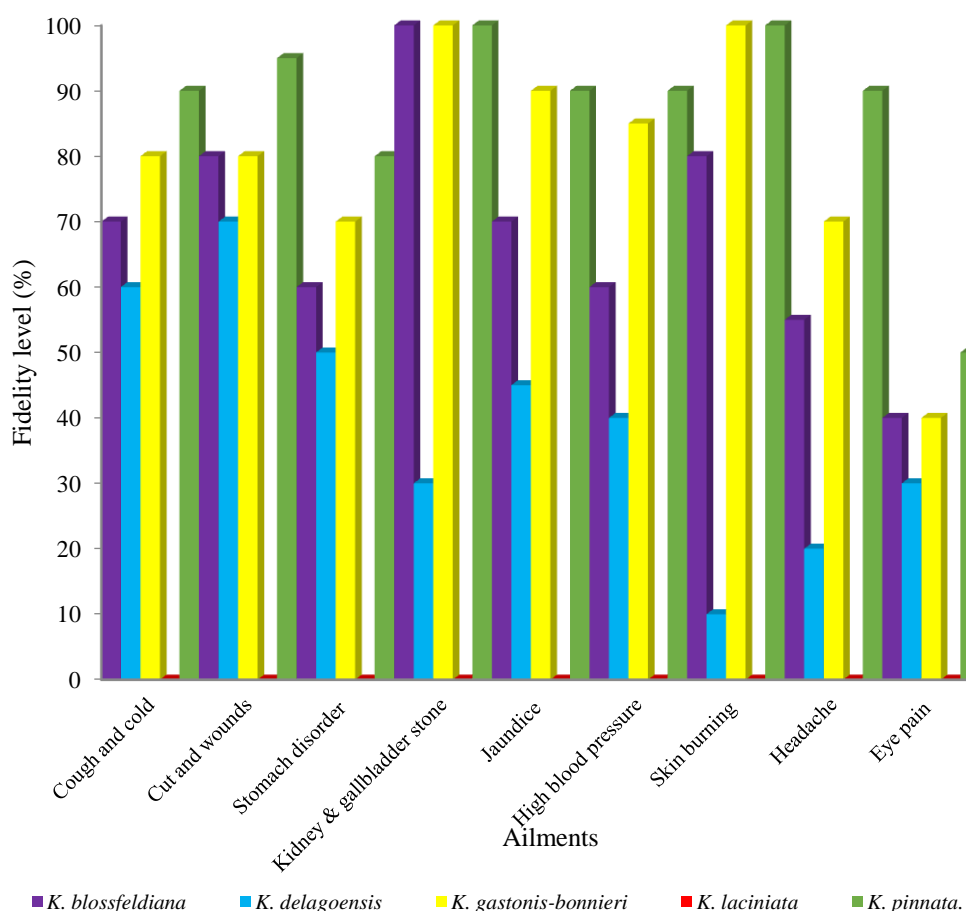
Information is not well known to them. In the category of cough and cold *K. blossfeldiana* had the highest citation frequency (80%) but *K. gastonis-bonnierii* had the lowest citation frequency (8%). In addition, in the ailment category cut and wound citation frequency ranged from 2% to 60% in which *K. pinnata* had the highest citation frequency (60%) but *K. delagoensis* has the lowest citation frequency. In the case of stomach disorder ailment citation frequency ranged from 10% to 45% in which *K. pinnata* and *K. blossfeldiana* had about 4 and 4.5 times citation frequency respectively than *K.*

*delagoensis* (10%). The highest citation frequency was found for kidney and gall bladder stone ailments (100%) which were five and ten times of *K. delagoensis* and *K. gastonis-bonnierei* respectively (Fig. 3). Moreover in the case of jaundice, 2% to 40% citation frequency had been found, in which *K. pinnata* had highest (40%) but *K. gastonis-bonnierei* had lowest (2%). In the ailment, High blood pressure *K. blossfeldiana* and *K. pinnata* had the same but highest frequency (20%) while *K. delagoensis* has the lowest (2%) citation frequency.



**Fig. 3.** Comparative citation frequency (%) with respect to ailments and five species of *Kalanchoe*.

The citation frequency for skin burning ranged from 3 to 85% with which *K. pinnata* had the highest (85%) value. In addition, in the case of skin burning *K. pinnata* and *K. blossfeldiana* had the highest (85% and 80% citation frequency respectively) but *K. gastonis-bonnierei* had the lowest (3%) citation frequency. In the ailment named headache, *K. pinnata* had 25% and *K. blossfeldiana* had 20% citation frequency which was about six times and five times greater than *K. gastonis-bonnierei* respectively. Moreover, in the category of eye pain *K. pinnata* had the highest (20%) and *K. blossfeldiana* had 15% citation frequency while *K. delagoensis* had the lowest (2%) (Fig. 3).



**Fig. 4.** Comparative fidelity level (%) with respect to ailments and five species of *Kalanchoe*.

### Fidelity level

Alike the citation frequency all the species of *Kalanchoe* had fidelity levels except *K.laciniata* in contrast to any ailment (Fig. 4). The species *K. blossfeldiana* and *K. pinnata* along with *K. gastonis-bonnierii* represented the highest fidelity (100%) with regards to kidney and gall bladder stone ailment. The species *K.delagoensis* had the lowest fidelity among all species of *Kalanchoe* having fidelity level in all ailments categories. The reason for this may be a variation in leaf morphology that creates a dispute about the systematic position. In addition, leaf juice, and baked leaves were used as a mode of administration, so that a colorful appearance restrained people from using. But experienced local people/healers found mentionable results. In the case of cough and cold, *K. pinnata* has highest fidelity level (90%) followed by *K. gastonis-bonnierii* (80%), *K. blossfeldiana* (70%), *K.delagoensis* (60%) respectively. In the ailment category cut and wounds *K. pinnata* was reported to have the highest fidelity level (95%) followed by

*K. blossfeldiana* (80%), *K. delagoensis* (70%) respectively (Fig. 4). In addition, *K. pinnata* was recorded for having highest fidelity level (80%) followed by *K. gastonis-bonnierii* (70%), *K. blossfeldiana* (60%) and *K. delagoensis* (50%) respectively in the ailment category of stomach disorder. The species *K. blossfeldiana*, *K. gastonis-bonnierii*, and *K. pinnata* independently had the highest fidelity level (100%) followed by *K. delagoensis* (30%) with regards to kidney and gall bladder stone ailment. In the ailment category of Jaundice, the fidelity level ranged from 45-90% in which *K. gastonis-bonnierii*(90%) and *K. pinnata* (90%) had two times the fidelity level than *K. delagoensis* (45%). Moreover, in the high blood pressure ailments, fidelity levels ranged from 40-90% in which *K. pinnata* (90%) had over two times the fidelity level than *K. delagoensis*(40%). In addition, in the ailment category of skin burning, *K. gastonis-bonnierii*(100%) and *K. pinnata* (100%) independently had ten times the fidelity level value than *K. delagoensis* (10%). Moreover, for the headache category *K. delagoensis* had about one-fifth fidelity level of *K. pinnata* (90%) while *K. pinnata* had the highest fidelity level (50%) followed by *K. blossfeldiana* (40%), *K. gastonis-bonnierii* (40%), *K. delagoensis* (30%) respectively (Fig. 4) for the eye pain ailment.

**Table 3.** Data matrix ranking of five species of *Kalanchoe* Adans

Use parameter	<i>K. blossfeldiana</i>	<i>K. delagoensis</i>	<i>K. gastonis-bonnierii</i>	<i>K. laciniata</i>	<i>K. pinnata.</i>	Total	Rank
Indoor ornamentation	4	5	2	5	4	20	<b>3</b>
Outdoor gardening	5	5	4	5	5	24	<b>1</b>
Medicinal	5	2	4	0	5	16	<b>5</b>
Irrelevant daily study	5	2	5	1	5	18	<b>4</b>
Personal cares	4	2	3	0	5	14	<b>6</b>
Botanical study	5	5	4	3	5	22	<b>2</b>
Total	28	21	17	15	29		
Rank	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>1</b>		

The presence of a wide range of secondary metabolites in the *Kalanchoe* taxa is related to ethnomedicinal applications (Stefanowicz-Hajduk, 2020). Bufadienolides have been postulated as responsible for many pharmacological activities (Kolodziejczyk-Czepas and Stochmal, 2017) despite the presence of other secondary metabolites viz. alkaloids (Biswas et al., 2012), phenolic acid (Singab et al., 2011), flavonoids (Nielsen et al., 2005), saponins and tannins (Pattewar, 2012). Bufadienolide compounds have antiviral, anticancer, antimicrobial, cardiotoxic, and antioxidant effects (Supratman et al., 2001; Cunha Filho et al., 2005; Wu et al., 2006). But the reason for the difference in

citation frequency and fidelity level among the species documented may be the availability and popularity of particular species.

### Data matrix ranking

The results of the DMR analysis on multipurpose uses enabled us to detect which of the five species is/ are under stress and the reasons that are threat to the plant species (Table 3). According to DMR analysis, *K. pinnata* was ranked first followed by *K. blossfeldiana*, *K. delagoensis*, *K. gastonis-bonnierii*, and *K. laciniata*. The multipurpose uses of *K. pinnata* and *K. blossfeldiana* tend to these two species are under great pressure as excessive harvesting by local people for a variety of purposes. Six factors are responsible for the decline of *K. pinnata* abundance in the area among which five factors were major while four factors were minor for reducing the availability of *K. blossfeldiana* that result from over-harvesting. On the other hand, *K. laciniata* is the lowest ranked and this may be due to a lack of proper knowledge regarding the systematic position, abundance, popularity, and lack of medicinal information. Sometimes traditional people mostly used whole plants or roots for ethnomedicinal recipes, as well as for other diverse uses.

### Conclusion

*Kalanchoe* is one of the most important medicinal plants in most countries of the world including Bangladesh. *K. pinnata* has the highest availability among the five species found in Bangladesh followed by *K. blossfeldiana*, *K. delagoensis*, *K. gastonis-bonnierii*, and *K. laciniata* respectively. All five species were used to treat 9 human ailments named cough and cold, cuts and wounds, stomach disorder, kidney and gall bladder stones, jaundice, high blood pressure, skin burning, headache, and eye pain. The diversified uses of the different species rely on the availability, ethnomedicinal knowledge, popularity, locality, and perceptions of local people against particular species. It can be concluded after completion of compiling the availability with respect to citation frequency that the higher the percentage of availability, the higher the rate of usage frequency except for *K. gastonis-bonnierii*, and *K. laciniata* against all kinds of ailments. The compilation of fidelity level (%) value reflects that *K. pinnata* possess the highest fidelity value followed by *K. gastonis-bonnierii*, *K. blossfeldiana*, *K. delagoensis*, and *K. laciniata* against all ailments. Compilation availability, citation frequency, fidelity level, and data matrix data reflect a dire need for conservation strategy to save the declining population of the top-ranked purpose plant species *K. pinnata* and *K. blossfeldiana* and extension strategy for middle and lower ranked species *K. gastonis-bonnierii*, *K. delagoensis* and *K. laciniata*.

### Conflicts of Interest

The authors declare no conflicts of interest regarding publication of this paper.

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